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Technical Review

History and Dietary Husbandry of Pangolins in Captivity

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The objective of this study was to establish a history of feeding and dietary husbandry of pangolin in captivity. Over the past 150 years, several zoos have attempted to maintain pangolins (*Manis* spp). Most of these zoos have not succeeded in maintaining these animals for long periods, associated largely with dietary problems. This study reviews the historic records of captive pangolins. The dietary husbandry of pangolins in Taipei Zoo is discussed in detail. Zoo Biol 26:223–230, 2007. © 2007 Wiley-Liss, Inc.

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INTRODUCTION

Pangolin comes from the Malayan word 'Pengolin,' which means that the animal can roll up into a bullet. Although quite common in zoos before the 1970s, pangolins are now almost unknown to visitors and are exhibited infrequently in zoos. These animals have historically been difficult to maintain, with most captive animals dying within a short period after capture.

There are seven species of pangolins; all are of the Class *Mammalia*, Order *Pholidota*, Family *Manidae*, and Genus *Manis*. Three Asian species exist (Chinese

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pangolin, *M. pentadactyla*; Indian pangolin, *M. crassicaudata*; and Malayan pangolin, *M. javanica*) [Allen, 1938], and four are of African origin (Cape pangolin, *M. temmincki*; giant pangolin, *M. gigantean*; long-tailed tree pangolin, *M. tetradactyla*; and white-bellied tree pangolin, *M. tricuspis*). None of the pangolin species are listed currently as endangered or threatened conservation status [World Conservation Union, 2007].

Due to hunting and the destruction of its natural habitat, wild populations in Taiwan have decreased greatly. Even so, Taipei Zoo still regularly takes in wounded pangolins or pangolins that have been picked up by the public. Over the last 17 years, Taipei Zoo has dealt with >100 pangolins. Our expertise in feeding and keeping pangolins has improved gradually, leading to a successful record of captive rearing. This study reviews the holding and breeding records of captive pangolins over the past 150 years, and summarizes dietary husbandry.

HISTORIC RECORDS OF CAPTIVE PANGOLINS

The first notes on keeping pangolins dated from 1859. Buddhist monks of Burma kept around 60 mammals in the animal park at the Monastery of Theybôo; one of them was a pangolin. The first scaly anteater was seen at the London Zoo in 1877 when a male white-bellied tree pangolin was purchased, and lived only 3 days. From Transvaal, a Cape pangolin arrived in London in 1896, and the first Chinese pangolin was presented to the London Zoo, by Sir Reginald Stubbs on 1925. Animals died within a short period in captivity [Cansdale, 1947; Crandall, 1964; Dickman, 1989].

Before 1970, pangolins were recorded in many different zoos (Table 1), but few facilities have maintained pangolins in more recent decades. No long-tailed tree pangolins, for example, are found in records after 1967 (Table 1). Perhaps this is because most captive pangolins have died within 6 months. Although some were held for 2–3 years, longevities from 12–19 years were rare exceptions [Wilson, 1994].

Other pangolins of unknown species were also reported in the zoos of Barcelona, Pretoria, Mysore, Copenhagen, Hannover, Berlin, Basel, London, Miami, Phoenix, the Southampton Zoo of the Chipperfields, and the Munda Wanga Trust in Zambia. The Milwaukee County Zoo built a small mammal house with a section for nocturnal mammals in 1960; the nocturnal section included Cape pangolins, with animals exhibited under red fluorescent light.

Pangolins in African/Asian Zoos

African pangolin species, particularly *M. temmincki*, have been exhibited sporadically in local zoo collections for almost 90 years (Table 1). Four of five captive births of African pangolin species have been recorded in African facilities with Bloemfontein Zoo in South Africa having the most success [Van Ee, 1966].

As with the Asian species, most juveniles were born in zoos in their homeland, such as Calcutta Zoo and Nandankanan Biological Park in India. The most successful breeding programs for the Chinese pangolin were found in Japan [Masui, 1967] and particularly Taiwan [Chao et al., 1993; Yang et al., 1999]. The first captive birth of the Formosan (Chinese) pangolin at Taipei Zoo occurred in 1997, where the animal still lives. May and June are months of elevated mating behavior at Taipei

TABLE 1. Zoo holding records for pangolins (*Manis* spp.) in captivity 1877–2001[a]

Species	**Giant pangolin (*Manis gigantean)***
Holding years	
(1949–1970)	New York Zoological Society, Royal Zoological Society of Antwerp, Fort Worth Zoo, Duisburg Zoo, Baroda Zoo (India), Barcelona Zoo, Abidjan Zoo, Munich Hellabrunn Zoo, Zoological Society of London, Miami Crandon Park, Milwaukee Zoo
(1978–2001)	Jardin des Plantes, Antwerp Zoo, Fort Worth Zoo
Species	**White-bellied tree pangolin *(Manis tricuspid)***
Holding years	
(1877–1968)	London Zoo, Hamburg Zoo, Berlin Zoo, Zoo Frankfurt, New York Zoological Society, Kinshasa, Antwerp Zoo, St. Louis Zoo, Barcelona Zoo, Cologne Zoo, Miami Crandon Park, Nigeria Zoo, San Diego Zoo
(1990–2001)	Rotterdam Zoo, Burger's Zoo, Miami Metro Zoo, Audubon Zoo, Metro Toronto Zoo
Species	**Cape pangolin *(Manis temmincki)***
Holding years	
(1896–1965)	London Zoo, Pretoria, Johannesburg Zoo, Bloemfontein Zoo, Basel Zoo, Duisburg Zoo, Washington National Zoo, Milwaukee County Zoo, San Diego Zoo, Milwaukee Zoo, Republic of Sudan
(1983)	Pretoria Zoo, Basle Zoo
Species	**Long-tailed tree pangolin *(Manis tetradactyla)***
Holding years	
(1928–1967)	Hamburg Zoo, New York Zoological Society, Antwerp Zoo, Basel Zoo
Species	**Chinese pangolin *(Manis pentdactyla*)**
Holding years	
(1877–1970)	Calcutta Zoo, Schönbrunn, Vienna ,Münster Allwetter Zoo Germany, Kwang Chow Zoo, China, London Zoo, Rangoon Zoo, Prague Zoo, Brookfield Zoo, National Zoo, Philadelphia Zoo, Ueno Zoo, Rochester Zoo, Houston Zoo, Tulsa Zoo, Antwerp Zoo
(1971–2001)	St. Louis Zoo, Tulsa Zoo, Prague Zoo, Audubon Zoo, Taipei Zoo, Riga Zoo, ([1.1] 1994; [2.3] 1995), Wuppertal Zoo, Cleveland Zoo, Ueno Zoo
Species	**Malayan pangolin *(Manis javanica*)**
Holding years	
(1929–1970)	Rotterdam Zoo, Tacoma, Washington, London Zoo, Artis Zoo, Amsterdam, San Diego Zoo, Miami's Crandon Park Zoo, Houston Zoo, Audubon Zoo, Antwerp Zoo, Jogjakarta in Indonesia, Ragoor in Burma, San Antonio Zoo
(1971–2001)	Prague Zoo, San Antonio Zoo, Oklahoma City Zoo, San Diego Zoo, Brownsville Zoo, Singapore Zoo
Species	**Indian pangolin *(Manis crassicaudata*)**
Holding years	
(1941–1970)	Jaipur Zoo, Simba Zoo and Madras Zoo in India, Ahmedabad Zoo, Calcutta Zoo, Colombo Dehiwala Zoo, Sri Lanka, Detroit Zoo, New York Zoological Society, Pittsburgh Zoo, Chicago Brookfield Zoo, Prague Zoo, Wilhelma Zoo, Stuttgart, Miami Crandon Park, Oklahoma Zoo, Antwerp Zoo, Mesker Park Zoo, St. Louis Zoo, Milwaukee Zoo
(1971–1981)	Nandankanan Biological Park in India, Mesker Park Zoo, Oklahoma City Zoo, Calcutta Zoo, Pakistan Zoo

[a]Information was gathered from ISIS records, International Zoo Yearbooks, and unpublished zoo reports.

Zoo. A female was placed in the same enclosure as a male on 15 June 1998, had swollen nipples on 9 November, and gave birth on 28 November, indicating a gestation period of <169 days. Pangolins can give birth every year. Males weigh between 5–8 kg and females between 3–6 kg.

Pangolins in European Zoos

Although, historically, numerous European zoos have exhibited the greatest variety of pangolin species and for the longest period of time (since 1877; Table 1), only London, Barcelona, and Antwerp zoos have held animals for more than a year or two, and very few have reproduced successfully. All the animals at the Antwerp Zoo before 1968 were housed in the old Reptile Building, with glass-fronted exhibits furnished with sand, trees, and rocks. Between 1968 and 1982, pangolins in Antwerp lived in a new nocturnal house, with flooring covered in beech leaves for digging and searching for insects (Antwerp Zoo, unpublished records). The Antwerp Zoo had two births of pangolins from wild-caught pregnant females in 1968 and 1970. The first baby lived almost a year, and the mother of the latter (a stillborn) died 24 hours after parturition. A Cape pangolin born at the Basel Zoo was 29 cm long and weighed 270 g. It is thought that female African tree pangolins in captivity will adopt young of others [Asdell, 1964].

Riga Zoo kept pangolins separately in enclosures measuring $1 \times 1.2 \times 0.8$ m, with floors covered with bark chips from leafy trees, temperatures of 25–27°C, and a humidity of 70–80%. One male survived in captivity 8.5 months, whereas the others died between 2–6 weeks. Pangolins exhibited most recently in Europe were seen in the Wuppertal Zoo, Germany. This pair of Chinese pangolins came from the Taipei Zoo, arriving on July 24, 1997. Both adult specimens survived for very little time at the zoo, with the female dying after only a month (August 29, 1997) and the male 7 months later (March 9, 1998).

Pangolins in United States Zoos

Although numerous zoos in North America have displayed pangolin, only a single Malayan pangolin birth was recorded, at the Tacoma Zoo in Washington state (Table 1) in 1938.

MISCELLANEOUS NOTES ON CAPTIVE HUSBANDRY OF PANGOLINS

It seems that many *Manis* sp. are well-adapted to water. Ram Bramha Sanyal reported in his "A Handbook of the Management of Animals in Captivity in Lower Bengal," that pangolins are good swimmers [Sanyal, 1892]. One *Manis* spp. has been found swimming across a tank 33.5 m wide. Another swimmer was found in the Prague Zoo, Czech Republic, where two Chinese pangolins escaped. One was caught immediately, but the other was caught as a "crocodile," 10 km from the zoo. It had, in November, swum across the 40-m wide Moldau River. The giant pangolins at the Antwerp Zoo also loved warm water. They played with the water from the hose when the keepers cleaned the exhibits. Sometimes they lay on their back in the water, or stood on the hind legs. They never used their claws to keep from being sprayed by the water (E. Block, personal observation).

For enclosure management, it is important to maintain a temperature approximately 15 to 18°C. Animals will huddle together when temperatures drop and, as weak animals may be crushed, it is best not to exceed three per enclosure. A diverse environment is also preferred. The Chinese pangolin is a hole-dwelling

nocturnal animal, so it is necessary for the enclosure to provide earth and netting, whereas tree pangolins should also have climbing apparatus. Nursing mothers should be kept separated from other adults to avoid injury to the young.

FEEDING ECOLOGY OF PANGOLINS

Perhaps the most difficult aspect of holding pangolins, and one that significantly impacts reproductive success, is providing a suitable diet. In the wild, pangolins live on a diet of ants, termites, and various other invertebrates including bee larvae, flies, worms, earthworms, and crickets [Yang et al., 1999], that can be quite difficult for zoos to provide in sufficient quantities. Despite their dietary specialization, pangolins do not seem particularly selective in choice of ant species. Swart et al. [1999] found that pangolins in South Africa fed on 15 species of ants and five termite species, with no apparent preferences. Similarly, Coulson [1989] identified six types of ants and four kinds of termites in the stomach of African pangolins.

In Taiwan, there are 198 species of ants and 16 species of termites. Five ant species have been identified in the stomach of pangolin including: *Crematogaster rogenhoferi* Mayr, *C. dohrni fabricans* Forel, *Polyrhachis dives* Smith, *Pheidologeton yanoi* Forel, and *Camponotus friedae* [Gao, 1934; Minami, 1941], with the first two genera the main food sources [Minami, 1913]. Likewise, two termite species have been identified in the stomach: *Odontotermes formosanus* Shiraki and *Reticulitermes flaviceps* [Gao, 1934].

A number of diets for maintaining pangolins in captivity have been published, with ingredients including: egg, meat (ground beef, horse, canned feline diet), evaporated milk products, milk powder, fish protein, orchid leaves, commercial chows, psyllium seed, carrots, yeast, multivitamins, and insects (mixtures of silkworm larvae, earth, ants, termites, meal worms, or crickets) [Anonymous, 1963; Heath and Vanderlip, 1988; Tenaza and Schultz, 1977; Wilson, 1994, 1997] (Table 2). Despite the variety of diets described, pangolins can be difficult to adapt to captive diets, and even ignored native termites offered by Calcutta Zoo [Chevenix-Trench, 1922].

DIETARY HUSBANDRY OF PANGOLIN IN TAIPEI ZOO

The Taipei zoo holds 8 male and 8 female Formosan (Chinese) pangolins currently. We believe that our recent success in rearing, breeding, and maintaining these animals for the natural duration of their life span is associated largely with the gradual development of a suitable diet.

Before 1989, the pangolin diet comprised cooked unpolished rice, cooked sweet potato, bread, egg yolks, bee larvae, milk powder, honey, feline food, and vitamin and mineral supplements. In 1989, milk powder, honey, and feline food were removed; each animal was fed 50 g of bee larvae, 60 g of cooked unpolished rice, 40 g of bread, 60 g of sweet potatoes, one egg yolk, a multivitamin and mineral supplement, vitamin D, and vitamin E. Overall, food intake improved but the incidence of digestive disorders remained unchanged. The 15 animals joining the zoo between 1987–1991 were reared for an average of 90 days. In 1991, after the diet was changed to cooked grains from the previously uncooked diet, health began to improve, with 13 pangolins between 1992–1994 surviving an average of 423 days [Yang et al., 1999].

TABLE 2. Diets fed to pangolins (*Manis* spp.) in captivity

Zoo	Food items
Antwerp Zoo, Belgium	• $^1/_2$ L porridge (cornflakes, condensed milk [no sugar], warm water, minced meat, ant eggs, wheat germ oil, Cérélac, Rovisol ADE, dog grains, eggs, ant acid) • 250 g meat
Oklahoma City Zoo, USA	• Nebraska brand feline diet, horsemeat, dry dog chow, egg yolk, cow's milk, protein powder
Wilhelma Zoo, Germany	• Mixture of minced meat, raw eggs, milk, flaked oats, vitamin supplements, sterile mineral powder
New York Zoological Society, USA	• Evaporated milk, Pabulum, ground raw meat, egg yolk, a multivitamin supplement
San Diego Zoo, USA	• Ground meat, precooked cereal, evaporated milk, water, raw egg yolk, Brewer's yeast, mealworms
Audubon Zoo, USA	• Porridge of Zupreem feline diet, feline maintenance. Diet, Esbilac, psyllium seed, raw egg yolk, warm water
Bloemfontain Zoo, South Africa	• Live ants (if available) • Full cream milk, minced meat, bonemeal, dog meal, raw egg yolk, cod liver oil, ant-heap soil, Pro Nutro
Fort Worth Zoo, USA	• Raw beef heart, precooked cereal, evaporated milk, warm water, ant's eggs, some wheat germ occasionally
Basle Zoo	• Mixture of chopped mealworms, boiled cockroaches, chopped horsemeat, raw eggs, cooked oatmeal
Kwang Chow Zoo, China	• Porridge of silkworm larvae, orchard tree leaves, fish protein, boiled egg yolk, yeast, powdered milk, soil
Prague Zoo	• Beef bouillon, scraped raw beef, raw egg yolk, powdered milk, oatmeal gruel, flour worms, ant chrysalis, vitamin and mineral supplement, salt • Baby food (HUMANA SL without lactose), later followed by puppy food (RC A-2), crickets together with sterile gravel and beef
Riga Zoo	• Mixture of glucose and mineral salts
Zoos in India	• Red tree ants, termites, ant eggs
Taipei Zoo, Taiwan	• Meal worm, bee larvae, egg yolk, apple, coconut powder, yeast, calcium carbonate, vitamin and mineral supplement, soil

At the beginning of 1994, 12 g of mixed silkworm larvae powder (silkworm larvae powder: low fat milk powder: yeast powder: coconut powder in a ratio of 10:1:2:1 wt:wt) were added to a diet composed of 1 slice of bread, 80 g of bee larvae, 80 g of cooked unpolished rice, 100 g of cooked sweet potato, and one egg yolk. At the end of 1994, high carbohydrate foods including the sweet potato and unpolished rice were removed. The diet was altered to 100 g of silkworm larvae powder, 100 g bee larvae, 50 g meal worm, one slice bread, one egg yolk, 1 apple quarter, and 0.5 cc infant's multivitamin solution. The animals' feces turned from a yellow-brown to dark brown and assumed a conical shape. Starting in 1995, the low fat milk powder, bread, and silkworm larvae powder were removed; the feces became even darker and more elongated.

After 1995, when a fixed diet was finally established, the survival rate showed considerable improvement. The fixed diet composed of: 100 g mixed silkworm larvae powder (silkworm larvae powder: yeast powder: coconut powder in a ratio of 10:2:1), 100 g bee larvae, 50 g meal worm, one egg yolk, 1 apple quarter, and 0.5 cc human infant's multivitamin solution (Poly-Vi-Sol, Mead Johnson & Company, Evansville, IN). Since 2003 until the present after several animal feeding trials were conducted, the pangolins have been fed on a diet composed of: 100 g bee larvae, 65 g apples, 45 g meal worm larvae, 2.7 g yeast powder, 1.4 g coconut powder, 10 g egg yolks, 0.9 g calcium carbonate, 1.5 g added powdered supplement (Vitamin and Mineral Supplement for Pig, China Chemical & Pharmaceutical Co., LD, Taiwan), 5 ml vitamin supplements (as above), and 5 g soil were added after 2005.

In the experience of Taipei Zoo, increasing the volume of high protein insects, and multivitamin and mineral supplements improved the pangolin's appetite as well as diet palatability, and animals adapted to captive feeding more rapidly. As Taipei Zoo is located in a subtropical region of high humidity, the natural foods of the pangolin are not preserved easily, and can become infested with microorganisms. For this reason, the substitute diet is blended in a food processor and then cooked, which apart from increasing the water content also improves the hygiene of the food. In addition, it is then possible to avoid the use of high carbohydrate foods and dairy products (that go sour easily under normal temperatures), as well as added chitin and soil into the diet. As a result, the feces of the animals tend to be darker in color and firmer in texture, with a defined shape.

Of the pangolins reared in captivity at Taipei Zoo, most died due to gastrointestinal problems. Necropsy indicated that many of the pangolins brought in from the wild had damage to the stomach wall or ulcers. After improving the diet, animals that survived the quarantine period died mostly from respiratory complications or infection caused by external injuries. Nevertheless, it is clear that the diet given to the pangolins in captivity can still be improved and is the topic of current investigation [Yang et al., 2007].

CONCLUSIONS

1. Over the past 150 years of historic record keeping many zoos have maintained pangolins for brief periods of time. Typically captive animals died within few years, and almost none bred successfully, due apparently to the poor acceptance of captive diets and digestive problems.
2. Since the development of a new diet in 1995, the Taipei Zoo has collected and maintained many pangolins that have lived longer and experienced less digestive pathology than in previous years.

REFERENCES

Allen GM. 1938. The mammals of China and Mongolia. New York: American Museum of Natural History.

Anonymous. 1963. Antwerp pangolin diet. Int Zoo Yearb 4:128.

Asdell SA. 1964. Patterns of mammalian reproduction. Ithaca, NY: Cornell University Press. p 182.

Cansdale GS. 1947. West African tree pangolins. Zool Life London 2:102–5.

Chao JT, Chen YM, Yeh WC, Fang KY. 1993. Notes on newborn Formosan pangolin, *Manis pentadactyla pentadactyla*. J Taiwan Mus 46:43–6.

Chevenix-Trench CG. 1922. Notes on a young Indian pangolin or scaly anteater *Manis*

crassicaudata. J Bombay Nat Hist Soc 24:590.
Coulson I. 1989. The pangolin (*Manis temmincki* Smuts, 1932) in Zimbabwe. Afr J Ecol 27:149–55.
Crandall LS. 1964. The management of wild mammals in captivity. Chicago, IL: University of Chicago Press. p 195–9.
Dickman CR. 1989. Pangolins. In: McDonald D, editor. The encyclopedia of mammals. London: Unwin Hyman Ltd. p 784–5.
Gao C. 1934. The feeling of pangolin study. Formosa Sci 4:370–1.
Heath ME, Vanderlip SL. 1988. Biology, husbandry and veterinary care of captive Chinese pangolins (*Manis pentadactyla*). Zoo Biol 7:293–312.
Masui M. 1967. Birth of a Chinese pangolin *Manis pentadactyla* at Ueno Zoo, Tokyo. Int Zoo Yearb 7:114–5.
Minami GH. 1913. Study of *Polyrhachis dives* with additional note on *Manis pentadactyla*. Insect World 16:10–4.
Minami GH. 1941. An investigation of the food source of *Manis pentadactyla*. Sci Taiwan 9:9–10.
Sanyal RB. 1892. A handbook of the management of wild animals in captivity in lower Bengal. Calcutta, India: Bengal Secretariat Press (reprinted by Central Zoo Authority in 1995).
Swart JM, Richardson PRK, Ferguson JWH. 1999. Ecological factors affecting the feeding behaviour of pangolins (*Manis temmincki*). J Zool 247:281–92.
Tenaza RR, Schultz TA. 1977. Natural and synthetic diets for Pholidota. In: Rechcigl M, editor. CRC handbook series in nutrition and food. Cleveland, OH: CRC Press. p 549–53.
Van Ee CA. 1966. A note on breeding the Cape pangolin *Manis temmincki* at Bloemfontein Zoo. Int Zoo Yearb 6:163–4.
Wilson AE. 1994. Husbandry of pangolins. Int Zoo Yearb 33:248–51.
Wilson AE. 1997. Pangolins. In: AZA minimum husbandry guidelines for mammals. Maryland: American Zoo and Aquarium Association.
World Conservation Union. 2007. IUCN red list of threatened species. Available at: http://www.redlist.org.
Yang CW, Chou CS, Chao MS. 1999. The feeding of the Chinese pangolin (*Manis pentadactyla pentadactyla*) at Taipei Zoo. AZA Annual Proceedings. Sept. 23–28, Minneapolis, MN. p 501–7.
Yang CW, Chen S, Chang CY, Lin MF, Block E, Lorentsen R, Dierenfeld ES. 2007. Rare occupants in zoos—pangolins. Aspects of digestive anatomy and physiology. Zoo Biol (in press).