ENVIRONMENTAL ENRICHMENT FOR AUSTRALIAN MAMMALS

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Abstract *Animal Welfare 1998, 7:* 415-425

Many of Australia's nocturnal mammals are rare or endangered in the wild. The behavioural integrity of captive populations of endangered species can be maintained through the application of environmental enrichment techniques. This study investigated the effectiveness of feeding enrichment in promoting behavioural diversity, enclosure usage and species-typical behaviours in the ghost bat (Macroderma gigas*) and the yellow-bellied glider* (Petaurus australis*). Animals were observed for 300 min day*$^{-1}$ *over three consecutive time periods: baseline (12 non-consecutive days); enrichment: (12 consecutive days); and post-enrichment: (12 non-consecutive days). The use of a live insect dispenser decreased grooming and increased out-of-sight and social behaviour in the ghost bat. Artificial gum trees promoted species-typical behaviours in the yellow-bellied glider. Enrichment for nocturnal mammals had variable results and different welfare implications for these animals.*

Keywords: *Australian mammals, enrichment, nocturnal, species-typical, welfare*

Introduction

Many of Australia's native nocturnal animals are threatened or endangered in the wild (Strahan 1995). Captive populations of such species are therefore of great conservation importance and form a vital gene pool for captive breeding and reintroduction programmes. Both the genetic diversity and behavioural integrity of species must be preserved to retain all the motor, social and cognitive skills required for survival in the wild (Carlstead & Shepherdson 1994).

Reduced activity in zoo animals may be indicative of reduced welfare and can also undermine the educational value of exhibits (Mahler 1984). The problem occurs in many captive situations (Reinhardt 1993) and may be largely attributed to a suboptimal environment (Wilson 1982). Both the physical characteristics of the enclosure and the husbandry regime, particularly with regard to feeding, can be limited in the captive situation. These factors are often highly predictable and may contribute to boredom and abnormal behaviour (Forthman Quick 1984). Behavioural enrichment techniques are an effective way to increase the complexity of the physical environment and the husbandry regime in captivity. It has been demonstrated for many species that such techniques result in enhanced enclosure usage (Mahler 1984), increased activity (Tripp 1985) and behavioural diversity, and a more natural temporal patterning of behaviour (Mench 1998). Despite the benefits of environmental enrichment techniques, their application to improving the welfare of nocturnal mammals has not been widely documented.

The Ghost bat, *Macroderma gigas*, is Australia's only carnivorous bat and commonly feeds on a variety of prey including small mammals, large insects and birds (Strahan 1991). Most prey capture occurs on the ground and requires both a swift downward flight onto the prey and subsequent food-handling skills. Bats are unique among mammals in their capacity for sustained flight, but since zoo environments restrict both space and the provision of predatory opportunities, they offer few occasions for natural foraging. Johnston (1997) reports that, although some information on the physical needs of captive bats is available, little information is available regarding their psychological well-being. Environmental enrichment techniques, particularly for cage design and furnishings have been described as methods of 'increasing the ''psychological size'' of captive animal environments' (Chamove & Anderson 1989).

The use of live insect dispensers has proved an effective form of enrichment for a variety of species including leopard cats, *Felis bengalis,* (Knowler 1989) and slender-tailed meerkats, *Suricata suricatta*, (Shepherdson *et al* 1989). They provide a temporally and spatially unpredictable food source and have been shown to increase general activity levels, promote a wider range of behaviours and enhance enclosure utilization (Mahler 1984). In this study, the use of such a device for increasing activity and behavioural diversity is assessed.

The Yellow-bellied glider, *Petaurus australis* is an arboreal marsupial whose diet in the wild is predominantly exudivorous. Exudivorous feeding involves making incisions into the bark of trees and ingesting the sap. In the wild, sap-feeding accounts for up to 85 per cent of the total time devoted to foraging (Goldingay 1990). When all feeding-related activity is considered, including grooming, gliding and brachiation, it accounts for 90 per cent of the time budget.

Simulated gum-feeding, originally developed by McGrew *et al* (1986), has been successfully used for captive marmosets, *Callitrix jacchus jacchus,* (Kidman 1990; Kelly 1993) with natural vertical clinging behaviour, bark-stripping and grooming activities of individuals all increased. Social behaviour was also enhanced through promoting the sharing of food sites. The rate of renewal of exudivorous sources in the wild is more or less constant and therefore conducive to group foraging (Goldingay 1990). Zoo diets are often presented in a highly concentrated form that requires little in the way of food-handling skills. In this study, the use of artificial gum trees to promote activity and food-handling skills was investigated.

Methods

Subjects and housing

All animals were housed in the Nocturnal House, Taronga Zoo, Sydney, Australia. Animals were maintained on a reverse daylight schedule, seasonally adjusted to local time. Sunrise and sunset occurred as a two-phase process with sunrise occurring between 1830h and 1900h during July and between 1800h and 1830h during August. Sunset was between 0500h and 0530h during July and between 0515h and 0545h during August. Feeding occurred daily at 1330h and exhibit cleaning between 0830h and 0930h each day.

Study one: Ghost bats and live insect dispenser

Subjects and housing

The subjects of this study were seven ghost bats. The group comprised five captive-born and one wild-born female and one wild-born male, of between 54 months and 10 years of age. They were housed in a glass-fronted enclosure measuring 4.5x3.5x3.3m with a separate cave area measuring 3.1x1.1x2.7m. An artificial rock wall formed a division between the cave and the main body of the enclosure and furnishings consisted of small trees and branches. Feeding (on dead chicks and mice) occurred on a raised platform in the main body of the enclosure.

Method of enrichment

A hollow plastic tube (sealed at both ends) with six, evenly spaced, 12mm diameter holes, was filled with sawdust and 10 crickets. It was fixed below the main feeding platform and a second platform was fitted between the tube and the floor. This had nine, evenly spaced, 12mm diameter holes and was designed to catch the insects as they fell from the tube to give the bats a second chance to obtain the prey before it fell to the ground. The bats were familiar with live insect prey, usually mealworms, grasshoppers or moths, but not with them being delivered into the enclosure in this way.

Data collection

An instantaneous time sampling method of data collection (Poysa 1991; Martin & Bateson 1993) was chosen. A 6min sample interval was used, since this was the maximum time required to collect data at each sample site by moving between the ghost bat enclosure and the yellow-bellied glider enclosure in study two. This time interval allowed for difficulties with visually locating animals due to the reduced lighting levels and enclosure furnishings. Furthermore, since reduced visibility did not permit consistent accuracy in identifying individuals, data were collected and analysed for the animals as a group, rather than as individuals. Table 1 illustrates the categories of behaviour chosen and their definitions.

Table 1 Definition of behavioural categories used in Study one: Ghost bats and live insect dispenser.

Behaviour	Definition
Roost	Resting with the wings folded and the eyes closed. Suspended upside down in any part of the enclosure
Locomote	Flight or movement between any points in the enclosure
Groom	Behaviour patterns pertaining to the cleaning of the body and hair. May also function as comfort behaviour
Feed	Feeding or any movement associated with food capture and ingestion
Social	Social interaction of a positive or negative nature between at least two individuals
Out-of-sight	When the location of a particular individual within the enclosure could not be determined
Other	Behaviour of a rare occurrence

Data were collected between 0900h and 1000h; 1100h and 1200h and between 1630h and 1730h. Data were also collected during feeding (between 1300h and 1400h) since the enrichment method involved the provision of supplementary food. There were three treatment periods, detailed below:

Baseline: The bats were observed for 12 non-consecutive days – this did not include weekends.
Enrichment: This period lasted for 12 consecutive days and included at least one weekend. It consisted of an equal number of experimental and control sessions. During the six experimental

days, the insect device was filled with crickets and removed and refilled daily during exhibit cleaning; during the six control sessions, the device was removed and replaced without crickets. *Post-enrichment*: all devices were removed and behaviour observed for a further 12 non-consecutive days.

To record area usage, the enclosure was randomly divided into sections and the position of the bats recorded at each sample point. It was not possible to identify individuals accurately each time, so the frequency of the bats being observed in each of the sections was recorded.

Statistical analysis

Daily percentages were calculated for the behaviour and area usage for the ghost bats and the yellow-bellied glider group and were analysed using Kruskal-Wallis tests to determine any differences between the three treatment periods (using Minitab for Windows, version 1.11, Minitab Inc, Pennsylvania, USA). Post hoc Wilcoxon-Mann-Whitney tests (Siegel & Castellan 1988) established where the significant differences between the three periods lay. The Shannon Diversity Index (H) was calculated as a measure of behavioural diversity under the different treatments.

Results

Behaviour

Figure 1 illustrates the behavioural time budgets for the ghost bats during the three experimental periods. The Shannon Diversity index values increased during the enrichment period and decreased in the post-enrichment period, relative to the baseline period. Significant effects on behaviour during the three time periods are given in Tables 2 and 3.

Table 2 Significant effects of the three treatment periods on the behaviour of the ghost bats. (B= baseline; E = enrichment; P = post-enrichment.)

Behaviour	Kruskal-Wallis (*H* value[1])	Wilcoxon-Mann-Whitney Test comparisons (*W* value)		
		B vs E	E vs P	B vs P
Groom	8.79*	2492.5*	1749.0	2349.5
Out-of-sight	8.45*	1846.5*	1929.0	1859.5*
Social	9.59*	1914.0*	2030.5	2064.0

[1] all df = 2; *$P < 0.05$;

The Kruskal-Wallis tests revealed significant differences in the time spent grooming. Post-hoc testing indicated that more time was spent grooming during the enrichment period than in the baseline. During the enrichment phase, the percentage time spent grooming was significantly higher when insects were present as compared with baseline and post-enrichment periods ($W = 966.5$; $P < 0.05$). There were no significant differences in grooming between control days (when insects were absent) and either pre- or post-enrichment days. The percentage of time spent out-of-sight was significantly higher than baseline in both enrichment and post-enrichment periods and social behaviour for the group increased during the enrichment phase (Table 2).

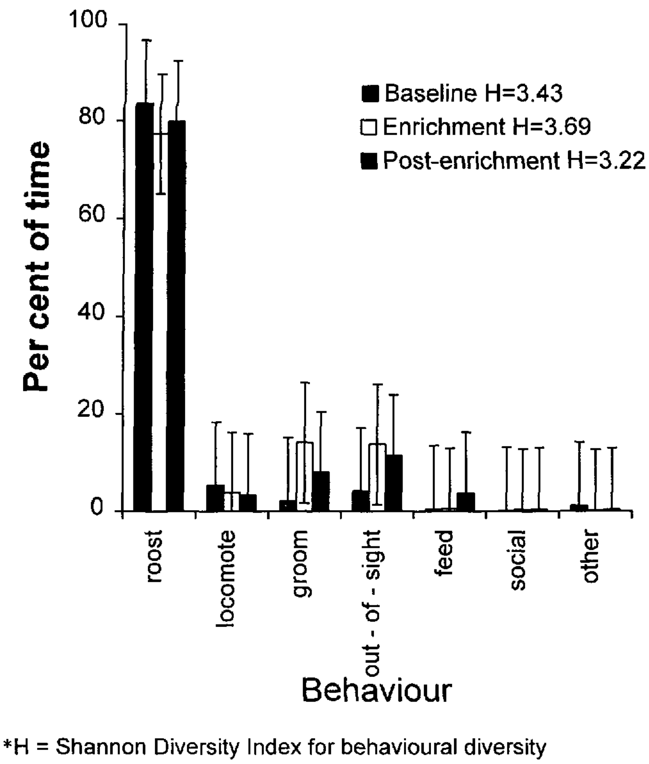

Figure 1 **Activity budgets of ghost bats during the three experimental periods (bars denote SEMs).**

Analysis of roosting behaviour over the entire study period did not yield any significant differences but, within-enrichment analysis revealed significantly higher roosting on control days when insects were not present than experimental days ($W = 1221$; $P < 0.0001$).

Table 3 **Mean per cent of observation time spent on selected activities by the ghost bats in behaviours during the three experimental periods.**

Behaviour	Mean values per treatment		
	Baseline	Enrichment	Post-enrichment
Groom	2.00	14.0	7.88
Out-of-sight	4.14	13.92	11.33
Social	0.11	0.30	0.41

Study two: Yellow-bellied gliders and artificial gum trees

Subjects and housing

The subjects of this study were two female yellow-bellied gliders. Both were captive-born and 13 years old. They were housed together in an enclosure measuring 3.8x4.8x3.3m. They shared the enclosure with three exclusively terrestrial Brushtail bettongs, *Bettongia penicilliata*. Enclosure furnishings consisted of a number of trees, two raised feeding platforms and two nest boxes. Feeding consisted of Leadbeater's mix (prepared at Taronga Zoo) in a liquid form and the provision of browse and flowers subject to availability.

Method of enrichment

The 'gum trees' were constructed from a bamboo branch with a narrow (0.5cm diameter) channel gouged out along two-thirds of its length. The channel was filled with a mixture of gelatine and honey that had been allowed to solidify. The 'gum trees' were attached vertically to trees within the enclosure.

Data collection and statistical analysis

The same three experimental periods and protocols were used as in study one. During the enrichment period, there were six experimental days when fresh 'gum trees' were replaced daily and six control days with fresh 'trees' but no gum. We employed the same methods of data collection and analysis as those used in study one and operated data collection concurrently, so that data were collected from the ghost bats' enclosure and then subsequently from the yellow-bellied glider enclosure, which was sited some distance away. As with study one, the enclosure was divided into areas and the position of each individual noted at each sample point. The behavioural categories used in the second study are listed in Table 4.

Results

Behaviour

Although no significant differences in behaviour were observed (Figure 2), 9 per cent of the time during the enrichment period was spent in using and investigating the gum trees. A new behaviour (nestbuilding) was noted during the enrichment period in one of the individuals. Nestbuilding occurred on a total of five occasions, 2.2 per cent of the time during the enrichment period and 0.52 per cent of the time during post-enrichment.

Table 4 Definition of behavioural categories used in study two: Yellow-bellied gliders and gum trees.

Behaviour	Definition
Feeding	Any behaviour pattern associated with obtaining or manipulating food
Locomotion	Any movement (walk, run or glide) between any points in the enclosure
Grooming	Behaviour patterns pertaining to the cleaning of the fur or skin on any part of the body
Out-of-sight	When the location of a particular individual within the enclosure could not be determined
Use or investigation of enrichment	Ingestion of gum or other manipulation/investigation of 'gum trees'
Other	Behaviour of a rare occurrence

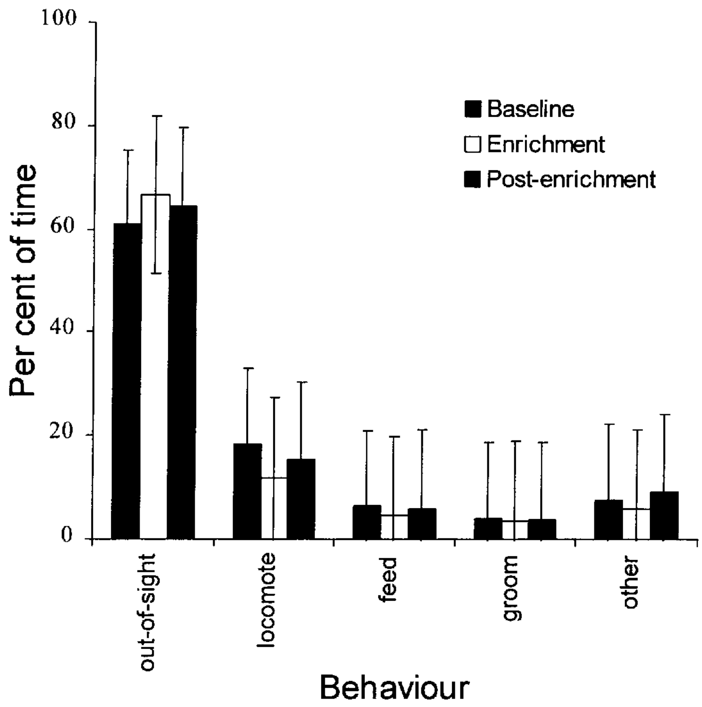

Figure 2 **Activity budgets of yellow-bellied gliders during the three experimental periods.**

Discussion

A major, commonly quoted goal of environmental enrichment programmes is the promotion of a more natural or desirable behavioural repertoire, or a reduction in abnormal or undesirable behaviours (Chamove & Anderson 1989). The results of this study, however, are difficult to interpret, particularly with respect to the ghost bats and the use of the live insect feeder. For example, a significant increase in grooming behaviour during the enrichment phase combined with no significant differences between control days when insects were absent and baseline and post-enrichment days, suggests that the increase in grooming activity observed during enrichment was related to the presence of insects. While grooming is a natural maintenance activity and often followed normal feeding bouts in these animals, over-grooming, can be considered abnormal and there are, therefore, two possible interpretations of this result.

Firstly, although the bats were seen to attempt to handle the crickets, they were often unsuccessful – and ingestion of the prey was never observed. An increase in grooming in this case, plus the fact that these animals were unfamiliar with this particular prey choice, may be indicative of disturbance or frustration induced by the device. The additional intrusion of keepers may also have adversely affected the behaviour or welfare of these animals. Bouts of grooming behaviour have been found to follow activation of the hypothalamic-pituitary adrenal axis (HPA) by various stressors, including novelty, in laboratory rats (Vanerp *et al* 1994); and Widmaier *et al* (1994) found elevated levels of glucocorticoids following routine handling of captive bats. The stress induced by the introduction of a novel object, could, therefore, have contributed to an increase in grooming behaviour in these animals. Further support for the suggestion that the increase in grooming may have been an indication of disturbance is provided by the observation that, during the enrichment phase, vocalizations increased. Ghost bats are known to vocalize more when disturbed (Strahan 1995). If these results represented an increase during the enrichment phase to an abnormal level of grooming, or were indicative of frustration resulting from a high number of unsuccessful capture attempts, this would suggest that the use of a live insect dispenser as enrichment for this group had been non-beneficial.

Alternatively, the observed increase in grooming behaviour may just have been due to an increase in the normal post-feeding behaviour of these animals following provision of supplementary food. The grouping of data for analysis (as daily totals, regardless of the time of day at which the observations were made) might have exacerbated this effect. While an increased amount of grooming behaviour was performed after the normal daily feeding during the enrichment period, it mostly occurred after the provision of insects (supplementary food) into the enclosure first thing in the morning.

The implications for the welfare of these animals are therefore dependant upon what constitutes a normal level of grooming behaviour for this species in captivity. More information would be needed to reach a definite conclusion.

An increase in social behaviour during the enrichment period may have been due to the presence of the insect device. Although most of the interactions observed were negative, they were not overtly aggressive and involved mild antagonistic disputes over attempted food-stealing between pairs of individuals. Other investigators have noted that the provision of supplementary resources can initiate competitive interactions between individuals (Chamove & Anderson 1989), but this does not necessarily constitute a welfare problem.

The use of enrichment for the yellow-bellied gliders did not result in any statistically significant changes in behaviour, although the 'gum trees' were used on a significant number of occasions and did promote species-typical behavioural activity. Vertical clinging behaviour, which is normally associated with feeding in the wild (Goldingay 1990) and which is not possible with the normal liquid diets fed to these animals, has also been reported in other studies using artificial gum trees in captivity (Kelly 1993). In addition, the nestbuilding that occurred during the enrichment period, although unlikely to be due to the enrichment per se, had not been observed in this group before (N Loomes personal communication 1996). In the wild, gliders are known to glean leaves from the trees and carry them in their tails back to their nest-sites (Strahan 1995). However, since on all occasions when this behaviour was observed, the individual was unsuccessful in its attempts at leaf gathering but repeated the behavioural sequence each time, its significance is difficult to interpret. It may be that this behaviour was associated with the breeding season, which occurs around August, in captive gliders.

One of the problems in interpreting results from small captive populations is accounting for the influence of extraneous factors. For example, the fact that the ghost bats spent a significantly greater amount of time out-of-sight during the enrichment and post-enrichment periods has two possible interpretations. Either, residual effects of the enrichment period carried over into the post-enrichment period, or, an independent variable (increasing daylight) may have been operating. Not only were the bats subject to changes in the artificial lighting regime during the study period, but the siting of their enclosure meant that they could conceivably have been affected by the natural lighting levels outside. Increased time out-of-sight in this case may have been due to the animals seeking out darker areas of the enclosure.

The ambiguity of results and small sample sizes used in this study suggests a need for caution in its interpretation or extrapolation. Furthermore, the lack of other scientific data reporting environmental enrichment techniques for these taxa, makes interpretation of some of the results difficult. In addition, the influence of extraneous factors, such as the public, on the behaviour of these normally elusive animals, requires further investigation. It has been noted that a common problem in research programmes conducted in zoos is that the behaviour of the public may have an undefined effect on the behaviour of the study animals or upon the actual methods of data collection (Hosey 1997). In this study, for example, the public may have had an effect upon the behaviour of these animals, due to their typically shy and elusive nature and the fact that the design of the housing exaggerated human noise and movement. In addition, predictable husbandry regimes, may have reduced the effectiveness of the devices in promoting appropriate behavioural responses in both groups. For example, the bats were reluctant to land on the lower platform, as feeding normally occurred higher up in the enclosure and the 'gum trees' were often not utilized by the gliders if placed in enclosure areas of general underutilization.

Animal welfare implications

Despite these limitations, environmental enrichment is a cheap, practical and effective way to increase the complexity of the captive environment, and the value of environmental enhancement methods to all species cannot be disputed. The results for the ghost bats, however, may have different implications for their welfare: if, as suggested, they found the insect device aversive or behaviourally frustrating, its continued use should be modified or stopped. The problems in interpreting the data from this study, highlight the effects of time-scale as a major problem for the evaluation of the effects of enrichment programmes. Chamove and Anderson (1989) suggest that it is usually the long-term changes in behaviour that are of most significance and should be measured in addition to the immediate effects. They also argue that behavioural changes need to be maintained for long periods to be deemed significant or worthy of the effort involved in implementing enrichment programmes. Undoubtedly, perseverance with the devices used in this study might yield more conclusive results regarding the value of this type of enrichment for the animals.

An additional problem in evaluating the extent to which enrichment techniques have been tried and found to be successful with different species is that many reports are anecdotal and experiments are not quantified (Chamove & Anderson 1989). Although Pope (1997), Chag (1996) and Illig (1993) all report the use of both food and non-food enrichment items in captive bats, the results are not scientifically quantified.

However, the use of enrichment techniques has proved a simple and effective way to introduce a degree of complexity into the captive environment of these animals. This study may serve as a stimulus for future environmental enrichment studies with nocturnal mammals, a field which has been somewhat neglected to date.

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