American Zoo and Aquarium Association
Chiropteran Advisory Group:

FRUIT BAT HUSBANDRY MANUAL

1995

TABLE OF CONTENTS

Table of contents, cont.

INTRODUCTION

This husbandry manual is, in large part, based on the collective experiences of the participants of the American Zoo and Aquarium Association's (AZA's) Bat Taxon Advisory Group (TAG) Husbandry Meeting held at the Lubee Foundation on 26-27 January 1994. The Manual was further edited during the January 1995 midyear meeting, held again at the Lubee Foundation (see *Appendix A* for list of participants). TAG members and advisors who were unable to attend the meetings were able to review and comment on several drafts of the manual. An enormous amount of time was put into creating this document by all those listed in Appendix A. Keith Atkinson, Jan Reiter and Darryl Heard deserve special credit for doing the majority of writing for the sections on reproduction, nutrition and health, respectively.

This document is intended to serve as general husbandry guidelines for managers of frugivorous bat species, by far the most common group of bats found in zoological institutions. Those who are considering keeping frugivorous bats should become familiar with the natural history of the species under consideration (see ***References*** for further reading). Additional assistance should be solicited from the TAG, who can refer inquiries to the appropriate curator, keeper, or researcher familiar with a particular species. Scientific names have been used throughout the text to avoid potential confusion over common names. A full list of scientific and common names of species held in zoos, along with their conservation status, can be found in *Appendix B.*

There are two families of fruit bats, Pteropodidae, which are found in the Old World tropics, and Phyllostomidae, found in the New World tropics (however, not all members of the Pteropodidae and Phyllostomidae are frugivorous). As you read these guidelines, please bear in mind the tremendous diversity of size, social organization, and behavior that exists among the frugivorous species. The TAG was, on the whole, reluctant to make species-specific recommendations given the diversity of taxa. In some cases, examples have been provided to illustrate the range of behavior.

There was widespread agreement among TAG members of the need for more systematic evaluation to support our husbandry experiences, particularly in the area of nutrition and reproduction. Therefore, the TAG will encourage data collection and husbandry research by member institutions housing bats. Venues such as the TAG Five-year Action Plan will facilitate this process. The Bat TAG intends to meet annually to update the husbandry manual. Readers are encouraged to send comments or suggestions to Nina Fascione, Husbandry Manual Editor (4014 Simms Dr., Kensington, MD 20895).

I. HOUSING

I.A. **Containment**

In general, enclosure surfaces should be smooth and non-porous, and all surfaces with which bats will come into direct contact should be non-abrasive. Wall and floor surfaces must be able to withstand a great deal of hosing and should be appropriately sealed. Galvanized steel cages and wire should be avoided because bat urine corrodes tinned surfaces and may cause zinc toxicity if ingested (Wilson, 1988). Therefore, if an enclosure contains wire, we recommend using vinyl coated, Teflon sprayed, or non-galvanized wire.[1] Polyethylene mesh is also an excellent material (Barnard, 1991). The size of the openings in wire or mesh should be small enough to prevent animals from pushing a wing or foot through it, but not so fine that animals' claws get stuck in the mesh (Wilson, 1988).

Enclosures with glass fronts present no special problems, although it may be necessary to tape or soap the windows for a few days after animals are newly introduced to alert animals to the presence of the glass. Piano wire has been used as a public barrier on some fruit bat exhibits, with plastic coated wire being the easiest to clean. The disadvantages of piano wire include bats getting caught in wire, especially when they are new to the exhibit, and urine and fecal material passing through to the public viewing area. To minimize the second problem, place roosts at the two ends of the exhibit, on sides adjacent to piano wire front. The bats will fly back and forth between the roosts (in front of the viewing public) and, because bats tend to defecate while turning at the ends of the exhibit, the amount of fecal material that is passed through the piano wire front will be minimized.

For exhibits that are constructed as "bat caves" (e.g., the shot crete wet mix design), the vault must be semi-rough to facilitate roosting. Also, it is important to create many small concave pockets in the vault to offer multiple territories and visual barriers favorable to the establishment of a social structure such as harems. Finally, the vault must be uneven and characterized by many elevation levels to simulate a natural environment.

For outdoor exhibits, use of a double enclosure will reduce the possibility of escape. This is mandated by the Lacey Act for *Pteropus* species. The second enclosure should be more than two inches from the first enclosure to minimize the risk of a bat's foot reaching through the first enclosure and getting entangled with the second. Use small wire openings (one-half inch by one-half inch) or a Plexiglass barrier for pest control (see Section II.F.). Thin wire (e.g., chicken wire) should be avoided as it may damage feet, especially with heavier bats (e.g., larger Pteropids).

I.B. **Furnishings**

Vinyl coated wire hung on the ceiling provides toeholds for bats. We particularly recommend using one inch coated wire, as it mimics the network of branches that bats use for a variety of behaviors including breeding, grooming, displaying, seeking food, roosting, and fleeing from aggressive encounters. Wire ceilings also promote wing walking by the bats and increases activity in the exhibit. Bats can be excluded from selected areas (e.g., over water or food dishes) by adding Plexiglas over the wire to prevent roosting.

Rough, naturalistic branches and vines should be provided as perches to help keep bats' nails from overgrowing. However, there should be no points or sharp edges that could puncture wings. Perches will need to be replaced occasionally; therefore, points of attachment should be designed into the exhibit. Roosting areas such as perches, branches or boxes should be positioned far enough apart that animals can space themselves out during stress or flights (MacNamara et al, 1980). Branches, vines, heavy ropes or crawl ladders (e.g., wire "ladders" attached to wall) should extend to the ground, especially if the exhibit contains solid or glass side walls. This will aid bats who are trying to move from the floor to ceiling roosting areas, as bats can exhaust and injure themselves attempting to fly up to their roost. Narrow gaps (e.g., one-half centimeter) should be avoided in cage furnishings because bats can get wings wedged in the gap.

Darkened roost boxes or other visual barriers (e.g., bamboo shades) are recommended to provide animals with an avenue of escape from stressful situations, especially if aggression among individuals is observed (Rasweiler, 1975). Consideration should be given to providing feeding stations accessible from wire walls, vines, or perches; or, with sufficient clearance to allow bats to fly to and away from them. Sprinklers or soaker hoses can be used for cooling or as water sources.

I.C. **Shelter Requirements**

Shaded areas must always be provided in outdoor enclosures (e.g., by use of vegetation, plywood structures, etc.). Shelter from rain & wind is also required. Supplemental heat needs to be provided when temperatures drop below 75 degrees Fahrenheit (24ºC) for an extended period, or bats may suffer from permanent damage to wing membranes and finger joints. In regions where temperatures drop below 50 degrees Fahrenheit (10ºC), an indoor facility is necessary (see Section I.G. for additional temperature requirements).

I.D. **Minimal Acceptable & Optimal Size of Enclosures**

Fruit bats require ample space to perform normal maintenance behaviors and do best in enclosures large enough to permit free flight (Wilson, 1988). However, many researchers and zoos have successfully kept bats in small enclosures provided the animals are taken out and exercised (i.e., allowed to fly) at least every other day. Muscles of bats that are unable to fly for a

month or more may atrophy and bats may lose the ability to fly (Wilson, 1988). For non-flight cages, a minimal acceptable enclosure height should be **no less** than one and a half times the bats' body length to avoid contact with fecal matter and spoiled food. Fruit bats should also have sufficient room to accommodate stretching and static flight behaviors (see ***Appendix C, Ethogram***, for definition of behaviors). Accordingly, minimal acceptable lengths and widths for primary enclosures should be **no less** than one and a half times the wing span.

Bats maintained for exhibition purposes should be housed in larger enclosures to allow for a broader spectrum of behaviors including flight. In this case, enclosures should be at least four times the wing span long and four times the body length high. To offer sustained flight, the enclosure should be much longer (at least eight times the wing span). For example, an enclosure housing *Pteropus giganteus*, a species with wing spans reaching six feet (1.83 meters), should be at least 24 feet (7.3 meters) long in order to allow short flight. Square enclosures are suitable for fruit bats but rectangular, u-shaped, doughnut, circular, and other novel designs may facilitate sustained flight more efficiently.

Bats appear to be more comfortable in enclosures above human eye level, and will usually move to the highest point in an exhibit. However, if an enclosure is too high, capture of bats for medicinal or husbandry purposes may be hindered. Generally, a cage height of six to seven feet will suffice for most species. However, larger bats, such as the *pteropids*, could be housed in taller exhibits. In addition, greater spaces are needed for larger colonies.

I.E. **Capture & Handling Facilities**

In free flight enclosures or exhibits where high ceilings make hand capture difficult, it may be beneficial to have an adjacent cage or cages for management purposes. If an enclosure is designed for intensive management (e.g., biological studies), a six to seven foot tall ceiling is suggested to facilitate capture and reduce trauma to nails and wings.

I.F. **Substrate**

As bats may occasionally descend to the ground, non-abrasive flooring should be used. Natural substrates such as soil, grass or mulch can be used with low densities of bats. We do not recommend the use of sand, as bats may ingest it. Flooring material should be easy to clean and floors should have good drainage.

I.G. **Temperature, Humidity, and Ventilation Requirements**

Fruit bats originate from tropical areas and do not tolerate low temperatures for extended periods.[2] Although researchers disagree on the optimal temperature to house bats, laboratory studies have found that tropical bats do best in temperatures ranging between 70 and 90 degrees Fahrenheit (21-33°C). According to Wilson (1988), Rasweiler (1975), and Barnard (1991), the

ideal temperature is 80 degrees Fahrenheit (26°C). Bats do best when a constant temperature is maintained.

In outdoor enclosures, supplemental heat is needed for temperatures below 75 degrees Fahrenheit (24°C) and, in regions where temperatures fall below 50 degrees Fahrenheit (10°C) for prolonged periods, indoor enclosures are necessary. If heat lamps or brood-rite heaters are used they should be properly shielded from bats so that the animals cannot burn themselves or chew through wires. In addition, we recommend creating multiple paths to heat sources to reduce aggression between bats.

There are few data available regarding the proper humidity for bats. However, bats appear to do well at relative humidities of 60-90 percent (Rasweiler, 1975; Wilson, 1988; Barnard, 1991). Low humidity appears to be a problem for some species. To maintain proper humidity, we recommend using mister hoses when temperatures go above 85 degrees (26°C). Symptoms of low humidity include dry skin or wing membranes and/or cracked nails.

A highly efficient ventilation system is necessary to avoid the buildup of unpleasant odors, especially in enclosures housing large colonies. A suggested rate of air change for larger colonies is six to ten exchanges per hour with 25% fresh air. Because of the bacteriological breakdown of bat guano, it is important that air leaving bat exhibits, especially that from large colonies, be vented outside and not recirculated or ducted into a public area (Wilson, 1988).

I.H. **Lighting**

Because there are few scientific studies describing circadian rhythms of bats, lighting is probably best when it imitates natural photoperiods (Wilson, 19488; Rasweiler, 1975). Fruit bats do well on a 10/12 to 12/10 light/dark cycle (Wilson, 1988; MacNamara et al, 1980), and should never be kept in 24 hour darkness or light. Fruit bats do not need to be kept in a nocturnal exhibit. Many species are diurnal or crepuscular, and therefore active during the day. However, many species, especially nectar-feeding bats, are more active at night and managers may prefer reversing the light cycle. Reverse red or blue lighting is acceptable for use for display purposes, as are incandescent or florescent lights (House and Doherty, 1975). If a reversed cycle is used, halogen lights, fluorescent tubes, and blue filters make up a good lighting system. The day cycle lights are fluorescent and the nocturnal lights are halogen with blue filters. Blue light can be used (rather than red) because it simulates the color and intensity of moonlight and does not change the color of the bats. We strongly recommend using a dimming/anti-dim cycle to reduce the shock of immediate bright light or complete darkness. During the fruit bat "day" cycle, shaded or darkened areas for roosting should be provided. Access to full sunlight is beneficial for *Pteropus*. Fruit bats can see most colors of light, including red.

I.I. **Utilities**

There are no special concerns or requirements for sewage disposal; however, requirements can vary by region and managers should be aware of local regulations.

There are no special light fixtures needed (see Section I.H. for lighting recommendations).

II. MANAGEMENT

II.A. **Water Sources**

Because water requirements are unknown for bats (Racey, 1970), water should be offered at all times, even though some species (e.g., nectar-feeding bats) may rarely be seen drinking. Several sources of water (e.g., bowls, pools, mister hoses, etc.) should be provided and water should be changed daily. Large colonies and exhibits housing mixed bat species or aggressive animals will need a greater number of water sources. Some of the larger fruit bat species are capable of learning to drink from watering devices fitted with tubes. These devices have the advantage of not becoming soiled by urine and feces. Some species or individuals may not be able to utilize these devices, however, and standard glass, plastic, or ceramic bowls should be used instead. To minimize contamination of water sources by urine and feces, place water source beneath areas of smooth ceiling where bats cannot hang.

Some naturalistic bat exhibits (e.g., the bat cave of the Biodome de Montreal) have shallow running water sources. This kind of water source is greatly used by Microchiropteran bats that glide over the water surface for a drink.

II.B. **Feeding Schedule**

One daily feeding is sufficient for most species. Large colonies, however, should be fed more frequently to insure that all individuals will have access to food.

II.C. **Individual Identification Methods**

All known identification methods have advantages and disadvantages and tend to be species specific. The following is a summary of selected identification methods used in bats (taken from Kunz, in prep.)

1. Transponders. The AZA Chiropteran TAG recommends all fruit bats be permanently identified using the Trovan Electronic Identification System (i.e., transponders).[3] To insert a transponder, pinch and pull the skin, insert needle under the skin, and inject transponder right

side up. The best placement is in the posterior dorsal region where it will not interfere with movement. Some managers have placed transponders between the shoulder blades; however, this location may interfere with muscles and shoulder blade movements associated with flight.

Advantages of this technique include relative permanence and few health/injury risks. The disadvantage of transponders is that the individual must be in-hand to read the identification.

2. Bead-chain necklace. Many field researchers have used bead-chain necklaces quite successfully and they seem to work well with some species. The advantages of bead-chain necklaces are that they can be seen from a distance and come in many color and/or number combinations. Disadvantages are that beads have been reported to fade, they can break, be abrasive, harbor mites and ticks, food can cake around necklace, and the public sometimes reacts negatively to the "jewelry."

3. Thumb bands. Some species do fairly well with thumb bands, while others, such as *Rousettus aegyptiacus* and *Pteropus rodricensis* are able to remove them. Use colored bands[4] that are placed on the animal loosely enough to turn easily and not cut off circulation. Aluminum bands are not recommended for fruit bats as they can be compressed if bats chew on them. The advantages of colored thumb bands is that they are fairly easy to read from a distance and there are many color and/or number combinations available. Multicolored band combinations as well as numbered bands should be read from distal end of thumb in toward the wing. Stainless steel bands are also available and work well with some species. However, stainless steel bands cannot be read from a distance (as colored bands can). Therefore, we recommend using transponders for close identification needs and colored bands for remote identification.

4. Forearm bands. Extreme care must be taken when using forearm bands because they can restrict circulation in the propatagium. They may also injure the underlying muscle and tendons if bats chew and bend the band. If used, band combinations or numbers should be read from the distal end of thumb.

5. Ear notching. This technique is not recommended because it disfigures the animal and there are relatively few combinations available.

6. Ear tags. Ear tags can cake with food and can tear out of the ear. In addition, they are difficult to read from a distance.

7. Tattooing (wing). Wing tattooing is a short-term identification method because the tattoo does not last long. Another disadvantage is the need to catch the animal in order to read the tattoo.

8. Freeze branding. This method of identification has not been successful to date.

9. Nail polish. Nail polish, when placed on the individual's back, is fairly useful for short-term identification purposes, and many color variations are available. The disadvantage of this

method is the frequent need to replace polish. In addition, while nail polish makes for easy identification because it is easy to see, it may be offensive to the visiting public.

All methods of identification, but especially bands, should be checked regularly.

II.D. **Methods of Capture, Handling & Restraint**

Chiropteran wing bones are delicate and can be easily broken during capture. If using a net, make sure it is wider than the bat's wingspan to avoid damage to wing bones and membranes. Mist nets can also be used to capture bats. Be sure to have experienced personnel and adequate staff on hand when using mist nets. It is important to remove bats from nets immediately so they do not get overly entangled. To remove bats that are hanging on wire or perches, be sure to unhook their nails rather than pulling on the bat. This will avoid injury to toes. In large, free-flight aviaries, it may be useful to erect a food trap. This is accomplished by feeding animals in a small enclosed area on a regular basis so that, when it becomes necessary to capture bats, the area can be sealed as the animal is eating.

Appropriate techniques for handling small mammals are generally adequate for bats, although care should always be taken to immobilize the wings. Do not hold any bat by the wing tips during restraint and always fold wings close to the body. Special care needs to be taken not to hyperextend the joints to avoid permanent damage. While we do not know if holding bats head-up for prolonged periods presents a risk to bats, we recommend trying to hold them head down (or at least horizontal) as a precaution.

It is a good idea to wear a long sleeved shirt and gauntlet gloves[5] when handling bats, especially the larger fruit bats. Welders gloves can be useful in handling large fruit bats to reduce keeper injuries; however, use of them may cause injuries to the animals. If used, **extreme care** should be taken not to apply excessive pressure. When weighing fruit bats, place the bat in a cloth bag before putting it on the scale to reduce stress. If a bat bites, do not pull away, but rather blow on the bat's face until the bat releases.

In most States, a bat that bites a human must be killed to test it for rabies. For this reason, we recommend that the public not have direct contact with bats. Only trained and qualified personnel should handle bats. In addition, all personnel who come into contact with bats should be immunized against rabies and have titers tested regularly (see Section VI.L.).

II.E. **Crating & Transporting Procedures**

Most bats can be shipped communally. Mothers with nursing infants should not be shipped. Some international shipments may require use of a lift-out internal cage so that bedding and fruit can be destroyed at the port of entry. Crates should be designed so that there is no leakage (e.g., of urine or feces) from the crate during shipment. Check with customs before shipping and prepare the crates prior to shipment.

Zoos must follow IATA standards for all importations. Once within the United States, IATA standards are still recommended by the Center for Disease Control (CDC), the United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS), and United States Department of Interior (USDI). However, the "secondary enclosure" technique, described under ***Megabats***, below, will be permitted (CDC and USDI, pers. comm.). Check with appropriate agencies prior to shipment.

1. Megabats. ***Pteropus*** species must be transported in double cages. A varikennel with an internal wire cage works well. Line the sides of the inside lower two-thirds of the crate with towels or cheesecloth. This provides the bats with some privacy but still allows air flow through the top. Care should be taken that there are no frayed edges on the towels with which the bats could become entangled. Cover windows and doors with cheesecloth as a visual barrier. Crates should be large enough so that when bats are hanging their faces do not reach the floor.

2. Microbats. Microbats such as ***Glossophaga soricina***, ***Carollia perspicillata***, and ***Artibeus jamaicensis*** can be transported in quart-sized cardboard cartons.[6] (See Figure 1). These containers, which can be purchased from paper goods companies, measure about four and one-quarter inches in diameter at the top, three and one-half inches in diameter at the bottom, and are six inches high. They should be moisture-resistant and have slip-on lids. To give the bats something to hang onto, line the interior by stapling one-eighth inch square mesh plastic aquaculture netting.[7] Punch air holes in the sides with a cork borer. Up to three ***Carollia***-sized bats can fit in one carton.

Fourteen of these cardboard cartons can be placed inside a screen-lined cardboard mouse shipping cage (with the partitions removed).[8] For extra protection, the mouse cages can be placed inside a strong protective container constructed of one inch square, hollow aluminum tubing which is lined on the sides with one-quarter inch galvanized wire mesh and has a plywood roof and floor.[9]

The bats should have access to food prior to shipment, and should not remain in the containers for more than 15 hours.

3. United States Regulations. A Centers for Disease Control (CDC) permit is required to import fruit bats into the United States ***and*** to ship bats between states. In 1995, CDC developed more stringent guidelines, so be sure to check with them prior to shipping bats.[10]

4. Canadian Regulations.

a. Shipments from the United States. There are no restrictions for bats being imported from the United States; however, shipments require a health certificate and permission from the Canadian Department of Interiors.

b. Other foreign importation. According to Section Ten of the Animal Health Regulations, administered by Agriculture Canada, an import permit must be issued by the Animal Health

Division of the Food Production and Inspection Branch of Agriculture Canada prior to importation. To receive the permit, an application form must be completed by the importer and submitted to the appropriate regional office. At their arrival in Canada, the bats will be confined for a 30 day quarantine period in a previously approved area. If there is no health problem after this period, the quarantine will be ended. *Appendix D* contains a copy of the application form (AGR 1551) for a permit to import animals.

Appendix B provides a table of bat species listed as endangered by the United States Fish & Wildlife Service and CITES that can be referenced for shipping information.

II.F. **Pest Control**

The best control is to exclude pests. Cleanliness in and near bat enclosures is of the utmost importance. Be sure the area around bat enclosures is free of places that harbor pests such as cardboard boxes or piles of trash. Seal all cracks and holes into the exhibit. Cockroaches are commonly found in and around fruit bat exhibits. Several methods for controlling cockroach populations are available. Glue boards and snap traps can be used but must be shielded from bats. Pyrethrin-based insecticides and diatomaceous earth can be used with care. Narrow-mouthed beer or soda bottles partially filled with fruit juices can be used as traps. Tracking powder (e.g., Sevin Dust) has been used by some institutions to control ants. However, we do not recommend it because bats will frequently descend to the floor of the exhibit and can be adversely affected by the dust.[11] Snakes can be a problem for small bats, especially in outdoor exhibits. Wire with small openings (e.g., one inch by one-half inch) will exclude most, but not all, snake species. For outdoor exhibits where snakes may present a problem, additional barriers may be needed.

II.G. **Sanitation**

Bats prefer to live in a less than sanitary environment and frequent cleaning may distress the animals. Scrubbing waste from surfaces is necessary, however, on at least a weekly basis, if not more frequently. Large colonies may require cleaning two or more times per week.

It is important to scrub exhibit walls because feces frequently adhere to them. Food and water dishes should be cleaned and sanitized daily to remove urine and feces. When disinfectants are used to clean dishes or exhibits, it is critical to rinse them well, as disinfectants may be toxic to bats (Wilson, 1988).

II.H. **Handrearing**

Handrearing fruit bats is similar to handrearing other small mammals. Be sure to wrap the infant in a towel or hang it on a stuffed animal for its comfort and security. Initially, infants

should be fed with milk replacer (e.g., Esbilac, Similac) every two hours from six a.m. until midnight. Feedings can be decreased gradually over time with pureed and then diced fruits being introduced until infants are weaned (large *Pteropus* species are usually weaned by six months; smaller fruit bats will be weaned earlier). Many suckling fruit bats remain on the nipple until they are weaned and should be given continuous access to a nipple. For additional information on handrearing, see Barnard, S., 1991; Young, J.A., 1987; and George, H., 1988.[12]

II.I. **Record Keeping**

All bats should be included in ISIS records. We further recommend that all neo-natal deaths, stillborns, and aborted fetus' be included in ISIS records. While this is not always an easy task, especially with large colonies of microbats, it is an important tool in determining population demographics.

III. BEHAVIOR & SOCIAL ORGANIZATION

III.A. **Optimal Social Groupings**

Because the majority of bat species are social, we recommend that no bats be maintained singly. The only exception to this recommendation is if an animal requires special medical care. The ideal number of individuals and sex ratio of bat colonies will be species specific and depend largely on the size of the enclosure. If bat densities are too high or low, the resulting stress may lead to detrimental physiological and/or behavioral changes (Rasweiler, 1975). While managers should observe colonies for excessive fighting and potential injuries, squabbles among bats are common in the wild and in captivity, and often result in harmless wing tears that heal quickly and are of little concern. (For more information on wing tears, see Section VI.F.). To help avoid undue fighting among animals, be sure to place sufficient feeding and roosting stations in the enclosure (see Section I.B for additional information on avoiding aggression).

If the husbandry objective is to increase the size of a population in an organized breeding program, we suggest maintaining more females than males, for instance in a ratio of 2.6 or 2.8. Problems that can occur with maintaining too many males in a group include decreased reproduction, possibly as a result of competition, and juvenile males pulling infants off dams. Often, subordinate females in the colony do not reproduce. Most bat species can also be maintained in single sex groups. In bat groups of any size, there may be minor dominance struggles, especially among males. Males, especially juveniles, will mount other males.

III.B. **Age of Dispersal/Removal of Young**

For an ideal breeding program, zoos should maintain a mixed-sex breeding colony and single sex groups of the same species in order to control breeding populations (this does not necessitate each zoo maintaining all three types of colonies, but rather zoos trade animals to coordinate breeding programs). Infant bats, especially males, should be removed from the colony between the time they are weaned and the time they reach sexual maturity. For the larger fruit bats (e.g., *Pteropus* spp.), this is between six months and two years of age. Smaller species are weaned and reach sexual maturity in less than six months. Be sure that juveniles are eating solid foods before removing them from the dam.

III.C. **Introductions and Removals**

Follow quarantine guidelines as required (see Section VI.M.). However, be careful not to overextend quarantine of individual animals or their social behavior may be adversely affected. If possible, quarantine bats in groups rather than singly.

Introducing and removing bats from a colony is generally not problematic. New animals can be introduced immediately into a group rather than maintained in a traditional "howdy" cage (i.e., a small cage placed within the main exhibit cage for the purpose of letting animals become familiarized). However, the use of a howdy cage for introducing a group of bats into a large free-flight exhibit can help new bats get acclimated to the environment and possibly reduce aggression between the new group and established colony.

Introducing new bats into an existing colony should take place at the start of a keeper shift, so as to allow maximum observation time. Newly introduced animals should be watched off and on for 24-48 hours to insure that the animal(s) is eating and has adjusted well. Juvenile and adult bats will frequently perform static flying when placed in a new exhibit as they grow accustomed to the new environment (Carroll, 1978).

In smaller Microchiropterans (e.g., *Carollia perspicillata* and *Artibeus jamaicensis*), stress induced by capture may cause torpor and/or a period of fasting that can last up to 24 hours. To help prevent this problem, we recommend that removal of individuals be planned for after the normal feeding period.

To minimize aggression toward new animals, we recommend offering unscheduled food to confuse the colony slightly and distract them from the new individual(s). It may also be beneficial to alter the environment by hanging a piece of cardboard, perch, or other props. Large pieces that act as visual blocks work well. There will initially be much bickering among the bat colony as the group's social structure is challenged and perhaps altered. New males may take over existing males' territories. Females tend to accommodate to new members more easily. Removing bats from colonies causes minimal stress.

If an animal needs to be treated for medical purposes, it is best to provide veterinary care while leaving the animal in the main enclosure. However, if it is absolutely necessary to remove the animal for treatment, be sure to minimize the amount of time it is separated from

the colony and follow recommendations for introductions when reintroducing the animal to the colony.

There appears to be no major effect of removing animals from a colony except that, if the individual removed is high ranking in the social order, there may be some jostling while everyone moves up a notch. This may affect reproduction, but usually just for a short time.

If maintaining the colony for genetic management, the breeding male should be removed immediately after the first young are born. If it is known that a female is pregnant, the male can be removed earlier; however, care should be taken not to stress the entire colony while attempting to capture males. New males or females being added to the colony should be introduced two to three months after the colony's females give birth. At this stage, the infants will be large enough to fend for themselves should the newcomers act aggressively.

III.D. **Seasonal Changes in Social Behavior**

Wild bats are seasonal breeders, the timing of which is mostly species specific. However, seasonality decreases in captivity, especially in indoor enclosures. Seasonality will also differ in different climates.

III.E. **Mating System, Courtship, Copulation and Parturition**

This section describes fruit bat behavior during various stages of the reproductive cycle. See Section V, Reproduction, for more detailed information.

During their breeding season, males tend to become more territorial and aggressive. Many, if not most, fruit bats form harems.[13] In some species, males will be seen hovering around a receptive female, showing interest by hooking the female with their thumbs. They will also "hook" another male with a thumb to try to dislodge them and thereby keep them away from the female. The colony hierarchy does not always hold for breeding, so do not assume that the dominant male is the sire. Also, multiple males will breed one female so paternity in multiple male groups can be difficult to ascertain.

Courtship with some of the larger bat species often involves male initiated allogrooming, especially around the genital area, followed by much bickering and then mating. Females are generally resistant; they may fly to get away from an interested male. Females may choose with whom they mate; however, more research needs to be done in this area.

Bats will usually mate in the ventral-dorsal position; however, ventral-ventral copulation may occur. Females will often release their hold of the roost and grasp the male's ankles during copulation. Bats can and will still mate even when housed in an enclosure too small for them to fly. Copulation is often very loud and boisterous and bats will breed several times in one day.

There is little behavioral change in the weeks and days prior to parturition. Female bats will pant immediately prior to and during parturition. For birthing, she will alternate hanging with all four limbs and clinging to the wire hanging from just her thumbs. In the Pteropodidae, infants are born head first and, as soon as the head is exposed, the female will bring her feet up and catch the pup as it emerges. The Microchiroptera are usually born rump or feet first.

III.F. **Behavioral Ontogeny**

Bat behavior is formed largely through observational learning. Young bats are generally poor flyers, and will often crash into things as they learn how to fly. Static flying is common among infant and juvenile bats (Carroll, 1979). Pups are very playful, and their need for environmental enrichment is great (see Section III.J.). At weaning, a pup will first learn to eat solid food by licking its mother's lips as she is feeding. Up to a year of age, pups will return to their mother's nipple when they are frightened. Occasionally, a female will have an older pup on one nipple and a younger pup on the other. Individuals of some *Pteropus* species may show non-sexual interest in juvenile captive-born females (Atkinson, in prep). Additional research needs to be done in this area.

III.G. **Parental Care**

Typically, parenting is done by the female. Allo-parenting is rare. In the wild it is quite common to find maternity colonies of many species (especially the smaller species) and zoos could replicate this behavior by removing males after birth. Mothers carry and hold their infants in a variety of positions including front and back. They will also "park" the infants for various lengths of time, especially during weaning and parent feeding time (the length of time infants are parked appears to be species specific). Should the infant fall or get knocked down, mother bats will pick their infants off the floor. However, in large colonies or crowded enclosures other bats, especially other species, will pick on lone infants. In overcrowded situations, maternal neglect is not uncommon. Infanticide will occur in bat colonies, and, while the causes are unknown, it does not appear to be directly related to overcrowding or sex ratio (Carroll, 1988). Mother-infant fights are common, especially during weaning, with the pup frequently getting attacked by the mother..

III.H. **Mixed Species Exhibits**

In general, bats do very well in mixed species exhibits, including housing bats with other bat species and bats with other taxa. The primary concern with maintaining multiple bat species is ensuring that the nutritional and spatial needs of each species are taken into consideration. Enclosure size, environment (e.g., most appropriate feeding time and light cycle), and species variability are important factors. It is also critical to offer enough food dishes of appropriate sizes to minimize competition. Ideally, mixed species exhibits would house multiple colonies, rather than a colony of one species and one or two individuals of

another (although this combination has worked well in some instances). The size of the bat species may be a factor; however, more information is needed. There are no documented cases of breeding between species in zoos.

There is tremendous potential to increase the amount of space available to bats in zoos and make exhibits more exciting by maintaining bats with other taxa. Care should be taken when housing bats in an enclosure with a body of water (e.g., pool). The water should be shallow enough to allow animals an easy exit from the pool. Shallow, running water sources cause the least injuries.

The potential problems that should be taken into consideration before implementing a mixed taxa exhibit are a lack of adequate space, competition and aggression between species, and provision of enough food and a proper diet. An additional concern when housing bats with terrestrial carnivores is that the carnivores may consume infant bats that fall to the ground. The TAG is currently collecting information regarding mixed species exhibits which we will make available as soon as possible.

With any mixed species exhibit, be sure to check with a veterinarian for disease cautions. Animals that are slated for possible reintroduction are of special concern in this regard.

III.I. **Behavioral Indicators of Social Stress or Social Changes**

Both males and females will cower when stressed, for instance when approached by a handler, and then try to escape by flying away. Stress levels will be increased for animals housed in small enclosures that have no room to move or escape. (For additional information on the effects of stress, see Widmaier and Kunz, 1993). When captured, most bats will immediately urinate and defecate and many will try to bite. Vocalizations may accompany any of these behaviors. Many bat species will shiver and jerk when stressed. Long-term stress may cause anorexia. Some bats, especially the microfruit bats (e.g., *Glossophaga soricina*), may go into stress-induced torpor. Behavior exhibited by *Vampyrops helleri* and *Glossophaga soricina* when food deprived includes unfolding of the wings, not attempt to fly when approached or prodded, and no audible noises emitted (Rasweiler, 1973).

III.J. **Environmental Enrichment**

Environmental enrichment is important for bats, and keepers and managers should spend some time developing new ways to stimulate their bat colonies. Methods of environmental enrichment that are known to be successful include providing naturalistic foods, varying the food presentation, supplying olfactory stimulation, adding props to the enclosure such as ropes, branches, mirrors and so forth, providing adequate flight space, and supplying bats with browse (for additional information on environmental enrichment for fruit bats, see Atkinson, 1993). Refer to *Appendix E* for a partial list of forages accepted by captive colonies of fruit bats.

III.K. **Notes on Individual Species and Unusual Behaviors**

ò *Epomophorus wahlbergi* will rock back and forth (laterally) with their wings wrapped around them when resting (Wickler and Seibt, 1976).

ò *Rousettus aegyptiacus* and other small bats will occasionally sleep on their backs on the floor of the cage (usually propped against a wall).

ò There are usually high levels of aggression between males in a breeding colony of *Cynopterus brachiotis*.

ò In outdoor enclosures (and indoor enclosures where browse is provided), many bat species will crawl to the ground in search of green foliage.

IV. REPRODUCTION

Fruit bats share many of the general reproductive characteristics present in other mammalian species. They reproduce sexually, produce live young, and females nurse pups from one or two mammae located on either side of their thorax. Fruit bats have a rather low reproductive rate, especially considering their size. Most field studies on bats, however, refer to sporadic observation collected only a few times a year. Thus, much of the information on bat reproduction is anecdotal. Some of the information in this chapter was collected through a TAG bat reproduction survey that was sent to all AZA institutions housing bats. Tables 1 and 2, taken from this survey, contain information on development in captive born bats and a summary of bat reproduction data, respectively. For additional information, see Galindo et al, 1995.

IV.A. **Age-Specific Fecundity**

Generally, females of larger species do not give birth until they are between one and two years old (Asdell, 1964; Nelson, 1965; Thomas and Marshal, 1984). *Pteropus poliocephalus* females reach sexual maturity at one and a half years, while males do not reach effective fertilization until they are two and a half years, even though they are considered sexually mature at 18 months of age (Martin et al., 1986). The males of some other *Pteropus* species also do not reach effective fertilization until two and a half years, even though they are sexually mature at 18 months (Martin et al., 1986). Smaller species are able to reproduce and give birth as soon as four to eight months of age (Heideman cited in Mickleburg, et al., 1992; Galindo et al., 1995), with males not becoming mature until between one and two years of age. Many species of fruit bats show a post partum estrus (Galindo et al., 1995; Mickleburgh et al., 1992). *Cynopterus*

brachiotis females are sexually mature at four to six months, while the males are mature at one year of age (Heideman, pers. comm., 1992).

IV.B. **Breeding Seasons**

Beck (1973) reports a monoestrous cycle (one single estrus per breeding season[McDonald, 1987]) in *Pteropus giganteus*, polyestrous cycles (multiple estrus cycles per breeding season [McDonald, 1987]) in *Rousettus aegyptiacus*, and three pregnancy peaks per year in *Cynopterus brachiotis*. There has been one reported case of possible sperm storage in *P. giganteus* in a captive environment, where one female gave birth after nine months of being in a single sex female group (Galindo et al., 1995). In general, larger species of fruit bats seem to be monoestrous, while smaller species are generally polyestrous. In captive *Pteropus poliocephalus* , mating increases in February, peaking in April (Martin et al., 1986).

IV.C. **Behavior**

Many species, including those of the genus *Pteropus*, present repeated copulations and high copulation activity in mating seasons, even though males will attempt to copulate throughout the year (Martin et al., 1986). When not in season, females will avoid copulation and will generally fly away from interested males. As part of the mating ritual, the interested male may flick his wings towards the female and vocalize loudly. He will then attempt to groom the female while he orients himself to her dorsal surface. He will attempt to clasp her with his wings and thumbs, grasping the thickened nape of her neck with his teeth. For a successful copulation, the female cooperates by hanging from the male's legs (Baker, 1991; Martin et al., 1986; West, 1986). Intromission is short and is accompanied by a quick ejaculation (Baker, 1991; Martin et al., 1986). Copulation is generally ventral/dorsal, however, *Eidolon helvum* have been observed copulating in the ventral/ventral position (Galindo, 1995).

IV.D. **Gestation**

As a general rule, bats carry only one young per gestation period. Twining is present occasionally, though survivability of both the pups and the dam is very low. At least one of the pups may need to be hand-raised to relieve the dam of the stress of raising twins. In the wild, however, smaller species such as *Artibeus jamaicensis*, *Eidolon helvum* and others have been seen to do quite well with twins (Skinner and Smithers, 1990).

Gestation in Pteropodid bats has been estimated at 105 days to 210 days. Examples include *Pteropus rodricensis* at 140-180 days, *Rousettus aegyptiacus* at 105-107 days, and *Epomophorus wahlbergi* at 180-210 days (West and Redshaw, 1987; Baker, 1991; Kunz et al., 1994; Carroll, 1988; West, 1985-86; Falanrow, 1988; Sowler, 1984).

Eidolon helvum are essentially monoestrous, and are thought to have two distinct breeding strategies in the wild. One strategy is to have a four month gestation with conceptions in the autumn and births in the spring (Anderson, 1912). Another is to copulate in June or July

and, utilizing a delayed implantation strategy, have gestation begin in November, with the young being born between March and April. This strategy usually coincides with the rainy season (Fayenuwo and Halstead, 1974; Funmilayo, 1979; Galindo et al., 1995). Births of *Pteropus rodricensis* in captivity occur mainly during October through April, with a peak between late March and April. They show synchronized births and can potentially have two birth periods a year with an interval of 260 days (Carroll, 1988). There are some suggestions that *Epomophorus wahlbergi* have conceptions that occur from May to December, with the peak occurring May through July. Births peak in November and December (Sowler, 1984), thus making gestation roughly six to eight months. *Rousettus aegyptiacus* breeds two times per year in East Africa and year-round in North Africa (Kingdom, 1974b).

IV.E. **Parturition**

A typical *Pteropus* birth and placental delivery may last only a few minutes to two hours (Baker, 1991). There are usually few warning signs to show when a female is about to give birth. The first signs are manifested two to three weeks prior to parturition. The bulk of the fetus shifts from its usual sprawled lateral position to a more centralized, ventral position on her abdomen, directly above the vaginal area, which seems to swell slightly. Hours prior to parturition, the expectant mother separates herself from others in the group and starts fanning herself. When she is ready to deliver, she hangs from her thumbs, as though she is attempting to void, and strains hard. As the pup emerges head first, it is positioned so that the wings are folded around the head. There is little blood loss. At the actual moment of birth, the female adopts a horizontal position, grooming and licking the genitalia and the emerging infant (West, 1986). There is usually a pause between expulsion of the head and rest of the body (Martin et al., 1986) which will generally last from ten minutes to several hours (Aldenhoven and Carruthers cited in Martin et al., 1986). During this time, the pup has its eyes open, twitches its nose, and occasionally will vocalize. The mother opens up her wings to make a "net" to protect the infant from falling. The offspring hangs on to the mother with its feet and thumbs and is guided to a nipple by the dam. The dam, and occasionally other cage mates, will then eat the placenta (Martin et al., 1986). Kunz et al. (1994) have documented alloparenting in *Pteropus rodricensis*.

IV.F. **Infant Development**

Fruit bats grow and mature quickly. Smaller species of fruit bats are born with their eyes closed and ears folded back, both opening after ten days (Lombard, 1961). *Artibeus jamaicensis* have an average birth weight of four grams, and wean at an average age of three and a half months (Galindo et al., 1995). All fruit bats are born with some fur, well developed claws to cling to the mother's ventral side, and deciduous recurved milk teeth (West, 1985-86; Nelson, 1965; Pook, 1977). *Pteropus rodricensis* have short, snubbed muzzles, small wings and large feet (Baker, 1991; West, 1985-86) with a body weight of 45 grams. Forearm length is 43% of adult length (West, 19486). *Pteropus poliocephalus* are an average of 76 grams at birth (Hood, 1989).

Milk cannot be expressed manually after about six months. However, many species of fruit bats have been seen still on the mother's nipple after one year of age (Galindo et al., 1995; West, 1985-86; Baker, 1991). From observations in the field and in captivity, many species show a post partum estrus (Galindo et al, 1995; Mickleburgh et al., 1992).

IV.G. **Neonatal/Infant Mortality**

According to the TAG's recently published survey on reproduction of frugivorous bats in North American Zoos (Galindo et al, 1995), 1370 individuals were born within the last ten years in responding institutions. Of those born, 458 (33%) were either stillborn or died before the age of two months. Some of the major causes of neonatal death included: environmental stress (overcrowding, extremes in temperature, capturing for medical procedures), cage mate inflicted trauma, hazards within the enclosure (drowning in pools, eaten by other species housed with the bats), and medical inflictions (cesarean section deaths, infections). The survey also reported that there were higher instances of neonatal deaths in larger species (100 grams and over) to pups born to first time mothers than those born to experienced mothers. Cannibalism was also seen in many instances where overcrowding was an issue. Birthing dams have been seen to partially consume stillborn pups.

IV.H. **Contraception**

Little or no information is available on reversible chemical contraceptive methods in bats. The most commonly used method of reversible contraception in mammals in AZA institutions are MGA implants. However, the efficacy of these in bats has yet to be determined. Barnard et al (1992) describes a method of male castration as a form of irreversible contraception.

Husbandry techniques, such as maintaining single-sex groups, is recommended as the most simple and inexpensive method of contraception. Downfalls such as lack of space to house separate groups of the same species can be overcome. One way to acquire additional space for single sex colonies is to house bats with other taxa (see Section III.A.). Another method is for institutions to trade the same species of bat, so each institution receives all of one sex.

V. NUTRITION

Development of the nutrition chapter has proven to be very complex and poses many challenges. For every institution that houses bats there are almost that many different diets utilized. The purpose of this chapter is to provide general guidelines for managers to consider when developing a diet for bats. Here we present target nutrient ranges and practical diets that meet these ranges. The Bat TAG Nutrition Subcommittee is continuing to research this

important topic, and this chapter will be updated on a regular basis as new information becomes available.

Meeting the nutritional needs of Megachiropteran and Microchiropteran fruit bats is essential if they are to thrive in captivity. Developing appropriate dietary guidelines is an extensive project that involves utilizing information from a number of sources. These sources include current feeding ecology data, published nutrient requirement data, food available to zoos, and food preferences of fruit bats, as well as input from academia and data on the nutrient content of successful diets currently in use.

V.A. **Foraging Ecology**

Currently, it appears that the majority of data about foraging ecology is a description of the bats' feeding or foraging habits in the wild. Some studies have involved collecting and analyzing food items for various nutrients (Morrison, 1978; Morrison, 1980; Thomas, 1984). Others examined excreta or stomach contents of bats in the wild (Stellar, 1986; Thomas, 1984). Each of these methods has its limitations and none quantitatively defines the daily nutrient requirements of fruit bats. Thus to date, there is little information available that describes the nutrient levels required by fruit bats. The only fruit bats for which estimates of nutrient requirements have been made are in the suborder Megachiroptera (Stellar, 1986; Thomas, 1984). Few, if any, quantitative nutrient requirement data for frugivorous Microchiroptera are available.

Many species regularly consume fresh green forages; however, the extent to which forages contribute to overall nutrition is unknown (Kunz and Ingalls, 1994; Kunz and Diaz, 1994; Marshall, 1985). Additionally, fruit bats consume other plant parts including flowers, nectar and pollen (Bradley-Law, Lowry, Marshall, 1983).

V.B. **Nutritional Requirements**

The nutrient requirements of Megachiropteran and Microchiropteran fruit bats remain unknown, although studies have been conducted on the protein and energy requirements for certain species of fruit bats (Delorme, pers. comm., Kunz and Diaz, 1994; Kunz and Ingalls, 1994; Morrison, 1978; Morrison, 1980, Reiter, 1993; Stellar, 1986; Thomas, 1984). To establish target nutrient levels, we will be using the previously mentioned data, new research data and data gathered from successful diets currently used.

Despite consumption differences among species of mammals, it is likely that bats, like other mammals, have similar qualitative nutrient requirements for tissue metabolism. Although few studies have been conducted to establish nutrient requirements, the National Research Council has described the nutrient requirements of a number of domestic and laboratory animals. Using the NRC guidelines along with data on feeding ecology and nutrient content of successful diets currently in use will allow us to formulate appropriate diets for frugivorous captive

Chiroptera. This appears valid at this time considering no extensive data exist specifically for bats.

Preliminary data for meeting target nutrient levels are presented below. These values are for reference only, as all the data needed to make firm recommendations are not compiled.

PRELIMINARY TARGET NUTRIENT LEVELS (dry matter basis)

Nutrient	Daily Diet Composition
Crude protein (%)	2.0-15.0*
Fat (%)	5.0-9.0
Vitamin A (IU/g)	4.0-14.0
Vitamin D2 & D3 (IU/g)	0.2-2.0
Vitamin E (mg/kg)	11.0-56.0
Calcium (%)**	0.5-1.0
Phosphorus (%)**	0.4-0.9

*Reported levels of protein consumed by free-ranging and captive Megachiropteran and Microchiropteran fruit- and nectar-feeding bats fall in this range (Morrison, 1980; Rasweiler, 1977; Reiter, 1993; Stellar, 1986; Thomas, 1984).
**For Mammals, Calcium:Phosphorus ratios of 1:1 to 2:1 are recommended (Robbins, 1993).

V.C. **Nutrient Content of Three Working Diets**

Because we have yet to delineate the target nutrient levels, we are providing diets that, on face value, appear to meet the above indicated nutrient levels. No examination of micro-nutrient levels has occurred. These diets have been provided by several institutions that consider their programs successful. Please note that these are presented only as suggestions and have not been subjected to thorough review. To provide suggestions for easily adaptable diets, the data have been modified slightly and presented as food groups rather than specific food items. The total quantity to feed is not given and is dependent on many factors. However, as a rough guideline, an average active adult bat may consume a total of approximately 10-15% of body weight per day (dry matter basis); or 50-120% of body weight on an as fed basis. If the animal is lactating this may increase to 1.5 times that per day. Care should be taken that the animals do not become obese when fed *ad libitum*.

Comparison of the Approximate Nutrient Content of Three Working Diets with Preliminary Target Nutrient Levels (dry matter basis)

Nutrient	Target Levels	Zoo A	Zoo B	Zoo C*
Crude protein (%)	2.0-15.0	12.3	19.0	4.9
Fat (%)	1.0-5.0	7.2	3.0	4.4

Vitamin A (IU/g)	4.0-14.0	26.0	14.9	8.1	
Vitamin D2 & D3 (IU/g)	0.2-2.0	6.2	3.2		0.1**
Vitamin E (mg/kg)	11.0-56.0	133.1	50.2	29.8	
Calcium (%)	0.5-1.0	0.4	0.8		0.1***
Phosphorus (%)	0.4-0.9	0.3	0.4		0.1

*Values reported are averages because daily diet composition varies at this Zoo.
**Animals at this facility are housed under full spectrum lights
***Animals have *ad libitum* access to a mineral wheel

V.D. **Working Diet Composition**

We are aware of a number of nutritional concerns about some of the diets being used in captive feeding regimes today. We hope to address these in the final document.

Food items: The proportions represented below are derived from the three working diets presented above. It is possible to achieve the nutrient levels of the Zoo diets outlined above by offering a diet consisting of the following food items. For adaptability to different institutional situations, we are presenting the diets as food groups in percent to be included in the total diet. This is percent contribution of each item (or food group) by weight, as fed.

COMPARISON OF THE PERCENT CONTRIBUTION OF FOOD GROUPS IN THREE
WORKING DIETS (AS FED BASIS)

Food group	Zoo A	Zoo B	Zoo C*
Fruit (%)	74.1	16.0	90.4
Vegetables (%)	-	7.0	-
Starchy vegetables (%)	-	7.0	-
Leafy, green vegetables (%)	-	14.0	2.3
Fruit juice/nectar (%)	-	-	6.5
Water (%)	-	41.0	-
Nutritionally complete products (%)	23.3**	7.5***	-
Protein supplements (animal-based) (%)	-	-	0.7
Home-made protein/ vitamin/mineral supplements (%)	2.6	7.5	0.1

*Values reported are averages because daily diet composition varies at this Zoo.
**This consists of 14.2% canned primate diet and 9.1% canned feline diet.

[***]Total contribution is from high protein monkey chow.

Food groups: The diet can comprise one or more of the following foods in the quantities outlined above.

Fruit: apple, banana, grapes, pear, papaya, dried figs, raisins, melon, kiwi, etc.
Vegetables: carrots, green beans, etc.
Starchy vegetables: sweet potatoes, corn, etc.
Leafy, green vegetables: lettuce, spinach, kale, collard, mustard, etc.

Please notice that all of the working diets outlined above use home-made supplements in conjunction with commercially-made, nutritionally complete products. If one or more of the products are not included in each of the diets as outlined, the diet will no longer reflect the nutrients presented in the previous section. Many of the home-made recipes are difficult, and sometimes expensive, to make. Therefore, in the final nutrition chapter we intend to provide recommendations for use of easily attainable, nutritionally complete diets that will allow formulated diets to meet target nutrient levels.

V.E. **Information Needed**

There remains a large amount of information to be collected in order to finalize recommendations for target nutrient levels and appropriate feeding procedures for Megachiropteran and Microchiropteran fruit bats. Much of this information will become available through our proposed pre-survey and following in-depth survey of diets and feeding practices in institutions currently housing fruit bats. The information still needed includes, but is certainly not limited to, the following: Nutritional deficiencies/toxicities, feeding behavior in captivity, quantities of food to offer (factors include: age, species, size of housing, number in group, etc.), form of diet offered (e.g., chopped vs. whole fruits, etc.), problems with obesity, seasonality (e.g., feeding different diets based on season), feeding schedules, feeding location, use and potential nutrient contribution of fresh green forages and other plant parts (see ***Appendix E*** for a partial list of forages accepted by captive colonies of fruit bats), behavioral enrichment for captive fruit bats.

VI. HEALTH

Ideally, all bats should be individually identifiable (see Section II.A.) and each bat should have a separate medical record.[14]

VI.A. **Inoculations**

There are no vaccinations presently recommended for bats. Bats should not be vaccinated against rabies for several reasons. First, there is no vaccine legally licensed for use in bats, second, the vaccine may interfere with tests for rabies detection, and third, the vaccine may allow the animal to survive and yet shed the virus.[15]

VI.B. **Neonatal Examinations**

Births, as well as birthing problems and neonatal deaths, should be recorded. The neonate should be visually assessed soon after birth to make sure it is suckling, has normal activity for its age, and there are no gross congenital abnormalities. Although not practical or advisable for most situations,[16] neonatal bats can be examined, weighed and measured immediately after birth and during development. Information from such a procedure can help to establish baseline information for the individual, as well as for the species. Growth curves are invaluable for evaluating health status of lactating females and hand-raised bats. (For more information on neonatal exams, see Barnard, 1994).

When examining neonates and suckling bats, it is recommended that the mother be anesthetized (see Section VI.H.) to decrease the likelihood of injury to both parent and pup. The pup can be removed from the nipple by gently placing a smooth probe (e.g., small rubber spatula) at the corner of the mouth of the pup until it releases its grip on the teat. Force should not be used and care should be taken to avoid damaging the milk teeth. Rubber spatulas work well to insure teeth and mouth do not get damaged. The pup is either placed on the mother before recovery, or placed in a small cage with the awake mother. Placement of the pup on the physically restrained mother is stressful, may result in injury, and is generally unnecessary.

VI.C. **Parasites**

1. Screening. All parasites collected should be submitted for identification. Fecal examination for parasites should minimally be done every six months for individuals and every month on a sample collected from the colony.[17] These tests should be performed by people capable of identifying the parasites likely to be found in bats.

2. Commonly observed parasites and treatments.

a. Ectoparasites: Ecotoparasites include mites, lice, chiggers, fleas, ticks and flies (Whitaker, 1988). No ectoparasites should be tolerated and several ectoparasites are potential

vectors for blood borne diseases. Imported animals should be examined and treated in the country of origin. Many ectoparasite species will spontaneously leave the wild caught bat. Some ectoparasites spend most of their time in the environment, and therefore any treatment program should include changing props, substrate and so forth, as well as disinfection, and in large cages, fumigation.

Pest strips work well to deter ectoparasites confined to the host (e.g., mites, chiggers and lice). However, animals in outdoor exhibits (where use of pest strips is not feasible), and those with heavy ectoparasite loads can be treated with ivermectin (200-400 _g/kg PO, IM, SC) every 10 to 14 days for three treatments. Repeated treatment may be necessary to kill the parasites that subsequently hatch from the protected eggs. Ivermectin has a narrow therapeutic index. Care should therefore be taken in calculating dosages. Signs of toxicity range from lethargy and decreased appetite to full paralysis. These signs occur within the first 24 to 48 hours. Treatment is supportive; there is no antidote. Ivermectin for injection must be diluted with propylene glycol, not water. This is because it is an oily substance and does not mix well with water. There is an oral liquid preparation for horses that can be diluted with water and administered orally.

Alternatively, some ectoparasites are susceptible to pyrethrin-based sprays. Take care to not use excessive amounts (e.g., soaking the animal), and do not use in confined, poorly ventilated areas. Rather than spray, it may be better in smaller bats to moisten a towel, and rub into the coat.

Whenever using a treatment for the first time, use in a few individuals first and observe.

b. Endoparasites (see Coggins, 1988 and Constantine, 1993):
The major endoparasite of concern is *Toxocara pteropodis*.

Round worms:
- ò Ivermectin 200 to 400_g/kg PO. Extreme care must be taken when diluting ivermectin, especially with smaller bats.
- ò Fenbendazole 75 to 100 mg/kg PO, repeat in 10 days.

Tapeworms:
- ò Praziquantel 7.5 to 15 mg/kg IM, PO.

Trematodes:
- ò Praziquantel: high dosages (50 mg/kg) are not very effective.

c. Hemoparasites: Hemoparasites (*Hepatocystis sp.*) have been observed in imported *Pteropus pumilus* from the Philippines. These parasites spontaneously disappeared from the blood over a 12 to 14 month period. No present treatment is recommended.

d. Protozoa: Metronidazole 75 to 100 mg/kg PO.

VI.D. **Behavioral Signs of Illness**

Behavioral signs of illness include: decreased appetite, wings constantly wrapped to the body (even when disturbed), lethargy, reluctance to move[18], not flying or abnormal flying, and animal found on floor (note: some healthy individuals will sleep on floor or retrieve food from floor).

VI.E. **Major Disease Problems and Their Treatments**

1. Viral. No treatment is available for viral diseases.

    a. Rabies (see Constantine, 1988 and 1993): Rabies is not a major disease problem for bats, although, when contracted, the virus will kill animals. The primary concern is for public health (see Section VI.L.). Do not vaccinate bats against rabies (see Section VI.A.). New World fruit bats are more likely to have rabies than Old World fruit bats.

    b. Equine encephalitis viruses

    c. Other viruses: further research required.

2. Bacterial. Treatment is based on culture and sensitivity.

    a. Salmonella

    b. Other

    Antibiotics used in bats include: fruit-flavored oral preparations, Baytril, Trimethoprim-sulfa combination, Amoxicillin, Chloramphenicol palmitate, and Keflin. Injectables include: TMZ, Amikacin, Enrofloxacin.

3. Parasitic (see Section VI.C.).

4. Nutritional

    Diets for long-term maintenance of bats need to be perfected (see Section V.)

    a. Dilated cardiomyopathy - probably vitamin E deficiency.

    b. Vitamins C and B12

    c. Metabolic bone disease.

5. Toxic

a. Zinc (galvanized wire)

b. Lead

c. Some plants

VI.F. **Common Injuries and Their treatment**

1. Band constrictions: Pay attention immediately after placement and check on a periodic basis (see Section II.A). Remove the band immediately if swelling and/or ulceration occur. Treat severe injuries with antibiotics.

2. Other thumb injuries (e.g., torn nails, simple fractures or abrasions as a result of contact with rough surfaces): Treat with antibiotics if deemed necessary.

3. Wing tears generally heal well by themselves. Wing tears that involve the leading or supporting wing edges require suturing.

4. Bandaging that incorporates the wing web may obstruct inflow of arterial blood causing subsequent necrosis (i.e., ischemic necrosis).

5. Fractures (wings and legs): Take special care not to pull too hard when removing bats from wire and perches. Rough handling in young bats may cause injuries at growth plates of long bones.

6. Dry skin and feet may be caused by low humidity (see Section I.F.).

7. Wing bone injuries: These injuries need to be carefully evaluated by a veterinarian to determine appropriate treatment.

8. Swollen joints: Swollen joints may be caused by septic (bacterial) arthritis. Treatment is based on culture and antibiotic sensitivity, as well as radiographs to confirm severity of lesions.

9. Infected marking glands on chest: These may respond to antibiotics. In severe cases, it may be necessary to excise the lesion surgically.

10. Torn lower lips. These may need to be sutured.

VI.G. **Physiological Reference Values**

1. Heart and respiratory rates: Rapid, except during torpor.[19]

2. Hematology and blood reference values: Available data are limited. The TAG encourages zoos to submit data from their collections to ISIS. In addition, more research is required to obtain normal reference values from free-ranging bats. Data that are available are sometimes compromised by poor blood collection and handling techniques. The following tips are recommended to facilitate collection: In a healthy bat, 10% of blood volume can safely be collected. This is approximately 1% of body weight in grams (1 gram = 1 ml). For example, in a 450 gm bat, 4.5 mls of blood can be collected for plasma biochemical determination. Blood should be collected into a heparinized syringe, immediately centrifuged, and the plasma refrigerated prior to analysis.

VI.H. **Immobilization and Anesthesia**

The following recommendations are for a one pound fruit bat. The dose will need to be higher per kilogram for smaller bats and lower per kilogram for larger bats.

The preferred method of anesthesia is isoflurane in oxygen. Mask down animal at 2-5% isoflurane until the animal is relaxed, then decrease to 2-3%. Maintain oxygen flow at 1.5-2 liters per minute.

If gas anesthesia is unavailable, a mixture of ketamine and xylazine can be utilized. For 30 minutes of immobilization, combine equal volumes of ketamine (100mg/ml) and xylazine (20mg/ml) to achieve a concentration of 50mg/ml ketamine and 10mg/ml xylazine and administer.

VI.I. **Recommended Routine Medical Procedures**

Ideally, each bat should be examined once a year. When applicable, this examination could include collection of blood for hematology, plasma biochemical analysis, and plasma for freezing (freezing temperature equals - 70^{o}F). When colony size renders individual exams impractical, a few individuals could be selected from the colony for examination.

VI.J. **Life Span**

More data need to be collected on bat life spans. In general, small fruit bats are likely to live 10 to 20 years, while large fruit bats can be expected to live 15 to 25 years or more.

VI.K. **Necropsy Protocol**

All bats that die should be necropsied. Gross necropsy alone is inadequate without submission of representative tissues (brain, skeletal muscle, heart, lung, liver, stomach, pancreas, small and large intestines, kidneys, gonads, bone and bone marrow) for pathology. A section of brain from new or wild-caught bats that have died in captivity should always be submitted for rabies testing. Accurate necropsy records should be made and mortality rates should be tracked on a yearly basis (including neonatal deaths).

VI.L. **Zoonotic Diseases**

Bats potentially carry diseases that can be passed to humans (see Constantine, 1988). Consult with your local health department for additional information on health issues.

1. Rabies: Signs of the rabies virus come in two forms. In the furious type, the infected animal goes berserk. In the dumb, or paralytic version, the individual becomes quiescent and dies. The furious version is rarely found in bats, and "outbreaks" of rabies in bat colonies is extremely rare. Contrary to common belief (even by medical "experts"), bats are not asymptomatic carriers of rabies. The statistics for the percentage of bats that contract rabies varies, ranging from less than one half of one percent to over ten percent, depending on region and type of sampling technique used for testing. No matter what the region or species, certain precautions should be taken to protect animal handlers from contracting this disease.

a. All personnel working with bats should be vaccinated against rabies.

b. Personnel should have their rabies titers checked every one to two years and be vaccinated as necessary.

c. The potential for bites should be minimized by wearing gloves, having only trained personnel handle the animals, and by anesthetizing even for routine handling.

d. Establish a bite protocol, and record all bites, even if the skin is not broken.

e. Minimize the number of personnel in contact with the bats.

f. Greatest care must be taken with new, wild-caught imports.

2. Histoplasmosis: Histoplasmosis (*Histoplasmosis capsulatum*) is an airborne fungus that affects the lungs of mammals. It is contracted from breathing dust in enclosed areas such as caves or mines which contain infected bird or bat guano. The fungus occurs primarily in the

Mississippi Basin of the United States, the tropics and subtropics. There has never been a record of anyone catching histoplasmosis from bat guano in the northeastern United States or Canada.

The risk of catching histoplasmosis from a captive colony of bats is small because these colonies rarely reach the large numbers needed for the build-up of the fungus, and fecal material is removed on a regular basis (i.e., not allowed to accumulate).

VI.M. **Quarantine**

We strongly recommend consulting with veterinarians and others experienced in quarantine procedures when receiving bats. In addition, the Centers for Disease Control (CDC) can provide quarantine information and recommendations.

Ideally, wild-caught animals should be held for one month prior to shipment from their country of origin. This has the benefit of allowing detection and removal of any sick animals, and it allows the animal to adapt to captivity prior to shipment.[20] During the holding period prior to shipment, the bats should be examined, preferably by a veterinarian, and treated for ecto- and endoparasites.

When captive-born bats are received from another institution, ideally they should be quarantined for 90 days. However, this may vary depending on the source of animals and their previous standard of care and medical testing. Minimally, they should be quarantined for 30 days. Wild-caught bats arriving from another institution should be quarantined for a minimum of six months. Quarantine conditions should closely mimic the bats' natural ambient conditions (torpor can lengthen the disease incubation time). All bats should be examined as soon as possible after shipment for evidence of disease. An additional exam should be performed before the animals are removed from quarantine. Any bats that die during quarantine must have a complete necropsy (see Section VI.K.). If a bat dies during quarantine and the cause is unknown, the quarantine period should be extended to allow sufficient time for detection of disease in the remaining animals.

Following completion of quarantine it is recommended that wild-caught animals placed on exhibit be isolated from other animals for at least one year, and housed in cages that protect the public from bat urine and feces (e.g., plexiglass-fronted cages). Animals to be introduced to a mixed collection should have been in isolation at least one year, and the group should be free of evidence of infectious diseases. It is preferable that animals to be introduced into mixed exhibits be first or second generation removed from wild-caught animals. The same is also true for education animals.

Except for the 90 day quarantine period following receipt of the bats, the other requirements (e.g., one year isolation and first and second generations) can be completed at other accredited facilities.

VI.N. **Sanitation**

Ideally, sanitation procedures should be done on a daily basis. Appropriate design and building materials for cages will greatly facilitate cleaning and sanitation (see Sections I.A. and I.C.). Raised, wire-floor cages allow feces and contaminated food to fall away from the animals and can facilitate cleaning. Appropriate disinfectants include diluted Clorox (1:30 dilution) or quartenary ammonium compounds, although the latter does not kill certain strains of pseudomonas. Do not expose bats to noxious vapors in enclosed, poorly ventilated areas. Do not allow contact with disinfectants. Ensure that all organic material is removed before applying disinfectants. Allow adequate contact time (> 15 minutes), scrub in disinfectant well, then rinse thoroughly.

Clean and disinfect food and water bowls daily. Stainless steel dishes are preferable to those made from other materials (e.g., plastic) since stainless steel disinfects well.

A good pest control program should be in place and be maintained and monitored continuously (see Section II.D.).

ENDNOTES

1. Available from Valentine Incorporated: (1-800-GET STUF)

2. Only two species, *Pteropus poliocephalus* and *Rousettus aegyptiacus* extend from tropical regions into cool temperate regions.

3. Trovar transponders can be obtained by contacting Infopet Identification Systems, Inc., 415 W. Travelers Trail, Burnsville, MN 55337, 612-890-2080.

4. One recommended brand is A.C. Hughes, 1 High Street, Hampton Hill, Greater London TW12 1NA, U.K. Tel.:081-797-1366.

5. Gauntlet gloves can be obtained through Fuhrman Diversified, LaPorte, TX (713) 470-8397.

6. Microbat shipping information was provided by Dr. John J. Rasweiler, The New York Hospital - Cornell Medical Center.

7. Netting is available from Naltex, Austin, Texas: tel. #1800-531-5112.

8. Available from The Jackson Lab, Bar Harbor, Maine #207-288-5845

9. Available from Corners Limited, Kalamazoo, Michigan #1-800-456-6780

10. For more information about CDC permits contact: Department of Health & Human Services, Public Health Service, Center for Disease Control, Office of Biosafety, Atlanta GA 30333. 404-329-3883.

11. At least one zoo has reported bat deaths due to tracking powder (K. Whitman, pers. comm).

12. Additional information can be obtained by writing to Susan Barnard, 6146 Fieldcrest Dr. Morrow, GA 30260; Helen George, Wombaroo Food Products, ass Vale Road, Beaumont, Australia 2577. Phone: 044-65-1328 and/or Helen Luckhoff, 52 Cardiff Road, Darru, Queensland, Australia 4076.

13. In addition, some researchers believe that *Pteropus pumilus* may show lek behavior (R. Spears, pers. comm.). However, there is little evidence to support this claim.

14. While recommended, individual identification may not be feasible for large colonies of microbats.

15. While this possibility is a concern, there is no experimental evidence to support this claim.

16. It is impractical to attempt to examine neonates of large colonies. In addition, it may lead to mother bats abandoning their infants. This process should only be undertaken when deemed necessary in order to gather specific scientific data for a research program.

17. Ideally, samples should be collected from individuals. In large collections, however, a survey sample number of specimens should be collected.

18. Lethargy and reluctance to move can also be caused by torpor, which is normal for chiropterans.

19. Many factors affect heart rate. It is necessary to calculate respiration for each species. Both heart rate and respiration vary with body size.

20. In addition, if an animal is not adapting to captivity, the possibility of releasing them remains.

REFERENCES

Anderson, K. 1912. *Catalogue of the Chiroptera in the Collections of the British Museum., 2nd Edition. I. Megachiroptera.* British Museum (Natural History), London.

Asdell, S.A. 1964. *Patterns of Mammalian Reproduction.* Cornell University Press, Ithaca.

Atkinson, K. Preliminary study of male interaction with females before, during and after parturition in *P. hypomelanus* within a captive environment. In Prep.

Atkinson, K. 1993. Environmentally enriching captive flying foxes. *Proceedings of the AAZPA Southern Regional Conference*, Lake Monroe, Florida. 21-23 March.

Baker, D. 1991. Management and behavior of the Rodrigues fruit bat (*Pteropus rodricensis*). *Proceedings of the AAZK Annual Conference,* Toledo, Ohio.

Barnard, S.M. 1991. *The maintenance of bats in captivity.* Self-published. Zoo Atlanta, Atlanta, GA. pp. 16-27.

Barnard, S. 1994. *Infant Diet Manual*.

Barnard, S., and S.M. Soloway. 1992. A note on the castration of two giant fruit bats (*Pteropus giganteus giganteus*). *Animal Keepers Forum.* Vol 19(11):398-400.

Beck, A.J., and L. Lim. 1973. Reproductive biology of *Eonycteris spalaea,* Dobson (Megachiroptera) in West Malaysia. *Acta. Tropical* . 30:251-260.

Buckland-Wright, J.C. and J.D. Pye. 1973. Dietary deficiency in fruit bats. *Int. Zoo Yrbk.*, 13: 271-277.

Carpenter, R.E. 1986. Old world fruit bats. In: *Zoo and Wild Animal Medicine*, 2nd ed. M.E. Fowler, ed. W.B. Saunders Co., Philadelphia, PA. pp. 634-637.

Carroll, J.B. 1978. Behavioural ovservations on the Rodrigues fruit bat following a move to new accommodation and reversal of light/dark regime. *Dodo*, J. Jersey Wildl. Preserv. Trust 15:52-60.

Carroll, J.B. 1979. The general behavioural repertoire of the Rodrigues fruit bat, *Pteropus rodricensis*, in captivity at the Jersey Wildlife Preservation Trust. *Dodo*, J.Jersey Wild Preserv. Trust:51-59.

Carroll, J.B. 1988. The Conservation Programme for the Rodrigues Island Fruit Bat. *Proceedings of the 5th World congress on Breeding Endangered Species in Captivity.* 9-12 Oct. p. 463. (Eds., Dresser, B.L., R.W. Reece, and E.J. Maruska).

Coggins J.R. 1988. Methods for the ecological study of bat endoparasites. In *Ecological and Behavioral Methods for the Study of Bats*, T.H. Kunz, ed. Washington DC: Smithsonian Institution Press. pp 475-489.

Constantine D.G. 1970. Bats in relation to the health, welfare and economy of man. In *Biology of Bats Vol. 2*, W.A. Wimsett, ed. New York: Academic Press. pp. 319-449.

Constantine D.G. 1986. Bats (Chiroptera). Introduction. In *Zoo & Wild Animal Medicine*, 2nd ed., M.E. Fowler, ed. Philadelphia: W.B. Saunders Co. pp 632-633.

Constantine D.G. 1988. Health precautions for bat researchers. In *Ecological and Behavioral Methods for the Study of Bats*, T.H. Kunz, ed. Washington DC: Smithsonian Institution Press. pp 491-528.

Constantine D.G. 1993. Chiroptera: bat medicine, management, and conservation. In *Zoo & Wild Animal Medicine. Current Therapy 3*, M.E. Fowler, ed. Philadelphia: W.B. Saunders Co. pp 310-312.

Dobat, K. 1985. Bluten und Fledermause. Im: *Verlag Von Waldemar Kramer Frankfurt*, 370 pgs.

Efind, M. and S.M. Barnard. 1991. Transporting Bats. *Live Animal Trade and Transport*. pp. 27-28. December.

Falanruw, M.V.C. 1988. On the status, reproductive biology of fruit bats of Yap. Micronesica. Vol. 21#1-2.

Fayenuwo, J.O. and L.B. Halstead, 1974. Breeding cycle of the straw-colored fruit bat (*Eidolon helvum*) at Ife-Ife, Nigeria. *Journal of Mammology*. 55(2):453-454.

Fedden, M.O. and H.L. Macleod. 1986. Bat research in West Cameroon. In: *Conservation of Cameroon Montane Forests*. Ed. S.N. Stuart. pp. 175-195. International Council for Bird Preservation. Cambridge.

Fenton, B. 1992. *Bats*. Facts on File. New York.

Fleming, T.H. 1988. *The Short-tailed Fruit Bat*. University of Chicago Press, Chicago. 365 pgs.

Fleming, T.H. 1993. Plant visiting bats. *American Science*. 81:460-467.

Fujita, M.S. and M.D. Tuttle. 1991. Flying foxes (Chiroptera: Pteropodidae): threatened animals of key ecological and economic importance. *Conservation Biology*: 5(4):455-463.

Funmilayo, O. 1979. Ecology of the straw-colored fruit bat in Nigeria. *Rev. Zool. Afr*. 93(3):589-600.

Galindo, A., K. Atkinson, and T. Gross. 1995. Reproduction Survey of Pteropodids in North American Zoos and Wild Animal Parks. Published by the Lubee Foundation for the AZA Bat Taxon Advisory Group.

George, H. 1988. The Hand-rearing and management of grey-headed flying foxes. In: *Care and Handling of Australian Native Animals: Emergency Care and Captive Management,* S. J. Hand. ed. Surrey, Beatty and Sons Pty limited, Chipping Norton, NSW. pp. 159-169.

Green, R., S.V. van Tonder, G.J. Oettle, G. Cole, and J. Metz. 1975. Neurological changes in fruit bats deficient in vitamin B12. *Nature*. 254: 148.

Herbst, L.H. 1986. The role of nitrogen from fruit pulp in the nutrition of the frugivorous bat *Carollia perspicillata*. *Biotropica*. 18(1): 39-44.

Herbst, L.H. 1988. Methods of nutritional ecology of plant visiting bats. In: *Ecological and behavioral methods for the study of bats*, T.H. Kunz, ed. Smithsonian Institution Press, Washington, D.C. pp. 233-246.

Hood, C.S. and J.D. Smith. 1989. Sperm storage in a tropical nectar-feeding bat, *Macroglossus minimus* (Pteropodidae). *Journal of Mammology*. 70(2):404-406.

House, B.H. and J.G. Doherty. 1975. The world of darkness at the New York Zoological Park. *International Zoo Yearbook*. 15:31-34.

Kingdom, J. 1974b. *East African Mammals: An atlas of Evolution in Africa*, IIA, (Insectivorous and Bats). Academic press. London and NY.

Kitchener, D.J., Boeade, B., Charlton, L., and Maharadatunkasi. 1990. *Wild Animals of Lombok Island: Nusa Tenggara, Indonesia: Systematics and Natural History*. Records of the Western Australian Museum. Supplement #33.

Kunz, T.H. and K.A. Ingalls. 1994. Folivory in bats: an adaptation derived from frugivory. *Funct. Ecol*. (in press).

Kunz, T.H., A.L. Allgaier, J. Seyjagat, and R. Calaguri. 1994. Allomaternal Care: Helper-Assisted Birth in Rodrigues fruit bat (Chiroptera: Pteropodidae). *Journal of Zoology*, London. 232:691-700.

Kunz, T.H. and C.A. Diaz. 1994. Folivory in fruit-eating bats, with new evidence from *Artibeus jamaicensis* (Chiroptera: Phyllostomidae). *Biotropica*, (in press).

Kunz, T.H. (ed.). 1996. A practical guide to marking bats. (in prep.).

Lombard, G.L. 1961. *Rousettus aegyptiacus*: Eygptian fruit bat.

Luckhoff, H. 1986. Rearing Orphan Pteropus Spp. (Chiroptera: Pteropodidae) for Release to the Wild. *Aust. Mammal*. 10:127-128.

MacNamara, M., J.G. Doherty, S. Viola, and A. Schacter. 1980. The management and breeding of hammer-headed bats at the New York Zoological Park. International Zoo Yearbook :260-264.

Makin, D. 1990. Aspects of the biology of the fruit bat, *Rousettus aegyptiacus*, in Israel. Unpublished PhD thesis. TelAviv University, Israel.

Marshall, A.G. 1983. Bats, flowers and fruit: evolutionary relationships in the Old World. *Biol. J. Linn. Society*. 29:115-135.

Marshall, A.G. 1985. Old World phytophagous bats (Megachiroptera) and their food plants: a survey. *Zool. J. Linn. Society*. 29:115-135.

Martin, L., P.A. Towers, M.A. McGuckin, L. Little, H. Luckhoff, and A.W. Blackshaw. 1986. Reproductive biology of flying foxes (Chiroptera: Pteropodidae). *Australian Mamm*. 10:115-118.

Martin, L., J.H. Kennedy, L. Little, H.C. Luckhoff, G.M. O'Brien, C.S.T. Pow, P.A. Towers, A.K. Waldon, and D.Y. Wang. The Reproductive Biology of Australian Flying Foxes (Pteropus). Thesis. Department of Physiology and Pharmacology, University of Queensland, Australia.

McDonald, L.E. 1987. Veterinaria: reproduccion y endcrinologia. Ed. Interamericana, Mexico.

McNab, B.K. 1969. The economics of temperature regulation in Neotropical bats. *Comp. Biochem. Physiol.* 31(2): 227-268.

McDowell, L.R. 1989. *Vitamins in animal nutrition: comparative aspects to human nutrition*. Academic Press, Inc., New York.

Mickleburg, S.P., A.M. Hutson, and P.A. Racey. 1992. *Old World Fruit Bats: An Action Plan for their Conservation*. IUCN. England, Switzerland.

Morrison, D.W. 1978. Foraging ecology and energetics of the frugivorous bat *Artibeus jamaicensis*. *Ecology*, 59(4): 716-723.

Morrison, D.W. 1980. Efficiency of food utilization by fruit bats. *Oecologia*, 45: 270-273.

National Research Council. Series, 1978-1985. *Nutrient requirements of domestic animals*. National Academy Press, Washington, D.C.

National Research Council. Series, 1983. *Selenium in nutrition*. National Academy Press, Washington, D.C.

National Research council. Series, 1987. *Vitamin tolerances of animals*. National Academy Press, Washington, D.C.

Nelson, J.E. 1965. Behavior of Australian Pteropodidae (Megachiroptera). *Animal Behavior*. 13:544.

Neuweiler, V.G. 1969. Verhaltensbeobachtungen an Einer Indischen Flughundkolonie (P.G. giganteus Bruss.) *Z. Tierpsychol*. 26:166-199.

Parry-Jones, K.M. and M.L. Augee. 1991. Food selection by grey-headed flying foxes (*Pteropus poliocephalus*) occupying a summer colony site near Gosford, New South Wales. *Wildlife Research*, 18(1): 111-124.

Pook, A.G. 1977. Breeding the Rodrigues fruit bat. *Dodo*. Journal of Jersey Wildlife Preservation Trust. 14:30-37.

Prater, S.H. 1971. *The Book of the Indian Animals*. Third Ed. Bombay Natural History Society.

Prociv, P. and R.A. Tracey. 1986. Faecel synthesis of vitamin B12 in Australian Pteropus species (Chiroptera: Pteropodidae). *Aust.Mammal*. 10: 5-9.

Rasweiler, J.J. 1973. Care and management of the long-tongued bat, *Glossophaga soricina*, in the laboratory , with observations on estivation induced by food deprivation. *Journal of Mammalogy*. 54:391-404.

Rasweiler, J.J. 1975. Maintainng and breeding Neotropical frugivorous, nectarivorous, and pollenivorous bats. *International Zoo Yearbook.* 15:18-30.

Rasweiler, J.J., IV and H. de Bonilla. 1972. Laboratory maintenance methods for nectarivorous and frugivorous Phyllostomatid bats. *Lab. Animal Sci*., 22(5): 658-663.

Rasweiler, J.J. IV and V. Ishiyama. 1973. Maintaining frugivorous Phyllostomatid bats in the laboratory: *Phyllostomus, Artibeus and Sturnira*. *Lab. Animal Sci*., 23(1): 56-61.

Rasweiler J.J. IV. 1976. The care and management of bats as laboratory animals. In *Biology of Bats* Vol 3. W.A. Wimsett, ed. Academic Press, New York. pp 519-617.

Rasweiler, J.J., IV. 1977. Bats as laboratory animals. In: *Biology of Bats*, v. III. W.A. Wimsatt, ed. Academic Press, New York. pp. 519-617.

Rasweiler J.J. IV. 1986. American leaf-nosed bats. In *Zoo and Wild Animal Medicine*, 2nd ed, M.E. Fowler, ed. Philadelphia: W.B. Saunders Co, 1986: pp 638-644.

Reiter, J.L. 1993. The intake of captive adult, male fruit bats (*Artibeus jamaicensis*) fed isocaloric diets of differing protein content. Master's thesis. Department of Nutrition and Medical Dietetics, University of Illinois at Chicago, Chicago, IL.

Robbins, C.T. 1993. *Wildlife feeding and nutrition*, 2nd ed. Academic Press, Inc., New York.

Ruempler G. Chiroptera.1982. In *Handbook of Zoo Medicine. Diseases and Treatment of Wild Animals in Zoos, Game Parks, Circuses and Private Collections*. Klos, H.G. and E.M. Lang, eds. New York: Van Nostrand Reinhold Ltd. pp 310-312.

Skinner, J.D. and R.H.N. Smithens. 1990. *Mammals of the South African Subregion*. University of Pretoria, South Africa.

Sowler, S.G. 1984. *Growth and Reproduction in the fruit bat Epomorphus wahlbergi*. Unpublished PhD thesis, University of Natal.

Stellar, D.C. 1986. The dietary energy and nitrogen requirements of the grey-headed flying fox *Pteropus poliocephalus*. *Aust. J. Zool*., 34: 339-349.

Studier, E.H. and D.E. Wilson. 1979. Effects of captivity on thermoregulation and metabolism in *Artibeus jamaicensis* (Chiroptera:Phyllostomatidae). *Comp. Biochem. Physiol.* 62A(2): 347-350.

Studier, E.H. and D.E. Wilson. 1983. Natural urine concentrations and composition in Neotropical bats. *Comp. Biochem. Physiol.* 75A(4):509-515.

Studier, E.H., S.J. Wisniewski, A.T. Feldman, R.W. Dapson, B.C. Boyd, and D.E. Wilson. 1983. Kidney structure in neotropical bats. *J. Mammal.* 64(3): 445-452.

Thomas, D.W. 1984. Fruit intake and energy budgets of frugivorous bats. *Physiol. Zool*., 57(4): 457-467.

Thomas, D.W. 1988. Analysis of diets of plant-visiting bats. In: *Ecological and behavioral methods for the study of bats*, T.H. Kunz, ed. Smithsonian Institution Press, Washington, D.C. pp. 211-220.

Thomas, D.W. and A.G. Marshal. 1984. Reproduction and growth in three species of West African fruit bats. *J. Zool. London* 202:265-281.

West, C.C. 1985-86. Reproductive Biology of *Pteropus rodricensis*. *Myotis* 23-24:137-141.

West, C.C. and M.E. Redshaw. 1987. Maternal Behaviour in the Rodrigues Fruit Bat. *Dodo*. Journal of Jersey Wildlife Preservation Trust. 24:68-81.

Whitaker, J.O. Jr. 1988. Collecting and preserving ectoparasites for ecological study. In *Ecological and Behavioral Methods for the Study of Bats*, T.H. Kunz, ed. Washington DC: Smithsonian Institution Press. pp 459-474.

Wickler, W. and U. Seibt. 1976. Field studies on the African fruit bat *Epomophorus wahlbergi* (Sundevall), with special reference to male calling. *Z. Tierpsychol*., 40:345-376.

Widmaier, E. and T. Kunz. 1993. Basal, Diurnal, and Stress-Induced Levels of Glucose and Glucocorticoids in Captive Bats. *The Journal of Experimental Zoology*. 265:533-540.

Wilson, D.E. 1988. Maintaining bats for captive studies. In: *Ecological and behavioral methods for the study of bats*, T.H. Kunz, ed. Smithsonian Institution Press, Washington, D.C. pp. 247-264.

Young, J.A. 1987. A note on the handrearing and integration of an infant Rodrigues fruit bat (Pteropus rodricensis) at the Jersey Widlife Preservation Trust. *Dodo*. 24:82-86.

APPENDIX A
List of Participants

1994 &/or 1995 AZA Chiropteran TAG Mid-year Meetings
The Lubee Foundation, Gainesville, Florida

Keith Atkinson, The Lubee Foundation
Bruce Bohmke, Phoenix Zoo
Bruce Brewer, Brookfield Zoo
Bryan Carroll, Jersey Wildlife Preservation Trust
Michel Delorme, Biodome De Montreal
Jan Dempsey, St. Louis Zoo
Ellen Dierenfeld, Wildlife Conservation Park/Bronx Zoo
Nina Fascione, Defenders of Wildlife
Adriana Galindo, University of Florida
Tim Gross, University of Florida
Roger Haagenson, Lubee Foundation
Darryl Heard, University of Florida

Scott Heinrichs, Lincoln Park Zoo
Karen Killmar, San Diego Zoo
Tom Kunz, Boston University
Norma Lewis, Birmingham Zoo
Dan Morris, Omaha's Henry Doorly Zoo
Terry O'Connor, Woodland Park Zoo
Dennis Pate, Metro Washington Park Zoo
Harry Reeve, Busch Gardens Tampa
Peter Riger, Wildlife Conservation Park/Bronx Zoo
Alan Rost, Jacksonville Zoo
John Seyjagat, The Lubee Foundation
Kim Tropea, The Wildlife Conservation Park/Bronx Zoo
Kim Whitman, Philadelphia Zoological Garden
Steven Wing, Folsom Children's Zoo
Roland Wirth, Munchen, Germany

Husbandry Manual Editors (in addition to those at the TAG Meetings):

Sue Barnard, ZooAtlanta
Sue Crissey, Brookfield Zoo
Brock Fenton, York University
Peter Myroniuk, Melbourne Zoo
Dominic Wormell, Jersey Wildlife Preservation Tr.
Janette Young, Jersey Wildlife Preservation Trust

APPENDIX B
List of Common and Scientific Names and Conservation Status of Fruit Bats held in AZA Institutions

Family - Pteropodidae

Scientific Name	Common Name	USFWS/CITES
Cynopterus brachyotis	Malaysian or dog-faced fruit bat	
Eidolon helvum	Straw-colored fruit bat	
Epomophorus wahlbergi	Wahlberg's epauletted bat	
Pteropus giganteus	Indian fruit bat	/II
Pteropus hypomelanus	Island fruit bat	/II
Pteropus poliocephalus	Gray-headed flying fox	/II
Pteropus pumilus	Little golden-mantled fruit bat	/II
Pteropus rodricensis	Rodrigues fruit bat	E/II
Pteropus vampyrus	Large fruit bat	/II
Pteropus voeltzkowi	Pemba fruit bat	/II
Rousettus aegyptiacus	Egyptian fruit bat	
Rousettus lanosus	Ruwenzori long-haired fruit bat	

Family - Phyllostomatidae

Scientific Name	Common Name	USFWS/CITES
Anoura geoffroyi	Tailless bat	
Glossophaga soricina	Long-tongued bat	
Carollia perspicillata	Short-tailed fruit bat	
Artibeus jamaicensis	Jamaican fruit bat	
Vampyrops helleri	White-lined bat	

APPENDIX C

PARTIAL ETHOGRAM OF BAT BEHAVIORS

(from Carroll, 1979)

Autogrooming: licking or nibbling the fur or scratching with one hind foot. Forelimbs are not used in grooming.

Allogrooming: seen quite frequently among all sex/age classes, although adult males confine allogrooming to adult females. Involves groomer licking groomee's fur.

Hanging Alert: animal is hanging stationary, but is awake and alert.

Play Chase: seen among immatures. Two or more animals fly from one location to another and rapidly leave again.

Play Wrestle: usually seen among immatures. Involves close ventral contact between individuals while giving inhibited bites to neck area of the other animal. More than two animals may be involved.

Roosting: animal is asleep, suspended by one or both feet from a perch.

Scent Marking: rubbing neck and chin glands against perches or the walls of cage. Seen most frequently by adult males.

Static Flying: flapping the wings as if to fly but retaining hold of the perch with the feet. Seen mainly among infants who cannot yet fly.

Walking on the Ground: animal will descend to ground to search for fallen food. Limb sequence is typical for quadrupedal gait and claw of the thumb is used to pull the animal along. While is may be difficult for some species, bats can take off from the ground.

Wing Fan: seen during hanging alert. Is a gentle fanning with half-folded wing, may be thermoregulatory.

Wing Shake: aggressive action. One or both wings held with arms outstretched from the body. Wings shaken with thumb pointing at addressee. Claw can be used in physical encounters and is capable of inflicting injury.

Wing Flick: short flick of the distal half of wing achieved by moving the digits. Seen sometimes during courtship by males.

APPENDIX D
Application Form (AGR 1551) for Permit to Import Bats Into Canada

APPENDIX E
Partial List of Forages Accepted by Captive Colonies of Fruit Bats

alder	dogwoods	kudzu
ash	elm	mangrove (Florida)
aspen	ficus	maple (not red)**
bamboo	forsythia	mulberry (not red)
banana	grape	ornamental pear
beech	hackberry	poplar (not tulip poplar)
black locust	honeysuckle (Japanese)	sweetgum
box elder	Kentucky coffee tree	torch ginger
crabapple		

** Although red maple has been fed in some institutions, there have been reports of health incidents possibly related to the ingestion of red maple. Therefore, it is not recommend.