EAZA Best Practice Guidelines

Babirusa (*Babyrousa*)

Picture: Female babirusa and piglets at Chester Zoo

Editors: Tim Rowlands, Amy Treanor. NEZS Chester Zoo,
Kate Edge and Francesca Ankers
Contact information: Chester Zoo, Cedar House, Caughall Road, Chester, CH2 1LH, 01244 389 879
Name of TAG: Tapir and Suiform
TAG Chair: Bengt Holst
Edition: 1
Publication 2018

Disclaimer

The information contained in these EAZA Best Practice Guidelines has been obtained from numerous sources believed to be reliable. EAZA and the EAZA Pig and Peccary TAG make a diligent effort to provide a complete and accurate representation of the data in its reports, publications, and services. However, EAZA does not guarantee the accuracy, adequacy, or completeness of any information. EAZA disclaims all liability for errors or omissions that may exist and shall not be liable for any incidental, consequential, or other damages (whether resulting from negligence or otherwise) including, without limitation, exemplary damages or lost profits arising out of or in connection with the use of this publication. Because the technical information provided in the EAZA Best Practice Guidelines can easily be misread or misinterpreted unless properly analysed, EAZA strongly recommends that users of this information consult with the editors in all matters related to data analysis and interpretation.

EAZA Preamble

Right from the very beginning it has been the concern of EAZA and the EEPs to encourage and promote the highest possible standards for husbandry of zoo and aquarium animals. For this reason, quite early on, EAZA developed the “Minimum Standards for the Accommodation and Care of Animals in Zoos and Aquaria”. These standards lay down general principles of animal keeping, to which the members of EAZA feel themselves committed. Above and beyond this, some countries have defined regulatory minimum standards for the keeping of individual species regarding the size and furnishings of enclosures etc., which, according to the opinion of authors, should definitely be fulfilled before allowing such animals to be kept within the area of the jurisdiction of those countries. These minimum standards are intended to determine the borderline of acceptable animal welfare. It is not permitted to fall short of these standards. How difficult it is to determine the standards, however, can be seen in the fact that minimum standards vary from country to country.

Above and beyond this, specialists of the EEPs and TAGs have undertaken the considerable task of laying down guidelines for keeping individual animal species. Whilst some aspects of husbandry reported in the guidelines will define minimum standards, in general, these guidelines are not to be understood as minimum requirements; they represent best practice. As such the EAZA Best Practice Guidelines for keeping animals intend rather to describe the desirable design of enclosures and prerequisites for animal keeping that are, according to the present state of knowledge, considered as being optimal for each species. They intend above all to indicate how enclosures should be designed and what conditions should be fulfilled for the optimal care of individual species.

Citation
Rowlands, T., Treanor, A., Edge, K., and Ankers, F., (2018) EAZA Best Practice Guidelines for the Babirusa (*Babyrousa*) – *First edition*. European Association of Zoos and Aquaria, Amsterdam, The Netherlands.

DOI
10.61024/BPG2018BabirusaEN

Introduction

These EAZA Best Practice Guidelines for the Babirusa (*Babyrousa*) have been compiled using information from a variety of different sources. The AZA "Husbandry guidelines for babirusa (*Babyrousa babyrussa*) Species Survival Plan", which were compiled in 2003 using information from babirusa holders and researchers from across Europe and America, have formed the backbone of these EAZA guidelines. A review of the AZA guidelines and other literature available, along with Chester zoo's own knowledge and experience with the management of babirusa have contributed to forming these guidelines. They also contain a collection of documents produced within the zoo community, such as body scoring sheets and hand rearing notes, a full list of the literature reviewed can be found at the end of this document.

Section 1: Biology and field data, includes the most up to date taxonomic information and covers our current knowledge of babirusa and their behaviour in the wild.

Section 2: Management in zoos, provides information and suggestions on enclosure size and design, feeding, social groupings, breeding management, transportation, handling and veterinary considerations for the species.

Gaps in knowledge

Despite babirusa having been kept in captivity for many years there are still areas of their biology and management that are poorly understood. The nutrition section in these guidelines as well as Chester Zoo's diet sheet (which can be found in the appendix) are based on materials authored by Kristin Leus ~2001 which were published as part of the SSP Husbandry Manual in 2003. Although the work is now over 15 years old it is still by far the best information currently available. Nutrition therefore is one of the areas that needs further research in order to make standardised recommendations for a captive diet.

Current conservation efforts

On the 16th of March 2016, after the completion of these guidelines, a Global Species Management Plan (GSMP) for Babirusa, convened by Jeff Holland from Los Angeles Zoo (USA) was approved. GSMPs follow the One Plan Approach to conservation and are to be used as a framework for global cooperation combining both ex situ and in situ conservation of a species. As well as providing financial and practical support to help babirusa in situ, it is important that zoos participating in breeding programmes are able to maintain healthy demographic and genetic insurance populations. In light of this global collaboration to try and ensure the future of these incredible animals it is has never been more important for the successful management and breeding of babirusa with in zoological collections.

Contents

Section 1: Biology and field data

1.1 Taxonomy

1.1.1 Order

Babirusa sits within the mammalian order of artiodactyla and the sub order of Suina.

1.1.2 Family

The sub order of Suina contains two families: *Tayassuidae* (peccaries) and *Suidae* (pigs) and *Babyrousa* (babirusa) are included within the latter. However, there is some controversy regarding the correct placement of the Babirusa within this family; historically Suinae has been considered the only subfamily of Suidae with Babirusa classified as a tribe within this clade and this view was supported by Meijaard *et al*. (2011) due to 'shared morphological characteristics'. However, a study of the genetics of existing genera of Suidae from Eurasia and Africa, conducted by Gongora *et al*. (2011), demonstrated that the Babirusa should be recognised as a second subfamily within Suidae, suggesting that a 'plausible evolutionary scenario for Suidae is that the Babyrousinae and Suinae lineages diverged from their common ancestor in Southeast Asia'.

1.1.3 Genus

The genus of Babyrousa is considered to either be monotypic within the subfamily of Babyrousinae or a tribe (Babyrousini) within the sub family of Suinae.

1.1.4 Species

Following a proposal from Meijaard and Groves (2002b) the three extant subspecies of Babirusa were upgraded to species level with the Moluccan Babirusa from the Buru and Sula Islands retaining the taxonomic identity of *Babyrousa babyrussa*. The distinction between species is based on features of their skull and teeth.

Under the new classification, *Babyrousa celebensis* specifically referred to individuals from northern Sulawesi; with animals originating from central, eastern and south-eastern Sulawesi as yet left undecided with further study required. In the absence of further clarification, all individuals originating on Sulawesi, Muna, Buton and Lembeh are grouped together, as they were under the previous taxonomy, and therefore are considered as *Babyrousa celebensis* (Macdonald, 2008).

Babyrousa togeanensis refers for individuals originating from the Togian islands.

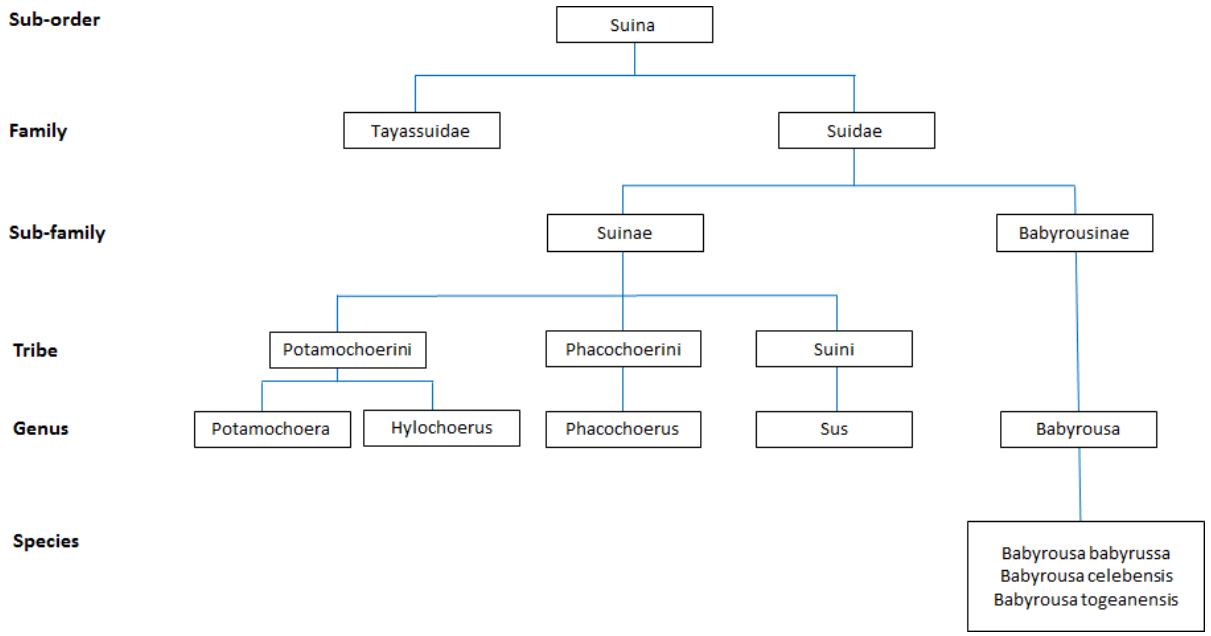


Figure (1.0) Classification of Babirusa within the sub-order suiformes based on recommendations from Gongora *et al*. (2011) and Meijaard and Groves (2002b).

1.1.5 Common Names

Babirusa can be literally translated to 'pig-deer' in the Malay language (Macdonald, 1993); their name derived from their unusual physical appearance. Common names for each species are listed below including translation into several European languages. **Table (1.0): Translation of the three extant Babirusa species into several European languages:** compiled from IUCN Red List (2008) and Meijaard *et al*. (2011).

Scientific Name	English	French	German	Spanish
Babyrousa celebensis	Sulawesi Babirusa	Babiroussa des Célèbes	Sulawesi-Hirscheber	Babirusa de Célebes
Babyrousa babyrussa	Moluccan Babirusa, Hairy Babirusa, Buru Babirusa, Babirusa, Deer Hog, Babiroussa	Babiroussa des Moluques	Molukken-Hirscheber	Babirusa de Molucas
Babyrousa togeanensis	Togian Islands Babirusa	Babiroussa des Togian	Togian-Hirscheber	Babirusa de Togian

1.2 Morphology

1.2.1 General Description

Babirusa are a relatively small member of the pig family with a barrel shaped body, slightly arched back, long slender legs and pointed snout. They differ from most other pig species in that they lack the adaptation that allows rooting; they lack the rostral bone in the nose that provides support for the rhinarium (Meijaard *et al*., 2011).

The skin is brownish grey and often has large folds or wrinkles; the underside of the body and inside of the legs can be lighter in colour. The upper canines are small or absent in females but in males they grow upwards (never entering the mouth cavity) up to a length of 31 cm piercing through the top of the snout (Schmidt, 1990); males also have prominent lower tusks. Females are approximately 30% smaller than males (Macdonald, 1993). Females also have two pairs of mammae.

Babirusa have acute olfactory and auditory senses and vocalise using a series of low grunting moans and squeals. They have been known to clatter their teeth when excited in a way similar to that observed in peccaries (Grzimek, 1990).

Specific descriptions sourced from Meijaard and Groves, (2002a)

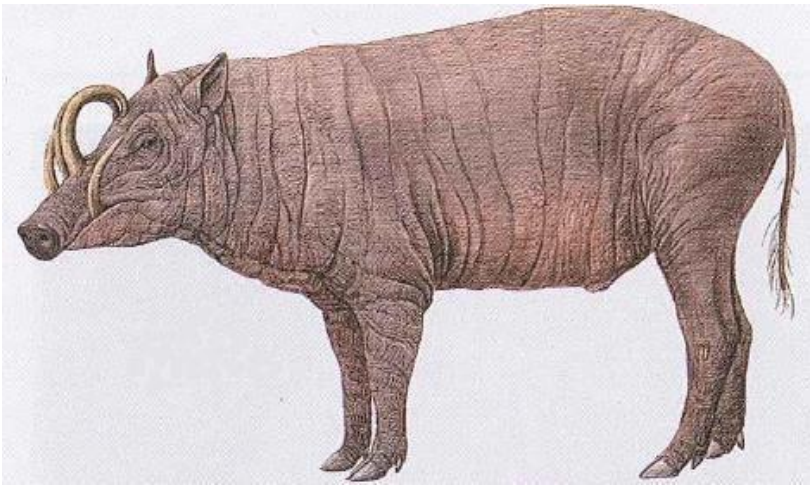


Figure (1.1): *Babyrousa celebensis* (male) extracted from *Handbook of the Mammals of the World. Vol 2. Hoofed Mammals*. (Wilson, D.E. & Mittermeier, R.A. editors) Page 274, Plate 9

B. celebensis is differentiated by the following features: a longer skull, sparse or absent body hair, sparse tail tuft and by the characteristics of the teeth. In males the upper canines are generally long and thick; they emerge vertically from the snout, converging slightly then arching backwards in a circle meeting the forehead. On the lateral view, they do not cross the lower canines. The molars (lower M_1 and M_3 and upper M^2 and $M^{3)}$ in this species are also longer than *B. babyrussa*.

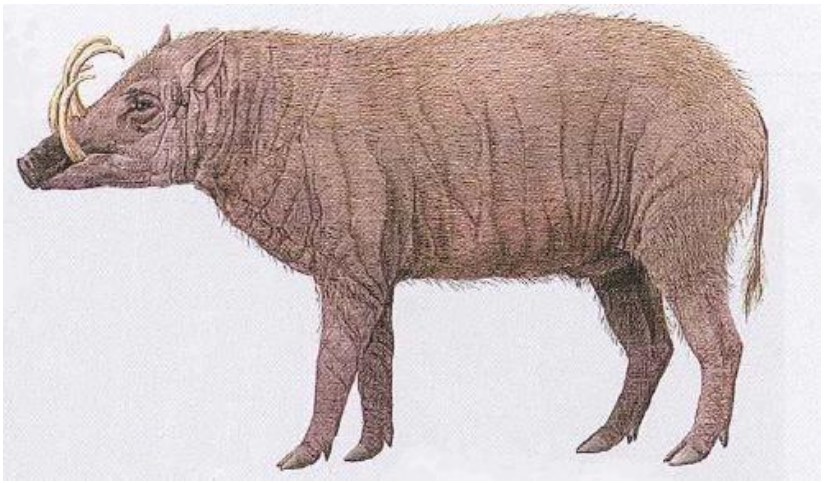


Figure (1.2):*Babyrousa babyrussa* (male) extracted from *Handbook of the Mammals of the World. Vol 2. Hoofed Mammals*. (Wilson, D.E. & Mittermeier, R.A. editors) Page 274, Plate 9

B. babyrussa is the smallest of the babirusa and is distinguished by long, thick, body hair, well developed tail tuft and by the characteristics of the teeth. In males the upper canines are short and slender; they are slightly convergent and grow back towards the forehead but remain sub-parallel unlike *B. celebensis*. On the lateral view, the upper canines cross the lower canines (Macdonald, 1993).

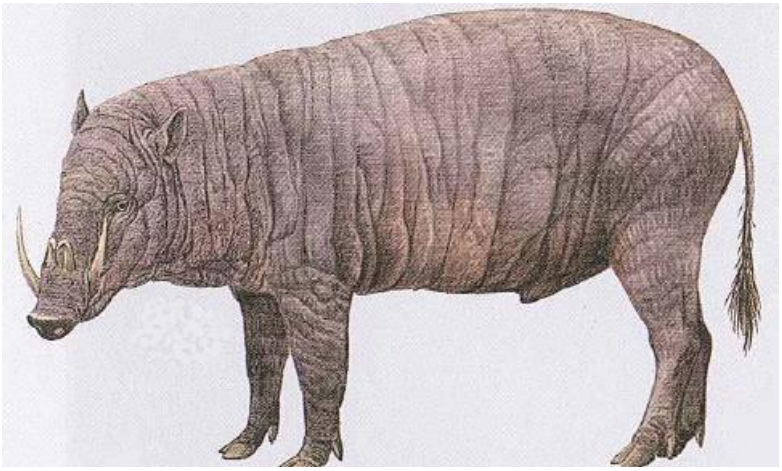


Figure (1.3): *Babyrousa togeanensis* (male) extracted from *Handbook of the Mammals of the World. Vol 2. Hoofed Mammals*. (Wilson, D.E. & Mittermeier, R.A. editors) Page 274, Plate 9

B. togeanensis is supposed to be largest of the babirusa (based on skull measurement) and has only a sparse covering of short, body hair but a well-developed tail tuft. Unlike the other two extant species, the upper canines of *B. togeanensis* are short, always converge and are rotated forwards instead of backwards. It also has relatively large premolars: lower P_3, P_4 and upper P^3.

1.2.2 Body Size

Body measurements below are based on *B. babyrussa* and *B. celebensis* only. There is some evidence to suggest that *B. togeanensis* may be the largest of the three species based on skull measurements but body measurements are unavailable (Meijaard *et al*., 2011).

Height: 65-80cm at shoulder
Length: Usually between 85-110cm with 20-32cm tail
Weight: Adult: 43-100kg New-born: less than 800g

N.B. Recommended body weights (Leus *et al*., 2002) for captive adult Babirusa are:
Adult Male: 90 kg
Adult Female: 60 kg

1.3 Physiology

- **Body Temperature**: 37.3°C +/- 0.9 (range 35-39°C)

- **Heart Rate:** Reference values for resting heart rate in domestic swine are widely recorded as 60-90 beats per minute. Heart rates of resting un-anesthetized babirusa are between 90 and 110 beats/min, (unpubl.obs. James et al, 1999).

- **Respiratory Rate:** Reference values for respiratory rate in pigs have been reported as 15 to 20 breaths per minute. No data could be found specifically for babirusa.

1.3.1 Tusks

The tusks are a distinguishing feature of the babirusa; they are most prominent in males and are much smaller and occasionally non-existent in females. The tooth cavity or alveoli from which the upper canine protrude rotates during development which causes the teeth to grow up through the rostrum and spiral over the face towards the back of the head, the lower canines will also grow in an upward direction and in a spiral shape (Miller & Fowler, 2014).

A recent study carried out by Macdonald, Leus and Hoare (2015) looked at the growth of the maxillary canine teeth and the remodelling of the alveolar processes during development. Using skulls from museums and private collections it was found that the first set of teeth in juvenile male and females will begin growing up to the rostrum and begin rotating dorsally, once the permanent teeth come through they continue growing in this way. As the maxillary canines grow Macdonald et al (2015) states that “The structure of the supporting alveolar process is in the meantime modified and develops a bony flange caudally”.

1.3.2 Digestive system

The structure of the stomach of the babirusa has been extensively studied due to its difference to other suid species (Sutherland-Smith, 2015). This difference is due to an extremely enlarged diverticum, making the stomach larger and more elongate than other suid species (Sutherland-Smith, 2015; Davis, 1940). The acidity of the larger area of cardiac glands (>70% internal surface area versus ~30% in *Sus scrofa*) which produce mucous at the entrance to the stomach

is able to support microbial fermentation, and does contain large populations of microorganisms which can ferment and digest plant structural components by use of enzymes that the babirusa cannot produce itself (Sutherland-Smith, 2015; Leus, 1994; Leus *et al.,* 1999). Longitudinally, the stomach has some similarities to that of a simple ruminant stomach (e.g. Domestic sheep), most parts are represented and have the same relative position, however this is due to convergent evolution and does not present a phylogenetic implication (Davis, 1940). The babirusa is therefore described as a non-ruminant foregut fermenting frugivore and concentrate selector (Sutherland-Smith, 2015). This microbial population gives them the ability to ferment easily digestible cell wall fractions and cell solubles which are most abundant in fruits and dicotyledonous plant parts rather than some monocotyledonous plants such as grasses, suggesting an adaptation to consume the former (Leus, 1996). The lack of constrictions/folds
in the stomach of the babirusa to separate the fermentation chamber from the lower pH of the gastric gland (as is usually present in other foregut fermenters as a means of slowing digestion), along with the observation that digestion in the babirusa takes no longer than that of the domestic pig, leads to the conclusion that bacterial fermentation in the babirusa stomach may be less efficient than in other forestomach fermenters (Leus, 1990; Conklin and Dierenfeld, 1994).

The small intestine is similar in proportional length to body size as that of the Warthog (*Phacochoerus spp*.), both being shorter in proportion than that of the domestic pig (Davis, 1940). The large intestine in the babirusa is slightly smaller relative to body size than that of the domestic pig and Warthog (*Phacochoerus spp*.) (Davis, 1940). The large intestine is mostly arranged in a large double spiral coil, except for its terminal part, which is characteristic of the suids (Davis, 1940). Although present, the difference in diameter between the proximal and distal parts of the spiral coil of the large intestine is less pronounced in babirusa compared with other suid species (Davis, 1940). A study found on digestibility of macronutrients concluded that hemicellulose is more efficiently digested by babirusa than cellulose (suggestion for high hemicellulose content diets in captivity); and that despite differences in digestive anatomy, neither peccaries nor babirusa had more efficient fibre digestion (Sutherland-Smith, 2015).

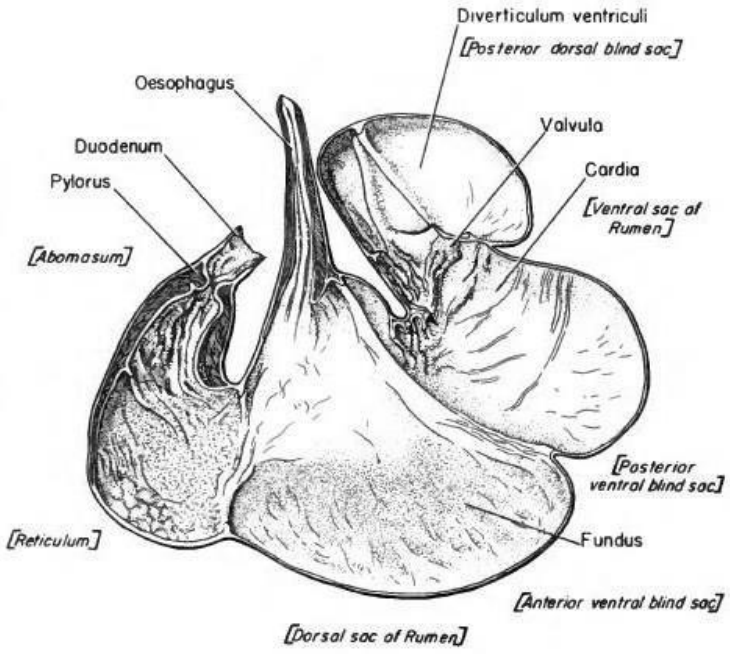


Figure (1.4): *Babyrousa babyrussa* (male) stomach sectioned and laid put flat. Regions corresponding to parts of the ruminant stomach are labelled in brackets. Extracted from Davis, D. D. (1940). *Notes on the anatomy of the babirusa.* Field Museum of Natural History. Page 387

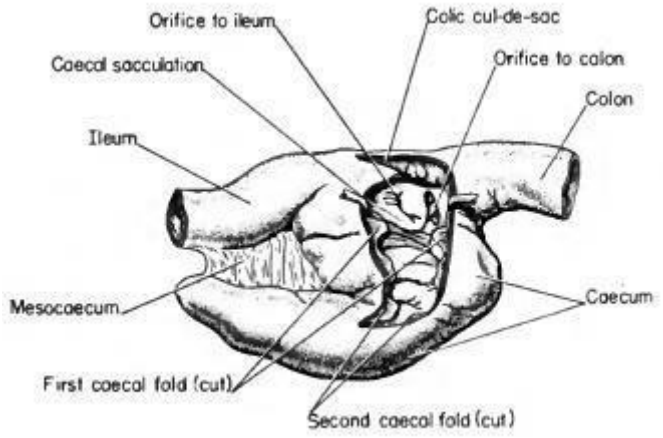


Figure (1.5):*Babyrousa babyrussa* (male) caecum with wall opened to show internal structure. Extracted from Davis, D. D. (1940). *Notes on the anatomy of the babirusa.* Field Museum of Natural History. Page 389

1.3.3 Reproductive Physiology – Female

Ziehmer *et al.,* (2010) found that female babirusa are able to ovulate 4 ova at one time, this can occur in females from puberty until around the age of 22 years. The uterine horn (fig h) has been reported to be smaller in babirusa when compared with other suid species and it is thought to be the reason why babirusa have smaller litters. The female's cervix forms a spiral shape which correlates with the shape of the male's penis (Fowler & Miller, 2010).

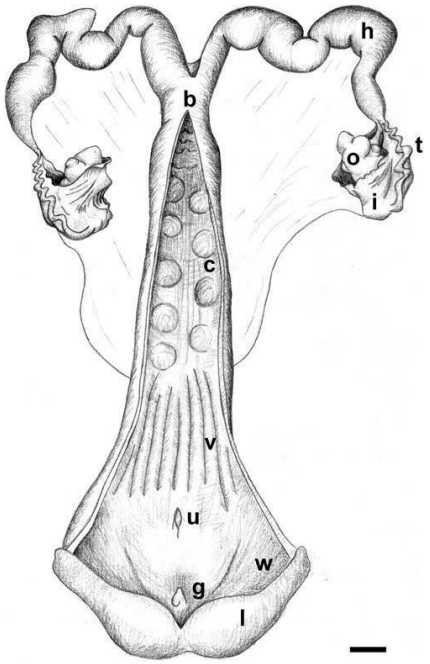


Figure (1.6) Diagrammatic representation of the dorsal view of the nonpregnant female reproductive tract of the Babyrousa, with sectional views of the cervix, vagina and vestibule. Scale 10 mm o, ovary; i, infundibulum; t, uterine tube; h, uterine horn; b, body of uterus; c, cervix; u, external urethral orifice; v, vagina; w, wall of vestibule; g, glans of clitoris; l, lips of vulva. Taken from Ziehmer, *et al.* *(*2010).

1.3.4 Reproductive Physiology – Male

The penis of a babirusa is curved in a sigmoid shape with the end resembling a corkscrew in appearance (Fowler and Miller, 2010). This specific shape corresponds to the shape of the female's cervix as described above. In a detailed study of the male reproductive physiology by Ziehmer *et al.,* (2013) it is reported that there is little difference between the shape, location and anatomy of a male babirusa's reproductive organs compared to descriptions of other wild and domesticated pigs. The same study also states that there were no seasonal differences found in testis weight from the data that was collected.

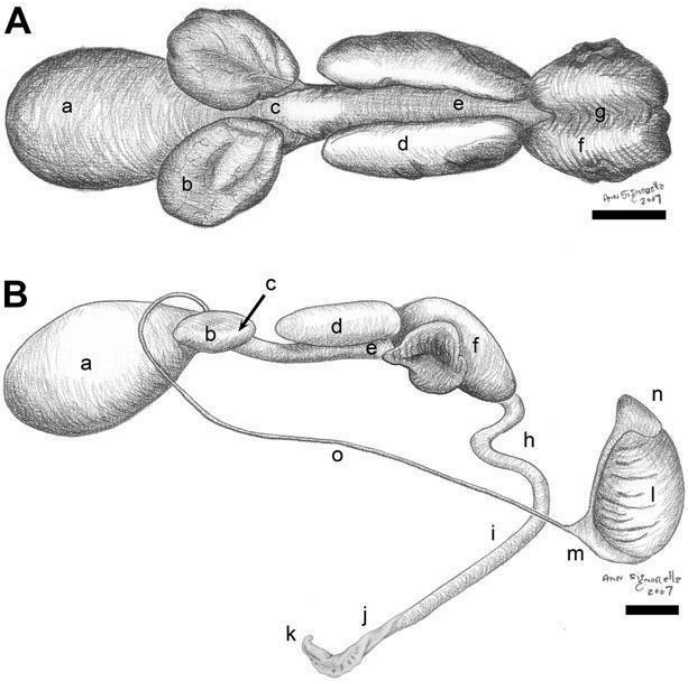


Figure (1.7): (A) Representation of the left lateral view of the reproductive tract of the male Babyrousa with the M. retractor penis removed for clarity. The prostate gland lies ventral to the vesicular glands and is partly embedded in the wall of the urethra. (B) Representation of the dorsal view of the reproductive tract of the male Babyrousa. The prostate gland lies between and ventral to the paired vesicular glands, and is partly embedded in the wall of the urethra. a, bladder; b, vesicular gland; c, position of the prostate gland; d, bulbourethral gland with Musculus bulboglandularis; e, pelvic urethra; f, Musculus bulbospongiosus; g, bulb of penis; h, (extended) sigmoid flexure of the penis; i, body of the penis; j, penis spiral; k, glans penis; l, left testis; m, head of epididymis; n, tail of epididymis; and o, ductus deferens. Scale bars ¼20 mm. Taken from Ziehmer *et al. (*2013).

1.4 Longevity

Meijaard *et al*. (2011) state that babirusa have lived up to 24 years of age in captivity (based on *B. celebensis*) but estimates their life-span in the wild at 7-12 years.

1.5 Zoogeography and Ecology

1.5.1 Distribution

Babirusa are endemic to the islands of Indonesia.

B. celebensis occupy the Island of Sulawesi. This taxonomic identity specifically refers to Babirusa from northern Sulawesi but, pending further investigation, the classification currently also includes individuals that originate from central, eastern and south-eastern Sulawesi and from the neighbouring islands of Muna, Buton and Lembeh.

B. babyrussa originate from the Moluccas archipelago; Buru and Sula (Mangole and Taliabu) Islands. It is thought that it also previously occurred on the island of Sulabesi but is now extinct in that region (Macdonald, 1993).

B. togeanensis are found within the Togian Archipelago, specifically: Batudaka, Togian, Talatakoh and Malenge (Akbar *et al*., 2007) and more recently Kadidiri (Meijaard *et al*., 2011).

A single skull was discovered in central Sulawesi that resembled a subfossil (*B. bolabatuensis)* found on the southwestern peninsula of Sulawesi. Meijaard and Groves (2002b) suggest that this may provide evidence for a fourth extant species however if this is the case then survey results of this region indicate that it is very rare (Riley 2002, Burton 2002).

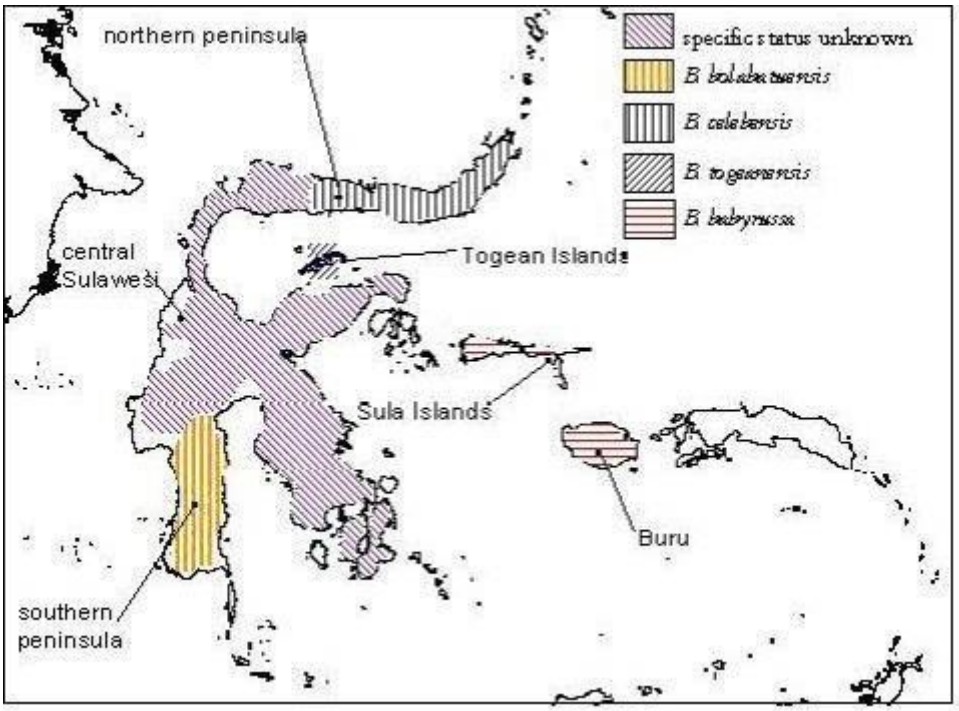


Figure (1.8): Approximate known range of native and introduced populations of Babirusa. Taken from Meijaard and Groves (2002a).

1.5.2 Habitat

Babirusa originate from the tropical climate of Indonesia, generally occupying 'lowland habitats near rivers and water sources' Riley (2002).

Historically, *B. celebensis* inhabited coastal areas but more recent anecdotal evidence and mammal survey reports suggest that populations are mainly located inland on higher ground (Macdonald, 1993). There is limited information regarding the preferred habitat of *B. babyrussa*, but Buru is described as mostly 'tropical lowland evergreen and semi-evergreen rain forest, with tropical montane rain forest occurring above 800 m above sea level' (Meijaard and Groves, 2011). Local people have reported sightings of *B. babyrussa* in hilly or mountainous rocky areas. *B. togeanensis* inhabit the wet forests of the Togian Islands and have been observed in the following habitats: 'mixed gardens, regrowing scrub of former ladang, secondary vegetation in the forest, village edges, freshwater swamps, and beaches' (Akbar *et al*., 2007).

1.5.3 Populations, Threats and Conservation Status

The IUCN Red List indicates the population trend as 'decreasing' for all three extant species of Babirusa.

Adult babirusa have few natural predators, due to the absence of large native carnivores, but young are vulnerable to being taken by pythons and civets (Whitten *et al*., 1987). Their slow reproduction rate and small number of offspring would indicate that babirusa have not historically experienced a high level of predation and therefore have not evolved to produce larger litters (Macdonald, 1993; McDonald, 2006). The mains threat to babirusa populations is from hunting by humans and from habitat loss due to deforestation.

Population information may be based on anecdotal evidence as there is a lack of survey information. Difficulty in recording these species may be due to the secretive nature of these animals, low densities of populations and the tendency for these species to stay in undisturbed forest away from human settlements (Wiles *et al*. 2002).

***Babyrousa celebensis*:**

With a growing demand for wild pig meat in the northern (non-Muslim) areas of Sulawesi, hunting is a severe threat to the northern and central populations of *B. celebensis* (Burton 2002; Milner-Gulland and Clayton, 2002; Lee *et al*., 2005). *B. celebensis* in other areas are suffering habitat loss through deforestation; the total lowland forest loss in Sulawesi is estimated at more than 75% (Riley, 2002).

A study conducted by Riley (2002) indicates that the distribution of Babirusa within Sulawesi may be limited to Bogani Nani-Wartabone National Park and Panua Nature Reserve; located in the western part of the north peninsula. A similar survey carried out in 2001 at the Lore Lindu National Park in Central Sulawesi did not find any evidence of Babirusa despite locals reporting sightings (Burton, 2002). Muna has suffered severe de-forestation and the occurrence of Babirusa on this island is now unlikely. Mammal surveys conducted on Buton also found no evidence of Babirusa (Meijaard and Groves, 2002b, Wiles *et al*., 2002). A study of the trade in babirusa in the North of Sulawesi, where babirusa are hunted alongside the alongside the Sulawesi Warty pig (*Sus celebensis*), was carried out by Milner-Gulland and Clayton (2002) and drew the conclusions that 'dealers drove significantly farther to buy wild pigs, paid more for them and bought fewer in 1997 than 1988' indicating that the population is being depleted.

The IUCN Red list has evaluated *B. celebensis* as 'Vulnerable' however if further research, leads to individuals from central/eastern/southeastern being given a separate taxonomic identity from the population in the northern peninsula then the Red List status will be upgraded. It is estimated that there has been a population decline of more than 30% in *B. celebensis* over past 18 years (three generations) with the current population estimated at less than 10,000 adults (Macdonald *et al.,* 2008). A further decline of more than 10% over next three generations is predicted.

Babyrousa babyrussa:

Although this species is hunted for meat by local non-Muslim communities, the main threat faced by *B. babyrussa* is habitat loss. Large scale commercial logging has degraded forests in the northern areas and coastal lowlands of Buru, however two large forest blocks remain and the current threat to this area is low (Wikramanayake *et al*., 2002). Taliabu has suffered some logging in the lowlands but remains mostly forested however Mangole has been heavily degraded.

There is very little information available regarding the population status of *B. babyrussa* but the IUCN Red list has evaluated this species as 'Vulnerable' due to its distribution being limited to less than 20,000km²; (Buru Island and Sula Islands). The population trend has been assessed as 'decreasing' with the number of mature individuals is expected to decline (Macdonald *et al.,* 2008).

Babyrousa togeanensis:

One of the main threats faced by *B. togeanensis* is habitat loss due to forest clearance and fires; two thirds of Malenge Island's forest was damaged by fire in 1998 and, although no babirusa carcasses were found, the damage may have had an impact on food availability. Hunting for food is not frequent due the small number of non-Muslim village communities but hunting is an issue where this species are perceived as a threat to crops. Predation by dogs is also a concern (Ito *et al*, 2005; Akbar *et al*., 2007).

The IUCN Red list has evaluated *B. togeanensis* as 'Endangered' due to its occurrence being limited to the Togian Islands over a range of less than 5,000 km² with a population size estimated at less than 2,500 adults. The population trend of this species has been assessed as 'decreasing' with a continued decline in the number of mature individuals (Macdonald *et al.,* 2008). The population of *B. togeanensis* in 1978 was estimated as 500-1000 individuals (Selmier, 1983) and an interview survey carried out more recently would appear to suggest that there has not been a sharp population decline between 1995 and 2000 (Akbar *et al*., 2007).

1.5.4 Conservation Actions

Babirusa have been afforded full protection by Indonesian Law since 1931 (Dammerman, 1950; Setyodirwiryo, 1959) and, although Macdonald (1993) states that international trade has not been a major threat to populations in recent times, this species has been listed on Appendix I of CITES since 1982. Conservation measures such as: checkpoints to examine vehicles, law enforcement, swift prosecution and public education are being implemented by the local authority (McDonald, 2006).

For *B. celebensis* specifically, protection is given in varying degrees within the following areas of Sulawesi: Bogani Nani Wartabone National Park, Lore Lindu National Park, Rawa Aopa Watumohai National Park, the Nantu Wildlife Reserve, the Panua Nature Reserve, Morowali Nature Reserve (Macdonald, 1993; Alvard, 2000, Riley, 2002; Wiles *et al*., 2002). However the species is still hunted in these areas. The founders of captive breeding populations are likely to have originated from northern Sulawesi but there is ongoing genetic research. An international studbook exists for the global captive population and the European Association of Zoos and Aquaria (EAZA) and the Association of Zoos and Aquariums (AZA) contribute to captive breeding programmes for the species cooperating with the South East Asian Zoos Association (SEAZA).

Within the range of *B. babyrussa* three areas of protected habitat exist. On Buru Island, 1430 km² of rainforest is protected within the areas of Gunung Kelpat Muda and Waeapo combined; Gunung Kelpat Muda is also an animal sanctuary by local custom. One protected area of 700 km² exists on Taliabu at Pulau Taliabu (Wikramanayake *et al*., 2001).

For *B. togeanensis,* Kepulauan Togean National Park within the Togian Islands has been protected since 2004, incorporating 336,773 ha of sea and 25,832 ha of land.

1.6 Diet and Feeding Behaviour

1.6.1 Food Preference

The anatomy of the babirusa digestive system is similar to that of other pig species but different in the apparent ability to support fermentation in the foregut, though the stomach of the babirusa is not ruminant. Babirusa are therefore most widely thought to be non-ruminant foregut fermenters, rather than hindgut fermenters (Sutherland-Smith, 2015; Leus, 1996).

Based on the digestive anatomy of the babirusa (see section 1.3.2 *Digestion*), it can be assumed that babirusa in the wild have a diet that is mainly made up of fruits and leaves, with only a little grass (Leus, 1996). Fruit is especially important in their diet and analysis of the stomach contents and faeces of wild babirusa indicated that the main part of the babirusa diet is fruits and seeds (Meijaard, *et al.,* 2011; Clayton, 1996). It has been implied that babirusa are dependent upon large fruiting trees for their habitats in the wild, as deforestation/clearing will eliminate babirusa from that area (though this could also be attributed to human disturbance and increased hunting pressure) (Meijaard, *et al.,* 2011). Leus (1994) details an extensive list of tree species with potential fruit sources for the babirusa in the wild. In the stomach and faecal samples of the wild babirusa, the following species/genera of fruit/seeds were found and identified: *Mangifera* sp. (mango and its relatives - Anacardiacae); *Dracontomelum mangiferum* (Anacardiacae), *Pothoidium lobbianum* (Araceae), *Dillenia serrata* (Dilleniaceae), *Pangium edule* (Flacourtiaceae), *Calophyllum* soullatri (Guttiferae), *Agloia* sp. (Meliaceae), *Lansium* sp. (Meliaceae), *Artocarpus* sp. (Moraceae), *Ficus* sp. (Moraceae), *Streblus* sp. (Moraceae), *Arenga pinnata* (Palmaceae), *Calamus* sp. (Palmaceae) and *Alpinia* sp. (Zingiberaceae) (Clayton, 1996). In the wild, the observation was made that the babirusa mainly consumed the fruit of pangi (*Pangium edule*) (Tulung *et al.,* 2013). The composition of nutrients in different fruits/seeds consumed by the babirusa in the wild can be seen in Table 1.1.

Table (1.1): Nutrient composition of several feed sources of Babirusa (*Babyrousa babyrussa celebensis*) in their habitat (on a Dry-Matter Basis): taken from Tulung *et al. (*2013).

DM = dry matter; CH = carbohydrate; Ca = calcium; P = phosphorus.

Feedstuffs	Nutrients, assayed						
	Protein (%)	Fat (%)	Fiber (%)	CH (%)	Energy (Cal)	Ca (%)	P (%)
Pangi :							
Pulp	17.70	52.08	31.50	12.33	165.84	0.40	3.15
Seed	18.05	43.86	30.02	13.06	520.98	0.20	6.43
Rao/Dao	6.24	3.34	28.12	28.34	168.38	0.74	1.06
Loyo/Leu	5.77	4.07	31.48	14.46	74.17	0.73	--
Seho hutan	14.81	3.06	22.55	18.85	162.18	0.85	1.44
Lamuta	6.54	4.75	46.14	25.85	172.31	0.20	0.34
Palango	14.82	3.86	23.16	14.44	151.78	0.57	2.78

The general anatomy and physiology of the babirusa digestive system suggests that they are omnivorous and although knowledge of diet composition of babirusa is the wild is limited, in both captivity and the wild they are reported to

consume fruits, leaves, roots, invertebrates and animal matter (Meijaard *et al.,* 2011; Leus and Morgan, 1995). The study on faecal matter and stomach contents of wild babirusa showed that as well as fruits and seeds, wild babirusa consume animal material, leaves, grasses and soil and rock fragments (Clayton, 1996). One observational wild study came to the assumption that mushrooms/fungi and insect larvae were also consumed by babirusa to aid their protein intake (Tulung *et al.,* 2013).

The presence of soil/rock fragments in the diet of wild babirusa could be attributed to their use of salt licks. Babirusa have been observed in the wild to gather at these volcanic salt licks and consume large quantities of the salt water there, lick the stones and eat the soil (Patry *et al.,* 1995; Clayton, 1996). The mineral composition of some of the visited salt licks (both water and soil) can be seen in Table 1.2 and suggests that because these areas contains higher quantities of specific minerals, the mainly frugivorous wild babirusa diet is lacking in some specific minerals (Patry *et al.,* 1995; Clayton, 1996).

Table (1.2): Chemical analysis of the water of the "Marisa" salt lick and the sediment of the "Lantolo" salt lick in North Sulawesi (for precise location see Patry *et al,* 1995). Samples collected by Mr. Maurice Patry. Analyses carried out by the Laboratoire Municipal de Brest, 16 rue A. Ribot, 29200 Brest, France, (1989).

Components	**Water salt lick**	**Sediment salt lick (Results on DM basis) ***
pH	7.4	
Loss after heating at 550°C		5.3 %
Insoluble hydrochloric		83.0 %
Calcium (Ca)	500 mg/l	10.5 g/kg
Magnesium (Mg)	170 mg/l	6.9 g/kg
Ammonium (NH_4)	0.33 mg/l	
Sodium (Na)	580 mg/l	0.70 g/kg
Potassium (K)	8.9 mg/l	0.50 g/kg
Manganese (Mn)		0.52 g/kg
Iron (Fe)		33 g/kg
Carbonate (CO_3)	0 mg/l	
Bicarbonate (HCO_3)	49 mg/l	
Sulphate (SO_4)	2740 mg/l	< 0.2 g/kg
Nitrite (NH_2)	0 mg/l	
Nitrate (NH_3)	< 0.1 mg/l	
Phosphate (PO_4)	< 0.01 mg/l	

1.6.2 Feeding

Most feeding is carried out through foraging behaviour, which largely consists of them moving along with their nose close to the ground whilst rooting through loose soil and leaf litter (Leus and Vercammen, 1996). Rooting through substrate will not be carried out if the ground is compact or dry, as babirusa lack the rostral bone that provides support for the tough connective tissue plate of the rhinarium of their snout, limiting their ability to root with their noses compared with other pig species (Leus *et al.,* 1992; Leus and Vercammen, 1996; Macdonald, 1993). Captive babirusa

have also been observed to select specific plant parts such as flower buds, grass ears and bramble leaves (Leus and Vercammen, 1996). The jaws and teeth of the babirusa are strong enough to easily crack nuts and seeds during feeding (Meijaard *et al.,* 2011).

In captive enclosures, grasses do not seem to be patchy and grazed but babirusa have been observed to graze and eat cut grass which is offered to them, even though they cannot be described as grazers and due to their reduced digestibility of grass compared to that of the domestic pig, it is highly unlikely that grass constitutes a vital part of the babirusa diet (Leus, 1996). Babirusa have also been observed in captivity balancing on their hind legs alone or supported in order to browse leaves off lower lying tree/bush branches (Macdonald and Leus, 1995).

In captivity, babirusa have been observed to hunt and eat small mammals and birds such as mice and pigeons that have accidentally entered their enclosures, suggesting that similar behaviour may be performed in the wild (Leus *et al.,* 1992; Meijaard *et al.,* 2011). Babirusa have also been observed to chase and eat juveniles that have accidentally entered their enclosure (Leus *et al.,* 1992).

In the wild, video recordings have shown babirusa and Sulawesi macaques (*Macaca nigra*) in close proximity to each another, suggesting that babirusa may consume the remains of the fruit that is partially eaten by the macaques (Leus, 1996).

1.7 Reproduction

The sex determination system of XX (female chromosome) / XY (male chromosome) is applicable to the babirusa. Like most other suids, babirusa have a diploid chromosome number of 38 in total (Macdonald, 1993). Understanding of the reproductive biology of babirusa is limited (Macdonald and Leus, 1995), despite its potentially positive implications for conservation of the species.

1.7.1 Sexual Maturity

Sexual maturity of male and female babirusa in captivity is usually 5-10 months (Meijaard *et al.,* 2011). The age at which babirusa become sexually mature in the wild may not be until they are more than one year of age, due to the constraints on the animals nutrition influencing this in the wild (Macdonald, 1993).

The youngest female with observed first oestrus was 190 days old (MacLaughlin & Thomas, 1991). Successful rearing of offspring has been observed as young as 1 year old and as old as 14 years old (Fischer, 2002). Male babirusa have bred successfully up to around 17 years of age in captivity (Ziehmer *et al.,* 2013).

1.7.2 Seasonality of Cycling

In captivity there does not seem to be a breeding season as babirusa births occur throughout the year, and females could produce two litters per year (Plasa, 1990; Macdonald, 1993). A faecal study on captive babirusa amongst other suid species showed that there is non-seasonal ovarian cyclicity in females (Berger *et al.,* 2006). There is a report that babirusa in the wild produce young in the winter months (Guillemard, 1886), however a more recent study based on

observations of social structure in babirusa concluded that there is no breeding seasonality based on the proportion of groups with young piglets in the wild at different times of year and the lack of seasonal affiliation of males with females (Clayton and MacDonald, 1999).

1.7.3 Reproductive Cyclicity in Females

Babirusa are a polyoestrus species, meaning that they will come into oestrus and become receptive to males multiple times throughout the year (Chaudhuri *et al.,* 1990). There is no evidence for seasonality in the oestrus cycles of female babirusa, based on the lack of evidence of seasonal breeding in both captive and wild populations (Plasa, 1990; Macdonald, 1993; Berger *et al.,* 2006, Clayton and MacDonald, 1999).

Reports of the oestrus cycle length in female babirusa range from 28-42 days, though more recent endocrine studies suggest a narrower parameter of between 35-37 days (Macdonald, 1993; Chaudhuri *et al.,* 1990; *Berger et al.,* 2006). Oestrus lasts approximately 2-3 days with females not being receptive to males at all other times and not allowing them to mount (Macdonald, 1993; Leus *et al.,* 1992).

In captivity, females generally begin cycling again within three months of giving birth (Macdonald, 2005). Due to this, captive females can produce two litters per year, with a female at the St. Louis Zoo producing four sets of twins with interbirth intervals ranging 9.5-10 months (Macdonald, 1993; Fischer, 2002). Litters are likely to be produced less frequently in the wild than in captivity due to the effect of environmental factors such as diet on the interbirth interval (Macdonald, 1993).

1.7.4 Gestation Period

Gestation period can range from 150 to 164 days, with a minimum reported duration of 125 days and a maximum reported duration of 171 days (Berger *et al,* 2006; McDonald, 2006; Macdonald, 1993).

1.7.5 Parturition

Captive babirusa tend to give birth overnight, with a study carried out at Antwerp Zoo showing that all but two out of sixteen births during the study period took place between the hours of 18:00 and 8:00 (Leus *et al.,* 1992).

Average litter size is 1-2 piglets, consistent with the relatively small size of the female reproductive tract (Meijaard *et al.,* 2011, Macdonald and Leus, 1995). There are also some instances of triplets being born in captivity and one unconfirmed report of a female babirusa producing four foetuses in the field (Patry, 1990). The below table (1.3) showing probability of each litter size was created at the Population and Habitat Viability Assessment Workshop in Cisarua, Indonesia in 2006 using a software modelling package called VORTEX.

Table (1.3): Population biology and modelling of the babirusa; Litter size distribution in a given year (Leus. et al, 1996)

Litter Size	% of females at breeding ages in a given year
0	20
1	46
2	31
3	3

Birth weight has been reported as less than 800g, but up to approximately 1kg (Meijaard *et al.,* 2011, Macdonald, 2000). Intervals between births in the same litter average around 30 minutes, but intervals of 4 minutes and up to 90 minutes have been recorded (Leus *et al.,* 1992; Saville and Hartley, 2000). Piglets are uniformly brown in colour when born, rather than striped like most other wild pig species (Macdonald, 1993).

Neonatal exams are not performed in many zoos due to their great risks to the mother and young. To carry one out, the benefit of the exam must be considered against the potentially detrimental effects to the dam based on the stress of removing the young, especially when females are very protective of the piglets (observations of aggression towards keepers) during the first few weeks of their life. If the exam would contribute to maternal anxiety and stress it should best be avoided because of the risk of infanticide. If a dam is assessed as being sufficiently calm to carry out an exam with minimal risk to the young, it should be carried out within the first 24-72 hours of life and all necessary preparation of equipment etc. should be carried out in advance to ensure that the procedure is as quick and harmless as possible. Once the young have be separated off they need to be taken into a separate room from the female to try and minimalise her stress from hearing their calls. This would provide an opportunity to carry out procedures such as weighing, sexing, vaccinations and microchipping. Blood should never be taken at this stage as, depending on the location used, the procedure would either take too long or possibly lead to haemorrhage and death in the young. Once the procedures have been undertaken, the young must be reunited with the female as soon as possible and all keepers/vets leave the building to minimalise any further stress (Fischer, 2002).

1.7.6 Development

After birth, neonates have been observed trying to stand and walk round straight away and are more precocious than other suid species (Leus *et al.,* 1992; Nowak, 1999).

Suckling usually begins within 30 minutes of birth, as colostrum provides a thermogenic substrate for juveniles and so needs to be consumed rapidly as neonates are very susceptible to heat loss (Macdonald, 2000). Young are reported to consume small amounts of solid food at 3 – 10 days old, which gradually increases in amount with age (Schmidt, 1990; Nowak, 1999; Leus *et al.,* 1992). Weaning of young is completed at 6-8 months (Schmidt, 1990).

Females in captivity have been observed to be very aggressive and defensive to keepers during the first nine days after parturition, attacking other animals and keepers when they came in close proximity to the piglets (Leus *et al.,* 1992).

1.8 Behaviour

1.8.1 Activity

Babirusa are a diurnal species, more active in the morning and late afternoon than at night (Nowak, 1999). In captivity, an observational study concluded that babirusa are diurnal, showing a greater range of activity during the day and sleeping at night (Leus *et al.,* 1992). In the wild, a study analysing the use of salt licks by babirusa found that night observations also showed minimal activity (Clayton and Macdonald, 1999).

Babirusa in captivity begin foraging just before dawn after they wake (Leus *et al.,* 1992). Most of the morning behaviour consisted of excreting/defecating waste and foraging, though rooting through substrate was not carried out if the ground was compact or dry (Leus *et al.,* 1992). Unlike other suid species, babirusa do not have the rostral bone that provides support for the tough connective tissue plate of the rhinarium, limiting their ability to root with their noses (Macdonald, 1993). Babirusa will also stand up on their hind legs in order to browse tree leaves (Macdonald and Leus, 1995).

After feeding, the foraging behaviour declined and animals either wallowed or rested until sunset when they were mostly asleep (Leus *et al.,* 1992). In the wild, wallowing in mud is a social behaviour carried out in groups (Tulung *et al.,* 2013). Mud wallowing is common in all pig species as it aids thermoregulation and skin care and forms a barrier against insects and parasites; the mud is left to harden then removed by rubbing against trees (McDonald, 2006; Macdonald and Leus, 1995). In the wild and in captivity, males wallow more often than females (Macdonald, 2005). Male babirusa in the captive study also tended to bathe in pool often, almost to the exclusion of females and up to a couple of hours at a time (Leus *et al.,* 1992). Babirusa are also known to swim well and cover large distances, with one observation recorded of a male in the wild swimming approximately 500m across a lake (Melisch, 1994). If no wallowing or bathing opportunities are provided in captivity, the skin of the babirusa can become dry and cracked (Leus *et al.,* 1992).

Although this activity is based on observations both in captivity and in the wild, it is important to point out that behaviours are highly variable between individuals (Leus *et al.,* 1992). For example, in this captive study the dominant male was seen to spend some of the afternoon time mating when most other individuals were resting and the elderly previous dominant male spent more time than the other individuals resting (Leus *et al.,* 1992).

1.8.2 Locomotion

Babirusa, like all other wild pigs, are quadrupedal. However, they have been observed to be bipedal in some behavioural situations (Macdonald and Leus, 1995). This includes when males engage in an agonistic behaviour termed ‘boxing’, in which males rear up onto their hind legs in a bipedal stance for 2-5 minutes at a time, but this can go on for up to 20 minutes (Macdonald *et al.,* 1993). Females do not engage in the same behaviour but have been observed balancing on their hind limbs in order to browse tree leaves in captivity (Macdonald and Leus, 1995). Although males can move around whilst on their hind legs engaging in this boxing behaviour, this is due to the pushing and shoving of the males (Macdonald *et al.,* 1993) and would be a result of each male propping up the other rather than a form of locomotion.

1.8.3 Predation

There does not seem to be many, if any, natural predators of babirusa in the wild (Macdonald, 2005). Though younger animals may be predated on by pythons (*Python reticulatus* and *P. molurus*) and Sulawesi civet (*Macrogalidea musschenbroeckii*), it is thought that predation is not a great threat to this species as they have a small litter size (1-3) and so do not appear to be adapted to high predation of young (Whitten *et al.,* 1987; Macdonald, 1993).

1.8.4 Social Behaviour

In the wild, social behaviour by babirusa was carried out every day, usually in the morning whilst foraging and wallowing (Tulung *et al.,* 2013).

Group Structure

In the wild, studies have been carried out on group sizes of the babirusa based on their use of salt licks, finding that the largest group size was 8-13 individuals, which seems to be on the lower side of group sizes amongst suids (Patry *et al.,* 1995; Clayton and Macdonald, 1999). The largest proportion of babirusa sightings were mostly solitary males and matriarchal groups comprising of adult and juvenile females (Clayton and Macdonald, 1999). Adult males were seen with adult females and their young occasionally, and pairs of adults were rarely seen (Clayton and Macdonald, 1999). Adult males were mainly solitary, only affiliating with females when they were in oestrus, and never forming bachelor groups (Clayton and Macdonald, 1999; Patry *et al.,* 1995). Based on the group structures seen, like most other suids, babirusa seem to be polygynous in the wild (Clayton and Macdonald, 1999).

The presence of relatively small group sizes compared to other suids, may be contributed to by the generally small litter size of the babirusa (Patry *et al.,* 1995). In the wild, females were seen to be travelling in groups with young from two separate litters, which supports the strong bond between females and young shown in captivity, though young from previous litters do not appear to have a clear role for staying with the female (Patry *et al.,* 1995). Matriarchal groups did not have an increased number of juveniles when there was an increased number of adult females, therefore the assumption can be made that there is some kind of reproductive suppression amongst females, which is poorly understood in the wild pigs (Clayton and Macdonald, 1999).

Dominance

In captivity, both dominant and subordinate behaviours have been observed between males and females (Leus *et al.,* 1992). Adult males were ranked based on factors such as weight and size and adult females were subordinate to males, displaying submissive behaviour such as retreating, lowering their head and shrieking when engaging in interactions (Leus *et al.,* 1992). Sub adults were the third in ranking, though they would engage in social play with both males and females and even the dominant male (Leus *et al.,* 1992). When adult males were place in adjacent pens and could see each other they displayed and rushed at the fence at each other, leading to reorganisation of the captive animal enclosures to prevent males being next to each other again (Leus *et al.,* 1992). Dominant and subordinate behaviours have also been observed at salt lick aggregations in the wild (Patry *et al.,* 1995).

Agonistic Behaviour

Agonistic behaviour has been observed both in captivity and in the wild, and one captive study has allowed the different agonistic behaviours to be categorised and named (Macdonald *et al.,* 1993; Patry *et al.,* 1995). Below is the different behaviours for male-male interactions as originally described in Macdonald *et al.,* (1993):

Threat at a Distance

Dominant male merely looks at or tosses/thrusts head up as a threatening behaviour to another male, causing the submissive to act more cautiously until an actual threat was perceived, then the submissive animal would lower his head and make a rumbling squawk.

Surprise Rush

Males suddenly charge, unprovoked, at other males, causing the submissive male to turn to face the charging male and lower his head and utter the rumbling squawk sound of submission. In the very rare instances when the charge was carried through, the males' canines would clash and if the attacked male was not submissive the attacker would then become the attacked.

Nose in the Air

Two or more males would approach each other with their heads high and their noses in the air, they would then feign forwards at each other and this interaction would develop further or they would walk away.

Head under Jaw Submission

When two males are near each other, the submissive male would angle itself to the dominant and position its nose under the jaw of the dominant and made a very short squawk or long rattling stream of sound which increased with perceived threat level. The dominant made a sucking sound and both males circled each other with the dominant nipping the subordinate. Usually the dominant was the one to break off the confrontation.

Front Half Supported

Two males would approach and manoeuvre themselves into a position where the dominant animal had his head/chest area totally supported by the subordinates head at an angle to each other. This would be held for a variable amount of time and the lower animal would sometimes make the subordinate squawk noise. The superior male would end the behaviour by dismounting and walking away.

Boxing

Only a small proportion of interactions ended in boxing behaviour. Usually 'nose in the air' would progress the males to a standing position on their hind legs facing each other and would begin to paddle each other. This behaviour could last for up to 20 minutes and could cover large distances. Both males would keep their snouts as high as possible and the superior male seemed to be the one who raised its nose the highest.

The Lying Lunge

Whilst lying down, the male would occasionally swing his head up and round towards an approaching animal which looked like it was about to join him. The subordinate would utter a loud, short shriek and would probably get a nip on the nose, flank or leg.

Between males and females where either could be dominant, 'threat at a distance', 'surprise rush' and 'the lying lunge' behaviours were seen (Macdonald *et al.,* 1993). 'Head under jaw submission' with squealing vocalisation was seen as a reproductive behaviour and perceived threat (Macdonald *et al.,* 1993). The female tended to nips the legs of the male both in attack and defence (Macdonald *et al.,* 1993). Rarely, the male and female would progress from 'nose in the air' into boxing (Macdonald *et al.,* 1993). In most adult male/adult female interactions the male was dominant, whereas the female was more dominant against sub-adult males (Macdonald *et al.,* 1993).

Between adult females, 'distant threat', 'surprise rush' and 'the lying lunge' have been seen, often with the dominant female chasing the subordinate (Macdonald *et al.,* 1993). 'Nose in the air' and 'head under jaw submission' were rarely seen and boxing and 'front half supported' were never witnessed between females (Macdonald *et al.,* 1993). Female interactions were often violent and fast and noisy, and in most interactions the large female was dominant. When adult females were in adjacent enclosures, they either ignored each other or showed aggression (Macdonald *et al.,* 1993).

There is no observational evidence that the elaborate teeth of the babirusa are used as a weapon during agonistic interactions between males (other than accidental collision), and they seem to be shallow rooted and brittle in structure which supports this (Macdonald and Leus, 1995; Macdonald *et al.,* 1993; Meijaard *et al.,* 2011).

Communication

Vocalisations are used by babirusa as part of submissive behaviour (See above) (Macdonald *et al.,* 1993). Particularly in female-female interactions which are reported to be very noisy (Macdonald *et al.,* 1993). Mostly it seems that communication is mainly done via stance and movements rather than vocalisations (Macdonald *et al.,* 1993). There are some vocalisations between males and females as part of their reproductive behaviour; males will follow males they wish to mate and make a deep clucking noise at a frequency of 3-5 per second (Leus *et al.,* 1992). If the female turned to face the male during his pursuit, she would vocalise in a continuous stream of sound towards him (Macdonald *et al.,* 1993). Both male and female make short staccato clucking noises during mating, but the male is louder (Macdonald *et al.,* 1993). Females also make some vocal communications after birth, for example, if she feels threatened (i.e. by keeper presence) she will make a low pitched long noise (Macdonald *et al.,* 1993). Females also vocalise with short clucking noises when young piglets venture too far away (Macdonald *et al.,* 1993). Though babirusa have relatively poor vision, they will use body posture for dominance displays and threats at close range (Meijaard *et al.,* 2011).

There is also evidence of chemical communication in babirusa. Ploughing behaviour has been observed and categorised in babirusa as a completely unique behaviour to the babirusa amongst other suids (Leus *et al.,* 1996). This behaviour is almost exclusively performed by males and performed for the longest amount of time in the enclosure of other adult males or in a freshly cleaned enclosure (Leus *et al.,* 1996). The enclosures in which this behaviour was evaluated had a sand substrate and the ploughing behaviour consisted of the individual lowering its snout until the sand was at eye level, kneeling down and pushing forward while canting left and right, hence 'ploughing' the sand (Leus *et al.,* 1996). Before this ploughing behaviour, saliva is accumulated in the corners of the individuals mouths as a foam and this disappears at the end of the activity (Leus *et al.,* 1996). This saliva and a secretion from the intra-orbital region were analysed and found to contain an unknown substance with steroidal properties (Leus *et al.,* 1996). The presence of steroids in the secretions and the fact that the ploughing behaviour is self-reassurance (new environment) and aggression/threat response (another male enclosure), support the idea that this behaviour is a form of scent-marking and chemical communication (Leus *et al.,* 1996).

1.8.5 Sexual Behaviour

In captivity, males were observed to check for oestrus in all the females first thing in the morning (Leus *et al.,* 1992). This involved the male nosing the perineal region of the females and the females would respond by arching their back and urinating/defecating, which the male would then nose and mouth (Leus *et al.,* 1992). When a female comes into heat, the male will follow her, keeping his nose close to her perineal region (Leus *et al.,* 1992). If a subordinate male is pursuing a female in oestrus, the dominant male will immediately take over and abandon the pursuit if the female is not in oestrus (Leus *et al.,* 1992). Females will sometimes hide and lie down in an attempt to prevent mating when coming into or in oestrus (Leus *et al.,* 1992). In most instances in captivity, the female will vocalise and turn to face the male at some point and nose-to-nose the male, progressing to her pushing her snout under his chin, nibbling his upper legs and nuzzling and licking his face (Leus *et al.,* 1992). It was the female who then terminated this behaviour and walked away (Leus *et al.,* 1992). Occasionally, the male would lie in front of the female and she would then nuzzle and lick him, to which the male seemed to adjust his body position to allow her easier access to his front side in response (Leus *et al.,* 1992). These behaviours could then be repeated several times (Leus *et al.,* 1992).

Eventually, the male would attempt to mount the female by nosing her pereneal region and placing his chin on her lumbar region and if the female was not ready to mate, she vocalises and wriggles out from under him (Leus *et al.,* 1992). If in full oestrus, the female would stand still to be mounted after feeling the males chin on her back (Leus *et al.,* 1992). In captivity, 1 mating was observed to last about 15 minutes; with 4 mounts lasting up to around a minute each time and mating's were repeated throughout the day (Leus *et al.,* 1992). After copulation, the male will dismount and guard the female for around 30 minutes before leaving her (Leus *et al.,* 1992). In one zoo males were other males were then observed to mate the female in oestrus after the dominant male, though the female showed no preference (Leus *et al.,* 1992).

Section 2: Zoo Management

2.1 Enclosure

2.1.1 Introduction

It is important that babirusa in captivity have access to both and indoor and outdoor enclosure. There ideally needs to be more than one den in the house and more than one outdoor enclosure to allow for separation/management of individuals. It is also important that the enclosure in a captive environment provides cover and opportunities for individuals to shelter from public view. Enclosures should aim to look as naturalistic as possible and encourage natural behaviours in the species. There should also be specific adjustments made to the enclosure in preparation for births, see section 2.4.3 *Pregnancy*.

2.1.2 Boundary/Layout

Interior walls of the house may be constructed from breeze blocks/concrete covered with wooden panels. Interior den walls may be approximately 1 m high partitions constructed from breeze blocks covered with wooden panels, or they may be full stabling with a solid bottom half and barred top half. The bottom 50 cm (at least) of any interior wall must be completely solid to prevent injuries to feet/legs or injury to young babirusa. There should be no gaps anywhere in the enclosure (doors, slides, bars, etc.) that have the potential to trap babirusa or their tusks. Ideally, there should be a slide from each den to outside that can be operated from the keeper area for ease of management. If this is not possible, there should be a minimum of two access doorways outside that can be left open to create a run around; always providing an escape route in the case of aggression between individuals. Slides may be manual or winch operated, depending on the indoor arrangement of dens. Internal slides may be similar, and should be left open if they link two outdoor slides to form part of the run around. Internal slides/doorways should be included for ease of separating individuals for feeding or training. A den that is set up for birthing should have outdoor access to a separate corral for when the piglets are a few weeks old, and should include a creep/nest area with some visual barrier. All indoor enclosures should be designed in a way that provides ease of management of the babirusa and ease of cleaning of the areas. Another useful feature that can be included in the babirusa house is a crate area specifically designed to hold a babirusa crate. At Chester Zoo, this has been included between two dens so the crate can be inserted and used as a tunnel or training area when not needed, allowing individuals to be easily crated up for internal moves/transfer.

There are many different types of outdoor boundary that have been used successfully for babirusa in captivity. The minimum height that should be achieved in a babirusa enclosure it at least 1.2m, to prevent the babirusa from jumping out. Fencing can be used (chain link, wooden panels, etc.) or a gently sloped dry moat with a vertical outer retaining wall rising directly from the moat (sometimes referred to as a ha-ha) can be used as a barrier also. Water moats would not be a sufficient barrier as babirusa can swim. Electric fencing may be used as a secondary barrier, especially around areas of planting as protection from foraging. Boundaries should be checked daily by keeping staff as babirusa can dig. Extra care should be taken when there are young in the enclosure that any gaps in the boundary are not large enough to allow escape.

2.1.3 Substrate

Getting the correct substrate is extremely important for babirusa as they are prone to foot problems which if unchecked will lead to further problems such as lameness or infection. Substrates should be non-abrasive in order to decrease unnecessary wearing of the hoof (Miller & Fowler, 2014); straw and shavings make good bedding materials. Due to the sensitive nature of the feet, positioning of large stones or rocks needs to be carefully considered as does the design of fencing and barriers due to babirusa's ability to jump and climb. Any type of overlay, such as rubber matting needs to be carefully considered as there will be the potential for the animal to chew and possibly ingest it. Although babirusa will nose soft soil and muddy areas in search of food they do not exhibit the same type of rooting behaviour that is seen in other pigs due to physiological differences in the rostrum (IUCN Red List, 2016), therefore hard compact ground is not recommended for outdoor enclosures.

2.1.4 Furnishings and Maintenance

Furnishings within an enclosure is important for any animal, they can provide enrichment, shelter and places to hide from view, having them will also provide means for the animal to display natural behaviours. Shelter can be provided in the form of a structure or with planting (see *Appendix I* for a list of toxic trees and plants) trees within the enclosure should be protected from damage, for this Chester zoo use a mesh covering around the base of the tree. Other natural behaviours such as wallowing and bathing will require access to water, pools can be provided within the enclosure to facilitate these behaviours.

Female babirusa construct nests on the lead up to giving birth (Macdonald 2000), extra straw and browse should be provided in the enclosure on the lead up to parturition, allowing the female to display this innate behaviour will reduce stress during pregnancy.

2.1.5 Environment

Indoor enclosures should always be heated for babirusa. The indoor temperatures of the house should be kept at around 18^{o}C and should be increased to around 22^{o}C if there if a female who is due to give birth or who has young piglets. There are different ways in which the house can be heated; heat lamps, pig mats, heating systems and hot water pipes under the floor. Extractor fans can be used as a means of regulating the temperature in indoor enclosures along with a thermostat. As the babirusa is a tropical species, humidity is another important factor of their husbandry. Artificial heating systems can dry out their skin and cause cracking, creating the need for keepers to apply aqueous cream to the babirusa regularly. Under floor heating may reduce the drying effect and humidity can always be increased by hosing down indoor areas; always taking care that this does not create a slippy surface where individuals may injure themselves. Arco strips should be attached the outdoor slide doors to try and prevent heat loss in the house when the slides are open. Nesting areas should also have a heat lamp suspended above to ensure that piglets do not become too cold as they are likely to be poor thermo-regulators. Straw bedding should also be provided all year round for extra warmth at night. Ventilation is not a major problem when only keeping a couple of individuals in one house and leaving slides open during the day will aid this naturally.

Natural lighting is always available on the paddock and sky lights may be incorporated into indoor houses to aid light levels during the day. Artificial lighting should be available in the indoor house during the dark times of year.

Outdoor enclosures should be naturalistic, with appropriate substrate and sufficient plan ting to encourage natural behaviours. There should be a separate outdoor corral for dams with young, separation and catch ups for veterinary procedures/moves, which should ideally be off show to the public. Babirusa should not be allowed access outside in extreme weather (snow/ice) and keepers should always leave outdoor slides open when they are outside to allow them access indoors if the weather becomes too cold. During cooler times of year, babirusa should be kept indoors; during warmer months the males and female may have outdoor access at night on alternative nights.

2.1.6 Dimensions

Indoor dimensions can be very variable between institutions and may be variable between dens in the same house due to the layout. Institutions should aim for den sizes from approximately 7-8m^2 in size, with ideally one pen per adult individual within the house.

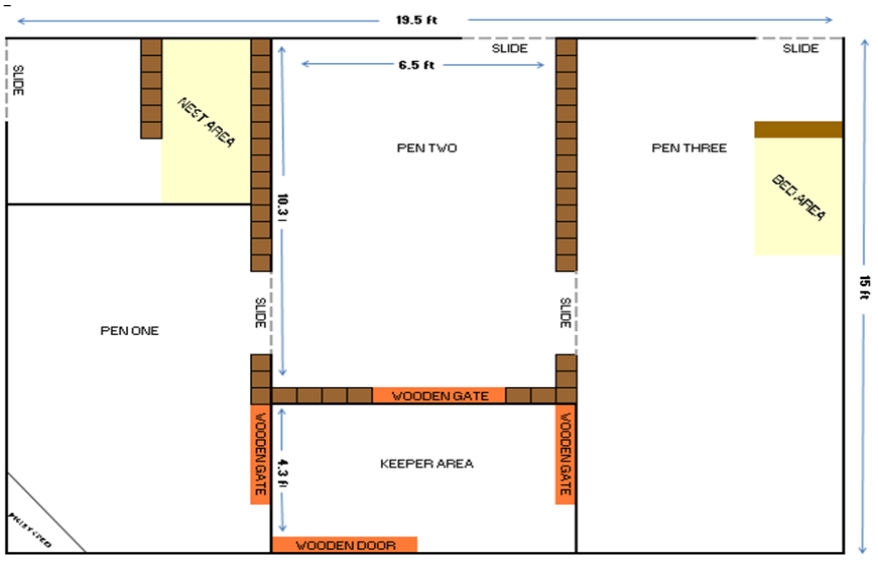


Figure (1.9) Example of indoor enclosure at Chester Zoo which has the potential to hold 1.2 adults and up to 4 offspring.

Outdoor enclosures need to be of a large enough size to encourage natural behaviours and have enough room to accommodate a breeding pair, a single sex group or a mother with piglets with their own opportunities to forage and avoid aggression. There should also be enough room in the enclosure for introductions of new individuals. Outdoor enclosures should aim to allow around 350m^2 per animal.

Figure 2.1 Examples of enclosures from Chester Zoo:
a) Off show corral area for catchment and dams and young.
b) Indoor enclosure showing low, partitions between dens and keeper area.
c) Outdoor enclosure with natural grass substrate and natural planting.
d) Outdoor enclosure with 4ft boundary constructing of public viewing glass.
e) Outdoor enclosure with ha-ha boundary, wooden den and pool area with waterfall.

2.2 Feeding

An essential consideration in the welfare of zoo animals is to provide a good diet that meets the natural feeding ecology as close as possible. Nutrition takes a big role in longevity, disease prevention, growth and reproduction (EAZA, 2014). As a member of EAZA, zoos are obliged to be aware of the latest information on animal nutrition (EAZA, 2014).

The domestic pig diet can be a model for the captive babirusa diet. However, diets aimed at commercial pig production are largely unsuitable for the babirusa, firstly due to the difference in digestive anatomy and fermentation processes between the two species (see section 1.3.2 *Digestion*). Unlike the domestic pig, babirusa have not been subject to

selective breeding for improvement of meat production and so have a slower growth rate than that of the pig and have a smaller mature body size which also needs to be taken into account when devising a captive diet (Leus, 2000). As part of their feeding ecology, babirusa seem to tend to browse more and root less (due to the anatomy of their snout, see section 1.6.2 *Feeding*), another difference to that of the pig. Finally, as with many captive situations, babirusa are prone to obesity in captivity and so the diet that is offered to them needs to be specifically calculated in order to prevent this whilst ensuring that enough food is offered so body condition does not deteriorate. Below are the guidelines for nutrition of babirusa in zoos as proposed by Leus & Dierenfeld, (2001).

Nutrition Recommendations for Babirusa in Captivity (Leus & Dierenfeld 2001):

- Diet comprising of approximately ¼ swine maintenance pellets or high fibre herbivore pellets
- ¾ "produce/browse" composed of ¼ fruit (maximum), ¼ yellow/orange/root vegetables, ¼ green leafy vegetables and ¼ locally available browse
- complete pellets are preferred to mixes of whole grains
- produce should be fed raw and with peels and/or stones
- total amount offered per day should equal no more than 2.5% of body mass on an as fed basis
- crude protein concentration of dietary DM is calculated to be approximately 13% and digestible energy approximately 13 MJ/kg
- vitamin and mineral requirements of the babirusa diet should meet the standards for domestic swine
- a small amount of pelleted concentrate diluted with various produce items is suggested to promote natural feeding behaviours, provide bulk and reduce calorie density
- the ration should be spread rather evenly throughout the day, for example 30% in the morning, 20% scatter-fed and 50% in the evening
- fresh water should be available at all times

Leus (2000) reviewed all the available data on babirusa diets and conducted a worldwide survey on captive babirusa diets in order to assess and compare them, making recommendations on the composition of future diets. Foods offered to captive babirusa in 19 zoos in Europe and North America can be found in Table 1.4, and the amounts of food/nutrients offered can be found in Table 1.5.

Table (1.4): List of Fruit and Vegetables (F&V), Commercial pellets, Grains, bread, nuts and oils (P&G), and Animal Products (AP) offered to babirusa in 19 zoos in Europe and North America. Taken from Leus, (2000).

Food item	**Form**	**No. zoos**	**Food item**	**Form**	**No. zoos**
F & V			Water melon	raw with peel	1
Apple	with peel	19	White cabbage	raw	2
Aubergine	raw with peel	2	Yams	raw or cooked	5
Avocado	raw with stone	1	Zucchini	with seeds and peel	1
Banana	with peel or without peel	18			

Broccoli	raw	3	*P&G*		
Cabbage (unspecified))	raw	4			
Carrots	raw or boiled	15	Acorns	raw	2
Cauliflower	raw	3	Barley	dry	1
Celery	raw	8	Biscuits	dry	1
Cherries	with stones	2	Bran	dry	4
Chicory	raw	2	Bread	brown or white	7
China cabbage	raw	2	Corn on the cob	fresh	1
Coconut	raw	1	Corn	fresh or dry	5
Corn-salad	raw	1	Corn oil	fluid	1
Cucumber	raw with peel	5	Dog chow	pellets/biscuits	5
Endive	raw	3	Germinated corn	fresh	1
Fennel	raw	3	Germinated wheat	fresh	3
Fodder beet	raw	3	Herbivore pellets	pellets dry	12
French beans	raw	1	Horse pellets	pellets dry	1
Grapefruit	without peel	1	Horse-chestnuts	raw	1
Grapes	with peel and seeds	4	Maize meal	dry	2
Green cabbage	raw	1	Nutritional yeast	dry	1
Kale	raw	1	Peanuts	dry	4
Kiwi	with peel	4	Pig pellet	pellets dry	5
Kohlrabi	raw	2	Rice	cooked	2
Lamb's lettuce	raw	1	Rolled corn	dry	1
Leek	raw	6	Rolled oats	dry	8
Lettuce (unspecified)	raw	15	Soya meal	dry	1
Mandarins	without peel	1	Sunflower seeds	dry	2
Medlar	raw	1	Sweet chestnut	raw	5
Melon	with peel	2	Textured grain	dry	1
Nectarines	without stone	1	Toast	brown or white	1
Onion	raw	3	Vegetable oil	fluid	1
Oranges	without peel	11	Walnuts	with shell	1
Parsley	raw	1	Wheat	dry	1
Peaches	with peel and stone	4	Wheat	ground	1

Pears	with peel	5			
Pineapple	with peel	6			
Plums	with peel and stone	7			
Potatoes	raw or boiled	8	Beef meat	raw or boiled	3
Pumpkin	raw with peel and seeds	2	Chicks (one day old)	whole	6
Radish	raw	1	Crickets	whole	1
Red beets	raw	2	Eggs	raw or boiled, with shell	5
Red cabbage	raw	1	Fish	raw	2
Salsify	raw	1	Grasshoppers	whole	1
Savoy	raw	1	Mice	whole, skinned	1
Soya sprouts	raw	1	Rats	whole, skinned	1
Spinach	raw	3	Skimmed milk powder	dry	1
String beans	raw	1			

AP

Table (1.5): Average amount of food (Total fresh weight), Fruit and Vegetables (F&V), Commercial pellets, Grains, bread, nuts and oils (P&G), and Animal Products (AP), dry matter (DM), crude protein (CP), Fat, englyst fiber (EF) and digestible energy (DE) offered to babirusa in 19 zoos in Europe and North America. (%BW = percentage of body weight for a 90 kg male or a 60 kg female; %DM = percentage of dry matter; CP:DE = protein to energy ratio). Taken from Leus (2000). (*) Average of nine zoos that did offer animal products.

	Total (g/day)	**F & V (g/day)**	**P & G (g/day)**	**AP* (g/day)**	**DM (g/day)**	**CP (g/day)**	**Fat (g/day)**	**EF (g/day)**	**DE (MJ/day)**	**CP:DE**
Male	3128±928	2151±983	878±577	209±233	1069±481	162±109	63.9±44.9	209±136	14.4±6.6	10.6±3.2
%BW	3.5				1.2					
%DM						15.2	6.0	19.6		
Female	2733±798	1856±831	806±512	148±133	956±425	142±84	54.4±32.4	184±120	13.0±5.7	10.5±3.2
%BW	4.5				1.6					
%DM						14.9	5.7	19.2		

In a study by Conklin and Dierenfeld (1994), it was found that the average wet weight of food offered to babirusa in captivity was almost twice the amount that the babirusa actually ate. The same study also found that dry weight that was offered to male babirusa was equal to the observed intake, whereas it was much higher in females due to their decreased body mass (Conklin and Dierenfeld, 1994). It has therefore been extremely important when designing a captive diet for babirusa to determine how much offered food is actually consumed, in order to lessen the risk of contributing to captive obesity (*Leus & Dierenfeld, 2001*). It also is important that the difference in weight/body size between the sexes is taken into account when designing a captive diet. The tables above show the large variation of

food offered and how this relates to a large variation in nutrient composition of the diet. The range of the values of nutrients offered is in fact so large that it's impossible that these diets are all meeting the nutritional requirements of the babirusa.

Protein

There is no data available on the protein and energy requirements of the babirusa (Leus, 2000). Whittemore (1998) used prediction equations to calculate the maintenance requirements (normal function, i.e. not lactating) for digestible energy (DE) and crude protein (CP) in the domestic pig. The maintenance DE requirement for a Large White domestic pig of 90 kg can be calculated from the equation: ME maintenance = $1.75Pt^{0.75}$ (ME=metabolisable energy, Pt=protein weight in the body), which gives an average protein weight of 16% of body weight (Whittemore, 1998). Metabolisable energy is digestible energy minus the energy contained in urine and excretory gases. Metabolisable energy relates to digestible energy as DE=ME/0.96, allowing digestible energy to be calculated from metabolisable energy in the domestic pig (Whittemore, 1998).

The protein content of the babirusa is not known, but can be estimated as around 15-16% based on a comparison between that of the domestic pig bred for leanness (16%) and a Chinese domestic pig bred for fatness (15%) along the fact that the babirusa has a smaller mature size yet a reasonably lean appearance in the wild (Leus and Morgan, 1995; Kyriazakis *et al.,* 1993; Close, 1994). This estimation of protein content can allow a prediction of maintenance digestible energy requirement in the babirusa; 13.4 MJDE/day for 90kg babirusa (average male) and 9.9 MJDE/day for a 60kg babirusa (average female), which are very similar to those derived using the equations from AFRC (1990) (see Table 1.6). These values are calculated as a maintenance state, and so would need to be increased for animals with an increase energy budget, e.g. lactating and pregnant dams (Leus, 2000). A similar equation can be used to estimate the maintenance requirement for crude protein (CP) for male and female babirusa (see Table 1.6), though this equation needs to take in to account more factors such as (i) the efficiency of use of ideal protein, (ii) the protein score (= the proportion of the dietary protein that is ideal) and (iii) the ideal digestibility (the proportion of the ideal protein that will be digested up to the end of the small intestine), which can be added into the equation (Whittemore, 1998).

Table (1.6): Predicted maintenance requirements for CP and DE for an average male (90kg) and female (60kg) babirusa. Predictions according to equations in Whittemore (1998). (CP:DE ratio = protein to energy ratio)

Maintenance requirement for:	**90 kg Babirusa**	**60kg Babirusa**
CP	139 g/day	93 g/day
DE	13.4 MJ/day	9.9 MJ/day
CP:DE ratio	10.4 g CP/MJ DE	9.4 g CP/MJ DE

It is important to note that growing animals will have a larger protein/energy ratio than that of mature babirusa (Leus, 2000). Growing animals have a greater protein requirement than that of mature animals as they are growing lean

tissue above the maintenance level, but mature animals have higher energy requirements to sustain body maintenance activities (McDonald *et al.,* 1995; Whittemore *et al.,* 1998). Differences would also be seen in lactating/pregnant females. It is important to offer the correct amount of protein as part of the babirusa diet as excess protein will be deaminated and the amino acids formed can form the precursors of fat formation or can be excreted in urea, which is a very energetically costly process due to the inefficiency of the deamination system (Whittemore *et al.,* 1998).

Fats

As obesity in captive babirusa is a significant risk, their offered diets must contain limited amounts of fat. The process of converting dietary fats to body fats is an energetically cheap process, and due to their higher gross energy content, they contribute a proportionally larger amount of digestible energy to the diet (Whittemore *et al.,* 1998; Leus, 2000). This can be a major problem in zoos where members of the public attempt to feed animals, so this must be prevented as much as possible.

Fibre

In the natural diet of the babirusa, fibre is mainly obtained from fruits rather than leaves (as they may be equally fibrous). There is no data available for the fibre requirements of the babirusa, however the 19% dry matter average value offered (Table 1.5) seems very low for a foregut fermenter such as the babirusa (Leus, 2000). Digestibility studies were carried out on the babirusa which found that they did not readily consume the amount of hay/dried grass offered as a source of fibre (Conklin and Dierenfeld, 1994; Leus, 1994; Leus 2000). It is therefore important when constructing a captive diet for the babirusa that browse is offered to supplement the amount of fibre in their diet, which most commercial fruits lack (Nijboer and Dierenfeld, 1996).

Vitamins and Minerals

The vitamin and mineral requirements of the babirusa have not yet been determined. Their use of salt licks in the wild as a supposed means of supplementing their vitamin/mineral intake may be an indication of specific requirements in this species or that their mainly frugivorous diet in the wild is deficient of some constituent's. The vitamin/mineral requirements of the domestic pig have been assessed and can be used as a model for the needs of the babirusa when devising a captive babirusa diet (Table 1.7).

Table (1.7): NRC (1998) and AFRC (1990) vitamin and mineral requirements for domestic pigs and the recommended vitamin and mineral contents of a babirusa diet based on the domestic pig as a model. * calculated from AFRC: 87%DM, 13DE/kg ** ideally Fe should not exceed 300 mg/kg

Nutrient **Dietary** **Concentrations** **DM basis**	**Adult Maint/** **Breeding Swine NRC, 1998**	**Growing Swine** **NRC, 1998** **(20-50 kg)**	**Breeding pigs** **>120 kg** **AFRC, 1990b***	**Babirusa** **Complete** **Diet**
Protein, %	12-13	16-20		
Crude Fat, %				
Vitamins				
Vitamin A, IU/g	2-4	1.4	6.9	5.0

Vitamin D_3 IU/g	0.22	0.2	0.9	0.5
Vitamin E, IU/kg	48	11	17	50
Vitamin K, mg/kg	0.5	0.5	1.1	1
Vitamin B_1, Thiamin, mg/kg	1.1	1.1	1.7	2
Vitamin B_2, Riboflavin, mg/kg	4.0	2.7	3.4	4
Vitamin B_3, Niacin, mg/kg	11	11	17	20
Vitamin B_6, Pyridoxine, mg/kg	1.1	1.1	1.7	2
Vitamin B_{12}, Cobalamin, µg/kg	15	11	17	20
Folacin, mg/kg	1.4	0.3		1.5
Pantothenic Acid, mg/kg	13	8.8	11.5	15
Vitamin C, mg/kg				
Minerals, %				
Calcium	0.75	0.66	0.97	1.0
Chloride	0.20	0.11		0.2
Potassium	0.22	0.25	0.29	0.3
Magnesium	0.04	0.04	0.03	0.04
Sodium	0.22	0.11		0.15
Phosphorus	0.66	0.55	0.75	0.75
Salt			0.40	0.4
Concentration, mg/kg				
Copper	5.5	4.4	5.7	6
Iron	88	66	69	90
Iodine	0.14	0.14	0.57	0.5
Manganese	22	2.2	17	25
Selenium	0.15	0.15	0.17	0.2
Zinc	55	66	57	75

2.2.1 Basic Diet

The Chester Zoo babirusa diet sheet can be found in *Appendix II*.

Concentrate

Leus & Dierenfeld, (2001) suggest that 25% of the captive babirusa diet should be made up of swine maintenance pellets or high fibre herbivore pellets. Pelleted compound feeds may be used to balance the vitamin, mineral, protein and fibre needs of the species.

Browse

Browse has been shown to be an important part of the babirusa diet to aid fibre content. Fresh browse should be offered daily, as a quarter of the total fresh produce/browse offered, though babirusa will also feed on naturally occurring trees/bushes within their enclosure (Figure 2.2). Table 1.8 is a list of different species of browse offered to babirusa in 19 zoos across Europe and America. Consumption of common European and North American browses would significantly add to the amount of fibre consumed and temperate species should therefore be given preference (Nijboer and Dierenfeld, 1996, Leus, 2000). Care should be taken when offering willow (*Salix spp.*), as in the case of langurs and observed in a female babirusa in Antwerp Zoo, babirusa may ingest long strands of bark which may form a fibre ball in the stomach (Leus, 2000). The fermentation of browse during digestion will contribute to protein and energy in the diet, though this has not been quantified (Leus, 2000). There should always be lots of browse offered in their diet.

Table (1.8): List of browse items offered to babirusa in 19 zoos in Europe and North America. Taken from Leus (2000).

Scientific name	English name	Form	Parts eaten	No. zoos
	Branches	fresh	bark, leaves, twigs, buds	8
	Grass	fresh	entirely	9
	Hay	dry	entirely	4
	Leaves	fresh and dry	entirely	2
Acacia sp.	Acacia	branches fresh	leaves only	3
Acer pseudoplatanus	Sycamore	branches fresh	bark, leaves, twigs	1
Acer rubrum	Red maple	branches fresh	?	1
Acer saccharinum	Silver maple	branches fresh	?	1
Acer saccharum	Sugar maple	branches fresh	?	1
Alnus sp.	Alder	branches fresh	?	1

Avicennia germinans	Mangrove	branches fresh	?	1
Betula sp.	Birch	branches fresh	bark, leaves, twigs, buds	3
Celtis occidentalis	Hackberry	branches fresh	?	1
Corylus sp.	Hazel	branches fresh	leaves	1
Crataegus sp.	Hawthorn	branches fresh	leaves	1
Fagus grandifolia	American beech	branches fresh	?	1
Fagus sp.	Beech	branches fresh	leaves	1
Ficus benjamina	Weeping fig	branches fresh	?	1
Forsythia sp.	Forsythia	branches fresh	?	1
Fraxinus sp.	Ash	branches fresh	bark, leaves, twigs	1
Gymnocladus dioicus	Kentucky coffee tree	branches fresh	?	1
Hibiscus rosa	Hibiscus	branches fresh	?	1
Hordeum vulgare	Hydroponic barley	fresh	entirely	1
Liquidambar styraciflua	Sweetgum	branches fresh	?	1
Malus sp.	Crabapple	branches fresh	?	1
Medicago sativa	Alfalfa	fresh and dry	entirely	9
Morus alba	White mulberry	branches fresh	?	1
Morus sp.	Mulberry	branches fresh and dry	leaves, bark	1
Musa sp.	Banana	leaves	?	1
Phleüm pratense	Timothy hay	dry	?	3
Phyllostachys aurea	Golden bamboo	branches fresh	?	1
Populus alba	White poplar	branches fresh	?	1
Populus euramericana	Poplar	branches fresh	bark, leaves, twigs, buds	2
Quercus rubra	American oak	dried leaves	leaves	1
Quercus sp.	Oak	branches fresh and dry	leaves, bark	2
Robinia pseudoacacia	Black locust	branches fresh	?	1

Salix babylonica	Weeping willow	branches fresh	?	1
Salix nigra	Black willow	branches fresh	?	1
Salix sp.	Willow	branches fresh	bark, leaves, twigs, buds	4
Trifolium sp.	Clover	fresh	entirely	1
Viburnum sp.	Fragrant honeysuckle	branches fresh	?	1
Vitis vinifera	Grape	branches fresh	?	1
Zea mais	Corn stems	fresh and dried	entirely	1
Zea mais	Corn stems with cobs	fresh and dried	entirely	2
Zingiber sp.	Torch ginger	?	?	1

Figure (2.0): Babirusa feeding on browse at Chester Zoo.

Fruit/Veg

Fruit is an important part of the babirusa wild diet (Meijaard, *et al.,* 2011). Fruit and veg should be offered as the rest of the produce/browse 75% of the diet. Produce should be fed raw with peels and stones (*Leus & Dierenfeld*, 2001). A wide range of fruit and veg is offered at many zoos globally (see Table 1.3). Locally available fruit and veg should be

assessed by a zoo nutiritonist to ensure that the correct amount of vitamins, minerals and nutrients are offered as part of the babirusa captive diet.

Hay

Lucerne can be offered as part of the browse portion of the diet. Although grasses and hays have been reported as being unpalatable and difficult to digest by the babirusa, some zoos report full consumption of the Lucerne offered and others report selective consumption of leaves or stems within the Lucerne hay offered (Leus, 2000). Lucerne hay is a part of the Chester Zoo diet and individuals will pick and root through the Lucerne piles, picking out leafy green bits and leaving the stems.

Supplements

Young developing males have been observed to show weakness in their hind quarters; 'swaying hind legs'. This issue was solved at Antwerp more than once with a temporary increase in Vitamin E/Selenium supplement in their diet.

2.2.2 Special Dietary Requirements

Babirusa young may be hand reared in captivity, though this is only in extreme circumstances. Section 2.4.7 *Hand rearing* contains one case study of hand-rearing in the babirusa, detailing milk formulas, hand-rearing and weaning.

As with all captive species, diets may need to be adjusted to replicate seasonal changes in the wild, life history changes, and to offset any seasonal changes that may be experienced in captivity that would not be experienced in the wild. At Chester Zoo, concentrate weight may be increased by 10-15% as a winter ration, due to the deterioration of natural browse in the enclosure as well as offered browse. This change in diet ration would depend on body condition of the individual and would follow a consultation with the zoo nutritionist. Concentrate weight is also increased for lactating females by 30-50% to balance out the energy required for lactation.

Diets may also be changed on an individual basis at Chester Zoo if there is a decline in body condition. Individuals can be assessed by keepers and the zoo nutritionist and concentrate feed increased/decreased accordingly (fruit/veg consumption is hard to control on an individual basis due to the scatter feeding method, see below).

2.2.3 Method of Feeding

It is recommended that the feeding of babirusa in captivity should be spread throughout the day to in order to try and replicate feeding patterns in the wild (Zutrition, 2013). The ration should be spread evenly throughout the day, for example 30% in the morning, 20% scatter-fed and 50% in the evening.

A smaller amount of food should be scatter fed in the morning so the babirusa are more likely to forage for food during the scatter feed in the afternoon, increasing their activity (Zutrition, 2013). It is important to recreate their natural foraging behaviours that are shown in the wild (moving around with their snout close to the ground), and so scatter feeding should be done as a way to recreate this behaviour in captivity (Leus, 2000) (Figure 2.1). Produce should be fed raw with peels or stones (Zutrition, 2016). At Chester Zoo, apples and pears that are fed are quartered, and carrots

cut lengthways, and produce may be cut smaller for scattering as a means of enrichment. Feed can also be presented in troughs/tubs (ground level) or on ground surfaces providing that they are clean.

Figure (2.1): Babirusa male foraging at Chester Zoo

If males tend to monopolise feed then individuals should be fed separately for any items that require precise amounts (Leus, 2000). Males will not tend to do this during the females oestrus but it is important that the majority of their diet is fed separately (concentrate feed) in order to ensure all individuals are eating enough (Leus, 2000).

Browse should be offered daily and can be offered at ground and higher levels as a means of enrichment and to encourage their standing browse behaviour (Leus, 2000). Both browse and any hay offered should be spread around the paddock to recreate foraging in the wild.

Medication can be added to a piece of fruit and hand fed to the babirusa or it can be added to the concentrate feed of the individual.

2.2.4 Body Condition Scoring

Body condition scoring is a good way to monitor the health of any zoo animal. Babirusa in particular can be scored on their body condition based on an adapted body scoring sheet for a wild pig, staff at Saint Louis Zoo have developed a body condition scoring sheet for babirusa which can be seen in *Appendix III*. Babirusa should be weighed regularly to monitor their health and general body condition, which they can be trained to do (Figure 4.1 & 4.2).

2.2.5 Water

Providing fresh water for animals is essential. Commercial pig waterers are available and work well. There are various brands of self-filling water bowls in different shapes and sizes made from either plastic or galvanised steel, which are also very effective. Large tubs of water can be used but animals tend to tip over tubs. All drinking containers should be cleaned with a scouring pad or brush and disinfected daily.

2.3 Social Structure

The social organisation of babirusa in the wild is described in chapter 1.8.4 Social behaviour. The following chapter describes the social structure and introduction procedures in captivity.

2.3.1 Basic Social Structure

In the wild babirusa group size tends to be no more than 15 individuals (Clayton & MacDonald, 1999), females will often be accompanied by offspring. A study on social structure by Clayton and MacDonald (1999) found after around 60 hours of observations that the majority of sightings were of either solitary males or matriarchal groups made up of one or more females and their young. Mature males and females with offspring were seen infrequently and male and female pairs were hardly ever seen.

2.3.2 Changing Group Structure

Group structure

The management of the group structure of the babirusa in captivity is largely dependent on the facilities at the individual institution balanced with the requirement of reproductive success. Different institutions have been known to keep babirusa in individual, mixed sex, single sex, permanent pair and family social groupings. The problem with mixed sex groups is that if there are multiple males mating multiple females, there is little certainty of sire in young and it is an extremely difficult group structure to manage with separating young, feeding etc. Permanent pairs of males and females also have the problem that reproductive behaviour may decline in this situation despite oestrus signs (Leus *et al.,* 1992), therefore individuals may need to be separated to increase reproductive success.

Chester Zoos social groupings of the babirusa depend on increasing reproductive success and the presence of young. The male will be introduced to the female as described in section 2.4.1 *Mating,* and may remain in the same enclosure with her until a few weeks before birth, then he will be kept away till young are eight months of age. Otherwise, he will be moved round between the other females in the same way and remain with them for one or more oestrus in order to maximise reproductive success. There is no seasonality with regards to moving round the male, as there is no seasonality in the females' oestrus and therefore this isn't necessary to achieve reproductive success. Young will

remain with the female and male in a 'family' group from eight months of age to around one year of age before they are separated due to female aggression (see section 2.4.6 *Development and care of young*).

Introductions

As with most species, when carrying out an introduction between babirusa it is important to initially only provide visual, olfactory and auditory contact between the individuals. Ideally this visual access should be carried out for a number of days (sometimes weeks) to allow the behaviours of all animals involved to be monitored closely. If positive behaviours are being observed, for example sp.'s lying next to each other either side of the barrier, then the physical introduction can go ahead.

If the acclimation period talked about above (and detailed further in the steps below) has been positive; physical introductions can take place. Experienced staff members should always be present for introductions and a plan for separating them should be in place, should this be required. It may be necessary to keep the animals separately when they are inside at night.

Steps in the introduction process - this applies to all introductions, the animals should be kept separated until step 4.

1. Animals in the same indoor enclosure or multiple outdoor enclosures should have olfactory and auditory exposure to each other. If the animals are not housed near each other (i.e., enclosures on opposite sides of the zoo, etc.) they should be moved to the same exhibit area.

2. Animals should be given visual contact with each other in addition to the above sensory modalities. If at any point during this process the animals display symptoms associated with stress (e.g., pacing, diarrhoea, excessive vocalisation) for more than two to three hours, the introduction should return to the previous step.

3. If animals are not already positioned adjacent to each other, they should be moved closer together (e.g., to adjacent stalls or adjacent outdoor enclosures).

4. The actual introduction (full tactile exposure) should take place in the largest enclosure available. Preferably, the enclosure should be familiar to the least dominant animal and include ample "run-arounds".

2.3.3 Sharing Enclosure with other Species

Mixed species exhibits can be both exciting and educational for visitors. Babirusa have been successfully mixed with other species, however when deciding if a mix is likely to work it is important not just to consider the temperament of the species in general but also the temperament of the individual animal. In other words a combination that works well in one zoo does not mean it will work at another with different group of individuals. The information below comes from a table created by the Pig, Peccary and Hippo TAG mixed species brochure (Haigwood, n.d.) and lists species that have shared an enclosure with babirusa.

2.1 Babirusa and 0.2 Asian Small Clawed Otters (Amblonyx cinereus) in Audubon Zoo
0.1 Babirusa and 0.1 Lowland Anoa (Bubalus depressicornis) in Los Angeles Zoo
1.0, 0.3 and 1.1 Babirusa 1.1 Siamang (Hylobates syndactylus)* in Louisville Zoo
*Animals not always exhibited together

1.1 Babirusa and 4.3 Asian small clawed otters currently share an enclosure successfully at Chester Zoo (Figure 2.4). However, if the female babirusa becomes pregnant she will be separated from the otters at least a week prior to the birth to give her privacy to build her nest. The female will remain separated from the otters after giving birth as they pose a threat to the newly born piglet, the two species will be reintroduced when the piglet is around 2 months old and large enough for the otters to no longer be a danger. It is also worth noting that if the otters produce pups the male babirusa will need to be removed from the enclosure, as he is likely to eat the pups when they start venturing out of the holts.

Figure (2.2): Babirusa and Asian small clawed otters at Chester Zoo

2.4 Breeding

2.4.1 Mating

Oestrus

Female babirusa have an oestrus cycle of around 35-37 days, with oestrus lasting for 2-3 days (Macdonald, 1993). There does not seem to be a reproductive seasonality in the babirusa as they can breed all year round, both in captivity and in the wild (Macdonald, 1993; Clayton and MacDonald, 1999). There are both physical and behavioural signs of oestrus that can be monitored in captivity to increase breeding success.

Physical

When in oestrus, the labiae of the female babirusa swell to twice the non-oestrus size and increase in length and thickness (Leus *et al.,* 1992). The skin will become stretched and pink and the labiae may slightly evert to expose the

mucous membranes and there may be some discharge (Leus *et al.,* 1992). Some zoos have a scoring chart for the size and colour of a female's vulva as a way of monitoring oestrus.

Behavioural

Males will test the urine/faeces of a female on a daily basis and will pursue her if he detects oestrus (Leus *et al.,* 1992). If in full oestrus, the female will allow herself to be mounted (Leus *et al.,* 1992) (see section 1.8.5 *Sexual behaviour*).

Hormonal

Oestrus can be detected by measuring urinary oestrogen metabolites (Chaudhuri *el al*., 1990). As oestrus cycles can be highly variable between individuals; therefore it is beneficial to monitor oestrus through collection of faecal samples and endocrine analysis. At Chester Zoo, faecal samples are collected from females when a problem arises, for example no oestrus signs or receptivity shown or no conception after mating, to allow facilitation of breeding management. Some females also have 'silent heats', where they are in oestrus but show little/no physical or behavioural signs of being so, for which endocrine analysis would be a useful tool to determine when males should be placed with females (Leus *et al.,* 1992).

Courtship and Copulation

In captivity, the observation has been made that if a male is constantly kept with the same breeding female, this may actually depress the production of young by the female (Macdonald and Leus, 1995). If a male is constantly kept with a female, oestrus behaviours have been observed to decline (though the physical signs of oestrus still occur) (Leus *et al.,* 1992). It is therefore suggested that when trying to breed a pair, males only be introduced into the female's enclosure when the female is in oestrus (Leus *et al.,* 1992). The presence of more than one boar adjacent to a female within sight and scent and the presence of more than one boar in the same enclosure as a female also stimulate competition and increases reproductive activity so this may be another option for management (Macdonald and Leus, 1995). At Chester Zoo the male and female are reintroduced every morning after being separated overnight in different pens during breeding management.

Courtship behaviour begins with the male pursuing the female after detecting her being in oestrus (Leus *et al.,* 1992). The male vocalises and pursues female around the enclosure, testing her urine. The female may they turn to face the male and they will nose-to-nose before she pushes her snout under his chin and they begin to groom each other (Leus *et al.,* 1992). Males may then lie down and the female will nuzzle his ears, legs, underside and prepuce (Leus *et al.,* 1992). The male will then go behind the female and place his chin upon her lumbar region, at which point if she is receptive she will stand and allow him to mate (Leus *et al.,* 1992) (see section 1.8.5 *Sexual behaviour*).

Matings generally last around 15-30 minutes, with several mountings and will be repeated throughout the day (Leus *et al.,* 1992). The female will generally move her tail to one side when she is ready for full penetration (Fischer, 2002). Intromiss can vary from 1-10 minutes with full copulation lasting approximately 3 minutes (MacLaughlin and Thomas, 1991, Leus *et al*., 1992). If there is a dominant male among other males in the enclosure, he will be the first to mate the female and will guard her for up to half an hour after mating (Leus *et al*., 1992).

2.4.2 Reproductive Endocrinology as a Management Tool

Pregnancy diagnosis can also be performed using hormone analysis; samples collected every other day can be used to distinguish an increase in progesterone metabolite concentration.

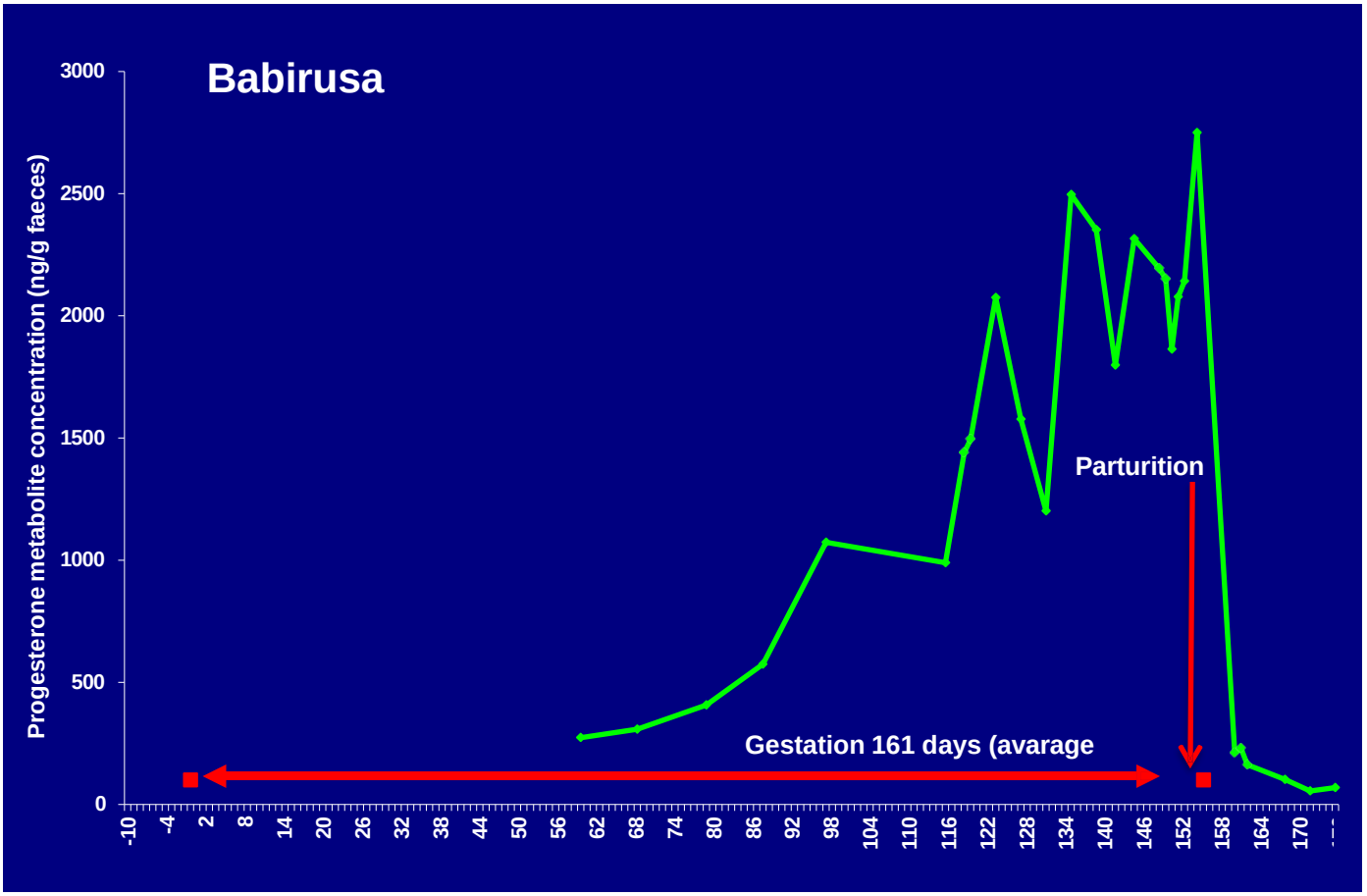


Figure (2.3): An example of hormone profile for a single babirusa Pregnancy at Chester Zoo, from 62 days post mating until parturition has shown us that progesterone concentrations increase significantly from approx. day 100 post mating and drop back to baseline around parturition.

To aid with pregnancy diagnosis it is recommended that at least a month's worth of samples be collected from what is approximated to be 90 days post mating. If the female is pregnant a sharp increase in progesterone concentrations will be evident from approx. 100 days post mating.

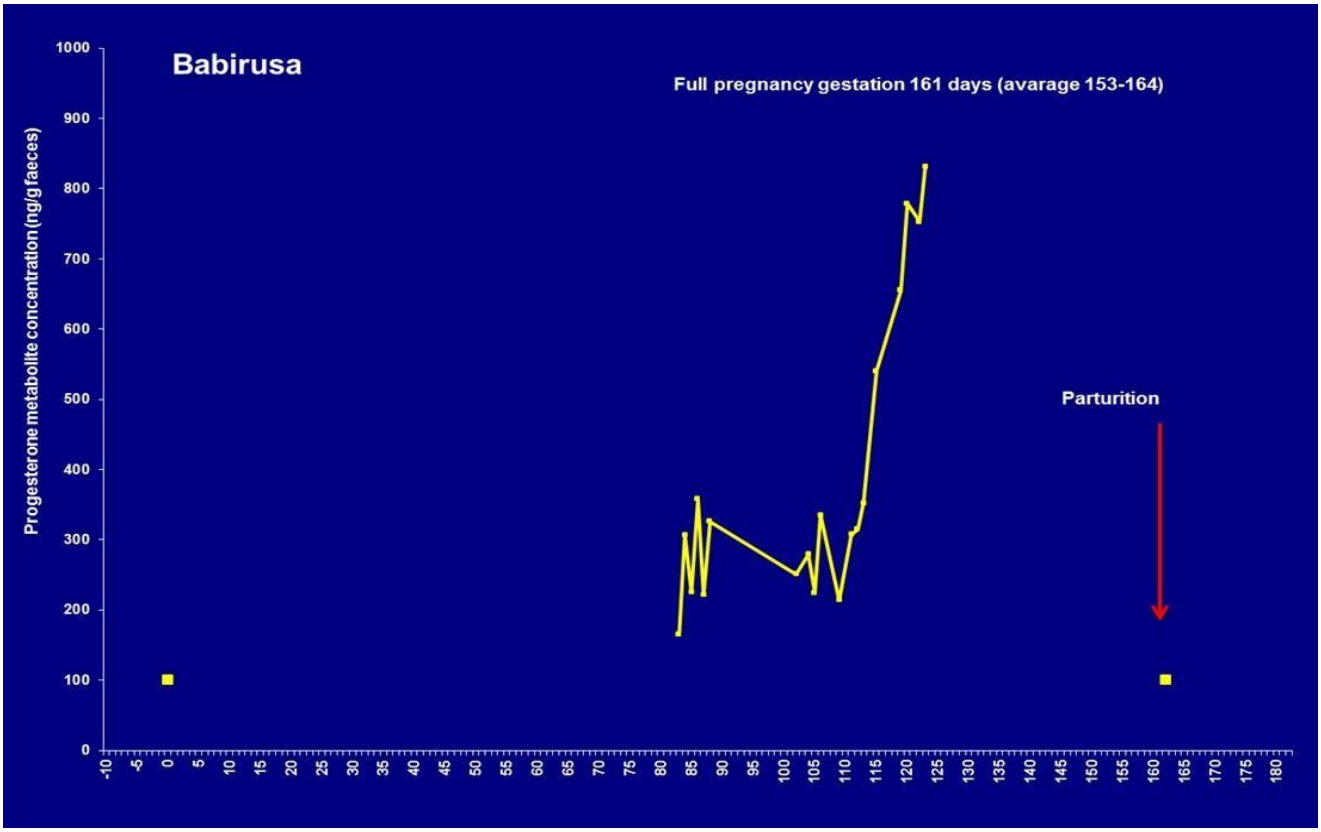


Figure (2.4): An example of a hormone profile showing samples collected between days 83 and 123, demonstrating the significant increase in progesterone concentrations from 100 days gestation that can be used to diagnose pregnancy.

2.4.3 Pregnancy

Pregnancy Detection

Ultrasound

Ultrasound can be used to detect pregnancy in a female babirusa 5 weeks after copulation and in one study; uterine changes were detected via ultrasound at only 30 days gestation (Miller *et al*., 1994; Houston *et al*., 2001). As part of desensitisation, females can be encouraged to lie down in the presence of a keeper, which can lead to training to accept an ultrasound examination. If the female will not lie down, ultrasounds can be carried out whilst standing. Ultrasound with training is a useful way of determining pregnancy at an earlier stage than physical/behavioural changes in a female babirusa in a non-invasive way causing her minimal stress.

Physical

Pregnant females' nipples will begin to develop 3-8 weeks prior to birth (Maclaughlin and Thomas, 1991; Bowles, 1986). The vulva of the female will start to swell 10-14 before parturition; the udder will increase in volume, the labiae will slightly evert and pink and there will be discharge from the vulva (Maclaughlin and Thomas, 1991; Leus *et al*., 1992). The degree of nipple and udder development will change between females and will usually be more pronounced in a female's first birth; the udder will remain somewhat distended after this (Fischer, 2002). Weights can also be used to determine pregnancy and how far into the gestation a female is. At Chester Zoo, females are weighed fortnightly; non-pregnant female's weight around 58 -60kg and pregnant females weigh approximately 67kg a week prior to parturition. Endocrine analysis of faecal samples can also be an indicator of pregnancy.

Behavioural

A few days before birth, females can become restless and agonistic towards keepers, though this isn't displayed in all females (Fischer, 2002). Imminent birth can also be indicated by a pregnant female becoming uninterested in her food (Maclaughlin and Thomas, 1991).

Parturition Preparation

A few weeks prior to parturition, the female becomes aggressive towards male; at this point the male and any other individuals should be moved out of enclosure and relocated within the zoo to give the female privacy.

It may be necessary to make some changes to the enclosure that the female will be in when she gives birth prior to birth. CCTV cameras should ideally be fitted above the nest with a monitor positioned away from the area in order to monitor without disturbance. Plywood partitions or blinds should be positioned as a visual barrier to minimise disturbance and provide a secure nest area. Piglet creeps may be created with bars fitted to the nest walls to reduce the risk of the piglets being crushed. A quiet, secure off-show corral area should be prepared outside so that the piglets can be exposed to the public gradually and the female receives some privacy after birth. Temperatures within the house should be maintained at a minimum of 21 °C, with heat lamps positioned above the nest to maintain the temperature at 25 °C.

Female babirusa are known to build nests in preparation for parturition both in the wild and in captivity (Guillemard, 1886; Clayton 1996; MacLaughlin and Thomas, 1991: Leus *et al*. 1992). Nests in the wild can be up to 3m in length (Meijaard *et al.,* 2011). Sufficient good quality nesting material should be provided to encourage this behaviour.

At St. Louis Zoo, isolation was not practical and so an alternative was to allow the pregnant female to become acclimated to the presence of humans in the weeks leading up to her birth, which worked successfully for five litters produced by two dams, with a keeper being present at most births (Fischer, 2002).

2.4.4 Contraception

There are no reversible chemical forms of contraception that have been proven to work in captive babirusa. The EAZA Group on Zoo Animal Contraception (EGZAC) are an active part of the European zoo community, they can provide contraceptive guidelines and product information for institutions as well as working alongside breeding programme coordinators and studbook keepers to give advice on all aspects of captive wildlife contraception. The SSP recommends caution in using chemical methods of contraception and the Taxon Advisory Group should be consulted when

considering various forms of contraception. The most effective way of preventing pregnancy in females in captivity is to separate males and females during oestrus.

2.4.5 Birth

Babirusa usually give birth overnight, producing a litter of 1-2 young with an interbirth interval of around 30 minutes in the same litter (see section 1.7.5 *Parturition*) (Leus *et al.,* 1992; Meijaard *et al.,* 2011).

2.4.6 Development and Care of Young

Young are precocial with a birth weight of less than 800g, though up to 1kg has been recorded (Meijaard *et al*., 2011; Macdonald, 2000). Young are not striped at birth unlike most other pig species. Noise and disturbance of the litter must be kept to an absolute minimum, therefore for the first few days the dam and litter should be observed on camera. On day one, keepers should only enter house once to feed daily ration of food. Then, after a few days the pens can be spot cleaned, increasing feeding times and visual checks. Dams are aggressive towards keepers for a few weeks post-partum so this should be noted when servicing the enclosure. Dam and piglets can be given access outside to corral (separate off show outdoor enclosure) after 2 weeks for short periods; increasing gradually over time. Piglets should be caught up, sexed, micro chipped and weighed at 3 $^{1/2}$ months.

Piglets begin to eat soft fruit in captivity from one month. Weaning occurs at six to eight months and compared with other pigs, babirusa are allowed to suckle for much longer, even though it is recorded that young will take solids at 10 days (MacLaughlin et al, 2000; Nowak, 1999). MacLaughlin et al (2000) hypothesised the fact that female babirusa nurse their young for longer could relate to small litter sizes compared to other suid species, they will need to invest more time into the piglets to improve their chance of survival to ensure their genes are passed on. Piglets are weaned at five months and should be separated from dam for independent feeding.

The male can be reintroduced when the piglets are 8 months. The dam will show aggression towards piglets when they reach 12 months of age. At 13 months the piglets should be removed from the enclosure and relocated in the zoo or moved to another collection.

2.4.7 Hand-rearing

There have been few institutions that are known to have successfully hand reared babirusa, these institutions include Port Lympne Wild Animal Park, South Lakes Wild Animal Park, both in the UK and Madrid Zoo in Spain. A full account of the hand rearing of twin babirusa at South Lakes Wild Animal Park, by Jo Dennis in 2007 can be found in *Appendix IV*. There is little information available on hand rearing babirusa, generally hand rearing protocols for domestic pigs have been used as a prototypical. Colostrum replacer should be fed during the first 24 hours and following that a pig milk replacer (such as Faramate) will be phased in. In parent reared animals weaning occurs at 6-8 months but young take solids at 10 days (Nowak, 1999).

2.4.8 Population Management

There is an international studbook for the captive population of babirusa and both EAZA and the AZA have combined breeding programmes for the species in which they also cooperate with the South East Asian Zoos Association (IUCN, 2016). Individually the regional populations are not large enough to guarantee a sustainable population, by joining together to create an international studbook the global captive population could be viable and guarantee a demographically and genetically healthy insurance population for the wild.

In 2015 EAZA signed a memorandum of understanding with the Indonesian Zoo and Aquarium Association, the Association of Zoos and Aquariums, the WPSG, the Asian Wild Cattle SG and the IUCN SSC with the objective to create Global Species Management Plans for babirusa (Meijaard, 2014).

2.5 Behavioural Enrichment

Animals kept in EAZA collections should be encouraged to perform as much of their natural behavioural repertoire as possible and acceptable (EAZA, 2014). One of the ways of achieving this is with behavioural and environmental enrichment (EAZA, 2014). Enrichment is a means of altering the environment of the animals in order to provide them with new stimuli and behavioural opportunities and keep them active and busy and 'enriches' their captive life. Enrichment can also be a means of providing animals with a choice Keepers should strive to make the enrichment as naturalistic as possible, and enrichment should encourage only natural behaviours (not unnatural). Some institutions have a formalised enrichment program, which is a good way of keeping it as a priority factor of husbandry.

One of the easiest ways of providing enrichment is within the enclosure. Providing varying topography, substrate, levels, rock piles and a variety of vegetation, allowing selective browsing, can be a means of enriching the lives of the animals. Also, incorporating a pool or mud wallow within the enclosure design is a good means of encouraging natural behaviour of the babirusa (Leus *et al.,* 1992). Varying feeding times, providing scatter feeds, hiding feeds, floating food in the pool and providing browse at different levels can be another fairly easy way and should be attempted in the case of the babirusa. Providing novel food items is another form of enrichment. It is important when using food as enrichment that it is taken away from the normal daily feed of the babirusa, not an extra feed, due to their susceptibility to obesity.

When designing an enrichment device, many factors should be taken into account in order to ensure that it is safe and will not harm the animal. Animals should not be able to swallow the device (other than food involved with it), the device should not be able to be torn/ripped or crushed/broken, the device should not be able to trap or tangle the animal and it should not be able to cut, poke or scratch the animal.

Some suggestions for enrichment devices for use with the babirusa include (Fischer, 2002):

- Boomer balls
- Boomer balls with holes, filled with food
- Scratch brooms
- Rotten logs

- Water tubs
- Barrels
- Rubber mats
- Hanging buckets/buoys
- Showers/sprinklers

One form of enrichment used by Chester Zoo, particularly in very hot weather, is to freeze a portion of the fruit/veg feed in ice. This gives the babirusa a novel stimulus, helps to keep them cool in extreme heat and means that they will spending a longer amount of time consuming the food (Figure 3.6).

Figure (3.4): Babirusa at Chester Zoo with fruit and veg ice blocks in

Operant conditioning can also be a form of enrichment for the babirusa in introducing them to new stimuli.

2.5.1 Training

Operant conditioning, or training, can be used to address husbandry issues, provide veterinary treatment, and avoid chemical restraint. Training can be used with captive babirusa to allow routine weighing of individuals to assess body condition, tusk trimming, hoof trimming and skin care as the babirusa in particular can be prone to this. Training can also be used when moving babirusa to another institution so they will enter the crate with ease (see section 2.5.2 *Crate training*). Operant conditioning using positive reinforcement can aid the husbandry of captive babirusa (Miller *et al.,* 1994; MacLaughlin and Thomas, 1991). With the aid of training, pregnant babirusa females will allow transabdominal ultrasound in order to monitor pregnancy (see section 2.4.3 *Pregnancy*).

Creating a Training Plan

When training an animal, a training plan should be written and approved in advance. The problem or reason for the training must be identified and justified and if there is a cause for this problem, whether this is environmental, social or psychological, this must also be identified and dealt with (Wood, 2006). For example, if a keeper is training for

access to an individual's hoof due to damage which has been worsened by water-logged paddocks, the problem of the water-logged paddock needs to be addressed at the same time to make sure the problem does not come up again. A training plan needs to set out clearly the problem, the desired behaviour that the trainer wishes to achieve and the discriminative stimulus of the training (audible, visual or tactile), along with an approximation of when the stimuli will be introduced. An estimated time scale should also be included in order to make sure the training is progressing. The training plan should include training steps or successive approximations, which are reinforced to ultimately form the desired behaviour; these can be marked off when achieved to track progress (Wood, 2006). The reward that will be given, the suggested time of the day when training will happen and any notes on the individuals' behaviour/temperament can also be included in the plan to aid the training process. Once the plan has been created, training can commence. During training, the plan must always be referred back to and reviewed according to the progress of the training; it is important to be adaptable once the practical training begins (Wood, 2006). A draft training plan from Chester Zoo can be found in *Appendix V* as an example.

Implementing Training

Training programs vary between zoos, with most institutions keeping a loose operant conditioning program that can be applied to training for different behaviours and some institutions have more informal training programs and use training only when needed and through protected contact (Fischer, 2002). Babirusa can be fairly easy to train as they are a relatively intelligent species and are very food orientated.

When training, it is important to clearly understand the criteria of each approximation so the reward can be given when the criteria for the desired behaviour has been met, and if unsure, the behaviour should not be rewarded until the trainer is certain that the criteria has been met (Wood, 2006). Use primary reinforcements and make sure each training session ends in a positive note, don't push the individual too far (Wood, 2006).

Individuals should be separated for training purposes, though if females with young piglets become too distressed they can enter the training area. It is recommended that training is completed with one person to begin with, then more trainers can be included and more people can enter the training area, e.g. if a second keeper is needed to treat the individual. A trust should be established between the keeper and the subject individual so the individual is used to their presence. It is also recommended that training be carried out in the same area each time, though this can change once individuals become more used to performing the desired behaviours. Any commands or targets should be agreed prior to training.

Both active (reward) and passive (no reward) desensitisation training may need to be included in training when it involves the introduction of new stimuli, e.g. scales, hoof trimmers or a crate (Wood, 2006). A bridge can be used as a secondary signal along with the primary reinforcement to reward the desired behaviour. Bridges can be a very effective tool to use when training, as animals can learn to associate the bridge with a food reward and so the bridge can be used to delay primary reinforcement until the end of a desired behaviour/sequence of behaviours (Ramirez, 1999). The individual should show consistency when presented with the bridge; otherwise the bridge training is weak and needs to be strengthened (Wood, 2006).

Figure (3.5): Babirusa male at Chester Zoo that has been desensitised to keeper and will lie down and allow brushing of skin in preparation for aqueous cream.

A male babirusa at Chester Zoo had an ongoing problem with developing abscesses on his skin. These abscesses can now be flushed with antiseptic by a keeper when needed as a result of training (Figure 4.0). Desensitisation training can be used to treat babirusa skin dryness and cracking which is a problem in captivity. Babirusa can be trained to lie down and accept brushing down of the skin by the keeper and then application of aqueous cream to the skin (Figure 3.7, 3.8 & 4.7).

If the individual receiving the training regresses at any point, the trainer should return to the point in the training where the animal last felt comfortable and begin again. This makes training very time consuming but will give more success in achieving the desired behaviour.

Figure (3.6): Babirusa at Chester Zoo lying down during training

Figure (3.7): Inspection of babirusa hooves during desensitisation session at Chester

Figure (3.8): Babirusa male at Chester Zoo with abscesses accepting antiseptic flush

Figure (3.9): Babirusa male being weighed at Chester Zoo.

Figure (4.0): Babirusa juvenile being weighed.

2.5.2 Crate Training

Babirusa can be easily crate trained to allow them to move enclosures/move institutions. Firstly, the crate should be introduced to the babirusa enclosure as a means of passive desensitisation. The crate may be placed in a doorway or in between pens to allow the babirusa regular use of it and allow them to become habituated to entering it (Figure

4.2). The next step is to close the far end of the crate with a slide and place food in the crate to encourage entrance. The keeper can then access the end and give a food reward to the babirusa when they enter the crate (Figure 4.2).

Figure (4.1): Babirusa male within crate that has been introduced into a doorway for habituation.

Ideally, there should be enough time to gradually introduce the closing of the other end slide of the crate to allow the babirusa to acclimatise to being enclosed within the crate. If there is not enough time to introduce the closing of the other end slide then this should only be closed when it is time for the animal to be moved in the crate. Criteria for a babirusa crate designed for transport can be found in section 2.6.4 *Transportation.*

Figure (4.2): Babirusa entering crate with one slide closed for food reward.

2.6 Handling

2.6.1 Individual Identification and Sexing

Permanent methods used for the identification of babirusa include micro-chip transponders, ear tags, ear notches or tattoos. At the Babirusa SSP Mid– year Meeting in 1996 it was decided that the SSP would recommend that all babirusa be permanently identified with a transponder at the base of the left ear, and that, in the future, ear notching would be used on a very limited basis. It is also a requirement of CITES that Appendix I species (including babirusa) are uniquely identifiable, i.e. possess an individual microchip transponder.

This species can be sexed visually by their sexual dimorphism: genitals and upper canines.

2.6.2 General Handling

How babirusa are kept will be dependent on many factors such as the facility's policy, the design of the enclosure and the personality of the babirusa. There a varying degrees of keeper/babirusa interaction from very hands on to completely hands off. Maintaining babirusa in a way which allows day-to-day, set-routine interaction will help facilitate medical and foot care, introductions, births and separations. If keeper and babirusa interactions begin at a young age the animal will easily become habituated to its keepers (Leus et al, 1992).

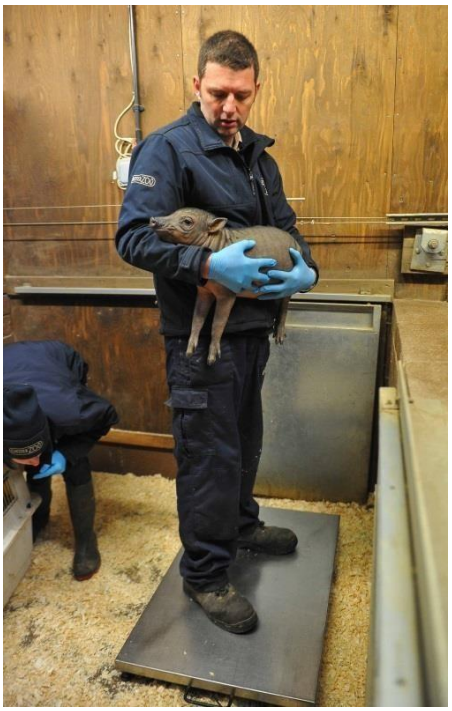


Figure (4.3): Young babirusa being handled for weighing at Chester zoo during animal's first health check.

2.6.3 Catching/Restraining

Manual restraint is only appropriate for piglets of up to four months old. The individual temperament of each babirusa determines whether keepers enter the enclosure with animals. Desensitisation to physical contact minimises the amount of stress experienced by the animal during medical examinations and basic treatments and adult babirusa can become accustomed hands on contact for routine weighing, hoof trimming and skin care through a process of operant conditioning. This method has also allowed abdominal ultrasound imaging to be carried out for pregnancy diagnosis and monitoring. Medical procedures which cannot be carried out by operant conditioning training will require sedation.

It is not recommended for keepers to enter the enclosure with babirusa at feeding times as they can be aggressive around food. It is recommended that animals are shut away while the enclosure is cleaned however keepers are able to work alongside babirusa as long as no food is present.

2.6.4 Transportation

Crating of babirusa for movement within an institution or shipping to another institution can be achieved by crate training (see section 2.5.2 *Crate training*).

Habituation: in a doorway introduce the crate so that the animal can go in and out and become habituated to its presence. Add in a slide on far end and add in food to encourage entrance into the crate. If there is enough time then ideally the animal should be allowed to gradually acclimatise to the slide being closed behind them; allowing the animal to retreat from crate if feeling uncomfortable. If no time is available for this then the slide should only be shut when ready to move.

Crates for babirusa should be sturdy and can be made from wood or metal. The crate should be large enough to allow the babirusa a to lay down, the top of the crate should provide a minimum of 15cm (6 inch) over the highest part of the babirusa's back when standing. The floor of the crate should be non-slip and either be bedded heavily to absorb urine or slatted over a leak-proof tray to catch excreta. Sufficient ventilation must be provided with slatted slides, ends and top and the slats must be spaced so the animal cannot get its nose, tusks or legs through the opening.

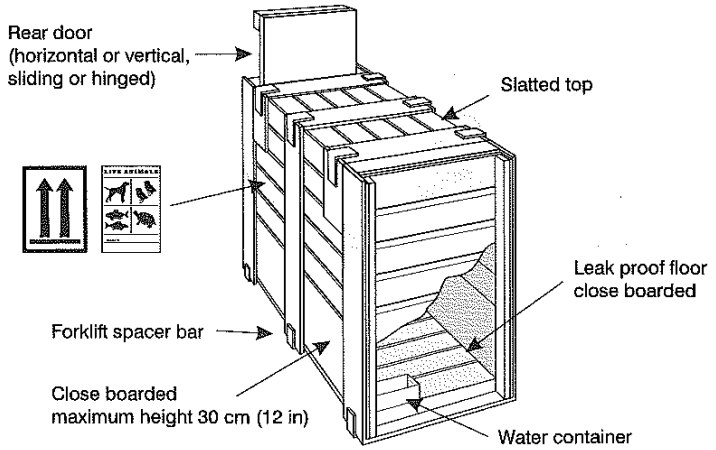


Figure (4.4): Example transport container for Babirusa (IATA, 2007).

Markings on transport container: The markings on the transport container must be durable and printed or otherwise marked on or affixed to the external surface of the live animal container.

English must be used in addition to the language which may be required by the state of origin (IATA, 2007).

Unless otherwise specified in these Regulations, each live animal container must be marked, durably and legibly on the outside of the container, with each of the following:

- The full name and address and contact number of the shipper, consignee and a 24-hour contact (if it is not one of the aforementioned persons responsible for the shipment).
- The scientific and common name of the animal(s) and quantity of each animal contained in the container, as shown on the shipper's certification.
- Containers carrying animals which can inflict poisonous bites or stings must be boldly marked “POISONOUS”. Aggressive animals or birds that can possibly inflict injury through the bars or ventilation openings of the container must have an additional warning label “This Animal Bites”.
- Affix special feeding and watering instructions to the container.
- In general, tranquillisation is not advocated for the transportation of live animals. However, certain wild species require the use of such medication. Whenever used, they must be administered under competent supervision and the name of the sedative, time of administration and the route of administration must be clearly marked on the container and a copy of the record must be attached to the documents relating to that shipment. Any further medication administered must be recorded and accompany the shipment with the name of the sedative, time of administration and the route of administration (IATA, 2007).

It is mandatory to attach at least one IATA “Live Animals” or one “Laboratory Animals” label or tag, properly completed, to each live animal container, unless otherwise stated in the individual container requirements. Animal containers may have the appropriate labelling imprinted (IATA, 2007). The label for live animals should have the following header “Live Animals”, the colour should be bright green on a light background. The minimum dimensions of the label are 10 cm x 15 cm and letters of 2.5 cm (IATA, 2007).

2.6.5 Safety

Some institutions do allow keepers to go in with babirusa, depending on assessment of their individual temperament. Keepers should be wary of entering an enclosure with the babirusa when there is food around as some individuals have been known to charge. Any keeper interaction with the babirusa should follow the safety protocols outlined by the institution and keepers should always be mindful of the behaviour of the babirusa when working in with or near them.

2.7 Veterinary: Considerations for Health and Welfare

Babirusa can be susceptible to many of the bacterial, parasitic and viral disease that are found in domesticated pigs (Fowler, 1996). Below is a brief outline of potential diseases as well as common injuries and issues that have been seen in captive babirusa.

2.7.1 Medical Procedures

Blood Draw

Chemical restraint is used to enable blood collection which can be achieved through venepuncture of a vein including femoral, saphenous, cephalic and aural. The jugular vein is not recommended as the skin is very thick at this point and finding the vein can be time consuming (Fowler & Miller 2003).

2.7.2 Diseases

Munro et al, (1990) states that there is not much known about how susceptible the babirusa is to diseases that affect other pigs. Fowler and Miller (2014) report that wild suids and peccaries (including the babirusa) can be susceptible to diseases that affect domestic swine and ungulates, below is a list of a few diseases taken from Fowler and Miller (2003) that are known to affect suids:

- **Leptospirosis**
  Leptospirosis can cause abortion and stillbirth weak offspring are considered a primary sign of chronic examples of this disease.

- **Pasteurellosis**
  Like many ungulates for all member of the suidae family there is a potential risk of contracting pasterellosis. The key sign of this disease is pneumonia and the treatment is antibacterial therapy.

- **Rabies**
  Babirusa as well as all other swine and peccary species are susceptible to this disease, though the prevalence in swine is so low that vaccination against it is not usually carried out. Rabies causes swelling of the brain or encephalitis, other signs will vary depending on which strain of virus the animal has contracted.

- **Salmonellosis**
  Salmonella can cause septicaemia, enteritis, fever and general signs of illness such as discomfort or restlessness. Usual treatment includes antibiotics and supportive care. Domestic swine have been vaccinated but the vaccine may not totally protect the animal.

- **Turberculosis**
  Symptoms can include severe inflammation of lymph nodes, enteritis, pneumonia and organ granulomas. In a herd situation importance is placed upon identifying and eliminating the infected animals. Treatment of an individual animal can be carried out using antimicrobials.

2.7.3 Common Injuries, Issues and Treatments

Skin Problems:
These can be caused by artificial heating and cold temperatures over the winter (less mud wallowing), the skin will become dry and crack leaving open lesions which if not treated could become infected. The skin is brushed and aqueous cream to the skin as a preventative measure, see figure 4.0.

Skin disease has also been reported in babirusa. This starts with dry skin but progresses to raised pustules that can burst leading to open sores which could again lead to secondary infection. There are various topical treatments that can be prescribed as treatment.
Dental and facial abscesses have been reported, abscesses can be treated with an antiseptic flush, see figure 3.8.

Figure (4.5): Babirusa male with aqueous cream being applied to skin at Chester Zoo

Foot Management:

Overgrown hooves are widely reported in captive babirusa, trimming can often be achieved through desensitisation training to overcome this.
Trauma to the feet can be common as their hoofs in comparison to other ungulates are less resilient. Fowler and Miller, 2014 state that untreated cases of hoof injury or defect can lead to osteomyelitis and infection. Hoof acrylics have been used to repair damaged hoofs.

Tusk Fractures:
Tusk fractures have been reported in captive babirusa, careful enclosure design and Intermittent tusk trims can be undertaken as a preventative measures. Root canals or endodontic therapy can be used for fractured tusks (Fowler & Miller, (2013).

Parasites:
Regular faecal testing for endo-parasites is carried out, and appropriate treatment is provided on positive testing.

Immobilisation:

Suids, in general have no specific negative reactions to anaesthetic agents (Flowler, 1996). As well as delivery via dart, crush crates can be used for injecting by hand, a fasting period of between 12 and 24 hours is recommended (Fowler and Miller, 2014).

2.8 Recommended Research

Although the babirusa has been kept in captivity for many years, there are some factors of their biology/management that are poorly understood. In particular, more research needs to be undertaken into their nutritional requirements, in order to make clear cut recommendations for their captive diet.

Section 3: Glossary

EAZA	European Association of Zoo's and Aquaria
WPSG	Wild Pig Specialist Group
IUCN	International Union for Conservation of Nature
SSC	Species Survival Commission
EEP	European Endangered Species Programme

Section 4: References

4.1 Books

Alvard, M. (2000). *The impact of traditional subsistence hunting and trapping on prey populations: data from Wana horticulturalists of upland Central Sulawesi, Indonesia* In: J. G. Robinson and E. L. Bennett (eds), Hunting for Sustainability in Tropical Forests, pp. 214-230. Columbia University Press: New York, USA.

Close, W.H. (1994). *Feeding new genotypes*: *establishing amino acid/energy requirements*. In: Cole, D.J.A., Wiseman, J. & Varley, M.A. Principles of Pig Science: Nottingham University Press, Nottingham, pp. 123–40.

Davis, D. D. (1940). *Notes on the anatomy of the babirusa*: Field Museum of Natural History.

Guillemard, F.H.H. (1886). *The cruise of the Marchesa to Kamschatka & New Guinea with notices of Formosa, Liu-Kiu, and various islands of the Malayarchipelago*. J. Murray: London, 2, pp 190-191, 200-205.

Miller, R. E., & Fowler, M. E. (Eds.). (2003). *Fowler's zoo and wild animal medicine* (Vol. 5): Elsevier Health Sciences.

Miller, R. E., & Fowler, M. E. (Eds.). (2014). *Fowler's zoo and wild animal medicine* (Vol. 8). Elsevier Health Sciences.

Leus, K. (2000). *Feeding babirusa (Babyrousa babyrussa) in captivity.* In: Nijboer, J., Hatt, J. M., Kaumanns, W., Beijnen, A., Gansloßer, U. (Eds.), Zoo Animal Nutrition, Filander Verlag, Fürth, pp. 237–250.

Macdonald, A.A. (2000). *Comparative anatomy, physiology and ecology of pregnancy and lactation in wild pigs: a review.* In (Nijboer, J., Hatt, J.M., Kaumans, W. Beijnen, A. and Gansloßer, U., eds.) *Zoo Animal Nutrition*, Filander; Fürth, pp. 213-236.

Macdonald, A.A. (2005). *The Conservation of the Babirusa (Babyrousa babyrussa)* In: N. Sugiri, A.H. Mustari, I. S. Suwelo & I. Djuwita (Eds.) Kumpulan makalah seminar sehari peduli anoa dan babirusa Indonesia, Bogor. Institut Pertanian Bogor, Bogor, Indonesia. pp 90-111.

McDonald, P., Edwards, R.A., Greenhalgh, J.F.D., Morgan, C.A. (1995*). A, 5th edition*. Essex, Longman Scientific and Technical.

McDonald, D.W. (2006). *Wild Pigs and Boars* In: *The Encyclopaedia of Mammals.* Oxford University Press: Oxford.

Meijaard, E., d'Huart, J.P. & Oliver, W.L.R. (2011). *Family Suidae (Pigs)* In: *Handbook of the Mammals of the World. Vol 2. Hoofed Mammals*. (Wilson, D.E. & Mittermeier, R.A. editors) Lynx Edicions: Barcelona, Spain, pp. 248-291.

Nowak, R.M. (1999). *Babirusa* In: *Walker's Mammals of the World Volume 2,* 6th ed. The Johns Hopkins University Press: London.

NRC (National Research Council) (1998). *Nutrient Requirements of Swine*. 10th ed. Washington DC, National Academy Press.

Ramirez, K. (1999). *Animal Training: Successful Animal Management Through Positive Reinforcement*. Shedd Aquarium.

Schmidt, C.R. (1990). *Pigs* In: *Grzimek's Encyclopaedia of Mammals.* McGraw-Hill Publishing Company: USA.

Sutherland-Smith, M. (2015). Chapter 58 - *Suidae and Tayassuidae* (Wild Pigs, Peccaries), In: *Fowler's Zoo and Wild Animal Medicine*, Volume 8, edited by Miller, R. E., Fowler, M. E. and Saunders, W. B. St. Louis, pp. 568-584.

Whitten, A. J. Mustafa, M. and Henderson, G. S. (1987). *The Ecology of Sulawesi* Gadjah Mada University Press: Yogyakarta: pp. 779.

Whittemore, C.T. (1998*). The science and practice of pig production,* 2nd ed. Oxford, Blackwell Science Ltd.

Wikramanayake, E., Dinerstein, E., Loucks, C., Olson, D., Morrison, J., Lamoreux. J., Mcknight, M. and Hedao, P. (2002) *Terrestrial ecoregions of the Indo-Pacific: a conservation assessment.* Island Press: Washington, DC, USA.

Wood, S. (2006). *ABC of Animal Training*. ABC Training Systems, Cancun, Mexico.

4.2 Publications

AFRC (Agricultural and Food Research Council) (1990). *Technical Committee on Responses to Nutrients, Report Number 4, Nutrient Requirements of Sows and Boars.* Nutrition abstracts and reviews 60: pp. 383-406.

Akbar, S., Indrawan, M., Yasin, M. P., Burton, J. and Ivan, J. (2007). *Status and conservation of Babyrousa babyrussa in the Togean Islands, based on direct observations and questionnaire surveys (intermittently, 1990-2001)* In: Suiform Soundings 7: pp. 1.

Berger, E.M., K. Leus., P. Vercammenc., F. Schwarzenberger (2006*). Faecal steroid metabolites for non-invasive assessment of reproduction in common warthogs (Phacochoerus africanus), red river hogs (Potamochoerus porcus) and babirusa (Babyrousa babyrussa):* Animal Reproduction Science, 9, pp. 155–171.

Bowles, D. (1986). Social behaviour and breeding of babirusa. *Dodo, Journal of the Jersey Wildlife Preservation Trust,* 23: pp. 86-94.

Burton, J. (2002). *Short notes on pigs in Lore Lindu National Park* In: *Asian Wild Pig News* 2(2): pp. 30.

Chaudhuri, M., Carrasco, E., Kalk, P. and Thau, R.B. (1990). *Urinary oestrogen excretion during oestrus and pregnancy in the babirusa.* International Zoo Yearbook, 29, pp. 188-192.

Clayton, L.M. (1996). *Conservation biology of the babirusa, Babyrousa babyrussa in Sulawesi, Indonesia*: Thesis (Ph. D.), University of Oxford.

Clayton, L. and MacDonald, D.W. (1999). *Social organization of the babirusa (Babyrousa babyrussa) and their use of salt licks in Sulawesi*: Indonesia Journal of Mammalogy, 80, pp. 1147-1157.

Conklin, N. L., Dierenfeld, E. S. & MacLaughlin, K. A. (1994). *Digestibility and passage of a zoo diet fed to babirusa (Babyrousa babyrussa):* Der Zoologische Garten N. F. 6, pp. 357 – 365.

Fowler M. E., (1996). *Husbandry and disease of captive wild swine and peccaries*. Rev Sci Tech, pp. 141-154.

Fischer, M. (eds) (2002). *Babirusa (Babyrousa babyrussa) husbandry manual*. St. Louis, Missouri: St Louis Zoological Park; Silverspring, Maryland: American Association of Zoos and Aquariums.

Houston, E. W., Hagberg, P., Fischer, M., Miller, M., Asa, C.S. (2001). *Monitoring Pregnancy in Babirusa (Babyrousa babyrussa) with Trans-abdominal Ultrasonography*: Journal of Zoo and Wildlife Medicine, 32(3). pp. 366-372

Kyriazakis, I., Leus, K., Emmans, G. C., Haley, C. S., Oldham, J. D. (1993). *The effect of breed (Large White X Landrace v. purebred Meishan) on the diets selected by pigs given a choice between two foods that differ in their crude protein contents:* Animal Production, 56. pp. 121-128

Lee, R. J., Gorog, A. J., Dwiyahreni, A., Siwu, S., Riley, J., Alexander, H., Paoli, G. D. and Ramono, W. (2005). *Wildlife trade and implications for law enforcement in Indonesia: a case study from North Sulawesi*: Biological Conservation 123, pp. 477-488.

Leus, K. (1994). *Foraging behaviour, food selection and diet digestion of Babyrousa babyrussa (Suidae, Mammalia)*: Edinburgh, The University of Edinburgh, College of Medicine and Veterinary Medicine, Royal (Dick) Veterinary School.

Leus, K., Miller, P., Ida, F., Mardiastuti, A., Masnur, I. and Prastiti, S. (1996). *Population Biology and Modelling of the Babirusa.* In: J. Manansang; A. A. Macdonald; D. Siswomartono; P. Miller; S. Seal, eds. (1996). *Population and Habitat Viability Assessment for the Babirusa (Babyrousa babyrussa)*: Apple Vally, IUCN/SSC Conservation Breeding Specialist Group, pp 31 - 41

Leus, K. (1996). *The habitat and diet of the Sulawesi babirusa (Babyrousa babyrussa celebensis)*. In: Population and Habitat Viability Assessment for the Babirusa (Babyrousa babyrussa). In: J. Manansang; A. A. Macdonald; D. Siswomartono; P. Miller; S. Seal, eds. (1996). *Population and Habitat Viability Assessment for the Babirusa (Babyrousa babyrussa)*: Apple Vally, IUCN/SSC Conservation Breeding Specialist Group, pp. 121 -143

Leus, K., Bowles, D, Bell, J. and Macdonald, A.A. (1992*). Behaviour of the babirusa (Babyrousa babyrussa) with suggestions for husbandry*: Acta Zoologica et Pathologica Antverpiensia. 82, pp. 9-27.

Leus, K. and Morgan, C. A. (1995). *Analyses of diets fed to babirusa (Babyrousa babyrussa) in captivity with respect to their nutritional requirements*: Ibex Journal of Mountain Ecology 3, pp. 41-44.

Leus, K., Goodall, G.P. Macdonald, A.A. (1999). *Anatomy and histology of the babirusa (Babyrousa babyrussa) stomach*. Comptes Rendus de l'Académie des Sciences, Série III - Sciences de la Vie, 322, pp. 1081-1092.

Leus, K., Morgan, C. A. and Dierenfeld, E. S. (2001). *Nutrition of the babirusa.* In: M. Fischer (ed.), *Husbandry Guidelines for the Babirusa (*Babyrousa babyrussa*) Species Survival Plan*, St Louis Zoo, St Louis, Missouri, USA, pp. 11-28.

Macdonald, A. A. (1993) The Babirusa (*Babyrousa babyrussa*) In: W. L. R. Oliver ed. (1993). *Pigs, Peccaries, and Hippos: Status Survey and Conservation Action Plan*, IUCN, Gland, Switzerland, pp. 161 -170.

Macdonald, A. A., Bowles, D., Bell, J., Leus, K. (1993). *Agonistic behaviour in captive Babirusa (Babyrousa babyrussa)*. Z. Säugetierkunde 58, pp. 18-30

Macdonald, A.A. and Leus, K. (1995). *Creating a public understanding of the biology of the babirusa (Babyrousa babyrussa) within a caring zoo environment*. IBEX Journal of Mountain Ecology 3, pp. 37-40.

MacLaughlin K, Thomas P. (1991). *The management of babirusa (Babyrousa babyrussa) at the New York Zoological Society*. In: AAZPA Regional Conference Proceedings, Wheeling, WVA. pp. 650-5.

Meijaard, E. & Groves, C. (2002a). *Proposal for taxonomic changes within the genus* Babyrousa. In: Asian Wild Pig News vol. 2 (1), pp. 9-10.

Meijaard, E. & C.P. Groves. (2002b). *Upgrading three subspecies of babirusa (Babyrousa sp.) to full species level* In: *Asian Wild Pig News* vol. 2, pp. 33-39.

Melisch, R. (1994). *Observation of swimming babirusa Babyrousa babyrussa in Lake Poso, Central Sulawesi, Indonesia:* Malayan Nature Journal, 47, pp. 431-432.

Miller, M, Fischer, M and Houston, E.W. (1994). *The use of behavioural conditioning in the management of babirusa, Babyrousa babyrussa, at the St. Louis Zoological Park*. AZA Regional Conference Proceedings, pp. 274-278.

Milner-Gulland, E. J. & Clayton, L. (2002). *The trade in babirusas and wild pigs in North Sulawesi, Indonesia.* In: Ecological Economics Volume 42, pp. 165-183.

Nijboer, J., Dierenfeld, E.S. (1996). *Comparison of diets fed to Southeast Asian colobines in North American and European zoos, with emphasis on temperate browse composition*. Zoo Biology 15, pp. 499-507.

Patry, M. (1990). *Babiroussa*: une vie jusqu'au bout du rêve. Fixot, Paris, pp. 221.

Patry, M. Leus, K. & Macdonald, A.A. (1995). *Group structure and behaviour of babirusa (Babyrousa babyrussa) in northern Sulawesi.* Australian Journal of Zoology, 43, pp. 64 –655.

Plasa, L. (1990). *Internationales Zuchtbuch für den Hirscheber (International studbook for the babirusa), Babyrousa babyrussa, 1989*: Wilhelma Zoologischbotanischer Garten, Stuttgart, pp. 24.

Riley, J. (2002). *Current Wildlife Conservation Society research and conservation of Sulawesi's suids*. In: Asian Wild Pig News vol. 2 (2), pp. 26-30.

Saville, R., and Hartley, M. (2000). *The growth and development of two hand-reared babirusa, Babyrousa babyrussa, at Port Lympne Wild Animal Park*. International Zoo News. Vol. 47 (1) (No. 298).

Tulung B., Umboh J. F., Pendong A.F. (2013). *A study on babirusa (Babyrousa babyrussa celebensis) in tropical forest of Northern part of* Sulawesi: Scientific Papers. Series D. Animal Science., vol. LVI, ISSN 2285-5750, pp. 107-112.

Wiles, R., Macdonald, A. A., Burton, J. and Mustari, A. H. (2002). *Records of babirusa and warty pigs in southeastern Sulawesi* In: *Asian Wild Pig News* vol. 2(2), pp. 31-32.

Ziehmer, B., Signorella, A., Kneepkens, A.F.L.M., Hunt, C., Ogle, S., Agungpriyono, S., Knorr, C., Macdonald, A. A. (2013). *The anatomy and histology of the reproductive tract of the male babirusa (Babyrousa celebensis)*: Theriogenology, 79 (7), pp. 1054 - 1064

Ziehmer, B., Ogle, S., Signorella, A., Knorr, C., Macdonald, A. A. (2010). *Anatomy and histology of the reproductive tract of the female Babirusa (Babyrousa celebensis)*: Theriogenology, 79, pp. 1054–1064

James, S. B., Cook, R. A., Raphael, B. L., Stretter, M. D., Kalk, P., MacLaughlin, K., Caalle, P. P. (1999). *Immobilization of Babirusa (Babyrousa babyrussa) with Xylazine and Tiletamine/Zolazepam and Reversal with Yohimbine and Flumazenil*: Journal of Zoo and Wildlife Medicine, Vol. 30, No. 4, pp. 521-525.

4.3 Online Material

Brown, D. (2015). *Plants poisonous to Livestock*. Cornell University College of Agriculture. Retrieved from: http://poisonousplants.ansci.cornell.edu/php/plants.php?action=display&ispecies=cattle. (Accessed 01/04/2016)

EAZA, (2014). *EAZA Standards for the Accommodation and Care of Animals in Zoos and Aquaria*. Retrieved from; http://www.eaza.net/about-us/eazadocuments/ (Accessed 01/04/2016)

Gongora, J., Cuddahee, R.E., Nascimento, F.F., Palgrave, C.J., Lowden, S., Ho, S.Y.W., Simond, D., Damayanti, C.S., White, D.J., Tay, W.T., Randi, E., Klingel, H., Rodrigues-Zarate, C.J., Allen, K., Moran, C. & Larson, G. (2011). *Rethinking the evolution of extant sub-Saharan African suids(Suidae,Artiodactyla)*. Retrieved from: http://community.dur.ac.uk/greger.larson/DEADlab/Publications_files/2011%20Zoo%20Scripta%20Suid%20Phylo.pdf (Accessed 19.11.14)

Hassanin, A., Delsuc, F. Ropique, A., Hammer, C., Jansen van Vuuren, B., Matthee, C.,Ruiz-Garcia, M.,Catzeflis, F.,Areskoug, V., Thanh Nguye, T.,Couloux, A. (2011). *Pattern and timing of diversification of Cetartiodactyla (Mammalia, Laurasiatheria), as revealed by a comprehensive analysis of mitochondrial genomes***.** Retrieved from: http://www.academia.edu/1185764/Pattern_and_timing_of_diversification_of_Cetartiodactyla_Mammalia_Laurasiatheria_as_revealed_by_a_comprehensive_analysis_of_mitochondrial_genomes (Accessed 18.11.14)

Macdonald, A.A., Burton, J. & Leus, K. (2008). *Babyrousa babyrussa*. *The IUCN Red List of Threatened Species. Version 2014.3.* Retrieved from: www.iucnredlist.org (Accessed 08/12/2014).

Macdonald, A.A., Burton, J. & Leus, K. (2008). *Babyrousa celebensis. The IUCN Red List of Threatened Species. Version 2014.3.* Retrieved from: www.iucnredlist.org (Accessed 26/11/2014).

Macdonald, A.A., Burton, J. & Leus, K. (2008). *Babyrousa togeanensis. The IUCN Red List of Threatened Species. Version 2014.3.* Retrieved from: www.iucnredlist.org (Accessed 08/12/2014).

Meijaard, E. (2014). *A call from the IUCN SSC Wild Pig Specialist Group to go pig crazy*: Zooquaria, Issue 88, pp. 26 Retrieved from: http://www.eaza.net/about-us/communications/ (Accessed 01/04/2016)

Montgelard, C., Catzeflis, F.M. & Douzery, E. (1997). *Phylogenetic relationships of artiodactyls and cetaceans as deduced from the comparison of cytochrome b and 12S rRNA mitochondrial sequences.* Retrieved from: http://www.ncbi.nlm.nih.gov/pubmed/9159933 (Accessed 18.11.2014)

Whittaker, G., Whittaker, M., Coe, J. C. (2005). *Prototyping Naturalistic Enrichment Features: A Case Study*. Retrieved from: http://activeenvironments.org/pdf/prototyping_naturalistic_enrichment_features.pdf (Accessed 01/04/2016)

4.4 Other Material

Leus, K. (1990) Inleidende studie tot de voedings en verterings – Karakteristieken van Babyrousa babyrussa L. (Hertezwijn); met vermelding van gastro-intestinale parasieten. Unpublished thesis, Universitaire Instelling Antwerpen

Section 5: Appendices

Appendix I: Table of Plants Poisonous to Livestock (Taken from Brown, 2015).

Aconitum spp.	Monkshood, Aconite, Wolfsbane	humans, cattle, goats	leaves, roots, all	aconitine
Aesculus spp.	Horse Chestnut, Buckeye	humans, cattle, goats	fruit	Unknown, possibly saportins, narcotic alkaloids, or glycosides.
Agrostemma githago	Corn Cockle	poultry, cattle, humans, goats	seeds	githagin
Allium spp.	Commercial Onions, Wild Onions, Swamp Onions, Chives	cattle, horses, children	bulbs, lleaves	SMCO
Amaranthus spp.	Pigweed	cattle, swine	leaves	nitrate
Amsinckia intermedia	Fiddleneck	horses, swine, cattle	seeds	intermedine, lycopsamine
Apocynum spp.	Dogbane	horses, cattle, humans, sheep, cats, dogs, goats	rhizome	apocynamarin
Asclepias spp.	Milkweed	sheep, cattle, goats	leaves, fruits, stems	desglucosyrioside, syrioside
Astragalus and Oxytropis spp.	Locoweed	horse,sheep, cattle	flowers, leaves, stems	selenium, nitro compounds, swainsonine
Brassica spp,	Rape, Cabbage, Turnips, Broccoli, Mustard	cattle, humans, swine, sheep, goats, poultry	roots, seeds	glucosinolates, brassica, anemia factor
Chelidonium majus	Celandine	cattle, humans	roots	isoquinoline alkoids
Chenopodium album	Lambs Quarters	cattle, horses, humans, sheep, swine	all	nitrates
Datura spp.	Jimsonweed, Downy Thornapple, Devils Trumpet, Angels Trumpet	cattle, humans, horses, goats	flowers, leaves, seeds	atropine, scopalamine, and hyoscyamine
Delphinium spp.	Delphiniums, Larkspurs	cattle, humans, goats	all	alkaloids delphinine, ajacine, and others
Dicentra spp.	Bleeding Heart, Squirrel Corn, Dutchmans Breeches	cats, cattle, humans	all	isoquinolone alkaloids

Digitalis purpurea	Foxglove	cats, cattle, dogs, goats, horses, humans	flowers, leaves, seeds	cardiac or steroid glycosides
Eupatorium rugosum	White Snakeroot	cattle, dogs, goats, horses, humans, rabbits, sheep	all	tremetone
Euphorbia spp.	Poinsettia, Spurges, Snow on the Mountain	cattle, horses, humans, sheep	leaves, stems and sap	phorbol esters
Festuca arundinacea	Tall Fescue	cattle, horses	all	diaziphenanthrene, pyrrolizidine, and ergot
Halogeton glomeratus	Halogeton	sheep, cattle	leaves, stems	soluble oxalates
Iris spp.	Irises	cattle, humans, swine	rhizomes and rootstocks	irisin, iridin, or irisine
Laburnum anagyroides	Golden Chain, Laburnum	cattle, dogs, horses, humans, swine	pods, seeds, all	cytisine
Lantana camara	Lantana, Red Sage, Yellow Sage, West Indian Lantana	cattle, dogs, goats, cats, humans, sheep	unripe, green berries	triterpenes
Linum usitatissimum	Flax	cattle, sheep	all	cyanogenic glycoside
Lotus corniculatus	Birdsfoot Trefoil	cattle, sheep		CN tannini
Lupinus spp.	Lupine	cattle, goats	seeds	lupinine, anagyrine, sparteine, and hydroxylupanine
Medicago sativa	Alfalfa, Lucerne	cattle, chickens, humans, sheep	all	canavanine, saponins
Metilotus alba and Melilotus officinalis	White Sweetclover, Yellow Sweetclover	horses, cattle, sheep	stem	dicoumarol
Nerium oleander	Oleander	horses, cattle, sheep, dogs, humans, goats	all, leaves, stems	nerioside, oleandroside, saponins, cardiac glycosides
Papaver spp.	Various Poppies including Opium Poppy	cattle, humans	all	codine, morphine, protopine
Phytolacca americana	Pokeweed	cattle, sheep, humans, turkeys, swine, horses	all	phytolaccatoxin, phytolaccigenin
Pinus ponderosa	Ponderosa Pine	cattle	needles, young shoots	unknown
Podophyllum peltatum	Mayapple, Mandrake	cattle, humans, swine	all	alpha- and beta- peltatin, podophylloresin
Prunus spp.	Wild Cherries, Black Cherry, Bitter Cherry, Choke Cherry, Pin Cherry	horses, cattle, moose, sheep, swine, goats	seeds, leaves	amygdalin, prunasin

Pteridium aquilinium	Bracken Fern	horse, cattle, sheep, humans, swine	all	prunasin, ptaquiloside, thiaminase
Quercus spp.	Oak Trees	horse, cattle	acorns, young leaves	gallotannins, quercitrin, and quercitin
Ranunculus spp.	Buttercup, Crowfoot	cattle, goats, horses	all	protoanemonin
Robinia pseudoacacia	Black Locust	horses, cattle, humans, poultry, sheep, goats	bark, leaves, seeds	robin, phasin
Rumex spp.	Dock	cattle, sheep	leaves	soluble oxalates
Sambucus canadensis	Elderberry	cattle, humans, goats	leaves, twigs, roots, unripe fruits	sambunigrin
Senecio spp.	Senecio, Groundsels, Ragwort	horse, cattle, goats, sheep, human	leaves	jacobine, seneciphylline
Solanum spp.	Common Nightshade, Black Nightshade, Horse Nettle, Buffalo Bur, Potato	cattle, humans, rodents, sheep, horses, goats	leaves, immature fruit	soladulcidine,solanine
Sorghum spp.	Sorghum, Milo, Sudan Grass, Johnson Grass	horses, cattle, goats	leaves, stems	dhurrin, nitrate
Tetradymia spp.	Horsebrush	sheep, cattle	leaves	
Trifolium spp.	Alsike Clover, Red Clover, White Clover	horse, cattle	all, leaves	nitrate
Triglochin maritima	Arrowgrass	cattle, sheep	all, leaves, flowers	taxiphillin, triglochinin
Xanthium strumarium	Cocklebur	cattle, humans, rodents, swine	seedlings, seeds	carboxyatractyloside

Appendix II: Chester Zoo Diet Sheet

Animal Feeding Programme
Babirusa

FOOD PREPARATIONS	Quantity as fed to
▪ Apples and pears are quartered. ▪ Potatoes should not be cooked. ▪ Food may be chopped smaller if preferred for scattering.	

FOOD PRESENTATION & COMMENTS	ENRICHMENT FEEDING
▪ Extra forage (especially browse) can be fed to 'hungry' animals. ▪ Dried fruit and nuts are very high in energy and so should be fed sparingly (less than one small handful per animal). ▪ Favoured foods (e.g. fruit) should be fed lastly in the day.	▪ Food is scattered throughout the day to encourage foraging activity.

DIET COMPOSITION

- Total as fed = 2.5kg (60% DM)
- Key nutrient concentrations (as %DM):

Protein	Fat	Calcium	Phosphorus
12%	2%	0.45%	0.11%

- Full analysis available in Zootrition
- Composition given here for male
- Cabbage is used as green veg for analysis
- Apple and potato is used as fruit/root veg for analysis
- Lucerne only is used as lucerne/browse analysis

EVALUATION

- Diet matches nutritional guidelines available for the species (Leus et al., 2001)
- No diet-related health problems diet at Chester Zoo
- No diet-related reproductive problems at Chester Zoo
- **Diet approved & cleared for distribution**

REFERENCES & CREDITS	PRODUCT INFORMATION
▪ Leus, K., Morgan, C.A. and Dierenfeld, E.S. 2001. Nutrition; in Fischer, M., Babirusa (*Babyrousa babyrussa*) Husbandry Manual. American Association of Zoos and Aquariums ▪ MacDonald, D. 2001. The New Encyclopedia of Mammals. Oxford University Press. Oxford, U.K ▪ Species photo: ©Chester Zoo ▪ Copyright (2011) for Species Diet Sheet by Chester Zoo, UK. All rights reserved. No part of this publication may be reproduced in hard copy, machine-readable or other forms without advance written permission from the Chester Zoo.	▪ www.dodsonandhorrell.com

Appendix III: Body condition scoring sheet created by Saint Louis Zoo

Babirusa Body Condition Scoring

Martha Fischer, Curator of Mammals/Ungulates
Ellen Dierenfeld, PhD, Nutritionist
Cyndi Manning, Senior Keeper
Saint Louis Zoo

The following document describes a body condition scoring system for babirusa, *Babyrousa babyrussa,* a species of wild swine native to Indonesia. The body condition scores for babirusa are summarized in Table 1.

Using both visual evaluation and physical touch best assesses a babirusa's body condition, however some babirusas may be too skittish or aggressive to allow tactile assessment. The written body condition score descriptions that follow in this document are accompanied by both illustrated and photographic examples to demonstrate each of the definitions more fully and to assist with the assessment of babirusas which do not tolerate handling.

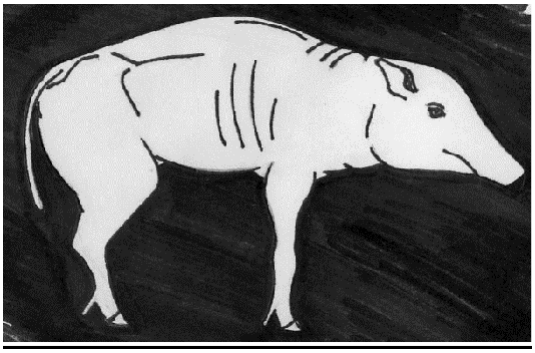
The body condition scoring for babirusa is similar to that utilized with domestic swine. There are three locations on a babirusa's body that should be considered when scoring body condition – Hips, Backbone and Abdomen/Loin. The scoring system starts at **Score 1: Emaciated** and runs to **Score 5: Obese**.

In **Score 1: Emaciated**, the babirusa's body condition is poor and skeletal. The bone structure on a Score 1 pig is clearly visible and prominent with no fat covering over the hipbones, vertebrae or ribs. A **Score 2: Thin** babirusa is lean and slender. The bone structure of a Score 2 pig is still apparent, though with some covering. **Score 3: Good** represents a babirusa which is healthy and fit. A Score 3 babirusa maintains a normal body condition with an appropriate amount of body fat. The hipbones, vertebrae and ribs are not readily visible, though the bone structure can be palpated with firm palm pressure. A **Score 4: Fat** babirusa is considered overweight. The bone structure on this pig cannot be visualized or felt. The final score, **Score 5: Obese**, would include a babirusa which carries an excessive amount of fat all over.

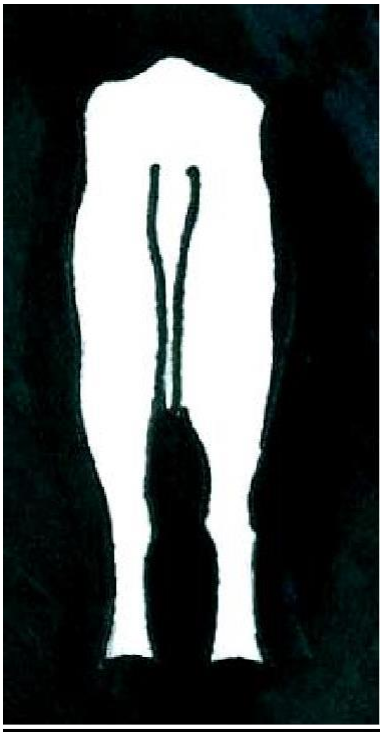
Table 1. Babirusa Body Condition Scoring Summary

SCORE	GENERAL CONDITION	HIPS	BACKBONE	ABDOMEN/LOIN
1 Emaciated	Poor, bony, skeletal	Hipbones easily visible, prominent,	Vertebrae easily visible; prominent all along backbone	Individual ribs very apparent
2 Thin	Adequate, slim, lean	Hipbones visible with some cover	Vertebrae visible with some cover	Individual ribs apparent with some cover
3 Good	Ideal, normal, fit	Good cover, hipbones can only be felt with firm pressure	Good cover, vertebrae can only be felt with firm pressure	Ribs not visible and difficult to feel
4 Fat	Unsatisfactory, plump, round	Hipbones well-padded, cannot be felt	Vertebrae well-padded, cannot be felt	Ribs cannot be seen or felt; abdomen/loin somewhat rounded
5 Obese	Poor, overweight, rotund	Hips rounded and hipbones thickly covered, cannot be felt	Vertebrae thickly covered, cannot be felt	Ribs thickly covered, cannot be felt; abdomen/loin grossly rounded

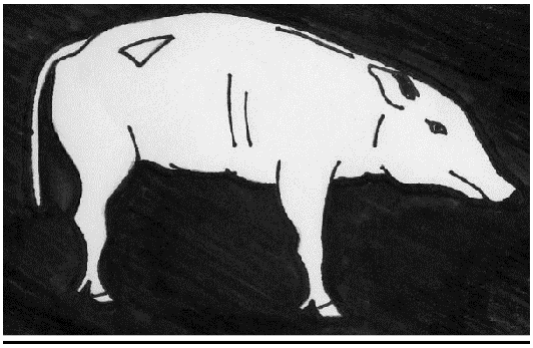
Score 1: Emaciated

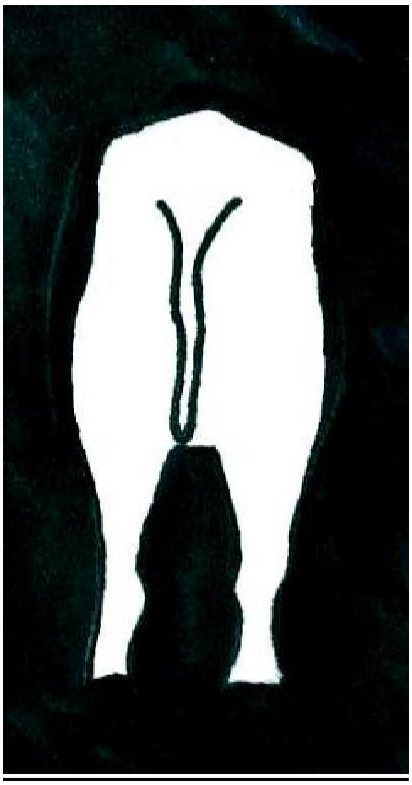


General Condition:	Poor, bony, skeletal
Hips:	Hipbones easily visible, prominent
Backbone:	Vertebrae easily visible, prominent, all along backbone
Abdomen/loin:	Individual ribs very apparent



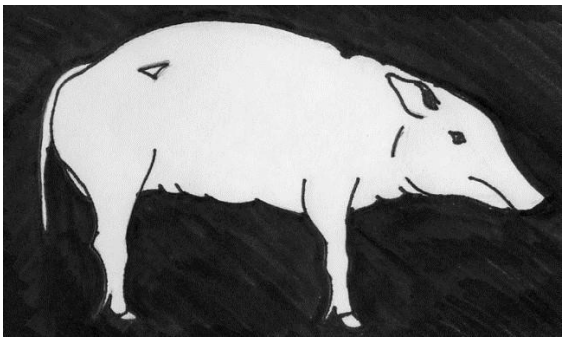
Score 2: Thin

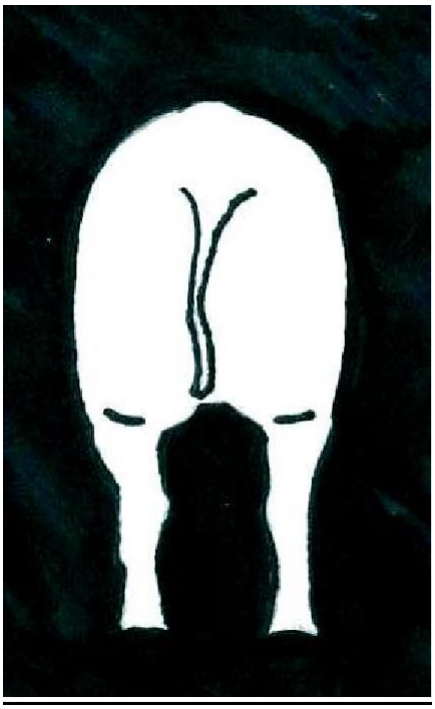




General Condition:	Adequate, slim, lean
Hips:	Hipbones visible with some cover
Backbone:	Vertebrae visible with some cover
Abdomen/loin:	Individual ribs apparent with some cover

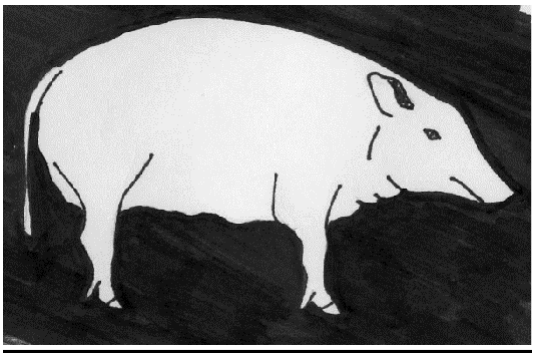
Score 3: Good

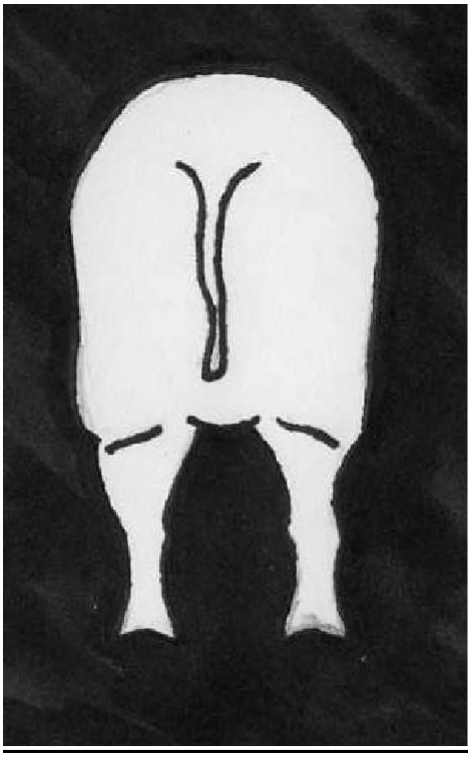




General Condition:	Ideal, normal, fit
Hips:	Good cover; hipbones can only be felt with firm pressure
Backbone:	Good cover; vertebrae can only be felt with firm pressure
Abdomen/loin:	Ribs not visible and difficult to feel

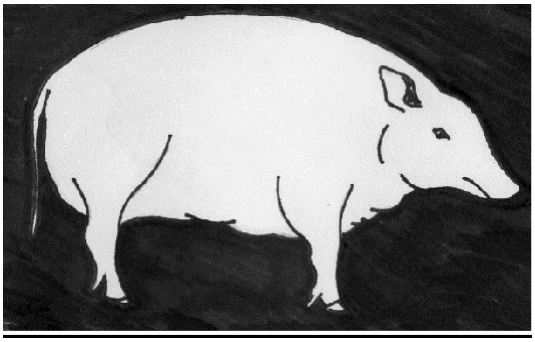
Score 4: Fat

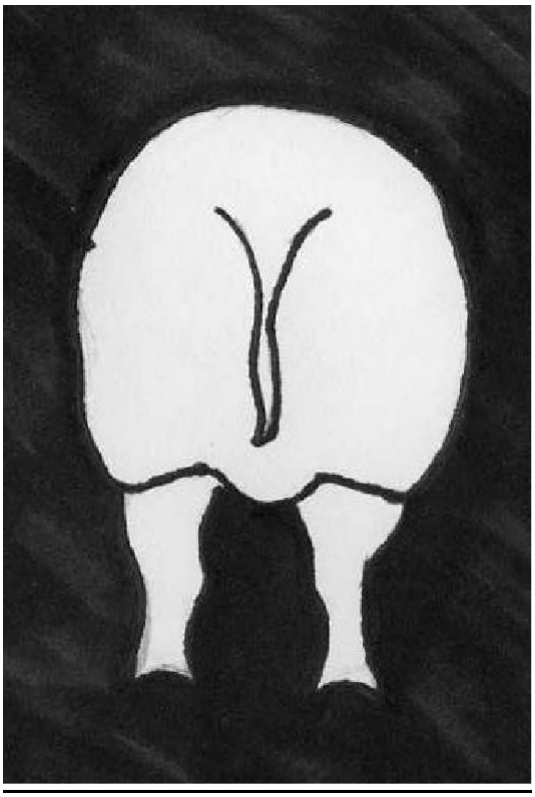




General Condition:	Unsatisfactory, plump, round
Hips:	Hipbones well-padded, cannot be felt
Backbone:	Vertebrae well-padded, cannot be felt
Abdomen/loin:	Ribs cannot be seen or felt; abdomen/loin somewhat rounded

Score 5: Obese





General Condition:	Poor, overweight, rotund
Hips:	Hips rounded and hipbones thickly covered, cannot be felt
Backbone:	Vertebrae thickly covered, cannot be felt
Abdomen/loin:	Ribs thickly covered, cannot be felt; abdomen/loin grossly rounded

Appendix IV: Hand-rearing case study (Joe Dennis, 2007)

CASE STUDY:

The hand-rearing of two Babirusa(*Babyrousa babyrussa)* at South Lakes Wild Animal Park 2007 By Jo Dennis

Figure (2.5): Pair of hand-reared piglets.

Introduction

Many problems have been found when breeding babirusa in captivity. Firstly, there are only few individuals maintained within breeding programmes worldwide and, secondly, success in breeding and rearing offspring is often extremely poor within captivity. This report briefly describes the hand rearing of twin Babirusa, a male and female, born at South Lakes Wild Animal Park in 2007. The decision was made to hand rear the offspring due to the risk of infanticide by the mother, seen in many previous litters. Due to the litter size of Babirusa only being small (averaging only two offspring) and the ageing of the breeding animals in question, hand rearing as many litters as possible from this date was the best chance of future success within the breeding programme.

History

South Lakes Wild Animal Park waited many years to gain a female with which to breed from but then, although she bred and produced offspring regularly, she only successfully reared one, a single-born male. Many ideas and attempts were performed to allow the female maximum privacy with each litter, but all had failed. Since her successful rearing in 2003, she has committed infanticide on every occasion, failing to rear any young. Her past pregnancies had lasted between 147-152 days, however on this occasion copulation had not been witnessed therefore she, instead, had to be monitored closely, watching for any noticeable physical and behavioural changes in order to estimate a date of birth.

She displayed many signs of nest building in the weeks prior to birth, becoming very protective of her surroundings and showing increased aggression towards certain keepers nearing parturition. Physical changes, such as milk development, only became obvious within the final week.

Previous births from this female appeared to have occurred during the latter part of the night and on this occasion it was believed that the young had been born approximately 15-30mins before keeping staff arrived. Thus, the first birth was estimated to be around 6.30am on the 29th August 2007.

Dam

Figure (2.6): Dam of hand reared piglets.

The mother had shown some basic maternal instinct at this stage as the babies were both clean and free from birthing material.

Past reports of the behaviour of this female suggested she killed the young 1-2 hours after parturition so in this case, every effort was made to remove the offspring immediately. Although it would have been preferred to allow the youngsters to take at least one or two feeds from the mother to provide them with some amount of colostrum, the risk was too great and she showed no interest in allowing her young to suckle whilst she was aware of keepers monitoring the situation. Great care had to be taken when removing the youngsters as the mother, naturally, showed tremendous aggression and keepers could only enter with adequate forms of protection. This involved a couple of sheets of strong plywood to separate mother from offspring and staff. Infant A, a male, weighed 625g at birth and Infant B, a female weighed a heavier 750g.

Rearing

Both infants were kept in a heated building on long straw and under a heat lamp. At night, both were taken to keeper accomodation and housed in a crate, inside of which contained a brand new, un-contaminated, 'igloo style' cat bed along with daily fresh towel bedding to keep them warm. A simple halogen heater added extra warmth of a night time. Finding information on hand rearing such animals proved very difficult, however, Port Lympne Wild Animal Park had previously been successful in rearing two Babirusa, and so with many thanks to them, their protocol was adopted initially. Commercial pig milk ("Volac Farmamate") was used along with a commercial pig colostrum substitute ("Volostrum"), supplied to the park by the vet. To begin with the infants were only fed 2mls of Volostrum each at two hourly intervals. On the third occasion this was combined with 7mls of Volac milk (warmed to body temperature). Both were fed using human baby bottles. Various basic teats were experimented with until the most preferred one for each was found. Patience was required as both fed quite slowly to begin with; it took time for them both to understand that the bottles meant food.

Sire

Figure (2.7): Sire of hand reared piglets.

The milk was fed alongside the Volostrum for a total of ten feeds (20mls Volostrum each), after which only the milk was fed. Fresh water was provided in a shallow bowl throughout the rearing process.

Figure (2.8): Hand bottle feeding of piglets.

By day two, the milk was gradually increased for both. The male began taking up to 12mls and the female was taking up to 14mls. Fear of allowing them to suckle too much in these initial days, was a slight concern so, at this point feeding was strictly kept to small amounts and often (every two hours). This however, could've been the stem to health issues, discussed later on. By the middle of day two, both infants had passed the meconium and had begun producing solid faeces by day three. On day four, the vet was contacted as both infants were scratching and had very dry skin. The straw was then replaced with, softer, meadow hay and the vet advised to apply Johnson's baby lotion twice daily to their skin.

By the end of day four, the male appeared to be showing signs of deterioration. He frequently began passing runny yellow/brown faeces, although initially he was still quite lively. The female, however, was still healthy, producing solid

brown stools. This contrast between the two made it very obvious that the male was unwell and the vet was contacted immediately. The milk was reduced, diluted and boiled water was also given to try and combat the problem. Initially, the thought was that the milk was too rich for his possibly, slightly under developed, stomach. However, although he was suckling the fluids through into day five, he was weakening rapidly. The decision was made to hand him over to the vet for intensive medical treatment and monitoring.

Medicinal treatment by the vet consisted of a Glucose injection along with fluids and the appropriate antibiotics. Over a period of five days, the vet brought him round to better health again. He was brought back to the park and reintroduced to his sister as the vet believed it to be a physical problem within his gut, rather than a bacterial infection. Medication was continued in order to finish his course. Following this, he blossomed! His faeces gradually returned to a healthy, brown stool and, over time, he began suckling well again.

Figure (2.9): Hand bottle feeding of piglets.

Reflecting on this problem, I believe the issue may have related to a slight lack of milk rather than it being too rich for him or him receiving too much. When the vet took the male, he allowed him to suckle to satisfaction, within reason, feeding up to 30mls per feed. I feel this may have been my downfall to his deterioration and my concerns of feeding too much may have been the cause. In hindsight, I would probably allow a little more freedom to suckle, although still remain cautious so not to over-feed. In this period of time, the female remained a strong and healthy individual and by day nine, she was also consuming around 30mls+ per feed and had put on 125g in body weight. She suffered a little with constipation, only passing faeces every couple of days. However, feeding a little boiled water between feeds seemed to combat this problem.

Due to the slight set back with the male, experimenting with a little fresh food was left until he appeared ready on day 16. Finely chopped lettuce/grated pear, carrot and apple/mashed banana/chopped grapes, were initially experimented with, prior to every few feeds. Surprisingly, the male showed the most interest. The milk feeds were also less strict at this point, feeding them at every 2-3 hours but still feeding through the night. The female was now consuming 40mls+ and the male, consuming up to 35mls per feed.

Figure (3.0): Pellet feed.

At three weeks old, a few commercial weaner pellets ("Massey, Turbo grow pig pellets") were given with the fruit and vegetables and the food was provided ad-lib throughout the day, allowing them to experiment. The milk feeds were still provided at 2-3 hourly intervals. The female was now weighing in at a substantial 1.5kg and the male, 850g, almost half her size due to his earlier health hiccup, however he was now growing at a similar rate to her.

Figure (3.1): Hand reared piglets.

At six weeks old, the youngsters began their weaning process. Night time feeds were gradually reduced to none. Bottles were stopped and instead, watered down milk was provided in bowls, alongside their fresh food and weaner pellets. This continued over a period of weeks, gradually reducing the milk and increasing their solid food intake.

At three months old, both youngsters were healthy weights. The female weighed 7.8kg and the male, 5kg. Both were now relying almost completely on solids.

Figure (3.2): Youngsters moving onto solid food.

At this point they were moved into the Babirusa house in the main park and continued their successful growth into adulthood. At five months of ages, the weaner pellets were gradually replaced with the Beef nut pellets, fed in the adult diet.

Figure (3.3): Youngsters in enclosure feeding on solids.

Further Information

If any further information is required, please do not hesitate to contact me:

South Lakes Wild Animal Park,
Dalton in Furness,
Cumbria, LA15 8JR, UK
T: (01229) 466086
F: (01229) 461310
jodennis@wildanimalpark.co.uk
www.wildanimalpark.co.uk

Appendix V: Chester Zoo Example Training Plan

TRAINING PLAN

Animals:

Species: **Babirusa**

Trainer:

Approved by _____ Risk Assessment: YES

Notes: Desensitise babirusa to having hands on contact to enable keeper to trim their hooves.

Medication: NONE

Behaviour name – Desensitise to having hooves trimmed

Behaviour description – Babirusa to be calm in keeper presence and with contact, animal to be comfortable having hooves trimmed, no negative behaviours displayed i.e. charging/biting

SD (discriminative stimulus) description: Visual – keeper present

Reward – Touch/keeper contact

TIME MANAGEMENT

Start time ASAP Estimated training time: 5mins/animal/3days

Completion date: ON GOING Total training time: 15 minutes/week/ 1.1

1	Enter enclosure while the sp. is on the paddock, trainer talking throughout, and calling sp's name to come over. Trainer to maintain natural posture and allow sp. to move around and approach trainer	
2	When babirusa approaches, trainers hand will be extended. When the animal is near and calm, trainer to touch the top of head, progressing gradually to the neck and along the body/back.	
3	When babirusa approaches, trainers hand will be extended. When the animal is near and calm, trainer to touch the top of head, progressing gradually to the neck and along the body/back. Trainer to touch under sp's stomach and legs	

4	When babirusa approaches, trainers hand will be extended. When the animal is near and calm, trainer to touch the top of head, progressing gradually to the neck and along the body/back. Trainer to touch under sp's stomach and legs. When babirusa is relaxed she may lie down on the floor, or remain standing. Whether sp. is in a standing or lateral position trainer to continue to touch sp. all over as long as she is calm	
5	Second keeper to enter enclosure with trainer. When babirusa approaches, trainers hand will be extended. When the animal is near and calm, trainer to touch the top of head, progressing gradually to the neck and along the body/back, stomach and legs. When babirusa is relaxed she may lie down on the floor, or remain standing. Whether sp. is in a standing or lateral position trainer to continue to touch sp. all over as long as she is calm, trainer to touch sp's feet and hooves	
6	Trainer and second keeper to enter enclosure. Trainer to introduce hoof clippers, trainer to take clippers into enclosure. When babirusa approaches, trainers hand will be extended. Trainer to touch the top of head and progress to neck and along body/back, stomach and legs. When relaxed the babirusa may lie down or remain standing with second person close by, trainer touches feet and hooves if animal calm. Trainer touches hooves with hoof clippers, open and closes them, so the noise is heard	
7	Trainer and second keeper to enter enclosure with hoof clippers. When babirusa approaches, trainers hand will be extended. Trainer to touch the top of head and progress to neck and along body/back, stomach and legs. When relaxed the babirusa may lie down or remain standing with second person close by, trainer touches feet and hooves if animal calm. One keeper has hands on contact with animal's body, and the other touches the foot and hooves with hoof clippers	
8	Trainer and second keeper to enter enclosure with hoof clippers. When babirusa approaches, trainers hand will be extended. Trainer to touch the top of head and progress to neck and along body/back, stomach and legs. When relaxed the babirusa may lie down, or remain standing with second person close by, trainer touches feet and hooves if animal calm. One keeper has hands on contact with animal's body, and the other touches the foot and hooves and is able to trim hooves	

Notes:

- Babirusa is already comfortable with hands on keeper contact. She is very nervous when male present, male never to be in view during training.

- Babirusa when relaxed and calm are known to lie on the floor, however Malam has never lay down during hands on contact with keeper. Malam however remains calm in a standing position only. Only when the sp. is really calm can hooves be trimmed
- Video diary and training reports will be completed weekly
- Risk assessment completed
- Keepers to be trained how to use hoof trimmers
- Second person (team manager/ lead keeper/vet) to trim hooves while trainer keeps animal relaxed by positive hands on contact

Reward:

Contact - progression to scratching behind ears/along body, under stomach and legs as this is thought to be rewarding and positive

Food reward may result in risk of being bitten.

Potential Aims:

Introduce hoof clippers, with the aim to trim the hooves without the need for general anaesthetic

Suggested Training Times:

During daily cleanout + additional times during afternoon when deemed enough time