CAPTIVE BREEDING OF THE NUMBAT

Myrmecobius fasciatus

J.A. Friend and D. Whitford

World Wildlife Fund Australia Project 50

Final Report

AUSTRALIA

Department of
CONSERVATION & LAND MANAGEMENT

CAPTIVE BREEDING OF THE NUMBAT

Myrmecobius fasciatus

J.A. Friend and D. Whitford

Final report to World Wildlife Fund Australia
on Project 50 :
Establishment of a captive breeding colony of the Numbat

Originator of project: Dr. J.A. Friend
Project Investigators: Dr. J.A. Friend and Mr. D. Whitford

Western Australian Wildlife Research Centre, Woodvale
Department of Conservation and Land Management
February 1988

CONTENTS

EXECUTIVE SUMMARY AND RECOMMENDATIONS

Summary

1) A captive colony of numbats was established at the W.A. Wildlife Research Centre at Woodvale in mid-1984 by taking from Dryandra Forest an adult male, an adult female and her litter of four young, which were still attached to her teats. These animals were housed in specially built cages which allowed them to dig burrows into the sandy substrate.

2) The numbats were fed initially on termites. The female raised her four young, which comprised two males and two females.

3) An artificial diet was adapted from an egg-milk custard previously fed to echidnas, to which 10% by weight of termites was added. Analysis showed that the diet was close to termites in amino acid composition, but higher in total fat and higher in saturated fatty acids than termites.

4) All numbats were kept on this diet except the older female, which was fed termites to allow a comparison with the artificial diet.

5) All three females bred with the older male and produced young in January 1985. Ten young were recorded but one disappeared from its mother's pouch within a week. The remaining nine young all survived to adulthood.

6) The growth of the young whose mothers were fed the artificial diet kept pace with those whose mother was kept on termites. The growth rates of both groups were within the range of variation encountered in the wild.

7) Two male numbats were released into the wild and four subadult males were transferred to Perth Zoo. Another male was captured at Dryandra Forest in December 1985. At the start of the next breeding season in January 1986 there were two males and eight females at Woodvale.

8) Although most females came into oestrus and the males showed normal seasonal changes associated with fertility, no mating was observed during the second breeding season, and no young were born. During the weeks when mating usually occurs, however, one male showed behavioural abnormalities, while the other may not have had time to adjust to captivity by then.

Recommendations

1) Further research into captive breeding in numbats and the effect of diet is required. This work should be carried out with access to a group of no less than twelve adult animals with an even sex ratio. The project should involve close monitoring of individuals leading up to the breeding season. Several diets, including termites, should be used to test whether nutritional or other factors inhibit breeding.

2) The involvement of zoos in this and similar projects should be encouraged. There is a strong desire in many zoos to become more involved with Australian endangered species. Where the manpower for maintaining the animals is available but the background in reproductive physiology or animal nutrition is lacking, collaborative projects with university or other research workers could be very productive.

3) WWFA should consider funding research into numbat captive breeding along these lines.

INTRODUCTION

Until about fifteen years ago, the future of the Numbat (<u>Myrmecobius fasciatus</u>) was thought to be reasonably secure. Despite the huge contraction of its range which followed white settlement of Australia, populations persisted in forests and remnant woodlands of south-western Australia (Calaby, 1960). By the late 1970s, however, attrition of woodland remnants in the southern wheatbelt, a five-year period of below-average rainfall (1975-1979) and an increase in numbers of the introduced Red Fox (<u>Vulpes vulpes</u>) in this region had combined to reduce further the species' numbers and range (Christensen, 1980; Connell and Friend, 1985; Friend, 1987) until it appeared that extinction might be imminent. A four-month survey of all known numbat habitat conducted in 1979-80 resulted in only two sightings of numbats (Turner and Borthwick, 1980).

Although there are a number of rare and endangered mammals in Western Australia whose basic biology is not well understood, and which are in urgent need of research aimed at their conservation, most either have reasonably secure populations on offshore islands or are breeding well in captivity. Neither of these situations applied in the case of the Numbat. The Western Australian Government therefore gave priority to the commencement of a study to determine ways to manage populations and habitat to ensure the species' conservation. This study was initiated in 1981 and concentrated on the ecology of the Numbat population at Dryandra Forest, one of the few strongholds of the species. It was felt, however, that as numbats had not been bred successfully in captivity, a simultaneous effort should be made to develop techniques for captive breeding, in order to provide a further safeguard in the event of another major decline. The additional funds necessary to support this project were sought from WWFA in June 1981. Although the project was adopted as part of the WWFA conservation programme as Project 50 in the same year, funds were not available until September 1983. This funding was provided to the Western Australian Department of Fisheries and Wildlife. In March 1985, the wildlife conservation functions of that department were transferred to the newly formed Department of Conservation and Land Management. Project 50 was therefore completed under the auspices of the new department.

Aims of the captive breeding project

The major obstacle to keeping numbats in captivity is the provision of food. As their natural diet consists almost entirely of termites (Calaby, 1960), the maintenance of a large number of captive animals on this food, collected from the bush, would be prohibitively expensive. Despite considerable effort, attempts to produce termites in artificial colonies have not been successful at the scale necessary here (Dr. J.A.L. Watson, CSIRO Division of Entomology, pers. comm.). The specific aims of this project, therefore, were

a) to establish conditions of captivity under which numbats will breed, and

b) to develop an artificial diet on which numbats will thrive, breed and raise young in captivity.

Project time scale and funding

Funds became available for this project in September 1983, but due to other commitments the employment of Dick Whitford began in December 1983. This was too late to set up a group of animals in time for the January 1984 breeding season. The two-year project therefore effectively included only one breeding season, as salary funding ran out in December 1985. In order to allow the project to run through another breeding season, the Department of Conservation and Land Management made available funds to extend Dick Whitford's employment for another year, and to provide casual wages for weekend feeding. By this time Perth Zoo had built facilities to house those numbats which had not been released into the wild, and the colony was transferred there in December 1986.

This report deals mainly with work which was carried out during the two-year period funded by World Wildlife Fund Australia. Where relevant, however, events of the following year are included. Graphs of the weights of individuals, for instance (Figures 7, 8 & 9), extend to 31 December 1986.

History of Numbats in captivity

Before the commencement of this project, a thorough review of previous experiences in numbat husbandry was undertaken, in order to take note of any lessons which might have been learned.

Although there were probably numerous early attempts to domesticate this attractive animal after its discovery by Europeans in 1831 (Dale, 1833), the first record of a numbat in captivity was due to Sir George Grey, who reported that his wife had seen several in captivity (Gould, 1863). The animals were being maintained on sugar and milk, probably the first artificial diet devised for this species. There is no record of the success of this diet, however, or indeed of the duration of the period of captivity. In a letter to Gould, John Gilbert mentioned that he had heard of numbats being kept for several weeks on a diet of bran alone (Wagstaffe and Rutherford, 1954).

Several more recent attempts to keep numbats have been documented. Glauert (1935) received a female with four young from an over-enthusiastic correspondent, and managed to keep them alive at the Western Australian Museum for three months, feeding them on termites. The female died during a bout of unusually cold September weather, and the young, which were well below size for their age (W.A.Museum specimens; unpublished data) lasted only a few more days. A valiant attempt to transfer a numbat from Western Australia to the cold, damp climate of Healesville, Victoria, kept David Fleay (1942, 1949) busy in the summer of

1942, searching for termite nests in old tree-stumps. On her arrival at the Sir Colin MacKenzie Sanctuary, "Little Miss Numbat" was presented with a veritable smorgasbord which included termites, several species of ants and their eggs, mealworms, beetles, "grubs", earthworms, raw egg, bread and milk, honey and jam. This numbat made it quite clear that termites were all she was really interested in, and no progress was made towards developing an artificial diet. She lasted only two months before dying suddenly, having shown no signs of ill health, and leaving Fleay to conclude that she must have fallen victim to a Red-back Spider (*Latrodectes mactans hasselti*).

A novel approach to the problem of feeding an insectivorous animal was described by Critchell (1969), a resident of Pingelly, W.A., who kept a numbat for a short time. Finding the provision of termites difficult, he decided to bring the mountain to Mohammed, and attached a lead to the animal so that it could be taken for a walk in nearby wandoo woodland, where it was allowed to feed itself.

Another recorded artificial diet was that used by Colin Bonney, of Corrigin, who had a numbat in captivity for two months. After finding that a raw mince-egg-Pentavite mixture gave the animal diarrhoea, he switched it onto minced chicken (letter to Department of Fisheries and Fauna, 19 November 1969). Like Fleay's captive, it died suddenly without having shown any prior signs of illness.

The most successful record of keeping numbats in captivity before the present project belongs to Taronga Zoo, where the species was kept continuously for a period of more than eight years (Strahan, 1978). The individual held captive longest was a female which was brought in as an adult and survived for a further five years and three months. Taronga Zoo's numbats were maintained on a diet of termites and bred on two occasions, but the young did not survive more than a few weeks. In both cases, the mother was the long-lived female, and the young were produced in her first two breeding seasons in captivity. At Dryandra, where numbats have been studied intensively, most females give birth during the second half of January (Friend, unpublished data). The first litter at Taronga was recorded on 21 January 1969, but the second was not recorded until 20 April 1970 (Taronga Zoo records). The second year's birth, therefore, was unusually late, and it appears that the female's reproductive physiology was out of phase with that of the wild female population. It is possible, however, that the birth had gone unnoticed for some time, and actually occurred closer to January. Collins (1973) suggested that the loss of these litters might have been due to physical interference by the male, which was kept continuously with the female. Collins had observed the male sniffing the female's pouch area while the young were attached, to which the female responded with apparent annoyance. This explanation for the loss of young is plausible, as numbats are solitary for most of the year (Calaby, 1960; Friend, unpublished data). The confinement of two animals may therefore promote interactions which do not occur in the wild.

The death of the last two numbats at Taronga followed their change of accommodation from a small enclosure which was exposed to sunlight for much of the day, to a display facility situated on a south-facing slope. Basking appears to be an important feature of thermoregulation in numbats, and this activity would have been restricted in the new quarters. The cage was provided with a running stream, the result being a shady, moist environment at all times of the year. The death of the numbats was attributed to a fungal infection, thrush (R. Strahan, pers. comm.).

The review of previous attempts to keep and breed numbats in captivity gave several promising indications. Firstly, there seemed to be no major difficulty in maintaining them while they were fed termites, given good access to sunlight. Secondly, mating and birth had occurred in captivity, although only on a diet of termites. Thirdly, numbats had been fed on other diets, so it was obviously possible to provide them with alternative food which they would accept. The problem was to find an artificial diet which would maintain them and on which they would breed.

General Approach

The philosophy which we adopted in deciding on conditions of maintenance and treatment of the captive numbats was as follows:

1) Within economic limits, the animals would be kept under captive conditions as close as possible to those encountered in the wild. Detailed information on diet, nests, seasonal changes in behaviour, breeding and care of young in the wild collected through recent radio-tracking studies of numbats was the basis for this approach.

2) As far as attempts to breed the animals were concerned, the animals would be allowed to "do their own thing". We would be guided by the behaviour of the individuals.

3) Disturbance and handling would be kept to a minimum, even if this meant losing the opportunity to study some aspects of the species' biology. Thus no physiological experiments would be run, and handling for photography, filming and general display would be minimal, while satisfying publicity obligations to WWFA.

MAINTENANCE OF NUMBATS IN CAPTIVITY

Enclosures

As there were no suitable facilities for holding numbats at the W.A. Wildlife Research Centre, one of the first tasks of the project was to design and construct appropriate enclosures. The Centre is situated about 25 km from central Perth, on 40ha of fenced bushland in the suburb of Woodvale, near the township of Wanneroo.

The cage complex in which numbats were housed was designed with a number of requirements in mind. These were as follows:

a) The floor would be the natural ground surface, to allow the animals to dig burrows. Burrows are used as night shelters in the wild by both males and females, particularly in winter, and females first deposit their young almost without exception in a nest burrow.

b) As much of the original plant cover as possible would be retained inside the enclosures. This would provide additional cover and nest material, and would bind the sand together more to facilitate the construction of burrows.

c) Sufficient cages would be constructed to allow each animal to be housed individually.

d) The complex would be situated in a sunny position.

The final layout of the cage complex is shown in Figure 1. The first two units, measuring 12m x 5m, were built in February 1984; one was subdivided into four cages, and the other left as one large enclosure. As the demand for separate cages grew with increasing numbers, this second cage was divided first into two (October 1984), then into four (November 1985), and finally two extra 5m x 3m cages were built onto one end of the first unit (December 1985).

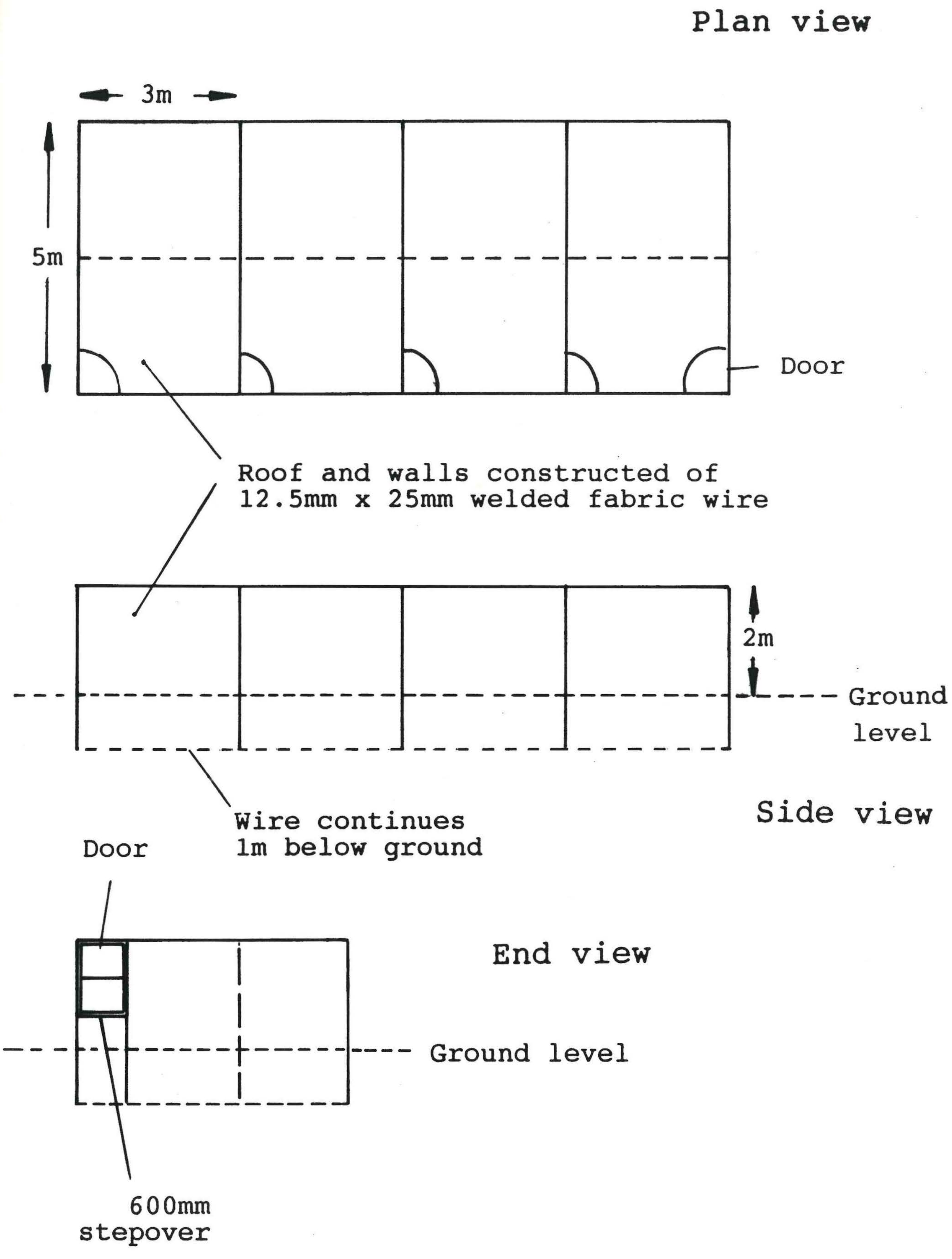

Plan view
3m
5m
Door
Roof and walls constructed of
12.5mm x 25mm welded fabric wire
2m
Ground
level
Wire continues
1m below ground
Side view
Door
End view
Ground level
600mm
stepover

Figure 1. Design of cage complex built at Woodvale to house the numbat captive breeding colony. A sigle 4-cage unit is shown; a 6-cage unit was also built. Details of materials and construction are given in Appendix 3.

To enable the numbats to dig burrows without escaping, the welded wire fabric which formed the cage walls continued to a depth of 1m below the ground surface. In the wild, burrows are almost straight shafts up to 2m long which slope at a shallow angle, ending in a spherical chamber. None were found with multiple entrances, so we were confident that the animals would not burrow down on one side of the wire and up to freedom on the other side. In fact, burrows dug in the cages were found to interconnect. This appeared to result, however, from the underground meeting of two separate burrows which were following the same wire mesh wall. The worst result of this, which did not happen at Woodvale, would be access from one cage into another under a separating wall.

The specifications for the cage complex as originally constructed are shown in Appendix 2. Access to each unit was by the doors at each end. These doors had a high step-over wall below the opening, to reduce the chance of animals escaping as a person entered the cage. Doors in the dividing walls gave access to the middle cages without any further risk of escaping numbats. This arrangement gave reasonable security while using all the floor space to accommodate numbats. Consideration was given to the addition of a double set of doors to further reduce the possibility of escape, but the lack of any apparent interest by the numbats in the open door convinced us that these were not necessary, at least at Woodvale.

Hollow logs were provided as "cage furniture" and in some cases provided with removable ends to allow access to uncooperative individuals when necessary. Nest boxes were also constructed, of marine ply, 900mm x 150mm x 150mm outside dimensions, with one side swinging open on a piano hinge, and a circular hole of 60mm diameter in the end or in one side.

Introduction into captivity

The first numbat brought to Woodvale for the breeding colony was a female with four attached young, captured on 6 April 1984. She was placed in a 12m x 5m enclosure in which hollow logs with removable doors had been placed. Fresh termite mound material (containing termites) was left in a tray, as were bowls of separated termites. Access to the area was closed off to other staff, and a hide was constructed to enable observation of the animal's behaviour. We were particularly interested to see whether she was eating the termites provided.

In fact she was not seen feeding during the first three days, and spent most of her active time either investigating the enclosure, or hanging from the enclosure wire. On 10 April the decision was made to take her back to Dryandra. She was released at her capture site the next day. At that stage her weight had dropped from 561g at capture to 440g (a loss of 21%), and her four attached young appeared to have become thinner. She was fitted with a radio-collar to enable her progress to be monitored. The female was recaptured and weighed seven days later, when her weight was found to be 513g, within 8% of her original capture weight. Subsequent monitoring saw her recover fully and raise her four healthy young in the wild.

As a result of this experience, we decided that the next captive would be kept in close proximity to our activity, to allow it to become accustomed rapidly to our presence. We decided to keep it in close confinement so that it would repeatedly encounter the termites provided, and actually to attempt to feed it by hand.

The next numbat brought in was a male, code-named 1M, which we had initially captured at Dryandra Forest on 28 March 1984. At that time he had been fitted with a radio-collar and released. He was recaptured on 9 May 1984 and brought to the W.A. Wildlife Research Centre at Woodvale, where he was placed in a glass aquarium (1200mm x 350mm x 460mm high) provided with a wire mesh lid. A small hollow log of inside diameter 10cm fitted with a removable panel at one end was placed in the aquarium, and the floor was covered with sand. A 75W light was placed for heat outside one end of the aquarium.

Despite our new strategy, the numbat did not start eating in earnest for three days, when he first fed from pieces of broken-up termite mound. Subsequent experience in bringing new animals in from the wild showed that the most successful tactic is to keep the animal in close confinement and provided with termites both in mound material and in bulk in a dish. The

Plate 1. Captive male 6M collecting nest material for his burrow. This photograph was taken on the morning after the first cold night of his first year of independence (April 1985). Photo: J.A. Friend.

animal is then left alone to come out of hiding and investigate the enclosure in peace, and to encounter the food frequently at an early stage. Once it starts feeding, the process of familiarization may begin.

During the course of this project, only two other numbats were brought into captivity. These were a female (2F) with four attached pouch young (3F, 4F, 5M and 6M), brought in on 10 July 1984, and an adult male (16M), brought in on 6 December 1986 after the release of 1M and 5M to the wild. Appendix 1 shows the history of each individual numbat held during the WWFA project.

Termite supply

Use of termites to feed the numbats in the early stages of the captive colony immediately created a demand for a constant supply of large numbers of the live insects. The first two numbats successfully taken into captivity each consumed between 80g and 120g live weight of termites daily. This represents 16,800 - 25,200 Nasutitermes exitiosus workers (Gay et al., 1955) per day. The most readily-available source of termites in the Perth region is from the large hemispherical mounds of N. exitiosus which are abundant in low-lying areas on the Swan Coastal Plain, and also in higher-rainfall areas on the Darling Scarp south of Perth. Mounds of this species commonly contain over 750,000 termites each (Holdaway et al., 1935).

Initially, termites were extracted from mound material and set up in jar colonies according to the technique of Gay *et al.* (1955), which was developed to provide experimental groups of termites to assess the resistance of various timbers to attack. One-litre jars were filled with moist termite mound material, wood and 25g of termites. The insects survived well under these conditions for up to six months, and the jar "colonies" could be emptied out at any time into a numbat's feeding dish. It was found desirable to minimise the number of soldiers which were put into the jars, to increase the palatability to numbats. *Nasutitermes exitiosus* soldiers exude a strong-smelling defensive secretion which seems to reduce their attractiveness to numbats. When the mound was first broken up, therefore, soldiers were brushed off as they swarmed out over the surface of the mound in response to the disturbance.

It was later discovered, however, that termites survived well in their mound material if large pieces of mound were placed in plastic 60L rubbish bins with one or two slabs of a susceptible timber (such as karri, *Eucalyptus diversicolor*) and sprayed regularly with water. The termites quickly sealed up the broken galleries and started to feed on the timber within several days. As well as maintaining their numbers over periods of weeks or months, this method allowed easy removal of the insects to feed to numbats. Termite workers would build up in large numbers on the side of the timber facing the mound material, so that it was a simple operation to pick up the wood and brush or knock the termites off into a tray. After the timber was replaced, it took only 3-4 hours before numbers built up on it again to the same level. As the activity of termites is profoundly influenced by temperature, it was necessary to keep the air temperature above about 17^{o}C to maintain this rate of replenishment. The relative humidity inside the bins was kept at a constantly high level by daily watering with a fine spray, as well as by carefully replacing the tight-fitting lids. This method of extracting termites from mound material proved to be very efficient, as the number of workers moving onto the wood only dropped off when the mound was almost empty.

The proportion of the workers of a N. exitiosus colony which are in the mound at any time is largely dependent on the weather. During cold periods, workers aggregate in the mound in order to maintain the temperature of the nursery with their metabolic heat (Holdaway and Gay, 1948). Consequently, it is advisable to collect termites from mounds in the early morning. When temperatures rise in early spring, numbers in the mounds decrease both through the release of the winged reproductive caste (alates) and through the movement of workers out to food sources. At this time of year, therefore, collection of mounds, especially in the afternoons, yields unusually low numbers of termites. It was discovered that a much greater yield resulted if the mound were chilled for 24 hours before collection. This was accomplished by spreading about 10kg of crushed ice over the top of a N. exitiosus mound, under some insulating material, such as heavy hessian sacks.

The environmental impact of collecting termites from the wild can be lessened by removing only part of the mound. In *N. exitiosus*, the nursery chamber, which houses the queen, is low in the mound, near ground level. If only the top of the mound is taken, the remaining workers will quickly seal off the broken sections, and given the right weather conditions, will rebuild the mound.

Following advice from Dr. Tony Watson, CSIRO Division of Entomology, a completely different approach was used to obtain supplies of another common species, *Coptotermes acinaciformis raffrayi*. This species does not build free-standing mounds in the Perth area; in this region its nests are commonly in the trunks of trees. It attacks sound timber which may therefore be used as a bait to entice individuals into traps set out in the forest. Old 30L fuel drums with holes near the base are filled with pine laths and the top is sealed with plastic sheet to prevent desiccation. The drum is then dug slightly into the ground beside a buried length of pine or karri timber, so that termites can pass directly from the timber through the holes into the drum. After 1-4 months (the actual time depending on the season), these traps become heavily infested with *Coptotermes*, and can be taken back and stored for up to a month. *Coptotermes* soldiers also produce a defensive secretion, but this appears to have little effect on numbats and these termites are eaten readily. Most of the *Coptotermes* trapping to supply the numbat breeding colony was carried out by Dr Geoff Kirkman.

Plate 2. Termites (<u>Nasutitermes exitiosus</u>) near the edge of the separating platform. Sifted mound debris containing termites is placed in the centre of the platform. Termites walk from the debris and fall off the platform into the tray in which it stands. Photo: J.A. Friend.

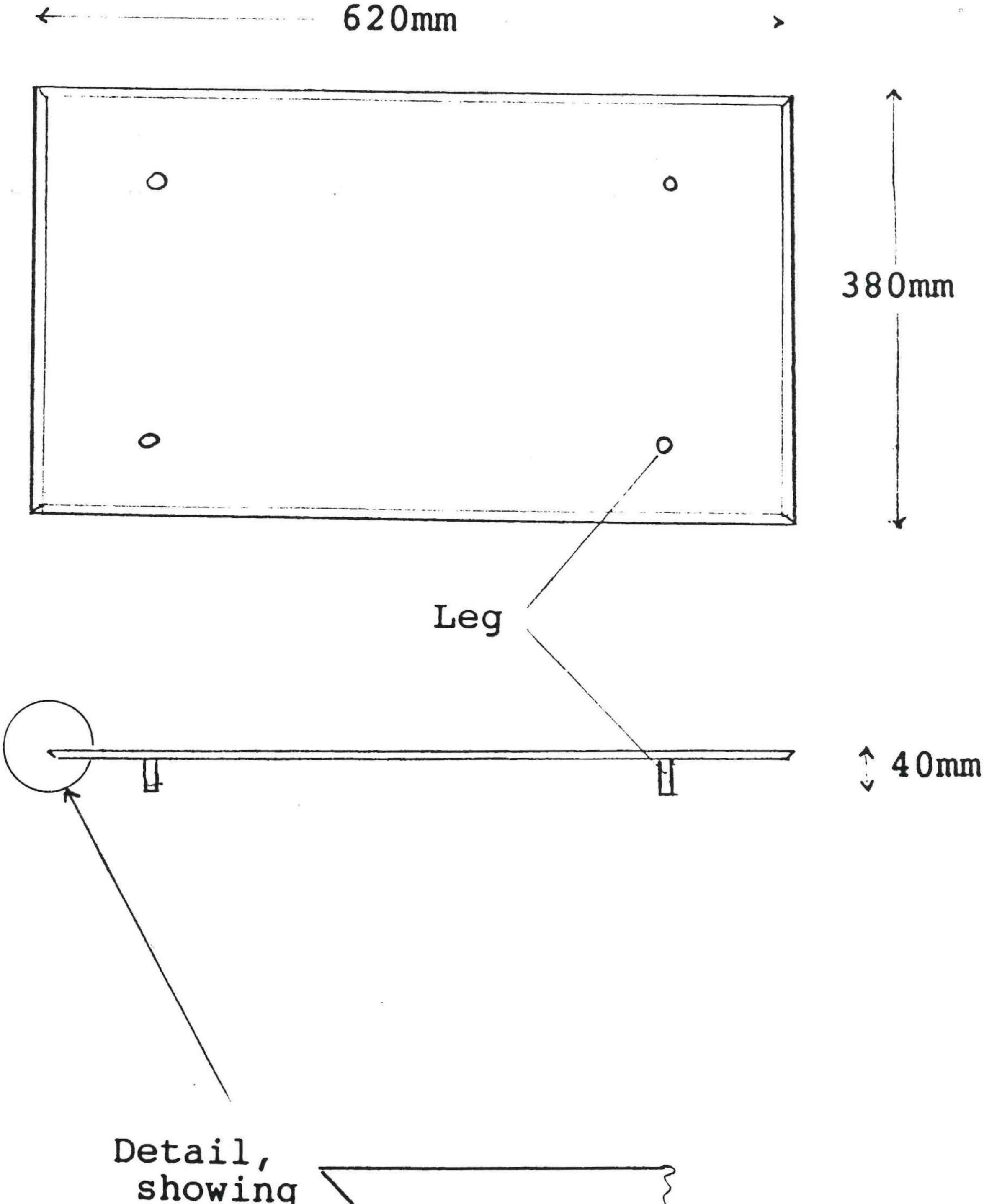
Rations of termites fed to the numbats were always weighed so that accurate records of food intake could be kept, and so that they could be measured into the mix when used as a supplement to an artificial diet. For this purpose, termites were separated from the material in which they were collected using platforms (Figure 2) constructed after the design of Gay *et al.* (1955).

Termites as food

In comparison with other invertebrates, termite workers and soldiers tend to be low in fat, high in ash and about equal in total nitrogen (Redford and Dorea, 1984). However, fat content increases up the reproductive line, peaking in the alates at release, when total lipids can exceed 50% dry weight (La Fage and Nutting, 1978). *Nasutitermes exitiosus* workers contain only 5-15% dry weight of lipid (1-3% lipid, Moore, 1969; this was on a wet weight basis, B.P. Moore, pers. comm.). The ratio of unsaturated to saturated fats is unusually high for insects (Moore, 1969).

Given that specialist termite-eaters feed mainly on workers (as these are more plentiful and lack the defence mechanisms of soldiers) and that most ingest large quantities of soil as they feed, this diet is relatively low in caloric content (McNab, 1984). This applies also to specialist ant-eaters. Possibly as a consequence, most ant- and termite-eating mammals have low metabolic rates. McNab (1984) concluded that the adaptive

Figure 2. Design of Perspex termite separation platforms, after Gay *et al*. (1955).



TERMITE-SEPARATING PLATFORM

Constructed of Perspex

advantage of this feeding specialisation was not due to any high value of the diet, but rather to the lack of competition with other mammals which resulted.

Artificial diet

Many diets have been developed previously to maintain ant- and termite-eaters in captivity. These are generally based on meat, eggs and milk, supplemented with vitamins, minerals, formic acid and other minor constituents. Some published examples of ant- and termite-eater diets are given below:

Aardvark (Sampsell, 1979)
- Dry dog food
- Pablum
- Mellins food (milk modifier)
- Honey
- Vitamin-mineral supplement
- Condensed milk
- Eggs

Aardwolf (Spinelli, 1970)
- Meat, bone meal and milk

Tamandua (Merritt, 1975)
- Meat mixture (horsemeat & mink developer chow)
- Canned milk and water
- Vitamins
- Gevral protein powder
- Paltone powder (vitamins and minerals)
- Tome powder (protein and vitamins)

Pangolin (Menzies, 1962)
- Ground meat
- Bran
- Milk
- Ants eggs or formic acid

Armadillos (Merritt, 1973)
- Ground horsemeat
- Mink developer chow
- Eggs
- Cod-liver oil
- Honey, molasses and vitamins

Echidna (Collins, 1973)
- Philadelphia Zoo
  - Milk
  - Egg
- St Louis Zoo
  - Pablum
  - Egg
  - Milk
  - Salt, calcium, minerals
- Taronga Zoo
  - Meat
  - Carrot
  - Blood
  - Egg
  - Milk
  - Lactogen
  - Clay
  - Lettuce
  - Formic acid

Echidna, aardvark and aardwolf (Young, 1966)
- Raw minced meat
- Pre-cooked cereal
- Skim milk
- Whey powder
- Corn meal
- Yeast
- Calcium phosphate and vitamins

Successes in captive breeding of many ant- and termite-eaters have been rare (Young, 1973; Spinelli, 1970), so the long list of zoo diets was approached with caution. While many individuals had been maintained on these diets, there is little information on their adequacy for growing young or lactating females, for instance. Griffiths (1978) compared the growth rates of young echidnas fed on termites, and on an egg-milk custard supplemented with termites. As the latter diet had actually produced the higher growth rates, we decided to try it with the numbats, and were given valuable assistance by Dr. Griffiths. Subsequent work had produced an improved version of the diet (Green et al., 1985) using a low-lactose milk powder, Digestelact (Sharpe Laboratories, Sydney). The enzyme lactase, which is responsible for the breakdown of lactose, is not present in all mammal species, and in some appears only in post-juveniles (van Reenen, 1986). There is a danger that lactose intolerance, which often results in severe scouring, will occur, and this has been noted frequently in marsupials (Stephens et al., 1974; Oglesby, 1981).

Woolley (1971) found that some dasyurids developed thin skulls and other symptoms of calcium deficiency in captivity unless their diet was supplemented with calcium. Calcium carbonate powder was therefore added to the custard, as well as a multi-vitamin supplement, Brisfarm SA-37.

After a certain amount of experimentation, the diet used was as follows;

6 eggs (55g each)
154g Digestelact = 16 scoops
680ml water
1/2 teaspoon calcium carbonate powder
1/4 teaspoon Brisfarm SA-37
100g termites

The milk powder is dissolved in cold water, and eggs added. This mixture is heated in a steamer until it stiffens, but before liquid separates out. Alternatively, cooking can be done in a

Plate 3. Young captive-bred numbats (7M, 8M, 9F and 10F) eating the artificial diet. Photo: J.A. Friend.

microwave oven. It is cooled as quickly as possible (in a refrigerator). Before the mixture is fed to the numbats, the calcium carbonate, vitamin supplement and termites are stirred in. About 5% by weight of sandy soil (sterilised by boiling) is then added. Scats of numbats living in the wild contain a large proportion of soil, and it has been suggested that sand particles actually assist in the physical breakdown of the termites eaten (Calaby, 1960). Our numbats frequently ingested sand from the substrate in their enclosures; their faeces were full of sand, whether or not it had been added to their food. For this reason, sand was added both to the artificial diet and to live termites which were being fed to any animal.

The resulting mixture is stiff in consistency, and allows the numbats to pick it up relatively easily with their long, slender tongues. They tend to scratch at it with their forepaws, and sometimes pull it out of the bowl, then lick up individual lumps.

Comparison between termites and artificial diet

Proximate constituents

The proximate constituents of termites as a diet for mammals have not been determined previously, due to the difficulties of reaching a meaningful estimate of the amount of available nitrogen. The usual method of estimating the protein content of a food is to determine total nitrogen by acid hydrolysis and then to multiply by a constant (usually 6.25) to give total protein. In the case of insects, however, chitin in the exoskeleton contains a significant amount of nitrogen, most of which is unavailable to insectivores. The fact that identifiable mandibles and other chitinous parts of termites come through in numbat faeces apparently unchanged indicates that very little, or no chitin is digested. Acid digestion used in nitrogen analysis, however, releases the nitrogen from the chitin so that it is included in the total nitrogen assay. Griffiths (1968) attempted to overcome this problem in his determination of amino acids available to echidnas in a diet of the termite <u>Nasutitermes exitiosus</u>. He used the enzyme pronase, a potent proteolytic enzyme of bacterial origin which is inactive on chitin, to perform the initial digest of the termite protein. Using his amino acid concentrations to calculate available protein gives a figure of 37% of dry weight. By contrast, Griffiths' (1965) figure of total nitrogen in <u>N. exitiosus</u> using acid digestion (8.5% dry weight of N) gives 53% protein.

Other data from the literature allow the estimation of the proximate constituents of <u>N. exitiosus</u>. The fat content given by Moore (1969), 1-3% of wet weight, encompassed seasonal variation (values were lower in winter), so 2% might be a realistic average for the species. According to Griffiths (1978: p.82) the water content of <u>N. exitiosus</u> is 74%. The ash content of workers is about 5% of dry weight (Abensberg-Traun, unpublished data). Carbohydrate content may be calculated approximately by subtraction, if the total nitrogen figure is used. A comparison of the proximate constituents of a diet of _N. exitiosus_ workers, and the artificial diet is shown below.

Table 1. Proximate constituents of termites (_Nasutitermes exitiosus_ workers, calculated from data of Griffiths, 1968 & 1978) and the artificial diet formulated for numbats, expressed on a wet (wwb) and dry (dwb) weight basis.

	N. exitiosus workers		Artificial diet	
	%wwb	%dwb	%wwb	%dwb
Water	74	-	81	-
Protein - total	14	53	7	36
- usable	10	37	7	34
Fat	2	8	6	32
Carbohydrate	9	34	6	27
Ash	1	5	1	5

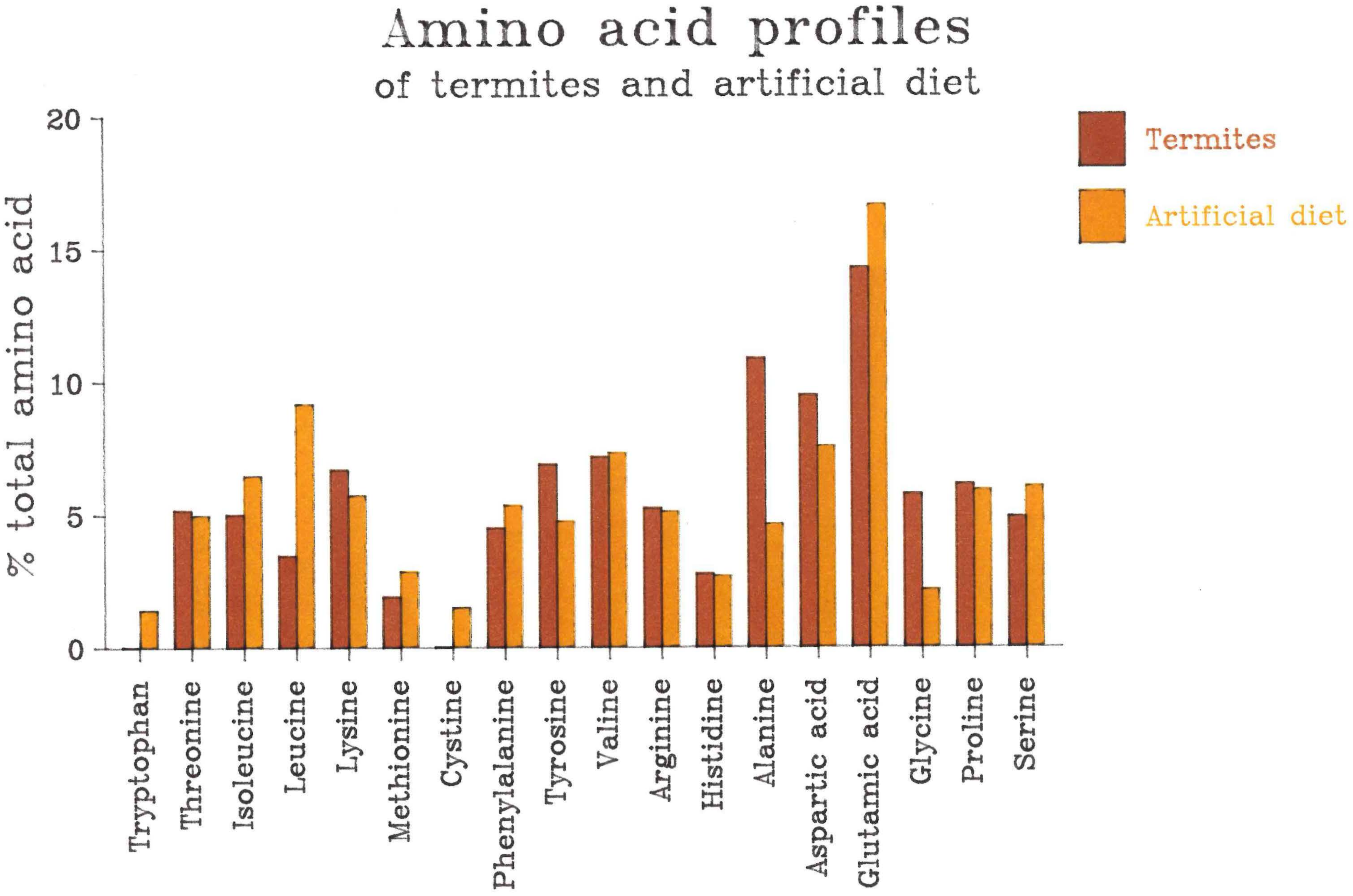
This comparison shows that a much greater proportion of the protein is available to the numbats in the artificial diet than in termites. It also shows that the artificial diet is much richer in fat than are _N. exitiosus_ workers. Two factors will work to reduce these differences, however. Firstly, the significant fraction of unusable protein in termites will increase the importance of fat in their food value. Secondly, numbats feeding in the wild will frequently encounter alates and pre-alates, which generally have a much higher fat content than workers or soldiers (La Fage & Nutting, 1978). Christensen _et al_. (1984) found one numbat scat (out of 7 examined) which contained the remains of 161 alates of one species of termite, indicating that the animal had located a point of release of alates and had fed from it continuously for some time.

Amino acids

It is also possible to compare the amino acid composition of the protein in termites with that in the artificial diet. Griffiths (1968) presented amino acid assays for pronase digests of N. exitiosus workers in terms of micromoles of nitrogen per gram (dry wt) of termite. These are here converted to weight of the particular amino acid per gram (dry wt) of termite, and then for each amino acid to a percentage of the total amino acid detected. To allow comparison, corresponding values have been calculated for the artificial diet. The amino acid composition of Digestelact protein was kindly provided by M. Sharpe of Sharpe Laboratories Pty Ltd, and that of egg protein was taken from the U.S. Food Composition Tables (USDA, 1976). Using these figures and those calculated for termites, an overall amino acid profile for the artificial diet was prepared, also in terms of percent of total amino acid. Figure 3 shows all these data in the form of histograms.

The proportions of most individual amino acids present in the artificial diet are surprisingly close to those in termites (Figure 3). Only glycine and alanine are present in significantly lower proportions in the artificial diet. Both are considered non-essential amino acids in animals; alanine can be synthesised by transamination from a-keto acids, which arise in the citric acid cycle, while glycine can be synthesised from the amino acid serine (White et al., 1978).

Figure 3. Amino acid profiles of termites and the artificial diet fed to the breeding colony numbats. The profile for termites is calculated from data given by Griffiths (1968) for analysis of pronase digests of _Nasutitermes exitiosus_ workers. The profile for the custard was calculated using USDA food tables (egg), figures for Digestelact provided by Sharpe Laboratories, and Griffiths' (1968) termite analysis.


Amino acid profiles
of termites and artificial diet
Termites
Artificial diet
% total amino acid
0
5
10
15
20
Tryptophan
Threonine
Isoleucine
Leucine
Lysine
Methionine
Cystine
Phenylalanine
Tyrosine
Valine
Arginine
Histidine
Alanine
Aspartic acid
Glutamic acid
Glycine
Proline
Serine

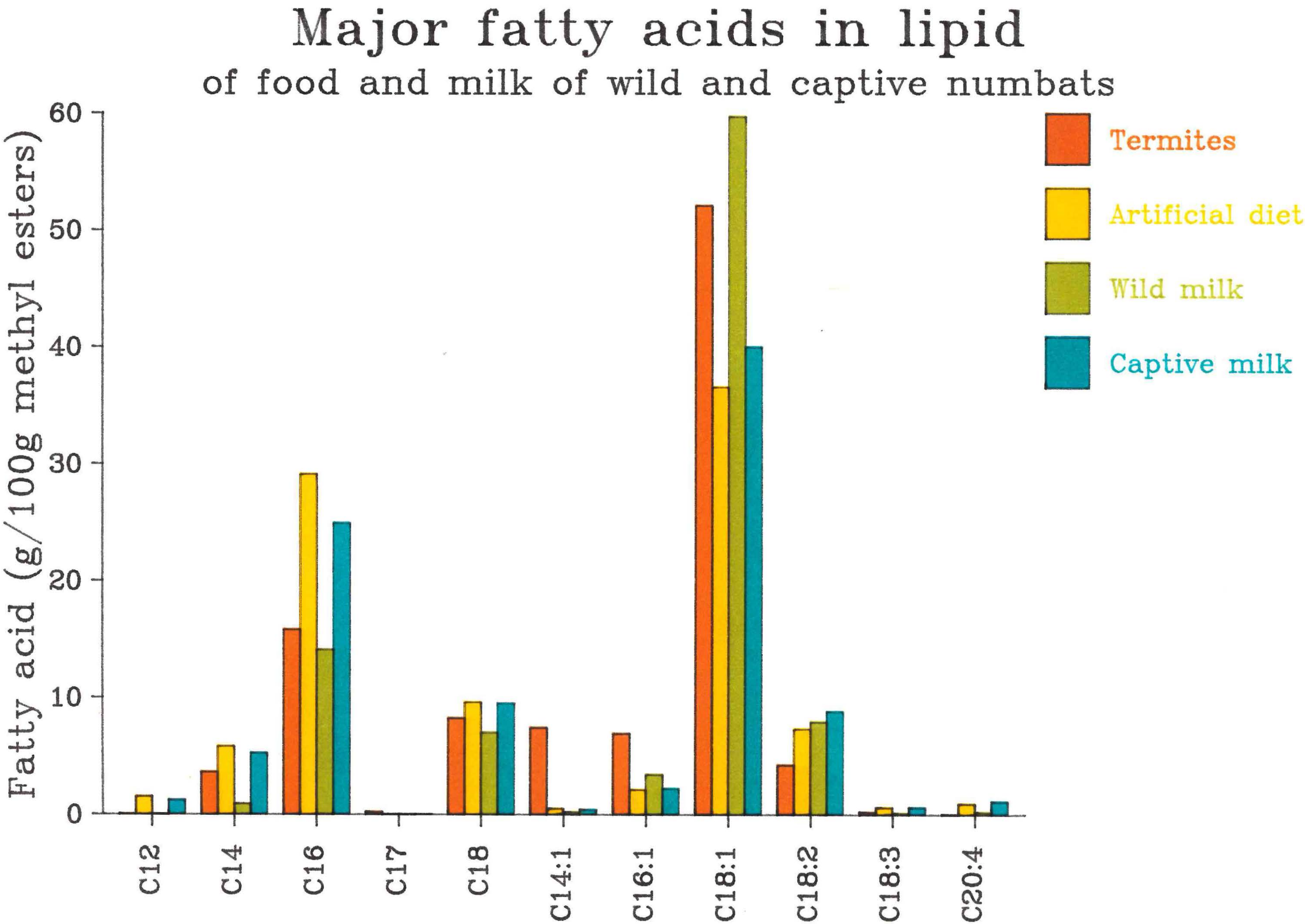
Cystine appears to be virtually absent from available termite protein according to the data of Griffiths (1968); however, later work (Griffiths, 1978) showed that this sulphur-containing amino acid was present in acid hydrolysates of N. exitiosus. Insect exoskeleton contains virtually no sulphur (Gilmour, 1965), so it appears that the cystine detected was in the termite flesh. Levels of sulphur-containing amino acids (cystine and methionine) are low in the artificial diet, but these correspond to low levels in the natural diet (Figure 3). The main requirement for sulphur, for the manufacture of keratin in hair and claws, can apparently be met by these low levels in the diet.

Leucine is present in the artificial diet in about twice the proportion found in termite protein. Massive imbalances involving high proportions of leucine can be toxic through the build-up of its breakdown products, but only at several orders of magnitude greater than the difference shown here (Harper, 1964).

Fatty acids of the lipid

A study of the fatty acids of the lipid in milk of wild and captive numbats by Griffiths et al. (in press) is summarised later. The proportions of different fatty acids in termites and in the artificial diet are shown with those in the two milks in Figure 4. The levels of fatty acids of the lipids in termites (N. exitiosus - various castes) are taken from Griffiths et al. (1984). The main difference between the two diets is in the relative proportions of palmitic (C16) and oleic (C18:1) acids.

Figure 4. Component fatty acids of the triglyceride fraction of the lipid in termites, the artificial diet fed to captive numbats, milk from wild numbats and milk collected from captive numbat 4F (fed on the artificial diet) just before the weaning of her two young. The fatty acid concentrations of termites used were given by Griffiths *et al* (1984) for a sample of *Nasutitermes exitiosus* (various castes). The other data are given in Griffiths *et al*. (in press).


Major fatty acids in lipid
of food and milk of wild and captive numbats
Fatty acid (g/100g methyl esters)
0
10
20
30
40
50
60
C12
C14
C16
C17
C18
C14:1
C16:1
C18:1
C18:2
C18:3
C20:4
Termites
Artificial diet
Wild milk
Captive milk

Moore (1969) remarked on the high degree of unsaturation present in termite fats. This is due in *N. exitiosus* to the high level of oleic acid in the triglyceride fraction. The artificial diet presents a more saturated lipid to the numbat. The response to this aspect of the diet is discussed later, with respect to numbat milk.

Cholesterol

There are no data available on the cholesterol content of termites, and given the high levels present in chicken's eggs, and hence in this artificial diet, deleterious effects of high dietary cholesterol levels should be watched for in captive colonies maintained on this diet.

Palatability of the artificial diet

The artificial diet was tried first in October 1984, when the captive-raised young of 2F (3F, 4F, 5M and 6M) were newly weaned. At this stage, the young numbats took to the custard more readily than the adults (Plates 3 & 4). Their mother was not interested in it at first and only ate it sparingly when given no choice. In order to compare the effect of diet, we transferred her back to termites after a few weeks. The young male 6M went off the custard after a week, however, and lost an alarming amount of weight. He was fed on termites for 10 days, then put back with his siblings. When 2F was taken off termites in late 1985 she

Plate 4. One of the captive-bred litter of female 2F demonstrating one method of eating the artificial diet. Photo: J.A. Friend.

was kept with one of her young, 10F, to encourage her to eat through competition for food. This strategy worked well, and no significant problems were experienced subsequently in the acceptance of the diet.

Adults maintained their weight on 80g of the mixture, weighed before the addition of termites and sand. Lactating females would eat up to 120g each day.

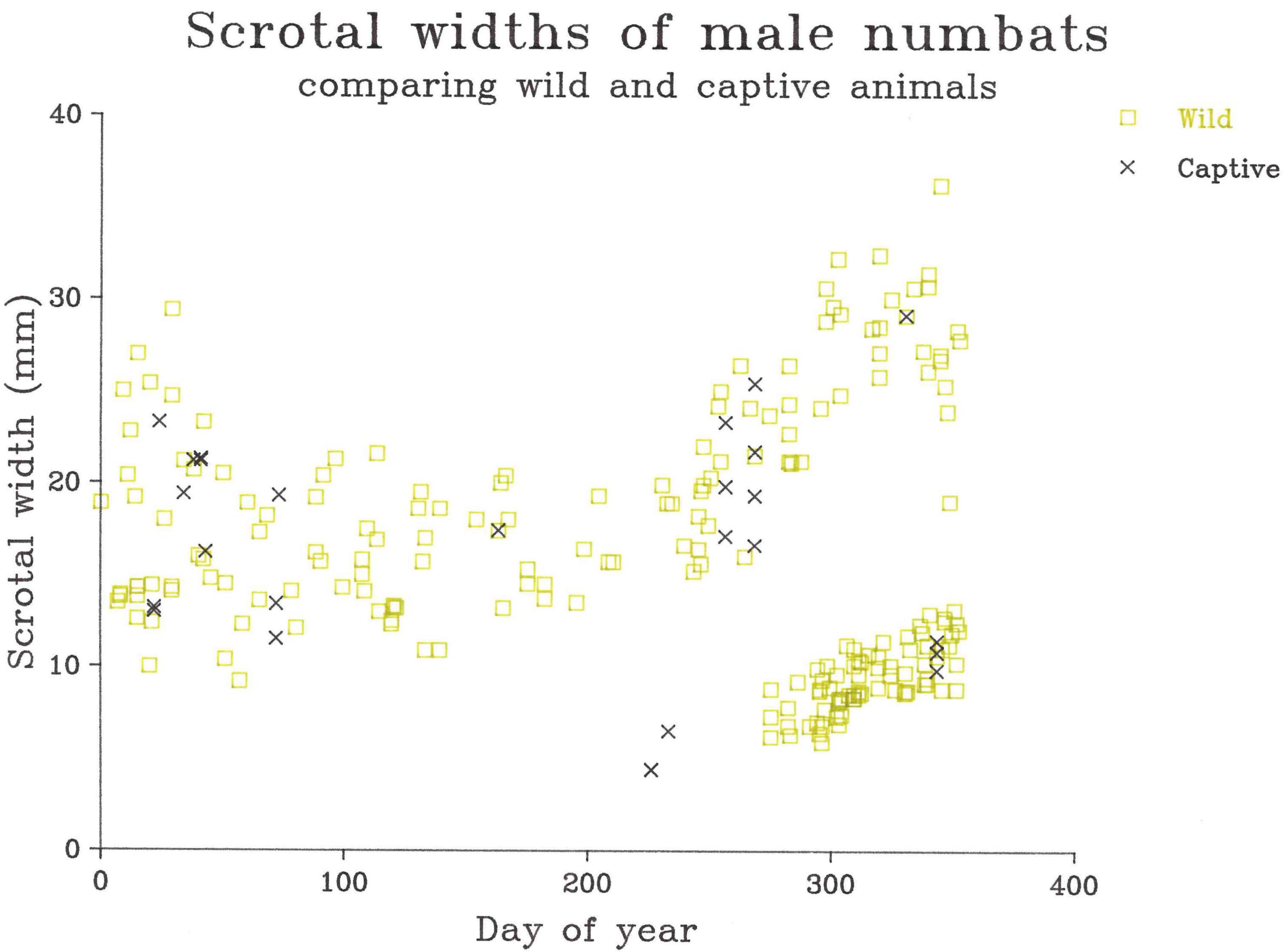
BREEDING AND DEVELOPMENT OF YOUNG

Breeding in the wild

Numbats are strict seasonal breeders, most young at Dryandra appearing on the females' nipples in the latter half of January (unpublished data). Two breeding seasons were therefore encompassed by the two-year project. On the basis of published information on breeding in dasyurids, we anticipated that the gestation period of our numbats would not be much in excess of four weeks. We therefore expected that mating would begin not long before Christmas.

This conclusion was also supported by evidence for a cycle of fertility in male numbats. The study at Dryandra had revealed that the testes of males change size dramatically during the course of the year, reaching their maximum size in November-December (Figure 5). The sternal gland, which has been

Figure 5. Comparison of scrotal widths of wild and captive male numbats measured throughout the year, showing seasonal variation. The two discrete groups of data in spring and early summer correspond to the young and adult males respectively.



Scrotal widths of male numbats
comparing wild and captive animals
Wild
Captive
Scrotal width (mm)
0
10
20
30
40
0
100
200
300
400
Day of year

thought to have a scent-marking role (Calaby, 1960), also shows an annual cycle of activity in wild animals (unpublished data). This gland shows its maximum level of secretion between October and January.

Field studies had also established that female numbats breed in their first year. By monitoring the development of radio-collared young it had been found, however, that the first-year males did not display any of the external signs of the annual breeding cycle observed in older males. Their testes showed steady growth over the summer and autumn, rather than the dramatic expansion and contraction referred to above (Figure 5). In addition, their sternal glands displayed minimal activity or none at all during that period.

Captive breeding at Woodvale, 1984-85

At the first breeding season, in summer 1984-85, the captive group comprised one adult male (1M), one adult female (2F), two one-year females (3F and 4F) and two one-year males (5M and 6M). For breeding purposes, then, only one male and three females were available at that stage.

The four young which had been brought in with 2F in July 1984 had been weaned in October as described earlier. The males were separated from the females on 12 December. The females (3F and 4F) were placed in cages on either side of 1M, while their mother

(2F) was in the fourth cage of that cage unit. At this stage, all animals were being fed the artificial diet. In order to determine the effect of diet on breeding and growth of young, the older female, 2F, was changed back on to a diet of termites on 3 January 1985. She had eaten the mix with greater reluctance than any of the other numbats, and had only been maintained on it since late November 1984.

On 25 December, the doors between the cages of 1M, 3F and 4F were opened. Although the male investigated the females occasionally, no mating was observed. After this day, the male was given access to one or other female for a short time on most days, always under observation. This was generally done in the late afternoon.

Commencing on 2 January 1985, daily collection of urine from the females was attempted so that the onset of oestrus could be detected through the appearance of cornified epithelial cells. It was necessary to catch the animal concerned in her cage outside, take her inside and place her in a glass-fronted box with a clean varnished wooden floor until she urinated. Some urine was then collected and placed on a microscope slide. It was then fixed and stained with Shorr's solution in order to detect cornification in any epithelial cells shed (Close, 1983). It was not always possible to catch the females for this purpose for fear of causing them undue stress. Table 2 shows the results of these checks. On 6 January, cornified epithelial cells were first seen in the urine of 3F. She mated with 1M late in the afternoon of the same day. Mating was a brief affair during which mounting, penetration and (presumably) ejaculation encompassed less than one minute. A few cornified epithelial cells were present in 4F's urine also on 6 January, but were much more prevalent the next day. When 1M was placed in 4F's cage later on 7 January, they also mated. Both 3F and 4F were kept isolated from the day of mating. The male 1M was let into 2F's cage daily, and mating was thought to have occurred on 14 January. She was subsequently isolated until 22 January, when the male was let in again. When he approached 2F, she growled and drove him off, so we again isolated her.

Table 2. Results of urine screening for cornified epithelial cells, in captive numbats, January 1985. (- no cornified epithelial cells; + cornified epithelial cells present)

Date	2F	3F	4F
2/1	-		
3/1		-	-
4/1		-	-
6/1		+ (mated)	few
7/1		+	+ (mated)
8/1			
9/1			
10/1			
11/1			
12/1			
13/1			
14/1	(mated)		
15/1			
16/1			
17/1			
18/1			
19/1			
20/1		young on teats	
21/1			young on teats
22/1			
23/1			
24/1			
25/1			
26/1			
27/1			
28/1	young on teats		

Pouch checks of mated females were made daily except on the occasions when it was impossible to catch the animal concerned. All pouches showed development apparently consistent with pregnancy. A swelling developed across the female's abdomen anterior to the mammary area, and swollen areas also appeared on the inside thighs, so the teats were enclosed in a distinct depression. During the later stages of this swelling, the interior of this depression was often moist, and the skin around the teats assumed a granular appearance. The anterior swelling observed in some animals at this stage is so large that it forms an engorged flap covering the mammary area. The teats of all females were now tiny and pink, even those of 2F, which as late as November had been 10mm long and pale in colour.

On 20 January, 14 days after mating, three young were found on 3F's nipples. Three young were also found on 4F's nipples on 21 January, but one had disappeared four days later. Four young were found in 2F's pouch on 28 January. In each case, a gestation period of 14 days was indicated.

1985/86 breeding season

After the successful mating of 1M with all three females in the first breeding season, it was considered undesirable to allow him to continue breeding in the group. He was therefore released into the wild, fitted with a radio-collar, on 25 November 1985. One of the two second-year males, 5M, was also released. Another

Plate 5. Female 2F with captive bred litter on 13 February 1985, two weeks after their birth. Photo: Dick Whitford.

adult male, 16M, was brought in from Dryandra Forest on 6 December. At the second breeding season (January 1986), therefore, the group of potential breeding animals comprised two males (6M and 16M) and eight females (2F, 3F, 4F, 8F, 9F, 10F, 12F and 15F). In order that all these individuals could be housed separately at Woodvale, the four first-year males (7M, 11M, 13M and 14M) were moved to Perth Zoo on 23 December.

One adult male was housed in each set of cages so that he could be given access to the females in the adjoining cages. Thus 16M could be let in with 2F and 10F (kept in the same cage), or with 3F, 4F or 12F. In the other set of cages, 6M could be given access to 8F, 9F or 15F.

On 7 January 1986, 4F was let in with 16M. Some interaction occurred while the animals were not being observed, because the hair on the female's neck and rump were later seen to be wet and ruffled. On the same afternoon, 6M was let in with each of the females in his cages. His response was to chase each female around the cage for several minutes, and no mating ensued. Over the next month, various pairings were set up, but no matings were observed. Pairs were frequently left together overnight. The male 6M continued his chasing behaviour when with a female until 3 February. At this stage his urine was checked and found to contain large numbers of sperm. However, measurements of their scrotal widths showed that the testes of both males had shrunk by early to mid February. On 3 February, 1M was recaptured and brought back to allow him to mate with the captive females. This was also unsuccessful.

Between 8 and 17 January, urine samples were taken from as many females as possible in order to detect the appearance of cornified epithelial cells. Pouch development and the appearance of a thick creamy discharge at the cloaca of the females were also noted. The results of these observations are shown in Table 3. At no time were sperm detected in the urine of females screened.

Detection of oestrus

The first year's results gave strong evidence that the gestation period of the numbat is 14 days. The appearance of cornified epithelial cells coincided with the first receptiveness of the female to the male. More detailed information was collected in the second year, when breeding did not occur. Despite the lack of births, most females showed strong swelling around the outside of the mammary area ("pouch development"). These swellings were present for less than a week. The duplication in unmated females of some of the external changes associated with pregnancy has been noted in dasyurids (Woolley, 1971), a group to which the numbat is closely related.

Table 3 shows the sequence of events in the second year. In both animals whose urine was screened on the same day as the creamy vaginal discharge appeared (2F and 4F), cornified cells appeared

Table 3. Results of urine screening and other observations on captive female numbats during January and February 1986. (-: no cornified epithelial cells present; +: cornified epithelial cells present; no + or -: no urine collected; CD: creamy vaginal discharge; PD: pouch development recorded)

Date	2F	3F	4F	8F	9F	10F	12F	15F
8/1	-	-	+CD					
9/1	-	-	-CD					
10/1	-	-				(CD)		
11/1								
12/1								
13/1	-							
14/1	+	CD						
15/1	+CD				-			
16/1	+	-		-	+			
17/1	-	-		+	-			
18/1								
19/1								
20/1								
21/1						CD		
22/1						CD		
23/1								
24/1		PD			-			
25/1								
26/1								
27/1								
28/1	PD							
29/1	PD			PD	PD			
30/1								
31/1								
1/2								
2/2								
3/2						PD		
4/2								
5/2								
6/2								PD

at the same time. This discharge may evidently be taken as an indication of the onset of oestrus. The periods from the first appearance of cornified cells (where checked) or the first vaginal discharge, until the maximum swelling around the pouch were as follows:

2F - 14 days   9F - 12 days

3F - 10 days   10F - 13 days

8F - 11 days

Male fertility

The lack of mating in the second year raises the possibility that the males used were not fertile; the evidence, however, does not support this suggestion. Firstly, all males used in breeding in both years displayed swollen and secreting presternal glands during the season at which these were active in the wild population (October to February). Secondly, measurements of scrotal width in the colony males showed that their testes were becoming enlarged in phase with the wild population (Figure 5). In addition, the region between the cloaca and the base of the tail was greatly swollen in all males. This is presumably due to the seasonal enlargement of the prostate glands, which provide transport fluid for the semen. Examination of urine for sperm was carried out on only two occasions during the second breeding season. On 10 January 1986, urine from 6M was examined and found to contain only a few sperm. On 3 February, however, both 6M and 1M were found to have high numbers of sperm in their urine.

If the impediment to mating concerned the males rather than the females, it is more likely to have been a behavioural than a physiological problem. In fact, there was some indication of a behavioural disorder in 6M as his response to being introduced into a cage with a female was to chase her. This contrasted with the behaviour of other males when introduced, which either ignored the female or paid a great deal of attention to her cloacal area. While 16M, the male brought in to replace 1M, did not display any such unusual behaviour, he rarely showed much interest in the females when caged with them. It is likely that the time allowed for his adjustment to captivity before the breeding season, about four weeks, was insufficient. He was seen out of his box much less than the other numbats during his first six months in captivity.

By the time 1M was brought back in from the wild, the testes of all the males had gone into decline, and it may well have been too late in the season.

The lesson to be learned here is that it is dangerous to rely on a small number of animals of either sex in captive breeding projects. If only one or two individuals of either sex are available, unforeseen problems even with one animal may result in failure, and in an annual breeding species, loss of a year's work.

Growth of young and the effect of diet

Some indication of the relative value of artificial and natural diets for breeding was gained by monitoring the growth and development of the young produced during the first breeding season. The older female, 2F, was maintained until November 1984 and from 3 January 1985 to 6 January 1986 on termites (mainly *Nasutitermes exitiosus*, but supplemented from time to time with *Coptotermes acinaciformis raffrayi*). The two younger females (3F and 4F) were fed the artificial diet described earlier, continuously from soon after their weaning in September 1984.

Breeding occurred in all three females in January 1985, so clearly the artificial diet was adequate to that stage. It may be significant, however, that only 2F, the female on the termite diet, produced a full litter. In fact, one of the three young of 4F was lost after a week. With only three individuals, it is impossible to draw any firm conclusions, but it is possible, in the light of the lack of breeding on the artificial diet in the second year, that diet also produced this lower fecundity.

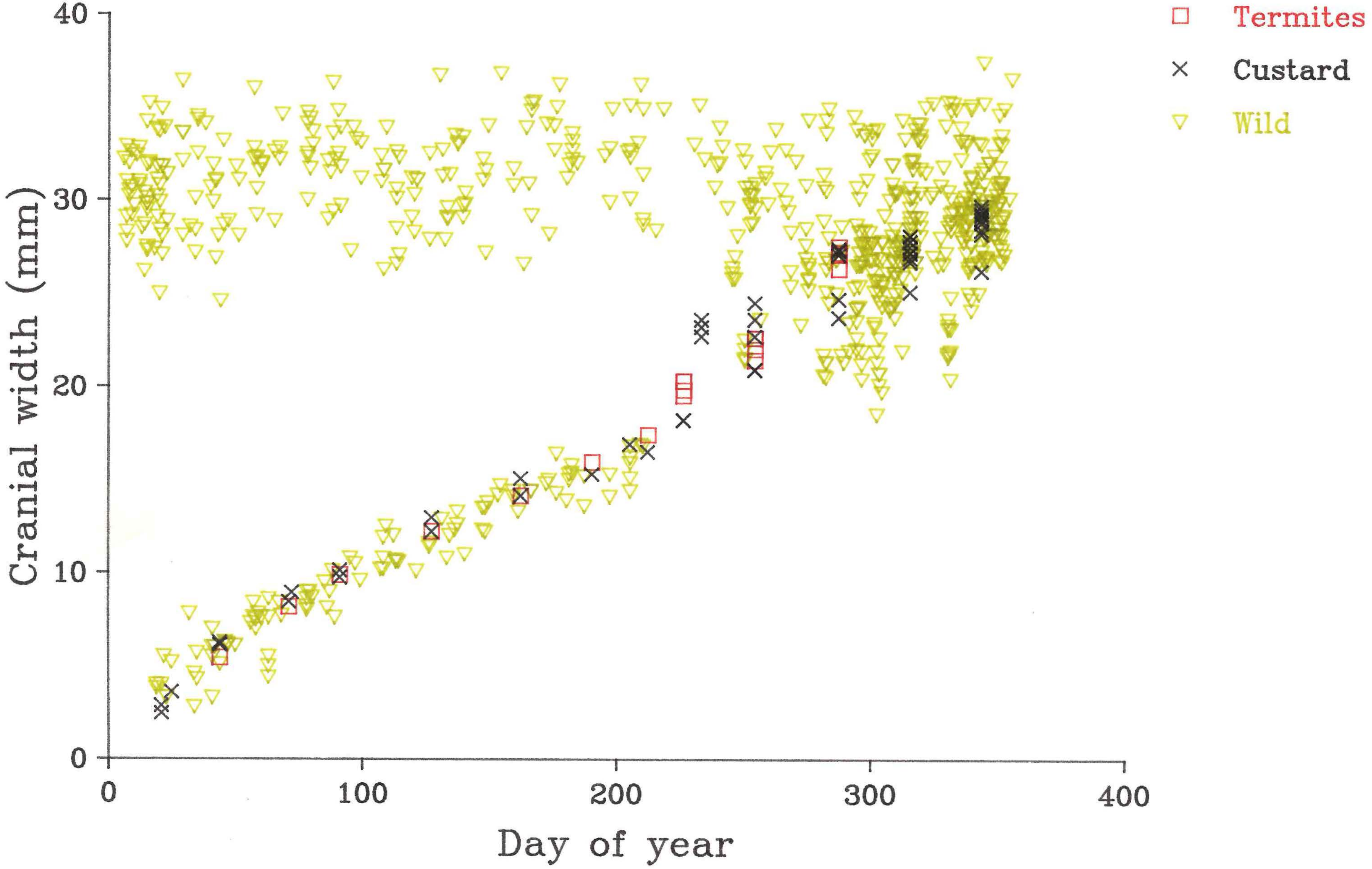
Figure 6 compares the growth of the captive young during the period of attachment with that of young measured in the wild during the period 1982-1987. Cranial width was used to monitor the size of the young, as it is easily measured during the period of attachment. Averages for each litter are given in Figure 6 for both wild and captive young during attachment, then individual measurements are shown after the young were first left in the nest.

The most important conclusion from Figure 6 is that the growth of the captive young, irrespective of diet, was within the range of that found in the wild. Differences between the growth of the captive litters were more easily explained by individual differences between the mothers as by diet. The young whose cranial widths were falling behind the others by late October belonged to 4F, and suffered a setback in mid-October when their

Figure 6. Cranial widths of numbats in the wild and young numbats in captivity measured throughout the year, comparing the growth of young raised by two females fed on the artificial diet (custard) with the growth of a litter raised by a female fed on termites. The points in the lower left part of the graph represent attached young. The data for attached young in captivity are shown for clarity as averages for each litter. The cloud of values at the top of the graph represents adult numbats in the wild.

Cranial widths of wild and captive numbats

Captive numbats fed on termites or artificial diet



mother began to act aggressively towards them. The male, 11M, lost part of his tail in one of these encounters, and the young had to be separated from their mother. They had not been weaned at this stage, and were placed with 2F. This female still had milk, although her young had recently been weaned, and she suckled 4F's young until they were also weaned about a week later.

Effect of diet on milk lipid constituents

Milk was collected from 4F near the weaning of her young and the constituent fatty acids in the triglyceride fraction of the milk fat determined, by methods described in Griffiths *et al.* (in press). Some mammals are incapable of synthesising certain of these fatty acids, so diet is important if the particular fatty acids are required. Samples of numbat milk collected at Dryandra Forest in October and some of the custard as fed to the captive numbats were analysed by the same methods. Figure 4 shows the concentrations of the important fatty acids found, as well as the results of an assay of termites (*Nasutitermes exitiosus*).

The most striking result of these comparisons is that it shows that the main elements of the fatty acid composition of the mother's diet are passed on in the milk to the young. Thus the milk produced by the females eating custard is correspondingly lower in oleic acid and higher in palmitic acid as is the custard compared with termites. This difference in the milk apparently has no effect on the growth and development of young, but the high levels of saturated fats in the artificial diet may be a starting point in the search for its deficiencies in other areas, such as breeding.

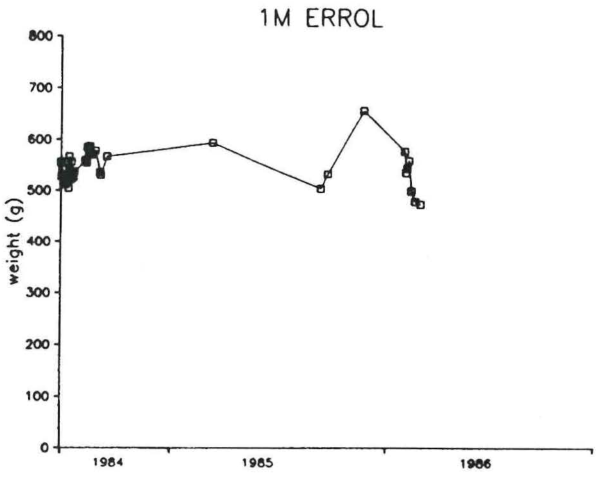
Observations on the lactation period in captivity

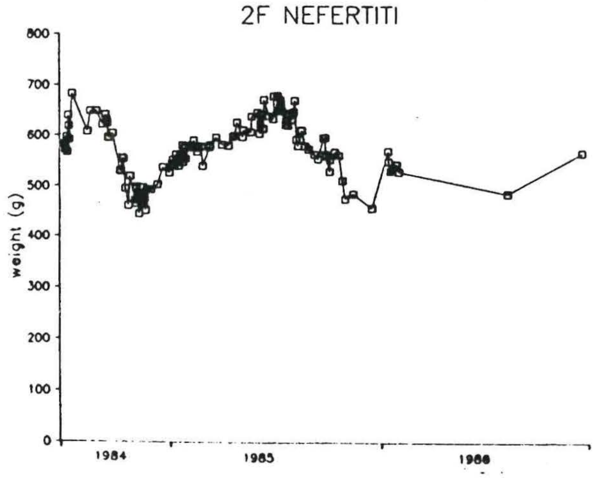
While many details of the development of young during the period of attachment had already been studied in the field (Friend and Burrows, 1983), holding females with young in captivity provided the opportunity to follow this phase more closely. The young were measured approximately monthly, and their increase in size is indicated by the change in cranial width shown in Figure 6. Two of the litters were able to be sexed on 1 April, so the sex of the individual on each nipple could be recorded. At this stage, 2F had four young (1 male, 3 females), 3F had three young (2 males, 1 female) and 4F had two (1 male, 1 female). The changes in pigmentation and growth of hair have been described by Friend and Burrows (1983). On 5 July, 3F left her young in the burrow in her outside enclosure during the day for the first time. By 9 July, 2F's young were found on different teats, indicating that they were releasing the nipples at night. On 12 July, 2F was brought inside and kept in a large glass-fronted box (1600mm x 700mm x 700mm) so that the development of the young could be monitored. 4F had been brought inside and placed in another box on 25 June when her newly-dug burrow collapsed. She came out of her nest box without her young on 24 July. The young still had their eyes closed, but their mouths were open and they were calling, with a chirping sound. By 31 July these young were quite mobile within the nest box. While 2F's young continued to move between nipples, she always emerged from her nest box with them attached, despite the fact that the eyes of one were open on 31 July.

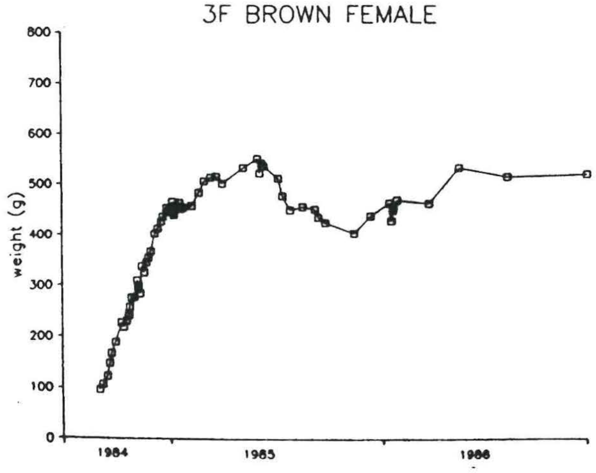
On 2 August we marked two of the three females in 2F's litter by clipping different hindfoot nails. As 4F's two young were male and female, they were not marked. One of 2F's young was the first to emerge from the nest, on 10 August. All of 3F's young were out on 21 August but 4F's did not emerge of their own volition until 4 September. At this stage they did not move around much, but spent a lot of time basking under the light or in the sun. They quickly became more active, however, and on 23 September 2F's young ate their first termites, followed on 1 October by 3F's young. Weaning occurred before the end of October, and all young were soon transferred to the artificial diet.

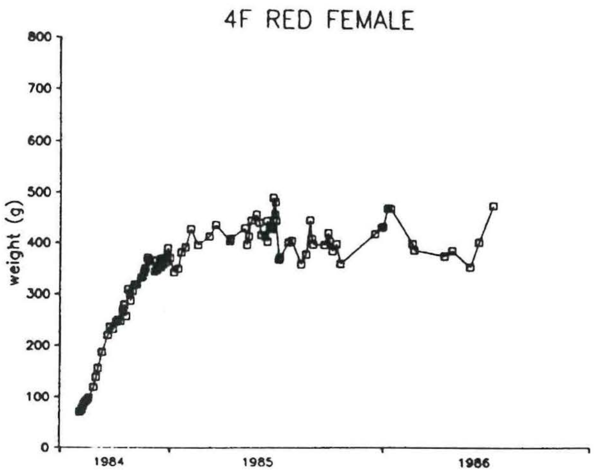
At this stage the adult females' nipples were 10mm long , pale and flaccid. By mid-December, they had shrunk and were tiny (1-2mm) and bright pink, in readiness for the next breeding season. Examination of the weight records of these three females (Figure 7) shows how female body weight fluctuates during the breeding and lactation periods. After reaching a minimum just before the weaning of their young, the female's weight increases as the breeding period approaches. At this stage there is a slight downturn, presumably as energy is diverted into the mating

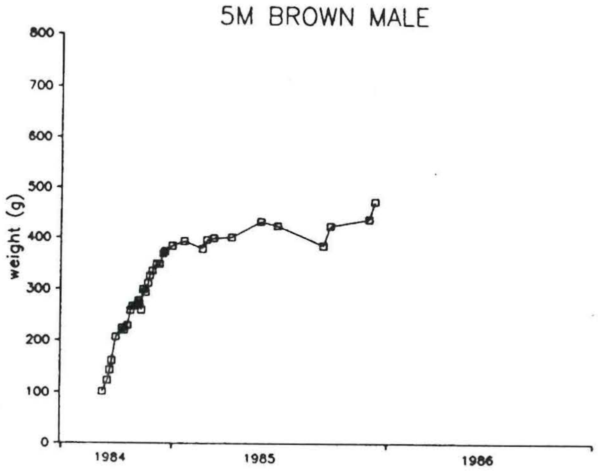
Figure 7. Weights of the numbats 1M, 2F, 3F, 4F, 5M and 6M in captivity during the period July 1984 - December 1986.


1M ERROL
weight (g)
0
100
200
300
400
500
600
700
800
1984
1985
1986


2F NEFERTITI
weight (g)
0
100
200
300
400
500
600
700
800
1984
1985
1986


3F BROWN FEMALE
weight (g)
0
100
200
300
400
500
600
700
800
1984
1985
1986


4F RED FEMALE
weight (g)
0
100
200
300
400
500
600
700
800
1984
1985
1986


5M BROWN MALE
weight (g)
0
100
200
300
400
500
600
700
800
1984
1985
1986

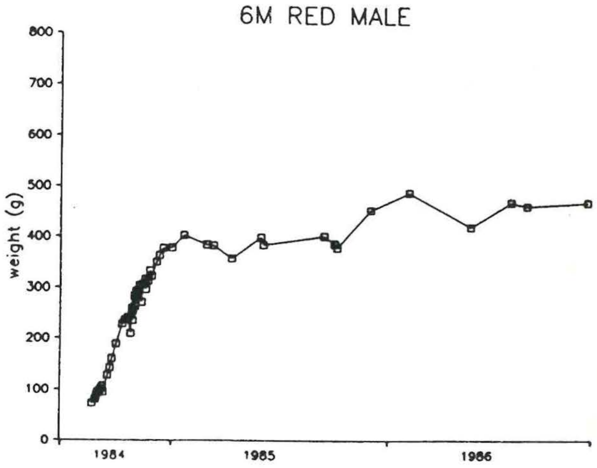
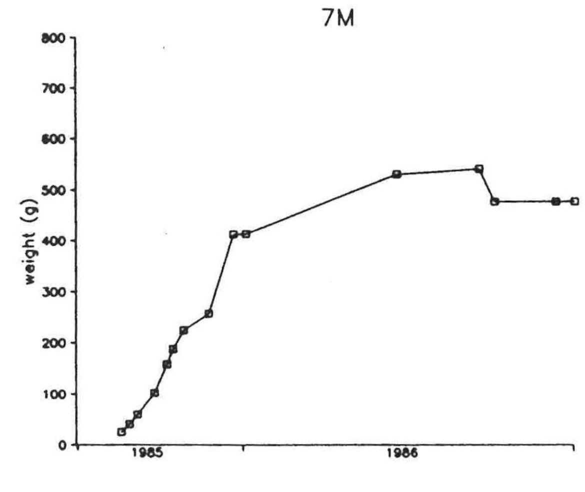
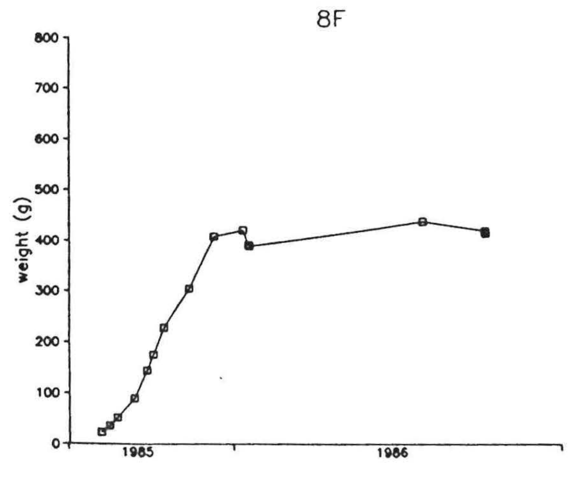
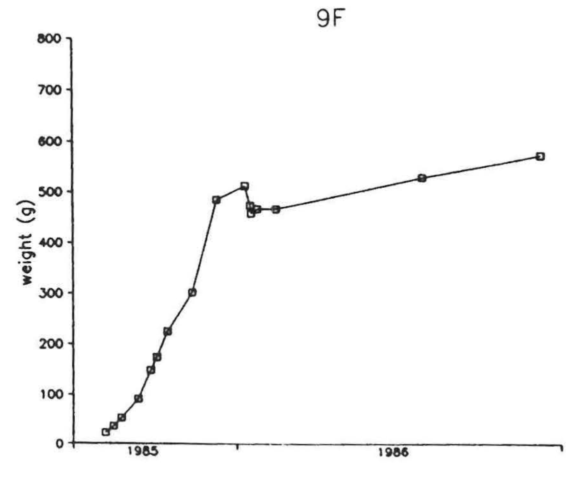
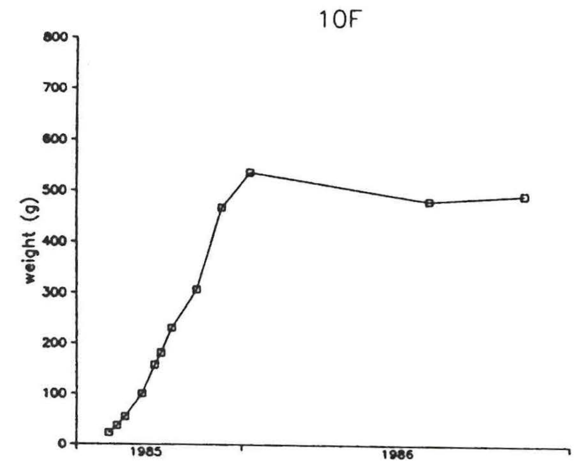

6M RED MALE
weight (g)
0
100
200
300
400
500
600
700
800
1984
1985
1986

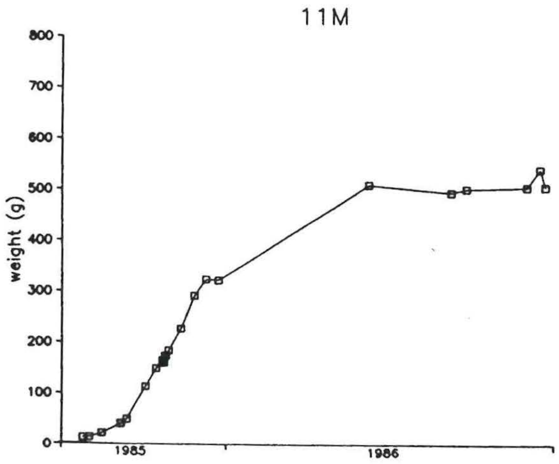
Figure 8. Weights of the numbats 7M, 8F, 9F, 10F, 11M and 12F in captivity during the period July 1985 - December 1986.


7M
weight (g)
800
700
600
500
400
300
200
100
0
1985
1986


8F
weight (g)
800
700
600
500
400
300
200
100
0
1985
1986


9F
weight (g)
800
700
600
500
400
300
200
100
0
1985
1986


10F
weight (g)
800
700
600
500
400
300
200
100
0
1985
1986


11M
weight (g)
800
700
600
500
400
300
200
100
0
1985
1986

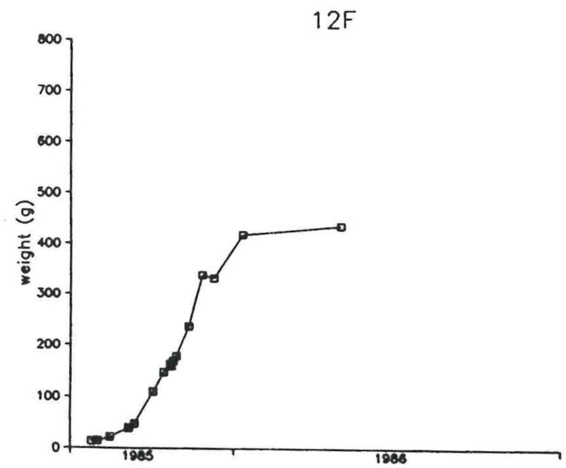
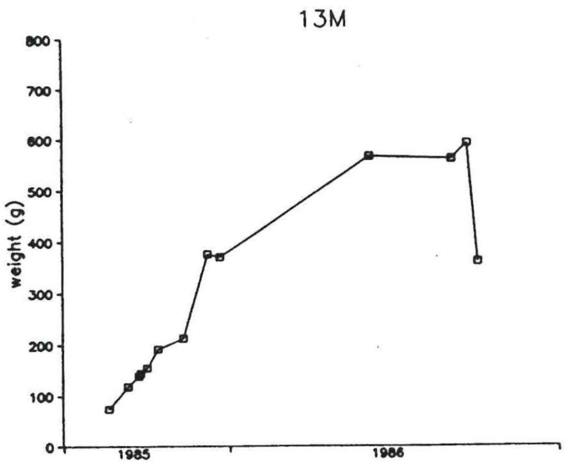
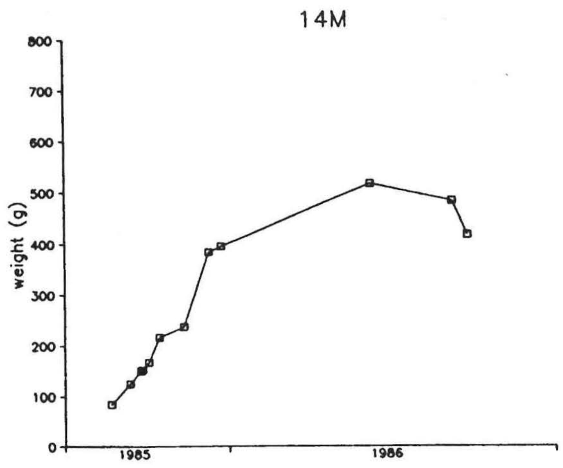
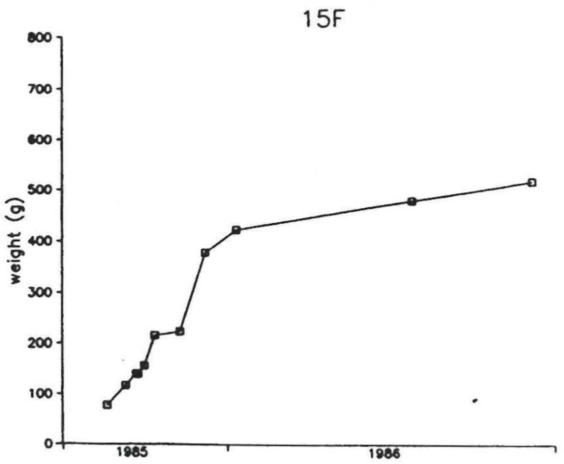
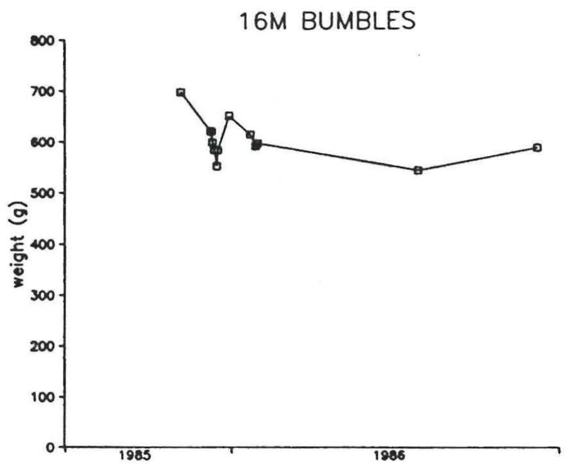

12F
weight (g)
800
700
600
500
400
300
200
100
0
1985
1986

Figure 9. Weights of the numbats 13M, 14M, 15F and 16M in captivity during the period July 1985 - December 1986.


13M
weight (g)
800
700
600
500
400
300
200
100
0
1985
1986


14M
weight (g)
800
700
600
500
400
300
200
100
0
1985
1986


15F
weight (g)
800
700
600
500
400
300
200
100
0
1985
1986


16M BUMBLES
weight (g)
800
700
600
500
400
300
200
100
0
1985
1986

process. Once the progeny appear, however, the combined weight of female and litter grows rapidly to a maximum in July, when the young are left in the burrow. Even the loss of their weight has only a small impact on the mother's weight, which has built up to a maximum. During the subsequent part of the period of lactation, however, the heavy suckling of the rapidly-growing young apparently causes a severe loss of weight, so that by November the female's weight has fallen back to its minimum. This fluctuation of weight in 2F involved a loss of over 30% of her weight between July and December. The graphs of 8F and 9F show the fall-off of weight during the breeding season, but as they did not conceive, their weights did not continue to grow rapidly afterwards.

EVENTS SINCE THE CONCLUSION OF PROJECT 50

Since the cessation of funding by WWFA in December 1985, a number of developments have occurred which will affect the future of the colony and the direction of further research.

Firstly, four individuals (1M, 2F, 5M amd 10F) have been released, fitted with radio-collars, at Boyagin Nature Reserve, as part of WWFA Project 94 ("Re-establishment of the Numbat in areas of its former occurrence"). Most importantly, the female 2F, which had bred in captivity in January 1985 but not in January 1986, was released in December 1986. Although by this time, she had been kept for almost a year on the artificial diet, she produced young in late January 1987, which had undoubtedly been conceived in the wild. This means that if diet produced an effect inhibitory to breeding, it was a rapidly reversible effect.

Secondly, all numbats remaining at Woodvale were transferred to Perth Zoo in December 1986, but remain the property of the Department of Conservation and Land Management (CALM). Techniques of husbandry have been essentially the same as those used at Woodvale. There was no breeding in either January 1987 or January 1988. This was despite the introduction into captivity of a female with four attached young in May 1987 and two adult males in early November 1987, and despite the fact that mating was observed on several occasions.

Thirdly, a joint proposal between CALM and Perth Zoo was put forward late in 1986 to set up a co-operative "breeding management programme" involving several Australian zoos. An agreement to implement this proposal has not yet been finalised with the Association of Zoo Directors of Australia and New Zealand.

SIGNIFICANCE OF RESULTS

Major advances in numbat husbandry made through this study include:

1) the breeding and raising of young in captivity,

2) the development of techniques for aquiring and keeping a large supply of live termites,

3) the first successful use of an artificial diet to maintain numbats in captivity and

4) the documentation of reproductive events through the close observation of individuals in captivity.

While numbats had produced young in captivity before, their survival had been very short, presumably because of the conditions under which the mother was kept. The high level of attention to the animals which was possible in this project through having one person full-time to look after them was no doubt significant in the survival of the young. The availability of sufficient space to house all animals individually, more closely resembling the natural solitary habits of the species, might also have enhanced their survival.

Even in Perth, termite availability is not guaranteed at certain times of year. However, with a little planning, by setting up traps for Coptotermes and making the most efficient use of Nasutitermes mounds, it is possible to have access to a constant large supply of live termites with the investment of a few hours a week. These techniques will not work in all parts of Australia, but could be adapted to suit the local species in the regions of several capital cities.

The ultimate solution to feeding insectivorous animals in captivity is to develop a diet composed of readily-available ingredients. While the custard diet developed during this project satisfies many of the criteria for a termite substitute, there is still some doubt that it supplies everything needed by numbats, since numbats fed on it for long periods have not bred. It is clear that further dietary manipulation is necessary, firstly to establish if non-breeding animals will breed again on a termite diet, and secondly whether a formulation even closer to termites will allow breeding.

The indication that oestrus can be accurately monitored in numbats is most significant for further research. It means that it should be possible to discover the reason for any future lack of breeding by following closely the changes in both males and females which occur at that time of year.

While the problems involved in breeding numbats in captivity are by no means solved, there is now a strong base upon which to carry out further research. Furthermore, there is now a group of animals in captivity which may be used in this research. Maintenance techniques have been passed on to, and are being further developed by staff at Perth Zoo. Several zoos have expressed interest in being involved in an expanded research and captive breeding programme. It is likely, however, that the research component will be beyond the resources of most zoos, and will require the input of expertise and possibly funds from other institutions.

DETAILED RECOMMENDATIONS FOR MANAGEMENT AND ACTION BY WWF AUSTRALIA ARISING FROM THE STUDY

Clearly, further research into techniques of captive breeding is required. A somewhat different approach needs to be taken than the one adopted in this study. While we tended to leave the numbats alone as much as possible, a more intensive monitoring of the physiological changes in both males and females is now warranted. The breeding season in numbats appears to be very precise in its timing, and it is possible that seasonal changes in the reproductive physiology of captive males and females are not coinciding due to the distortion or lack of some environmental cue. In order to address this question, rather precise information on the timing of these events in the wild and in captivity is required.

While the artificial diet appears adequate for maintenance of adults and growth of both suckling and weaned young, the poor breeding record of animals fed on it requires examination. A controlled experiment, with several pairs on each of several different diets, should be carried out, in an attempt to separate the effect of diet from other influences. One of these diets should be termites alone. In order to carry out these studies, a minimum of twelve adult animals (six males and six females) would need to be used.

In many ways, zoos provide an ideal location for this kind of research. For much of the year, intensive monitoring would not be required, yet in a research institution which did not have a major animal house, a group of animals sufficiently large for these purposes would tie up personnel in a chiefly maintenance role. While extra resources might be required to construct suitable enclosures at a zoo, much of the infrastructure involved in the care of animals is already there. It is more likely to be practical than the establishment of a large colony of numbats in an institution which is not geared up for caring for animals. Our strong recommendation is that WWFA seriously consider requests for funding along these lines.

The problems which have surfaced during this attempt at breeding numbats in captivity serve to highlight the importance of the wild populations. It is gratifying that WWFA has supported work on re-establishing numbats in the wild as well as attempts at captive breeding.

PUBLICATIONS ARISING FROM THE STUDY

Friend, J.A. and Whitford, D. (1986). Captive breeding in the Numbat (Myrmecobius fasciatus). Australian Mammal Society Bulletin 9(1): 54.

Friend, J.A. (1988). Numbat conservation. Australian Bulletin of Zoo Management (in press).

Griffiths, M.E., Friend, J.A., Whitford, D. and Fogerty, A.C. (1988). Composition of the milk of the Numbat, Myrmecobius fasciatus (Marsupialia) with particular reference to the fatty acids of the lipids. Australian Mammalogy (in press).

ACKNOWLEDGEMENTS

World Wildlife Fund Australia provided most of the resources to run this project. We would like to express our gratitude to the organisation for giving us the opportunity to undertake this study, and to the WWFA staff members who gave their constant encouragement. The Western Australian Government, through the Department of Fisheries and Wildlife, and later the Department of Conservation and Land Management, provided vital facilities and staff time.

Many other people contributed to the success of this project. In particular, we are indebted to Dr Merv Griffiths for invaluable advice on an artificial diet, and to Dr Tony Watson (CSIRO Division of Entomology) for passing on techniques for developing our termite supplies. Dr Geoff Kirkman devoted much time and energy to setting up termite traps and providing us with a steady supply of Coptotermes. Dr Bill Gaynor (Perth Zoo) was always prepared to diagnose and treat sick numbats, and Dr Graham Robertson and Dr Julie Lloyd (Department of Agriculture) readily took on the task of bacteriological analysis of numerous faecal samples.

Assistance at Woodvale from W.A. Wildlife Research Centre staff was always forthcoming, and we are particularly grateful to Mr Allen Mangini for constructing cages, and to Mr Mike Churches for cheerfully taking over weekend feeding. Mr Bruce Turner and Mr Neil Thomas assisted in the compilation of data for this report. Finally, we are greatly indebted to Dr Andrew Burbidge, who, as head of Wildlife Research throughout the project gave it his utmost support, and most importantly, managed to find extra funds which allowed work to continue well beyond the original timetable.

REFERENCES

Calaby, J.H. (1960). Observations on the Banded Ant-eater *Myrmecobius fasciatus* Waterhouse (Marsupialia), with particular reference to its food habits. *Proceedings of the Zoological Society of London* 135:183-207

Christensen, P.E.S. (1980). A sad day for native fauna. *Forest Focus* 23:3-12

Christensen, P., Maisey, K. and Perry, D.H. (1984). Radio-tracking the Numbat, *Myrmecobius fasciatus*, in the Perup Forest of Western Australia. *Australian Wildlife Research* 11:275-288

Close, R.L. (1983). Detection of oestrus in the kowari *Dasyuroides byrnei* (Marsupialia: Dasyuridae). *Australian Mammalogy* 6:41-43

Collins, L.R. (1973). *Monotremes and Marsupials - a reference for zoological institutions*. Smithsonian Institution Press: Washington

Connell, G.W. and Friend, J.A. (1985). Searching for numbats. *Landscope* 1(2):21-26

Critchell, M.W.G. (1969). A weekend with a numbat. *Gilliana* 1969:19-24

Dale, R. (1833). Letters from Mr Dale, giving a summary description of the country passed over in going to Mount Bakewell, and, also, in an expedition to examine the country to the north and south of that place. Pp.155-160 *in* J. Cross (ed.) *Journals of Several Expeditions Made in Western Australia During the Years 1830, 1831, and 1832*; under the sanction of the Governor, Sir James Stirling, containing the latest authentic information relative to that country, accompanied by a map. J. Cross: London

Fleay, D. (1942). The Numbat in Victoria. Victorian Naturalist 59:3-7

Fleay, D. (1949). The peculiar little Numbat. Animal Kingdom 52(5):144-148

Friend, J.A. and Burrows, R.G. (1983). Bringing up young numbats. SWANS 13(1):3-9

Friend, J.A. (1987). Local decline, extinction and recovery - relevance to mammal populations in vegetation remnants. Pp.53-64 in D.A. Saunders, G.W. Arnold, A.A. Burbidge and A.J.M. Hopkins (eds) Nature Conservation: the Role of Remnants of Native Vegetation. Surrey Beatty and Sons: Sydney

Gay, F.J., Greaves, T., Holdaway, F.G. and Wetherly, A.H. (1955). Standard laboratory colonies of termites for evaluating the resistance of timber, timber preservatives, and other materials to termite attack. CSIRO Bulletin 277:1-60

Gilmour, D. (1965). The Metabolism of Insects. Oliver and Boyd: Edinburgh

Glauert, L. (1935). Answers to correspondence. Our Rural Magazine June 1935:147-150

Gould, J. (1863). The Mammals of Australia. J. Gould: London

Green, B., Griffiths, M. and Newgrain, K. (1985). Intake of milk by suckling echidnas (Tachyglossus aculeatus). Comparative Biochemistry and Physiology 81A(2):441-444

Griffiths, M. (1965). Digestion, growth and nitrogen balance in an egg-laying mammal Tachyglossus aculeatus (Shaw). Comparative Biochemistry and Physiology 14:357-375

Griffiths, M. (1968). Echidnas. Pergamon Press: London

Griffiths, M. (1978). The Biology of Monotremes. Academic Press: New York

Griffiths, M., Green, M., Leckie, R.M.C., Messer, M. and Newgrain, K.W. (1984). Constituents of platypus and echidna milk, with particular reference to the fatty acid complement of the triglycerides. Australian Journal of Biological Sciences 37:323-329

Griffiths, M., Friend, J.A., Whitford, D. and Fogerty, A.C. Composition of the milk of the Numbat, Myrmecobius fasciatus (Marsupialia), with particular reference to the fatty acids of the lipids. Australian Mammalogy (in press)

Harper, A.E. (1964). Amino Acid Toxicities and Imbalances, in Mammalian Protein Metabolism Vol.II. Academic Press: New York

Holdaway, F.G., Gay, F.J. and Greaves, T. (1935). The termite population of a mound colony of Eutermes exitiosus Hill. Journal of the Council for Scientific and Industrial Research 8(1):42-46

Holdaway, F.G. and Gay, F.J. (1948). Temperature studies of the habitat of Eutermes exitiosus with special reference to the temperatures within the mound. Australian Journal of Scientific Research series B - Biological Sciences 1(4):464-493

La Fage, J.P. and Nutting, W.L. (1978). Nutrient dynamics of termites. Pp.165-232 in M.V. Brian (ed.) Production ecology of ants and termites. Cambridge University Press: London

McNab, B.K., (1984). Physiological convergence amongst ant-eating and termite-eating mammals. Journal of Zoology, London 203:485-510

Menzies,J.I. (1962). Feeding pangolins (Manis spp.) in captivity. International Zoo Yearbook 4:126-128

Merritt, D,A. (1973). Edentate diets. I. Armadillos. Laboratory Animal Science 23(4):540-542

Merritt, D.A. (1975). The lesser anteater Tamandua tetradactyla in captivity. International Zoo Yearbook 15:41-45

Moore, B.P. (1969). Biochemical studies in termites. Pp.407-432 in K. Krishna and F.M. Weesner (eds) Biology of Termites. Academic Press: London

Oglesby, R. (1981). Management of young marsupials. Keeping Marsupials 1(2):21-34

Redford, K.H. and Dorea, J.G. (1984). The nutritional value of invertebrates with emphasis on ants and termites as food for mammals. Journal of Zoology, London 203:385-395

Sampsell, R.N. (1969). Hand rearing an aardvark Orycteropus afer at Crandon Park Zoo, Miami. International Zoo Yearbook 9:97-99

Spinelli, N. (1970). Hand-rearing an aardwolf Proteles cristatus. International Zoo Yearbook 10:82-83

Stephens,T., Irvine, S., Mutton, P., Gupta, J.D. and Harley, J.D. (1974). Deficiency of two enzymes of galactose metabolism in kangaroos. Nature, London 248(5448):524-525

Strahan, R. (1978). Status and husbandry of Australian monotremes and marsupials. Pp.171-182 in R.D. Martin (ed.) Breeding Endangered Species in Captivity. Academic Press: London

Turner, J. and Borthwick, J. (1980). Status of the Numbat Myrmecobius fasciatus population in Western Australia. Unpublished report, Department of Fisheries and Wildlife, Western Australia

United States Department of Agriculture, (1976). Composition of foods. Dairy and egg products: raw, processed. Agriculture Handbooks 8-1. USDA Agricultural Research Service: Washington, D.C.

van Reenen, G. (1986). Scouring fawns - a new approach. The Deer Farmer 28:22-23

Wagstaffe, R. and Rutherford, G. (1954). Letters from Knowsley Hall, Lancashire. III. John Gilbert. North Western Naturalist 25:487-503

White, A., Handler, P., Smith, E.L., Hill, R.L. and Lehman, I.R. (1978). Principles of Biochemistry (6th edn). McGraw-Hill Inc.: New York

Woolley, P. (1971). Maintenance and breeding of laboratry colonies of Dasyuroides byrnei and Dasycercus cristicauda. International Zoo Yearbook 11:351-354

Young, E., (1966). A suitable milk substitute for the Aardvark Orycteropus afer and Echidna Tachyglossus aculeatus. International Zoo Yearbook 6:68-69

Young, E. (1973). The general care and nutrition of wild mamals in captivity. Pp.134-147 _in_ E. Young (ed) _The Capture and Care of Wild Animals_. Human and Rousseau: Cape Town

APPENDIX 1 Identification of individuals

Code	Birthdate	Born	Raised	Mother	Father	Name
1M	pre 1984	W	W	?	?	Errol
2F	pre 1984	W	W	?	?	Nefertiti
3F	1984	W	C	2F	?	Brown o
4F	1984	W	C	2F	?	Red o
5M	1984	W	C	2F	?	Brown o
6M	1984	W	C	2F	?	Red o
7M	28/1/85	C	C	2F	1M	
8F	28/1/85	C	C	2F	1M	
9F	28/1/85	C	C	2F	1M	
10F	28/1/85	C	C	2F	1M	
11M	21/1/85	C	C	4F	1M	
12F	21/1/85	C	C	4F	1M	
13M	20/1/85	C	C	3F	1M	
14M	20/1/85	C	C	3F	1M	
15F	20/1/85	C	C	3F	1M	
16M	pre 1985	W	W	?	?	Bumbles

W = wild C = captivity

APPENDIX 2. Notes on maintenance of numbats in captivity distributed to interested zoos in February 1986.

NOTES ON THE MAINTENANCE OF THE NUMBAT IN CAPTIVITY

J.A. FRIEND and R.W. WHITFORD

W.A. Wildlife Research Centre
PO Box 51, WANNEROO W.A. 6065

These notes have been prepared for the benefit of zoos participating in the numbat captive breeding programme. They contain unpublished information and are not intended for general distribution or publication. Prepared 19 February 1986.

1. ENCLOSURES

The specifications of the cages in which our numbats are housed at present are attached. Note the following points, however:

a) We used welded fabric wire of 1.6 mm diameter rather than 1.3 mm, for security and to extend the life of the buried wire.

b) It is sufficient to bury the wire mesh on outer walls only 600 mm. Numbat burrows are up to 2 m long, fairly straight, sloping steadily down at a shallow angle, with a chamber at the end. This is usually at a depth of 400-500 mm. We have never observed multiple tunnels; we are confident that numbats will not dig under wire at this depth and up the other side.

c) The cage size of 5 m x 3 m x 2 m is regarded as a minimum for the containment of one animal for more than a short period of time.

d) The design of external doors with a high step-over wall below is essential, unless a double set of doors is constructed. Numbats are accomplished escape artists!

e) A roof of the same small-aperture wire is necessary to prevent escape by climbing, at which numbats are also adept. Entry by predators (cats, raptors, reptiles) will also be prevented. Part of the roof should incorporate shelter such as translucent corrugated fibreglass sheeting. This provides some dry areas within the enclosure but does not completely exclude rain for vegetation growth (watering is not recommended!). Translucent roof panels maximise sun for basking in winter. We used shadecloth in summer to provide a shady section in each enclosure.

2. SITE

It should be borne in mind that numbats were never known to occur in areas without a regular annual drought. The captive numbats are from Dryandra Forest, which experiences an annual average rainfall of 500 mm, of which 80% falls in late autumn and winter. There are only 2-3 rain days each month in December, January and February. Thus the presence of free water in enclosures should be minimised.

The site of the enclosure should, therefore, be sunny and well-drained. The ground must not become waterlogged. Numbats can cope with excess sunshine but not with dampness. It may be necessary to control drainage from upslope or even to modify the substrate.

3. SUBSTRATE

As well as providing a well-drained base, the floor of the enclosures should allow the construction of burrows, which are important for thermoregulation in both hot and cold weather. The ideal substrate is a heavy sand or light clay soil in which the roots of shrubs or trees provide some structure, to facilitate burrowing. In the absence of shrubs, our numbats have burrowed down beside the buried wire mesh at the sides of the cage. It may be necessary to lighten heavy clay soils with sand to allow burrows to be dug.

The numbats which were at Taronga Zoo during the 1970s were kept in a small enclosure, the floor of which was covered with a deep accumulation of spent termite mound material. Eventually this was sufficiently deep that the numbats could burrow into it. Lumps of solid mound material apparently provided the structure which the animals utilized to support their burrows as they excavated the friable material from the crevices.

4. SHELTER

Apart from burrows, hollow logs form the natural shelter used most frequently by numbats. Logs with wide hollows are useful as "cage furniture", but logs selected as night shelters in the wild usually have hollows of less than 8 cm internal diameter. The animals are adept at the "flip-turn" even in very narrow cavities. We have also used long, narrow waterproof nest boxes fitted with hinged lids, when it was foreseen that we would need to catch individual animals regularly.

Nest logs and nest boxes have only one entrance; a nest is built as far as possible from it. Nest material should be provided at regular intervals, although most nest-building in captivity occurs as overnight temperatures drop in early winter. At this time there is a flurry of activity as each animal carries large quantities of nest material into the log, burrow or nest box in use as a night shelter at that time.

Dry grass is ideal as nest material although fibrous bark and eucalypt leaves are also used. There is a record of the use of newspaper in a nest, so it is probable that any similar available material will be incorporated. If suitable material is not provided, the animals will strip their enclosures of vegetation.

5. FOOD

We have kept numbats on three diets - termites, egg/Digestelact mixture supplemented with 10% termites, and pure egg/Digestelact mixture (ingredients below). All of these diets are sufficient to maintain adults and to promote growth in young before and after weaning.

Artificial diet

6 eggs, (55 g each)
154 g (16 scoops) Digestelact (low-lactose milk formulation - Sharpe Laboratories)
680 ml water
The milk powder is dissolved in cold water, and eggs added. This mixture is heated in a steamer or microwave oven until it stiffens, but before liquid separates out. It is cooled as quickly as possible (in a refrigerator). Before it is fed to numbats, ½ teaspoon of vitamin supplement (we used Brisfarm SA-37) and 2 heaped teaspoons of calcium carbonate powder are stirred in. About 5% by weight of sandy soil is then added.

Each animal eats about 80 g per day, (weighed before adding sand) although lactating females will take more. Animals eating termites alone consume 60-120 g per day, depending on their sex and reproductive state. Sand is also mixed with live termites before feeding as it appears to be important in breaking up the insects' bodies in the gut. Our numbats often ingested sand from the cage floors; their droppings are full of sand, whether or not large quantities are actually added to their food.

Breeding occurred in 1985 in animals on both termites and Digestelact mixture plus termites, but did not occur in 1986 on the latter diet. We are not sure that the diet was deficient as no animals were kept on termites leading up to the 1986 breeding season. Other possible explanations exist for the lack of breeding this year. We would like to continue research on artificial diets with the co-operation of participating zoos. This would mean that animals would be maintained on several diets. One of these diets should be termites alone; this should be feasible at Perth Zoo. It may also be possible to procure enough termites at Taronga or Western Plains Zoo.

5. BREEDING

This occurs in the wild at Dryandra over a period of 2-3 weeks in January (Friend, unpublished). In 1985, mating in captivity occurred on 6, 7 and 14 January. This was preceded for 2-3 days by the appearance of cornified epithelial cells in the female's urine. Significant pouch development occurs at this time also, through the engorgement of tissue anterior to the mammary area, and of ventral areas medial to each femur. Thus three walls of swollen tissue enclose the teats, which are small and bright pink at this stage. The interior of the pouch is kept moist by licking and possibly by vaginal secretions.

Females are most likely to lose young in the first 2-3 weeks after parturition. If males and females are left together during the mating season, therefore, they should be separated as soon as young are found in the pouch.

The pouch virtually disappears within a few weeks of parturition, and the young are protected by the mother's long ventral hair which covers them. They grip on with their forefeet to fine, crimped, yellow hairs around the teats and are held also by mouth to the teat, as is the case in other marsupials.

If a female with young is left in an enclosure where a burrow has been dug, she will deposit them in the burrow. This occurred in June or July in our colony. The young start to emerge between early August and late September, and the first will be weaned in late September. We were not able to wean the young straight on to the artificial diet, but after being fed on termites for 2-3 weeks they readily accepted the mixture.

6. GENERAL POINTS

(a) Basking appears to be an important activity in the early morning and during the cooler months. As emphasised earlier, entry of sunlight into the enclosure is essential. If animals are kept inside for any time, a lamp should be provided and left on all day to allow basking.

(b) Animals fed on termites were never observed drinking water, but use of the artificial diet makes the provision of water essential.

(c) We maintained a supply of termites throughout the life of our breeding colony. During this time, we developed several techniques which made the collection and maintenance of termites much more efficient. Our methods depended on two local species, _Nasutitermes exitiosus_ and _Coptotermes acinaciformis raffrayi_. The former species builds large hemispherical mounds which can be wholly or partly removed. The numbers of termites obtained is greatly increased by chilling the mound for up to 24 hours with crushed ice spread over the top, under some insulating material (e.g. hessian sacks). Chunks of the mound are then cut off and quickly collected into large plastic rubbish bins. The termites are maintained in a bin by keeping the lid tightly clamped on, and regularly spraying the mound material so that it is always damp. Sections of milled timber on top of the lumps of mound material provide food for the termites and allow large numbers of them to be removed by merely brushing them off the wood into a tray. Western Australian karri is the most palatable local timber. To allow accurate measurement of food provided, the termites can be separated from the rubbish by use of the platform (diagram attached).

Coptotermes do not build free-standing mounds in southwest Western Australia, but can be enticed into old fuel drums filled with pine laths (*Coptotermes* are attracted to exotic pine, unlike *Nasutitermes*). Holes in the base allow termites to enter the drums. After 2-3 months these traps are filled with termites, and can be taken back and stored for up to a month. There are probably *Coptotermes* species living near Sydney which will be trappable in this way. Some New South Wales *Coptotermes* species build mounds also.

(d) Some of the numbats here are carrying *Salmonella* (serotype *meunchen*). We are treating them in an attempt to remove it, as it is extremely rare in wild numbats. If this infection is of concern, it may be necessary to quarantine animals and treat them on arrival at the zoo.

WRCJAF:MAINTENANCE

W.A. WILDLIFE RESEARCH CENTRE

WOODVALE NATURE RESERVE - ANIMAL CAGES

Two cage complexes, each divided internally into four cage units, will be built on Woodvale Nature Reserve (site map appended), to hold small mammals. Each complex will be 12m x 5m, aligned across the slope, each cage being 3m x 5m as shown in Fig. 1, and of minimum height 2m.

The basic framework will be of 32mm (corner uprights and outer roof cross-pieces) and 25mm (side uprights, inner roof and lower horizontals) inside diameter steel pipe, with joints of cyclone-type clamp fittings. The sides and roof of the cages will be covered with "welded fabric" wire mesh (aperture 12.5mm x 25mm, wire diameter 1.3mm). Wire mesh on the sides will be stretched on to a horizontal side-member as near as possible to ground level, and from this side member a wall of mesh will continue vertically down into the ground to a minimum depth of 1m. Doors will connect each middle cage to the end cage, and also give access to end cages from outside. These will swing outwards and be of dimensions 1500mm x 900mm leaving 400mm cage wall below the door base (to prevent escape of animals while door is open : Fig.).

The two cage complexes will have identical framework, but number two will have internal walls left free of wire mesh. This will allow the closing of internal walls if desired at a future date.

The original ground surface is to be preserved for the cage floor. It is very important that minimal disturbance of the vegetation and ground surface occurs. Therefore the only excavation required will be to sink footings for the yprights and to bury the wire mesh at the base of the cage sides. Trees (small banksias) will have been lopped to below the cage roof height.

The sites are gently sloping (up to 1 in 8 slope). To avoid levelling the site it will be necessary to stagger the lower horizontals at each end of each cage complex and in interior walls (Fig.).

During construction it is essential also that minimal damage to the nature reserve occurs. Machinery to be used will be brought in along established roads and firebreaks, using a single access route to the erection site.