Husbandry Guidelines for the Babirusa (*Babyrousa babyrussa*) Species Survival Plan

Edited by Martha Fischer, St. Louis Zoo

AZA American Zoo and Aquarium Association

Species Survival Plan

Saint Louis Zoo

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Cover photo: **Homer.** ***Chuck Dresner, St. Louis Zoo.***

(Photo: C. Dresner, St. Louis Zoo)

HOUSING AND ENCLOSURE REQUIREMENTS

Effective management of the babirusa requires proper housing. This chapter of the Husbandry Guidelines for the Babirusa SSP is a compilation of a survey sent to eight institutions housing babirusa. Using the survey results and the AZA Mammal Standards for wild swine, these guidelines have been developed on the suggested housing of this species in captivity. Managers are asked to use these guidelines and to report any experiences that may improve the guidelines to the SSP Coordinator. Constructive comments have also been gathered from European zoos housing babirusa.

Babirusa need indoor enclosures and should have the opportunity to spend time in an outdoor enclosure. Housing animals together in pairs and as single sex groups have been successful in North America, Europe and Indonesia. Pregnant sows usually need to be separated from other babirusa prior to parturition, as boars as well as other sows have been known to kill infants.

INDOOR ENCLOSURE REQUIREMENTS

Size: Dimensions of indoor stalls vary among zoos from 2.9 to 28 square meters (32 to 312 square feet). The recommended size for indoor enclosures is 4.5 square meters (~50 square feet) for each individual or female with litter. If a single sex group is housed together, the group must be monitored for aggression prior to decreasing the amount of available space per individual (in a single indoor enclosure) from 4.5 square meters to 2 square meters per individual.

Structure: Enclosure walls and doors need to be solid for the bottom ½ meter to prevent foot/leg injuries and/or neonates escaping the enclosure. Most enclosures are made with concrete but wood has been used at one facility. All enclosures need to be able to be cleaned properly. Doors have been constructed in a variety of ways. Doors which are barred with spacing of bars from 3-31/2 inches can be utilized for trimming tusks. Care must be taken to avoid large gaps between bars, around doorways, between walls, etc., as males may get tusks caught or broken. Each enclosure should have two animal doors to aid in introductions. With two animal doors, a "run around" can be created to prevent animals from being cornered.

Substrate: Babirusa can be susceptible to foot and leg problems. These problems, which are associated with confinement lameness, may be a result of the flooring since most enclosures are concrete. The inflexibility of concrete and its roughness have been the suspected causes of these problems. Several options have been

experimented with to reduce the risk of health problems. A rubber coating, much like that found in horse barns, has been used at two institutions. Rubber mats that can be removed and cleaned have also been utilized. Rubber mats can be a problem if not cut carefully to fit the size of the floor because animals will chew on the ends of the mats if they are exposed.

(Photo: D. Wilson, St. Louis Zoo)

Bedding, such as hay, straw, wood shavings and/or fine mulch have also been used as substrate. The hay or straw provides not only a cushion between the animal and the concrete but also serves as bedding material used by both sexes to form nests into which they burrow at night. This is particularly important for females prior to and after birth. Prior to parturition, the female will build a large nest into which she can burrow. These nests are believed to be important for reducing female stress before and after birth.

Water: Providing fresh water for animals is essential. Commercial hog waterers are available and work well. Other waterers that have been used successfully include Nelson waterers and lixits. Large tubs of water can be used but animals tend to tip over tubs. All drinking containers should be cleaned and disinfected daily.

Lighting: Natural or artificial lighting needs to be provided for each area. Natural lighting may not be sufficient on overcast or winter days, so supplemental lighting should be available in all indoor areas. Additional artificial lighting may be needed at doors if these are to be used as ports to trim tusks.

Heating: All indoor enclosures need supplemental heat. Depending on location of the facility, heating can be accomplished using heat lamps, pig mats, forced heat or a combination. One facility has built hot water pipes under the flooring to provide heating without the drying properties of most heat sources. Babirusa piglets, like their domestic cousins, are likely to be poor thermoregulators and may need supplemental heat beyond that normally provided for adults. Providing adult and infant domestic pigs with a gradient of temperatures allows each to select a preferred microclimate (Liptrap, *et al*., 1980). During those months when animals are not given the opportunity to go outdoors, forced heat can cause skin problems. Mineral or baby oil can be applied topically to alleviate cracked and dry skin. Maximum and minimum temperatures of indoor areas need to be monitored to provide the most comfortable range for animals. Maximum indoor temperature ranges from 24 – 35°C (75 – 95°F) and minimum indoor temperature ranges from 4.5 – 20°C (40 – 68°F), because this is a tropical forest species. If winter housing is maintained at the low end of the range, ample bedding must be provided. If housing is maintained at the high end of the range, air needs to be circulated within the facility.

Ventilation: Good ventilation in indoor areas is essential. Exhaust fans or air exchange units are necessary, but drafts can be a problem especially with neonates and young. If temperatures exceed 30°C, air needs to be circulated. Exhaust fans and portable fans will aid in the circulation of air within the facility.

(Photo: B. Meng, WCS/Bronx Zoo)

OUTDOOR ENCLOSURE REQUIREMENTS

Size: Outdoor enclosures should be available to all animals, at least on a rotating basis. Outdoor areas range from 66 - 1324 square meters (720 - 14,400 square feet) with the average size being 225 square meters (2500 square feet). AZA Mammal Standards for wild swine state that minimum size for outdoor enclosures need to be double the size of indoor housing (minimum recommended size for indoor enclosures is 4.5 square meters per animal). The Babirusa SSP recommends areas larger than this minimum size to enable natural behaviors to occur. These outdoor areas need to be able to accommodate breeding pairs, small single sexed group or sow and offspring. These areas should also be large enough to allow for the introductions of new animals.

Structure: A variety of barriers have been used successfully with babirusa. Minimum barrier height needs to be 1.5 meters (5 feet). Barriers include gunite rockwork, bollards, wooden fencing, chain link fencing, and commercial hog fencing. All have contained animals but neonates should not be allowed outdoors with open weave fencing until young are large enough to be contained. Water moats can not be used as barriers since babirusa swim. Fence lines need to be monitored because babirusa will dig, although they do not root as aggressively as other swine. Electric fencing is a reliable barrier for babirusa but it should only be used as a secondary, not primary, barrier. It is especially useful in protecting plantings. Pools for drinking and bathing are recommended. Wallows should either be constructed in the enclosure or animals should be allowed to make their own.

(Photo: WCS/Bronx Zoo)

Substrate: A soft, natural substrate should be used in outdoor enclosures. Several species of trees, shrubs and grasses have been successfully grown in enclosures with babirusa. These include bamboo, sweet olive, tallow, honeysuckle, elm, maples and conifers. Each institution needs to determine which plant species are appropriate for their specific climates. Plants that are potentially toxic should not be used inside animal areas as babirusa will chew or consume them. Plantings can be protected by physical barriers such as fencing, electric wire or log planks. Rocks around plants may deter animals but care should be taken as animals may climb rocks risking leg injuries.

Temperature: Animals can be given access to outdoors with temperatures as low as 1.7°C (35°F) if there are sunny conditions with no wind chill. Many institutions have the capability to give animals "open house", where they can go into heated indoor areas if temperatures drop below 4°C (40°F).

FURNISHINGS - INDOORS AND OUTDOORS

Furnishings are used for enrichment and as sight barriers. Many institutions provide items such as logs, plant material and Boomer balls in outdoor enclosures. Scattering of food items throughout the enclosure and/or in pools encourages foraging behavior and swimming. Animals in the wild reach up for fruit on tree trunks or hanging from branches. Food items suspended in this way allow babirusa to exhibit their natural ability to stand on their hind limbs while browsing. Boomer balls with holes can be filled with pelleted grain or other food items as part of an enrichment program. As with all food items used as enrichment, the weight of the animals most be monitored closely to avoid overweight individuals. Non-natural items, including "kiddie" pools, rubber tubs, push brooms for rubbing, are used indoors for enrichment.

(Photo: WCS/Bronx Zoo)

(Photo: T. Motoyama, Los Angeles Zoo)

Pregnant females need additional bedding to create nest sites prior to parturition. Several different hays have been used for this purpose including sudan, alfalfa and bermuda. Enrichment items for pregnant females are important to decrease boredom and the stress of parturition.

SPECIAL FEATURES

Many institutions do not allow animal staff to enter enclosures with babirusa, especially males, so the use of specialty equipment improves the ability to monitor animals. Video monitoring equipment is advantageous when births occur, especially with inexperienced females. Continuous monitoring of mother-infant interactions for the first 30 days gives insight to health and well-being of neonates. Walk-on scales are helpful with monitoring weights of all animals. Babirusa are highly intelligent and can easily be trained to stand on a scale.

ADJACENT SPECIES

Babirusa have been housed next to several different species. Swine species housed next to babirusa include red river hog and bearded pig. Other species within visual contact include wallaby, Indian hog deer and several types of water fowl. Audubon Park and Zoological Garden has successfully housed babirusa and small clawed otters in the same outdoor enclosure.

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(Photo: S. Trim, Oklahoma City Zoo)

MANAGEMENT, RESEARCH AND ENRICHMENT

IDENTIFICATION

Adult babirusa are usually kept in pairs and are easy to distinguish from each other. However, all babirusa should be identified using some permanent method, such as transponders, ear notches, ear tags or tattoos. Over half of the zoos surveyed used at least one method of permanent identification, predominantly transponders. 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.

HANDLING

There are as many ways to manage babirusa as there are institutions exhibiting babirusa. Each zoo has a daily routine that is designed to fit their facilities and the personalities of the babirusa at their facility. The type of interaction between keeper and babirusa varies from extremely hands-on to completely hands-off.

(Photo: T. Motoyama, Los Angeles Zoo)

(Photo: WCS/Bronx Zoo)

The individual temperament of each babirusa determines whether the keeper enters the enclosure with the babirusa. Some babirusa are extremely tolerant of a keeper working in close proximity to them and/or to manually handling them within the enclosures, while some babirusa are too aggressive for a keeper to safely enter the enclosure with them at all.

RESTRAINT

Manual restraint has only been used to restrain babirusa piglets and juveniles up to 4 months of age. Fortunately, many management concerns pertaining to adult babirusa can be addressed using operant conditioning. Some management concerns that have been addressed using operant conditioning include routine weighing, tusk trimming, hoof trimming, skin care and pregnancy detection via transabdominal sonography.

Any procedures that cannot be accomplished with operant conditioning usually require chemical immobilization of the animal. Some of the procedures accomplished using chemical restraint include transfer to a new enclosure, tusk trims, hoof trims, pregnancy detection via transabdominal sonography, and preshipment and quarantine testing.

SHIPMENT

The crating of babirusa for moving within an institution or shipping to another institution is fairly easy. All of the institutions used food to gradually acclimate the babirusa to the crate prior to shipment. After crating, babirusa can be either transported by air or by trailer.

Crates for babirusa should be sturdy and can be made from wood or metal. The crate should be laarge enough to allow the babirusa to lay down. The top of the crate should provide a minimum of 15 cm (6 in) 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 sides, ends and top.

OPERANT CONDITIONING

Operant conditioning using positive reinforcement can be a useful management tool with babirusa. (Miller *et al*, 1994; MacLaughlin and Thomas, 1991). Babirusa are quick learners and will do just about anything for food. Many institutions exhibiting babirusa currently have a loosely-structured operant conditioning program in place and are able to address a wide range of management concerns without the need for chemical restraint.

Tusk trimming. ***(Photo: WCS/Bronx Zoo)***

Some of the management concerns addressed include pregnancy detection using transabdominal sonography (Houston *et al*, in prep), routine weighing, tusk trimming, hoof trimming, skin care and crate training for shipment.

Acclimation training. ***(Photo: St. Louis Zoo)***

Operant conditioning programs for babirusa vary from institution to institution. Some institutions have very formalized operant conditioning programs in which a keeper devotes 30-60 minutes each day to handling each babirusa from within the animal's enclosure. Other institutions have more informal programs and use operant conditioning only as needed from behind a protective fence or barrier. Whether formal or informal, an operant conditioning program has many benefits for babirusa, including a reduced need for chemical restraint for minor husbandry, veterinary and research procedures, acclimatization of nervous animals, and behavioral enrichment.

Weighing. ***(Photo: T. Motoyama, Los Angeles Zoo***

RECORDS

All institutions holding babirusa currently maintain a written daily keeper log noting medical problems, reproductive activity and any unusual behaviors. Additionally, some institutions keep daily records on the sow's vulva swelling to track her reproductive cycle or pregnancy. Two institutions have utilized time-lapse infrared video to record behavior of their babirusa.

Transabdominal sonography. ***(Photo: St. Louis Zoo)***

ENRICHMENT

Enrichment can be defined as a way of changing the daily routine or the enclosures of captive animals to improve their environment and encourage more naturalistic behaviors. All of the zoos exhibiting babirusa offer sporadic and varied types of enrichment to the babirusa as the keepers' time allows. Many expressed the desire to initiate a more formalized enrichment program for this species.

Enrichment. ***(Photo: St. Louis Zoo)***

RESEARCH

All Babirusa SSP institutions participated in genetic research which confirmed the oral and written history indicating that the global captive population of babirusa is highly inbred.

Two institutions had participated in or were currently participating in research projects involving babirusa. Bronx - mother/infant behavior (MacLaughlin *et al* 2000) and Nutrition (Conklin *et al*, 1994; Brongo, 1999)). St. Louis - mother/infant behavior (on-going) and semen collection (future).

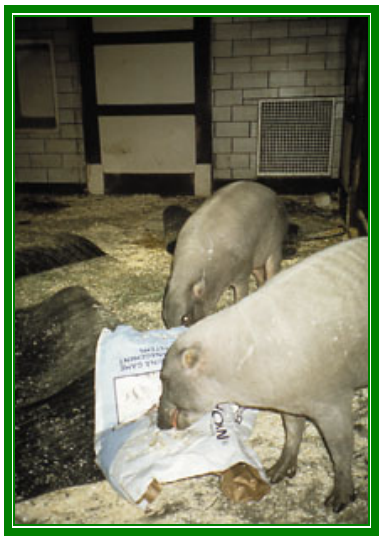
Enrichment. ***(Photo: WCS/Bronx)***

Babirusa are prone to obesity which may reduce fecundity and may contribute to arthritic symptoms in this species. If food items are offered as enrichment, the rations at regular feedings should be reduced so that the daily recommended intake remains consistent.

Below are a few ways that institutions are currently enriching their babirusa...

Feeding routine: Rather than offer a babirusa's daily allowance of food at one feeding, it is offered at different times throughout the day (for example, produce on exhibit in am, browse midday, and hay/grain in barn in pm). Several zoos periodically toss produce into the exhibit to encourage the babirusa to be more active during the day.

Food items: Some suggestions for enriching food items include various types of browse, apples, pears, grapes, cantaloupe, watermelon, sweet potatoes, squash, carrots, and greens. Some additional treats suggested include sunflower seeds, raisins, popcorn, cereal, pumpkins, molasses, frozen fruit treats and peanut butter.



Enrichment. *(Photo: St. Louis Zoo)*

Food Presentation: Spreading food throughout the enclosures, hiding chunks of produce under rocks and in logs, and floating produce in pools are just a few ways to offer treats to babirusa while encouraging increased activity and exercise. Food can also be suspended in such a way that the babirusa can only reach it by standing on its hind limbs.

Operant Conditioning: Babirusa are intelligent animals and daily interaction with the keeper can be enriching for babirusa. Operant conditioning gives the keeper a chance to address minor husbandry concerns such as tusk trimming or skin care and gives the babirusa a chance to interact with the keeper for a reward.

Exhibit Design: The exhibit should be an enriching place for the babirusa. Babirusa will usually use mud wallows or pools if offered. Heavily planted exhibits provide a naturalistic environment and allow selective browsing.

Toys: Many everyday items can be used as toys for enrichment for babirusa. Some suggestions include boomer balls, boomer balls with holes and filled with grain, peanuts or raisins, scratch brooms, rotten logs, water tubs, barrels, rubber mats, hanging buckets or buoys, and showers or sprinklers. All of the zoos were in agreement that babirusa become bored with toys easily. It is necessary to rotate these toys often for them to be effective.

(Photo: T. Motoyama, Los Angeles Zoo)

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NUTRITION

BACKGROUND INFORMATION TO THE FEEDING ECOLOGY

Information from the Wild

Information on the diet of wild babirusa is largely descriptive and qualitative in nature. A detailed review of all information available from the literature can be found in Leus (1996). The lack of quantitative information does not allow much more to be said than that babirusa appear to show a preference for fruits and seeds but that they also consume a variety of leaves, grasses, fungi, invertebrates and small vertebrates, and garden products.

Very few wild food items are mentioned by name in the older literature: leaves of the "waringi" tree (most likely a fig species (*Ficus* sp.)), "canari" seeds (almond-like seeds of the fruits produced by trees of the genus *Canarium*) (Valentijn, 1726), *Elatostema* sp. (a non-stinging member of the nettle family Urticaceae), acorns (*Lithocarpus* sp.) (Selmier, 1978, 1983), "pangi" (*Pangium edule* – a large fruit of the family Flacourtiaceae) (Whitten *et al*., 1987). Among the garden products consumed were mentioned: coconuts, mangos, maize plants, millet, sweet potatoes, sugar cane and small herb trees. More recent investigation of stomach contents and faeces of wild babirusa in North Sulawesi (Clayton, 1996) indicated that the wild babirusa diet indeed mainly consists of fruit and/or seeds as well as some animal material, leaves, grasses and soil and rock fragments. The following genera/species of fruit/seeds could be clearly 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).

Hunters and guides of Lore Kalamanta claim to be able to distinguish between furrows made by *Sus celebensis* (the Sulawesi warty pig) and those produced by babirusa. Babirusa are said to make shallow, straight-lined furrows whereas *Sus celebensis* dig deeper and thrust their snouts in lines that radiate from one spot (Selmier, 1978). Babirusa in captivity appear equally unable to root in compact ground and only appear to turn over loose soil or wet mud (Leus *et al*., 1992; Leus and Vercammen, 1996). The lack of a well developed rostral bone in the nose of the babirusa (Macdonald, 1993) may explain their limited ability to root in more compact substrates and may imply that roots are a less important category in the diet of the babirusa compared to that of the other wild pigs.

Table 1: 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 "Marisa"	Sediment salt lick "Lantolo" (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	

** Analyses carried out on the insoluble fraction of the sediment*

Babirusa in the wild visit volcanic salt licks to drink large quantities of the salty water, to lick the stones and to ingest the soil (Patry *et al*., 1995; Clayton, 1996). Results of the analyses of the water of the "Marisa" salt lick and the sediment of the "Lantolo" salt lick in North Sulawesi can be found in Table 1 (Patry pers. comm., 1989 – for details of locations see Patry *et al*., 1995). Additional analyses of soil and water samples from salt licks in the same region by Clayton were compared with results from control samples (soil taken 25m away from the salt lick and water taken from the Nantu river) (Clayton, 1996). Results from these two studies indicate that the soil from these salt licks appears to contain higher quantities of SO_4, Iron, Sodium, Zinc and Manganese than the surrounding soil and that the water contains higher quantities of particularly Chloride, SO_4, Boron, Sodium and Calcium. This may well imply that babirusa have very specific mineral requirements or that their largely frugivorous diet is lacking in one or more components. Indeed soil and stones were common in the stomachs investigated by Clayton (1996).

Information from Captivity

Foraging behavior: The foraging behavior of the babirusa mainly consists of walking around with the nose close to the ground while probing through the loose soil and leaf litter (Leus and Vercammen, 1996). Captive babirusa in a semi-natural enclosure showed the ability to very carefully select and obtain certain plants and plant parts such as individual flower buds, grass ears, bramble leaves, cherry fruits, etc. (Leus and Vercammen, 1996). Valentijn (1726) writes that wild babirusa stand on their hind legs while leaning against a tree to "sample the smells of approaching enemies". An equally likely explanation for this behavior is that the animals are foraging for fruits or leaves on trees. In fact, babirusa in captivity have frequently been observed browsing leaves on trees while standing on their hind legs unsupported or with their front legs leaning against the tree trunks or uprights in their enclosure (e.g. Macdonald and Leus, 1995).

Digestive anatomy: Although consisting of one large compartment without any narrow constrictions separating one part from the other, the babirusa stomach contains an enlarged area of mucus-producing cardiac glands (>70% of internal surface area *v.* 30% in *Sus scrofa*) with a near-neutral pH and large populations of microorganisms (Leus,

The domestic pig should be considered the dietary model for the babirusa. However, diets designed solely for commercial swine production are unsuitable for babirusa considering:

- **the babirusa is an unimproved breed with a slower growth rate and a smaller mature body size**
- **babirusa appear to browse more and root less and thus may be consuming a diet of lower nutrient density**
- **babirusa have a unique stomach structure containing large microbial populations**
- **babirusa are prone to obesity in captivity**

(Photo: C. Dresner, St. Louis Zoo)

1994; Leus *et al*., 1999). A frequently discussed function of such microorganisms is bacterial fermentation of plant structural components by means of enzymes, which the host is unable to produce itself. The cardiac gland area of the babirusa is therefore likely to be a fermentation area. The anatomy of the intestinal tract of the babirusa appears to be very similar to that of the domestic pig and other wild pigs although no detailed studies have been carried out (Mitchell, 1905, 1916).

Two groups of animals appear to share with the babirusa the possession of an enlarged and elongated stomach part lined almost exclusively with cardiac glands: the Colobinae monkeys and Macropodidae marsupials. Forestomach fermenters usually show a system of folds, blindsacs or narrow constrictions in the stomach which slow down the passage of digesta and which separate the fermentation chamber from the low pH of the gastric gland area. Apart from therelatively small diverticulum (typical for the stomach of all pigs but larger in the babirusa), no such

structures were found in the babirusa stomach. Passage time experiments on captive babirusa suggested that no part of the digestive tract selectively held digesta longer than any other part and that the transit time of digesta for the babirusa is not longer than that for the domestic pig (Leus, 1990; Conklin and Dierenfeld, 1994). Thus, bacterial fermentation in the babirusa stomach may be somewhat less efficient than is the case for other forestomach fermenters.

Digestion: Two digestibility studies were carried out on the babirusa (Conklin and Dierenfeld, 1994; Leus, 1994, 1997) and in both cases the animals did not readily consume the amount of hay or dried grass offered as a source of fiber. These therefore appear not to be palatable fiber sources for the babirusa.

When consuming a zoo diet (mostly composed of low fiber grain and fresh produce), the babirusa digested the NDF and ADF fractions of the diet equally well (Conklin and Dierenfeld, 1994). Babirusa consuming a barley-soy basal diet with dried grass added as a source of fiber digested NDF slightly better than ADF although the difference appeared to become smaller the more grass was added (Leus, 1994). In comparison to the domestic pig (Large White x Landrace) the babirusa appeared to digest NDF equally well (for dried grass fiber) or better (for barley-soybean + dried grass fibers) than the domestic pigs but ADF equally well (for barley-soybean + dried grass) or worse (for dried grass fiber) than the domestic pig (Leus, 1994, 1997). The low metabolic fecal nitrogen losses in babirusa consuming a zoo diet, together with the absence of a secondary marker excretion peak in the transit time

study, suggest that hindgut fermentation may be less important in the babirusa than in the other pigs (Conklin and Dierenfeld, 1994). In the domestic pig almost all cellulose and 80% of hemicellulose digestion occurs in the large intestine (Keys and DeBarthe, 1974). Similarly, in the peccary, another forestomach fermenter and close relative of the pigs, practically no cellulose digestion occurred in the forestomach (Shively *et al*., 1985; Lochmiller *et al*, 1989). If hindgut fermentation is indeed less important in the babirusa and if in pigs and peccaries digestion of cellulose occurs mainly in the caecum and colon, then we would expect less efficient digestion of cellulose by the babirusa. All of the above strongly suggests that the babirusa is a non-ruminant forestomach fermenting frugivore/concentrate selector specialized in the fermentation of more easily digestible fibers and other cell components.

(Photo: C. Dresner, St. Louis Zoo)

Recommended body weights

Adult male babirusa ~90 kg

Adult female babirusa ~ 60 kg

(Photo: WCS/Bronx Zoo)

ZOO DIET SURVEY

Between March 1991 and May 1993, all zoos with babirusa (16 in Europe, 7 in the USA and 2 in Indonesia) were sent a questionnaire requesting information on the constituents of the diet, the daily amounts fed, the preferences and dislikes of the animals and the way in which the food was offered. Results from 13 zoos in Europe and 6 in the USA (containing 38 male and 41 female babirusa) were of a sufficiently detailed nature to be used in further analyses. A detailed account of the results of this questionnaire can be found in Leus (1994) and short reports were published in Leus and Morgan (1995) and Leus (2000).

a. Feeding schedule and feeding locations

One zoo that replied to the questionnaire only fed once a day, thirteen zoos fed twice a day, three zoos fed three times a day, one zoo fed four times and another five times a day. Most of the zoos that fed twice a day offered a smaller portion of the daily ration in the morning and a larger portion in the late afternoon/evening. Those zoos that fed more than twice a day offered browse and/or scatter feeding (fruit, vegetables, seeds and grains etc.) at other times of the day.

Eight zoos fed the main part of the diet on the floor, eight zoos offered the meal in a trough and three offered the food on a bed of grass, hay or alfalfa on the floor.

Eight institutions had an automatic water supply whereas the remaining eleven institutions used water troughs.

(Photo: C. Dresner, St. Louis Zoo)

b. Food items and quantities offered

For the analyses, the food items offered were divided into 4 categories: 1) fruit and vegetables (F&V), 2) commercial pellets, grains, bread, nuts and oils (P&G), 3) animal products (AP) and 4) browse (grass, hays, branches, leaves etc.). The babirusa received a very wide range of food items: 54 different F&V, 30 P&G, 9 AP and 41 different browses were offered to the animals (Tables 2 & 3). In most zoos, the diet was built up around a relatively fixed set of core items which were easily available all year round. These core items were then supplemented with smaller amounts of seasonal fruits, vegetables and browse.

Nutritional Recommendations for Babirusa in Captivity

- diet comprising approximately ¼ swine maintenance pellets or high fiber herbivore pellets and 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 behaviors, 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

Browse offered to the babirusa came in many forms and shapes (Table 3). A number of zoos did not specify the species of browse fed and their accounts were included under the general terms branches, grass, hay and leaves. In some zoos, alfalfa hay was eaten completely whereas others stated that the animals tried to pick out the leaves and would sometimes chew the stems but not eat them. Many zoos offered fresh branches, grass, herbs or alfalfa during the spring and summer seasons and fed dried branches and hays during the winter. The inclusion of browse in the diet was often not on a regular or controlled basis. In fact, information on the amounts and types of browse offered was too vague to allow calculation of the percentage of browse in the diet in relation to the other food categories. The data shown below are for the daily diet of adult male and adult female babirusa without the browse.

Table 4 shows the mean amounts of the different food categories offered to the babirusa. As is obvious from the large standard deviations there was a huge range in the amounts and proportions of the different food items fed. On average, the diet consisted of 2/3 fruit and vegetables and 1/3 commercial pellets and other grain products. Nine zoos added small amounts of animal products (such as chicks, eggs, and beef) to the diet on some days of the week.

Table 4: Average amount of food (Total fresh weight), fruit and vegetables (F&V), commercial pellets, grains, bread, nuts and oils (P&G), animal products (AP) and dry matter (DM) offered to babirusa in 19 zoos in Europe and North America. (%BW = percentage of body weight for a 90 kg male and 60 kg female)

	Total (g/day)	F&V (g/day)	P&G (g/day)	AP* (g/day)	DM (g/day)
Male	3128±928	2151±983	878±577	209±233	1069±481
%BW	3.5				1.2
Female	2733±798	1856±831	806±512	148±113	956±425
%BW	4.5				1.6

(*) Average of nine zoos that did offer animal products

(Photo: WCS/Bronx Zoo)

Table 2: 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.

Food item	Form	No. zoos
F & V		
Apple	with peel	19
Aubergine	raw with peel	2
Avocado	raw with stone	1
Banana	with peel or without peel	18
Broccoli	raw	3
Cabbage (unspecified))	raw	4
Carrots	raw or boiled	15
Cauliflower	raw	3
Celery	raw	8
Cherries	with stones	2
Chicory	raw	2
China cabbage	raw	2
Coconut	raw	1
Corn-salad	raw	1
Cucumber	raw with peel	5
Endive	raw	3
Fennel	raw	3
Fodder beet	raw	3
French beans	raw	1
Grapefruit	without peel	1
Grapes	with peel and seeds	4
Green cabbage	raw	1
Kale	raw	1
Kiwi	with peel	4
Kohlrabi	raw	2
Lamb's lettuce	raw	1
Leek	raw	6
Lettuce (unspecified)	raw	15
Mandarins	without peel	1
Medlar	raw	1
Melon	with peel	2
Nectarines	without stone	1
Onion	raw	3
Oranges	without peel	11
Parsley	raw	1
Peaches	with peel and stone	4
Pears	with peel	5
Pineapple	with peel	6
Plums	with peel and stone	7
Potatoes	raw or boiled	8
Pumpkin	raw with peel and seeds	2
Radish	raw	1
Red beets	raw	2
Red cabbage	raw	1
Salsify	raw	1
Savoy	raw	1
Soya sprouts	raw	1
Spinach	raw	3
String beans	raw	1
Water melon	raw with peel	1
White cabbage	raw	2
Yams	raw or cooked	5
Zucchini	with seeds and peel	1
P&G		
Acorns	raw	2
Barley	dry	1
Biscuits	dry	1
Bran	dry	4
Bread	brown or white	7
Corn on the cob	fresh	1
Corn	fresh or dry	5
Corn oil	fluid	1
Dog chow	pellets/biscuits	5
Germinated corn	fresh	1
Germinated wheat	fresh	3
Herbivore pellets	pellets dry	12
Horse pellets	pellets dry	1
Horse-chestnuts	raw	1
Maize meal	dry	2
Nutritional yeast	dry	1
Peanuts	dry	4
Pig pellet	pellets dry	5
Rice	cooked	2
Rolled corn	dry	1
Rolled oats	dry	8
Soya meal	dry	1
Sunflower seeds	dry	2
Sweet chestnut	raw	5
Textured grain	dry	1
Toast	brown or white	1
Vegetable oil	fluid	1
Walnuts	with shell	1
Wheat	dry	1
Wheat	ground	1
AP		
Beef meat	raw or boiled	3
Chicks (one day old)	whole	6
Crickets	whole	1
Eggs	raw or boiled, with shell	5
Fish	raw	2
Grasshoppers	whole	1
Mice	whole, skinned	1
Rats	whole, skinned	1
Skimmed milk powder	dry	1

Table 3: List of browse items offered to babirusa in 19 zoos in Europe and North America.

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
S*alix 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

In the study by Conklin and Dierenfeld (1994), the animals showed a dry matter intake of 1.2% of their body mass. The wet weight intake was about 2.3% of body weight. If we assume an average weight of 90kg for males (a wild caught full grown adult male babirusa weighed 90kg (E. Wahyuni, pers. com.) and 60kg for females, then the average amount of dry matter offered to male babirusa is equal to the observed intake, whereas that offered to the females is higher. The average wet weight offered to the babirusa as a percentage of body weight (average of 4%) was almost twice the intake observed by Conklin and Dierenfeld (1994). Considering the wide variation in amounts offered, babirusa holders should consider it a priority to determine how much of the offered food the pigs are actually consuming!

c. Quantities of nutrients offered

Table 5 shows the amounts of the different nutrients contained in the diets offered to babirusa in captivity. The large variation in the amounts of different food items fed translates into a wide range of nutrient amounts offered. In fact, the range of values for the different nutrients offered is so wide that it is impossible that all these diets are meeting the nutritional requirements of the animals.

Table 5: Average amount of food (Total fresh weight), 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)

	Total (g/day)	DM (g/day)	CP (g/day)	Fat (g/day)	EF (g/day)	DE (MJ/day)	CP:DE
Male	3128±928	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	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		

(*) Average of nine zoos that did offer animal products

RECOMMENDATIONS

Feeding schedule and feeding locations: A foraging babirusa typically walks around with the nose to the ground or probing through the leaf litter while, slowly, bit by bit, picking up food items that it comes across. Foraging is therefore likely to occupy a significant proportion of the wild babirusa's day. To duplicate this activity level, feeding in captivity should be spread throughout the day. For example, animals could be fed about 30% of the diet in the morning, 20% (scatter feeding and browse) throughout the day and 50% in the afternoon. Feeding not too much in the morning will hopefully still result in babirusa willing to forage for scatter food rather than to snooze. However, feeding nutrient-rich items during the night may result in more obesity because of less activity during the night time hours.

In order to have sufficient control over the intake of individual animals, and because males tend to monopolise the food when fed in the company of females, food items requiring more precise dosage such as vitamin and mineral supplements and nutrient-rich items such as commercial pellets, starchy fruit and vegetables, larger quantities of nuts and seeds etc., should be offered individually, for example during the morning and/or evening meals.

Ground surfaces as well as troughs can be used for feeding the main portion of the diet as long as they are cleaned thoroughly and regularly. When using food troughs, these should be placed at ground level.

In order to prevent soiling of the drinking water it is recommended to have automatic drink nipples/pressure pads in the stables. These should be placed as close as possible to a drain so that spillage of water during drinking does not wet the rest of the stable and the bedding.

Nutrient content of diet:

Main nutrients

No data are available on the protein and energy requirements of the babirusa. Using prediction equations for the domestic pig based on the protein weight in the body (Whittemore, 1998), the babirusa maintenance requirements for digestible energy (DE) and crude protein (CP) can be calculated. A state of maintenance can be defined as a situation where the body composition of the animal remains stable, the animal is not producing any products e.g. milk and it is not performing any work on its surroundings (McDonald *et al*., 1995).

The maintenance DE requirement for a Large White domestic pig of 90 kg can be calculated from the equation:

$$\text{ME maintenance} = 1.75Pt^{0.75}$$

with ME = Metabolisable Energy and Pt = protein weight in the body (Whittemore, 1998). The average Pt for a Large White pig is 16% of its body weight (Whittemore, 1998). The metabolisable energy is the digestible energy minus the energy contained in the urine and excreted gasses. It has been established that DE and ME relate to each other as DE = ME/0.96 and the requirement for DE can therefore be estimated from the ME value (Whittemore, 1998).

The protein content of an adult babirusa body is not known. Taking into account that the babirusa has a smaller mature size and is a non-developed pig (i.e. not intensively selected for leanness) and could thus be expected to be fatter and have a lower body protein content, we had previously estimated its Pt to be 12% of body weight (Leus and Morgan, 1995), leading to a maintenance DE requirement of 10.9 MJ/day for a 90 kg adult babirusa. However, it has since transpired that even young Chinese Meishan pigs (a Chinese domestic breed selected to be fat) had a body protein content of 15% (Kyriazakis *et al*., 1993). Given this evidence and the appearance of the mature wild babirusa, which shows it to be a reasonably lean animal, a reassessment of the original assumption of body protein content seems appropriate. It is more likely that the babirusa is similar to an unimproved pig in having a body protein content of around 15 to 16% (Close, 1994). A 90 kg babirusa with a Pt 16% of body weight (i.e. 14.4 kg body protein) is then predicted to have a maintenance DE requirement of 13.4 MJDE/day. For an average female babirusa of 60 kg (i.e. 9.6 kg body protein) this amounts to 9.9 MJDE/day (Table 6). These values compare favorably with those derived from the equations of AFRC (1990a) of 14.4 and 9.7 MJ DE, respectively .

Because the maintenance state relates to a state where the body is neither anabolising nor catabolising body tissues, the formula can be used to predict the energy requirements of adult, non-growing, non-gestating and non-lactating animals. In other words, very active animals, growing animals and pregnant or lactating will have higher requirements. For example, in commercial pigs, mature pregnant sows have a DE requirement about 30% greater than maintenance and each kg of milk requires 8.4MJ DE.

The maintenance requirement for crude protein in the diet can be estimated in a similar way to that for energy. The amount of ideal protein for maintenance at tissue level can be calculated from the formula: 0.004Pt (Whittemore, 1998). The balance of the different amino acids in the food is generally different from that in pig protein, but pigs still need to transfer food proteins into pig proteins. It is therefore not just the total amount of protein that indicates the quality of the diet but rather the amount and balance of those amino acids that are necessary for the construction of pig protein. That part of the total protein intake that contains the right spectrum and balance of the amino acids essential for the functions of maintenance and production is called "ideal protein" (Whittemore, 1998). Using the same Pt values (16% of body weight for babirusa) and body weight values (90kg for a babirusa male and 60 kg for a babirusa female) as above, the ideal protein requirements for maintenance for a male and female babirusa can be calculated to be 57.6 and 38.4 g respectively. In order to derive from this the requirements for CP intake, these values have to be divided by (i) the efficiency of use of ideal protein, (ii) the protein score (= the proportion of the dietary protein that is ideal) and (iii) the ileal digestibility (the proportion of the ideal protein that will be digested up to the end of the small intestine). If we estimate the efficiency of use to be 0.85, the protein score to be 0.65 (a value appropriate for lower quality diets containing a high proportion of vegetable protein sources) and the ideal digestibility to be 0.75 (high fiber diets) (Whittemore, 1998), then the required amount of crude protein in the diet for maintenance is 139 g and 93 g for a male and female babirusa respectively (Table 6).

Table 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

Mature animals have a smaller need for protein because there is no longer any above maintenance lean tissue growth, but have a higher need for energy to sustain body maintenance activities (McDonald *et al*., 1995; Whittemore *et al*., 1998). Mature animals will therefore have a smaller protein:energy ratio than young growing animals. A protein:energy ratio of 13gCP/MJ DE is considered to be appropriate for pregnant adult female domestic pigs or growing domestic pigs above 80kg (Whittemore, 1998). The required protein:energy ratio for an adult non-gestating, non-lactating babirusa can therefore be expected to be somewhat lower than that. Indeed, if the ratio is calculated from the predicted CP and DE requirements (see Table 6) then we obtain 10.4 and 9.4 g CP/MJ DE for a 90 kg and 60 kg babirusa respectively. For males this corresponds well to the average CP:Energy ratio offered whereas females receive on average too much protein in relation to energy (Table 5). Proteins and amino acids fed in excess of the animal's requirements will be deaminated and will either form precursors for the formation of body fats or will be excreted in the form of urea (Whittemore, 1998). Feeding excess protein therefore puts a large strain on the animal's deamination system. In addition, the deamination of proteins is a very inefficient process and is therefore a large drain on the animal's energy supply (Whittemore, 1998).

Fats have a higher gross energy content than the other nutrients in the diet and thus make a proportionally larger contribution to the DE of the diet and the transfer of dietary fats to body fats is a very efficient process costing the animal very little energy (Whittemore, 1998). Considering the problems with obesity in captive babirusa, care should be taken not to feed large amounts of fat. In particular, preventing the feeding of animals by the public may contribute to this. For example, 50g of peanuts (about half the average packet for sale) contributes 1.23 MJ DE. Babirusa are very fond of people and particularly those that bring food! *Feeding by the public should be prevented*!

In many ways, the problems of feeding of babirusa in captivity appear similar to those of feeding Asian colobines in captivity. For the colobine monkeys, zoo diets contained much less fiber and more protein than the natural food stuffs and it was therefore recommended to either include locally available browses or a specially designed commercial product (Nijboer and Dierenfeld, 1996). For the babirusa, no data on the fiber and protein content of natural food stuffs is available. However, the anatomy of their digestive system and the similarity of the stomach anatomy to that of colobine monkeys could mean that the digestive strategy of the babirusa may not be so far removed from that of these monkeys. The main difference may be that the fiber fraction in the natural diet of the babirusa is mainly derived from tropical fruits (which in some cases may be equally, or even more, fibrous than leaves (eg. Rogers *et al*., 1990; Remis *et al*., in press) rather than from leaves.

Although no data are available on the requirements for fiber, a fiber content of about 19% of dry matter appears very low for a forestomach fermenter. Because of the lack of fibrous commercial fruits, daily inclusion of common European and North American browses would significantly improve the amount of fiber consumed (Nijboer and Dierenfeld, 1996). However, care should be taken with species such as willow (*Salix* sp.). As is the case with langurs (Colobinae), the babirusa will ingest long strips of the bark that may form a fiber ball in the stomach, as was the case with one female babirusa in Antwerp (De Meurichy, pers. comm.). Browses should not only be fed at ground level but can occasionally also be offered at higher levels so that the animals have to reach high, and if necessary stand on their hind legs, to reach for food. Grasses and hays appear to be less palatable to the babirusa.

Table 7: Proposed criteria for a test diet for an average male (90kg) and female (60kg) babirusa in captivity. BW = Body Weight; DM = Dry Matter, CP = Crude Protein, DE = Digestible Energy, CP:DE ratio = protein to energy ratio, NDF = Neutral Detergent Fiber, ADF = Acid Detergent Fiber.

	90 kg babirusa	**60 kg babirusa**
Total DM intake	1.2% BW = 1080g	1.2% BW = 720g
CP	129g/kg DM	129g/kg DM
DE	12.4 MJ/kg DM	13.8 MJ/kg DM
CP:DE ratio	10.4	9.4
NDF/ADF	daily browse	daily browse

Taking all of the above into account, a diet with a target nutrient composition as set out in Table 7 emerges as a diet to be tried. Because the babirusa is a non-improved pig species which has a slower growth than domestic pigs, reaches a smaller mature size and has problems with obesity in captivity, the CP and DE levels were left at the predicted levels for maintenance requirements.

As far as dry matter is concerned, the diet in Table 7 could be achieved by feeding ¼ swine maintenance pellets or high fiber herbivore pellets and ¾ "produce/browse" composed of ¼ fruit (maximum), ¼ yellow/orange/root vegetables, ¼ green leafy vegetables and ¼ locally available browse. Many commercial pellets used for babirusa today are too rich in energy and/or protein so that with a 25% ration, the animals could receive too much of these nutrients. Because most of the dry matter fed is derived from the P&G fraction, further reduction of this fraction to bring down the energy and protein content of the diet makes it very difficult to obtain the required intake of DM unless large amounts of fruit, vegetables and browse are fed. The challenge will be to either locate a pellet that is not too rich in energy and protein, or to devise a new pellet that can replace the pellet and browse fractions.

Because no data are available on the nutritional composition of the diet in the wild, experimentation will be necessary to try out and refine the recommended diet. In addition, there is an urgent need for feed intake data of the current diets being fed, including the browse fraction. Equally urgent and essential are quantitative diet studies in the wild.

Problems Related to Nutrition

- Obesity, which could lead to locomotion problems, reduced reproductive output, circulation problems, excess cholesterol, among other problems
- Young growing males may show weakness in hind quarters ("swaying" hind legs) which Antwerp solved on several occasions by a temporary increase in Vitamin E/Selenium supplement
- "Arthritic like" symptoms can occur in both young and old captive babirusa. Further research is needed to clarify or rule out the role of nutrition in the onset of this disease

(Photo: WCS/Bronx Zoo)

Vitamins and Minerals

The specific vitamin and mineral requirements of the babirusa are unknown. Their habit of visiting salt licks to drink the water and ingest the soil may however indicate that this species has either specific requirements, or that their largely frugivorous diet is deficient in one or more components. Until further research has been carried out the domestic pig forms the best model for this species. The NRC and AFRC requirements for domestic pigs and the recommended vitamin and mineral contents of a babirusa diet based on the pig as a model can be found in Table 8.

Table 8: NRC and AFRC 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.

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

* calculated from AFRC: 87%DM, 13DE/kg

** ideally Fe should not exceed 300 mg/kg

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HANDREARING

The only institutions known to have hand reared babirusa in recent times are Port Lympne Wild Animal Park in the United Kingdom and Madrid Zoo in Spain. The only analysis of the composition of babirusa milk was carried out at the Durrell Wildlife Conservation Trust, Jersey, where samples from a single sow on days 27, 28 and 37 post partum were pooled. The milk contained 23% solids, 13% Fat, 7.8% Protein and 2.7% Lactose (Bowles, pers. comm).

Until further information is available, hand rearing protocols for domestic pigs or commercial wild boar form the best model for this species. These can be obtained from standard agricultural and veterinary sources.

(Photo: WCS/Bronx Zoo

Few birthweights of babirusa piglets are known. One stillborn piglet at Antwerp zoo weighed 820 gr (Vercammen, 1991). Female twins in Antwerp weighed respectively 1005gr and 1205gr one day after birth, while a single male weighed 890gr one day after birth. Based on experience in Antwerp, piglets tend to weigh about 3-4kg at one month of age, 10-12kg at four months and about 25kg at 7-8 months (Antwerp zoo, pers comm.; Vercammen, 1991). (See Reproduction Chapter. Physical Development and Growth Characteristics)

Babirusa piglets start nibbling small amounts of solid food from one week of age onwards. The amount of solid food is then gradually increased as they grow older. However, piglets as old as 5 months were still seen to have occasional suckling periods (Leus *et al*., 1992).

CASE STUDY: PORT LYMPNE WILD ANIMAL PARK *BY ROBERT SAVILLE AND MATT HARTLEY*

Introduction

There are approximately 170 babirusa maintained in 35 collections worldwide. The animal is listed as vulnerable and is in Appendix 1 of CITES.

Many problems have been experienced with the husbandry of the species in captivity including a small genetic base, poor reproductive performance, maternal aggression towards young and stringent restrictions on importation. These factors have meant that the captive population has to be intensively managed to ensure the species' survival.

Handrearing is an important aspect of the management of small, endangered populations maintained in captivity especially in a species such as the babirusa where litter size is small, averaging 2 young and successful rearing is erratic. Few babirusa have been hand-reared to maturity.

Here we describe the management of two male babirusa, born at Port Lympne Wild Animal Park, which were taken for handrearing due to the failure of the female to rear previous litters and the risk of infanticide.

Case History

The mother was a fourteen-year old animal who had had three previous full term pregnancies but had committed infanticide on each occasion and thus failed to rear any young. She had been mated 162 days before parturition and had shown some nest building and pre-partum behaviour over the week but had not shown the full spectrum of preparations described by other authors. [1,2]

It is preferable to allow the female maximum privacy as it has been suggested that infanticide occurs if the female is disturbed during parturition. Video monitors were used to observe the female in order to remove the youngsters

before she could harm them. Previous youngsters were killed at around 36 hours post-partum. The female had shown good maternal behaviour up to this point and no reason for the infanticide could be determined.

Previous reports suggest that the vast majority of births occur during the night however the first young was born at 15:30 on the afternoon of the 13th December 1996. It had been reported that the interval between the birth of the youngsters averaged 30 minutes (Leus *et al*., 1992). However in this case the second youngster was born 90 minutes later at 17:00. (See Reproduction Chapter. Parturition)

Infant A followed the female closely and did attempt to suckle however the female showed very little maternal instinct but no aggression. The two youngsters were removed from the mother at 17:30.

The first infant (A) weighed 600 grams whilst the second (B) weighed 400 grams.

Nutrition

Due to the lack of published information on artificial diets for babirusa, a protocol used for hand-rearing domestic swine was adopted.

The infants were each fed 2mls of "Volostrom" commercial pig colostrum substitute every two hours. On the third feeding this was combined with 7mls of "Farrowmate" milk replacer. This was continued throughout the night at two hour intervals. Human infant bottles and nipples were used.

After a total of 10 feedings (20mls) of colostrum substitute had been administered only the milk replacer was fed. By the end of the 14th December infant A was consuming 12ml per feed whilst infant B was taking 8ml every two hours. The animals were allowed to suckle until satisfied. This protocol was continued for the next 2 days so that by the 17th December infant A was taking 30ml of milk per feed and had gained 150g body weight since birth and infant B was taking 15ml per feed and had gained 100g body weight.

Five days after birth an ad-lib feeding protocol was adopted with bottle-feedings reduced to three hourly intervals. The frequency of feedings was reduced as intake increased.

By 14 days of age both young had started taking solid food such as mashed bananas and grated apple and were now drinking 1.5 litres of milk replacer daily. At this age it was first noted that the infants were ingesting hay from their bedding. Over the next week the variety of solid food increased with bananas, apple, lettuce, carrot and parsnips being eaten. Fresh water was also provided at this stage.

At four weeks old a few commercial weaner pellets were given with the fruit and vegetables. The amount gradually increased each day until they were given ad lib too. The youngsters were weaned over four days when they were six weeks old by gradually watering down the milk replacer so that by seven weeks old their food intake was ad lib weaner pellets, 6-7 bananas, 2-3 apples, lettuce, grapes, parsnips and carrots.

Starting at three months of age the weaner pellets were gradually replaced with 12.5% protein pellets used for the adult babirusa.

Husbandry

The infants were housed in a one-metre square plywood box with 50 centimetre high sides and lived in the keepers flat. A standard infra-red heat lamp was fitted above the box. Oat straw and grass hay was used for bedding. They were allowed 5 hours of free exercise daily. The animals were moved to the zoo's babirusa house at 7 weeks of age. For the first few weeks the heat lamp was provided in addition to the heating in the house. As the weather got warmer the animals were provided with access to a small sand yard and at 6 months of age they were moved to an outside grass paddock.

It was not necessary to stimulate the animals to defecate, the meconium was passed during the first twenty-four hours and they continued to defecate spontaneously.

Medical Management
The two animals were generally very healthy and only required veterinary attention on two occasions.

At four weeks of age during the weaning process both animals developed diarrhoea for a 48-hour period. They remained bright, alert and active and were not ill in any other manner. All milk and solid food was stopped and they were given only electrolyte replacer ad lib. Faeces samples submitted for culture revealed no pathogens. Normal rations were re-introduced but apple was omitted from the diet as it is thought that the milk and apple, in combination, was too acidic.

At six weeks of age infant A became constipated. This was treated by administering glycerine enemas and glycerine per os twice daily for 3 days. Food intake was not altered.

Glycerine and warm water baths were given regularly to prevent the skin drying and cracking.

No vaccinations were given as no clinical disease has been seen in this species in our collection.

Discussion
Very little information is available on the composition of babirusa milk and thus how closely this protocol reflects the natural formula is not known. In this case two animals were successfully hand-reared using commercial domestic swine products.

Due to the lack of medical problems experienced and the fact that it is highly unlikely that the young suckled from their mother it can be concluded that the colostrum paste used provided a reasonable level of immunity to the animals.

Previous reports suggest that those animals started eating solid food and had been weaned at younger ages than maternally raised animals. Jersey Zoo reports that youngsters born in their collection first started eating solids at 3 weeks and continued suckling for approximately one year. [2]

The diets provided for the animals when fully weaned are comparable to those reported in other sources (Leus *et al*, 1992; Lindsay, N., 1988; and, Parker, R., 1991)

The short periods of illness in these animals can be explained by dietary changes during weaning rather than pathological conditions.

These two animals have grown to full maturity and are still healthy individuals suggesting that they have developed comparably to mother raised individuals. They are also re-integrated with other animals showing that they are not imprinted on humans.

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SOCIAL GROUPING

GROUP STRUCTURE IN THE WILD

The babirusa has been observed alone and in-groups of up to eight animals in the wild. These sightings have taken place primarily around water, salt licks, or mud wallows (Macdonald, 1993). In a recent study of the babirusa on the Minahasa peninsula in North Sulawesi the majority of sightings were of solitary males (84% of all solitary animals). Single adult males were observed with adult females, but never with two or more adult females. Bachelor groups of four or more adults were never observed. Adult males were rarely seen with young animals without the presence of adult females in the group. At times adult females were observed with other adult animals, but more often than not they were with young babirusa (M. Patry *et al*., 1995).

The median group size of babirusa in the study area (including solitary animals) was two animals. Almost half of the sightings were of single animals, whereas groups of five or more animals represented less than 20% of the groups recorded. The second most frequently observed group size were single adult females with young; the group size ranged from two to six animals. There were never more than three adult females in a group and no group had more than five young. No group of adult females and young were seen with more than two adult males present. Twice as many family groups without adult males were observed as there were with males (M.Patry *et al*.; 1995).

(Photo: C. Dresner, St. Louis Zoo)

GROUP STRUCTURE MANAGEMENT IN CAPTIVITY

In captivity the babirusa has been managed in a variety of different ways. They have been kept in large social groups, individually, male and female, male and female and offspring, and in single sexed groups. Often times the space availability of an institution will dictate the type of management structure utilized.

Management as Mixed-Sex Social Groups: Most notably, the Surabaya and Jakarta (Rangonon) zoos in Indonesia manage babirusa in large mixed-sex social groups comprising of many males and females. In these situations adults and/or juveniles of both sexes are managed in one enclosure. The estrus females are commonly mounted by more than one male, thus making it very difficult to determine which male is the actual sire (Leus et. al., 1992). This situation may also give rise to cannibalism of the young if the female is not removed from the group prior to parturition. It is worth noting, that although under this system males have greater opportunities to injure each other in male-to-male combat, they invariably tend not to do so. Only when a male (or female) is identified at the bottom of the pecking order, does agonoistic behaviour create an animal welfare problem. In order to introduce the opportunity for more normal behaviour, the chosen male and female should be separated out for breeding, in the same way that those females ready to give birth are given separate accommodation (Leus et. al., 1992). This particular management scheme relies heavily on the ability of keepers to recognize impending estrus/parturition and requires an adequate amount of space in order to manage properly and effectively.

Management as Individuals: Housing babirusa individually has its advantages and disadvantages. Although more space may be needed, depending upon the number of individuals to be managed, it has proven to be one of the more successful management schemes for the production of babirusa. Both the Antwerp zoo in Belgium and the Bronx zoo in New York have kept several males and females, rotating the individuals as needed to maintain reproduction. The presence of additional males in the adjacent enclosures may stimulate libido in babirusa boars, as has been documented for domestic boars (Foote, 1974). In one particular case a second male was brought in and housed in an enclosure adjacent to a non-breeding pair of babirusa. Within a year the pair had reproduced for the first time. It is not known whether the presence of multiple males has any parallel effect on the reproductive physiology of babirusa females. For domestic gilts approaching puberty, exposure to a male is known to accelerate to onset of puberty (Alexander, *et al*., 1974) so there is some basis to believe that a male's presence might influence the reproductive physiology of a female in other ways.

Individuals are kept in separate enclosures, usually adjacent to one another, with a gate or door between each enclosure. Under one commonly practiced management scheme the male is introduced to the female as she comes into estrus. If feasible the breeding pair should be given both enclosures so as to provide as much space as possible. This also provides the ability to quickly separate the pair if necessary. Once breeding has taken place or the estrus cycle has ended the male is separated and returned to his own enclosure. Assuming the space is available several males and females can be managed in this manner and rotated among one another.

A similar management scheme involves separating the male and female at night and housing them together during the day. This type of management has been effective at the Saint Louis Zoo in Missouri where they have produced nine offspring. In addition to Saint Louis, both the Lowry Park Zoo in Florida and the Audubon Park and Zoological Garden in Louisiana have successfully reproduced babirusa under this management.

(Photo: D. Wilson, St. Louis Zoo)

Management as Permanent Pairs: This social grouping is commonly employed in zoos for a variety of rare species where the institution only has access to a single pair of animals. As it is applied to babirusa, the pair is often kept together at all times and the animals are only separated if and when the sow becomes pregnant. Zoos who wish to manage babirusa in this fashion need to understand that adjustments may be necessary should reproduction fail to ensue. Such adjustments might include temporary separation and isolation of the individual animals, providing the pair with a change in venue, and, in some cases, breaking up the pairing to formulate a new pair. All of these adjustments are geared towards stimulating production in a non-reproducing pair. Factors such as the mean kinship ranking of your animal and the overall status of the babirusa SSP population should influence how long you try a particular pairing that is not initially successful before making adjustments under this management scheme.

Five institutions in North America have managed their animals in this manner. Three of the five have produced offspring on at least one occasion. In each of the three institutions that were initially successful under this management scheme (Los Angeles, Cincinnati, and Roger Williams Park), the animals were introduced to one another for the first time when they arrived at their respective zoos and bred quickly, producing offspring in the first year of their pairing. At all three zoos the male was separated from the female prior to parturition and at least through the first six months of the youngsters lives. Of the five zoos practicing this form of management, in at least two cases where the pairings either failed outright to reproduce, or failed to produce any subsequent litters, breaking up the pairing and moving the animals to another institution was followed by a return to reproductive success for two females. While this success cannot be definitively attributed solely to the re-pairing and change of venue (at

least one of the females involved was also found to have a sub-clinical uterine infection that responded to antibiotic therapy) such adjustments should be kept in mind by the animal manager practicing this form of management.

Management as a Family Group: Managing babirusa in this manner requires careful supervision. However, on a few occasions it has been tried with some positive results. These family groups are made up of the parents and their offspring. The male should always be separated from the female at least 3-4 weeks prior to parturition, and the re-introduction of the male should not be attempted until the offspring are at least three months of age. At that point the male should be given visual access through a "howdy door" for at least 2 weeks. The length of time here will be determined by the behavior of the sow and her offspring. Often times it will take quite awhile for them to adjust to the sight of the male. Once they have adjusted, the male can then be given physical access to the sow and offspring. This part of the introduction should be carried out where there is a lot of space (such as the exhibit, if large enough) or in the den area where the situation can be controlled through a series of doors. When the male is introduced he will often ignore the offspring and pursue the sow, particularly if she is in estrus. The offspring will become particularly excited with the male's presence, and will initially stay at a distance from him. As they become more comfortable they will approach him and often times interfere with his pursuit of the sow.

On the few occasions that this type of grouping has been tried the males have been relatively tolerant of the offspring. A male may chase after the offspring once he tires of their "play" or if their interference with his pursuit of the sow persists. These incidences of chasing are usually "half-hearted" in nature and quickly end without incident. Generally by the end of the first day of introduction the family is seen resting together, and frequently the offspring will be resting atop the male. The male should be separated from the sow and offspring at night when observations can not be made.

Management as Single Sex Groups: The SSP encourages development of strategies to manage single sex groups in order to optimize the use of limited space among institutions.

The Saint Louis Zoo has managed a single-sex herd of five sows for over four years. Two unrelated adult sows were allowed to acclimate to each other for a period of approximately one month before proceeding with a full introduction. Within two weeks post-introduction, the two sows were cohabiting peacefully 24 hr per day and we proceeded to increase the size of this single sex herd. Two related sows (mother and juvenile daughter) were moved into the area, given approximately one month to acclimate to the adult female pair before proceedint with a full introduction of the two pairs. Again, within two weeks post-introduction, the four sows were cohabiting peacefully 24 hr per day and we proceeded to incorporate the last sow into the herd. The largest and most dominant of the adult sows was acclimated for approximately one month before a full introduction was attempted. As expected, this final introduction produced more interaction and aggression than the previous two, but the two most dominant sows quickly worked through their differences and within two weeks the herd could be considered established. This herd of five females was successful for nearly four years at which time one sow was humanely euthanized for health reasons and another sow was separated for breeding. The remaining herd of three adult sows continues to successfully cohabitate.

The Audubon Park and Zoological Garden has had success with a managing a father-son pair for a period of time. The Gulf Breeze Zoo managed two littermate brothers together into adulthood.

INTRODUCTION PROTOCOL

The introduction process for babirusa is generally non-problematic. Prior to proceeding with a full introduction, a period of acclimation should be allowed. The acclimation period should begin with housing the animals in adjacent stalls so that they have olfactory and auditory contact for a few days. Visual access should be given next through a "howdy door/window" between the two stalls or enclosures. The visual access should be carried out for several days to weeks, depending on the reactions and behavior of the individuals involved. The behavior of the animals during this period of time will determine whether visual access needs to be continued for a longer period of time. Often the animals will begin lying side by side at the "howdy door/window" as early as two days into the introduction. In this case the actual physical introductions can be conducted sooner rather than later.

The physical introduction can be conducted in the exhibit area or the holding stalls. If the introduction is to take place in the holding stalls, it is desirable to utilize the maximum number of stalls available in order to provide as much space as possible and to have more control over

the introduction. The individuals who will be involved in the introduction should be given exclusive access to the introduction space for a few days prior to the introduction to allow him/her to become familiar with the space. Suitable visual barriers should be provided to allow subordinates to drop out of sight of the more dominant animals.

Male/Female Introductions: When first introduced the male will begin pursuing the female and these pursuits can be either performed at a walk or a run. The female will usually initiate the chase by attempting to get away from the persistent male. The femalewill often turn and face the pursuing male and give out a loud scream, before she turns and runs again with the male in pursuit. For the first few hours the male will pursue the female relentlessly, but within at least four hours the pair will normally have settled down and can often be found lying side by side. If the pair is familiar with one another and is being introduced for the purpose of breeding, then the step by step process of introduction as described above is not necessary. Generally when the female comes into estrus the pair can be put together without any unusual aggression.

(Photo: M. Fischer, St. Louis Zoo)

Single Sex Herd Introductions: When first introduced, the most dominant individual will often aggressively pursue the subordinate individual(s) in the herd. If cornered, the subordinate individual will fight, but will preferably flee to avoid confrontation with the dominant individual. Typcially, the aggression decreases within an hour and disappears almost completely in a day or two.

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REPRODUCTION

BREEDING

Birth Season: Babirusa in captivity reproduce throughout the year (Reinhard and Fradrich, 1983, and MacLaughlin and Thomas, 1991.) While there is one report that wild babirusa are primarily born during November, December and January, (Guillemard 1886), recent studies have found no evidence of seasonality in the affiliation of male babirusa with females nor any evidence of a birth peak (Clayton, 1996).

Estrous Cycle Length/Duration of Estrus: First estrus has been observed in females as young as 190 days old (MacLaughlin and Thomas, 1991). Females as young as one year and as old as fourteen years have conceived and successfully reared their offspring. Cycle lengths have ranged from 30 to 40 days (Bowles, 1986, and MacLaughlin and Thomas, 1991). Estrus lasts 1 to 3 days. Post-partum estrus starts at 4 to 5 months (Bowles, 1986). One female at the St. Louis Zoo had four sets of twins with interbirth intervals ranging from 9.5 to 10 months.

(Photo: WCS/Bronx Zoo)

Estrus Detection: Physical and behavioral changes associated with estrus in babirusa are accurate external markers of reproductive events.

Physical: The vulva swells to at least twice its normal size increasing in both length and thickness. The skin around the vulva becomes more stretched and pink in color and the labiae become slightly everted exposing the mucus membranes. The vulva often has a fluid discharge (MacLaughlin and Thomas, 1991; Leus *et al*., 1992).

Some zoos monitor cycles by vulva scoring using a chart to score the size and color the sow's vulva over time (M.T. Fischer, pers. comm.).

Behavioral: When kept in large social groups, males check the female's perineum daily. The female responds by arching her back and urinating and defecating. The male then tests the urine and feces by mouthing it. If the female is in estrus, the male pursues her (Leus *et al*., 1992).

For babirusa kept as pairs interest in breeding often declines when they are constantly kept together (Leus *et al*., 1992). Managers often have more success breeding babirusa when pairs are put together only when the female is in estrus.

Hormonal: Estrus can be detected by measuring urinary estrogen metabolites (Chaudhuri *et al*., 1990).

Silent heats: While estrus is often detectable by physical or behavioral changes some females have silent heats (Leus *et al*., 1992) in which they exhibit little or no physical or behavioral signs of estrus. Monitoring urinary hormones can help managers decide when to place females who have silent heats with males. Since breeding activity can decline when pairs are constantly kept together another breeding strategy for females with silent heats is to put male and female together just long enough each day for the male to test the females status by checking her perineum and sampling her urine.

COURTSHIP AND COPULATION

Courtship behavior varies with the experience and disposition of the pair, but will include ritual behavior. Generally the female solicits the male, the male pursues the female who often runs, but eventually turns and faces the male. The female will push her snout under the chin of the male; both animals will groom each other's limbs and genitals.

Often at this point during courtship, an experienced male will lie on his side while the female nuzzles and nibbles his ears, limbs, belly and prepuce. Eventually the male approaches the female from behind, nuzzles her perineum, and then puts his chin on her back. If the female is ready to mate she stands; if not, she will run off (Leus *et al*., 1992).

Copulation sessions generally take from 15 to 30 minutes often with several mountings before intromission. When the female is ready for full penetration she generally moves her tail to one side. Intromission varies from one to ten minutes with an average copulation lasting about 3 minutes (MacLaughlin and Thomas, 1991; Leus *et al*., 1992; Kalk, unpublished). When given the opportunity babirusa will copulate several times each day while the female is receptive (MacLaughlin and Thomas, 1991)

PREGNANCY

Gestation: Gestation ranges from 155 to 175 days with an average of 163 days.

Pregnancy Detection:

Sonography: Pregnancy can be detected by transabdominal sonography at five weeks after conception (Miller *et al*., 1994). Uterine changes associated with pregnancy can be detected as early as 30 days into the gestation (Houston *et al*., in prep). Many female babirusa will lie down when given a massage starting behind the ears or inside the legs. Starting with this behavior females can be trained to accept a sonogram. Sonography can be a useful non-invasive and non-stressful method for determining pregnancy before external physical changes become apparent.

Physical: Nipples begin to develop two months (MacLaughlin and Thomas, l99l) to three weeks (Bowles, l986) prior to parturition. The vulva starts to swell l0-l4 days before the female gives birth. The udder increase in volume and the labiae become slightly everted, and pink. Fluid is often discharged from the vulva (MacLaughlin and Thomas, 1991; Leus *et al*., 1992). Nipple and udder development varies from sow to sow but the change in size is usually the most pronounced during the sow's first pregnancy. Once a sow has had her first litter the udder remains somewhat distended.

Behavioral: A few days before parturition the female usually becomes restless and somewhat antagonistic towards her keepers. However, some sows do not display aggressive behavioral changes associated with parturition (S. Taylor pers comm). For some pregnant sows lack of interest in food is an additional indicator that parturition is imminent (MacLaughlin and Thomas, 1991). The sow will spend increasingly large portions of time nest building prior to parturition.

(Photo: WCS/Bronx Zoo)

PARTURITION PREPARATION

Privacy: Prior to parturition the sow should be separated from her exhibit mates and provided with a den, blind, or some means of increased privacy.

(Photo: D. Wilson, St. Louis Zoo)

Nest building: Babirusa in nature (Guillemard, 1886; Clayton 1996) as well as in captivity (MacLaughlin and Thomas, 1991; Leus *et al*. 1992) build nests for parturition. Extra nesting material such as timothy hay or good quality straw should be provided. Heat lamps or some supplemental heat should be added if necessary to provide a thermostable environment for the piglets.

Stress Reduction: Extra effort should be made to reduce stress for the female. A video camera is ideal for monitoring the progress of the newborns while still giving them privacy. For several days following parturition the female is often aggressive towards animals and keepers who get too close to her or her offspring. Approximately two weeks after parturition the female's behavior will return to normal. Females will sometimes cannibalize newborns. While inexperience sometimes accounts for maternal aggression, giving the female as much privacy as possible for several days prior to and for one to two weeks following parturition often ameliorates maternal anxiety and aggression. The female and piglets should be given privacy following parturition. Keepers should not enter the enclosure for cleaning or feeding for one or two days following parturition.

An alternate strategy that worked well at the St. Louis Zoo where isolation was not practical was to have the keeper staff spend extra time in and around the pregnant sow's enclosure for several months prior to parturition to acclimate her to the proximity and activity of humans. This worked well for 5 litters produced between two sows, with births occurring in the presence of the keeper staff in most instances (M.T. Fischer, pers. comm).

PARTURITION

Timing: Babirusa in captivity usually give birth at night. Fourteen out of sixteen births in Antwerp, for which delivery times were known, occurred between l8.00 and 08.00 (Leus *et al*., l992).

Number: One, two or rarely three offspring are born per litter. The average is 1.4 offspring per litter. Intervals between births in the same litter range from 4 to 90 minutes (Leus *et al*. 92; Saville and Hartley, see earlier).

Neonatal Exam: Many zoos do not give neonate exams to babirusa. The benefit of neonate exams when weighed against the risk of contributing to maternal anxiety and potential aggression to her offspring needs to be carefully considered for each individual sow. With many sows the risk is not merited. Infanticide from stressed sows has been document In some cases in which the sow is of a calm disposition and well acclimated to close human activity the manager may judge the neonate exam to be desirable. If the managers judge the sow calm enough to accept the separation of the piglet(s) for a neonate exam it is usually performed in the first 24 to 72 hours.

(Photo: St. Louis Zoo)

The procedure and necessary equipment are organized prior to the exam so that it can be completed as quickly as possible. The piglet(s) are shifted away from the sow, caught and moved to a room where their intense squealing is muffled. The piglets are sexed, weighed, transpondered, given iron and BoSe injections, and the umbilicus swabbed. Blood should not be collected during the neonate exam. Blood collection from the major vessels of the thoracic inlet has led to extensive hemorrhage and death in babirusa. Venipuncture from the neonate's leg vessels is too difficult, time intensive and stressful. Upon completion of the exam the piglet(s) are released into their stall and the sow is given access to them. Humans then leave the area as this helps calm the sow.

PARENTAL CARE

The usually docile female will become increasingly aggressive towards the keeper and other babirusa 2-4 days prior to parturition. There was one incident of a female at Los Angeles that did not become aggressive until after giving birth. This aggressive state will continue for up to three weeks post partum (Macdonald, 1993). Females are normally avid defenders of their young, attacking other animals and keepers if they come to close. The female will usually position herself between the piglets and the perceived threat so that the piglets stand either behind her or underneath her. When threatened, the female will point her ears forward and produce a low-pitched continuos squeal. If the piglets wander too far away the female will vocalize with short clucking noises. Two to three weeks after giving birth the female aggressiveness will subside and the behavior of the female towards the keeper will return to normal (Leus et. al., 1992).

Incidences of females neglecting or killing their young are unusual and uncommon. There have been only four such cases since 1984. Three of those involved the females killing or mutilating their offspring immediately after birth. In two of those cases it could not be determined if the offspring had been born alive or not. One of the females that had previously killed her offspring went on to successfully raise three separate piglets after being moved to another facility and paired with a different male. The fourth incident involving parental neglect was with a first time parent. This particular female was very high strung and nervous and had been inadvertently let out on exhibit where she gave birth to a single piglet. After giving birth she paid little or no attention to the piglet. The piglet subsequently died due to exposure.

(Photo: C.Dresner, St. Louis Zoo)

Parental care by the male is virtually non-existent, since the male is separated from the female either immediately after the breeding or prior to parturition. Thus, he is never allowed with the offspring. On the few occasions in which the male has been given access to the piglets, generally when the piglets are at least three months of age, no parental care on the males' part has been observed.

However, in the situations at the Bronx zoo and Los Angeles zoo in which the male was introduced to the piglets, both males were reported to have been very tolerant of the offspring. The male in Los Angeles would often allow the piglets to climb on him and lie next to him. At times he would chase after them if they became too annoying. The male at the Bronx zoo was also very well mannered with his offspring, but the offspring continuously harassed him to the point that he had to be removed.

PHYSICAL DEVELOPMENT AND GROWTH CHARACTERISTICS

Birth Weights: At 2 hours old one male was 600 grams while his twin brother was 400 grams (Saville and Hartley, see earlier). The sow had a history of infanticide at about 36 hours on several previous litters.

The St. Louis Zoo reports neonatal weights taken from nine individual piglets at ages ranging from 24 to 120 hours old: 24 hour weights were 856, 939, and 1064 grams for females and 1076 grams for a male; 48 hour weights were 901 grams for a female and 888, 901, and 1124 grams for males; one female at 72 hours weighed 811 grams and a male at 5 days weighed 1410 grams (Houston, 92; M.T. Fischer, pers. comm.). Weights on two 10.5 week old

males at the Bronx Zoo were 15 and 17 lbs (P. Kalk, pers. comm.).

Babirusa from birth to 30 days nurse an average of l8 times per 24 hours with the duration of nursing bouts ranging from 8-10 minutes (MacLaughlin *et al*., 2000). Babirusa nurse their offspring for longer periods than most other ungulates. Offspring are weaned between the 25th and 32nd week with twins being weaned earlier (27 weeks) than single births (30 weeks) (MacLaughlin *et al*., 2000). Piglets will start eating small amounts of solid food at less than one week old (MacLaughlin and Thomas, 1991; Leus *et al*., 1992).

(Photo: D. Wilson, St. Louis Zoo)

AGE OF DISPERSAL/REMOVAL OF YOUNG

In the wild sexual maturity is likely to be influenced by the level of nutrition, and thus the animals probably do not breed until at least one year of age. In captivity female babirusa have been known to become pregnant at 5 months of age though puberty is typically attained closer to 10 months of age (Leus et. al., 1992). Pregnancy at such an early age can lead to the development of calcium problems which will affect the sow's growth later on (pers. Comm. Paul Vercammen).

(Photo: WCS/Bronx)

Piglets can be removed from their dam as early as 4 months of age to facilitate her return to reproduction. The removal process should begin at 90 days of age with the offspring being separated from the sow for 5 minutes a day. This is increased by 5 minutes each day until there is permanent separation at 120 days of age. This process will allow for the female to breed back within a relatively short period of time. During the initial separation period the sow and youngsters may become very upset. At times the sow may go off feed or her udder may become very swollen. The swollen udder can be corrected by withholding grain for a few days. Moving the young as far away from the sow as possible at the time of permanent separation may ease the transition for mother and young alike.

Young babirusa can be shipped to other facilities as early as 6 months of age. If at all possible it is better to allow them to develop for one year and adjust to being away from the sow prior to shipment.

CONTRACEPTION

No successful reversible chemical contraceptive methods with babirusa have been reported. The Roger Williams Park Zoo conducted trials with PZP (porcine zona pellucida) vaccinations to contracept two females. Titre levels indicated that it was not effective (A. Vecchio pers. comm.).

Separating males from females during estrus remains the most safe and effective contraception method. The SSP recommends caution in using chemical methods of contraception, as reversibility needs to be established. The AZA's Contraception Advisory Group should be consulted when considering various forms of contraception.

Reproduction Summary

- Age at first estrus — As early as 190 d
- Earliest recorded conception — 12 mo
- Latest recorded conception — 14 yrs
- Average length of cycle — 30-40 d
- Average length of estrus — 1-3 d
- Average gestation length — 163 d
- Postpartum estrus — 4-5 mo
- Litter size — 1-3 piglets
- Prior to farrowing, an expectant sow should be separated from her exhibit mates and provided with extra nesting material, a den, a visual barrier or some means of increased privacy
- Sows become antagonistic for several days prior to and after farrowing and caretaker contact and disturbances should be minimal

(Photo: WCS/Bronx Zoo)

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(Photo: C. Dresner, St. Louis Zoo)

(Photo: D. Wilson/St. Louis Zoo)

HEALTH

INTRODUCTION

The data from which this overview was prepared is based upon the review of submitted medical records from 14 institutions currently holding babirusa in the United States. Further information was gleaned from discussions with veterinarians having experience with this species and from retrospective studies and clinical trials performed at the Wildlife Conservation Society's Bronx Zoo. In addition six of the contributing 14 institutions submitted MedARKs records on disk which were used to create a MedARKs Library Reference Disk.

The information herein is an accumulation of experiences or responses to unique medical situations. Those who refer to this section are therefore advised that each veterinary situation requires individual assumptions and input which are beyond what is provided in this chapter. It is still best practice to communicate directly with experienced veterinarians and husbandry personnel to delineate the most up-to-date, safe and efficacious plan of action.

PHYSIOLOGICAL NORMALS

With the assistance of Dr. Andrew Teare of ISIS a library disk of physiological norms was created from the contributed information from six cooperating institutions. 115 clinical pathology records were provided from both males and females, 72 of which were described as being in normal health and 33 of which were deemed in abnormal health. The results on the normal population are included in:

Appendix I:	Combined Clinical Pathology Reference Values
Appendix II:	Male Clinical Pathology Reference Values
Appendix III:	Female Clinical Pathology Reference Values

VACCINATION PROTOCOLS FOR BABIRUSA

There is little uniformity in vaccination protocols between responding institutions. Vaccines that were reported as being used were:

- Rabies
- Tetanus Toxoid
- Leptospirosis,multi-serovar (Leptoshield 5)
- Parvovirus/Erysipelothrix rhusiopathiae, Leptospira multiple serovars (Farrowsure, Smith Kline Beecham)
- Erysipelothrix rhusiopathiae, Bordatella bronchiseptica (Pleuroguard)
- Erysipelothrix rhusiopathia bacterin (E-Bac)
- Experimental EMC vaccine

(Photo: C. Dresner, St. Louis Zoo)

PARASITOLOGY

In general, parasites have not appeared to be a major cause of clinical illness. Most findings occurred during routine preventive health checks and as portions of clinical disease work-ups unrelated to the final diagnosis of concern. Below are a listing of organisms identified and treatments administered. The treatment dosages appeared to be empirically derived and future administration should be based on the animal's illness and present knowledge of medications and dosages.

Recommended Treatments for Parasitic Infections in Babirusa

Coccidia	sulfatrim suspension - 480 mg 15 mg/kg BID PO x 10 days
Oesophagostomum	Ivermectin - 0.2 mg/kg SQ repeated 30 days Pyrantel pamoate - 22 mg/kg PO repeated 14 days
Undiagnosed skin irritation	fenbendazole 500 mg SID PO x 5 days (RWPZ)
Coccidia (Emeria)	amprolium 18 ml/3 gallons of water SID PO x 5 days
Oxyurids	fenbendazole - 500 mg SID PO x 5 days (RWPZ)
Routine deworming	pyrantel pamoate - 5.5 mg/kg PO

MAJOR DISEASE PROBLEMS AND TREATMENTS

Three clinical presentations were most frequently listed by contributing institutions:

Lameness: Babirusa of both sexes and varying ages are affected by degenerative joint disease maladies. The most frequent presentation is a progressive lameness of one or multiple limbs which can be localized to affected joints. In a number of cases animals presenting with acute lameness have undergone extensive evaluation including radiography, joint fluid collection and culture for a variety of aerobic and anaerobic bacteria including mycoplasma. In addition joint biopsies and serology for a range of generalized infectious possibilities have been included. To date, a definitive etiology has not been ascertained despite extensive investigations in the area of infectious and metabolic disease, immune mediated causes, nutritional imbalances and environmental provisions. Typically the lesions have progressed to marked arthritis of multiple joints easily visible on radiographs. The signs can be palliated via treatment with a number of anti-inflammatory agents listed in Table 9.

Skin disease: The affected animal typically presents with dry skin coat and in addition many have multiple raised pustules which subsequently rupture leaving open healing lesions. The causes of skin disease in babirusa have been attributable variously to traumatic events, abscessation secondary to infection and unknown causes simply described as "dermatitis" with or without pruritis (itching) and urticaria (raised lesions). A variety of treatments have been administered on a empirical basis and are listed in Table 9.

Hoof cracks/abscesses: This diagnosis was seen at one park and appropriate medications administered as listed in Table 9.

Tusk fractures: Multiple institutions reported this problem secondary to traumatic injury. The identification of periosteal bleeding and/or possible pulp exposure was cause for greater levels of concern and treatment. The treatments are listed in Table 9.

IMMOBILIZATION

Twenty-four anesthetic events on nine male and five female babirusa were reviewed by James et. al. (1999) from the records at the Wildlife conservation Park/Bronx Zoo. The animals weighed between 38 and 106.8 kg and included individuals in good health as well as those with degenerative joint disease and/or dermatitis. Food was withheld for approximately 12 hr prior to immobilization and drugs were administered with a projectile dart. Animals were immobilized with xylazine (x = 1.25 +/- 0.33 mg/kg, range 0.82-2.07 mg/kg) given via IM dart. 20 minutes later the animals were darted with Telazol (teletamine and zolazepam [x=1.82 +/- 0.63 mg/kg, range 0.86-3.59 mg/kg]). If prolonged procedures were required, supplemental dosages of ketamine HCL were given IV or isoflourane was administered via face mask. Anesthesia was reversed with yohimbine (x= 0.15 +/1 0.04 mg/kg, range 0.09-0.24 mg/kg) and in most cases flumazenil (1mg/10 mg of zolozepam) was also given either i.m. or i.v. at least 20 minutes post Telazol administration. Further information is also available Calle and Morris (1999).

(Photo: St. Louis Zoo)

Table 9: Common Babirusa Health Problems and Treatments. Key: Audubon (a), Bronx (b), Cincinnati (c), Denver (d), Houston (e), Louisville (f), Lowry Park (g), Oklahoma (h), Philadelphia (i), Providence (j), St. Louis (k), San Diego Zoo (l), Gulf Breeze (m) and San Antonio (n).

Lameness – Idiopathic, arthritis, other		Lameness - Trauma	Skin - Trauma	Skin - Abscesses	Skin - Dermatitis	Hoof cracks & abscesses	Tusk Fractures
Pain Management	Antimicrobial						
Banamine 1-2 mg/kg PO S/BID[a, b, f, I, k, j]	TMS 15-20 mg/kg PO BID[a, k]	Dilute Betadine[a]	Topical povidone iodine 10%[a, f, j]	TMS 13-15 mg/kg PO BID[a, k]	Dexamethazone 0.04 mg/kg once IM[a]	Procaine penicillin G 8.8 ml SQ (55 kg)[d]	None or Monitor[a, d, f, h, I]
None or Monitor[a, f, h, I]	Enrofloxacin 0.68 mg/kg PO BID[k]	Supplemented diet with biotin[a]	None or Monitor[a, d]	Enrofloxacin 3-5 mg/kg PO SID[f, k]	Peanut oil in diet[k]	Banamine 1 mg/kg[d]	Betadine[f]
Diclofenac 0.25-0.5 mg/kg PO BID[a, b]	Tribrissen 7.5 mg/kg PO SID[k]		Topical A&D ointment[n]	None[a, k]	Enrofloxacin 2.8 mg/kg PO BID[k]	Furazone powder wrap[d]	Nitrofurazoone dressing 0.2%[h]
Cosequin 2-4 capsules[f, k, b]	Ampicillin 9-10 mg/kg PO BID[k]		Silver sulfaciazine cream[n]	Topical K iodine[a]	Clavamox 13 mg/kg PO BID[k]	Procaine-benzathine penicillin 6 ml SQ[f]	Clavamox 12 mg/kg SID[j]
Tramadol 1.6 mg/kg PO BID[b, k]	Oxytetracycline 20 mg/kg[b]		Amoxicillin trihydrate 12 mg/kg PO SID[n]	Aspirate, lance, flush with nolvasan[a]	Ampicillin 6.8 mg/kg[k]	Bandage feet[i]	Banamine mg/kg SID[j]
Phenylbutazone 3-5 mg/kg PO SID[a, n]			Betadine[j] and dryclox[f]	Amoxicillin infusion 1-2 ml topically SID[b]	Fenbendazol 5 mg/kg PO SID[j]	Tecnovit[d]	Clean, flush socket hetacillin[b]
Etodolac 8.9 mg/kg PO SID[a]			Topical panalog ointment BID[j]		Topical povidone-iodine 10% BID[j]		
Palaflex 83 mg/kg PO SID[a]			Fly repellant[i]		Topical Panalog ointment BID[j]		
Topical Fentanyl Citrate[b]					Topical mineral oil[l]		
Cimetidine 3.75 mg/kg PO SID[d]					Urea hydrating mist[i]		
Aspirin 10 mg/kg[d]					Oxydex shampoo[i]		
Ketoprofen 0.5-1.0 mg/kg PO BID[k]					Isoniazind 10 mg/kg PO SID[b]		
Voltarin 0.12-0.64 mg/kg PO BID[b]					Butorphanol Tartrate 33.1-125 mcg/kg[b]		
Carprofen 2.4 mg/kg PO BID[f]					Doxycycline hyciate 2.5 mg/kg PO SID[b]		
Others: Epsom salt soak[h], Buprenorphine[b], Prednisone[b], Polysulfated glycosaminoglycans[a], Polyflex ampicillin[f]					Amoxi-Mast infusion 2 ml topically SID[b]		

109 anesthetic events (67 males and 42 females) were reviewed from the assembled MedARKs Library disk. While the Telazol, xylazine combination was most frequently used, the combinations were often times given together in the same dart with varying success. The other combination of note was the use of butorphanol, detamidine and midazolam given simultaneously.

QUARANTINE PROTOCOLS

There was some variation in the quarantine protocols used by different institutions. In general they included a minimum of:

General Quarantine Protocol for Babirusa

- 30 days in a quarantine environment
- 3 negative fecal exams (ova and parasite float)
- CBC and Biochemistry panel either pre-shipment or during quarantine
- Fecal culture

The depth and breadth of quarantine work-up also varied with the animal's origin. Animals arriving from an AZA institution with a known medical history and pre-shipment evaluation were more likely to have less diagnostics performed in quarantine. Animals arriving from outside AZA institutions or without good medical histories were more likely to undergo greater diagnostic evaluation. Serologic evaluations and vaccination administration varied widely between institutions.

POST-MORTEM FINDINGS

A total of 12 necropsy reports were reviewed from participating institutions. Some animals were euthanized due to poor prognosis.

Causes of Death of Babirusa in SSP Population

- Abdominal abscessation of unknown etiology
- Cardiac arrest during handling of a juvenile
- Acute bacterial gastritis and enterotoxemia
- Subacute to chronic ulcerative gastritis with gastric ulceration
- Spondylosis with fracture and spinal cord trauma suggestive of Disseminated Idiopathic Skeletal Hyperostosis
- Stillborn
- Chronic severe degenerative joint disease of multiple joints, Dermatitis
- Orphaned neonate being handreared with necrotizing gastritis and possible enteritis
- Anesthetic death with underlying myocardial fibrosis
- Chronic severe degenerative joint disease of multiple joints, Dermatitis

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(Photo: C. Dresner, St. Louis zoo)

Appendix I. Combined Clinical Pathology Reference Value for *Babyrousa babyrussa*

		ISIS Values Mean S.D.	Min.	Max.	(N)
WBC	*10^3/UL	7.943 ± 2.985	3.500	17.80	(47)
RBC	*10^6/UL	6.58 ± 1.40	4.56	10.50	(39)
HGB	GM/DL	12.9 ± 1.8	9.1	16.9	(41)
HCT	%	41.0 ± 7.5	28.8	66.0	(46)
MCH	MG/DL	19.8 ± 2.5	15.7	28.1	(39)
MCHC	uug	31.7 ± 1.7	26.3	35.7	(40)
MCV	fL	62.5 ± 7.9	51.5	93.8	(39)
SEGS	*10^3/UL	3.988 ± 2.102	1.280	12.10	(41)
BANDS	*10^3/UL	0.121 ± 0.066	0.057	0.240	(10)
LYMPHOCYTES	*10^3/UL	3.478 ± 2.099	0.755	9.870	(43)
MONOCYTES	*10^3/UL	0.369 ± 0.333	0.038	1.780	(39)
EOSINOPHILS	*10^3/UL	0.243 ± 0.245	0.057	1.176	(28)
BASOPHILS	*10^3/UL	0.159 ± 0.193	0.011	0.540	(8)
NRBC	/100 WBC	1 ± 0	1	1	(3)
PLATE. CNT.	*10^3/UL	354 ± 234	89	1086	(19)
GLUCOSE	MG/DL	71 ± 34	24	192	(45)
BUN	MG/DL	16 ± 5	6	25	(45)
CREAT.	MG/DL	1.3 ± 0.3	0.7	2.1	(42)
URIC ACID	MG/DL	0.3 ± 0.4	0.0	1.3	(10)
CA	MG/DL	10.1 ± 0.7	8.9	11.9	(45)
PHOS	MG/DL	5.5 ± 1.2	3.9	9.5	(38)
NA	MEQ/L	144 ± 4	134	154	(37)
K	MEQ/L	4.3 ± 0.5	3.5	5.4	(37)
CL	MEQ/L	104 ± 3	94	110	(36)
IRON	MCG/DL	204 ± 95	137	271	(2)
MG	MG/DL	1.40 ± 0.00	1.40	1.40	(1)
HCO3	MMOL/L	30.0 ± 0.0	30.0	30.0	(1)
CHOL	MG/DL	87 ± 23	25	136	(38)
TRIG	MG/DL	45 ± 26	12	98	(23)
T. PROT (C)	GM/DL	7.4 ± 0.7	6.0	8.8	(40)
ALBUMIN (C)	GM/DL	4.3 ± 0.5	3.3	5.7	(35)
GLOBULIN (C)	GM/DL	3.1 ± 0.9	1.4	4.7	(34)
AST (SGOT)	IU/L	20 ± 14	4	58	(43)
ALT (SGPT)	IU/L	39 ± 12	19	85	(40)
T. BILI.	MG/DL	0.3 ± 0.2	0.1	0.9	(39)
D. BILI	MG/DL	0.1 ± 0.1	0.0	0.3	(8)
I. BILI	MG/DL	0.2 ± 0.1	0.0	0.4	(8)
AMYLASE	U/L	554 ± 314	134	914	(8)
ALK. PHOS.	IU/L	71 ± 47	18	209	(41)
LDH	IU/L	503 ± 163	285	897	(21)
CPK	IU/L	268 ± 127	127	481	(7)
Body Temperature:		37.3 ± 0.9	35.0	39.0	(26)
CO2	MMOL/L	26.0 ± 8.7	13.0	45.0	(10)
FIBRINOGEN	MG/DL	327 ± 142	0	500	(11)
GGT	IU/L	67 ± 18	39	108	(17)
LIPASE	U/L	4 ± 0	4	4	(2)

Appendix II: Male Clinical Pathology Reference Values for *Babyrousa Babyrussa.*

Test	Mean	St. Dev	Min.	Max.	(N)	
Alanine Aminotransferase	31.95	± 8.282	16.00	55.00	(57)	IU/L
Albumin (Colorimetry)	4.120	± 0.579	2.600	5.100	(55)	GM/DL
Albumin Globulin Ratio	1.322	± 0.387	0.800	2.400	(16)	GM/DL
Alkaline Phosphatase	49.89	± 24.49	18.00	125.0	(57)	IU/L
Amylase	272.1	± 194.9	88.00	797.0	(13)	U/L
Anion Gap	20.00	± 2.646	17.00	22.00	(3)	MEQ/L
Aspartate Aminotransferase	17.36	± 10.40	4.000	53.00	(59)	IU/L
Atypical Lymphocytes	4.000	± 0.000	4.000	4.000	(1)	
Basophils	0.015	± 0.045	0.000	0.210	(24)	*10^3/UL
Bicarbonate	28.00	± 0.000	28.00	28.00	(1)	MMOL/L
Bile Acids – Bile Salts	10.40	± 0.000	10.40	10.40	(1)	UMOL/L
Blood Urea Nitrogen	17.37	± 5.346	8.000	30.00	(60)	MG/DL
BUN/Creatinine Ratio	12.47	± 4.987	5.200	21.90	(13)	MG/DL
Calcium	9.972	± 0.667	8.900	11.80	(60)	MG/DL
Carbon Dioxide	22.00	± 4.950	13.00	31.00	(13)	MMOL/L
Carbon Dioxide, Serum	24.67	± 2.517	22.00	27.00	(3)	
Chloride	103.0	± 4.776	89.30	115.0	(56)	MEQ/L
Cholesterol	81.16	± 22.47	25.00	136.00	(54)	MG/DL
Copper	276.0	± 0.000	276.0	276.0	(1)	UG/DL
Creatine Phosphokinase	372.2	± 345.5	127.0	1243	(13)	IU/L
Creatinine	1.387	± 0.334	0.900	2.100	(60)	MG/DL
Direct Bilirubin	0.104	± 0.054	0.000	0.200	(12)	MG/DL
Eosinophils	0.222	± 0.202	0.000	0.826	(44)	*10^3/UL
Fibroinogen	286.7	± 255.9	0.000	800.0	(15)	MG/DL
Gamma Glutamyl Transferase	76.29	± 14.79	39.00	108.0	(21)	IU/L
Gamma-Glutamyl Transpeptidase	83.00	± 0.000	83.00	83.00	(1)	
Globulin (Colorimetry)	3.708	± 0.874	1.900	6.000	(52)	GM/DL
Glucose	63.37	± 29.76	22.00	143.00	(60)	MG/DL
Hematocrit	37.71	± 6.076	27.80	54.30	(58)	%
Hemoglobin	11.85	± 1.779	6.900	16.30	(56)	GM/DL
Heterophils	4.689	± 2.447	1.280	12.18	(56)	*10^3/UL
Indirect Bilirubin	0.165	± 0.123	0.000	0.410	(11)	MG/DL
Iron	183.6	± 75.75	137.0	271.0	(3)	MCG/DL
Lactate Dehydrogenase	456.3	± 161.8	74.00	868.8	(32)	IU/L
Lipase	22.91	± 53.24	1.000	173.1	(10)	U/L
Lymphocytes	2.828	± 1.476	0.426	7.473	(59)	*10^3/UL
Magnesium	1.481	± 0.303	1.200	2.070	(7)	MG/DL
MCH	20.32	± 2.684	14.11	28.13	(56)	uug
MCHC	31.73	± 2.398	21.97	35.95	(54)	GM/DL
MCV	63.95	± 7.392	49.38	93.75	(54)	FL
Mean Platelet Volume	4.250	± 0.743	3.100	5.500	(22)	FL
Monocytes	0.391	± 0.311	0.000	1.431	(52)	*10^3/UL
Myelocytes	0.030	± 0.042	0.000	0.060	(2)	*10^3/UL
Neutrophilic Bands	0.056	± 0.094	0.000	0.340	(21)	*10^3/UL
Neutrohilic metamyelocytes	0.142	± 0.197	0.000	0.367	(3)	*10^3/UL
Nucleated Red Blood Cells	1.833	± 2.041	1.000	6.000	(6)	/100 WBC
Osmolality	289.3	± 12.10	280.0	303.0	(3)	MOSMOL/KG
Osmolality, Calculated	286.0	± 0.000	286.0	286.0	(1)	
Parvovirus Antibody	8.000	± 0.000	8.000	8.000	(1)	
Phosphorus	5.198	± 0.916	3.700	7.500	(55)	MG/DL
Platelet Count	365.6	± 160.2	104.0	784.0	(36)	*10^3/UL
Polymorphonuclear leukocyte	52.00	± 26.63	24.00	77.00	(3)	
Potassium	4.280	± 0.426	3.400	5.400	(57)	MEQ/L
Reactive lymphcytes	0.600	± 0.000	0.600	0.600	(1)	*10^3/UL
Red Blood Cell Count	5.901	± 1.096	4.370	9.150	(56)	*10^6/UL
Selenium	7.880	± 0.000	7.880	7.880	(1)	UG/DL
Sodium	142.8	± 4.430	130.3	152.0	(57)	MEQ/L
Sodium Potassium Ratio	35.00	± 0.000	35.00	35.00	(1)	
T.S. (Total Solids)	7.900	± 0.622	7.400	8.800	(4)	
Total Bilirubin	0.289	± 0.145	0.100	0.800	(54)	MG/DL
Total Protein (Colorimetry)	7.829	± 0.657	6.400	9.100	(59)	GM/DL
Total Protein (Refractometer)	7.767	± 0.802	7.00	8.600	(3)	GM/DL
Total Solids (Refractometer)	7.200	± 0.000	7.200	7.200	(1)	
Toxic Changes	1.000	± 0.000	1.000	1.000	(2)	
Triglyceride	43.83	± 24.62	12.00	98.00	(24)	MG/DL
Uric Acid	0.114	± 0.186	0.000	0.500	(7)	MG/DL
White Blood Cell Count	8.255	± 3.167	3.100	17.80	(59)	*10^3/UL

Appendix III: Female Clinical Pathology Reference Values for *Babyrousa Babyrussa.*

Test	Mean	St. Dev	Min.	Max.	(N)	
Alanine Aminotransferase	37.12	± 9.969	23.00	64.00	(42)	IU/L
Albumin (Colorimetry)	4.203	± 0.571	2.600	5.700	(35)	GM/DL
Albumin (Electrophoresis)	3.300	± 0.000	3.300	3.300	(1)	GM/DL
Albumin Globulin Ratio	1.630	± 1.812	0.000	6.300	(9)	GM/DL
Alkaline Phosphatase	59.80	± 32.47	4.000	142.0	(41)	IU/L
Alpha-1 Globulin (Electrophoresis)	0.800	± 0.000	0.800	0.800	(1)	MG/DL
Alpha-2 Globulin (Electrophoresis)	1.100	± 0.000	1.100	1.100	(1)	MG/DL
Amylase	477.8	± 345.4	75.00	814.0	(6)	U/L
Anion Gap	13.50	± 3.536	11.00	16.00	(2)	MEQ/L
Aspartate Aminotransferase	4.46	± 18.27	7.000	94.00	(41)	IU/L
Atypical Lymphocytes	3.000	± 0.000	3.000	3.000	(1)	
Basophils	.065	± 0.105	0.000	0.384	(23)	*10^3/UL
Beta-1 Globulin (Electrophoresis)	1.700	± 0.000	1.700	1.700	(1)	MG/DL
Bicarbonate	30.00	± 0.000	30.00	30.00	(1)	MMOL/L
Blood Urea Nitrogen	15.10	± 7.135	5.800	47.00	(43)	MG/DL
BUN/Creatinine Ratio	13.59	± 7.145	7.700	29.00	(8)	MG/DL
Calcium	9.807	± 0.655	8.200	11.30	(44)	MG/DL
Carbon Dioxide	30.25	± 8.180	20.00	40.00	(4)	MMOL/L
Chloride	103.6	± 3.228	95.00	110.0	(37)	MEQ/L
Cholesterol	90.43	± 21.64	49.00	130.0	(42)	MG/DL
Creatine Phosphokinase	495.2	± 334.3	156.0	950.0	(6)	IU/L
Creatinine	1.230	± 0.336	0.100	1.800	(43)	MG/DL
Direct Bilirubin	0.133	± 0.071	0.100	0.300	(9)	MG/DL
Eosinophils	0.203	± 0.213	0.000	0.810	(36)	*10^3/UL
Fibroinogen	375.0	± 205.3	0.000	700.0	(8)	MG/DL
Gamma Globulin (Electrophoresis)	1.500	± 0.000	1.500	1.500	(1)	GMDL
Gamma Glutamyl Transferase	74.86	± 29.81	39.00	137.0	(14)	IU/L
Globulin (Colorimetry)	3.446	± 1.092	0.800	6.200	(35)	GM/DL
Glucose	67.93	± 23.99	27.00	132.00	(44)	MG/DL
Hematocrit	38.54	± 6.801	24.10	54.20	(44)	%
Hemoglobin	12.24	± 2.566	7.500	19.70	(45)	GM/DL
Heterophils	5.233	± 2.597	0.673	11.95	(46)	*10^3/UL
Indirect Bilirubin	0.200	± 0.112	0.000	0.400	(9)	MG/DL
Lactate Dehydrogenase	674.5	± 362.5	316.0	1759	(15)	IU/L
Lipase	38.00	± 42.40	4.000	100.0	(4)	U/L
Lymphocytes	3.363	± 1.511	1.147	7.584	(45)	*10^3/UL
Magnesium	1.700	± 0.141	1.600	1.800	(2)	MG/DL
MCH	20.66	± 3.163	14.71	33.00	(45)	uug
MCHC	32.88	± 5.504	26.77	65.00	(43)	GM/DL
MCV	63.69	± 7.139	49.22	74.12	(42)	FL
Mean Platelet Volume	3.546	± 0.541	3.000	5.000	(13)	FL
Metamyelocytes	0.055	± 0.077	0.000	0.109	(2)	*10^3/UL
Monocytes	0.496	± 0.391	0.000	1.459	(44)	10^3/UL
Myelocytes	0.036	± 0.063	0.000	0.109	(3)	10^3/UL
Neutrophilic Bands	.105	± 0.193	0.000	0.858	(24)	*10^3/UL
Neutrohilic metamyelocytes	.145	± 0.167	0.000	0.327	(3)	*10^3/UL
Nucleated Red Blood Cells	.500	± 2.121	1.000	4.000	(2)	/100 WBC
Osmolality	295.0	± 12.73	286.0	304.0	(2)	MOSMOL/KG
Osmolarity	297.0	± 0.000	297.0	297.0	(1)	MOSMOL/L
Phosphorus	4.869	± 0.960	3.000	8.300	(35)	MG/DL
Platelet Count	232.2	± 120.5	36.00	550.0	(20)	*10^3/UL
Potassium	4.253	± 0.342	3.460	5.400	(37)	MEQ/L
Red Blood Cell Count	6.090	± 1.315	4.300	10.58	(43)	*10^6/UL
Selenium	2.80	± 0.000	72.80	72.80	(1)	UG/DL
Sodium	143.8	± 3.259	136.7	154.0	(37)	MEQ/L
Sodium Potassium Ratio	38.00	± 0.000	38.00	38.00	(1)	
T.S. (Total Solids)	.860	± 1.122	6.200	9.300	(5)	
Total Bilirubin	0.333	± 0.133	0.100	0.600	(40)	MG/DL
Total Protein (Colorimetry)	.565	± 0.775	5.800	9.700	(40)	GM/DL
Total Protein (Electrophoresis)	8.300	± 0.000	8.300	8.300	(1)	
Total Protein (Refractometer)	8.200	± 0.548	7.600	8.800	(4)	GM/DL
Total Solids	8.000	± 0.000	8.000	8.000	(1)	
Toxic Changes	4.000	± 0.000	4.000	4.000	(1)	
Triglyceride	44.29	± 23.33	20.00	98.00	(17)	MG/DL
Uric Acid	0.467	± 0.723	0.000	1.300	(3)	MG/DL
White Blood Cell Count	9.405	± 3.307	3.700	16.60	(48)	*10^3/UL

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(Abstract: There is fear expressed that the babirusa may be shot. They are very rare.)

Anonymous (1931) Nieuwe Jacht-en Dierenbeschermingsbepalingen. Mededeelingen [van de] Nederlandsche Commissie voor Internationale Natuurbescherming, 9, 9-13.
(Abstract: A permit will be issued for up to two adult male babirusa. Only up to two babirusa permitted to be exported alive.)

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(Abstract: A request for: former range and numbers, present range and numbers, causes of depletion (or extinction), economic uses or importance, what measures are being taken for the preservation of the species concerned. List of vanishing mammals in the Malay archipelago. Suidae Babirussa *babyrussa* (babirusa)).

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(Abstract: Appendix I. shall include all species threatened with extinction which are or may be affected by trade. ...Artiodactyla, Suidae, *Babyrousa babyrussa*)

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(Abstract: *Babyrousa* Perry, 1811, Arcana, sig. C, Recto. ISIS number 5301419001001000000. *Babyrousa babyrussa* (Linnaeus, 1758). Syst. Nat., 10th ed., 1;50. TYPE LOCALITY; "Borneo" (=Buru Isl., Indonesia). Distribution; N. and C. Sulawesi; Buru (N. Molucca Isls.); Sula Isls.; Malengi Isl. (Togean Isls.). Protected status; CITES - Appendix I and U.S.ESA - Endangered. ISIS number 5301419001001001001.)

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(Abstract: Babirusa were reported (in 1923) to be found in the area of he volcanoes Kalabat en Doea Saudara, in Minahassa, North Sulawesi. It is proposed that this area become an extension of the neighbouring nature conservation park.)

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(Abstract: Babirusa are rare. Dozens of carcasses are brought to the markets of north Sulawesi each month. Babirusa are uncommon or absent from the east end of the Dumoga Bone park probably as a result of hunting, but are still fund in the west.)

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(Abstract: Gunung Tongkoko Batoeangoes. Date of institution: February, 1919.
Location: Northeastern part of the Minahassa, opposite the island of Lembeh.
Characteristics: In this nature reserve two of Celebes' most remarkable mammals are still found, the hogdeer (Babirussa *babyrussa*) and the pigmy buffalo or anoang (Anoa depressicornis). It contains the volcanoes Gn. Tongkoko (1373 M.) and the Gn. Batoeangoes (1173 M.), an exceptionally fine preserve of the wild plant and animal life of North Celebes.)

Dammerman, K. W. (1929) Preservation of wildlife and nature reserves in the Netherlands Indies. The Proceedings of the Congress 4th Pacific Science Congress. Java. 1929 (99pp).
(Abstract: Gunong Tongkoko Batoeangoes. Reserved: February 1919.
Site: The area bounded on the north and the east by the Molluccan Sea, on the south by the imaginary line which connects the summit of the Mt. Tongkoko with Tanjoeng Batoeangoes, and on the west by the river Batoe Poetih and the imaginary which connects the source of this river with the summit of the Tongkoko. Area: 446 hectares.
Reason for protection: In the reserved areas two kinds of mammals, characteristic of Celebes, the hog-deer (Babirussa) and the dwarf buffalo (Anoa) still occur. Moreover this area with its interesting volcanoes, the still active Gn. Tongkoko (1373 m) and the Gn. Batoeangoes (1173 m), reaching down to the sea, is exceptionally suitable for the preservation of the plant and animal life of the extreme north of Celebes.)

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De Graeff, (1931) Dierenbescherming. Staatsblad van Nederlandsch-Indië, 134, 1-4.
(Abstract: The law permits "named species of animals" to be collected for research or teaching purposes.)

De Graeff, (1931) Dierenbescherming. Staatsblad van Nederlandsch-Indië, 266, 1-4.
(Abstract: It is forbidden to hunt, trap, kill, deal in living or dead parts of...babirusa (Babirussa). Export of up to two babirusa may be permitted. Skins of wild pigs with the exception of babirusa may be exported. The hunting regulations can be extended to babirusa beyond the area of enforcement under the 1931 ruling.)

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(Abstract: It is forbidden to hunt, trap, kill or deal in the animal parts of the babirusa.)

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reported Sulawesi warty pigs, babirusa, the macaque, a large marsupial and a wild goat. Possibly it was so easy to catch the babirusa that people hunted this animal almost exclusively. The babirusa is now extinct in south Sulawesi.)

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(Abstract: brief description of the babirusa, and that it prefers to eat fruit and leaves.)

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(Abstract: The babirusa is not so plentiful and widely distributed. It is found around the Amurang bay and round Kalabat.)

Groves, C. P. (1976) The origin of he mammalian fauna of Sulawesi (Celebes). Zeitschrift für Säugetierkunde, 41, 201-216.
(Abstract: Strictly speaking, *Babyrousa* occupies a special position, as it is not restricted to Sulawesi but occurs also on the Sula islands and Buru; it might therefore better have been placed in group 4 (migrants from Sulawesi), but it is the only species of the genus and has doubtlessly originated on Sulawesi.

Groves, C. P. (1980) Notes on the systematics of *Babyrousa* (Artiodactyla, Suidae). Zoologische Mededelingen. 55, 29-46.
(Abstract: Skins and skulls of *Babyrousa babyrussa* have been studied; the species is divisible into three living subspecies: B. b. *babyrussa* (syn. frosti) from Buru and Sula, B. b. togeanensis from Malenge, and B. b. celebensis from the northern arm of Celebes. A skull from near Kulawi, central Celebes, tends towards *babyrussa*, and may represent a suviving population of the inadequately characterised B. b. bolabatuensis, known as a subfossil from the southern arm of Celebes. Teeth of the latter form decreased in size through time. The possibility of the species having been introduced into Buru and Sula is discussed.)

Groves, C. P. (1981) Ancestors for the pigs: taxonomy and phylogeny of the genus Sus. Technical Bulletin No. 3 Department of Prehistory, Research School of Pacific Studies. Australian National University Press: Canberra, pp 1-6.

Groves, C. P. (1985) The Sulawesi "specials" ; archaic, strange, endemic. Australian Natural History. 21, 442-444.
(Abstract: Babirusa appear to be crepuscular, i.e., most active around dawn and dusk. They love to wallow in mud, and swim well. In the Togian islands they have been seen swimming a kilometre or more between small islands. Unlike true pigs, they are unable to dig deeply, because their snouts are not as strong and the rooting disc at the end is not as developed. They do not eat deep lying roots, but grasses, fallen fruit, mushrooms, and grubs which they gnaw from rotten wood.

Groves, C. P. & Grubb, P. (1993) The Eurasian suids Sus and *Babyrousa*; taxonomy and description. In "Status survey and conservation action plan; pigs, peccaries and hippos" (Ed: Oliver, W. L. R.), IUCN: Gland, Switzerland, pp 107-111.

Grubb. P. (19993) Order Artiodactyla. In "Mammal species of the world: a taxonomic and geographical reference" 2nd edition. (Eds. D. E. Wilson & D. M. Reder). Smithsonian Institution Press: Washington and London.

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 Malay archipelago. J. Murray: London, 2, pp 190-191, 200-205.
(Abstract: (Maim bay, on Sulawesi) The Babirusa, according to the natives, generally has one or two young at birth; more often one, but sometimes, though rarely, three. They are born in the months of November, December, and January, and the sow makes a small underground hole for their reception, lining it with leaves - generally of the Livingstonia. The young, however, are able to move about on the second day of their existence. We were told that they were of two colours - nearly black and light brown - and that the female can have young of both of these colours just as a sow has black and white pigs... These colours were said to approximate with age, but the natives

spoke of "white" and "black babirusas" even in the adult stage, and the one I have mentioned (young male) was certainly lighter in colour than others we afterwards killed on Limbe island. Our hunters also told us that, when assailed by dogs, the animal sometimes ascended the procumbent trunks of trees, and got out upon the larger lower branches. The natives told us that almost all the babirusa would come along the ridge. On Limbe island we caught four babirusa, the first being a female which had produced "a peculiar barking grunt".)

Hamerton, A.E. (1931) Report on the deaths occurring in the society's gardens during the year 1930. Proceedings of the Zoological Society, 1931, 527-555.
(Abstract: A remarkable case of mass infestation of the lungs with the cysticeric of one of the Taeniidae (Echinococcus) occurred in a young Babirusa (Babirussa *babyrussa*) that died a few weeks after arrival from Celebes. The weight of the animal was 24 lb., and the lungs weighed 2 lb. 5 oz. The connective tissue throughout the whole structure of the lungs was so closely infested with cysticerci that the organs bore a rough resemblance to bunches of grapes. The lung parenchyma between the cysts showed no pathological change except for emphysema at the apices and some congestion and oedema of the bases. The pleurae were adherent, and the lobes of the lungs were stuck together by adhesive pleuritis. The intercoastal spaces were obliterated. The pressure effects of the mass of cysts on the heart and great vessels must have been considerable, and it was strange that the respiratory function could have been so long maintained. The liver and spleen were also infested with numerous large cysticerci containing hooked scolices.
Babirussa (Babirussa *babyrussa*) Class of parasite: Cestoda, Tissue affected: Lungs, liver and spleen, Lesion Pleurisy; cysticerci in lungs.)
Single infections Microfilaria, host Babirussa *babyrussa*.

Hamerton, A.E. (1941) Report on the deaths occurring in the society's gardens during the years 1939-1940. Proceedings of the Zoological Society, London, Series B, 111, 151-185.
(Abstract: A female Babirusa (Babirussa *babyrussa*) that had been eight years in the Gardens and had reared several young, died from tuberculosis of the Bovine type - with deposits "pearles" in the parietal pleurae and sessile tubercules in the pericardium. Both lungs were consolidated by caseous masses of agglomerated tubercles. Secondary tuberculous lesions were found in the spleen, kidneys, cervical mediastinal and mesenteric lymph-glands.)

Hamerton, A.E. (1943) Report on the deaths occurring in the society's gardens during the year 1942. Proceedings of the Zoological Society of London. Series B, 113, 149-160.
(Abstract: a male Babirusa (Babirussa *babyrussa*) that had been in the Gardens for 10.5 years died from senile atrophy of the intestinal mucosa and muscularis, causing the gut walls to be thin and diaphanous in texture. The jejunum and ileum in particular appeared to be denuded of all epithelial and glandular structures.)

Hart, C. (1853) Reize rondom het eiland Celebes en naar eenige der Moluk che eilande. K. Fuhri: 's-Gravenhage, pp 72, 128, 134.
(Abstract: babirusa were found in the region of Taboenkoe of East Sulawesi, and Balank Manado in north Sulawesi. They are also found in the Ambon islands. They are also found on Buru.)

Hartadi, I. (1996) Sekilas mengenai babirusa (Babirussa *babyrussa*) di Sulawesi. Informasi, WWF Indonesia 2pp.

Hasselt, J.C.van (1880) De onderfdeeling Bangkala, geographisch en ethnologisch geschetst. Tijdschrift van het Aardrijkskundig Genootschap, 4, 362-381.
(Abstract: There are no babirusa in the south-west point of south west Sulawesi.)

Heekeren, H.R. van (1941) Over Toala's en de Toala-cultuur (Zuid-Celebes). Natuurwetenschappelijke Tijdschrift voor Nederlandsch Indie, 101, 229-237

Heekeren, H.R. van (1950) Rock paintings and other prehistoric discoveries near Maros (Sout west Celebes). Laporan Tahunan Diras Purbakala Republik Indonesia 1950. 22-49.
(Abstract: Cave fauna; *Babyrousa babyrussa* (L). Now vanished from southwest Celebes. Oldest example in caves larger than the *Babyrussa* still living in central Celebes. The type from the Bola Batu Cave was named *Babyrousa babyrussa* bolabatuensis. He describes the discovery of the cave painting of the ?babirusa?)

Heekeren, H.R. van (1966) Handen aan de wand. Verre naasten naderbij. (Rijksmuseum voor Volkenkunde te Leiden), 1, 2-8.
(Abstract: A leaping pig was found in a cave at Leang Pattae. The thin legs and the thick body made him think immediately that it was a babirusa, but the tufts of hair on its back and neck made him unsure.)

Heekeren, H.R. van (1972) The stone age of Indonesia. Verhandelingen van het Koninklijke Instituut voor Taal-, Land-, en Volkenkunde. M. Nijhoff: The Hague, 2, 61, 69-71, 116-122.

Heinroth, O. (1908) Trachtigkeits-und Brutdauern. Zoologischer Beobachter; Der Zoologische Garten, 49, 14-25.
(Abstract: babirusa gestation length 158, 160 (Heinroth), 5 months and 5 days. The babirusa has at most two young, which are no larger than other pigs despite the month longer gestation. The lack of carnivores on Sulawesi may mean that the babirusa has retained the palaeontological gestation length.)

Herring, S.W. (1972) The facial musculature of the suoidea. Journal of Morphology, 137, 49-62.

Herring, S.W. (1972) The role of canine morphology in the evolutionary divergence of pigs and peccaries. Journal of Mammology, 53, 500-512.

Herring, S.W. (1972) Sutures - a tool in functional cranial analysis. Acta Anatomica, 83, 222-247.

Heynsius-Viruly, A. & Heurn, F.C. van. (1935) Overzicht van de uit Nederlandsch-Indie ontvangen gegevens, gerangschikt door Mevrouw A. Heynsius-Viruly. Met biologische aanteekeningen omtrent de betreffende diersoorten door F.C. van Heurn. Nederlandsche Commissie Voor Internationale Natuurbescherming, Supplement op Mededeelingen. No. 10, 35-77.
(Abstract: There is word from the region Mamoedjoe that the babirusa are in no danger of being exterminated in that area, however, there is more of a problem in the Minahassa region of Sulawesi. In the region around Laiwoei the babirusa are still found in Kendari, and sporadically on Buru behind Kajeli village. There is no word from the Sula islands or Lembeh.)

Hickson, S.J. (1889) A Naturalist in north Celebes. J. Murray: London pp 18, 69, 353-354.
(Abstract: At the village of Koa, Talisse island, of the north coast of the northern peninsula of Sulawesi, Mr. Cursham had a fine specimen of the babirusa in a bamboo kraal.)

Hodgden, R. (1985) Behaviour of Babirusa (*Babyrousa* babirussa) in captivity; a comparison of behaviour within the suborder of Suiformes. Unpublished report, Jersey Wildlife Preservation Trust.
(Abstract: A study of the behaviour of three captive babirusa).

Holland, J.S. (1994) North American regional studbook for babirusa (*Babyrousa babyrussa* celebensis). Los Angeles Zoo: Los Angeles, 51pp.

Holland, J.S. (1995) North American regional studbook for babirusa (*Babyrousa babyrussa* celebensis). Los Angeles Zoo: Los Angeles, 49pp.

Hooijer, D.A. (1948) Pleistocene Vertebrates from Celebes. III. Anoa depressicornis (Smith)
subsp., and Babyroussa babirussa beruensis nov. subsp. Proceedings of the section of Sciences [of the] Koninklijke Nederlandsche Akademie van Wetenschappen, 51, 1322-1330.
(Abstract: Neither the anoa nor the babirusa are living today in the region where their fossil remains were found. In the Southwestern peninsula of Celebes the anoa still only lives on the Peak of Bonthain in the extreme S. (Weber, 1890, p. 112; Sarasin, 1905, p. 32), while the babirusa has vanished from the whole of the Southwestern peninsula of the island (Sarasin, l.c., p. 41). The occurrence of both species in the prehistoric collections from caves near Lamontjong in S. Bone (ca. 60 km ENE of Macassar) and from the neighbourhood of Tjani (Lamontjong), Watampone (Central Bone, ca. 120 km N.E. of Macassar) and Bonthain on the S. coast, was described by Sarasin (1905) and Dammerman (1939) respectively. Sarasin (1905, p. 39/40) reported that the subfossil teeth of the babirusa agree well in size with the recent, but the subfossil teeth of the anoa (l.c., p. 30) average smaller than the recent.)

Hooijer, D.A. (1950) Man and other mammals from Toalian sites in southwestern Celebes. Verhandelingen der Koninklijke Nederlandsche Akademie van Wetenschapen, 46, 1-164.
(Abstract: In most of the Toalian sites the fauna of which I have studied the babrisua is present, while at this day the babirusa has vanished from the whole of the southwestern peninsula of Celebes.
The babirusa is but one element to an interesting Pleistocene Vertebrate fauna which is now already known to contain extinct forms like a peculiar giant pig, Celebochoerus heekereni Hooijer (1948b).
The Pleistocene babirusa, then, is larger than the living races of babirusa from Celebes, Taliaboe, and Boeroe, and was baptized *Babyrousa babyrussa* beruensis Hooijer (1948d). This was the very first example I found for the island of Celebes of a living form averaging larger in former times than it does now.
Thus it is pretty evident that is southwestern Celebes the babirusa has undergone a gradual diminution in size in the course of the Quaternary, thereby passing through the stage of size today represented by the Central and Northern Celebes babirusa, and this line came to an end while it was about of the size of the living insular races East of Celebes. The babirusa became extinct in southwestern Celebes at the time of the formation of the Toalian caves, but if the species would have been in existence today in southwestern Celebes it would certainly have been regarded by neozoologists as a separate subspecies peculiar to this region. *Babyrousa babyrussa* bolabateunsis nov. subsp. is the terminal form of one of the longest continuous clines of which we have now evidence in the island of Celebes, and the future finds of subfossil and Pleistocene babirusa teeth in other regions of Celebes, in the Soela Islands, and in Boeroe will show us how long the various lines leading to the extinct Toalian cave form and to the three subspecies we distinguish today have already been separate. The babirusa was smaller in theToalian caves than it is nowadays in Northern Sulawesi, but about the size of the babirusa races now found on the islands of Buru and Taliabu, but in the Pleistocene of southwestern Sulawesi it was definitely larger. All the material from caves north of Tjani are Sus and not babirusa as described by Dammerman 1939. P69).

Hooijer, D.A. (1958) The pleistocene vertebrate fauna of Celebes. Archives Neerlandaises de Zoologie, 13, supplement, 89-96.

Houston, E. (1992) Babirusa born at the St. Louis Zoo. AAZPA Communique, March 1992, 11
(Abstract: A pair of babirusa on loan from the Los Angeles Zoo produced two female piglets at the St. Louis Zoological Park on 16 December 1991. This represents the first ever birth of this species at the zoo. The piglets were up and walking within 15 minutes of the birth. Nursing was observed within 20 minutes. A neonatal exam was performed on one piglet at 48 hours postpartum; the other piglet was examined at 72 hours. Their weights were 901 grams and 811 grams, respectively. The sow readily accepted both piglets back after their exams and has proven to be an excellent mother. To date, both the piglets and their mother have been kept separate from the boar.)

Houston, E.W., P.K. Hagberg, M.T. Fischer, M.E. Miller, and C.S. Asa (in press). Monitoring Pregnancy in Babirusa (*Babyrousa babyrussa)* with Trans-abdominal Ultrasonography.

International Union for the Conservation of Nature (1972) Red data book, Mammalia. (Eds. H.A. Goodwin & C.W. Holloway). IUCN: Morges, Switzerland, 2nd edition.

International Union for the Conservation of Nature (1990) IUCN Red list of threatened animals. IUCN, Gland, Switzerland, and Cambridge, UK, p 25.

James, S.B., Cook, R.A., Raphael, B.L., Stetter, M.D., Kalk, P., McLaughlin, K. and Calle, 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, 30, 521-525.

Jardine, W. (1836) The naturalists library: Mammalia 5 The natural history of the pachydermes, or thick-skinned quadrupeds. W.H. Lizars: Edinburgh pp 216-217.
(Abstract: The figure is from F. Cuvier from live specimens brought back on the Astrolab. The male was aged and remarkably fat. The cold gradually produced diseased lungs, which killed them three years after they arrived. The male's short life (in Europe) was spent sleeping, eating and drinking. The female was younger, and more active; when the male retired to his litter (to sleep), she would cover him completely over, and afterwards herself slip under the straw, so that both were entirely concealed from sight. The skin was thinly furnished with hair; and that which grew upon them was long and hard.)

Kaspe, L. and Wahyuni, E. (1988) Panaritium. Prociding simposium nasional penyakit satwa liar. Fakultas kedokteran hewan Universitas Airlangga dan Kebun binatang Surabaya: Surabaya
(Abstract: Panaritium was found in babirusa in 1981 (4), 1982 (3), 1983 (1), 1986 (2), 1988 (10) and was treated.)

Kaudern, W. (1944) Ethnographical studies in Celebes. 6, Art in Central Celebes. Elanders Boktryckeri Aktiebolact: Gotenborg.

Keirans, J.E. & Robbins, R.G. (1987) Amblyomma babirussae Schulze (Acari: Ixodidae): redescription of the male, female, and nymph and description of the larva. Proceedings of the Entomological Society of Washington, 89, (4), 646-659.
(Abstract: The male, female and nymph of A. babirussae are redescribed and the larvae is described for the first time. Adults and immatures are illustrated with black and white and colour drawings and with scanning electron photomicrographs of specimens collected primarily on artiodactyl mammals (wild and domestic pigs, domestic buffalo, cattle, Bubalus depressicornis and Cervus timorensis) and from vegetation on the island of Sulawesi, Indonesia.)

Kilveron, J.M. (1936) Natuurmonumenten. Dierenbescherming. Manado. Straatsblad van Nederlandsch-Indie, 521, 1.
(Abstract: Establishment of nature reserve "Berbak")

Kilveron, J.M. (1938) Natuurmonumenten. Groote Oost. Staatsblad van Nederlandsch-Indie, 630, 1-2.
(Abstract: The establishment of a nature reserve called "Panoea" near Gorontalo, North Sulawesi.)
Kilveron, J.M. (1939) Natuurmonumenten. Dierenbescherming. Groote Oost. Staatsbland van Nederlandsch-Indie, 626, 1-2.
(Abstract: The establishment of three islands near Gorontalo as a nature reserve called "Mas-Popaja-Radja")

Kinnaird, M.F. (1996) North Sulawesi: a natural history guide. Wallacea Development Institute: Jakarta, 83pp.

Kinnaird, M.F. and O'Brien, T.G. (1996) Ecotourism in the Tangkoko DuaSudara Nature Reserve: opening Pandora's box? Oryx, 30, 65-73.
(Abstract: Tourist brochures for Tangkoko state that it is possible to see babirusa *Babyrousa babyrussa*, which are extinct within the reserve.)

Kneepkens, A.F.L.M. Badoux, D.M. & Macdonald, A.A. (1990) Descriptive and comparative myology of the forelimb of the babirusa (*Babyrousa babyrussa* L. 1758). Anatomia Histologia Embryologia, 18, 349-365.

Kooders, S.H. (1898) Verslag eener botanische dienstreis door de Minahassa. Mededeelingen van's Lands Plantentuin. G. Kolff: Batavia, pp 103.
(Abstract: Babirusa are very scarce in the Minahassa due to the increased hunting in the region. People are hunting them for food. Even the wild boar are shy.)

Kruyt, A.C. (1930): De To Loinang van den Oostarm van Celebes. Bijdragen tot de Taal-, Landen Volkenkunde (van Nederlandsch-Indie), 86, 327-536.
(Abstract: The babirusa are largely caught by members of the Lingketeng clan when they go hunting for bamboo.)

Krumbiegel, I. (1954) Biologie der Saugethiere. Agis: Krefeld, pp 16, 39, 86, 181, 316, 323, 343, 367.
(Abstract: Babirusa can swim in the sea and reach islands. The babirusa does not make much sound. The babirusa had a gestation length of 158 days. Newborn babirusa are coloured black, those from B. b. alfurus are dark brown-red coloured.)

Kruska, D. (1970) Uber die Evolution des Gehirns in der Ordnung Artiodactyla, Owen 1848, in besondere der Teilordnung suina, Gray 1868. Zeitschrift fur Saugetierkunde, 35, 214-238.

Kruyt, A.C. (1932) Balantaksche Studien. Tijdschrift voor Indische Taal, Land en Volkenkunde, 72, 328-390.
(Abstract: The babirusa (Balantak, east Sulawesi??) must have been here earlier, but it has been exterminated, or withdrawn, because you do not find it in the forest anymore.)

Kuroda, N. (1933) Birds of the island of Java. Published by the author: Tokio, 1, xiii
(Abstract: Babirusa are also regarded as natural monuments.)

Langer, P. (1973) Vergleichend-anatomische Untersuchungen am Magen der Artiodactyla (Owen 1848) 1. Untersuchungen am Magen der Nonruminantia (Suiformes). Gegenbauers morphologisches Jahrbuch, Leipzig, 119, 514-561.

Langer, P. (1974) Stomach evolution in the artiodactyla. Mammalia, 38, 295-314.

Langer, P. (1988) The Mammalian Herbivore Stomach: Comparative Anatomy, Function and Evolution. Gustav Fischer: Stuttgart, New York, pp 1-493.

Lesson, R.P. (1827) Manuel de mammalogie. Roret: Paris, pp 337-338.
(Abstract: He examined many individuals in Surabaya, males, females, and many more young. In captivity, their character is not quiet but ferocious. They prefer to eat maize.)

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.

Leus, K. (1993) La grande expedition des babiroussas dans la "presque-jungle" de St-Martin. Magazine trimestriel St martin la Plaine Espace Zoologique, 30, 4.

Leus, K. (1994) Foraging behavior, food selection and diet digestion of *Babyrousa babyrussa* (Suidae, Mammalia). Unpublished PhD thesis, The University of Edinburgh.

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

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, 237-250.

Leus, K., Bland, K.P., Dhondt, A. A. and Macdonald, A.A. (1996) Ploughing behaviour of *Babyrousa babyrussa* (Suidae, Mammalia) suggests a scent-marking function. Journal of Zoology, London, 238, 209-219.

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, 9-27.

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**, 1081-1092.

Leus, K and Macdonald, A. A. (1996) Gastrointestinal anatomy, diet selection and digestion in mammals: a brief overview. In "Research and captive propagation" (Eds. U. Ganslosser, J. K. Hodges & W. Kaumanns), Filander: Furth, Germany, pp 99-114.

Leus, K.; Macdonald, A.A. (1997) From babirusa (*Babyrousa babyrussa*) to domestic pig: the nutrition of swine. Proceedings of the Nutrition Society. 56, 1001-1012.

Leus, K and Morgan, C.A. (1996) Analysis of diets fed to babirusa (*Babyrousa babyrussa*) in captivity with respect to their nutritional requirements. Ibex Journal of Mountain Ecology, 3, 41-44.

Leus, K. and Vercammen, P. (1996) Behaviour of a male and female babirusa (*Babyrousa babyrussa* Suidae, Mammalia) during the first five days after their move to a semi-natural enclosure. Der Zoologische Garten N.F., 66 133-155.

Lith, P.A. van der (1875) Nederlandisch Oost Indie. J.C. van Schenk: Doesbourgh, pp 30
(Abstract: Babirusa do not dig with their nose; they mostly eat fruit.)

Macdonald, A. A. (1990) Israel's kosher pig. Independent, 21 July, 17.

Macdonald, A. A. (1991) Monographie des Hirschebers (*Babyrousa babyrussa*). Bongo, Berlin, 18, 69-84.

Macdonald, A. A. (1991) Comparative study of functional soft tissue anatomy in pigs and peccaries. Bongo, Berlin, 18, 273-282.
(Abstract: The available information on the anatomy of tissues comprising the digestive tract, liver, scent glands, and male and female reproductive systems of the pigs and peccaries was reviewed together with new anatomical data on the pigmy hog (sus salvanius), bush pig (Potamocherus porcus) and babirusa (*Babyrousa babyrussa*). The similarities between pigs in the anatomy of the stomach and intestinal tract was discussed and the different morphology of the peccary stomach indicated. The histology of the liver and distribution of the scent glands illustrated other differences between the pigs and peccaries, with inter-suid differences in scent gland distribution becoming apparent. The anatomy of the reproductive tracts followed the same basic pattern in all the animals considered; the functional significance of the differences in testicular and uterine structure which were not accounted for by relative body size remain a matter for future study.

Macdonald, A. A. (1993) The Babirusa (*Babyrousa babyrussa*). In "Status survey and conservation action plan: Pigs, Peccaries and Hippos" (Ed. W. L. R. Oliver), IUCN: Gland, Switzerland, pp 161-171.

Macdonald, A. A. (1994) The placenta and cardiac foramen ovale of the babirusa (*Babyrousa babyrussa*). Anatomy and Embryology, 190, 489-494.

Macdonald, A.A. 1997. The babirusa (*Babyrousa babyrussa*). In Monk, K.A., de Fretes, Y. and Reksodiharjo-Lilley, G., The Ecology of Nusa Tenggara and Maluku, The Ecology of Indonesia Series, volume V. Periplus: Singapore. pp 374-378.

Macdonald, A. A. (1999) Background to recent developments in the conservation of babirusa (*Babyrousa babyrussa*). In (F. Reitkerk, S. Smits, K. Brouwer & M. Kurtz, eds.) EEP Yearbook 1997/98 including the Proceedings of the 1998 EAZA Conference, Berlin. EAZA Executive Office: Amsterdam. pp 550-552. (Also in North American Regional Studbook for Babirusa (*Babyrousa babyrussa celebensis*) fifth edition (Ed. J. Holland) 1999, Los Angeles Zoo: Los Angeles. 5pp.)

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. & Gansloßer, U., eds.) Zoo Animal Nutrition, Filander; Fürth, pp. 213-236.

Macdonald, A. A. Bell, J., Munro, S.A., Kaspe, L., Harwono Gepak, V., Sasmita, R. & Bowles, D. (1988) Observations on the behaviour and health of captive babirusa. Prociding Simposium Nasional Penyakit Satwa Liar. Universitas Airlangga dan Kebun Binatang Surabaya: Surabaya, Indonesia, pp 244-253.
(Abstract: The babirusa slept from just after night fall to shortly before sunrise. They lay together in groups either inside the small sheds or outside on the concrete pads. In the morning animals rose and moved to an area near the centre of the pen where they excreted urine and faeces. Commonly male animals appeared to inspect freshly voided material by both smell and taste. Usually a large adult male inspected the vulva of each female when she moved to this part of the pen.
As the sun rose, pairs of adult males were often seen to face each other with their heads elevated, and then began jousting. In many instances they would raise up onto their hind legs and "box" against the chest of their opponent. These competitions were of varied duration, and in all cases the animal whose head was lower than that of its opponent seemed to submit and lose the fight; in most instances the inferior animal emitted a shrieking vocalisation during the encounter. The tusks of the males did not appear to be used as weapons in these confrontations and

infrequently caused damage. The incisor teeth were used by both male and female animals to nip other animals, particularly on the lower limb. There was rarely any fighting between male and female animals. The numbers of helminth eggs, protozoal and coccidial oocysts in 1 g of freshly voided faecal material from male and female babirusa was measured.

Macdonald, A. A., Bowles, D., Bell, J. and Leus, K. (1993) Agonistic behaviour in captive Babirusa (*Babyrousa babyrussa*). Zeitschrift fur Saugetierkunde, 58, 18-30.

Macdonald, A.A. and Frädrich, H. (1991) Les suides: que sont-ils? Pigs and peccaries: what are they? In "Biology of Suidae, Biologie des Suides" (Eds. R. H. Barrett & F. Spitz), IRGM, Imprimerie des Escartons: Briancon, France, pp 7-19.

Macdonald, A. A. and Kneepkens, A. F. L. M. (1995) Descriptive and comparative myology of the hindlimb of the babirusa (*Babyrousa babyrussa*) L. 1758). Anatomia, Histologia, Embryologia, 24, 197-207.

Macdonald, A. A., Kneepkens, A.F.L.M., Bosma, A.A. (1984) Anatomical studies on the female and male reproductive tracts of wild pigs. In "Symposium International sur le Sanglier" (Eds. F. Spitz and D. Pepin), Les Colloques de l'INRA, 22, 93-104.\

Macdonald, A. A., Kneepkens, A.F.L.M., Kolfschoten, T. van Houtekamer, J. L., Sondaar, P.Y. & Badoux, D.M. (1985) Comparative anatomy of the limb musculature of some suina. In "Functional Morphology of Vertebrates" (Eds. H. R. Duncker and G. Fleischer), Fortschritte der Zoologie, 30, 95-97, Gustav Fischer: Stuttgart & New York (Abstract: From the results of these studies on the soft tissues of these four members of the Suina we conclude that the babirusa and the pig are more closely related to one another than to either of the hippopotami.)

Macdonald, A.A. and Leus, K. (1994) A framework of ideas for research in zoos as illustrated by the study of babirusa (*Babyrousa babyrussa*) and other pig species. International Union of Directors of Zoological Gardens: Scientific sessions of the 48th annual conference, 48, 37-49.

Macdonald, A.A. and Leus, K. (1995) Taxonomic hierarchy - *Babyrousa babyrussa* - The babirusa. http://www.vet.ed.ac.uk/tol/chordata/mammalia/artiodac/suidae/babirusa/

Macdonald, A.A. and Leus, K. (1996) Creating a public understanding of the biology of the babirusa (*Babyrousa babyrussa*) within a caring zoo environment. Ibex Journal of Mountain Ecology, 3, 37-40.

Macdonald, A.A., Leus, K., Florence, A., Clare, J. & Patry, M. (1996) Notes on the behaviour of Sulawesi Warty pigs (sus celebensis) in North Sulawesi, Indonesia. Malaysian Nature Journal, (in press).
(Abstract: Babirusa (*Babyrousa babyrussa*) and Sulawesi Warty pigs (Sus celebensis) use the same wallow and face rub on precisely the same flat spot.)

Macdonald, A. A. and Oliver, W. L. R. (1992) Pigs and peccaries specialist group. Species, 19, 56-57.

MacKinnon, J. (1979) A glimmer of hope for Sulawesi. Oryx, 15, 55-59.
(Abstract: Babirusa (*Babyrousa babyrussa*). Endangered. This extraordinary endemic pig has disappeared from large areas of its former range. Having evolved in a more or less predator-free environment, and because of its low recruitment rate (only two young at a time), it is highly vulnerable to all hunting pressures. Good populations still occur in remote forests where human activities are slight or recent, and also in Muslim pockets of this predominantly Christian region.)

MacKinnon, J. (1981) The structure and function of the tusks of babirusa. Mammal Review, 11, 37-40.
(Abstract: An examination of twenty-four male babirusa skulls indicates that the long tusks have an important function in intraspecific fighting. The upper tusks have developed a shielding, protective function whilst the lower tusks are offensive and daggerlike. As the upper tusks do not hone the lower canines as in other suids, the babirusa male actively sharpens his lower tusks on trees. Wear patterns on the tusks suggest that mainland babirusa use the upper tusks to interlock and hold their opponents' lower tusks during combat. In the Buru race this hooking function appears to have been lost and the upper tusks have a butting function instead.)

MacKinnon, J. & Artha, B. (1981-1982) National conservation plan for Indonesia, FO/INS/78/061, FAO: Bogor.

MacKinnon, J. & MacKinnon, K. (1986) Review of the protected areas system in the Indo-Malayan Realm. IUCN: Gland, Switzerland, pp 180-186, 228, 231.

MacKinnon, K. (1985) Indonesie: Natuur en natuurbehoud. M & P Boeken: Weert.

MacLaughlin, K.A. and Thomas, P.R. (1991) The management of babirusa (*Babyrousa babyrussa*) at the New York Zoological Park. AAZPA Regional Proceedings, 650-657.

MacLaughlin, K., Ostro, L.E.T., Koontz, C. & Koontz, F. (2000) The ontogeny of nursing in *Babyrousa babyrussa* and a comparison with domestic pigs. Zoo Biology, 19, 253-262.

Manansang, J., Macdonald, A.A. Siswomartono, D., Miller, P. and Seal, U. (eds) 1996. Population and habitat viability assessment workshop for the babirusa (*Babyrousa babyrussa*): Report. Conservation Breeding Specialist Group (SSC/IUCN), Apple Valley, MN

Martys, M. (1977) Das Flehmen der Schweine, Suidae. Zoologischer Anzeiger. 199, 433-440.
(Abstract: babirusa did not appear to produce a flehmen response to the same test which was positive in Sus scrofa.)

Matur, H.P. (1989) Usaha penangkaran dan pelestarian Babirusa (*Babyrousa babyrussa*) di kebun binatang Surabaya. Unpublished Proceedings of the Indonesian Zoo Association Meeting, Jakarta Zoo, 1-20.

Melisch, R. (1994) Observations of swimming Babirusa *Babyrousa babyrussa* in Lake Poso, Central Sulawesi, Indonesia. Malayan Nature Journal, 47, 431-432.
(Abstract: At about 09.00 hours a single male babirusa as observed crossing Lake Poso from east to west. The babirusa dived and remained submerged for about 30 secs.)

Melisch, R. (1995) Babirusa skulls on sale in south Sulawesi. Traffic Bulletin, 15, 99.
(Abstract: The tourist area in Rantepao, Tana Toraja, Sulawesi was surveyed in October 1993. 22 shops were visited, of which six (27%) sold babirusa skulls and contained 3.5 on average. 20 skulls were of adult males, and one of a sub-adult male. They were said to come from the mountains around Nanggala, Quarles Mountains, Telondokalondo Mountain and the forest between Rantepao and Palopo. The prices asked were 60-90k rupiah. One of the traditional Toradja houses had tusks and a complete (skull?) attached to a beam.)

Mellink, C.H.M., Bosma, A.A., de Haan, N.A. and Macdonald, A.A. (1992) Numerical variation of nucleolar organizer regions after silver staining in domestic and wild suidae (Mammalia). Animal Genetics, 23, 231-239.

Meyer, A.B. (1896) Saugethiere von Celebes - und Philippinen-Archipel. II. Celebes-Sammlungen der Herren Sarasin. Abhandlungen und Berichte des Koniglich zoologischen und antropologisch-ethnographischen Museums zu Dresden, 7, 28-29.

Miller, J.A. (1984) Kosher pig? Hold the bacon. (Babirusa). Science News, 126 (Nov. 24, '84), 327.
(Abstract: The babirusa, an allegedly cud-chewing pig, has recently been touted as a breakthrough pord-producing animal with a potential appear to those who don't eat pork. Several groups, including the U.S. Agency for International Development, have published enthusiastic support for cultivation of this ruminant-like creature. Rabbis at the Jewish Theological Seminary have reserved opinion until they view the animal's innards. Officials at the Los Angeles Zoo, where babirusas are housed, deny the validity of these claims, which rely on a 1940 autopsy report. They also note that babirusas breed slowly and would be poor food producers. American and Indonesian scientists will study a dozen of the animals to determine their suitability.

Miller, M.E., Fischer, M.T. and Houston, E.W. 1994. The use of behavioral conditioning in the management of babirusa (*Babyrousa babyrussa*) at the Saint Louis Zoological Park.. AAZPA REGIONAL PROCEEDINGS 274-278.

Mitchell, P.C. (1905) On the Intestinal Tract of Mammals. Transactions of the Zoological Society of London. 17, 437-536.

Mitchell, P.C. (1916) Further observations on the intestinal tract of mammals. Proceedings of the general meetings for scientific business of the Zoological Society of London, 1916, 183-251.

Moeffaert, N.Van (1994) Gedrag en vokalisatie bij de babirusa (*Babyrousa babyrussa* L.). Unpublished thesis, Universitaire Instelling Antwerpen.

Mohr, E. (1958) Zur Kenntnis des Hirschebers *Babyrousa babyrussa*, Linne 1758. Der Zoologische Garten, 25, 50-69.

Mohr, E. (1960) Wilde Schweine. Ziemsen: Wittenberg Lutherstadt, pp 12-18, 109-119.

Munro, S.A. Kaspe, L. Sasmita, R. & Macdonald, A.A. (1990) Gastrointestinal helminthosis in the babirusa (*Babyrousa babyrussa*) and response to albendazole. Veterinary record, 126, 16.

Muskita, Y. (1994) Babirusa di Cagar Alam Tangkoko Duasudara Sulawesi Tinggal Kenangan. WWF Radio Bulletin Indonesia Programme, 1, (3), 9-10.

Musser, G.G. (1987) The mammals of Sulawesi. In "Biogeographical Evolution of the Malay Archipelago". (Ed. T.C. Whitmore), Clarendon Press: Oxford.

Muttaqin, I., Sinaga, D.W., Mustari, A.H. Clayton, L.M. & Lagurusu, Z.H. (1993) Laporan survey kehidupan babi rusa di kab. Gorontalo Sulawesi Utara. Tim Aphi - Dephut - IPB, Bogor, Indonesia.

National Research Council (1983) Little known Asian animals with a promising economic future. National Academy Press: Washington D.C., pp 89-94.

Nishihara, J. (1991) Walker's mammals of the world. John Hopkins University Press: Baltimore and London, 5th edition.

Nowak, R.M. & Paradiso, J.L. (1983) Walker's mammals of the world. John Hopkins University Press: Baltimore, 4th edition, pp 1181-1182.

O'Brien, T.G. and Kinnaird, M.F. (1996) Changing populations of birds and mammals in north Sulawesi. Oryx, 30, 150-156.

Oliver, W.L.R. and d'Huart, J.P. (1990) Pigs and peccaries specialist group. Species, 15, 59-60.
(Abstract: There is direct evidence of the continued existence of the "hairy" babirusa known only from buru and the Sula islands. A survey conducted in July 1990 yielded photos of skulls of recently caught males. There is a threat to the babirusa from logging and trans-migrants. The babirusa population in Sulawesi is also declining. The babirusa population in captivity (from Sulawesi) is now thought to have come from only four animals.)

Oliver, W.L.R. (1991) Pigs and peccaries specialist group. Species, 16, 55-56.
(Abstract: The status of the hairy babirusa on Taliabu in the Sula islands will be investigated by a group from the University of East Anglia. There is the possibility of small numbers of babirusa in remnant patches of forest in the southwest of Sulawesi.

Oliver, W.L.R. (1993-94) Pigs and peccaries specialist group. Species, 21-22, 80-82.
(Abstract: Lynn Clayton started the first detailed study of wild populations of Sulawesi babirusa in Sulawesi. Alastair Macdonald and Paul Vercammen carried out studies on captive animals, assisted collection of data on wild babirusa on Buru and in the Togian islands and southwest Sulawesi.)

Oliver, W.L.R. (1994) Pigs and peccaries specialist group. Species, 23, 75-76.
(Abstract: In October 1994, 4500 copies of a high-quality conservation-education poster featuring all seven species of pig wild to southeast Asia was produced and distributed free. Paul Vercammen reported the status of babirusa in the Togian islands. They may only survive on four islands, Malenge (numbers low), Talataco (secure as long as forest remains intact), Togian (relatively secure, but coconuts have replaced much former forest), Patudoka (present but threatened by deforestation). Rowland Melish reports that trade in babirusa skulls continues at Tana Toradja, south central Sulawesi in 1933.)

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

Patry, M. & Capiod, J.A. (1989) Pour la premiere fois, le babiroussa. Connaissance de la Chasse, 156 (April 1989), 45-46.
(Abstract: Il observe le comportement d'une jeune femelle ejectant une autre jeune femelle du meme rang, une femelle arrivant avec son petit qui se met a teter devant lui, puis c'est un cerf sambar qui vient se souiller, enfin un autre babiroussa en compagnie d'un babi hutan - ils se tolerent mais ne fraterniscent pas. Ce sont enfin deux grands males aux dents profondement recorbees qui se rencontrent et s'affrontent. Mais, particularite de l'espece, un animal paraissant, malgre l'absence d'ennemis naturels directs, constamment sur le qui-vive: il fait trois pas, redresse la tete, ecoute, repart, refait trois pas, tend la tete. En fait, detail interessant la encore, il ne flechit pas l'avant-train - comme le font les sangliers et les phacocheres par exemple - et surtout ne fouille pas le sol. Il mange des fruits, des larves trouvees dans des troncs pourris, de jeunes pousses de rotin, tres abondants ici.)

Patry, M. Leus, K. & Macdonald, A.A. (1995) Group structure and behaviour of babirusa (*Babyrousa babyrussa*) in northern Sulawesi. Australian Journal of Zoology, 43, 643-655.
(Abstract: The total number of babirusa sightings recorded on videotape was 586. These comprised 161of adult males, 155 of adult females, and 11 of adults of unknown sex; there were 78 of subadult males, 53 of subadult females and a further 34 cases where it was not possible to determine the sex of the subadult animal; juveniles were observed 94 times of which 19 could be identified as males and 12 as females, the sex of the other 63 remaining unclear. The babirusa were present in groups which ranged in size from one to eight animals, with 160 groups observed at the "Marisa" site and 66 groups at the "Lantolo" site (Table 1). The median group size (including solitary animals) was two babirusa for both "Marisa" and "Lantolo". The adult males tended to be solitary whereas the adult females tended to be accompanied by young animals of one or two generations. Large bachelor groups were not seen. Groups rarely contained three or more adult females. The range of agonistic and ploughing behaviours observed were indistinguishable from those exhibited by babirusa in zoological collections.)

Persulessy, Y (1996) Babirusa (*Babyrousa babyrussa*) sebagai salah satu species babi liar Asia Tenggara. Unpublished report, BirdLife International, Ambon, Indonesia.

Persulessy, Y. and Poulsen, M.K. (1996) Notes on the distribution of babirusa *Babyrousa babyrussa* in Buru, Maluku province, Indonesia. In Manansang, J., A. Macdonald, D. Siswomartono, P. Miller and S. Seal (eds.). 1996. Population and Habitat Viability Assessment for the Babirusa (*Babyrousa babyrussa*). IUCN/SSC Conservation Breeding Specialist Group: Apple Valley, MN.

Peters, C.T.M. (1985) De babiroesa: het hertezwijn. Dieran, 1, (5), 135-139.

Piso, W. (1658) Appendix. De Baby-Roussa. In "Bondt, J. De Indiae utriusque re naturali et medica libri quatuordecim ...annotationes & additiones. Apud Ludovicum et Danielem Elzevirios: Amstelaedami, 2nd edition, pp 61-62.

Plasa, L. (1990) *Babyrousa babyrussa* 1989: Internationales Zuchtbuch fur den Hirscheber/International studbook for the babirusa. Wilhelma Zoologisch-Botanischer Garten: Stuttgart, 2nd edition.

Plasa, L. (1991) Das Hirscheber-Zuchtbuch. Bongo, Berlin, 18, 258-253.
(Abstract: The first issue of the International Studbook for the babirusa was published in 1988 with data from all babirusas kept in captivity since 1820. From 1974 to 1977, 6.6 animals were imported to Europe from Indonesia. The present stock in Europe and North America are descendants of these animals. All of them belong to the subspecies B.b.celebensis. At the end of 1989 there were kept in Europe 25.25 babirusa in 11 zoos. 7.6 animals

lived in the USA in 3 parks and 36.29.3 in Indonesia in 4 institutions so that the total world stock of babirusa in captivity on December 31, 1989 was 68.60.3 animals. Insufficient communication from the Indonesian zoological gardens seems to be the biggest problem for the studbook keeper because more than 50% of the world stock are being kept there and it is very hard to get data from that country. Another difficulty is the lack of space. So it would be very important to find new keepers for this endangered species.)

Plasa, L. (1991) Babirusa (*Babyrousa babyrussa*) EEP Annual Report 1990. EEP Yearbook 1990, EEP executive office: Amsterdam, pp 131-133.
(Abstract: It would be worthwhile if we could import a number of wild-caught animals, as the founder stock of the babirusa in captivity is very small. Perhaps there is a possibility if all keepers of this species could work together in this regard.)

Plasa, L. (1991) *Babyrousa babyrussa* 1990: Internationales Zuchtbuch fur den Hirscheber/International studbook for the babirusa. Wilhelma Zoologisch-Botanischer Garten: Stuttgart, 3rd edition.

Plasa, L. (1992) Babirusa (*Babyrousa babyrussa*) EEP Annual Report 1991. EEP Yearbook 1991/92, EAZA/EEP executive office: Amsterdam, pp 147-149.

Plasa, L. (1992) *Babyrousa babyrussa* 1991: Internationales Zuchtbuch fur den Hirscheber/International studbook for the babirusa. Wilhemla Zoologisch-Botanischer Garten: Stuttgart, 4th edition.

Plasa, L. (1993) Babirusa (*Babyrousa babyrussa*) EEP Annual Report 1992. EEP Yearbook 1992/93. EAZA/EEP executive office: Amsterdam, pp 167-168.

Plasa, L. (1993) *Babyrousa babyrussa* 1992: Internationales Zuchtbuch fur den Hirscheber/International studbook for the babirusa. Wilhelma Zoologisch-Botanischer Garten: Stuttgart, 5th edition.

Plasa, L. (1994) *Babyrousa babyrussa* 1993: Internationales Zuchtbuch fur den Hirscheber/International studbook for the babirusa. Wilhelma Zoologisch-Botanischer Garten: Stuttgart, 6th edition.

Plasa, L. (1995) Babirusa (*Babyrousa babyrussa*) EEP Annual Report 1994. EEP Yearbook 1994/95. EAZA/EEP executive office: Amsterdam, pp 237-238.

Plasa, L. (1996) *Babyrousa babyrussa* 1994/95: Internationales Zuchtbuch fur den Hirscheber/International studbook for the babirusa 1994/95. Wilhelma Zoologisch-Botanischer Garten: Stuttgart, 7th edition.

Pocock, R.I. (1943) The external characters of a forest hog (Hylochoerus) and a babirusa (Babirussa) that died in the society's gardens. Proceedings of the Zoological Society of London, 113, 36-42.
(Abstract: The anatomy of the head, mouth, face, nose, ears, and feet of the young babirusa.)

Poulard, J. (1990) Geheimnisvolle Hirsch-Eber. Das Tier, Jan 1990, 70-75.

Quoy, J.R.C. & Gaimard, J.P. (1830) Voyage de decouvertes de l'Astrolabe. Zoologie. J. Tastu: Paris, 1, 125-132.

Quoy, J.R.C. & Gaimard, J.P. (1833) Voyage de la Corvette l'Astrolabe. Atlas Zoologique. J. Tastu: Paris, 22-23.
(Abstract: adult male babirusa from Sulawesi viewed from the left side. Adult female babirusa from Sulawesi viewed from the right side and a juvenile male babirusa viewed from the left side.)

Ramaer, J. (1936) Natuurmonumenten. Dierenbescherming. Manado. Staatsblad van Nederlandsch-Indie, 122, 1-2.
(Abstract: Establishment of the nature reserve "Tanggala" near Gorontalo, north Sulawesi.)

Raphael, B.L., James, S., Calle, P.P., Kalk, P., McLaughlin, K. and Cook, R.A. (1997) Analgesic Therapy for Management of Chronic Osteoarthritis in Babirusa (*Babyrousa babyrussa*). Proceedings of the American Association of Zoo Veterinarians. Pp. 191-193.

Reinhard, R. and Fradrich, H. (1983) Bemerkungen zur Zucht von Hirscheber (*Babyrousa babyrussa*) im Zoo Berlin. Bongo, Berlin, 7, 65-70.

Reksowardojo, D.H. (1995) Ringkasan disertasi studi kemampuan reproduksi dan produksi babirusa (*Babyrousa babyrussa* celebensis Deninger) melalui upaya budidaya. Unpublished PhD thesis, Bogor, Indonesia.

Rewell, R.E. (1948) Diseases of tropical origin in captive wild animals. Transactions of the Royal Society of Tropical Medicine and Hygiene, 42, 17-25, 26-36.
(Abstract: In the list of animals in which microfilaria were found during the years 1925-1939 was babirusa.)

Rosenberg, H. von (1878) Der Malayische Archipel. G. Weigel: Leipzig, pp 269.
(Abstract: The babirusa is only to be found in the northern half of Sulawesi. At Tulabollo it was possible to see babirusa daily which were not particularly shy.)

Roulin, F.D. (1849) Dictionnaire universel d'histoire naturelle. Renard, Martinet, Langlios et Leclerc, Victor Masson: Paris, 2, 397-408.

Rubenstein, S. (1984) Woman who ate "kosher" pig says it's not tasty or kosher. San Francisco Chronicle, December 14.
(Abstract: Victoria Selmier ate the babirusa in 1978. She spent 2 years in the Indonesian jungle studying the animal. She never saw it chew the cud. She said that there were only 1000 of the animals left. The babirusa is a gentle and peaceful beast that settles its differences with its fellow babirusa in an unusual manner, worthy of preservation.)

Rumphius, G.E. (1743) Het Amboinsch Kruid-boek, Herbarium Amboinense. Meinard Uijtwerf: Amsterdam, 3, 171.
(Abstract: He reports on the wonderful pigs from Buru and the Sulu islands. Notes are given of their feeding habits and the rubbing of resin on their skin.)

Sanyal, R.B. (1892) A handbook of the management of animals in captivity in lower Bengal. Natraj: Dehra Dun.
(Abstract: The length of life of the pair held in captivity in Calcutta was from April 1880-May 1884. The food they ate was fruits, roots, vegetables, and grain. They showed no preference for a meat diet. Both died suddenly, the female undoubtedly from fat. They appeared to suffer from heat during the fierce hot days of May and June, probably more from radiated heat than from the effects of the temperature; at such a time they enjoyed a cold bath; though generally retiring (shy) they were less shy than even a wild Indian pig.)

Sarasin, P. & Sarasin, F. (1905) Reisen in Celebes. C.W. Kriedel: Weisbaden, 2, 6-48, 285
(Abstract: The babirusa can be found beside the Lindu Lake.)

Schinz, H.R. (1824) Naturgeschichte und Abbildungen der Saugetheire. K.J. Brodtmann: Zurich, 1, 284.
(Abstract: babirusa eat the leaves of banana and other trees, as well as fruit and roots.)

Schmidt, C.R. (1990) Pigs. In "Grzimek's encyclopedia of mammals". McGraw-Hill: New York, 5, 20-55.

Schrader, R. (1941) Het Landschap Banggai. Nederlandsch-Indische Geographische Mededeelingen, 1, 125-132.
(Abstract: babirusa are present in the Banggai countryside.)

Schwarze, E. S. (1934) Der Hirscheber von Sula. Zeitschrift fur Saugetierkunde, 9, 433-434.
(Abstract: The discoverer of the Sula babirusa, W. C. J. Frost has imported four babirusa from that island, three males and a female. They are not grey coloured, which is characteristic of the Buru babirusa, but have black hair. The ventral side is whitish, and one has whitish cheeks and anal region.)

Selmier, V. J. (1978) Only in Indonesia; the babirusa. Unpublished report to LIPI and PPA, Indonesia, 51-64.

Selmier, V. J. (1983) BestandsgroBe und Verhalten des Hirschebers (*Babyrousa babyrussa*) auf den Togian-Inseln. Bongo, Berlin, 7, 51-64.

(Abstract: In the Togian islands there is an estimated babirusa population of 500-1000. The main threats are disease, native and feral dogs, trapping as pests by farmers, destruction of the habitat by logging. The prevalence of the Muslim faith protects the babirusa.)

Stevens, C.E. (1988) Comparative physiology of the vertebrate digestive system. Cambridge University Press: Cambridge.

Sody, H. J. V. 91949) Notes on some primates, carnivora, and the Babirusa from the Indo-Malayan and Indo-Australian regions. Treubia, 20, 121-190.

Soebakah, R. (1988) Beberapa penyakit satwa liar didalam kebun binatang Surabaya dan usaha pengendaliannya. Prociding simposium nasional penyakit satwa liar. Fakultas kedokteran hewan Universitas Airlangga dan Kebun binatang Surabaya: Surabaya, pp 135-144.
(Abstract: anaplasmosis had been seen in babirusa, as had Panaritium.)

Stavorinus, J. S. (1798) Voyages to the East Indies. G. G. & J. Robinson: London, 2, 350-351.
(Abstract: Among the wild animals, which inhabit the woods of the island Bouro, there is one which bears the name of babi-roussa, or the hog-deer; it has been fully described by Valentyn, who has given us a representation of it; but it appeared to me, when I compared the figure with one of the animals alive, that its legs were longer than they are there represented.
The translator, S. H. Wilcocke added: The babi-roussa ... are easily hunted down; but they frequently hurt the dogs with their lower tusks; the upper tusks are too far recurvated to admit of their defending themselves with them. Their flesh more resembles venison than pork; there is little fat upon it, it being mostly solid meat. They do not live, like the other wild hogs, upon sago and canari, a sort of almonds, but chiefly upon grass and the leaves of trees. They never associate with the wild hogs, and when hunted, they generally take to the water, where they are very expert in swimming and in diving, and sometimes swim over from one island to the other.)

Teijsmann, J.E. (1861) Verslag van den honorair inspecteur van kultures J. E. Teysmann, over de door Z. ED. In 1860 gedane reize in de Molukken. Natuurkundig Tijdschrift voor Nederlandsch Indie, 23, 290-369.
(Abstract: We did not see any babirusa in the wild though they are present in this area (Minahassa). Those that people had caught for us soon died. They seem to be more difficult to catch alive than the anoa. There are plenty Sus celebensis.)

Teysmann, J. E. (1879) Bekort verslag eener Botanische dienstreis naar het Gouvernement van Celebes en Onderhoorigheden. Natuurkundig Tijdschrift voor Nederlandisch Indie, 38, 54-125.
(Abstract: Babirusa can be found infrequently in the eastern part of Sulawesi and on Buru. Sus celebensis is all over Sulawesi like a plague for the population.)

Thenius, E. (1970) Zur Evolution und Verbreitungsgeschicht der Suidae. (Artiodactyla, Mammalia). Zeitschrift fur Saugetierkunde, 35, 321-342.

Thomsen, P. D., Hoyheim, B & Christensen, K. (1996) Recent fusion events during evolution of pig chromosones 3 and 6 identified by comparison with the babirusa karyotype. Cytogenetics and Cell Genetics, 73, 203-208.

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(Abstract: Animals of the Suidae family were very susceptible; the babiroussas (Babirussa *babyrussa*) were affected and, after inoculation with antiserum and virus, four wild boars contracted the infection. All recovered after treatment with antiserum; pigs had lesions confined mainly to the feet.)

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AUTHORS

(Photo: D. Wilson, St. Louis Zoo)

Introduction and Description

Penny Kalk, Wildlife Conservation Society
Mammal Department
2300 Southern Boulevard
Bronx, New York 10460
Tel: 718-220-5161
Fax: 718-365-0307
Email: pkalk@wcs.org

Housing and Enclosures

Fran Lyon, White Oak Conservation Center
3823 Owens Road
Yulee, FL 32097
Tel: 904-225-3396
Fax: 904-225-3395
Email: franl@wogilman.com

Management, Research and Enrichment

Martha Fischer, St. Louis Zoological Park
Forest Park
St. Louis, MO 63110
Tel: 314-781-0900 ext. 210
Fax: 314-647-7969
Email: fischer@stlzoo.org

Nutrition and Handrearing

Kristin Leus, Royal Zoological Society of Antwerp
Koningin Astridplein 26
2018 Antwerp, Belgium
Tel: +32 3 202 45 80
Fax: +32 3 202 45 47
Email: kirstin.leus@zooantwerpen.be

AUTHORS (CONT.)

Nutrition and Handrearing (cont)

C.A. Morgan, Scottish Agricultural College
Animal Biology Division
Bush Estate
Penicuik EH26 0PH
Scotland, UK
Tel: +44 131 535 3230
Fax: +44 131 535 3121
Email: c.morgan@ed.sac.ac.uk

Ellen Dierenfeld, Wildlife Conservation Society
Nutrition Department
2300 Southern Boulevard
Bronx, NY 10460
Tel: 718-220-7102
Fax: 718-220-7126
Email: edierenfeld@wcs.org

Robert Saville and Dr. Matt Hartley,
Port Lympne Wild Animal Park
Hythe, Kent CT21 4PD
England, UK
Tel. +44 130 3264 647
Fax. +44 130 3264 944

Behavior and Social Organization

Jeff Holland, Los Angeles Zoo
5333 Zoo Drive
Los Angeles, CA 90027
Tel: 213-666-4650
Fax: 213-662-9786
Email: jholland@zoo.ci.la.ca.us

Reproduction

Penny Kalk, Wildlife Conservation Society
Mammal Department
2300 Southern Boulevard
Bronx, New York 10460
Tel: 718-220-5161
Fax: 718-364-0307
Email: pkalk@wcs.org

Jeff Holland, Los Angeles Zoo
5333 Zoo Drive
Los Angeles, CA 90027
Tel: 213-666-4650
Fax: 213-662-9786
Email: jholland@zoo.ci.la.ca.us

Health

Dr. Robert Cook, Wildlife Conservation Society
Wildlife Health Sciences
2300 Southern Boulevard
Bronx, New York 10460
Tel: 718-220-5100
Fax: 718-220-3133
Email: rcook@wcs.org

AUTHORS (CONT.)

Bibliography

Dr A.A.Macdonald, The University of Edinburgh
Preclinical Veterinary Sciences
Summerhall, Edinburgh, EH9 1QH, Scotland
Tel: 44 131 650 6120
Fax: 44 131 650 6576
Email: A.A.Macdonald@ed.ac.uk

Albert F.L.M. Kneepkens
Hendrik van Viandenstraat 66
8266 DS Kampen, The Netherlands
Tel: 31 52 022 5335
Email: A.F.L.M.Kneepkens@hetnet.nl

Penny Kalk, Wildlife Conservation Society
2300 Southern Boulevard
Bronx, New York 10460
Tel: 718-220-5161
Fax: 718-364-0307
Email: pkalk@wcs.org

Kristin Leus, Royal Zoological Society of Antwerp
Koningin Astridplein 26
2018 Antwerp, Belgium
Tel: +32 3 202 45 80
Fax: +32 3 202 45 47
Email: kristin.leus@zooantwerpen.be

BABIRUSA SSP PARTICIPATING INSTITUTIONS

Audubon Zoo
PO Box 4327
New Orleans, LA 70178
504-861-2537

Bronx Zoo
2300 Southern Boulevard
Bronx, NY 10460
718-220-5100

Denver Zoo
2300 Steele Street
Denver, CO 80205
303-376-4800

Disney's Animal Kingdom
PO Box 10000
Lake Buena Vista, FL 32830
407-939-6381

Houston Zoological Gardens
1513 N. MacGregor
Houston, TX 77030
713-284-1300

Louisville Zoo
PO Box 37250
Louisville, KY 40233-7250
502-459-2181

Los Angeles Zoo
5222 Zoo Drive
Los Angeles, CA 90027
323-644-6400

Lowry Park
1101 W. Sligh Avenue
Tampa, FL 33604-4756
813-935-9486

Oklahoma City Zoo
2101 NE 50th
Oklahoma City, OK 73111-7199
405-424-3344

Peace River Refuge
4300 SW County Road 769
Arcadia, FL 34266-5956
863-993-4529

Philadelphia Zoological Garden
3400 West Girard Avenue
Philadelphia, PA 19104-1196
215-243-1100

Roger Williams Park Zoo
1000 Elmwood Avenue
Providence, RI 02907-3659
401-785-3510

San Antonio Zoological Garden
3903 N. St. Mary's Street
San Antonio, TX 78212-3199
210-734-7184

San Diego Wild Animal Park
15500 San Pasqual Valley Road
Escondido, CA 92027-7017
760-746-7081

St. Louis Zoological Park
One Government Drive
St. Louis, MO 63110
314-781-0900

The ZOO
5701 Gulf Breeze Parkway
Gulf Breeze, FL 32561
850-932-2229