The Captive Environment for Old World Fruit Bats

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Introduction

The captive environment for Old World fruit bats (*Megachiroptera*) should be based on the natural history of each species since this large group includes approximately 42 living genera and 166 species (Koopman, 1993). Megachiroptera have a variety of roosting requirements, feeding strategies and sensory capabilities. They also vary in size ranging from the African long-tongued fruit bat (*Megaloglossus woermanni*) which may weigh 8 – 15 grams to the Malayan flying fox (*Pteropus vampyrus*) which may weigh over 1000 grams (Jones, 1971; Lekagul and McNeely, 1977). This chapter will discuss the captive environment for bats in the sub-family *Pteropodinae* such as flying foxes (*Pteropus spp.*), straw-colored fruit bats (*Eidolon helvum*), Rousette fruit bats (*Rousettus spp.*), dog-faced fruit bats (*Cynopterus brachyotis*), and epauletted fruit bats (*Epomophorous spp.*). Bats in the sub-family *Macroglossinae* are obligate nectarivores, and will be covered in a chapter on nectarivorous bats.

Roosting Habits

Bats in the wild, spend more than half their lives in their roost environment and the quality of captive roost will have a direct effect on the stress level of bats in captivity (Kunz and Pierson, 1994; Carlstead, 1996). Roosts vary in several specific qualities such as light intensity, temperature, ventilation, and humidity. The roosts of Old World fruit bats can be divided into three main categories: 1) Tree roosts with groups of tens to thousands of bats, 2) Tree roosts with solitary bats or bats in small, scattered groups, and 3) Roosts in hollow trees, rock overhangs, and caves (Marshall, 1983). Bat colonies may range from being solitary to highly colonial, and should be kept in groupings based on their natural behavior (Kunz and Pierson, 1994). Straw-colored fruit bats (*Eidolon helvum*) and several flying foxes (*Pteropus vampyrus*, *Pteropus giganteus*, *Pteropus lylei*, *Pteropus poliocephalus, Pteropus voeltzkowi, Pteropus hypomelanus, Pteropus rodricensis*) are moderately to highly colonial while little golden-mantled flying foxes (*Pteropus pumilus*) are more solitary (Pierson and Rainey, 1992). Wahlberg's epauletted fruit bats (*Epomophorous wahlbergi*) roost in small groups in thick foliage, hollow trees, and in palm fronds (Kingdon, 1974).

Light Quality

Light plays a significant role in the life cycle of a bat, whether their roosting under intense natural light or roosting deep within the recess of a cave (Barnard, 1995). Photoperiod and light quality have been connected with the reproductive biology of birds and mammals (Farner and Lewis, 1971; Sadleir, 1969; van Tienhoven, 1968). Lighting is probably best when it imitates natural photoperiods such as outdoor caging or by placing cages in rooms with natural sunlight (Fascione, 1995; Barnard, 1995; Wilson, 1988; Rasweiler, 1975). Light intensities and photoperiods can also be controlled with full-spectrum, fluorescent lights set on timers with 12 hours of daylight and 12 hours of darkness (Wilson, 1988). Tree roosting species that roost under intense natural light may require ultraviolet wavelengths for vitamin D production. While cave-dwelling species like the Egyptian fruit bat (*Rousettus aegyptiacus*) or the Ruwenzori long-haired fruit bat (*Rousettus lanosus*) will show stress if not given dark areas to hide and roost. All captive bats should be given the option of avoiding light during daylight hours by providing them with appropriately designed roosts. Cave-dwelling megabats can be managed in a nocturnal exhibit on a reversed lighting cycle. This allows the public to view the animals during their active period. For this purpose, a combination of blue and red bulbs work well to stimulate moonlight (Barnard, 1995). Timers with dimmers can be set so that light changes can be gradual rather than all or nothing, which can create stress.

Temperature and Relative Humidity

Megachiroptera are found in a wide variety of habitats throughout the Old World tropics and sub-tropics from Africa through southern Asia to Australia and on islands in the Indian and western Pacific Oceans (Mickleburgh et al. 1992). Tropical species do best in temperatures ranging between 70 – 85 ° Fahrenheit (21-30 °C) with an ideal temperature of 80 °F (27°C) (Wilson, 1988; Fascione, 1995; Barnard, 1995; Heard, 1998). Relative humidity for tropical species should be 60-90% (Rasweiler, 1975; Wilson, 1988; Fascione, 1995; Barnard, 1995). Bats should be maintained in enclosures that provide them with a temperature gradient so they may seek out their own thermal preference.

In outdoor enclosures, supplemental heat is needed for temperatures below 70 ° F (21 ° C). Bats that are given an opportunity to slowly acclimate to cooler temperatures at the Lubee Foundation, Inc. became more resistant to cooler temperatures and grew dense fur coats and utilized wing wrapping for thermal insulation (Carpenter, 1986). These bats could be observed to roost normally at 60 ° F (15.6 ° C) even though heated areas were provided. Heat can be provided with space heaters and heat lamps. Brood-all heaters® are an excellent source of direct heat, which do not heat the wire mesh of the enclosure like infra-red heat lamps. Heating devices must be maintained in a manner that will prevent accidental burning. All bat species need roosts that they can retreat into during cool weather that are free of drafts (Barnard, 1995).

During summer in outdoor enclosures, misters, fans, and shade cloth can provide relief from temperatures that go over 90° F (32° C). Heat stress in bats can be observed with bats wing flapping and panting (Carpenter, 1986; Heard, 1998). Misters can also be utilized to elevate the enclosure humidity, since low humidity can cause dry skin or wing membranes and/or cracked nails (Fascione, 1995).

In indoor enclosures, most institutions provide a constant temperature of 78 – 80 °F (25 -27 °C) and relative humidity is maintained with humidifiers and by spraying the enclosure floor with water during cleaning (Wilson, 1988; Barnard, 1995). Ventilation is also important to avoid a buildup of unpleasant odors. The AZA Bat Taxon Advisory

Group suggests six to ten air exchanges per hour with 25% fresh air (Fascione, 1995). The air leaving bat exhibits, should also be vented outside and not recirculated into public areas (Wilson, 1988).

Enclosures for Old World fruit bats

Enclosure design and the captive environment more than any other variable will determine the variety of behaviors which captive animals will display, and the goal should be to maximize their ability to express their natural behavior. Since bats are the only group of mammals that can truly fly, they have special needs in enclosure design because flight is severely limited in captivity (Wilson, 1988). In the United States, 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 space to allow all individuals to rest simultaneously. Bats deprived of flight for periods of a month or more may lose the ability to fly, and develop problems with obesity (Carpenter, 1986; Wilson, 1988; Heard, 1998). The minimum caging requirements for sustained flight recommended by the AZA Bat 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 be facilitated in u-shaped, doughnut or dumbbell shaped enclosures, and is minimized in square enclosures since bats fly from one wall straight to another (Seyjagat, 1994; Fascione, 1995; Heard, 1998). Many researchers and zoos have successfully kept bats in small enclosures provided the animals are given opportunities for exercise (example: allowed to fly or given opportunities for static flight – cage length and width are 1 ½ times the wing length with no impediments) (Fascione, 1995; Barnard, 1995).

The height of a bat enclosure is also important and will determine management options for restraining bats for vet exams and emergencies. Bat enclosure design has been guided by the principle that a bat drops from the ceiling to become airborne to fly, and thus requires an enclosure with a very high ceiling (Greenhall, 1976). Bats do gravitate to the highest point in the enclosure and prefer roosting above human eye level. But, even the largest megabat in captivity, the Malayan flying fox (*Pteropus vampyrus*) can be managed with a minimum ceiling height of 6.5' (2 m) which allows an adequate height for flight and also allows for animal inspection at human eye level (Seyjagat, 1994).

Megachiropterans in captivity are contained in four major types of enclosures:
1) Free-flight exhibits with multiple species, 2) Day roost exhibits with tree-dwelling megabats, 3) Reverse-lighting enclosures for cave-dwelling megabats, and 4) Universal cages for maintaining a smaller groups of bats. Several zoological institutions have utilized colonial megabats such as straw-colored fruit bats (*Eidolon helvum*) and flying foxes (*Pteropus spp.*) in large free-flight, walk through aviaries which allows the public a unique view of these flying mammals (Fascione, 1996). These large exhibits offer captive bats a wide variety of enrichment options and a life that is most similar to a wild existence.

The most appropriate exhibit for colonial tree-dwelling species such as straw-colored fruit bats (*Eidolon helvum*) and flying foxes (*Pteropus spp.*) is a day roost enclosure that simulates a tree top environment that is flooded with intense natural light (Snell, 1994; Heard, 1998). These species are mostly nocturnal or crepuscular in their feeding activities, but are socially active during the day in their roost setting. Several institutions offer feedings at opening and closing, which allows the public to observe feeding activities.

Cave-dwelling megabats like the Egyptian fruit bat (*Rousettus aegyptiacus*) or the Ruwenzori long-haired fruit bat (*Rousettus lanosus*) are best displayed in a reverse lighting nocturnal cave exhibit. Bat caves can be made with a shot crete wet mix design providing semi-rough ceiling domes to facilitate roosting (Barnard, 1995; Fascione, 1995). Fluorescent tubes and halogen lights with red and blue filters make up a good lighting system (House and Doherty, 1975). The day cycle lights are usually fluorescent while halogen lights with blue filters provide the night cycle to simulate moonlight. Blue light has the advantage over red light because it doesn't change the color of the bats and is visually more esthetic (Fascione, 1995). During the day light cycle, bats should have access to shaded or darkened areas that simulate their natural day roosts.

Rectangular universal cages have been utilized since bats have been kept in captivity for isolating and maintaining smaller groups of bats (Wilson, 1988). For non-flight cages, a minimal acceptable enclosure height should be no less than one and a half times the bat's body length to avoid contact with fecal matter and spoiled food (Fascione, 1995; Barnard, 1995). Universal cages should also have sufficient room to accommodate stretching and static flying behaviors with the minimal acceptable length and widths for primary enclosures being no less than one and a half times the wing span (Fascione, 1995).

Enclosure surfaces should be smooth, non-porous, and non-abrasive (Fascione, 1995). Galvanized wire mesh should be avoided because bat urine corrodes tinned surfaces and may cause zinc toxicity if ingested (Wilson, 1988). The AZA Bat Taxon Advisory Group recommends polyethylene mesh and vinyl-coated non-galvanized wire mesh for bat enclosures (Fascione, 1995). The size of the mesh should be approximately 14 gauge, 1"x ½" (1.27 cm x 2.54 cm) to prevent bats from pushing a wing or foot through it (Wilson, 1988; Seyjagat, 1994). Thin wire (example: chicken wire) should be avoided as it will damage the feet of larger megabats (Fascione, 1995). Glass viewing windows allow for close-up viewing and present no special problems, as long as they are covered by soap or taped with paper, when introducing new animals into the enclosure to allow them to adapt to their new surroundings (Fascione, 1995). In the United States, the Lacy Act of 1900 (18 U.S.C. 42; 16 U.S.C. 3371-3378) has designate bats in the genus *Pteropus* as injurious wildlife, and they must be maintained in a double enclosure to reduce the possibility of escape. The second enclosure should be more than two inches from the first enclosure to minimize the risk of a bat's foot getting entangled in the second containment field (Fascione, 1995).

Pteropus bats in enclosure at Lubee

Enclosure Furnishings

Complexity of the environment rather than space alone may be the key to the behavioral repertoire of the animals contained in that environment (Carlstead, 1996). This complexity encourages foraging, scent-marking, hiding, and facilitates social play (Poole, 1997). Although bat workers should never fool themselves that they can truly replicate a natural environment in a captive setting. Institutions should instead direct their efforts toward providing inhabitants with as many biologically and ecologically relevant stimuli as possible such as providing opportunities for flying, exploration and foraging, predator avoidance, and security (Hediger, 1950; Shepherdson, 1997; Barnard and Hurst, 1996).

Bat roosts

Bat enclosures require 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 areas to rest. Day 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). Tent-building bats such as dog-faced fruit bats (*Cynopterus brachyotis*) and Jamaican fruit bats (*Artibeus jamaicensis*) are documented tent-builders, and this behavior can be stimulated in captivity when housing bats with the proper plants such as palms and bananas (Kunz et. al. 1994; LeBlanc, 1997). Night and feeding roosts are varied for all species, but generally occur in trees and shrubs. These roosts can be stimulated by natural plantings and offering perching options with non-toxic branches, vines, and ropes. Bats will usually roost at the highest points of an enclosure in captivity, and should be given multiple roosting options, which permits segregation into social groups (MacNamara et. al. 1980). The vertical dimension of the roosting niche is important in addition to the horizontal space since this allows bats of different dominance levels to segregate themselves and minimizes conflicts in the colony. Once bats have selected a roost, they may display roost loyalty for extended periods.

Lesser dog-faced fruit bats taking up residence in their penthouse apartment

Visual barriers

Visual barriers simulate the natural screening effect of forest foliage and may increase roosting density and concealment while minimizing aggression (Mckenzie et. al. 1986). Several bat species such as Wahlberg's epauletted fruit bats (*Epomophorous wahlbergi*) and little golden-mantled flying foxes (*Pteropus pumilus*) will seek cover and should be provided with multiple types of barriers to allow these bats to display natural predator avoidance (Shepherdson, 1997). Plywood boxes provide an excellent source of cover and act as visual barriers for species that like to roost in shaded areas. 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, 1999). Commercially available shade cloth can be attached to outside walls along high traffic service areas to minimize stress to animals and to give them shelter from the sun and wind. Southern wax-myrtle cuttings (*Myrica cerifera*) and sabal fronds (*Sabal spp.*) can be utilized as long-lasting foliage barriers (LeBlanc, 1999).

Opportunities for Locomotion and Natural Substrates

All bat species move on a wide variety of substrates during foraging and roosting, and should be given opportunities for this natural locomotion (LeBlanc, 1999). Crevice-dwelling species should be given opportunities to utilize crevices or ceiling domes with hard surfaces to assist in natural nail wear since these species are able to land and climb on vertical rock or rough cement walls. Foliage-dwelling bat species climb on vertical and horizontal branches and vines, and this helps to wear down continuously growing nails (Barnard, 1995). All plant material should be non-toxic and vary in texture, diameter and degree of firmness. A variety of trees and shrubs can be planted with Old World fruit bats to provide perching sites (LeBlanc, 1997). Since Old World fruit bats are folivorous, special care should be given when selecting plants for use in their enclosures. Non-palatable trees and shrubs with waxy leaves and edible flowers such as bottlebrush (*Callistemon spp.)*, pittosporum (*Pittosporum tobira*) or Japanese privet (*Ligustrum japonica*) have been utilized at the Lubee Foundation, Inc. Palatable plant material can be utilized as browse to stimulate foraging enrichment. If the browse is hung densely, the network of branches with thick leaves will stimulate the bats to use these areas as temporary roosts (LeBlanc, 1999). When hanging browse or utilizing live plants, flight paths should not be blocked, and all sharp edges should be trimmed to minimize objects which could damage bat wings (Fascione, 1995). Special care should be given to minimize leaving gaps between the walls of the enclosure and the browse that could trap an animal. Points of attachment for perching should be designed into bat exhibits.

Grapevines, artificial vines and heavy ropes are particularly useful to promote horizontal locomotion (Goss, 1999; LeBlanc, 1999). Ropes can be hung around the outer perimeter of the enclosure to facilitate landing. Flying foxes will fly over the ropes, and then land on them. The ropes must be at least twice the bats' total length (Head to feet length) from the wall of the enclosure and drop this same length from the ceiling of the enclosure from points of attachment (LeBlanc, 1999).

Ladders are also important furnishings in bat enclosures, and are utilized to allow bats that have landed on the floor of the enclosure a simple method of returning to the uppermost levels. The vertical dimension of the ladder also allows less dominant bats an escape route from aggressive animals. The composition of the ladder can range from vinyl coated wire mesh to durable plastic mesh. Rope ladders with natural branches can be utilized to promote climbing skills on a stable to unstable substrate.

Enclosures designed for bats should provide a soft non-abrasive landing area. Natural substrates such as grass can reduce injury to animals that fall to the ground (Fascione, 1995; LeBlanc, 1999). In indoor enclosures, mulch can be utilized with small colonies of Old World fruit bats. Newspaper or brown Kraft paper can be utilized to cover the floor of universal cages with excellent results (Barnard, 1995).

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