Ten Enrichment Priorities for Bats in Captivity

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INTRODUCTION

Bats are managed in captivity by a variety of institutions such as zoos, living museums, and research facilities. In the wild, these unique mammals have a life that is filled with dynamic experiences such as those associated with avoiding predators, searching for and acquiring food, defending territories and producing viable offspring (Martin, 1996). Traditionally, humans have provided captive animals few choices or opportunities for activity when fulfilling their primary survival needs. Zoo animals are usually fed a basic diet at a given time of day in the same location, with emphasis being placed on nutritional requirements, economy, and ease of cleanup. This practice allows animals only the opportunity to consume their food, not search for, pursue, or process it, which can lead to boredom and the development of stereotypies (Hutchins et al. 1984). Advances in environmental enrichment and training are giving animals the freedom to make more choices in their captive environment (Martin, 1996). Environmental enrichment is an animal husbandry principle that seeks to enhance the quality of captive animal care by identifying and providing the environmental stimuli necessary for optimal psychological and physiological well-being (Shepherdson, 1998).

COMMITMENTS, ETHICS, AND ENRICHMENT

Animals managed in zoological parks, living museums and educational organizations serve the important role of being ambassadors for their species, and for this reason we owe them the best quality of life (Maple et. al., 1995). Jamieson (1995) argues in Ethics on the Ark that keeping an animal in captivity is a privilege that involves assuming special obligations for the animal's welfare. This welfare must include not only physical criteria such as longevity and freedom from disease, but also psychological criteria such as exhibition of species-typical behavior and the ability to adapt to changes in their environment (Poole, 1997; Maple et. al. 1995; Snowdon, 1991). A key to this environment and animal welfare is creating a situation in which animals feel secure (Poole, 1998). Enrichment is also a high priority for mammals that have a complex social structure, mammals that exhibit complex anti-predator behaviors, and for mammals that are adapted to environments where resource availability is highly variable (Poole, 1998; Mench, 1998). Therefore, enrichment and training have become essential tools in captive husbandry to provide them with a stimulating environment to meet both physical and psychological obligations of animal care.

THE NATAL ENVIRONMENT AND ENRICHMENT

The captive environment has an immediate effect on development of all mammals after birth. The results of this development are visible as mammals learn to exert "control" over their surroundings (Moltz, 1965; Joffe et.al. 1973; Renner, 1988; Thompson, 1996; Carlstead, 1996). The majority of captive environments are less complex than dynamic wild environments (Carlstead, 1996). Enriched environments can have positive effects on behavior, physiology, and brain morphology (Uphouse, 1980; Renner and Rosenzweig, 1986; Henderson, 1980; Carlstead and Shepherdson, 1994). The development of any complex behavior pattern is the result of extensive interaction between genetic heritage, exposure to the appropriate stimuli and experience (Polsky, 1975; Miller et. al. 1998). In considering appropriate forms of environmental enrichment, it is therefore essential to be aware of the rearing environment of the individual. Bats that haven't received enrichment before and are housed in a more sterile environment need time to adjust and respond to this important stress. To ensure normal psychological development, a complex and stimulating rearing environment must be provided (Poole, 1998).

TEN ENRICHMENT PRIORITIES

Bats maintained in captivity belong to four different groups: plant-visiting bats, insectivorous bats, carnivorous bats, and sanguinivorous bats. The biology of each of these groups varies in their feeding strategies that range from being generalists that feed on a wide variety of resources to specialists that prey on a particular type of food item. Although each bat species has its own requirements, ten enrichment priorities can be made for all species based on their natural history, their physical design, and essential behaviors to survival.

1) Flight

Bats are the only group of mammals that can truly fly, and this trait is limited by captivity (Wilson, 1988). The Animal Welfare Act as Amended (7 USC, 2131-2156) Policy #24 states that bats must be provided with sufficient unobstructed enclosure volume to enable movement by flying and sufficient roosting space to allow all individuals to rest simultaneously. Flight is one of the most important enrichment priorities with bats, and some species may develop weight problems if not allowed to exercise in this fashion. Animals that are deprived of flight for periods of a month or more may lose the ability to fly (Wilson, 1988). The minimum caging requirements for sustained flight recommended by the AZA Bat Taxon Advisory Group (TAG) are at least eight times the wing span with a minimum width of no less than one and a half times the wing length (Fascione, 1995). Sustained flight can also be facilitated in doughnut or dumbbell shaped enclosures. If the possibility of flight does not exist, fully flighted bats can be exercised by skillful keepers who can stimulate static flight with these bats (LeBlanc, 1999a). A bat that cannot fly due to injuries has lost an integral part of its existence, but maybe able to achieve an adequate quality of life with social enrichment and training.

2) Locomotion on natural substrates and environmental complexity

All bat species move on a wide variety of substrates during foraging and roosting, and should be given opportunities for this natural locomotion. Foliage-dwelling bat species climb on vertical and horizontal branches and vines, and this helps to wear down continuously growing nails. All plant material should be non-toxic and vary in texture, diameter, and degrees of firmness. Crevice-dwelling species roost in caves, rock crevices, hollow trees, beneath tree bark, and in man-made structures. These bats are able to land and climb on vertical rock or rough cement walls. Vampire bats are able to walk and jump on the ground and have a terrestrial foraging pattern. In captivity, nail wear is limited in wire mesh caging, and nails may need to be trimmed to minimize breakage (Carpenter, 1978). Nail care management can be minimized by providing captive bats with a wide variety on natural substrates in roosting and foraging areas (Barnard, 1991).

Natural substrates can also provide complexity to the bat enclosure. Environmental complexity can be increased by adding a variety of furnishings such as roosting niches, bat boxes, ropes, ladders, visual barriers, and natural ground covers (Maple and Perkins, 1996). Complexity of the environment rather than space alone may be the key to behavioral improvements (Carlstead, 1996). This complexity allows for foraging, scent-marking, hiding, and facilitates social play (Poole, 1997).

3) Secure environment and predator avoidance

All animals require a secure environment in order to prosper (Poole, 1998). This security translates into predator avoidance which means providing sufficient space in the enclosure to exceed the animal's flight distance, providing companions that help to protect the group by warning of danger, or providing concealed areas for hiding (Hediger, 1955; Carlstead et al. 1993; Shepherdson, 1997).
A special requirement for bat enclosures is a variety of roosting niches. These roosts can be subdivided into day roosts, night roosts, and feeding roosts. Roosts are secure locations that provide

concealment, a proper flight distance from potential predators, preferred temperature regimes, access to conspecifics, and resting areas. Bat roosts are varied with most species having specific requirements where they hang or rest such as rock crevices, caves, bat boxes, hollow logs, under loose bark, in foliage, and in tree canopies (Wilson, 1997). Bats will usually roost at the highest points of an enclosure, and should be given multiple roosting options that allow bats to segregate themselves into social groups such as bachelors, females with pups, and breeding animals (MacNamara et. al. 1980). The vertical dimension of these roosting niches in addition to the horizontal space is important, and may allow bats to separate themselves according to dominance. Bats also display roost loyalty for extended periods. Therefore, to provide a secure environment, bats should be given a variety of roosting opportunities and visual barriers.

Visual barriers simulate the natural screening effect of forest foliage and may have an effect on levels of aggression, roosting density, and concealment (Mckenzie et. al. 1986). Bats may seek cover and should be provided with several types of barriers to allow these bats to display natural predator avoidance (Shepherdson, 1997). Lollar and Schmidt-French (1998) provide crevice-dwelling insectivorous bats with fabric roosting pouches, which are attached to walls with Velcro®. Plywood bat boxes provide an excellent source of cover and act as visual barriers for species that roost in dark areas such as Egyptian fruit bats (*Rousettus aegyptiacus*), Jamaican fruit bats (*Artibeus jamaicensis*), and short-tailed leaf-nosed bats (*Carollia perspecillata*). Corrugated vinyl roofing sheets can be hung vertically as a simple visual barrier that is easy to clean and disinfect with large fruit bats (LeBlanc, 1999b). Commercially available shade screen can also be attached to outside walls along high traffic service areas to minimize stress to animals.

4) Social Enrichment

Each bat species has different degrees of sociability and social organization, and social groups should be modeled after wild groupings. Native foliage-roosting bats such as red bats (*Lasiurus borealis*), Seminole bats (*Lasiurus seminolus*), yellow bats (*Lasiurus intermedius, L. ega, L. xanthinus*), and hoary bats (*Lasiurus cinereus*) are noted to be solitary as adults and should be housed separately (Lollar and Schmidt-French, 1998). Neotropical false vampire bats (*Vampyrum spectrum*) are documented to live in pairs or small family groups, and they should be maintained in captivity in these units due to their monogamous nature (Vehrencamp et. al. 1977; Altringham, 1996). Wahlberg's epauletted fruit bats (*Epomophorous wahlbergi*) have a lek mating system, in which males set up breeding stations at which they perform courtship displays to attract females (Wickler and Seibt, 1976). This species is polygamous and does well in small colonies with one breeding male. Egyptian fruit bats (*Rousettus aegyptiacus*), straw-colored fruit bats (*Eidolon helvum*), and Malayan flying foxes (*Pteropus vampyrus*) are strongly colonial, and they form multi-male harem groups in large aggregations (Pierson and Rainey, 1992; Nowak, 1994). Males in these species may form male bachelor groups when not breeding. Little brown bats (*Myotis lucifugus)* form large maternity colonies of up to several thousand with mother-pup pairs as the social unit (Kunz and Pierson, 1994). While male little brown bats are usually solitary. The sexes of little brown bats are therefore separated during the day and the females invade male occupied areas at night (Altringham, 1996). Social contact in colonial species must provide a great psychological enrichment and colonial species should be housed with a natural social grouping and sex ratio (Barnard, 1995; Lollar and Schmidt-French, 1998; LeBlanc, 1999b). An abnormal number of males in a colonial breeding group or males in a maternal colony can lead to social conflicts as has been noted with common vampire bats (*Desmodus rotundus*) and big brown bats (*Eptesicus fuscus*) (Harmon, 1999; Barnard, 1989). The addition of social companions and social enrichment can introduce several potential hazards such as aggression due to territoriality, incompatibility between the sexes, and increased competition for food, water, or preferred roosting sites.

At times, bats must be separated from the group for medical reasons, and direct contact is not possible. Social enrichment can be indirect by allowing visual, vocal, and olfactory communication. Bat workers can also provide a rich source of stimulation to bats. Training and positive reinforcement may reduce animal stress during medical procedures and capture.

5) Dietary enrichment

Dietary enrichment is the simplest form of behavioral stimulation (LeBlanc, 1999a, b). The captive diet is relatively stable and unchanging due to economics, nutritional requirements, cage restrictions and husbandry practices. Bats in the wild feed on a wide variety of resources that are unavailable in captivity. They also spend a higher proportion of their daily activity budget searching for, processing, and eating food. The key to this type of enrichment is novelty, which stimulates natural foraging behavior and exploration and minimizes boredom.

Dietary enrichment for plant-visiting bats can take many forms such as offering novel fruits, vegetables, juices, nectars, teas, browse, and flowers (LeBlanc, 1999a,b). Diet presentation can be changed by not peeling fruit, offering novel shapes, offering whole food, or offering items frozen as popsicles or mixed with gelatin to make bat jigglers.

Dietary enrichment for native insectivorous bats is more complicated since these bats show a strong preference for mealworms (Barnard, 1991; Barnard, 1995; Lollar and Schmidt-French, 1998). The following insects have been offered to captive bats: mealworms (*Tenebrio molitor*), waxmoth larvae (*Galeria mellonella*), crickets (*Acheta domestica*), silvery moths (*Autographa gamma*), angle shades (*Phologophora meticulosa*), green lacewings (*Chrysopa septempunctata*), house flies (*Musca domestica*), fruit flies (*Drosophila melanogaster*), and Carolina sphinx moths (*Manduca sexta*) (LeBlanc, 1999a; Courts, 1997; Pope, 1997). Insectivorous bats appear to be stimulated by a variety of sizes of the same insect so this should also be considered. Nocturnal insects can also be lured into outdoor enclosures with a variety of lights, but wild-caught insects may serve as intermediate hosts for parasites or contain pesticide residues (Pope, 1997; Barnard, 1991; Barnard, 1995). Several species of New World fruit bats [Jamaican fruit bats (*Artibeus jamaicensis*), short-tailed leaf-nosed bats (*Carollia perspicillata*), Palla's long-tongued bats (*Glossophaga soricina*), and Geoffroy's long-nosed bats (*Anoura geoffroyi*)] are also documented insectivores in the wild (Courts, 1998; Nowak, 1994). Recent studies with Old World fruit bats have shown that Rodrigues fruit bats (*Pteropus rodricensis*), Livingstone's fruit bats (*Pteropus livingsonii*), and Malayan flying foxes (*Pteropus vampyrus*) will consume insects in captivity (Courts, 1998; Courts, 1997; Pope, 1997). Straw-colored fruit bats (*Eidolon helvum*) and Egyptian fruit bats (*Rousettus aegyptiacus*) have also been reported to eat non-flying insects in captive diets (Carpenter, 1986; LeBlanc, 1998). Further studies on insectivory in pteropodids both in the wild and captivity are required to learn more about this aspect of their biology.

Dietary enrichment for omnivorous greater spear-nosed bats is easy because they will accept a variety of fruit, mealworms, crickets, waxworms, anoles, and rodents (Nowak, 1994). Bulldog bats are more difficult, but they respond to floating insects, pieces of fish, and fish that are allowed to float in a shallow pool (Suthers and Fattu, 1973). Common vampire bats are more restrictive in their feeding habits, and once acclimated to bovine blood they appear to prefer this source in comparison to blood of other mammals (Harmon, 1999). Other types of blood given to common vampire bats may include blood from horses, deer, sheep, goats, and swine. White-winged vampires are allowed to feed on live chickens at the Burnet Park Zoo, which is as naturalistic as possible for these avian parasites (LeBlanc, 1999a).

Water can also be an important source of dietary enrichment (LeBlanc 1999a,b). The taste of water can be altered by giving bottled water, mineral water, by adding Avimin® liquid, or by flavoring with tea. This type of enrichment can stimulate hydration and investigation while not increasing calorie consumption. Water can also be offered as ice and allowed to drip while hanging from a ceiling. Mineral blocks and salt licks can also be moved around in the enclosure to keep the bats searching for these dietary supplements.

6) Foraging Enrichment and Exploration

Exploration and foraging are two key information-gathering activities that are ingredients in the natural selection process, and these are important in environmental enrichment (Shepherdson, 1997; Mench, 1998). Both of these approaches must be sensitive to the degree of plasticity and flexibility that different species adopt, and how difficult the enrichment task is for each group of animals. For example, puzzle feeders may be an acceptable functional alternative to more “natural” foraging situations (Shepherdson, 1997; Gilloux et. al. 1992). Novel foraging devices such as nectar feeders, log rolls, weighted plastic chain, grenade feeders, pollination poles, spinning rakes, and PVC puzzle feeders can be utilized to stimulate bats to explore, forage, and test themselves (LeBlanc, 1999 a, b). Nectarivorous bats such as long-tongued bats can also hover and forage from Oriole feeders® that are made by Opus products (Bellingham, MA).

The most popular form of foraging enrichment for plant-visiting bats is simply hanging “fruit kabobs” or whole fruit throughout the enclosure (LeBlanc, 1999a). Pieces of food can also be placed on shower curtain rings, which can be attached to plastic chain, bungee cords, ladders, ropes, swinging rakes, logs, grapevine wreaths, and branches (Atkinson, 1993; Porter, 1993, LeBlanc, 1999a). Live minnows can be offered to bulldog bats in shallow pools while fresh-killed mice can be hidden in spear-nosed bat exhibits. Blood can be offered frozen to common vampire bats.

The key to this foraging and exploratory enrichment is to stimulate the bats to spend a higher more naturalistic proportion of their daily activity budget searching for and processing their daily diet (Allgaier, 1992). Dietary enrichment should be placed in areas where the bats have to search it out. Thus, fostering natural food retrieval behaviors rather than having bats simply taking it out of a bowl in the same location on a daily basis (Reinhardt, 1993). Items can also be offered in smaller quantities several times during a normal feeding period rather than receiving all of the food at once. In reverse lighting conditions, bats that are crepuscular could be fed both at dusk and dawn.

7) Olfactory enrichment

Bats have a well-developed sense of smell; therefore, olfactory enrichment may promote a wide variety of natural behaviors such as exploration and scent marking (Suthers, 1970; Laska, 1990; Kunz and Pierson, 1994). Olfactory enrichment also has the benefit over dietary enrichment in that it creates activity without providing calories beyond the normal diet.

Bats identify individuals in their colony by scent. Intraspecies scent marks can be placed on muslin sheets and given to bachelor groups giving them access to bats of the opposite sex (Stevens et. al. 1996). The introduction of a male scent mark may result in changes in the female estrus cycle. Male scent marks can also be given to male bachelor groups to promote territoriality and scent marking behavior. Rodrigues fruit bats were shown to display more interest in intraspecies scent marks than fruit or floral scents in their enclosure (Stevens et. al. 1996).

Olfactory enrichment also allows bats to explore other scents in their territory such as other species of bats, birds, plants, and flowers. A variety of cooking extracts, spices, fresh herbs, hunting lures, and perfumes can be utilized for enrichment with nocturnal mammals (LeBlanc, 1999b, Nicklaus, 1997; Rosenberg, 1997; Stevens et. al. 1996). Scented herbs can also be planted in window boxes or hanging baskets to allow bats to interact directly with these pungent plants which may encourage scent marking (LeBlanc, 1999b).

Snake sheds and live corn snakes (*Elaphe guttata*) are also potential sources of olfactory enrichment with Old World fruit bats (Van Wormer, 1999). These potential predator scents may stimulate natural protective behaviors. Common vampire bats may respond to scent marks and prepared hides of potential prey animals (Harmon, 1999).

8) Acoustic Enrichment

Acoustic enrichment is seldom utilized in zoos, although background noise is utilized routinely with dairy cattle to reduce stress and increase milk production. Audio recordings of bat vocalizations may be beneficial for enrichment (Livingstone, 1997). Noisy colonial bat species such as flying foxes may benefit from background noise. Some institutions report providing continuous audio enrichment utilizing a radio, environmental theme audiotapes or by running water in a pool within the exhibit (LeBlanc, 1998). Outdoor caging offers the opportunity for a wide variety of acoustic enrichment.

9) Training enrichment

Training provides an opportunity for an animal to earn its living, not exactly as in the wild, but in a way that it can use its adaptations and senses to experience the consequences of its choices (Martin, 1996). Animal keepers utilize training daily although most do not realize it. Bats quickly learn to perform certain behaviors in response to even the most subtle cues in their environment (Martin, 1997). Effective training is based on operant conditioning. Training is also most effective if it has a purpose (Laule and Desmond, 1997). Bats can be trained to take medication from a syringe by getting them accustomed to taking juice from a syringe. Insectivorous bats can be trained to accept mealworms by hand feeding and to feed themselves out of containers (Barnard, 1991; Barnard, 1995; Lollar and Schmidt-French, 1998). Bats can also be trained with positive reinforcement to shift from one enclosure to another or to adapt to handling for educational presentations. Several species of fruit bats at the Lubee Foundation, Inc. have been target trained for public demonstrations. This training has lead to a closer relationship between the keepers and the animals (Nemcik, 1998).

10) Novelty of enrichment

Novelty has been shown to affect the level of enrichment benefit over time as animals become habituated to the enrichment (Sambrook and Buchanan-Smith, 1996; Kuczaj et al. 1997). Enrichment varies in intrinsic qualities such as complexity and responsiveness. Objects that an animal can control, and which respond to the animal in some way, are utilized for longer periods of time than objects that are less responsive (Markowitz and Line, 1989). Complexity may also promote activity (Tripp, 1985). Enrichment programs should provide a variety of enrichment types that vary in complexity and responsiveness and evaluate what provides the most benefit. Rodrigues fruit bats (*Pteropus rodricensis*) are very adaptable and due to their curious nature they react quickly to new and novel enrichment ideas. Common vampire bats initially appear less curious in their reaction to enrichment, but this is an area that deserves more intensive study.

Enrichment should be scheduled to make sure that it becomes part of the animal care routine. A variety of enrichment techniques can be offered to minimize habituation to enrichment. Scheduling of enrichment is also important to ensure there is sufficient labor to install and clean up after the enrichment.

ENRICHMENT PRIORITIES

Environmental enrichment for bats should include as many of the above priorities as possible.
These priorities can also act as a checklist in evaluating bat care, and deciding what types of enrichment are the most important to begin with in a particular captive colony. All enrichment techniques should be assessed for risks and benefits with each group of bats, in order to maximize benefits and minimize risks, since every animal is different and may respond differently (Carlstead, 1999).

CONCLUSION

Bats are managed in captivity by zoos, living museums, research facilities, educational organizations, rehabilitation centers, and wildlife sanctuaries. Since wildlife conservation has been designated the highest priority of all zoological institutions, bat conservation and captive husbandry will become a higher priority as bat species suffer from human proliferation and habitat lost (Hutchins and Wiese, 1991; Stevens, 1991; Wilson, 1992). Animals managed in zoological parks, living museums, and educational centers serve the important role of being ambassadors, and for this reason we owe them the best quality of life (Maple et. al. 1995). Jamieson (1995) argues in Ethics on the Ark that keeping an animal in captivity is a privilege that involves assuming special obligations for the animal's welfare. Criteria for animal welfare must include not only physical criteria such as longevity and freedom from disease, but also psychological criteria such as exhibition of species-typical behavior and the ability to adapt to changes in their environment (Maple et. al. 1995; Snowdon, 1991). Enrichment can be offered in many different forms to help animals display their natural behavioral repertoire and to help to reduce or eliminate abnormal behavior (Carlstead and Shepherdson, 1994). Bats have several enrichment priorities. The most important are sustained flight, climbing activities that help to manage weight and continuously growing nails, a secure environment, and a natural social grouping. Research on many species of bats is limited due to their nocturnal habits, and their ability to fly long distances. If the species record from wild data is minimal, bat workers can try to stimulate survival behaviors such as feeding and foraging, predator avoidance, and exploration, which are likely to confer a strong biological advantage in their evolutionary environment (Shepherdson, 1997; Barnard and Hurst, 1996).

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