JZAR JOURNAL OF ZOO AND AQUARIUM RESEARCH
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Research article

# Food preparation behaviour of babirusa (*Babyrousa celebensis*)

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**Keywords:**
diet, enrichment, food washing, wild pig

**Article history:**
Received: 11 November 2016
Accepted: 15 March 2017
Published online: 30 April 2017

**Abstract**
Food preparation behaviour of sand-contaminated food articles by two zoo-based Sulawesi babirusa (*Babyrousa celebensis*) was observed and recorded as video imaging data at Bali Zoo, Indonesia during an observation period of six days in July 2012. In earlier preliminary studies of four animals, comprising two mother-infant pairs, three animals held pieces of cut sweet potatoes in the mouth, carried them to a neighbouring water trough, dropped or dipped them in the water, and then began eating. This behaviour was repeated at almost every feeding time. To characterise and elucidate this food preparation behaviour further, and within the management constraints of a zoo environment, experiments with various test feeds were designed; the dipping of food articles into water was video-recorded on 37 occasions. This behaviour by the babirusa was related to (1) deliberate sand-contamination of the surface of the food; (2) deliberate provision of large-sized pieces of food, and (3) the supply of large amounts of food at one time. The distance of the water source from the food seemed to play a role in the expression of the 'food washing' behaviour, with short (1.5 m) distances preferred over longer (6 m) distances. The frequency of this type of babirusa food preparation behaviour was higher during the second half of a feeding period.

## Introduction

The babirusa (*Babyrousa* spp.) is a wild pig endemic to the Indonesian island of Sulawesi and a number of smaller neighbouring islands (Macdonald 1993; Macdonald et al. 2008a, 2016; Leus et al. 2016). Studies have indicated that babirusa eat fruit and leaves (Valentijn 1726; Leus 1996), and can stand on their hind limbs to reach these (Leus et al. 1992; Macdonald et al. 1993; Macdonald and Leus 1995). Other research has confirmed this plant-eating behaviour (Leus and Vercammen 1996; Figure 1). Although many of the fruits and plants consumed by babirusa have been listed (Leus et al. 2001), and the unique anatomy of the babirusa's digestive system described (Leus et al. 1999, 2004; Macdonald et al. 2008b), there have been very few direct studies of food manipulation and digestion by babirusa (Leus 1996; Leus et al. 2001; Clauss et al. 2008). Video footage of four babirusa collected in Bali Zoo (Kebun Binatang Bali) on 10 July 2012 revealed a never before recorded food preparation behaviour: the animals carried articles of food in their mouths to water, dropped or dipped them into the water, picked them up again, and then chewed and consumed them (Ito 2013). According to the animal keepers this behaviour had begun after both pregnant sows had been transferred to this sand-covered enclosure. It was subsequently noted that the feet of the juvenile males that climbed onto the feed troughs were covered in the black sand from the enclosure. Based on these preliminary observations, a series of experimental studies was designed to look more closely at factors that might influence this food preparation behaviour in babirusa. Would the adult

**Figure 1.** A female babirusa, Shela, standing on her hind limbs to reach tree leaves.

female babirusa differentiate between clean food items and those contaminated with sand by dipping the latter in water before eating? If large amounts of clean food were supplied, would these babirusa continue to exhibit this food preparation behaviour? Would the size of the food item supplied to the sows have any bearing on their food preparation behaviour?

## Methods

### *Study sites and periods*

Preliminary behavioural observations of babirusa were made from 30 December 2004 until 23 April 2010 at Babirusa Park (Bali, Indonesia). Observational studies were then carried out at Bali Zoo (Kebun Binatang Bali), Singapadu village, Bali, Indonesia for one month from 10 July 2012. Follow up experiments were conducted at the same zoo from 19 August 2016 until 1 September 2016.

### *Animals*

Four zoo-born babirusa, two adult females (named Shela, born 7 January 2003, and Priska, born 10 October 2003) from Surabaya zoo and their male offspring (Toti, born 12 August 2011, and Tito, born 11 October 2011, respectively), both born in Bali Zoo, were observed during the studies at Bali Zoo. All animals were adapted to the circumstances of their enclosures.

### *Enclosures*

In July 2012, each mother–infant pair of babirusa was accommodated in adjacent 48 $m^2$ enclosures separated by a 1.2 m high horizontal wooden fence. The surfaces of both enclosures were covered with a thick layer of sand. In the daytime, approximately 50–80% of the ground surface of enclosures lay in the shade of a mango tree (*Mangifera indica*), a coconut palm tree (*Cocos nucifera*) and an ylang-ylang tree (*Cananga odorata*). In each enclosure there was a simple shelter, a mud wallow and a concrete feed trough. The latter had a height of about 20 cm and a diameter of approximately 35 cm. Adjacent to it was a water trough with a height of approximately 35 cm and diameter of approximately 45 cm. Bedding or nest material was not provided, but fodder tree branches, offered as feed materials by keepers, were often used by the babirusa to make sleeping nests.

In August 2016, the environmental conditions of the enclosures were altered. The young males were removed, the wooden partitions were taken away and the adult females were housed together. Thus the ground area per individual female doubled. The sand layer was removed, and the underlying hard soil and gravel was exposed.

### *Diets and feeding schedules*

Until the end of July 2012, a relatively large, ad libitum amount of such food items as sweet potato (*Ipomoea batatas*) (6 kg), peeled banana (*Musa acuminata*) (2.3 kg) and commercial swine pellets (750 g) had been provided to the animals daily, with 2.1 kg residue removed daily. Irregularly, approximately 1 kg of rain tree (saman, *Albizia saman*) leaves or water spinach (*Ipomoea aquatica*) was also given at mid-day. From August 2012, an improved diet formulation was offered which included these three core items as well as other constituents such as papaya (*Carica papaya*), green vegetables and tree leave fodder. In addition, based on the result of palatability trials, water spinach, yard long bean (*Vigna unguiculata sesquipedalis*), water hyacinth (*Eichhornia crassipes*) and corn on the cob (*Zea mays*) were added to the diet. Throughout the 2012 study period, keepers fed the animals three times a day, at approximately 0930, 1300 and 1600.

During the 2016 experimental study period the two babirusa sows were fed twice a day, morning and late afternoon, with extra fodder at mid-day. Experiments were conducted with the two adult females at the first feeding time. Water troughs were filled with fresh water before the experiments. 1.4 kg of sweet potato (cut into approximately 65 g per piece), 1 kg water spinach (with a length of approximately 10 cm) and 400 g of rice bran or commercial swine pellets were prepared in the morning. Babirusa keepers provided all feed items to the animals. The total daily amount of feed provided was 4 kg sweet potato, 1 kg water spinach, 1 kg of yard-long bean, 1 kg of other green foods and 1.8 kg of rice bran or commercial swine pellets.

The babirusa sows' responses to the food were carefully observed from outside the enclosure through the fence. The animals were observed every morning from 0900 until 1100, when the zoo had very few visitors. The range of behaviours that were recorded is shown in Appendix 1. Video recordings were made in 2012 and again in 2016 to determine the duration of individual feeding behaviour and the frequency of food preparation behaviour by dipping food items in water. These recordings were made about 1 m from the feed and water troughs on cameras that had a range of 8 m. We defined 'feeding time' to be the period from onset of food provision by the keepers until the termination of eating. In July 2012 the total length of recorded video on the feeding behaviour for six observation days was 1 hr 21 min 22 sec. In August 2016 we recorded all behaviour from the start of feeding (approximately 0930) until its end and for an additional 15 minutes after the animals lay down or had moved away from the feeding trough; the total length of video recorded over 14 days was 4 hr 27 min.

In comparison with the ground condition in 2012, the sand layer of the enclosure in 2016 was very thin due to erosion of the sand by tropical rainfall.

### *Experiments*

*Experiment 1*

To test whether the behaviour exhibited by adult female babirusa was to remove ground 'substrate' off food, we prepared sand-coated sweet potato as follows. We rinsed river sand many times with fresh water and shook it together with four pieces of cut sweet potatoes, in a plastic bag such that the sand evenly covered the surfaces of the sweet potato. Three kinds of clean food items were placed in the feed trough, and the test food items comprising sandy pieces of sweet potatoes were placed at three paired sites on the ground, 10 cm (once), 1.5 m (eight times) and 6 m (twice) away from the water trough. Each site was 1.5 m away from its pair and comprised two clean and two sand-covered pieces of sweet potato placed approximately 10 cm apart from one another.

*Experiment 2*

To test whether adult female babirusa exhibit the food preparation behaviour when a large amount of clean, cut sweet potato was provided, we observed the behaviour of one female babirusa (Priska) for three days when she had access to almost twice the amount of clean food items, because the other female, Shela, was in oestrus and showing a much reduced appetite.

*Experiment 3*

To test whether the adult female babirusa exhibited the food preparation behaviour selectively for large food items, on eight occasions we placed clean, cut sweet potatoes of two sizes, 65 g and 200 g, in the feed trough.

### *Data analysis, interpretation and presentation*

Based on both direct observation and the time-recorded video data, we were able to determine the duration of every feeding behaviour to the nearest second, and to record the frequency of the exhibited water-dipping food preparation behaviour. Because of the variation in the amount of time taken from the start to the

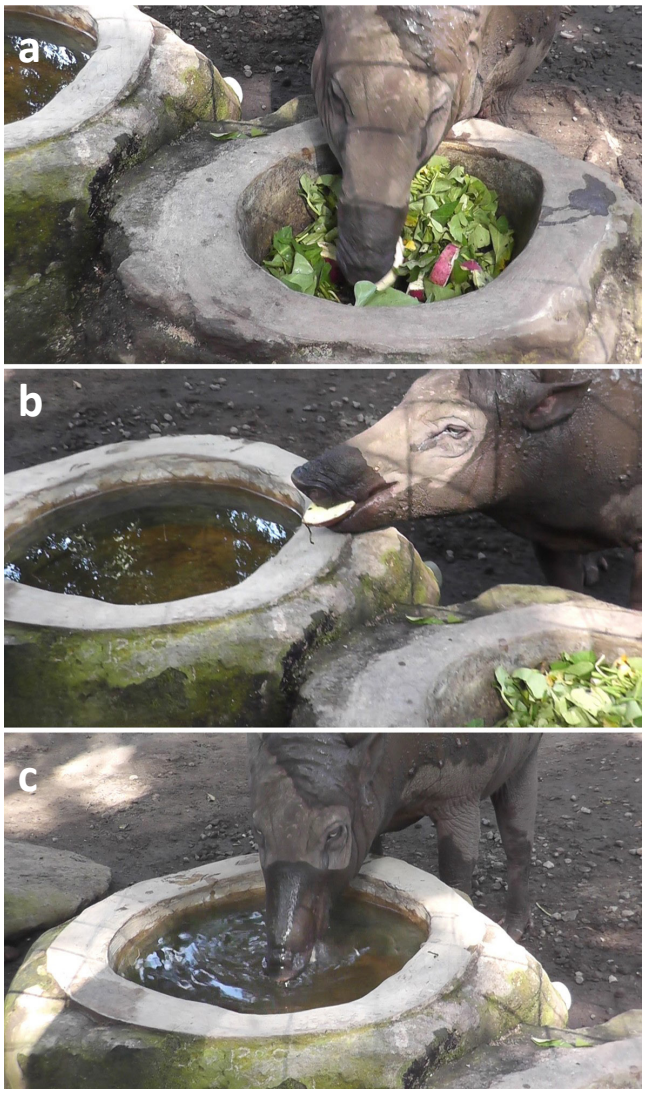


**Figure 2.** a) A female babirusa, Priska, holding a 65 g piece of sweet potato (*Ipomoea batatas*) in her mouth. b) She carries the sweet potato to the water trough. c) She dips the sweet potato deep into the trough. Note the watermark on her nose.

end of any period of feeding, and the variation in the frequency of the water-dipping food preparation behaviour, these durations were normalised on a relative scale of 0 to 100 (from start to finish).

## Results

### *Preliminary observations*

In videos taken in July 2012, three of the babirusa (the two adult females and one sub-adult male) were seen to dip an item of their food into water before eating it. In each case the animal put a piece of sweet potato in its mouth, carried it to the water trough, dipped it into the water, chewed it and then swallowed it (Figure 2). This was observed on 32 recorded occasions amounting to 81 min 22 sec over a period of six days. On one occasion (video, 11 July 2012), Shela held a piece of feed in her mouth when she walked round the rear of Toti, who was blocking her way to the water (Figure 3). On another occasion, after dipping a piece of sweet potato in the water trough, Tito began to eat it, but dropped it on the ground behind the water trough. He walked round the trough to pick up the piece (now partially covered in sand), carried it to the water again, dipped it and then ate it (video, 13 July 2012). In all cases, the babirusa carried out food preparation behaviour even if there was an obstacle in its way.

During the August study period when 37 occasions of food preparation behaviour, by dipping the food item into water, were recorded, Priska performed these on 31 occasions (84%), and Shela performed them on six occasions (16%).


**Figure 3.** a) A female babirusa, Shela, picked up a piece of cut sweet potato (*Ipomoea batatas*), made sandy by the feet of her juvenile male, Toti. b) Shela walked round behind Toti with the sweet potato in her mouth. c) Shela reached the water trough to dip the sandy sweet potato in water. d) Shela dipping the sandy piece of potato in the water.


**Figure 4.** a) A female babirusa, Priska, noticed a piece of "sandy slice of sweet potato" (*Ipomoea batatas*) placed on the ground 1.5 m away from the water trough. b) Priska placed the sweet potato in her mouth. c) The moment when the dropped food made contact with the water surface. d) Priska lifted up the sweet potato up out of the water.

***August 2016: Experiment 1***

The babirusa ate the clean food in the trough first, and then the clean food on the ground. They did not dip into water clean food items placed into the feed trough before eating them. However, the animals did carry sand-covered food items placed on the ground to the water trough, dipped them in the water and then started eating them (Figure 4). A total of 14.7 kg of sweet potato, equivalent to 225 pieces, were used as test foods in experiment 1. Out of 45 pieces of sandy cut sweet potato set on the ground 1.5 m away from the water, 16 pieces (35.6%) were carried to the water trough to be dipped into the water, 24 pieces (53.3%) were left on the ground and four pieces (8.9%) were held in the mouth but spat out and not eaten. The remaining piece (2.2%) of sandy sweet potato was directly eaten without being dipped in the water by Shela (video, 22 August 2016). None of the sand-covered food items placed 6 m from the water were carried to the water and dipped in; only one of six pieces was picked up, but dropped after 2 m. In the following four trials of sand-covered food items, the babirusa never ate the sandy foods before putting them in water. When two pairs of two clean foods and two sandy foods were put on the ground, three pieces of clean sweet potato were directly consumed and one piece ignored; three of the pieces of sand-covered sweet potato were carried to water and dipped in prior to them being eaten. The remaining sandy piece was ignored. The experiment was repeated on 28 August, and again four pieces of the sand-covered food items at 6 m were ignored (after being examined with the tip of the snout several times), whereas three of the four clean food items there were eaten.

***August 2016: Experiment 2***

On 29 August, two types of sand-covered and clean cut sweet potatoes were set up on the ground 1.5 m away from the water. Clean food for two animals was put into the feed trough. Shela was in oestrus and did consume some food, but soon returned to the shelter to lie down. Within a minute of the start of feeding behaviour, the other female examined the cut sweet potatoes on the ground with her snout, but left them for the feed trough to start consuming the clean food items. She ate 20 pieces of clean, cut sweet potatoes, five of which were carried to the water trough after a latency of 3 min 45 sec, 7 min 41 sec, 10 min 11 sec, 12 min 27 sec, and 18 min 10 sec of her starting to feed. At the end of the 19-minute feeding behaviour, much more food, including sweet potato, was left over than was usually seen in the food trough. On 30 August 2016, Priska consumed 16 pieces of clean sweet potatoes placed in the feed trough, and she carried two of these pieces to the water trough and dipped there after elapsed times of 6 min 35 sec, and 9 min 10 sec from the start. A large amount of leftover food remained in the trough. On the third day Priska ate 12 pieces of clean sweet potatoes, and four of these pieces were treated by water-dipping food preparation behaviour after elapsed times of 2 min 28 sec, 9 min 50 sec, 11 min 37 sec, and 14 min 13 sec respectively. More clean food was eaten than originally sandy items of food. Again, a large amount of food was uneaten.

***August 2016: Experiment 3***

In the experiment on 31 August 2016, both pieces of clean, large-sized sweet potatoes generated water-dipping food preparation behaviour. After 1 min 50 sec from the start of feeding behaviour, Priska tried to bite into one large-sized sweet potato placed in the food trough, but could not hold it in her mouth. After 2 min 17 sec, she managed to bite a part of it off to eat. She then carried the remaining part to the water trough, dropped it into the water, and picked it up again to eat. After an interval of 12 min 50 sec, she crunched another large lump into two pieces. One part was eaten at the food trough, and the other was carried to the water trough, dipped in the water, and consumed (Figure 5). The experiment on the second day yielded a similar result. After an elapsed time of 12 sec from the start, Priska dropped a large lump of sweet potato into the water, and then ate it. Another large piece of food was carried to the water by Shela and dropped into the water; however, it was left under water. After 4 min 35 sec from the start, Priska detected it, but gave up holding it in her mouth, and returned to the feed trough. She approached it again 8 min 20 sec from the start, and finally ate it, spending 1 min 30 sec in the process. The animals did not display any food preparation behaviour with


**Figure 5.** a) A female babirusa, Priska, bit into the narrow part of a clean, large-sized (200 g) piece of sweet potato (*Ipomoea batatas*). b) She carried the large sweet potato to the water trough. c) She dropped the sweet potato and it sank into the water. d) Priska retrieved the sweet potato. e) Priska chewed the water-dipped, sweet potato. Note the watermark on her snout.

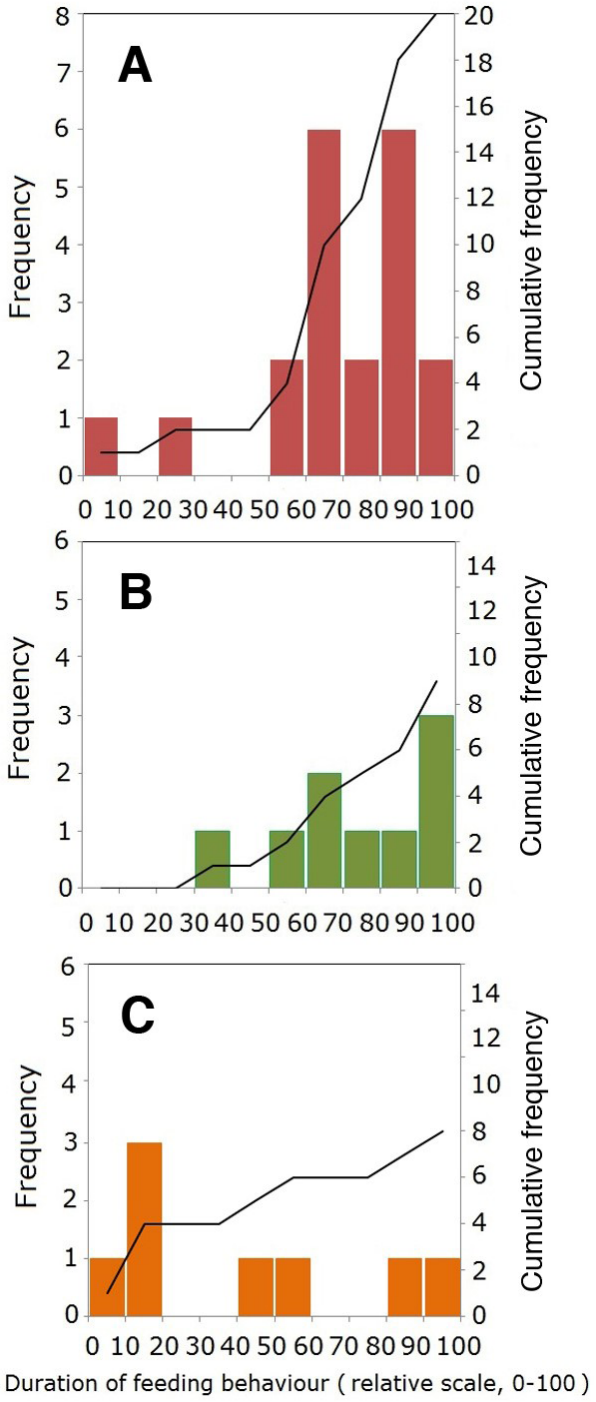


**Figure 6.** Histograms of the frequency distributions of the accumulated food preparation behaviour (dipping food article in water) of two adult female babirusa with respect to the normalised times from when feeding behaviour commenced (A) during experiment 1 (B) during experiment 2 and (C) during experiment 3.

smaller (regular-sized) clean-cut sweet potatoes. However, in the middle of a period of feeding behaviour, we did observe Priska pick up a piece of cut sweet potato that had fallen onto the ground from the feed trough, carried it to the water trough, dipped it in water, and then ate it. During the 13-minute feeding behaviour, all the sweet potatoes were consumed, and only the water spinach remained in the food trough.

The frequency and time distribution at which all water-dipping food preparation behaviour commenced are shown in Figure 6.

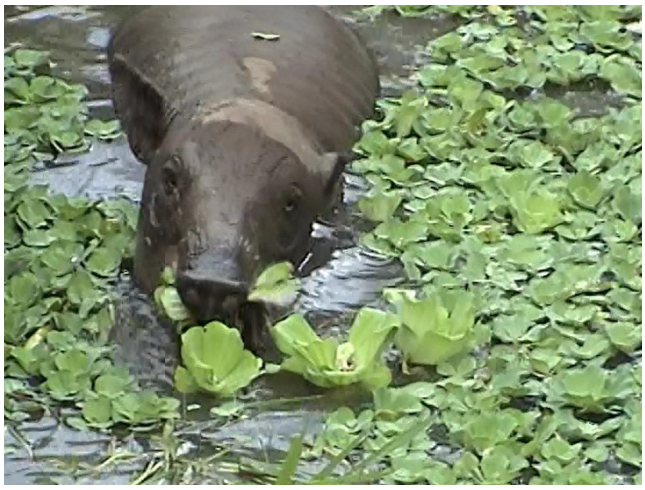

**Figure 7.** A female babirusa, Shela, immersed in water and eating fresh water lettuce (*Pistia stratiotes*).

## Discussion

These newly observed patterns of food preparation behaviour by babirusa greatly expand upon a comment made in 1990 by a hunter in the village of Wai Mange on the north west coast of Buru, Maluku, Indonesia; he used to hunt near Rana lake, and he said 'babirusa only eat clean food which hasn't touched the soil'. He went on to say 'It only eats food which is stuck on a tree branch, or [hangs as] fruit' (Tjiu and Macdonald 2016). Babirusa stand on their hind limbs (Figure 1) to gather leaves and fruit from trees (Macdonald et al. 1993; Macdonald and Leus 1995). Indeed, a long time ago the babirusa had been observed standing against trees (Valentijn 1726), but this behaviour had been ascribed to 'scent gathering' rather than to leaf and fruit collection. Our observations are also somewhat comparable to the recently reported 'food washing behaviour' by European wild pig (*Sus scrofa*) in Basel Zoo (Sommer et al. 2016). They gave a detailed analysis of the relevant literature and drew attention to the food cleaning behaviour of several different primate species: tufted capuchin monkeys (*Cebus apella*), crabeating macaques (*Macaca fascicularis*), chimpanzees (*Pan troglodytes*), bonobos (*Pan paniscus*), and orangutans (*Pongo abelii*) (Visalberghi and Fragaszy 1990; Allritz et al. 2013).

Our first experimental protocol demonstrated that the babirusa differentiated between food that was clean and food that was contaminated with sand; the animal was motivated to prepare its food by dipping it in water before it was eaten (Figures 2 & 4). The sweet potato was fresh and so had no need to be moistened or soaked (Sommer et al. 2016). In the second and third experiments, where clean food items were available, the water-dipping food preparation behaviour was restricted to a small numbers of larger items of food (Figure 6). The underlying motivation for this aspect of the behaviour was not immediately clear. However, Sommer et al. (2016) noted that *Sus scrofa* would sometimes re-wash pieces of apples they had already cleaned, before consuming them. It has been known for some time that babirusa can differentiate between the mineral composition of different substrates, selecting perhaps by taste not to ingest washed sand, as in these experiments; in North Sulawesi they elect to travel to volcanic 'salt-licks' where considerable amounts of particulate mineral matter are swallowed (Patry et al. 1995).

The results of this study contribute significantly to the growing body of information underpinning an increased potential for enrichment of babirusa in zoological collections. The use of water to create wallows and areas for babirusa to bathe in has been recognised for some time (Houston 2016), and where sufficiently large stretches of water are available, they enable swimming (Jaga et al. 2005; Audobon 2016), as well as clean-food gathering (Figure 7); these are behaviours in the wild to which attention has previously been drawn (Melisch 1994; Macdonald et al. 1996; Macdonald 2017). Jaga et al. (2005) also reported that the babirusa 'often eats Water Convolvulus (water spinach), Water Hyacinth, Water Lettuce [growing] in the pool. Interestingly, they completely soak their heads in water of the pool, and search out Apple Snails (*Pomacea canaliculata*) on the wall of the pool, and then carry the snails to the outside of the pool to eat.'

The placement of food for babirusa in zoological collections as it is usually found in the wild has generally not been addressed. We suggest based on these studies that steps could be taken, by providing water nearby, to enable babirusa to prepare food by dipping it in water, if they elect to do so. The results of experiment 1 suggested that the distance between the feeding site and water supply could be one factor controlling the expression of this food preparation behaviour. Under these zoo conditions the short walk of 1.5 m was tolerable, but the slightly longer 6 m walk seemed to exceed some limit for the babirusa. The results of experiment 2 indicated that over-provision of apparently clean food need not prevent this food-preparation behaviour from being expressed. Indeed, the data summarised in Figure 6 revealed that the dipping of food items into water seemed to be undertaken largely during the second half of a feeding period. It is not clear from the studies carried out so far in what way the physiological satiety of an animal with such a complex stomach (Leus et al. 1999, 2004; Macdonald et al. 2008b) might be linked to water-dipping food preparation behaviour. Various additional questions about how the babirusa might behave were also raised: what if food availability was more random in amount and distribution, and was less routinely provided? These may be better answered in other zoos with perhaps more appropriate feeding and water-supply facilities. It was clear from the current series of experiments that variation in food portion size and amount could elicit behaviours that have escaped notice up until now.

It has been known for some time that there is a link between enclosure substrate and the expression of various behaviours (e.g. Leus et al. 1992). Adult male babirusa exhibit territorial marking behaviour if areas of sand to a depth of about 30 cm are provided, through which they can plough (Leus et al. 1996). The babirusa in the current studies had lived in pens with concrete floors for about 14 months, but had not shown this water-based food-preparation behaviour until they moved to the sand-covered enclosure.

The repertoire of agonistic behaviour is denied in collections that hold a solitary male (Macdonald et al. 1993). Appropriately placed fencing or sapling poles would enable marking behaviour to be expressed. Additional purpose to behaviours such as these would be gained from the presence of an additional adult male in a nearby pen. Questions associated with such 'environmental enrichment', particularly with respect to the potential for enhanced breeding success, remain largely unexplored.

## Conclusion

Babirusa (*Babyrousa celebensis*) have within their behavioural repertoire the ability to prepare food for eating by bringing pieces of food to water and dipping them therein. This behaviour is expressed more frequently during the second half of a period of feeding, and appears to be undertaken if the water source is relatively close to the supply of food articles. Larger-sized pieces of food appear to stimulate water-dipping food preparation

behaviour even if not noticeably contaminated with dirt. In a zoological setting the design of a water source should keep in mind the multiple uses to which the babirusa might employ it: drinking, food gathering, water-dipping food preparation behaviour, swimming, and wallowing.

## Acknowledgements

The authors are grateful to the editors of JZAR and the three reviewers of the manuscript for their constructive comments and warm encouragement. We thank the Director and the keepers at Babirusa Park for their careful observations and valuable recordings of the animals for five years, and also the Director of Bali Zoo for permitting us to collect data for one year. Special thanks go to the Managers, Mr Dedi Ramlan and Mr I Made Londra Swantara, and all the zoo kitchen staff at Bali Zoo for their full support of our project. We are also grateful to the babirusa keepers, Mr I Wayan Sukradana and Mr I Wayan Armianta at Bali Zoo, not only for assistance during the period of this experimental study but also for their devoted care of the babirusa. Without their co-operation, this experimental study would not have been completed. This study was conducted under research permits: No.115/SIP/FRP/SM/V/2012 issued by the Indonesian Ministry of Research and Technology (RISTEK) for 1 year from May 2012 to May 2013; No. 070/914/Kespollin/2012 issued by local government of Gianyar-Bali, Indonesia for 6 months from June 2012 to December 2012; and No. 070/914/Kespollin/2012 issued by the local government of Gianyar-Bali, Indonesia for 6 months from December 2012 to May 2013. Our observations and experimental study from December 2004 to August 2016 received long-term financial supports from Babirusa Foundation Tokyo. Additional support was provided by the Balloch Trust, Scotland.

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