Fruit Bat Enrichment at The Lubee Foundation, Inc.

By Dana LeBlanc

Photographs by John Seyjagat

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INTRODUCTION

The Lubee Foundation, Inc. (Lubee) was founded by the late Luis F. Bacardi in 1990, and is dedicated to the conservation of Old World fruit bats. The foundation manages a diverse collection of *Chiroptera* to promote basic bat research, captive breeding and education.

Flying Fox complex at the Lubee Foundation, Inc.

In the world today, almost one quarter of all known mammal species are bats (950 species) (Wilson, 1997; Kunz and Pierson, 1994; Mickleburgh and Carroll, 1994). Zoos have traditionally displayed large charismatic animals and bats have been, for the most part, neglected (Jamieson, 1995; Hancocks, 1995; Wilson, 1988). In 1962, Desmond Morris described zoo bat exhibits as being "small, totally inadequate cages that displayed bats as hairy canaries or discarded aircraft." Currently, 44 species of bats are recorded in the International Species Inventory System (ISIS) in 100 institutions worldwide (ISIS, 1994). Exhibits for bats are becoming more complex and multiple species of bats are being housed together (Mellen et. al. 1998; Fascione, 1996; Seyjagat, 1994). In Europe, Jersey Wildlife Preservation Trust established the first captive breeding colonies of Rodrigues fruit bats *(Pteropus rodricensis)* and Livingstone's flying foxes (*Pteropus livingstonii*) (Mickleburgh and Carroll, 1994). In North America, zoos accredited by the American Zoo and Aquarium Association (AZA) voluntarily participate in a Species Survival Plan (SSP) for the Rodrigues fruit bat (*Pteropus rodricensis*), a critically endangered species (Fascione, 1996).

According to E.O. Wilson and Paul Ehrlich, nearly one quarter of all species on earth (close to 30 million species) will be lost in fifty years if tropical forests continue to be felled at the current rate (Stevens, 1991; Wilson, 1992). In conjunction to habitat loss and human proliferation, Old World fruit bats suffer the additional pressure of human predation that has seriously affected some populations (Wilson, 1997; Pierson and Rainey, 1992; Mickleburgh and Carroll, 1994). Therefore, since wildlife conservation has been designated the highest priority for zoos (Hutchins and Wiese, 1991), bat conservation and husbandry will become a higher priority for zoological institutions in the future (Mickleburgh and Carroll, 1994). At this critical point in captive management, husbandry techniques including enrichment need to be documented.

COMMITMENTS, ETHICS AND ENRICHMENT

Wild Malayan flying foxes (*Pteropus vampyrus*) in flight at Subic Bay, Philippines.

Bats in the wild 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). The theory of natural selection predicts that only the fittest survive (Darwin, 1859). Traditionally, humans have provided few choices or opportunities for activity when fulfilling the primary survival needs of captive animals. Advances in environmental enrichment and training are giving captive animals the freedom to make more choices in their daily lives (Martin, 1996).

Egyptian fruit bats (*Rousettus aegyptiacus*) in captivity.

Animals managed in zoological parks and living museums 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) also 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 a long life 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 animal welfare is creating a situation in which animals feel secure (Poole, pers. com.). Thus, enrichment and training are essential tools in captive husbandry to provide animals with a stimulating environment to meet physical and psychological obligations of animal care.

Rodrigues fruit bat (*Pteropus rodricensis*) is a bat species managed in a Species Survival Plan in North America.

THE NATAL ENVIRONMENT, ENRICHMENT AND PLAY

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). 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 primary focus of enrichment is towards the adults of the collection, but it can also have a positive impact on younger animals.

Little golden - mantled flying fox pup (*Pteropus pumilus*).

Play is nearly universal among mammals, and has been documented with Old World fruit bats (Thompson, 1996; Carroll, 1979). Play can be divided into three basic categories: object, locomotor and social (Thompson, 1996). Object play involves repetitive manipulation of items in the environment. Locomotor play is composed of vigorous body movements such as running, crawling, climbing, body twists and flight. Social play differs from the other types of play in that it is truly interactive. Group size influences play by affecting the number and proximity of potential playmates. Large social groups that contain a high number of immature conspecifics will usually facilitate play in mammals.

Captivity has a significant effect on play behavior (Stevenson and Poole, 1982). Adult mammals, in particular, play more frequently in captivity than in the wild (Fagen, 1981). Play in adult captives might provide a means of maintaining a healthy physical condition in an environment where opportunities for vigorous exercise are otherwise absent. Play is also indicative of a relaxed minimal stress environment and is a good indicator of animal well-being (Poole, pers. com.). Enrichment can be used to stimulate play with captive mammals.

DEFINITIONS OF ENRICHMENT

Enrichment is becoming a standard component of animal husbandry, and should no longer be thought of as an extra (Maple et. al. 1995). During this revolution in zoos, there has been a profusion of articles, arguments and confusion regarding the process of enrichment. The following definitions will help to define this topic.

1) Enrichment is the act or process of making something richer in some quality (Webster's New Collegiate Dictionary, 1980).
2) Enrichment is a process of providing a complex and diverse environment which increases the possibility that the captive animal's own behavior will produce what it needs: finding food, demarcating a territory, building a nest, maintaining its physical condition, escaping conspecifics or hiding. An animal with more behavioral options will have more control over its environment and will be better able to alleviate boredom and cope with stressful events in its surroundings (Carlstead, 1996).
3) Enrichment is an act of altering the living environment of captive animals in order to provide opportunities for them to express their natural behavioral repertoire and to reduce stereotypic or abnormal behavior (Weerd and Baumans, 1995).
4) Enrichment is an essential tool for encouraging species-typical behavior and to encourage normal levels of activity and foraging while allowing animals to adapt to changes in their environment (Maple et. al. 1995; Snowdon, 1991).

The Malayan flying fox (*Pteropus vampyrus*) is an Old World fruit bat.

SPECIES TYPICAL BEHAVIOR – THE STARTING POINT

The pursuit of animal well-being in captivity requires a thorough understanding of the animal's life in the wild (Maple et. al. 1995). As each generation of captive animals are bred, we must be concerned with not only the physical and genetic characteristics of the animal (phenotype and genotype), but also the behavioral repertoire, which can be extinguished through generations of captive breeding (Bukojemsky and Markowitz, 1997). Evaluation of animal behavior is the key to animal welfare. Increases in the level of species-appropriate activities indicate an enhanced well-being along with decreases in stereotypical and abnormal behaviors (Duncan, 1997; Carlstead, 1996; Gavazzi and Markowitz, 1994). Thus, the starting point for our discussion of enrichment begins with species typical behavior of fruit bats and how they perceive their world.

Plant-visiting bats live in the tropical and sub-tropical regions of the Old and New World (Fleming, 1993). These bats belong to two families of the order *Chiroptera*: Old

World *Pteropodidae*, which belong to the Suborder Megachiroptera (megabats) and New World *Phyllostomidae*, which belong to the Suborder Microchiroptera (microbats). Megabats find their food resources through vision and sense of smell, and can see as well as the domestic cat (*Felis catus*) (Graydon and Giorgi, 1987). Flying foxes are documented to have cone-like bodies in their retina so they may see in color (Kunz and Pierson, 1994; Suthers, 1970). Microbats utilize echolocation for navigation and locating food resources such as insects. Echolocation involves active sonar with a number of adaptations that allow these bats to "see" with sound (Kunz and Pierson, 1994). The ears and neurons of the brain of echolocating bats are tuned to the frequencies of the emitted sounds and their returning echoes (Novick, 1977). Vision plays a supplemental role in their daily lives while their olfactory senses are highly developed (Kunz and Pierson, 1994; Laska, 1990).


Wahlberg's epauletted fruit bat (*Epomophorous wahlbergi*) is a megabat from Africa.

By their very nature, plant-visiting megabats and microbats pollinate or disperse the seeds of hundreds of species of plants, but each has a very different biology. Both of these groups are known to feed on flowers, nectar, pollen, fruit and leaves (Marshall, 1983; Marshall, 1985; Kunz and Ingalls, 1994; Kunz and Diaz, 1994).

OLD WORLD FRUIT BATS

Old World fruit bats and flying foxes (*Pteropodids*) live in Africa, Asia, Australia and the South Pacific, and are represented by 166 species (Wilson, 1997). In North America, twelve species of megachiroptera are managed in American Zoo and Aquarium Association (AZA) institutions. These bats can be divided into three different groups based on ability to echolocate and roosting behaviors: 1) megabats with audible echolocation; 2) megabats that cannot echolocate and roost in dense cover in small groups; and 3) megabats that cannot echolocate and roost in larger groups in tree canopies.

Megabats with audible echolocation

In North America, two species of Rousette fruit bats are housed in zoological collections: the Egyptian fruit bat (*Rousettus aegyptiacus*) and the Ruwenzori long-haired fruit bat (*Rousettus lanosus*). These fruit bats are nocturnal and feed predominately on fruit, flower resources and leaves (Marshall, 1985; Nowak, 1994). In captivity, Rousette fruit bats will also consume mealworms (*Tenebrio molitor*) (Courts, 1998). In the wild, Rousette fruit bats roost in large crowded colonies in caves. These cave-dwelling bats have a rudimentary echolocation system based on audible tongue clicking for navigation. When feeding these bats rely on vision and sense of smell for locating food resources (Nowak, 1994).


Egyptian fruit bat (*Rousette aegyptiacus*)

Megabats without echolocation that roost in dense cover

Three species of megabats kept in North American institutions roost in dense cover and do not utilize echolocation: Wahlberg's epauletted fruit bats (*Epomophorus wahlbergi*), dog-faced fruit bats (*Cynopterus brachyotis*), and little golden-mantled flying foxes (*Pteropus pumilus*). Wahlberg's epauletted fruit bats roost in small groups in hollow trees, under palm fronds and in thick foliage (Nowak, 1994). Dog-faced fruit bats roost in shaded areas and build "tents" in palm fronds and banana leaves. The little golden-mantled flying fox roosts alone or in small groups in inconspicuous sites in primary forest vegetation (Mickleburgh et. al.1992; Pierson and Rainey, 1992). Although these species have similar roosting preferences, they have very different breeding systems. Wahlberg's epauletted fruit bats utilize display grounds or a lek where they compete against other males. Females of this species select mates on the basis of the male display (Wilson, 1997; Nowak, 1994). Male dog-faced fruit bats form large harems (resource defense polygyny). Flying foxes also form harems, but colonial forms have multi-male groups (Altringham, 1996).


Dog-faced fruit bat
(*Cynopterus brachyotis*)

Megabats without echolocation that roost in open tree canopies

In North America, several species of non-echolocating tree roosting megabats are maintained in captivity: straw-colored fruit bats (*Eidolon helvum*), Indian flying foxes (*Pteropus giganteus*), island flying foxes (*Pteropus hypomelanus*), grey-headed flying foxes (*Pteropus poliocephalus*), Rodrigues fruit bats (*Pteropus rodricensis*), Malayan flying foxes (*Pteropus vampyrus*) and Pemba fruit bats (*Pteropus voeltzkowi*).


Straw-colored fruit bat
(*Eidolon helvum*)

Flying foxes and straw-colored fruit bats roost in large active colonies in emergent trees that rise above the forest canopy, although *Eidolon* has been found in caves (Nowak, 1994; Pierson and Rainey, 1992). *Pteropus* range in roosting habits from being solitary or living in small groups to being moderately to strongly colonial. Straw-colored fruit bats are strongly colonial and have been documented living in colonies of 100,000 to 1,000,000 individuals. Straw-colored fruit bats are migratory and may exhibit delayed implantation.

The grey-head flying fox (*Pteropus poliocephalus*) is also a migratory species in Australia. These large bats feed on fruit, flowers and leaves (Marshall, 1983). Flying foxes may have a preference for certain foods on a seasonal basis, and are likely to be "sequential specialists." These bats will migrate to follow the bloom cycle of eucalyptus and other food resources. Some species such as the Rodrigues fruit bat, Livingstone's flying fox and the Malayan flying fox have also been observed to consume insects in captivity (Pope, 1997; Courts, 1998). Insectivory in the wild has been difficult to document, but has been recorded with the grey-headed flying fox and the Ryukyu fruit bat (*Pteropus dasymallus*) (Funakoshi et al. 1993; Parry-Jones and Augee, 1992).


Island flying fox
(*Pteropus hypomelanus*)

NEW WORLD FRUIT BATS

New World fruit bats are colonial species that live in Central and South America. These microbats can be divided into two groups based on feeding behavior: 1) Short-tongued species and 2) Long-tongued species.

Short-tongued species

Jamaican fruit bats (*Artibeus jamaicensis*) and short-tailed leaf-nosed bats (*Carollia perspicillata*) are two species of short-tongued New World fruit bats that are maintained in captivity in North America. These echolocating bats feed predominately on fruit and insects but will take nectar, pollen and leaves (Nowak, 1994). Both of these species pluck fruit from trees and fly to feeding roosts to avoid predators that would be attracted to trees containing a large number of feeding bats (Wilson, 1997). Jamaican fruit bats and short-tailed leaf-nosed bats roost in small groups or large colonies, often with other bat species in caves, mines, sinkholes, hollow trees and buildings (Kunz and Diaz, 1994; Fleming, 1988). Jamaican fruit bats have also been documented to build “tents” in palm fronds (Nowak, 1994).

Jamaican fruit bat
(*Artibeus jamaicensis*)

Long-tongued species

The common long-tongued bat (*Glossophaga soricina*) and Geoffroy’s long-nosed bat (*Anoura geoffroyi*) are two species of long-tongued New World fruit bats that are maintained in captivity in North America. These echolocating bats feed predominately on nectar, pollen and insects but will take fruits and flower parts (Nowak, 1994). These bats are capable of hovering like a hummingbird to feed on nectar and pollen. Both species roost in small colonies in caves. The common long-tongued bat is also reported to roost in buildings, rock crevices and hollow trees.

Species Overview

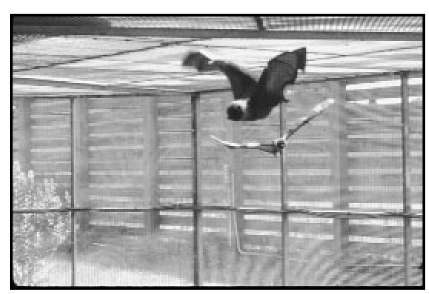
Research on many species of bats has been limited due to their nocturnal habits and their ability to fly long distances. If the species record from wild data is minimal, managers can try to stimulate behaviors essential to physical survival, which include foraging, predator avoidance and flight (Shepherdson, 1997).

ENRICHMENT TYPES

Enrichment can be offered in many different forms to help animals display their natural behavior (Carlstead and Shepherdson, 1994; Marriner and Drickamer, 1994; Van Hoek and King, 1997). Some basic types of enrichment are: dietary and foraging enrichment, exploratory enrichment, olfactory enrichment, auditory enrichment, novel objects or “toys”, social enrichment and training. Enrichment can also be labeled as passive (inanimate), responsive (animate) or social (Gavazzi and Markowitz, 1994; Champoux et. al. 1990).

ENRICHMENT PRIORITIES

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 is a width of four times the wingspan, a length of at least eight times the wingspan, and a height of two meters [6.6’] (Fascione, 1995). Sustained flight can also be facilitated in doughnut or dumbbell shaped enclosures.



Rodrigues fruit bats
(*Pteropus rodricensis*) in flight.

Climbing is also an integral behavior for health. This natural locomotion helps to wear down continuously growing nails. In captivity, nail wear is limited in wire mesh caging, and nails may need to be trimmed to minimize

Little golden - mantled flying fox (*Pteropus pumilus*) climbing on branch.

breakage (Carpenter, 1978). Nail care management can be minimized with enrichment (Barnard, 1991).

Providing opportunities for roosting is another enrichment priority with bats. These flying mammals usually roost at the highest point of an enclosure. Bats should be given multiple roosting options to minimize problems with aggression and to allow for a vertical dominance hierarchy. The height of the exhibit will be a critical factor that influences animal management and husbandry.

Malayan flying foxes (*Pteropus vampyrus*) roosting in a group.

David Shepherdson (1997) has suggested that animals are highly motivated to perform some activities such as predator avoidance, foraging, and exploration because these behaviors are likely to confer a strong selective advantage in their evolutionary environment. These natural selection behaviors should be priorities for enrichment programs (Barnard and Hurst, 1996).

ENCLOSURE DESIGN

Hediger (1969) stated "In every good zoo, the animal does not feel itself in any way a prisoner, but as in the wild it feels more like the tenant or owner of that unit of space to which the animal instinctively lays claim." More than any other variable, enclosure design and the captive environment will determine the variety of behaviors that zoo animals will display. The goal in designing animal enclosures should be to maximize each animal's ability to express their natural behavior. Some considerations in exhibit design are: useable space versus total space, space for unobstructed flight, cover and visual barriers, feeding areas, access to water, drainage, ease of cleaning and maintenance, substrate, pest control, lighting, temperature, humidity, ventilation, and capture or restraint (Guerrero, 1997; Fascione, 1995).

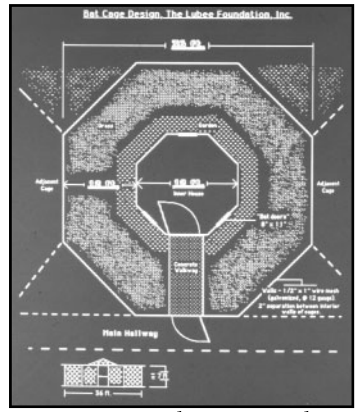
Flying fox enclosure at the Lubee Foundation, Inc.

Hediger (1950) also argued that managers of captive animals should never fool themselves into thinking they can truly replicate a natural environment in a captive setting. Zoos should instead direct their efforts toward providing their inhabitants with as many biologically and ecologically relevant stimuli as possible (Maple et. al. 1995).

Several large zoos exhibit megabats in large naturalistic free flight exhibits, which allow these bats to display a large behavioral repertoire and to be mixed with a wide variety of birds, mammals and reptiles (Fascione, 1996). The Oregon Zoo exhibits three species of megabats (straw-colored fruit bats, Egyptian fruit bats, Rodrigues fruit bats) with one species of microbat (Jamaican fruit bats) in a large horseshoe shaped nocturnal exhibit. This exhibit has a filigree of branches and vines similar to a natural tree canopy, a shallow pool for skimming, and encourages flight (Mellen et. al. 1998).

Exhibits that are constructed as a "bat cave" (the shot crete wet mix design) should have a semi-rough uneven ceiling or vault to facilitate roosting (Fascione, 1995). Multiple concave pockets that vary in depth are important to offer a variety of roosting options and visual barriers. The abrasive surfaces of these cave-like domes will facilitate nail wear (Barnard, 1991). Water features in these exhibits will also assist in maintaining a high humidity, which may be important for tropical bat species.

Lubee has prioritized continuous flight in its octagonal *Pteropus* enclosures which are built in a doughnut design that is nine meters [29.5 feet] in diameter with a three meter [9.8 feet] wide octagonal night house in the center (Seyjagat, 1994). This octagonal structure allows for a joint wall between enclosures, which minimizes the materials needed to build multiple units. Each wall of the enclosure has a double wall of 2 mm gauge [14 gauge] wire mesh (1 cm x 2.5 cm) [.39" x .975"] and galvanized iron tubing that is 5 cm [1.95"] apart. This double wall meets the requirement of the Lacey Act and United States Department of the Interior standards for housing injurious wildlife such as bats of the genus *Pteropus* in a double enclosure (Carpenter, 1986). The flight cages are two meters [6.6 feet] high, which allows for better visual inspection of the collection for management and research. The night house acts as a central roosting area for cave dwelling species, and also serves as a feeding area that can be easily cleaned and disinfected. Bats can be isolated in the temperature controlled night house in winter and for management. The outside flight area is landscaped with small shrubs and a soft turf that minimizes injuries. Multiple species of grasses can be utilized in the enclosure for foraging enrichment (LeBlanc, 1997). The design of the flight cages allows for a natural photoperiod, access to direct sunlight and shaded areas, good ventilation, natural acoustic cues, and allows for the passing of olfactory and visual signals between enclosures that have joint walls.



Design of flight cages at the Lubee Foundation, Inc.

FURNISHINGS

Complexity of the environment rather than space alone may be the key to behavioral improvements (Carlstead, 1996). Several zoos have found that larger, more natural-looking exhibits do not necessarily lead to greater activity or more normal behavior (Spinelli and Markowitz, 1985). Adding a variety of furnishings and enrichment can increase environmental complexity (Maple and Perkins, 1996).

Rodrigues fruit bats *(Pteropus rodricensis)* with enrichment.

Roosting Niches

Bats roost in a variety of locations with most species having specific requirements for where they hang or rest. These roosts include rock crevices, caves, hollow logs, under loose bark, in foliage and in tree canopies (Wilson, 1997). These roosts can be subdivided into day roosts, night roosts and feeding roosts. Bats are also adept at returning to the same roost for extended periods. Therefore, bats should be given multiple roosting opportunities that allow them to select from a variety of locations.

Roosting niches can be spaced to allow bats to segregate themselves into social groups such as bachelor males, females with pups or breeding animals (MacNamara et. al. 1980). Both the vertical and horizontal aspects of the roost are important in minimizing aggression and allowing the bats a secure environment. The Lubee Foundation, Inc. has utilized wire mesh canopies in the ceiling design to allow fruit-eating microbats and dog-faced fruit bats (*Cynopterus brachyotis*) to have varied roosting heights in holding cages.

Dog - faced fruit bat (*Cynopterus brachyotis*) roosting under a palm frond.

The AZA Bat Taxon Advisory Group recommends utilizing vinyl-coated wire mesh (2.54cm x 1.25 cm) [1.0" x .5"] as a roosting surface for bats. Polyethylene plastic mesh can also be utilized for smaller species (Barnard, 1991). Bats that are maintained in mesh cages require nail trimming or other surfaces for nail wear (Carpenter, 1978; Barnard, 1991).

Tent-making bats such as dog-faced fruit bats (*Cynopterus brachyotis*) and Jamaican fruit bats (*Artibeus jamaicensis*) utilize a variety of plants for tents such as palms with palmate fronds, bananas and philodendrons (Nowak, 1994; Kunz et. al. 1994). At Lubee, dog-faced fruit bats have made "tents" in Washington palms (*Washingtonia robusta*) and banana leaves (*Musa paradisiaca*). Dog-faced fruit bats will also roost under sabal palm fronds (*Sabal spp*.) that are cable tied to the ceiling of the enclosure (LeBlanc, 1999a).

Branches, Vines, and Logs

When the golden lion tamarin (*Leontopithecus rosalia*) reintroduction program began, the captive-reared tamarins appeared to be physically unable to cope with natural substrates and were deficient in their arboreal locomotion skills (Kleiman et. al. 1986; Buchanan-Smith, 1998). If captive primates had these problems then arboreal bats would be expected to have similar problems. Therefore, captive enclosures should be furnished with a variety of natural branches, vines and logs. All plant material should be non-toxic and vary in texture, diameter and degrees of firmness. Lubee utilizes a variety of plant material such as Southern wax-myrtle (*Myrica cerifera*), willow (*Salix spp*.), grape (*Vitis spp*.) and sweet gum (*Liquidambar styraciflua*). These items provide secure and flexible surfaces for locomotion and allow nails to be worn down in a normal fashion (Buchanan-Smith, 1998).

Malayan flying fox (*Pteropus vampyrus*) in tree branches.

The placement and aspect of branches, vines and logs are critical so flight paths are not interrupted. Grapevines are particularly useful in promoting horizontal locomotion. These vines can be attached to the walls of the enclosure with screw hooks. Small diameter grapevines can be woven into wreaths to facilitate climbing and folivory. Vertical logs can be hung from the ceiling of the enclosure with eye screws and add-a-links or buried in the ground like a post. Branches can be hung in the enclosure with cable ties to allow bats to climb on furniture that ranges in firmness from stable to unstable. All of these plant products hold scent marks and are difficult to sanitize. Such material should be removed and replaced on a regular basis. Artificial vines made of double-braided synthetic rope, wire and a sealant such as silicone, latex, rubber urethane or epoxy have a longer life than natural material but are more expensive (Goss, 1999).

Rodrigues fruit bat *(Pteropus rodricensis)* hanging from a vertical log.

Ropes and ladders

Polyethylene braided ropes can be hung in outdoor enclosures in lieu of branches and vines for horizontal climbing. These ropes can be utilized for several years with minimal maintenance, although sunlight will break them down. Large diameter ropes (2.7 – 4.6 cm) [1" – 1.75"] are hung around the circumference of the octagonal flight cages at the Lubee Foundation to provide landing surfaces for flying foxes (LeBlanc, 2000a). The ropes are attached at each corner of the octagon and drop one and a half to two times the total body length of the bat between points of attachment. The ropes are also placed one and a half times the total body length of the bat away from the walls of the enclosure. The bats land on the ropes instead of the wire mesh walls, and this behavior minimizes abrasions to the rostrum and the wings. Large diameter ropes can be hung vertically to promote vertical climbing. Smaller diameter ropes can be utilized with smaller species of fruit bats.

Malayan flying foxes *(Pteropus vampyrus)* and ropes.

Malayan flying foxes *(Pteropus vampyrus)* and rope ladder with enrichment.

Ladders are also important furnishings in bat enclosures and are utilized by bats that have landed on the floor of the enclosure as a simple method of returning to the uppermost levels. The vertical dimension of the ladder allows less dominant bats an escape route from threatening animals that may not allow roosting at an equal level. The composition of the ladder and length can also be varied to promote climbing skills on a stable or unstable substrate. Lubee utilizes two ladder designs: 1) plastic mesh ladders on the smooth walls of the night house and 2) rope ladders with natural branches.

Spinning rakes

Spinning rake.

A simple device that promotes flight and foraging behavior is a spinning rake (Porter, 1993). Lubee utilizes a heavy design that consists of a large diameter wooden dowel, which is loosely screwed into a fence post using stainless steel fasteners and washers on both sides of the dowel (LeBlanc, 1999a; 1999b). This design allows the wooden dowel to swing freely. Four small diameter holes are drilled into the dowel at even distances for the attachment of cable ties for hanging dietary items. Bats are required to fly to this swinging dowel to obtain enrichment. The swinging rake is mounted in bat flyways, but is approximately 1.3 meters high, so it does not interfere with continuous flying.

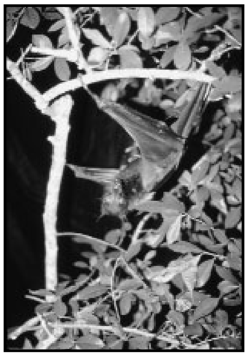
Pollination Pole

Another simple device that encourages flight and foraging behavior is the pollination pole (Seyjagat, 1998). This design includes a simple fence post with four wooden strips attached around the circumference of the pole and plastic funnels cut into the shape of flowers. Each funnel is sealed at its smallest end with non-toxic silicone. The funnels are then plugged into holes drilled diagonally into the fence post. A variety of dietary enrichment can be placed into the funnels including fruit flavored gelatin, pollen and fruit juice. Rodrigues fruit bats have been observed to fly and land directly on the post and

Rodrigues fruit bats *(Pteropus rodricensis)* flying to a pollination pole.

climb vertically to each of the funnels on the pollination pole. After the enrichment, the funnels are easy to remove and clean for storage. The silicone plug will have to be replaced occasionally, depending on use.

Visual barriers



Malayan flying fox
(Pteropus vampyrus)
with a visual barrier.

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). Fruit bats may seek cover and should be provided with several types of barriers to allow these bats to display natural predator avoidance behaviors (Shepherdson, 1997). Carlstead et. al. (1993) showed that the provision of concealed areas was an important factor in reducing stress in captive leopard cats (*Felis bengalensis*). At Lubee, corrugated vinyl roofing sheets are utilized as a simple visual barrier that is easy to clean and disinfect. Browse and long-lasting foliage barriers are a natural visual screen that can minimize animal stress (LeBlanc, 1998). Commercially available shade screen is utilized to provide visual barriers along high traffic service areas and to provide shaded areas along flight cages.

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, Wahlberg's epauletted fruit bats, little golden-mantled flying foxes, Jamaican fruit bats and short-tailed leaf-nosed bats. These boxes have an open bottom to allow for free flight into and out of the box; they also trap warm air and serve as a warmer microclimate. In winter, these boxes can be heated with brood-rite heaters$_{®}$.

Natural substrate and live plants

Self - heading
Philodendron
(*Philodendron selloum*).

Enclosures designed for bats should provide a soft landing area. Natural substrates such as grass can reduce injury to animals that fall to the ground. Grasses have also been identified as a source of dietary enrichment for several species of Old World fruit bats such as Rodrigues fruit bats and island flying foxes (LeBlanc, 1997).

Live plants and shrubs have an important place in large flight cages. They provide natural foliage cover, promote climbing and are an esthetic addition to enclosures. Herbaceous plants can also be utilized in hanging baskets. Plants utilized for landscaping with fruit bats should be non-toxic and resistant to defoliation and mechanical damage. Lubee has had excellent results with Japanese aralia (*Fatsia japonica*), pittosporum (*Pittosporum tobira*), Southern wax-myrtle (*Myrica cerifera*), Japanese privet (*Ligustrum japonicum*), passion flower (*Passiflora incarnata*), bottlebrush (*Callistemon rigidus*), and self-heading philodendron (*Philodendron selloum*) (LeBlanc, 1998). Several of these species offer the extra benefit of producing seasonal flowers, which also offer olfactory and dietary enrichment.

DIETARY AND FORAGING ENRICHMENT

Dietary and foraging enrichment is the most popular and simplest form of behavioral stimulation (LeBlanc, 1999a). Fruit 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. In contrast, the captive diet is relatively stable and unchanging due to economics, nutritional requirements, cage restrictions and husbandry practices.



Rodrigues fruit bats *(Pteropus rodricensis)* and dietary enrichment.

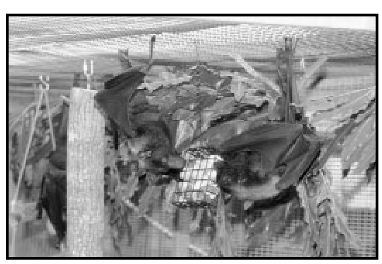
Dietary enrichment takes many forms such as offering novel fruits, vegetables and juices that are not in the standard diet. Appendix 1. categorizes the acceptance of different fruits and vegetables by the bat collection at Lubee. Diet presentation can be changed by not peeling fruit, offering novel shapes, or by offering whole food. Fruit, vegetables and juices can be presented frozen as popsicles or mixed with gelatin to make bat jigglers (Chag, 1996b).

Foraging enrichment aims at fostering the expression of natural food retrieval behaviors by offering the diet in less accessible ways (Reinhardt, 1993). Food enrichment can be placed in areas where the bats have to search it out (Allgaier, 1992). It can also be offered in smaller quantities several times during a normal feeding period, rather than being offered all at once. In reverse lighting conditions, bats that are crepuscular could be fed both at dusk and dawn.

Fruit and vegetables can be strung on stainless steel rods to make "fruit kabobs." 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 and branches (Atkinson, 1993; LeBlanc, 1999b). Fruit and vegetables can be offered to bats in novel items such as puzzle feeders, commercially available suet feeders or grapevine wreaths. Juice or flavored water can be offered in water bottles with ball-bearing tips, hummingbird feeders and nectar feeders (LeBlanc, 1997). In addition, bats are willing to work for dietary enrichment when fruit is offered in grenade feeders or presented in pine cones (Chag, 1996a; Chag, 1996b).

Malayan flying foxes feeding on fruit kabobs.

In the wild, Old World fruit bats consume flowers (nectar, pollen, petals and bracts), leaves, shoots, buds, twigs and bark in addition to fruit (Marshall, 1983; Courts, 1998). At Lubee, a variety of non-toxic flowers and browse such as roses (*Rosa spp.*), wisteria (*Wisteria frutescens*), daylilies (*Hemerocallis spp.*), bottlebrush (*Callistemon rigidus*), willow (*Salix spp.*), poplar (*Populus spp.*), dogwood (*Cornus florida*), sweet gum (*Liquidambar styraciflua*), and sugarberry (*Celtis laeviata*) are offered as dietary enrichment. Flowers serve as both dietary and olfactory enrichment. Sources of flowers and browse must be pesticide and fertilizer free and must be checked for hidden pests like eastern wood ticks (*Dermacentor spp.*) and spiders. Flowers and browse can be tied in bundles with plastic cable ties and hung in the enclosure. Smaller flowers can also be placed in bowls that are secured to vertical posts. Fruit bats will consume a variety of grasses, fruit and vegetable seedlings, herbs, and flowering annuals that can be grown in planter boxes or hanging baskets then given to the bats (LeBlanc, 1998). Appendix 2. lists a variety of browse, flowers and non-commercial fruit that are utilized for enrichment with captive fruit bats in North America (LeBlanc, 1998).



Malayan flying foxes *(Pteropus vampyrus)* feeding on fruit in a suet basket.

Rodrigues fruit bat feeding on silk tree flower (*Albizia julibrissin*).

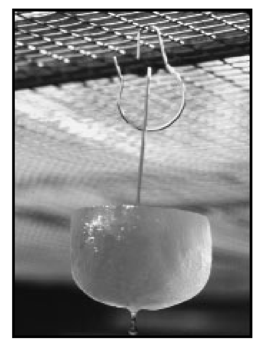
Willow flowers
(*Salix spp.*)

Malayan flying fox
(Pteropus vampyrus) feeding
on sweet gum leaves
(*Liquidambar styraciflua*).

Several species of New World fruit bats (Jamaican fruit bats, short-tailed leaf-nosed bats, long-tongued bats, and Geoffroy's long-nosed bats) are documented insectivores in the wild (Courts, 1998; Nowak, 1994). Recent studies with Old World fruit bats have shown that Rodrigues fruit bats, Livingstone's flying foxes, and Malayan flying foxes will consume insects in captivity (Courts, 1998; Pope, 1997). Straw-colored fruit bats and Egyptian fruit bats have also been reported to eat non-flying insects in captive diets (Carpenter, 1986; LeBlanc, 1999a). The following insects have been offered to captive fruit bats: mealworms (*Tenebrio molitor*), waxmoth larvae (*Galeria mellonella*), crickets (*Acheta domestica*), silvery moths (*Autographa gamma*), angle shades (*Phologophora meticulosa*), green lacewings (*Chrysopa septempunctata*), and Carolina sphinx moths (*Manduca sexta*) (LeBlanc, 1999a; Courts, 1998; Pope, 1997). In outdoor flight cages, nocturnal insects can be lured into enclosures with red incandescent lights (Pope, 1997). Further studies on insectivory in *Pteropodids*, both in the wild and captivity, are required to learn more about this aspect of their biology.

Tube - nosed fruit bats
(*Nyctimene rabori*) feeding on insects.

Dietary enrichment also incorporates offering flavored water such as herbal teas, dilute apple cider vinegar (5% solution), liquid vitamins and minerals, or even bottled water because it will taste different than the normal water source. Water is offered in water bottles with ball-bearing tips, hummingbird feeders or in nectar feeders (LeBlanc, 1997). Water can also be offered as ice and allowed to drip while hanging from a ceiling. Mineral blocks and salt licks can be moved around in the enclosure to keep the bats searching for these dietary supplements.



Juice popsicle.

Foraging Devices

Exploration and foraging are two key ingredients in the natural selection process that are important in captive animal enrichment (Shepherdson, 1997). Both of these enrichment approaches must be sensitive to the degree of plasticity and flexibility that different species possess. For example, puzzle feeders may be an acceptable functional alternative to more "natural" foraging situations with primates (Shepherdson, 1997; Gilloux et. al. 1992). The Lubee Foundation, Inc. utilizes several novel foraging devices such as nectar feeders, log rolls, weighted plastic chains, grenade feeders and PVC puzzle feeders to stimulate bats to explore, forage and test them selves.

Nectar feeders

This feeder is a simple sweet gum (*Liquidambar styraciflua*) log that is approximately 12.8 cm [5"] long and 15.5 cm [6"] in diameter with twelve holes to accommodate twelve plastic 16 ml vials that are deeper than the bats can reach with their tongues (LeBlanc, 1997). The tubes are fitted flush with the top of the wooden log. The nectar feeder is then suspended with a plastic chain of varying length, and the bats have to either fly or climb to it. The nectar feeder can be filled with a wide variety of different fluids such as a 5 % solution of apple cider vinegar, juice, nectar, herbal tea or bottled water so the device remains novel. Both island flying foxes and Malayan flying foxes have been observed at Lubee to rotate the device with their thumbs and manipulate the device in order to tip it so they can get more of the fluid left in the tubes. Since the bats will not be able to reach all of the fluid in the tubes, the bats will work for several hours trying to get as much fluid as they can from the device.

Island flying fox *(Pteropus hypomelanus)* and nectar feeder.

Log Roll

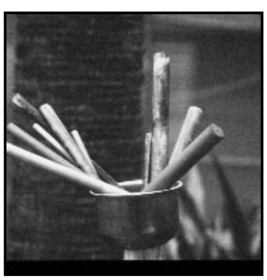
This simple foraging device spins as bats fly and climb on the feeder. The device is made of 5.1 cm [2”] PVC pipe covered with small diameter plastic mesh and sealed with two end caps. A stainless steel rod is mounted through the middle of the pipe, and the rod is hung on both sides with two equal lengths of plastic chain and S hooks. The PVC pipe rotates freely and fruit mash can be applied to the plastic mesh. Rodrigues fruit bats have been observed flying to the device and displacing other bats that are feeding, so that these bats have to fly to the device again.

Weighted Plastic Chains

Malayan flying foxes, island flying foxes and Rodrigues fruit bats have all been observed lifting plastic chains that are weighted with cut fruit and weights. This type of foraging enrichment makes the animal work harder and possibly utilize alternative methods of foraging to get to the reward. By making the reward more difficult to obtain, keepers have observed how these bats solve problems.

Malayan flying fox *(Pteropus vampyrus)* lifting a weighted plastic chain.

Pick-up Sticks



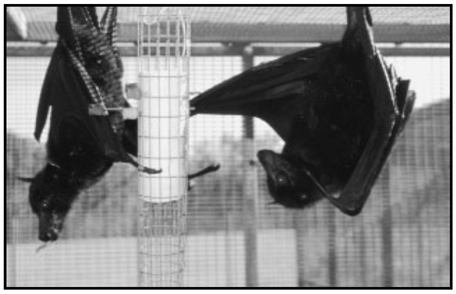
Pick-up sticks.

“Pick-up sticks” are non-food objects that can be manipulated. Observations of Rodrigues fruit bats have shown a social aspect of this enrichment in which multiple bats will compete against others for ownership of the objects (Pope et. al. 1997). The sticks can simply be varying lengths of hard wood dowels or other shapes that can be colored with food coloring and sealed with non-toxic shellac. The bats manipulate and pick up these objects, while some bats have been observed to fly with them (Pope et. al. 1997). Since “pick-up sticks” are inanimate, the bats will quickly habituate to this enrichment so it should only be given occasionally.

Grenade Feeders

Grenade feeders are a complex foraging device (Chag, 1996). With this device, a bat must remove a pin to trigger a piece of fruit to fall from inside of a wire mesh tube. The materials required to build a grenade feeder are easy to find and inexpensive: one 20.5 x 50 cm [8” x 19.5”] rectangular sheet of 25 x 12.5 x 2 mm [1” x 1/2” 14 gauge] wire mesh, J clips“, cable ties, a 16 cm long piece of 6 cm PVC, three stainless steel pins that are 0.25

cm [0.1"] in diameter and 8 cm [3.12"] long with a wooden peg head, 60 cm [23.4"] of string and two shower rings. The wire mesh is rolled into a 6 cm [2.3"] diameter tube that is closed with J clips. Then, the PVC is inserted and mounted in the center of the wire mesh tube with cable ties. Six 0.5 cm [1/4"] holes are drilled through the PVC wire mesh unit, and these holes will accommodate the stainless steel pins. The string is tied to the top of the mesh tube, and runs through the center of it. A shower curtain ring is tied to the other end of the string, and this ring will be baited with a small piece of fruit. This baited shower curtain ring is then pulled up the tube, and a stainless steel pin is inserted to hold this ring in the PVC insert. The other pins can be placed above or to the side of the baited pin, so when the bat pulls the right pin, the shower curtain ring and the fruit will fall to the bottom of the tube. Because the device is light it can be hung with a shower curtain ring or an S hook.



Malayan flying foxes
(Pteropus vampyrus) with
a grenade feeder.

This device has been tested with Rodrigues fruit bats, island flying foxes, and Malayan flying foxes. All three species have learned to pull pins in order to obtain the fruit reward. This animate enrichment allows a bat to control the feeder after some trial and error learning.

Malayan fying foxes
(Pteropus vampyrus) with a
grenade feeder.

PVC Puzzle Feeders

PVC puzzle feeders have been utilized with individually housed rhesus monkeys (*Macaca mulatta*) with excellent results (Novak et. al. 1998). These feeders are also animate enrichment for Old World fruit bats. Lubee uses two basic designs that reinforce manipulation. The first design is a vertical puzzle feeder (gravity feeder) that is made out of 3.2 cm [1 1/4"] PVC with two end caps and two 3.8 cm [1 1/2"] PVC connectors (LeBlanc, 2000b). The length of the feeder is dependent on the length of species that will utilize the device, and should be 9 cm [3.5"] longer than the length of the bat. A 2.54 cm [1"] hole should be drilled in the PVC pipe at the bat's head length on the bat. The PVC connectors will cover this hole, and the bat will have to pull one connector above the hole to get the fluid reward, which is in the base of the device. The device can be hung from an eye screw and a swivel snap, which are mounted on the top of the feeder. Observations of Malayan flying foxes at the Lubee Foundation, Inc. have shown that these bats rapidly figure out how to utilize the device and are able to lift the device at an angle to get all of the fluid out of the reservoir of the feeder.

The second puzzle feeder design is a horizontal model, in which there is a 2.54 cm [1"] hole drilled through both the PVC connectors and the 3.2 cm [1 1/4"] PVC tube, and the bats have to rotate the hole in the PVC connector until it lines up with the hole in the smaller PVC tube. This design is more complex to build and preliminary observations with Rodrigues fruit bats at the Lubee Foundation, Inc. have shown that the bats have only gained access to the juice reward through accidental alignment of the holes.

PVC puzzle feeders are inexpensive, and are easy to clean and disinfect. Both of these designs were created for use with Old World fruit bats, but they may also be suitable for small New World primates.

New England Exotics Commercial Puzzle Feeder

New England Exotics, Inc. is testing a prototype commercial enrichment for Old World fruit bats at Lubee that is based on a similar design for small primates and birds. The puzzle feeder is designed with three stacks of hard plastic disks that are held together with a stainless steel metal rod in the upper third of the disk that allow each disk to rotate away from the other disks. Each disk has three small diameter cavities that can be baited with a variety of food rewards. The bats utilize their thumbs and nose to move the disks and explore the device. The three stacks of disks allow for three different bats to interact with the device at once.

OLFACTORY ENRICHMENT

Fruit bats have a well-developed sense of smell, therefore olfactory enrichment may promote a wide variety of natural behaviors including 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.

Fruit bats identify individuals in their colony by scent. Intraspecies scent marks can be placed on muslin sheets and given to bachelor groups which gives them access to the scent of 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).

Rodrigues fruit bat *(Pteropus rodricensis)* interacting with a day lily (Hemerocallis spp.).

Olfactory enrichment offers bats the opportunity to explore other scents that would naturally occur in their territory such as other bats, birds, plants and flowers. A variety of cooking extracts, spices, fresh herbs, hunting lures and perfumes have been utilized for enrichment with nocturnal mammals (Nicklaus, 1997; Rosenberg, 1997; Stevens et. al. 1996). Scented vinegar is a simple olfactory enrichment that is made by adding whole fresh herbs to distilled white vinegar and aging the mixture for several months (Powell, 1994). A wide variety of herbs can be stored in this manner over winter to keep enrichment programs novel.

Island flying fox *(P. hypomelanus)* interacting with sweet gum (*Liquidambar styraciflua*).

Horticultural plantings such as window boxes or hanging baskets containing scented plants such as spearmint (*Menta spicata*), peppermint (*Menta x piperita*), oregano (*Origanum vulgare*), creeping marjoram (*Origanum spp.*), English lavender (*Lavandula angustifolia*), catnip (*Nepeta cataria*), basil (*Ocimum basilicum*), thyme (*Thymus vulgaris*), lemon balm (*Melissa officinalis*) and rosemary (*Rosmarinus officinalis*) can offer fruit bats a variety of olfactory experiences (LeBlanc, 1998). Most fruit bats will interact with the foliage while causing minimal damage to the plant.

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.

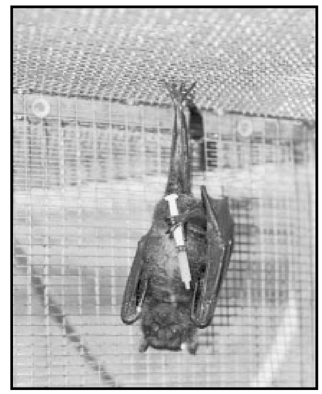
ACOUSTIC ENRICHMENT

Dog - faced fruit bat (*Cynopterus brachyotis*) in an outdoor cage.

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, 1999a). Outdoor caging offers the opportunity for a wide variety of acoustic enrichment.

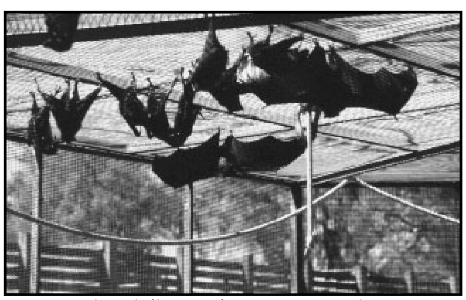
UNNATURAL ENRICHMENT

Enrichment does not have to be natural to have a place in enriching the lives of captive bats (Bureau, 1997). The captive environment is usually less complex than the wild environment and bats are not able to exhibit the full gamut of their natural behaviors. Incorporating unnatural enrichment can increase the complexity of the captive environment. Under this category falls the wide classification of “toys” such as mirrors, teething rings, parrot toys, gummy bones and bells (Atkinson, 1993; Seyjagat, 1996; Pope et. al. 1997). Bats initially show interest in these novel objects, but if the objects are left for long periods in the enclosure the bats become habituated to their presence (Kuczaj et. al. 1997). Toys can be excellent surfaces for scent marking and olfactory enrichment if they can be moved between enclosures that house the same species of fruit bat.



Island flying fox *(Pteropus hypomelanus)* with a syringe filled with juice.

BREIF NATURAL STRESS AS ENRICHMENT



Island flying foxes responding to a corn snake (*Elaphe guttata*) in their enclosure.

Bats in the wild and in captivity live with stress, and a key to animal management in captivity is to provide a secure environment. Moodie and Chamove (1990) have suggested that exposing captive wildlife to brief periods of stress from a perceived predator can stimulate natural protective behaviors and reduce the impact of stress resulting from captivity. Shepherdson (1997) has suggested that predator avoidance behaviors are an important goal to encourage in enrichment programs. Lubee has encouraged natural protective behaviors by using short-term natural stress of raptor calls and small constricting snakes (Van Wormer, 1999). Island flying foxes have responded to these brief threats by freezing, making open wing displays that were directed to the threat, and surrounding a corn snake (*Elaphe guttata*) in an action that resembles mobbing.

Corn snake (*Elaphe guttata*) on a hanging T perch.

SOCIAL ENRICHMENT

Malayan flying fox *(Pteropus vampyrus)* day roost.

Fruit bats are social creatures and social contacts provide great psychological enrichment (LeBlanc, 1999b). Each species has different degrees of sociability and social organization, and social groups should be modeled after wild groupings. The sex ratio of each colony should be evaluated since an imbalance towards males can lead to social conflicts. The addition of social companions, can also introduce several potential hazards such as aggression due to territoriality and increased competition for food, water and preferred roosting sites.

At times, bats must be separated from their groups for medical reasons, and direct contact is not possible. Social enrichment can be indirect by allowing visual, vocal and olfactory communication. Keepers can also provide a rich source of stimulation to bats. Long-term positive reinforcement with keeper interaction/training may reduce stress during medical procedures and capture.

TRAINING AS ENRICHMENT

Training provides an opportunity for an animal to earn its living, not exactly as in the wild, but by using its adaptations and senses to experience the consequences of its choices (Martin, 1996). 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 and is 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. Bats can also be trained for handling in educational presentations with positive reinforcement. Training can be used to shift bats from one enclosure to another. Several species of fruit bats at Lubee have been target trained for public demonstrations. This training has lead to a closer relationship between the keepers and the animals (Nemcik, 1998).

Syringe training with a Malayan flying fox.

NOVELTY OF ENRICHMENT

Novelty has been shown to affect the level of enrichment benefit over time as animals become habituated to the enrichment (Line et. al. 1991; Sambrook and Buchanan-Smith, 1996). 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 used by a larger proportion of animals and 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. Fruit bats are very adaptable and due to their curious nature they react quickly to new and novel enrichment ideas.

Malayan flying foxes feeding on fig branches with fruit *(Ficus spp.)*.

Offering a variety of enrichment types can minimize habituation and possible boredom. Enrichment should be scheduled to make sure that it becomes part of the job routine. Scheduling is also important to ensure there is sufficient labor to install and clean up after the enrichment.

RISK AND BENEFIT ASSESSMENT

Three questions should be asked of all potential enrichment items: 1) Does the enrichment itself pose any risk to the animals? 2) What benefit will the animals derive from the enrichment? and 3) Is the manner of enrichment delivery leading to problems? (Duncan, 1997). Behavioral changes should be evaluated on an individual level since this sometimes reveals significant increases and decreases in levels of aggression (Bloomstrand, 1986). Individual evaluation may also allow managers to fine-tune enrichment to work on modifying complex abnormal and stereotypic behaviors or simple low activity levels.

Enriched environments are by definition more complex and therefore more dangerous (Duncan, 1997). Individual enrichment ideas can be thought of as falling somewhere within a continuum of low to high risk and within a continuum of low to high benefit. The goal of enrichment programs should always be to maximize the benefit while minimizing the risk. Keepers should be encouraged to evaluate new and creative ideas with their managers and to fine tune existing enrichment techniques.


Indian flying fox (*Pteropus giganteus*) and cage furniture.

Each enrichment category has its own inherent risks and benefits. Dietary enrichment can lead to obesity, and moderate deviation from the standard diet can lead to nutritional problems. Food items must be removed before spoiling occurs. Foraging enrichment may give rise to aggression between bats, which can lead to bite wounds and fractures. Foraging enrichment can also lead to social displacement and competition for food resulting in an inadequate diet. In addition, keepers must be able to correctly identify non-toxic browse or flowers. Cage furnishings and foraging devices may interrupt flight paths and cause injuries. Toys or toy parts might be swallowed resulting in choking or asphyxiation. Bats may be caught in cage furniture, toys or foraging devices. Olfactory enrichment with intraspecies scents can lead to dominant animals reestablishing hierarchies with possible aggression.

Enrichment is also stressful for animals that have not received it yet. Animals that are chronically deprived of stimulus diversity may respond poorly when highly stimulating, novel situations arise, and may have difficulty coping with these situations (Carlstead, 1996). Animal managers should treat the symptoms of poor coping skills as any other potential medical problem. A strict regime of enrichment should be conducted to allow the animals to gradually adjust to small changes over time, therefore, developing skills to cope with stressful situations. Severe behavioral, physiological and emotional consequences can occur if a captive animal loses the ability to cope with adverse stimuli (Carlstead, 1996).

EVALUATION OF ENRICHMENT

In order to gauge the risks and benefits of enrichment, there must be some evaluation of each technique. These evaluations may be formal research projects or simple keeper observation and scan sampling. Scientific evaluation allows keepers and managers to recognize situations that are difficult to identify by casual observation. Behavioral research projects can even provide a source of enrichment for animals (Lyndaker and Houck, 1998). Enrichment evaluation gives an opportunity to fine tune enrichment and to maximize benefits.

The concern of enrichment, overall, must be with the animal's welfare. Animal welfare can be evaluated by observing behavioral repertoires, looking at activity budgets, monitoring body weight and strength of immune function, measuring stress-related hormones, and looking for the presence of abnormal behaviors (Duncan, 1997; Gavazzi and Markowitz, 1994; Thomas and McCann, 1997; Coe and Scheffler, 1989).

Rodrigues fruit bat *(Pteropus rodricensis)* flying to a pollination pole.

It is important to acknowledge that what works for one individual or group of animals may not work with others. Bats kept in larger colonies may accept enrichment more readily than those in smaller groups, because there are a larger number of animals willing to risk interacting with the enrichment. When offering new enrichment to bats that are unaccustomed to receiving it, the best method is to introduce it slowly to reduce stress and risk. The enrichment can be placed below and at a distance from the bats to allow them time to become familiar with it in a less threatening position. The enrichment can be judged over a period of time as the bats gain confidence, display natural curiosity and grow accustomed to the routine of having objects placed in their exhibits.

Finally, enrichment results should be documented to promote dissemination of ideas between institutions. Collaboration between zoological facilities should also be promoted to pool resources and to compare the results of enrichment techniques with several different species under different conditions.

ENHANCING PUBLIC PERCEPTIONS

Vistors at Lubee

Fruit bat enrichment can be placed in strategic areas to provide visitors with a better view of these unusual mammals. The public is also challenged to see bats in unexpected circumstances such as feeding on fruit, flowers and leaves. The use of enrichment to encourage activity may also increase observation times by the public at exhibits. Thus, enrichment may become a tool that allows institutions to provide the public with a better understanding about bats and their importance.

CONCLUSION

Animals managed in zoological parks and living museums serve the important role of being ambassadors, and for this reason we owe them the best quality of life (Maple et. al. 1995). Criteria for animal welfare must include not only physical criteria such as a long life and freedom from disease, but also psychological criteria such as the 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 abnormal and stereotypic behavior (Carlstead and Shepherdson, 1994; Shepherdson, 1998). Bats have several enrichment priorities. The most important are sustained flight, climbing activities that help manage continuously growing nails and options for roosting. 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, managers can try to stimulate survival behaviors such as feeding, foraging, predator avoidance, and exploration, which are likely to confer a strong biological advantage in their evolutionary environment (Shepherdson, 1997; Barnard and Hurst, 1996).

Straw - colored fruit bats *(Eidolon helvum)* are a common bat ambassador in zoos.

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Commercial Resources

Brood-rite heaters – Distributed by Animal Spectrum, Inc. 1-(800)-228-4005
Commercial Puzzle Feeder – New England Exotics, Inc. 71 Michaels Rd., Wells, ME 04090
(207)-646-7173

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Appendix 2. List of plants utilized by fruit bats for browse, flowers, and non-commercial fruits.

1. Acer saccharum	Sugar maple (leaves)
2. Howeia spp.	Sentry Palm (flowers)
3. Howeia spp.	Sentry Palm (flowers)
4. Acer saccharinum	Silver maple (leaves)
5. Acer negundo	Boxelder (leaves)
6. Agastache foeniculum	Anise hyssop (leaves and flowers)
7. Ajuga repens	Carpet bugleweed (leaves and flowers)
8. Albizia julibrissin	Silk tree (flowers)
9. Alnus spp.	Alder (leaves)
10. Antirrhinum majus	Snapdragons (flowers)
11. Aphelandra tetragona	Zebra plant (pollen)
12. Astrocaryum alatum	Astrocaryum (pollen)
13. Beta vulgaris	Beet greens (leaves)
14. Betula nigra	River Birch (leaves)
15. Betula papyrifera	Paper Birch (leaves)
16. Brassica juncea	Mustard greens (leaves)
17. Brassica olearacea	Broccoli, Collard, Kale, Cabbage (leaves)
18. Brassica rapa	Bok Choy (leaves)
19. Buddleia spp.	Butterfly bush (leaves and flowers)
20. Calathea crotalifolia	Calathea (pollen)
21. Callistemon spp.	Bottle-brush (flowers)
22. Calliandra haematocephala	Powderpuff (leaves and flowers)
23. Camellia japonica	Camellia (flowers)
24. Cannas x generalis	Canna (flowers)
25. Celtis occidentalis	Hackberry (leaves)
26. Celtis laevigata	Sugarberry (leaves)
27. Cercis canadensis	Redbud (flowers and leaves)
28. Chamaedorea spp.	Household Palm (leaves)
29. Cichorium endivia	Escarole (leaves)
30. Chrysalidocarpus lutescens	Areca Palm (leaves)
31. Chrysophyllum oliviforme	Satin leaf (pollen)
32. Citrus aurantifolia	Lime (United Kingdom) (leaves)
33. Coleus x hybridus	Coleus (leaves)
34. Columnea spp.	Goldfish plant (pollen)
35. Coriandrum sativum	Coriander (leaves)
36. Cornus florida	Dogwood (leaves)
37. Costus spiralis	Spiral ginger (pollen)
38. Crataegus sp.	Hawthorns (leaves)
39. Cucurbita pepo	Summer squash (flowers and fruit)
40. Curcuma cordata	Amethyst Hidden Ginger (flowers)
41. Cydonia oblonga	Quince (leaves)
42. Dianthus chinensis	Dianthus (flowers)
43. Diospyros kaki	Japanese Persimmon (fruit)
44. Dracaena fragrans	Corn plant (leaves)
ers)	
45. Elaeagnus angustifolia	Russian-olive (leaves)

68. Hibiscus syriacus	Rose of Sharon (flowers and leaves
69. Hibiscus moscheutos	Hybrid Rose Mallow (flowers
70. Hibiscus rosa-sinensis	Tropical Hibiscus (flowers and leaves)
71. Jacaranda mimosifolia	Jacaranda (leaves and flowers)
72. Lactuca sativa	Romaine lettuce (leaves)
73. Lagerstroemia indica	Crape myrtle (flowers)
74. Ligustrum japonicum	Japanese Privet (flowers)
75. Liquidambar styraciflua	Sweet gum (leaves)
76. Lolium multiflorum	Annual ryegrass
77. Lonicera japonica	Japanese honeysuckle (flowers)
78. Magnolia grandiflora	Southern Magnolia (fleshy petals)
79. Malus spp.	Apple (leaves and fruit)
80. Malvaviscus arboreus	Turk's cap (flowers)
81. Malvaviscus drummondii	Dwarf Turk's cap (flowers)
82. Medicago sativa	Alfalfa (leaves)
83. Monstera deliciosa	Monstera (fruits)
84. Morus spp.	Mulberry (leaves and fruit)
85. Musa spp.	Banana (flowers, fruit, leaves)
86. Myrica cerifera	Southern Bayberry (flower buds)
87. Nasturtium officinale	Watercress (leaves)
88. Nyssa sylvatica	Black Tupelo (leaves)
89. Ocimum basilicum	Basil (leaves)
90. Passiflora incarnata	Passion flower (flowers)
91. Petunia x hybrida	Petunias (flowers)
92. Pelargonium spp.	Lemon-scented geranium (leaves)
93. Philadelphis cornanus	Mock Orange (leaves and flowers)
94. Photinia spp.	Red tip Photinia (leaves)
95. Phyllostachys aurea	Bamboo (leaves)
96. Pittosporum tobira	Pittosporum (flowers)
97. Platanus occidentalis	Sycamore (leaves)
98. Populus alba	White Popular (leaves)
99. Populus deltoides	Eastern Cottonwood (leaves)
100. Populus tremuloides	Quaking aspen (leaves)
101. Portulaca oleracea	Purslane (stems and flowers)
102. Portulaca grandiflora	Moss rose (stems and flowers)
103. Prosopis spp.	Mesquite (leaves and flowers)
104. Prunus serotina	Black cherry (fruit only) – leaves are toxic
105. Psidium littorale	Cattley guava (fruit)
106. Pueraria lobata	Kudzu (leaves)
107. Pyrus calleryana 'Bradfordi'	Bradford Pear (flowers)
108. Pyrus pyrifolia	Asian Pear (leaves)
109. Raphiolepis indica	Indian Hawthorne (flowers)
110. Rosa spp.	Rose (flowers and hips)
111. Salix spp.	Willow (leaves and flow-
112. Salvia officinalis	Garden sage (leaves)

46. Elaeagnus pungens	Silverthorn (leaves)
47. Eremochloa ophiurides	Centipede grass
48. Eriobotrya japonica	Loquat (fruit)
49. Erythrina herbacea	Southeastern Coralbean (flowers)
50. Eucalyptus spp.	Eucalyptus (flowers)
51. Fagus grandifolia	American Beech (leaves)
52. Feijoa sellowiana	Pineapple guava (flowers)
53. Ficus carica	Edible Fig (leaves and fruit)
54. Ficus lyrata	Fiddle-leaf fig (leaves)
55. Ficus benjamina	Benjamin fig (leaves and fruit)
56. Forsythia spp.	Forsythia (leaves)
57. Fraxinus spp.	Ash (leaves)
58. Fuchsia x hybida	Hybrid fuchsia (U.K. leaves and flowers)
59. Gardenia jasminoides	Gardenia (flowers)
60. Gazania spp.	Treasure flower (flower)
61. Gleditsia tricanthos	Honey locust (leaves)
62. Gordonia lasianthus	Loblolly bay (flowers)
63. Grevillea spp.	Grevillea (flowers)
64. Hamelia patens	Firebush (pollen)
65. Hedychium coronarium	Butterfly ginger (flowers)
66. Heliconia psittacorum	Heliconia (flowers)
67. Hemerocallis spp.	Daylily (flowers)

113. Sambucus canadensis	American Elder (fruit only)
114. Sassafras albidum	Sassafras (leaves)
115. Spinacia oleracea	Spinach (leaves)
116. Spiraea reevesiana	Bridal wreath spirea (leaves)
117. Stenotaphrum secundatum	St. Augustine grass
118. Tagetes erecta	Marigolds (flowers)
119. Taraxacum officinale	Dandelion (flowers and leaves)
120. Thumbergia spp.	Clock-vines (flowers)
121. Torenia fournieri	Torenia (flowers)
122. Trachelospermym jasminoides	Star Jasmine (UK) (leaves and flowers)
123. Trifolium repens	White clover (flowers)
124. Tropaeolum majus	Nasturtiums (flowers and leaves)
125. Typha latifolia	Common Cattail (leaves and flowers)
126. Ulmus spp.	Elm (leaves)
127. Viburnum trilobum	Highbush cranberry (leaves)
128. Viburnum odoratissimum	Sweet Viburnum (flowers)
129. Viburnum tinus	Compact Viburnum (flowers)
130. Viola x wittrockiana	Pansys (flowers)
131. Vitis spp.	Grape (leaves and fruit)
132. Wisteria spp.	Wisteria (leaves and flowers)
133. Xylosma congestum	Shiny Xylosma (leaves)
134. Zea mays	Corn stalks (leaves and fruit)

Appendix 1. Fruit Enrichment Ratings

Produce Description	Rating for enrichment
Apples	Desirable
Avocados	Desirable
Bananas	Preferable
Beets	Poor
Blueberry	Poor
Bok Choy	Desirable
Broccoli	Desirable
Cabbage	Fair
Calabaza	Desirable
Cantaloupe	Preferable
Carambola	Poor
Carrot, cooked	Preferable
Cauliflower	Fair
Celery	Desirable
Collard greens	Fair
Corn	Preferable
Cucumber	Poor
Eggplant	Poor
Escarole	Desirable
Fig	Desirable
Grapes, bunch	Preferable
Grapes, muscadine	Preferable
Grapefruit	Fair
Honeydew	Preferable
Kale	Fair
Kiwi	Fair
Lettuce, Romaine	Preferable
Mango	Preferable
Mustard greens	Fair

Produce Description	Rating for enrichment
Nectarines	Desirable
Onion, cooked	Fair
Orange	Fair
Papaya	Preferable
Peaches	Desirable
Pears	Desirable
Pepper, Green	Preferable
Pepper, Red	Preferable
Persimmon, ripe	Preferable
Pineapple	Fair
Plum	Desirable
Pomegranate	Desirable
Potato, Idaho - cooked	Poor
Potato, Sweet - cooked	Desirable
Pumpkin, cooked	Desirable
Rutabaga, cooked	Desirable
Spinach	Fair
Sprouts, Alfalfa	Poor
Squash, Acorn - cooked	Desirable
Squash, Butternut - cooked	Desirable
Squash, Chayote - cooked	Desirable
Squash, Spaghetti - cooked	Desirable
Squash, Yellow	Fair
Squash, Zucchini	Fair
Strawberries	Desirable
Tangerines	Desirable
Tomato	Desirable
Turnips, cooked	Poor
Watermelon	Preferable

* The above rating system was based on acceptability by the fruit bat collection at the Lubee Foundation, Inc.
Fruits and vegetables were rated as preferable, desirable, fair, or poor based on consumption of each item.
Items that were preferable had a 90 -100% consumption rate when offered as enrichment with a normal diet.
Items that were desirable had a 70 - 90% consumption rate when offered as enrichment with a normal diet.
Items that were fair had a 50 - 70% consumption rate when offered as enrichment with a normal diet.
Items that were poor had a consumption rate less than 50% when offered as enrichment with a normal diet.