

Husbandry Manual
for
Ghost bat

Macroderma gigas

Mammalia: Megadermatidae



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Date: 18/09/2008

Western Sydney Institute of TAFE, Richmond

Course: Certificate III in Captive Animals RUV30204

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1 Introduction

Warnings and OHS in Regards to Ghost Bats:

The Ghost bat-*Macroderma gigas* has a classification of Innocuous-Low risk potential of causing any injury to Hazardous-an animal that may cause serious injury. This classification is due to the relative risk of the zoonoses ABL (Australian Bat Lyssavirus).

An example of an institutional OHS policy regarding the handling of Ghost Bats and Lyssavirus is as follows: Classification Innocuous* (*Only trained, inoculated staff are permitted to handle Ghost Bats, due to the risk of Lyssavirus infection). Non inoculated Keepers may enter the enclosure, with consent from Unit Supervisor, but make no attempt to handle or capture Ghost Bats.

Regarding relative risk, particularly non staff policy is as follows: Classification Hazardous: No volunteer, work experience students or members of the general public are to enter the Ghost Bat enclosure due to potential risk of Lyssavirus exposure, (Institutional policy Taronga Zoo, Australian Mammals Division, Nocturnal House)

The Ghost Bat is carnivorous, possessing strong, sharp teeth and claws used for hunting/killing prey. As such Ghost Bats have the potential to inflict quite severe wounds including lacerations and/or punctures should they scratch or bite potentially causing Lyssavirus, Tetanus or infection. (Pers.Coms. K.Jones-2008)

The Ghost Bat will generally be reluctant to approach humans and in a captive environment would rarely attack a human, although if they did there is always a potential of exposure to Lyssavirus. As a result, anyone considering the handling of bats in any way must be inoculated against the Rabies virus before they do so. (Pers. Coms. 26-7-07-Davies P.) *See Appendix 1*

If there is a chance of coming into contact with Ghost Bats the following OHS points are to be taken into consideration to minimize the risks of any potential injury:

- Do not handle Ghost Bats at all unless there is no alternative option available.
- If handling Ghost Bats in any way ensure that inoculation against Lyssavirus and Tetanus are current.
- Correct PPE must be worn at all times including mask, long sleeves, gloves. As Ghost Bats can bite through leather, chain mail gloves are most suitable if available.
- Never let bats near your face and do not attempt to kiss or cuddle bats.
- Always ensure that hands are washed before and after handling bats or undertaking any husbandry. Always maintain high hygiene standards.
- If cleaning the enclosure, avoid unnecessary exposure/kicking up of guano, (fecal matter), (Churchill.S-1998) and do not remain in the enclosure for longer than necessary, (5-10 mins. each day is adequate for general husbandry). (Richards. J-1988)

- Generally Ghost Bats would be very reluctant to show aggressive tendencies towards or attack a human, and if so it would be reasonable to assume that a bat may be sick.
- Keepers/careers must be willing to have sick Ghost Bats euthanased if it is reasonable that the bat may be carrying a disease.
- Both soap and iodine can render the rabies virus inactive, they are to be used liberally. Should a scratch/bite occur wash the area with soap for at least 5 minutes, apply iodine and seek medical treatment, (in the form of a post rabies exposure vaccine). (Churchill.S-1998)
- If a scratch/bite should occur the bat will also need to be tested for the disease, remembering that no-one should re-enter the enclosure under any circumstances.
- If you are scratched and/or bitten by a bat you must contact your supervisor immediately with the details of the attack. Your supervisor will know the correct procedure in regards to First Aid and assessing the animal in question. (Institutional Policy, Australian Mammals Division, Nocturnal House, Taronga Zoo)
- Being in captivity does not render a bat/human immune to ABL). If considering a 'catch up' relative risk must be assessed as to whether it is imperative that the Ghost Bats be caught, is there any other way to undertake the task without coming into contact with the animal? (Institutional Policy, Australian Mammals Division, Nocturnal House, Taronga Zoo) *See Appendix 1*

Safe Practice for Food Delivery:

Never attempt to touch or pat a bat when you are delivering food. It is likely you may be bitten. The animals must not be disturbed whilst in feeding mode.

Keepers must ensure that they be extremely careful if delivering food via pulley system. **Pulleys are heavy and can fall quickly** seriously injuring a keeper or animal. If using a pulley system to deliver food ensure the following precautions are taken:

1. Do not stand under the pulley. Even if you have hold of it as there **could** be a mechanical fault.
2. Check the pulley system regularly including: ropes, frame and bowl holders. They must all be in good working order. If not do not use them. Inform a supervising keeper.
3. Always ensure you have hold of the ropes and do not let go. Remember it is a pulley system. As you slacken the rope the pulley falls so don't drop it.
4. Always pull slowly and carefully. Do not be in a rush or become careless as it can sway when raised quickly (and it is guaranteed you will get wet!)
5. You must ensure that the entire length of the rope is tied up when finished. Do not leave rope ends hanging. Figure 8 the rope around the wall bracket until you reach the end. Secure the end under the last figure 8 created.

Please follow procedure with the pulley. If you take a shortcut you may know what you have done, but the next keeper using it may not. They may be seriously injured or worse a keeper or animal killed.

Use of Ladder, Tools and Chemicals:

High feeding platforms are often used for captive bat feeding and you may be required to use a ladder to reach them. If so please follow the following:

- Never reach for a dish. If you cannot reach use a ladder.
- If you suffer dizziness, lightheadedness, vertigo or blackouts do not use a ladder.
- Check ladder regularly for any faults.
- Ensure that no animals are under the ladder as you use it. You may injure them
- Ensure the ladder is spread over an even surface (sweep substrate aside to expose even ground before you step on the ladder).
- Never step on the top step of a ladder as it may be unstable.

As a keeper you will be required to use tools and chemicals as part of your job description. When using these:

- Follow all manufacturers instructions when using any tools or chemicals and read MSDS (Material Safety Data Sheets) where available. *See Appendix 2*
- Ensure that you have had appropriate training in the use any equipment you require.
- If you do not feel comfortable with any aspect of husbandry always ask another keeper for assistance and/or advice before starting.
- Never feel uncomfortable asking for training or assistance. Appropriate training and assistance from both the employer and other employees is required by law-OH&S Act 2000. (Pers.Coms. K.Jones-2008) *See Appendix 3.*

2 Taxonomy

2.1 Nomenclature

Class	Mammalia
Order	Chiroptera (Greek: chier 'hand' and pteron 'wing')
Family	Megadermatidae
Genus	<i>Macroderma</i>
Species	<i>Gigas</i> (Latin: <i>Macroderma</i> 'large skin' and <i>gigas</i> 'giant') (Gleen.W-1997) (Straughn.R-2002) (Online-Batcon website)

2.2 Subspecies

First described as *Macroderma gigas* by Dobson (1880) there were no changes made to the genus until 1962 when Douglas discovered a group of *Macroderma gigas* in the Kimberley region that was found to have a much darker ventral surface than those of other regions causing Douglas to propose a new sub species, *Macroderma giga saturata*. This synonym is still in current use following Koopman in 1984.

Wide colour variation has been found throughout the species and after much debate and taxonomic study it was accepted that the colour variation is a sub specific characteristic of the species. (Gleen.W-1997 and Pers.Coms, Gleen.W 2-8-07)

2.3 Recent Synonyms

Recent authors have been found to use the synonym *Macroderma gigas saturata* following Koopman, (1984). *See 2.2-Subspecies*

2.4 Other Common Names

- False vampire bat
- Giant false vampire bat
- Australian false vampire bat
- Australian giant False vampire bat (Online: Animal Diversity Website-2007)

3 Natural History

Biological Details:

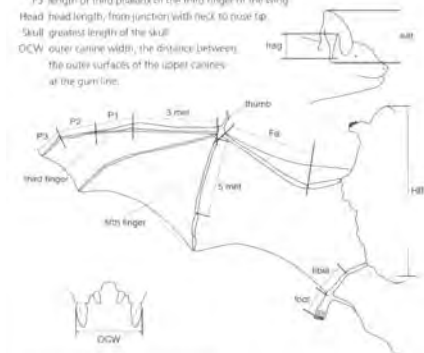
- The Ghost Bat has a resting heart rate of 235 beats per minute (at 35° C).
- A mean breathing average of 55 breaths per minute.
- A call range between 2 kHz (kilohertz) and 70 kHz with echolocation calls (some audible to the human ear) made through the nostrils. *See Appendix 6*
- Is endothermic: absorbing heat from outside sources with core body temperature remaining relatively low (Ghost Bats must have an available heat source).
- Unable to enter torpor/hibernation (it is important not to disturb Ghost Bats when roosting).
- In the wild the Ghost Bat competes with medium sized owls for food. (Online: Animal Diversity Website, 2007)
- The Ghost Bat is carnivorous and known to eat other bats including the: “Bent wing, horseshoe, leafnosed and sheath-tailed bats and the Little Cave Bat” as part of a wild diet. (Straughn.R.-2002)

3.1 Morphometrics

3.1.1 Mass And Basic Body Measurements

List of measurements that may be used for bat identification (abbreviations from species account measurements.) All measurements are in millimetres.

- Wt weight in grams
- Fa forearm length
- Tb tibia or lesser leg length
- Ear length of ear from notch to tip
- Trag length of tragus in ear
- 3 met length of metacarpal in third finger of wing
- 5 met length of metacarpal in fifth finger of wing
- HB head and body length, from nose tip to anus
- WS wing span, from wingtip to wingtip
- Foot foot length, from heel to toe tips, excluding claws
- P1 length of first phalanx of the third finger of the wing
- P2 length of second phalanx of the third finger of the wing
- P3 length of third phalanx of the third finger of the wing
- Head head length, from junction with neck to nose tip
- Skull greatest length of the skull
- OCW outer canine width, the distance between the outer surfaces of the upper canines at the gum line.



Source: Howland et al. (1982); Harrison & Powell (1991)

Fig. 1. List of measurements that may be used for bat identification.

Measurements

	Wt	Fa	Ear	Trag	Foot	3 met	5 met	HB	WS
Mean	104.6	102.8	52.0	25.4	23.9	73.2	85.3	107.4	686
Min.	74	96.3	43.8	20.6	20.5	67.1	77.5	98	640
Max.	144	113	56.3	29.1	26.8	78.4	89.6	118	720
No.	64	65	16	16	15	16	16	16	12

S. Churchill

References: Baudinette et al. (in press), Churchill (1991a,b), Churchill and Helman (1990), Pettigrew et al. (1986), Tidemann et al. (1985), Toop (1985).

Fig.2. Field Measurements of the Ghost Bat. (Mean minimum and maximum measurements included).

Ghost Bat pups weigh approx. 20 grams at birth and measure approx. 4.5cm length.

(If measurements are taken of the Ghost Bat it is recommended that plastic calipers be used (not metal) as a struggling bat may damage/break the delicate pertagium (wing membrane) or wing bones against the metal. Plastic calipers may not be as accurate as metal but for the small difference it is a safer alternative for the animal. (Churchill.S-1998)

The measurements shown in Fig.1 are generally used only in field and research work due to most captive institutions implementing a 'minimum interference' policy meaning only simple measurements will be carried out including: head to tail length, weight and possibly full wing span.

There may be occasions where more thorough measurements may be required (such as data collection for young bats in captivity or post mortem records) in which case these measurements will be very relevant. (Pers.coms, Davies.P.-23-7-07)

Although there is little geographical pattern in morphological variation, morphometric studies carried out show that Ghost Bats found in Northern Australia (excluding North eastern Australia) tend to be smaller than those found in Southern areas. This may prove that Bergmans' Rule is correct in this species. "Within species of warm blooded animals, the races living in colder climates are generally larger than the races living in warmer regions" (Rensch-1938). Species in colder climates must be larger to physically generate the body temperature they do not naturally derive from their climate. (Hand.S and York.A.)

3.1.2 Sexual Dimorphism

Females of the species are slightly smaller than males.

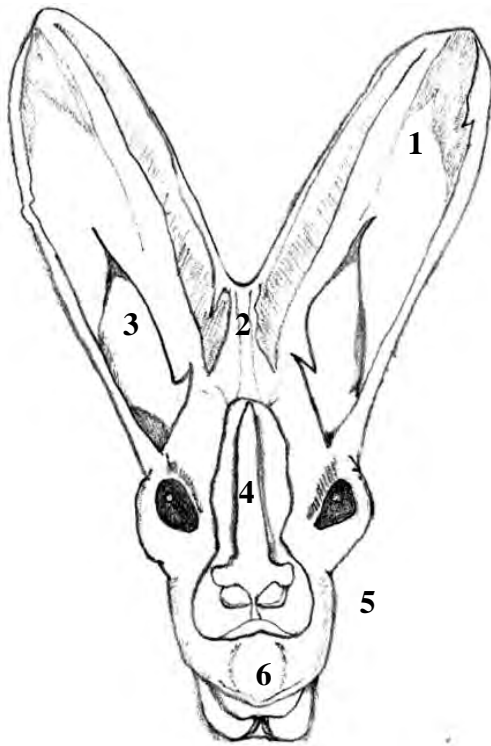
Both males and females share the same characteristics. When sexing, Ghost Bats are simple to differentiate between as the males of the species have an obvious penis. (Pers. Coms, Davies. P.-27-8-07)

3.1.3 Distinguishing Features

Distinguishing features that separate Ghost Bat from other similar species are:

- The Ghost Bat is endemic to Australia.
- The Ghost Bat is the only carnivorous bat found in Australia. (Straughn. R-2002)
- It is the largest microchiropteran (Microbat) found in Australia and around the world.
- It is the only bat found in Australia that belongs to the family Megadermatidae possessing a large tail membrane yet lacking a tail. (Churchill.S.-1998)
- Ghost Bats possess a pale grey/white appearance with ashen grey/brown back, wing tips and ear tips and pale, almost white under belly. Wing membranes tend to be pale cream through brown.

- Colours in the wild may differ in individuals. Inland populations have been observed as almost entirely white whereas in Regions such as Pilbara (Western Australia) Kimberly, Arnhem Land (Northern Territory) and Rockhampton (Queensland) these bats are generally darker in appearance a sooty grey being the usual colour. All young are sooty grey all over. (Online: Animal Diversity Website, 2007)
- The Ghost Bat has a distinctive call that includes high pitched twittering, trilling and chirping that they will alternate between in quick succession. These calls are most audible when the roost has been disturbed. (Churchill.S.- 1998)



1. Large, prominent, elongated ears.
2. Skin membrane joining ears is well above skull/head.
3. Long, forked tragus is easily visible.
4. Prominent, elongated, simple noseleaf.
5. Thin, elongated, skeletal face.
6. Long, round, protruding muzzle.
7. Full tail membrane, but no tail present. (*not illustrated*). (Churchill.S-1998)

Note the heavy elongation of most features of the Ghost Bat as a key point of identification. (Pers.obs, K.Jones-2007)

Fig.3. Key Features for Identification of the Ghost Bat. (Image K.Jones.–2007)

3.2 Distribution and Habitat

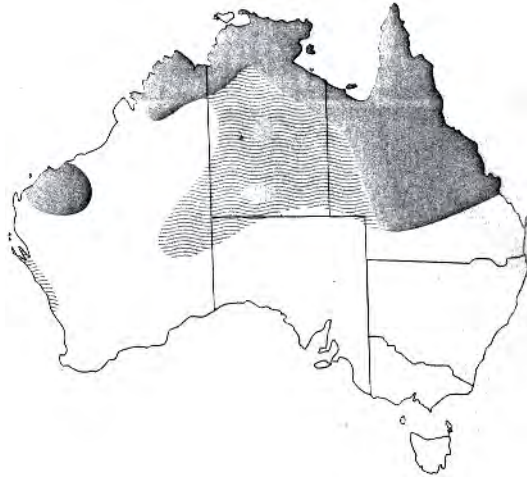


Fig.4. Distribution map of Macroderma gigas

Note: Fig.3. Coloured areas show current distribution, shaded areas show past distribution.

The Ghost Bat has a long fossil history in Australia. Tertiary species have been found in the rich Oligo-Miocene deposits of Riversleigh Station North West Queensland and Pleiocene sediments/deposits exist in Wellington Caves NSW. Early widespread distribution with sub fossil remains, have been found within South Western Australia and Eastern NSW ranges. It is thought that the Northern population contraction that has occurred was due to arid conditions causing lack of food for predators, about 10.000 yrs ago. (Straughn.R.-2002)

The Ghost Bat is endemic to Australia and once had a distribution that included most of inland and northern Australia and south Western Australia with its southern most recorded location being the Flinders Ranges (the two latter being not less than 200 yrs ago). The Ghost Bat was also recorded inhabiting Central Australia until 1960 but is now restricted to a wide but patchy distribution across tropical Northern Australia. (Gleen.W.-1997)

The Ghost Bat inhabits a broad range of environments from the arid regions of Pilbara (W.A.) across Arnhem Land and the Kimberley (Top End) to the rainforest region of Northern QLD with one of the largest, most famous and controversial roost sites being found in Mt. Etna caves in Rockhampton (QLD) and another at Pine Creek (N.T.) in a series of gold mines. (Gleen.W.-1997 and Straughn.R.-2002) *See Appendix*

Depending upon the availability of suitable roost sites Ghost Bats may occur in any of the following habitats:

- Arid climates (including arid spinnifex hillsides)
- Black-soil grasslands
- Open savannah woodlands
- A broad range of forests including tall open forests
- Deciduous vine forest
- Rainforests
- Scrub forests (Churchill.S.-1997)

In the wild roost sites are found in caves of sandstone or limestone (sandstone caves are shallow and generally found skirting cliff lines whereas limestone caves are deep).

Although the Ghost Bat has a large local forage range (of up to 60 Ha) there is no migration range. (Churchill.S.-1997) and Pers.coms, Davies .P.-9-8-07)

3.3 Conservation Status- (see appendices for further details)

- The Ghost Bat is classified as VU (Vulnerable) according to the IUCN Red List criteria. With this classification the species is facing a high risk of extinction in the near future.
- The Ghost Bat is protected by National Legislation in Australia (UNEP-United Nations Environment Program, 2001).
- There is no special status for the Ghost Bat according to CITES (Convention of International Trade in Endangered Species of Flora and Fauna). (ICUN Website-2007)
- The Ghost Bat is protected by the FPA (Fauna Preservation Act) along with 4 other bat species that rely on Mt. Etna for protection. (Online-Batcon Website-2007)

3.4 Longevity

3.5.1 In the Wild

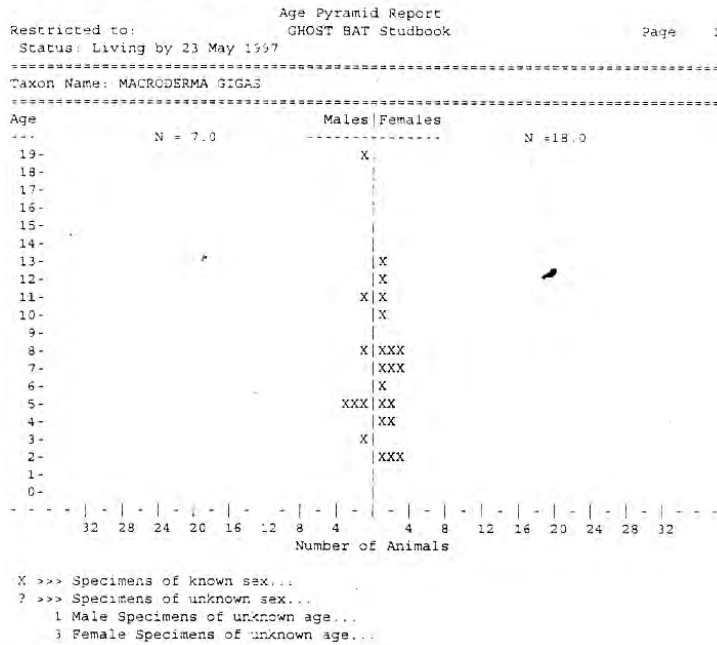
Not much is known in regards to the longevity of the Ghost Bat in the wild however it is thought that the Ghost Bat has a high juvenile mortality rate and a skewed male/female sex ratio as found in captive populations. (Gleen.W-1997)

3.5.2 In Captivity

The Ghost Bat has been bred successfully in captivity since 1977. In captivity the Ghost Bat has an average life expectancy of approx. 8-13 years and a current maximum life expectancy of approx. 19+ years. (Age Pyramid Report-1997). Many of the original animals that founded the current captive population are still alive with the trend seeming to be a high juvenile mortality rate with the survivors living a long life.

Some of the original known founders from the N.T. group of 1985 are still known to be alive and are now over 20 years of age. The graphs below will show Census reports of captive populations. (Pers.coms, Davies. P.-26-7-07)

Appendix 2: Age Pyramid Report



Graph.1. Age pyramid report showing ages of *Macroderma gigas* in captive populations. (Gleen.W-1997)

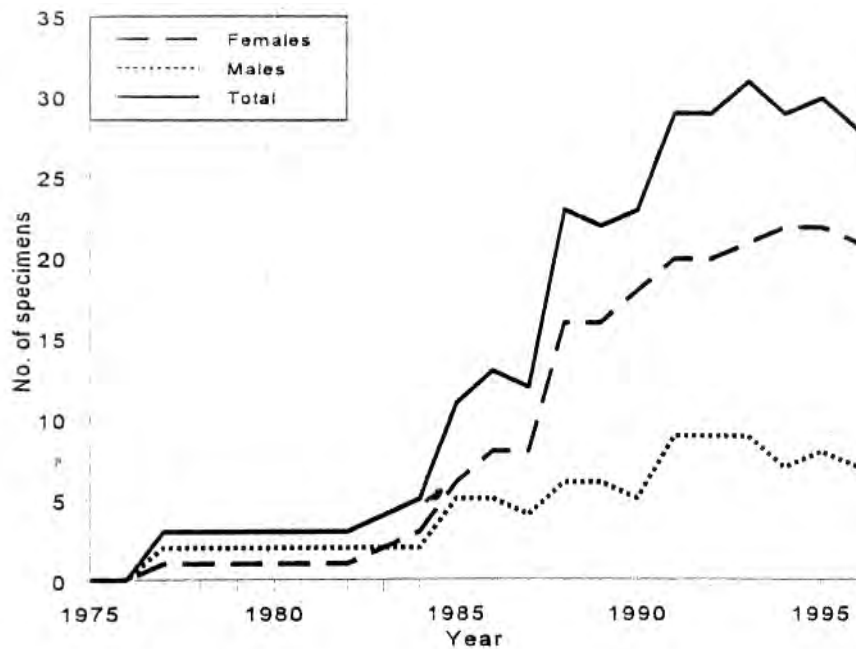


Figure 2: Annual census of the captive population of *M. gigas*: 1977 to 1996.

NOTE: The most recent data is currently being sourced and added to this information. Will obtain information from Wendy Gleen (former studbook keeper and Zoo Keeper at Taronga Zoo-Australian Mammals division).

3.5.3 Techniques Used to Determine Age in Adults

Age in can be split into three categories:

ADULTS:

- Adult Ghost bats will be either: Sexually sensate (too old to breed) in reproductive condition or have already reproduced in previous years.
- Wing bones are fully formed in adults with no cartilaginous matter between the joints which look 'knobbly'.
- Adults possess worn teeth (the older the bat the more worn the teeth, particularly the canines).
- Adults may have a number of small scars found on wings and ears from fights and general wear and tear that comes with age.

SUB ADULT:

- Sub adult Ghost bats will adult sized but will not have reached sexual maturity yet.
- Sub Adults possess unworn teeth.
- Sub adult Ghost bats are sexually juvenile in terms of tiny nipples in nulliporous females (Nipples in females will be enlarged if the bat has previously given birth) and testes that have yet to descend into the scrotum in males.
- Sub adults possess much smoother wing joints with cartilaginous bands around the wing. Joints and small blood vessels in the wings are easily recognized.
- Sub adults have few if any scars on wings or ears.

JUVENILE:

- Juveniles are smaller than adults or sub adults and possess dark grey fur as opposed to the lighter shades of the adults.
- Will possibly be attached to the mother (hanging on to the ‘false teat). The wing joints will have very large bands of cartilage surrounding them. (Churchill.S.- 1998 and Pers.coms, Davies.P.- 26-7-07)

4.1 Exhibit/Enclosure Design:

General principles and provisions	Mistakes to avoid in planning
Planning the Exhibit: Always include the following in a plan: Your name, enclosure name, client, date, scale, North point, habitat, keeper access/ease of maintenance, OH&S/safety features, plant list, key/legend, public access/view to enclosure and any other features you feel may be necessary for the plan.	A plan is not created causing confusion and mistakes in the design. This creates undue stress for all concerned in the creation of the enclosure.
Costing: Include as an attachment a cost estimate for the exhibit so the institution has a rough idea of costs and can make changes to the plan accordingly.	A costing is not included in the planning and the institution cannot afford to design the enclosure to the specified plans. Cutting corners can be dangerous.
Submission: Of the plan to the appropriate supervisor for confirmation of plan.	The supervisors do not know about the plans creating confusion for all concerned.

<p>OH&S: must always be factored into the enclosure including: ensuring that doors are the right height, enclosure is easy to access and maintain and that there are no OH&S risks in regards to heights, furniture, slip/trip hazards etc. Ensure that large furniture is bolted to the enclosure for safety.</p>	<p>If OH&S is not factored into the planning and building serious accidents and injury may occur to humans and animals when they are in the enclosure.</p> <p>OH&S accidents are cost prohibitive due to lost time, labour and workers' compensation.</p>
<p>Building: Ensure that any paints, wires, chemicals etc. are non toxic if used in the enclosure.</p> <p>Always clean up well after any building, renovations or modifications (cable ties, wire, metal rings, nails, screws, etc) to prevent any injury to bats.</p>	<p>The use of any toxic or harmful substances can cause adverse reaction, injury and death to the bats.</p> <p>Not cleaning up after working on an exhibit is irresponsible and can cause injury, illness or death in both animals and humans.</p>
<p>EAPA regulations being adhered to: Ensure that all EAPA regulations have been followed, particularly if housing more than one species together.</p> <p>Bats must have ample flight room within enclosure and not be competing with other animals for space. (Pers. Cons. K.Jones and B.Walker-2008)</p>	<p>Institutions are bound by law to follow EAPA regulation. If not the exhibit can be closed down wasting time, money and leaving nowhere for animals to be housed.</p> <p>Ghost Bats must have enough room for short flights and distance from other bats to reduce anxiety and aggressiveness.</p>
<p>Walls of roosts: being non - abrasive and able to withstand regular cleaning. (Online, Basically Bats Website-2007)</p>	<p>Abrasive walls can cause injury to bats (grazes to wrists and wings). If walls cannot withstand regular cleaning they become unhygienic and hard for keepers to maintain.</p>
<p>Wire-mesh being provided on roof: for hanging as vertical hanging is preferred.</p> <p>Also ensure that all wire is treated to prevent corrosion from urine. (C.H. and J.R.-1987)</p>	<p>Lack of wire mesh causes bats to have limited places to hang which can lead to lethargy and aggressiveness towards each other.</p> <p>Untreated wire can become corroded from urine, can fall apart and will need frequent replacement.</p>
<p>Incorporation of multiple feed stations and roosts (boxes or cloth roosts): into the design and spread throughout the exhibit. Feed stations can be platforms,</p>	<p>Too few feed stations and roosts can cause aggression over food and shelter in bats. Unlike other Microchiroptera, Ghost Bats need individual space to feed and hang.</p>

<p>pulley systems or rock and logs.</p>	
<p>Heavy weight branches: being cemented/bolted to floor. (Pers. Coms. K.Jones-2008)</p>	<p>Unsecured heavy furniture can fall down within the enclosure causing injury/death to animals and keepers.</p>
<p>Main foliage: being small shrubs with heavy, soft foliage. Low shrubs to suit a desert theme no higher than 2 metres provide an easy circular flight path for bats overhead and are a good choice.</p> <p>Shrubbery and furniture should be matched to suit the theme of the enclosure. Do not mix environments. E.g. Arid only and not Arid mixed with Rainforest</p> <p>Shrubs can include: Grasses/tussocks, Banksia, Lillypilly, Lomandra, Westringea, Ptosperum, Acacia, and Eucalypt. (C.H. and J.R. 1987).</p>	<p>Twisted, sharp or protruding branches may tear pertagium and possibly break delicate wing bones if a struggling bat should become entangled in them. (Ghost Bat memo, Anon-1990)</p> <p>Mixed environments will not be aesthetically pleasing to view.</p> <p>Toxic plants may cause adverse reactions in Bats. Check plants to ensure they are safe before planting. Plants of incorrect size planted may outgrow the enclosure and create problems in the future.</p> <p>Placing browse near any heat sources including lamps is a fire danger. (Pers.coms, Davies.P.-26-7-07)</p>
<p>Substrate: mimicking wild environment (Red sand) is a good choice. Sydney sand is a great substitute as is compacted dolaride. Sand has the benefit of being hygienic and easy to clean and maintain.</p>	<p>Use of pine, cedar or any other highly aromatic substrates in enclosure can cause respiratory distress in bats.</p>
<p>Water being used appropriately. Fine mist in enclosure or pond in enclosure provides environmental enrichment. Ensure adequate drainage is incorporated.</p> <p>If using ponds ensure that bats are able to climb out should they fall in by placing pebbles, rocks and branches in and around pond.</p>	<p>Ponds/water features not plumbed in correctly or inadequate drainage in enclosure means water can become stagnant causing health hazards. Incorrect plumbing can cause OH&S and flood risks. Bats can drown if they fall in a pond with no way to get out.</p>

<p>Visual barriers Can be browse, rocks, cave walls and roosts. Visual barriers provide safety, shelter and warmth for animals.</p> <p>Bats must have access to private places (roosts, behind trees or shrubs) that they cannot be seen in by public</p>	<p>Not enough visual barriers increase stress and anxiety in animals.</p>
<p>Light and heat: being maintained. Light must be minimal and diffused (tinted blue, red or yellow) and heaters can take various forms, e.g. Heat lamps (tinted red or blue), wall heater or heat pad buried under substrate.</p> <p>Ensure that heat sources are covered with wire mesh to prevent contact/injury with bats.</p> <p>Do not house Ghost Bats near open doors due to drafts, bright light and excess noise.</p>	<p>Conditions not fit for Ghost Bats can cause anxiety, illness and death in bats.</p> <p>Ghost Bats require a temperature of approximately 26°-36°c and humidity of approximately 80% to simulate wild cave habitat.</p>
<p>Ventilation: being adequate so bats do not suffocate. As temperature and humidity are high in Ghost Bat enclosures ventilation is paramount.</p>	<p>If adequate ventilation is not provided bats can suffer from stress disorders or suffocation and death.</p>
<p>Visual access to enclosure: Use Perspex or heavy glass fronted enclosures so the public can enjoy watching the bats.</p> <p>Clean glass regularly (Pers. Coms. K.Jones)</p>	<p>Without visual access the public will become bored by not being able to view bats. The public will then not bother with the enclosure wasting time, money and labour.</p>
<p>Adequate climbing opportunities: being provided with branches/apparatus from the ground to climb up should they fall down. (Online-Basically Bats Website-2007. Pers.coms-2-8-07)</p>	<p>Without climbing opportunities fallen bats may have trouble getting back up to a hanging position suffering stress, injury and death. Pups and juveniles cannot be retrieved from floor by mothers and may die if left. Fallen bats can become prey to other animals within the enclosure e.g. Bilbies.</p>

<p>Airlock in design: As Ghost bats are very agile flyers and can outmaneuver humans easily an airlock should always be incorporated into the design.</p>	<p>An airlock limits risk of escape from enclosure. Without an airlock bats may escape.</p>
<p>Tools, PPE and other equipment can be stored in a small part of the airlock for ease of use for cleaning and maintenance.</p>	<p>Makes tools, PPE etc. easily accessible to keepers for ease of cleaning and maintenance leaving no excuses for unhygienic husbandry.</p>

For more on Enclosure Furnishings: (See 9.7 Behavioural Enrichment)

4.1 Holding Area Design

- Holding area requirements must be the same as minimum exhibit holding areas. *See 4.2 Spatial Requirements.*
- Can be a cage of ¾ inch treated wire mesh (to prevent corrosion from urine) or ¾ inch plastic polythene mesh. Holding cages (including Noegel cages) must be high enough so that the bats head is well off the floor as they will get their ears caught in excrement causing tissue necrosis. (Online-Batcon Website-2007).
- Any heating lamps should be positioned on the outside of the cage or wire covered to prevent accidental burns. 250 watt wall mounted lamps at 1 end of the cage and 25 watt lamps in smaller cages should suffice. (Online-Bat Care website-2007)
- If housed in a timber structure the walls must be grooved to hold bats (approx. ¾ inch apart grooves). (Online-Batcon Website-2007).

4.2 Spatial Requirements

EAPA (Exhibited Animals Protection Act) minimum requirements for housing for Ghost Bats are as follows:

Head body length	Total length	Min encl. area (m2)	Min encl. height	Added floor for extra individuals
13cm	13cm	9.00	240cm	1.5m x 1.5m per animal

- The above measurements are for housing 2x animals of the same species. If housing different species of animals the enclosure must be the sum of each species' minimum EAPA area requirement.
- Ghost Bats do not need require designed for sustained flight but must have room enough for short bursts of flight.
- Ghost bats do not require flight time outside of EAPA sized cage.
- Several different roosting sites will be required for different microclimates and hierarchy within groups. (Online:EAPA Website, 2007)

4.3 Position of Enclosures

- Ghost Bats should be housed in a Nocturnal House for the best public view at the most active times (usually feeding).
- Enclosures should be positioned away from any enclosure or feature that is noisy (as Ghost bats are highly sensitive to noise). (Pers.obs, K.Jones-2007)
- Enclosures need to be shielded from bright lights including that of 'exit' signs that require a shield to diffuse any light that may shine into the enclosure. (Ghost Bat memo-Anon-1990)
- Enclosures should be positioned to avoid all bright light, (including that at the entrance to the Nocturnal House). (Pers.obs, K.Jones, 2007)
- Perspex should be used on the front of the enclosure so as to give the public a clear view of the bats with clear vision to the top of the enclosure.
- Either a glass front or stand-off barriers are required if using a wire fronted enclosure. (Online, basically bats website, 2007) to minimize any risk of injury to the public.
- The enclosure usually takes the form of a cave or mine shaft simulating wild habitat. Ensure there is visual access for the public within these areas. (Pers.obs. K.Jones.-2007)
- Ghost Bats are hard to house outside due to light and heat not being constant. As a result the bats may never leave the roost or be seen. (Chuchill.S.-1998)

4.4 Weather Protection

Since captive institutions usually house Ghost Bats in a nocturnal house the conditions will be well controlled and there should be no natural weather elements to be combated. Even so, the following will still apply:

- All housing for Ghost Bats should be in a controlled environment including light, temperature and daylight hours set on rotational timer.
- Be careful that any ventilation within the enclosure does not expose bats to drafts.
- Open grates or fronts of enclosures should not face directly onto a doorway to prevent light, noise, draughts and other whether.
- Protection from the elements is required if housing outdoors in the form of roost boxes, roofed enclosure and solid walls to protect bats from possible pneumonia.
- (Pers.coms, Davies.P.-26-7-07)

4.5 Temperature Requirements

Temperatures of different institutions vary and Ghost bats will adapt to small variations but generally the enclosure temperatures should be as follows:

- Heat lamps are not an absolute requirement provided the enclosure/cave temperature is kept between a range of 23° C-30 °C (average temperature is usually 23° C-26° C) with regular misting (watering of soil/substrate) to keep the humidity high (average 80% humidity)
(Taronga Zoo, Keeper husbandry information-2007)
- Heating may be installed under the floor with advantageous results as well.
- A lower temperature range of 18° C-22° C lowest and 22° C-27°C in adequate for Ghost Bats housed in Perth Zoo.
(Richards.J-1998)
- Temperature requirements for breeding purposes may need to be slightly increased to a constant temperature of 26° C+
- Heat lamps that may be used include: 20 watt blue, yellow or red diffused spotlights or approx 80 watt blue fluorescent tube lights. Either light should be used to simulate moonlight as would be found naturally during waking hours and feeding times and also provide a heat source.
- Red diffused lights can be an advantage due to the fact that they remind keepers of the lamp being a heat source and to not place browse near it (**danger!**).
- Even with high humidity, adequate ventilation in the form of a mesh grill must be incorporated to prevent respiratory problems and the formation of mould and mildew in enclosure. (Pers.coms, Davies.P.- 26-7-07).
- Grates should be covering all heat sources within the enclosure to prevent any injury, burns. (Pers.obs, K.Jones-2007)

4.6 Substrate

- Painted concrete can be used as flooring but is fairly sparse and cold and does not offer the most natural conditions for a bat. (C.H & J.R.-1998)
- Substrate is preferable to a bare floor as bats will swoop upon prey on the ground to catch and consume. Ghost Bats have been observed sitting on the ground with prey before returning to feeding roost. Substrate is also preferred for activity feeding for a soft landing if the bats fall to the ground. (Pers.Obs, K.Jones-2007)
- Sand substrate is preferred and makes cleaning guano and other waste matter from floor much easier.
- Use local soil as found in the natural environment if available (red sand as found in Northern Australia has been used with success in Perth Zoo). (Richards.J-1998)
- Grass is great as it is natural, soft and looks aesthetically pleasing, but can prove problematic in maintaining indoors for nocturnal animals. If grass can be incorporated into a section that is advantageous.
- Pine bark may also be used successfully as a two tone substrate. ½ pine bark and ½ sand separated by a log “fence” causes no problem or distress to the bats in a large enclosure but may be harder to maintain from a keepers perspective. Sand is much easier to sift for guano. I have only ever observed Ghost Bats land on sand, never on any other substrate. (Pers.obs, K.Jones, 2007)
- Pine bark or wood chip substrate should never be used in transport boxes/cages as the particles in a small enclosure may cause respiratory distress in the bats.
- Substrate must be free of any waste and changed regularly to prevent disease and make catching food on the ground easier for bats. (Online, basically bats,website, 2007)

4.7 Nestboxes and/or Bedding Material

Multiple nestboxes and roosts should be available to minimize aggression in Ghost Bats. Nestboxes and bedding can include:

- Cloth roosts suspended from wire grates attached to the roof. The cloth should be made of lightweight, soft, dark coloured cloth to provide: a visual barrier, extra warmth if required, and for use as a feeding/resting roost site. Cloth should be approx.3 folds thick. (*Image to be inserted*). (Pers.obs, K.Jones-2007)
- Roost boxes may also be constructed from timber with measurements of approx. 1.0 - 1.5 m² with an entrance hole at the top and cloth from the bottom of the box to the ground. (Husbandry note, Taronga Zoo, Australian Mammals Division- Anon-no date)
- Ghost Bats will use cloth roosts for all functions: resting, eating, mating, and maternity roosts).

- Taronga Zoos' Ghost Bats have been observed preferring cloth roosts over roosting boxes when offered a choice. (Pers.obs, K.Jones-2007)

4.8 Enclosure Furnishings

- If feeding from the ground rocks as feed platforms are considered good enrichment as this is how the Ghost Bat would naturally hunt for some food (Richards.J-1998) providing there are no scavengers to eat food e.g. Bilbies (As are at Taronga Zoo).
- Multiple feed stations are required and should be spread throughout the exhibit to avoid aggression over food.
- Adequate climbing opportunities with branches/apparatus from ground should be provided to climb up should bats fall down. (Online-Basically Bats Website-2007. Pers.coms, K.Jones-2-8-07)
- Walls and roosts must be non-abrasive to avoid injury to bats (grazes on wrists and wings) and to withstand regular cleaning. (Online- Basically Bats Website-2007)
- Wire mesh should be provided on the roof for hanging as vertical hanging is preferred. (C.H.& J.R.1987)
- Low shrubs to suit a desert theme no higher than 2 metres to provide easy circular flight path for bats overhead. Shrubs can include: Grasses/tussocks, Banksia, Lillypilly, Lomandra, Westringea, Ptosperum, Acacia, and Eucalypt. (*Images to be inserted*)
- Heavy weight branches to be cemented/bolted to floor to avoid any injury to animals or keepers.
- Main foliage to consist of small shrubs with heavy foliage and no sharp, twisted or protruding branches as this may tear delicate patagium (wing membrane) and possibly break delicate wing bones if a struggling bat should become entangled in them. (Ghost Bat memo-Anon-1990)
- Shrubbery/furniture must be matched to suit the theme of the enclosure. Do not mix environments. E.g. Arid only, not Arid mixed with Rainforest as this is aesthetically displeasing. (C.H.& J.R.-1987)
- Do not place browse near any heat sources including lamps as this is fire hazard. (Pers.Coms, Davies.P.-26-7-07) *See 4.1 Exhibit/Enclosure Design*

5 General Husbandry

5.1 Hygiene and Cleaning



List of tools needed for cleaning enclosure:

- Face mask, PPE (do not enter the enclosure without this due to zoonoses risk)
- Gloves, PPE (do not enter the enclosure without this due to zoonoses risk)
- Sieve: to sift waste from substrate.
- Dustpan and broom: to sweep small areas, and remove waste
- Rake: to rake over substrate after sifting and to 'flush' bats and ensure they can fly.
- Water container: to wash down any hard to remove waste and replace dirty water with clean, fresh water. (Pers.obs, K.Jones, 2007)
- Torch: to assist in sighting bats for stock count. NEVER shine a light directly into a bat's eyes. (Pers.coms, Gleen.W.-9-9-07)

Fig.5. Equipment Used in Ghost Bat Enclosure.

General Husbandry Duties:

- Ensure that PPE (Personal Protective Equipment) is worn at all times in the enclosure.
- A quick spot clean every day to ensure no carcasses and guano build up on the walls and furniture. Cleaning must be done quickly with a minimum of noise/disturbance to the bats. Ensure that branches of shrubs and behind rocks are checked for food scraps fallen/discarded carcasses. Clean well under feed stations as this is where the guano usually builds up.
- A full disinfectant of all furnishings and enclosure fittings must be done approximately once a month (bats should be removed prior to a large clean) with enclosure and all fittings well rinsed and dry before bats are reintroduced. This is also a good time to reconfigure the enclosure furnishings *See 9.7- Behavioural Enrichment.*
- Clean water must be provided daily.
- Ensure that all bats within the enclosure can fly and that claws are not caught in wire grates. Do this **gently** with a broom handle or plastic rake. Do not make contact with bats. If bats do not immediately take flight they may be caught and notify a Supervising Keeper.

- Temperature within enclosure and main Nocturnal House thermostat controls will need to be checked. (Husbandry memo, Australian Mammals Division, Taronga Zoo, Anon-1987).
- Browse change 2-3 times a week or when browse becomes dry. (Pers.Obs, K.Jones-2007)
- Mist substrate 3 times a week to keep humidity levels high. (Keeper Signage, Taronga Zoo-2007)
- Full substrate change once every 6 months with bats being removed from the enclosure before this takes place to minimize stress, escape risk and dust inhalation. (Gleen.W. from Taronga Zoo Husbandry Calendar for Nocturnal House-2007))
- Do not use Ghost Bat cleaning tools for any other enclosure to prevent the spread of any disease from guano, discarded food etc. (Husbandry memo, Australian Mammals Division, Taronga Zoo, Anon-1987)
- Cloth roosts will need washing every few months, rinse with detergent, clean water. (Pers.coms, Davies.P. 26-07-07)

Products safe for use in enclosures and husbandry include:

- F10 - Hand cleanser
- Hi Clean - Detergent
- Halesept - Disinfectant/sterilizer
- Milton - Sterilizer
- Unique Pine - General all purpose cleaner
- Viraclean - Disinfectant/sterilizer. *See Appendix 2*
- NOTE: Do not use bleach or anything with an acid base to clean enclosures as all chemical substance should be fairly inert.

5.2 Record Keeping *See Appendix 5.*

- Ensure that all enclosures have cage cards and that they are current and easily read. The cage cards should list: Classification, Scientific name, common name, I.D. numbers, enclosure numbers, any other additional information required on the bats e.g. Breeding/special diets, veterinary results, escape risks, behaviours, husbandry etc. The data on the cage card is to some degree dependent upon the situation at the time.
- Ensure that all chick and mouse carcasses are counted each morning (both discarded on ground and those in feed bowls) to ensure the bats are eating properly. Record any changes to eating patterns in daily diary.
- Record temperature and humidity levels of enclosure regularly. (Temperature may need to be changed for breeding purposes etc.) (Anon, 1987, Husbandry memo, Australian Mammals Division, Nocturnal House, Taronga Zoo)
- Daily stock count to be carried out and a daily stock sheet filled in.

- All bats are to be identified prior to any breeding attempts to ensure genetic diversity (with no in breeding) occurring.
- Any observations during the breeding season are to be recorded along with current diets and food intakes in regards to breeding etc.
- Daily diary notes are to be made recording any changes or notable events in behaviour of the Ghost Bats.
- ISIS codes are to be used for any notable events that take place.
- All Keeper signage to be altered when required. E.g. after internal transfers occur. (Pers.obs, K.Jones-2007)

NOTE: Any note worthy behaviours **must** be entered into the daily diary using the appropriate ISIS codes and reported to a Supervising Keeper.

5.3 Methods of Identification

Preferred method of I.D. for Ghost Bats:

- Micro chipping

Advantages:

- Microchipping is a permanent form of I.D., is very secure and once inserted cannot be removed, lost, or worn out.
- Microchips are aesthetically pleasing as they cannot be seen by the general public when bats are on display.
- Micro chipping is also a very uniform record keeping system for larger institutions as one method is easier to learn and use than many different methods especially when multiple bats are housed in one division or enclosure.

Disadvantages:

- Microchips must be inserted correctly and require a licensed person to do so.
- Microchips require a scanner to be read, must be bought in batches and must be inserted in the correct place, (interscapular in Ghost bats).
- The bat will usually have to be 'caught up' to be scanned for a chip as oppose to a visual method (tattoos) and it is best that bats in particular are not caught up unless absolutely necessary due to Lyssavirus.
- Micro chipping may cause localized abscesses in very small animals e.g. Ghost bat pups.
- Migration around the body may occur at times but will usually pose no major problem.
- Microchips have to be applied internally and are invasive. This may cause some stress to the animal as the chip is inserted.

- Once trained, any keeper is capable of scanning for an implanted microchip. The most current scanners do not need to touch the flesh and it is enough to run the scanner over the area of the bat and even if chip has migrated scanning will be successful.

Does the I.D. Method Change?

It would be advantageous to change the form of I.D. to Thumb Tags, (a plastic Finch tag) if being released into the wild as these are easy to sight without making contact with the bat. They would also clearly indicate that the individual bat had at some stage been in captivity, handled, or is being researched.

The only problem with thumb tags is they may be liable to come off in the wild.

Alternate forms of I.D.:

Thumb tags, (a plastic Finch tag) and ear tattooing are both alternate methods of I.D. Thumb tags are light, inexpensive and don't easily come off, but they can be seen by the public when viewing the bats.

Ear tattoos have many of the same advantages and disadvantages as microchips.

Wing/leg tagging is not widely used as an industry standard due to the fact that the wing membrane must be cut to fit leg tag around femur. (Pers.Coms, Jones.K.-2007)

For appropriate forms of identification for Ghost Bat pups

See 9.10 Identification Methods

5.4 Routine Data Collection *See Appendix5*

- Visual inspection of each individual Ghost bat for any noticeable changes in health and/or behavior. This inspection should be done during the regular daily husbandry routine.
- Fecal samples are taken twice a year and sent to a veterinarian to check for internal parasite loads.
- Weight is checked whenever Ghost Bats are caught.
- Length is checked whenever Ghost Bats are caught.
- General health checks are provided as required. (See institutional guidelines in workplace)
- Sexing and/or reproductive condition of animals if required (Pers.coms, Davies.P.-26-07-07)

Within most captive animal institutions there is usually a 'minimum interference' policy in place such as Taronga Zoo and Perth Zoo. (Richards.J.-1988) Due to the nature of this policy records and routine data collection are based whether they are absolutely required. If it is not necessary the Ghost Bat is usually left in the enclosure with little routine data collection. (Pers.coms, Davies.P.-2-9-07)

6 Feeding Requirements

6.1 Diet in the Wild

The Ghost Bat is the only truly carnivorous bat in Australia. It is also insectivorous and ingests no plant matter whatsoever. The wild diet of the Ghost Bat varies quite considerably to the captive diet that must be fed.

Wild diet of the Ghost Bat includes:

- Small birds
- Frogs
- A range of small lizards, including Geckos
- A variety of small mammals
- Other bats (unlike any other Chiropteran species). Bat species preyed upon by the Ghost Bat include: Bentwing, Horseshoe, Leafnosed, Little Cave Bat and many species of Sheath-tailed bats. (G.C. Richards & S.Hand.-2002)

Variety of Invertebrates in Wild Diet Include:

- Locusts
- Millipedes
- Spiders
- Cockroaches
- Termites
- Flies
- Crickets
- Moths
- Beetles
- Caterpillars
- Ants

Forms of Hunting Used by Ghost Bats:

Bats have three varied forms of hunting that are used depending upon the species. Ghost Bats are the only known species to use all three forms of hunting when feeding in the wild. These forms are:

1. Active hunting with echolocation (generally inaudible to the human ear).
2. Passive sit and wait hunting using eyesight and passive hearing and
3. Gleaning food from cave walls after listening for noises made by prey. (generally used for catching insects clinging to cave walls and plucking prey out of the air whilst in flight).

Another hunting variation used by the Ghost Bat is 'whispering echolocation' to avoid alerting potential prey. Whispering echolocation means that echolocation is 'turned off' intermittently as a form of 'silent running' to aid in a more successful hunt. (Chuchill.S.-1998)

Wild Hunting Behaviour in Ghost Bats:

Ghost Bats are known to swoop on prey taking birds and other species of bat from behind whilst in flight or snatching whilst on tree branches. (Encyclopedia of Australian Wildlife-1997) The Ghost Bat swoops upon the prey catching it up in powerful claws and enveloping the prey in its wings. The prey will then be killed with powerful bites around the head. After making the kill, the Ghost Bat will then return to a temporary feeding roost where the bat will eat its prey, dropping larger unpalatable pieces to the ground (generally heads and feet).

Radio tracking studies have shown that Ghost Bats forage 2 km from the roost cave and use the same forage areas (about 60 ha each night). Within this area the Ghost Bat will hunt from tree roosts moving to a new vantage point every 15 minutes. Foraging areas are not exclusive and up to 20 bats may have overlapping ranges. Wild feeding roosts will be found by the heavy concentration of guano found under feeding roosts. (Churchill. S.-1998)

6.2 Captive Diet

The standard captive diet of the Ghost Bat although far more simple than a wild diet, is readily accessible and provides all of the nutritional requirements and behavioral enrichment needed to manage Ghost Bats successfully in captivity. For these reasons all institutions that manage Ghost Bats within a captive environment offer a very similar diet.

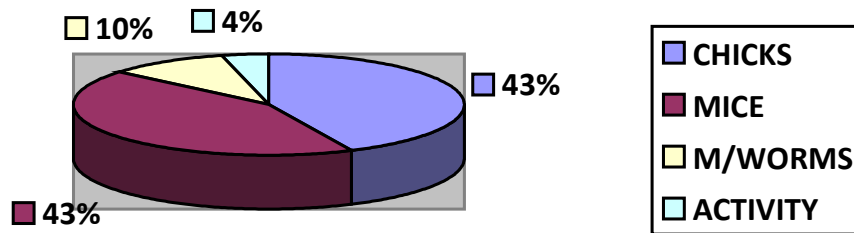
Frogs, lizards, and other bat species are protected by law and NPWS (National Parks and Wildlife Services) would not allow them to be consumed as part of a captive diet when elements/substitutes of wild diet can be used. Many species of invertebrate are also not used regularly as they are generally cost prohibitive to feed regularly as part of a captive diet. Continued propagation of these animals for regular use would not be viable but do not discount them on occasion for activity feeds. (Pers.Cons.Jones.K & Every.P & Davies.P.-18-11-07)

A balanced captive diet for the Ghost Bat consists of:

- 1x day old chick per Ghost bat and/or
- 1x Adult mouse per Ghost bat
- Ad lib mealworms, cockroaches, crickets, locusts, moths (twice daily as available)
- Activity feeds
- Fresh water at all times (Taronga Zoo and Perth Zoo diets)



Chart.1 Pie chart showing percentages of various foods eaten by Ghost Bats in captivity. Chicks/mice are by far the greatest proportion of food eaten.



In winter and during breeding the amount of mealworms and activity feeds will increase to provide more food. Do not decrease the chicks/mice though as the extra food is required. (K. Jones-2007)

Notes on daily feeding regimes:

- 1x each of day old chick and mouse per Ghost Bat ensures that each bat has a choice. This also minimizes aggression as there is no shortage of any particular food.
- Any day old chicks and mice (regardless of age) must be fed dead. The feeding of these animals live is prohibited for the following reasons:
 - 1) It would be distressing to visitors.
 - 2) If the animals were unable to catch the food (due to being captive) they may starve.
 - 3) It is common that Ghost Bats are housed with Bilbies (*Macrotis lagotis*) and they would vie for the food source.
 - 4) The animals may become aggressive over food (particularly males).
 - 5) Mice have the potential to breed and as they are not part of the institutions collection they may not breed outside a controlled environment.
- Mealworms, crickets, locusts, moths and other invertebrates may be fed live and are a good form of activity feed.
- All food must arrive at the institution either fresh on the day or frozen, whether supplied from internal or external sources.

- All frozen food must be thawed out in a fridge under 4°C for 24 hours and then taken out to meet room temperature prior to feeding out to bats. Do not offer Ghost Bats frozen food. They will not consume food frozen and it will spoil by the time thawing has occurred in such a humid environment. Frozen food may cause health problems in bats and it is not a healthy practice.
- All ‘feeder’ animals should be bred for the specific purpose of feeding other animals and captive Ghost Bats should only consume feeder animals bred for this purpose. Pest/wild caught rodents and cockroaches are generally not used as there is a potential that they may carry disease or cause cross contamination within the environment.
- Any discarded pieces or carcasses must be removed and disposed of. Never re-feed discarded or spoiled food to bats.
(Pers.Cons, Jones.K. & Davies.P.-1-10-07. & Pers.Obs, Jones.K.-2007 from Taronga Zoo husbandry)
- Ghost Bats will eat bones, cartilaginous matter and exoskeletons of mealworms as roughage that is required in the diet. If not fed roughage the animal will become fouled with loose excreta covering both the animals and the roost).
(Online-Animal Diversity Website-2007)
- Feed Ghost Bats twice daily. Perth Zoo feed at approx. 1.00pm and 3.00pm daily (about 1/2 way through their night cycle). (Richards.J. Perth Zoo memo-1998). Alternatively, Taronga Zoo feed at approx. 11:00am and 1:30pm each day. This is done for the following reasons:
 - It keeps the Ghost bat on consistent display for visitors.
 - Irregular feeding times provide a more ‘natural’ approach to feeding.
 - Keeps the food fresher as if fed too much, the bats could not consume it all before it spoiled. (Pers.Comms, Davies.P.-1-10-07)

6.3 Supplements

There are little in the way of supplements that are required in a captive diet for Ghost Bats as nutritional value is gained mostly from the food they are provided with.

Vitamin supplements may be added to the water or in powdered form in the substrate used for mealworms/or sprinkled over mealworms prior to feeding (these mealworms are to be fed to Ghost Bats alone). Vitamin D is of particular importance as a deficiency may cause alopecia and undue stress. Supplements may be provided with veterinary consultation as part of a routine diet or if signs of lethargy, fatigue or stress are observed.

As mentioned previously bones and cartilaginous matter are required in the diet as roughage. If not fed roughage the animal will become fouled with loose excreta covering both the animals and the roost. (Online-Animal Diversity Website-2007)

The other way a Ghost Bats diet can be of a higher quality is to provide the best quality 'feeder' animals there are. If providing Mealworms for instance house and/or feed them bran or boiled egg crumble and add cereal/supplements to make them nutrient rich for the animals that consume them. *See 9.8 Diet and Feeding Routine-Other Foods* (Jackson-2002) Do not feed mealworms alone to Ghost Bats as they do not provide a balanced diet on their own.

When breeding or if pregnancy is suspected, increase activity feeds and food in general. Do not decrease the amount of chicks or mice. The animals require the extra nutrients. Increase: mealworms, crickets, locusts, neo natal mice and moths and flies (when available). (Taronga Zoo diet)

Unlike many other microchiropterans, the Ghost Bat is unable to go into torpor (hibernation) during the cooler months. (Churchill.S.-1998) Even though conditions are controlled within a Nocturnal house it is still good husbandry to treat the animals seasonally and offer increased activity feeds as specified above. Ghost Bats must have enough energy to generate and maintain extra body heat during cooler months if required. If housed outside, Ghost Bats will roost together but never as tightly as other species of microchiropteran, when extra feeding during colder months becomes almost essential. (Churchill.S.-1998 & Pers.Coms.Jones.K.-2007)

6.4 Presentation of Food

Presentation of food is all important when considering the diet of any animal. If this aspect of husbandry is managed poorly the animal may starve and require either medical attention or in severe cases even die (although there may be a food supply within easy reach of the animal). Good feeding practice also allows for the animals to be given behavioural enrichment so the wild instincts of the animal do not atrophy. As such the following standards must be followed to ensure the safe feeding requirements of Ghost Bats:

Food Delivery:

- Food can be served on feeding tray (large enough to accommodate all food easily and separately, not overlapped) and left on feeding platform. Trays can be steel or hard plastic. Ensure a portion of the animal tails or heads hang over the side to make the food easily accessible. *See image right* (K. Jones-2007)
- Any feeding platforms must have a grate above them for perching when bats take hold of any food (as bats hang upside down as they take food with their mouths). A wire mesh grate with approx. $\frac{3}{4}$ inch square holes will be adequate. Alternatively wire rings



- may be bolted to trees or branches for food delivery by placing bowls into rings. Be sure to ensure that the branches are not sharp and cannot injure the delicate peritragium (wing membrane) (Taronga Zoo memo, Anon-No Date)
- Alternatively food can be placed in a bowl and placed in a wire ring if being delivered via pulley system. *See 1-Introductions and OH&S* (Pers.Obs. K.Jones-2007 from Taronga Zoo husbandry)
 - Food left on rocks or low to ground for bats to swoop on as if in wild is undertaken by Perth Zoo. (Richards.J. Perth Zoo memo-1998)
 - Bottles can be successful for water delivery as they are a clean method of delivery if the bats will use them. If using bottles keepers must at first observe that the animals are adequately hydrated. (Taronga Zoo memo, Anon-No Date). If bottles are not used water dishes should not be too deep in case of bats falling in and drowning. Bowls should have a diameter of approx. 15-20cm to easily accommodate the animal. (Pers.Obs. K.Jones-2007)

Feeding Methods for Keepers:

- All food must be checked for freshness and quality prior to feeding out, discarding any food below standard.
- Count food items ensuring that there is enough food for each animal.
- Be aware of how many carcasses were collected from the previous day to monitor how well the bats are eating. Most of the food should be consumed with some larger parts discarded (heads and feet).
- Food must be placed appropriately within the enclosure. If the temperature/humidity is very high wait to feed until late afternoon so the food does not spoil.
- Keepers must leave the enclosure immediately after having placed the food out as bats must be left to eat without disruption.
- Any carcasses dropped or discarded will not be picked up by the bats and must be removed from enclosure the next time it is entered. (Pers.Obs. K.Jones-2007)

Behavioural Enrichment Feeding:

Activity feeds include mealworms scattered throughout the enclosure which encourages the animals to use all areas of the enclosure and use natural hunting instincts. It also provides physical exercise for the bats. Irregular feeding times (both routine and activity feeding) provide a more ‘natural’ approach to feeding.

Perth Zoo offer dead mice/day old chicks at ground level, placed on large flat rocks to simulate more natural feeding. (Richards.J. Perth Zoo memo-1998)

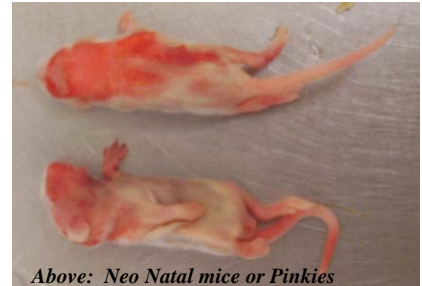
Taronga Zoo does not use this method as Ghost Bats there are housed with Bilbies- *Macrotis lagotis* and as Bilbies are foragers they would consume the food before the bats had a chance or aggression would ensue over the food source.

Different size/aged mice can also be used instead of a regular adult mouse to offer different textured/sized food as the bones are much softer and they have less hair. (Pers.Cons. Jones.K. & Davies.P.-18-11-07)

If changing the mouse size, follow the chart below:

1x Adult mouse = approx 6x Pinkies (neo natal mice)
1x Adult mouse = approx 3x Fuzzies (around 2-3 wks.old)

Food sources that can be placed upon rocks, the sides of cave walls or freely scattered through the enclosure include mealworms, cockroaches, locusts and crickets.



Above: Neo Natal mice or Pinkies offer texture and variety. (Image, Jones.K.-2007)

Because these animals move quickly and erratically all 3x forms of hunting instincts (*See 6.1 Forms of Hunting*) are used, providing excellent enrichment for the Ghost Bats. (Pers.Obs. Jones.K.-2007).

It has been observed that bats will quickly catch any occasional stray cockroaches at Perth Zoo if found in the enclosure. (Richards.J. Perth Zoo memo-1998)

When moths can be sourced and supplied they may be let go at random within the enclosure providing another very natural form of feeding for the Ghost Bat. (Pers.Coms. Davies.P.-18-11-07)

7 Handling and Transport

7.1 Timing of Capture and Handling

When capturing and handling Ghost Bats the following points must be remembered:

ONLY KEEPERS INNOCULATED AGAINST LYSSAVIRUS AND TETANUS MUST ATTEMPT TO CAPTURE OR HANDLE THE GHOST BAT.

See 1. Introductions – Warnings and OH&S

Capture Plan:

- Must be made before any capture attempt.
- Be sure that you must capture the animal. Is there any other alternative that may be used as oppose to capture? The Ghost Bat is a timid animal and capture should be avoided if possible.
- Only ever attempt to capture, bag or transport 1x Ghost Bat at a time. Males particularly can inflict serious wounds to one another if a multiple catch up is attempted.



Above: Gloves must always be worn during a capture. No exceptions. (Image, Jones.K.-2007)

- Ensure that the receiving party is notified that they will be receiving the animal and that they are ready for the arrival.
- Have 2x staff members that are available for the duration of the capture. Keepers should communicate clearly with each other throughout the capture.
- Ensure all equipment has been checked and is safe and ready for use (including PPE). Gloves **are a must** (due to the OH&S risk of scratch or bite injury) even if dexterity is minimized and handling clumsier as a result. As risk must be managed, gloves are a necessity.
- Ensure that the supervising keeper has been notified of the capture well in advance.
- Do not wear any jewellery or objects that may injure the bats.
- If the capture is not working according to the capture plan that was created, or is taking many attempts or too long to do be ready to abort the capture and try again at another time notifying all parties that this is the case.

Time of Day:

Consider the time of day and light conditions. The animals are best captured during the coolest time of day and when they are quiet. This is best done when they are roosting in the early morning or later in the afternoon.

In a Nocturnal House this must be done early before the light cycle reverses to dark or in the evening when the lights are back on. If outdoors any time during the day is possible. Whether in a Nocturnal House or held outdoors the lights should be on or natural lighting available. This will be the middle of the night for the animals (due to the reversed cycle nocturnal animals are naturally accustomed to).

The animals will be tired, quiet and fairly docile making capture less challenging for the Keepers and less stressful for the animals. As Ghost Bats are prone to stress it must be cool. Do not capture in the heat as the bats will overheat.

Capture/handling should be as quick as possible to avoid undue stress on the bats.

(Pers.Cons. Jones.K.&Gleen.W.& Davies.P.-Oct-Nov, 2007. Jackson-2002)

Feeding Prior to Capture:

Although in other cases food may be used to attract an animal for easy capture, do not use food to lure the Ghost Bat as it will cause confusion within the enclosure and the bats will immediately take the food to roost.

Netting a bat with food in its mouth would be more difficult. It is also not a good form of husbandry to remove food immediately after presentation. The bats may refuse food thereafter and throw diet and feeding patterns into disarray.

In regards to using food for trapping: Although I have read that food traps may be used for capturing Megchiroptera, I would avoid the use of food to lure the Ghost Bat for the

reasons specified above. This is a more suitable method for capturing fruit eating bats. (Pers.Obs. Jones.K.-Jan-Nov 2007. Jackson-2002)

7.2 Catching Bags

Correct Equipment:

Although carnivorous and fairly large the Ghost Bat is easily panicked and injury is likely if they are handled incorrectly or with equipment not suited to the job. When capturing the Ghost Bat (or any other bat species) keepers must ensure that the correct equipment is used.

- Any catching net or bag that is used should have an approximate diameter of 45cm (to ensure easy flight into the net/bag) and a depth of 60cm. This will ensure easy movement and room to tie net/bag off.
- The catching net must have a padded hoop. This is vital to the bats safety as the animals may crash into the hoop or be accidentally struck with it. As wing bones and membranes are very fragile and easily prone to injury as is the nose-leaf a padded hoop is essential to a safe capture.
- The handle of the net may be made from aluminium, wood, bamboo or any lightweight material. Ensure the handle is long enough to reach to the top of the enclosure if required. The Keeper with the net must be able to use it comfortably. (Do not give a long handled net to a shorter person).
- Both capture and holding bags must be constructed from very fine weave netting, mesh or gauze. Mosquito net or calico is perfect. Any netting large enough for a bats claws to pass through must not be used as the bat is likely to catch its thumbs/claws in the net and break them. The netting should be so fine a weave that there are no visible 'holes' in the fabric.
- Capture nets/bags must be checked for any tears, holes, or frays. It is easy for a bat to become caught in a hole or tear or catch sharp claws on any frays.
- A rubber 'lip' may be placed around the inner edge of the net/hoop to further prevent animals from escaping the net once caught. (Jackson.-2002)
- Holding bags must be made of the same fabric (mosquito net/calico) and also must be free of holes or tears.
- The net or bag may be twisted and held with a firm grip, better still, twist and then tie the top off with a band or tie ensuring that no body parts are caught up in the twist or tie. (Pers.Coms. Jones.K. & Davies.P.-18-11-2007)

*Below: Correct catching net. Note the Fine mosquito netting and padded hoop.
(Image, Jones.K.-2007)*



*Above: This net should NOT BE USED. The hoop is not padded and the netting too large potentially causing serious injury to the animal.
(Image, Jones.K.-2007)*

A smaller, portable version of a harp trap may be used for free range/large enclosures. They have been successful in the capture of the Flying fox but will be of little use in most

small enclosures. Bats have been known to learn how to avoid them. This trap was developed by Tidemann and Loughland if further investigation is required.

An alternate method of a holding container would be to convert a round plastic bin (e.g. Kitchen tidy bin) by inserting 3mm wire mesh over the bottom of the bin and inverting so the animal has a place to hang. By covering the bottom the container will be secure and the mesh will create the ventilation required.

(Jackson.-2002)

7.3 Capture and Restraint Techniques

Keepers Required, Positions and How to Capture:

Confirm the Bat:

2 x Keepers are best used for any capture of any Ghost Bat. The identification of the correct bat can then be confirmed and maintained. It can be difficult for a single Keeper to maintain sight on a single bat should they be roosting together and all fly from the roost at once. If confusion is caused and the wrong animal caught this will cause a stressful situation to all concerned in the capture.

To Catch the Bat:

Animals should be captured before any public/visitor arrival to minimize FFF (Fright, Flight and Fight) impact on the animals. The curious visitors will naturally crowd at the window to watch the 'show' and the animals will have even less FFF distance. This will stress the animals greatly. (Pers.Comms. Jones.K.-Nov.-2007)

Once the correct bat is confirmed by both Keepers the first Keeper must maintain sight on the correct bat and block any available flight path they may try to use. Initially let any animals that will not be captured pass through to avoid confusion. The second Keeper will be ready with a catching net to hold in the only flight path available to the bat after it has been cornered. As it flies (usually back to the roost) the net should be raised and capture will be possible. Always use deliberate movements and be gentle and firm. All movements must be calculated.

Ghost Bats may be captured by hand if possible but as the bats could easily out manoeuvre a human with no assistance it is unlikely that a Keeper would be able to catch the bat in this way. As the bats will naturally fly to the highest point of the enclosure to escape capture it may prove far more stressful and dangerous for the animal (clumsy human hands) and the Keeper (tripping, falling or being bitten) than a net capture. The surface area of a net is also far greater than human hands making capture easier with a net. Regardless of the method of capture gloves must be worn at all times.

Check the Bat:

Once caught Keepers must check that the bat is not entangled within the net. Ensure that wings are inside the net and not injured in any way (wing membranes not torn, thumbs or claws not caught, joints or bones not broken).

Leave the bat in a catching net if it is large enough to secure with a firm twist and grip at the top or transfer the bat to a catching bag if required, twisted at the top with a firm grip used on the bag. The bat will naturally gravitate towards the top of the bag to maintain a grip. Let the bat get a hold to roost within the bag and then it can be carried in the net for a short time.

If housing with other species e.g. Bilby – *Macrotis lagotis* ensure that they are also safe during the capture. If possible ensure they are nesting away from the confusion of the capture e.g. in a hollow log. If this is not possible Keepers are to ensure they are not trodden on, hit with the net or injured or stressed.

- Don't worry if the capture is not successful on the first attempt.
- Don't wildly swing the net as it may cause injury to Keepers and animals but let the bat fly into the raised net of its own accord.
- Do not try to catch multiple bats in a single net 1x net = 1x bat as they would panic and/or fight within the net and injury to the bats would be almost unavoidable. (Pers.Cons. Jones.K. & Gleen.W. Sept-Oct.-2007)

Restrain the Bat:

Once captured the Ghost Bat will usually become docile and let the restraint take place with a minimum of fuss. Be firm but gentle and always be aware of the delicate wings.

- Remove the animal from the bag/net/container. This is best done with a towel. It will minimize stress to the bat and give it something to cling to and keep warm with.
- Two free hands will be required for the handler to properly restrain the bat. One hand will wrap around the body whilst the other hand will be used to restrain the head and minimize movement and prevent biting.
- It is best that the bat be held in an inverted position if possible. Holding the bat upright is a very unnatural position as bats live their lives upside down. Natural positions should always be used in restraint where possible.
- One wing should always be held against the body so that the bat cannot wildly flap, injuring the wings. The other wing can then be extended by taking the **wing joint** never the thumbs or tips of wing as they are easily broken.
- The head may be secured by placing the thumb and middle finger around the bats' jaws and placing a forefinger over the top of the head providing easy control of the head for examination.

- Cupping the bat gently but firmly in the palm of the hand will make restraint manageable. Wrap the bat in a towel when the head or face is being examined. It will keep the bat warm as well as minimizing movement from the rest of the body. (Pers.Comms. Jones.K. Nov.-2007and Jackson.-2002)
- The muscles in the feet will naturally try to cling so always have something for the bat to wrap its' feet around or it will cling to the Keeper. Clinging is natural and the bat has to physically think to make the muscles let go.
- Animals are to be examined as quickly as possible. Stress is a major concern with Ghost Bats and they can grow weak very quickly if not monitored carefully. Keeper must monitor the animal constantly.
- Do not scruff the animal to restrain it. Ghost Bats are not large enough to be scruffed and it would be inhumane due to the pain that could be avoided.

Behaviour of the Bats When Captured:

- The bats are likely to become stressed very quickly and as a result there may be a great commotion within the enclosure when the first catch is attempted.
- Scratching/biting is the most likely form of defense though seldom ever used.
- Always be aware of the head and claws when catching a Ghost Bat.
- Animals will audibly vocalize chirping, clicking and screeching.
- They are likely going to crash into walls and possibly the Keepers as they try to escape capture.
- Initially they **may** try to bite, flap wings wildly and try to kick to escape capture, (again, this is unlikely). (Jackson.-2002)
- Although the bat **may** initially display these behaviours if Keepers are not disturbed/stressed and act calmly, deliberately and gently (but firmly) the Ghost Bats will very quickly give up any fight and become subdued quite quickly. Once this occurs they are reasonably easy to handle. (Pers.Coms. Davies.P.-18-11-2007)



Above: This is an effective transport sign. Bold, clear and easy to read, with the name of the sending institution. (Image, Jones.K.-2007)

7.4 Weighing and Examination

When weighing/examining be sure to weigh and examine the bats as quickly as possible to minimize stress caused from capture and restraint. Keep the bat wrapped and warm where possible letting the feet protrude to grasp.

Ghost Bats may be weighed easily and safely in the capture bag to prevent double handling. Weight can be measured using hanging or electronic scales. Be sure that the scales have been tared for an accurate measurement. (Jackson.-2002 & Pers.Coms. Jones.K. Nov.-2007)

Observation must be a regular form of examination that Keepers use whenever the bat is fed or the enclosure cleaned. Everything on the following checklist should be observed if possible. Due to the size of Ghost Bat this can be quite difficult therefore a more detailed examination will be required whenever a Ghost bat is handled.

Any physical examination of Ghost Bat should always include:

Coat condition: Is the coat smooth and well groomed? No parasites.
Is coat the right colour?

Injuries: Are there any noticeable scratches, bites, chunks out of animal?
Any tears/fractures to wings?
Do feet grasp/climb properly?
Animals should be alert and bright. Animals should follow visual, noise and light cues.

Appetite: Are the animals leaving whole, uneaten carcasses regularly? As the Ghost Bat is unable to go into a state of torpor they don't fast and will continue to eat a regular diet throughout the year. Food should not be consistently left uneaten.

Face and Head: Is there any unusual discharge coming from the ears, eyes, nose, or mouth?
Do the eyes open and close normally?
Are there any tears/injuries to ears/noseleaf?

Anus: Should be clean and free of any waste particles as Ghost Bats are particularly well groomed bats.
Is there any discharge coming from the anus?

Faeces: Check consistency (should be small, cylindrical pellets) and number. There should be a concentration of guano under the roosting sites and preferred feeding sites.
See 8.2 Detailed Physical Examination.
(Jackson.2002. Pers.Coms. Jones.K. Nov.-2007)

7.5 Release

Once the bat is returned to the enclosure Keepers will need to release quickly to minimize stress or injury. Wild and captive releases are performed using the same methods. Keepers must be aware of both the health and safety of the animal to be released and the animals already existing within the enclosure.

Before Release:

- Ensure that the all of the animals have been well fed prior to release. This will help to raise energy levels of the animal being released and lessen the likely hood of aggressive behavior over food within the enclosure.
- Release should take place at the same time of day as a capture (Early morning or later in the afternoon.). As the animals are roosting, there will not be as much dispute about the new animal arriving. Ensure that all lighting, sound, and visual cues are minimized before release. It should be performed out of view of the public.
(See notes on capture)
- Check the enclosure and other animals within. The animals must be settled prior to a new animal arriving. If the enclosure is unsettled, wait prior to re-release until the animals are calm.
- Do not release the animal as food is being offered as this may provoke the animals to display aggressive behavior. Once these points are considered release may take place.

To Release the Bat:

- Place the bag/box/container onto the floor of the enclosure. The best position is near a textured wall that the animals can cling to and climb upon to become oriented to the enclosure and fly to a perch/roost.
- Carefully open the bag/container to release the animal.
- Self release from the bag/container should occur reasonably quickly, the animals flying out to find a secure roosting site.
- If the animals do not self release from the bag, a keeper may use a gloved hand to gently remove from the bag/container and place upon the floor (as *Ghost Bat* is able to take to flight from the floor) where they may sit for a moment before taking flight. The other alternative is to see if the animal will fly directly from the hand.
- Keepers must observe animal at this point, looking for signs of stress/physical injury that may have taken place during transport. Note wings, speed, and feet when attaching to perch. Do they all look normal?
- Continue observations overnight, as signs of shock may not always be apparent at first. Ensure that the animal is strong enough to be re-released successfully.
- In the first few hours if the animal will not leave the ground, looks lethargic, is very disoriented, or in any other way ill, re-capture must take place and/or veterinary advice sought immediately.
- If the animal is a female with a pup, time must be allowed to ensure the pup has a firm grip onto the mother before she takes flight, if not the pup will be left on the ground to die, or become prey itself. The mother will not retrieve the pup if it falls to ground.
- Ghost Bats can be aggressive towards one another so re-introduction must be observed carefully to ensure that the animals do not 'gang up' on the introduced animal. (Males have a particular tendency toward this behavior). If fighting occurs, the animal is to be re-captured and separated from the group until a solution can be actioned. (Pers Comms. K.Jones, Nov, 2007 Pers. Cons. K.Jones, P. Davies, W Gleen Sept 2007and Aust. Mammals. Biology and Captive Management)



Above: Towels can be used for handling the animal or using in place of substrate in travel containers.

(Image, Jones.K.-2007)



A pet pack nearly ready for temporary transport. It will need a grate or perch added to the roof. The towel will cover the front grate. (Image, Jones.K.-2007)

7.6 Transport Requirements

Transportation Checklist:

- Before individual transport, the animal should be separated from any other animals it is being housed with for a period of at least 24 hrs. (preferably 72 hrs.) in which time:
- The supervising Keeper of the department as well as the Curator of the institution and any other individuals have both allowed/confirmed the transport.
- The receiving institution will have received confirmation of transport and any other agencies required will have knowledge of the procedure (incl. Govt. depts. Animal agencies, Transport companies, etc.). The receiving institution should have by now made preparations for the arrival of the animal at their end. Make sure these arrangements are confirmed (date, time, etc. Be aware of any international time changes if a time zone is crossed).
- Be sure to check that any transport changes mid journey are organized well. The animal must be met on time at every leg of the journey and not left in a holding area indefinitely awaiting collection.
- Ensure that permission has been obtained for any transportation of food animals (chicks, mice, mealworms) as if they are required they will also need their own storage container, refrigeration and packing requirements. Notify the appropriate parties of this. Worst case scenario is that the transport is delayed and the animal has no food/water source.
- For overseas flights that are greater than 15 hrs. ensure that a Keeper is available to tend to the animal on any stopover periods. The keeper from the sending institution should be travelling with the animal.
- Arrange a keeper from another institution near the location of the stopover that the animal will be travelling and may need attention if there is any unexpected transport delays. Do not leave the management of the animal to anyone that is not a Keeper or anyone inexperienced with the animal.
- Standard/required veterinary checks must be carried out before the animal is dispatched. This is to ensure all parties, particularly the receiving institution are aware of the animals' health prior to shipping.
- All appropriate and correct paperwork must be attached to the outside of the box to ensure that it is readily accessible to anyone that may require it throughout the journey and still legible (not torn) at the destination.
- If travelling interstate/overseas Keepers must ensure that all quarantine restrictions are known and adhered to (including institutional and legislative).

- Correct signage must be on the box. Do not rely on non keeping staff to handle the animal carefully on its journey. Boxes have been Signage must be clear, easy to read, bright and bold. IT MUST STAND OUT. Signage will include: Live animal transport, fragile, this way up. Do not clearly indicate what animal is in the box, lest someone should feel the need to try and tamper with the box/animal. (Box lids screwed shut and opaque interiors help deter people from box tampering)
- The correct container/shipping requirements must be adhered to. See 4.3.1. Box Design for further details. (Pers. Comms. K. Jones and P. Davies. Nov. 2007)



Left: signage MUST be displayed upon all transport boxes. This box has a tamper proof lid that is screwed on for security. (Image, Jones.K.-2007)

Right: Ventilation holes surrounding the transport box provide adequate air flow for the animal. (Image, Jones.K.-2007)



7.6.1 Box Design

When found roosting in the wild, Ghost Bat generally keeps an individual roosting area approx 30 cm away from another animal/obstruction. Wing span must also be accounted for and wing movement possible. It is quite appropriate and often safer if the animal is restricted to being able to stretch only 1 x wing at a time within the box. If the animal has free movement it may flap wildly, potentially injuring the wings. Therefore, when designing a transport box for Ghost Bat a box of approx 45cm wide is required.

A fairly standard box/container dimension for Ghost Bat is 45cm-50cm square x 55-60cm deep.



Above: This pet pack is quite sufficient for short term travel, when furnished with a perch and towel. (Image, Jones.K.-2007)

Pet Packs:

Should the travel distance be short, (walking, driving) it is quite appropriate that the animal be secured in a plastic pet pack that can be secured tightly and locked. If using a pet pack ensure the following design elements are taken into consideration:

- Ventilation along both sides of pet pack, can be covered with opaque fabric to diffuse light. Ensure that air can still pass freely through the box.
- The box must be solid and able to absorb shock of jolting/packing without harming the animal.
- The animal must have room to be able to stretch 1 x wing at a time within the pack.
- There must be a perch for the animal to comfortably hang from. This can be either a wire grate that is attached to the top of the pet pack (bolted or cable tied very tightly so thumbs cannot get caught) or by a perch being suspended across the top of the container (leaving room for the feet to be able to grasp between the perch and the roof). If attaching grates ensure they are secure and cannot fall out or slide. Only smooth dowel is to be used for perches and no sharp objects are to go into the box due to risk of injury to bats.
- A towel is best laid around, up the sides of the pet pack, to absorb any shock incurred during transport. If using a towel, ensure you do not cover the vent holes.
- Never house adults in any type of styrofoam container (except for pups). *See 9.6 Housing* as it is likely to come away as the animal tries to grasp it. It could be ingested and is not solid enough to prevent any transport injury to the animal. (Aust. Mammals Biology and Captive Management. Pers. Cons. K. Jones and P. Davies Nov, 2007 Pers. Comms. K. Jones, Nov. 2007)



Left: Box interior. It can be clearly seen where the perch is going to be put above ventilation windows. The interior of the box is smooth and will be lined with fine gauze to dampen light and sound. Image, K. Jones.-2008

Box and Packing Requirements:

- Ventilation is an absolute priority when transporting. All transport boxes must have enough ventilation holes to let air circulate freely through/within the box. Any ventilation holes should be approx. 1cm square and covered with fine wire mesh.
- Ensure constant dim light is used in the travelling box is used. Both flickering, bright, and white lights should be avoided. Try to diffuse light if possible, red, blue and yellow works well.
- Environments that suffer temperate extremes must be avoided as the animals will be unable to thermoregulate effectively (especially without food/water or temperature control).
- Any loud noises/constant noise should be avoided where possible (for instance car radios, loud voices, vehicle engines). Ghost Bat has particularly sensitive hearing and this must be considered when travelling.
- Ghost Bat are very sensitive to these factors and any extremes will stress the animals considerably. To help minimize these problems line the walls of the transport box with thick, dark gauze to assist in controlling light, warmth and noise. When using a lining for any transport box ensure ventilation holes are not compromised in any way. An air current must still be able to pass through the box.
- The interior of the container must be padded to prevent crashing in the box, particularly whilst being loaded in/out of transport. Pad sides with toweling, covered, solid foam.
- Keepers must ensure that all transport containers have handles on the side of the box for 2 reasons. This makes carrying easier and ensures that if the containers are being stacked side by side, the ventilation holes will not be compromised. (Pers Comms. P. Davies 18-11-07. Aust. Mannals Biology and Captive Management and Pers. Comms. K. Jones, Nov. 2007))



Above: An ideal transport box. Solid and smooth it has ventilaion, handles and signage.box. A perch, towel and some gauze will complete the box. (Image, Jones.K.-2007)

7.6.2 Furnishings

Box furnishings for Ghost Bats are quite simple. Any materials within the box must be well secured. There must be no possibility of furniture/substrate sliding around and injuring the animal. No sharp objects (nails, screws, rough edges.) are to be placed in the box. Timber boxes must have a smooth interior with no splinters. Ghost Bats are unable to stand therefore must have a perch that can be suspended from the roof that they may easily suspend themselves from. Round, smooth dowel is best as animals cannot injure wings on it.

Substrate cannot move around and must be soft (towels are ideal). Pine bark, Cedar and other odiferous plants must not be used.

Do not put plants or branches into the box as sharp edges may cause injury to wings.

7.6.3 Water and Food

- When transporting Ghost Bats it is good husbandry to ensure that the animal has eaten well prior to transport. This is to ensure that the animal has enough energy to thermoregulate during the journey and does not become weak.
- Food/water should not be required for a journey that is less than approx 15 hrs. (if the animal has been fed before the journey)
- If the flight is going to be longer than 15 hrs. ensure that there is food/water travelling with the animal on route.
- Arrange a keeper from another institution near the location of the stopover that the animal will be travelling and may need attention if there is any unexpected transport delays. Do not leave the management of the animal to anyone that is not a Keeper or anyone inexperienced with the animal. (Pers. Comms. P. Davies 18-11-2007)
- Food and water are not to be travelling inside the cage with the animal for the duration. The animal must be tended properly as they rely on a carnivorous diet/animal food source that will spoil easily.
- Water must not be left inside the box as it may spill and wet the animal, alternatively, the animal may fall into an open dish of water and drown inside the box. Water bottles cannot be used either as the end would be too sharp to pack with the animal into such a confined space without causing injury.

7.6.4 Animals per Box

When transporting Ghost Bats regardless of the distance or type of transportation, never pack more than 1x animal per box/bag. The bats will show aggression towards each other within an enclosed space and fights will definitely ensue. The animals must have very definite individual roosting areas should they require it and individual packing is the only way to provide this.

Catching net/bag =	1 x animal only
Pet Pack=	1 x animal only
Transport box (short distances) =	1 x animal only
Transport box (short distances) =	1 x animal only

7.6.5 Timing of Transportation

Do not transport the animal in peak hour/busy traffic. Due to more extreme temperatures than the animal can cope with, it will become stressed if left in a vehicle in extreme conditions. All transport for Ghost Bat is best carried out very early in the morning or later in the day. Keepers are to be aware of any international datelines that are crossed and time changes that they may incur. Be sure to check that any transport changes mid journey are organized well. The animal must be met on time at every leg of the journey and not left in a holding area indefinitely awaiting collection.

7.6.6 Release from Box

See 4.3.2 Release. Release from box employs the same methods of release.

If travelling interstate/overseas Keepers must ensure that all quarantine restrictions are known and adhered to (including institutional and legislative).

(Pers. Cons. K. Jones, W. Gleen and P. Davies, Sept.-Oct. 2007. Aust. Mammals Biology and Captive Management. Pers. Comms. K. Jones, Nov. 2007)

8 Health Requirements

8.1 Daily Health Checks

If enclosure is in a nocturnal house a small spotlight may need to be used briefly for visual examination. Do not shine light directly on bats. Also check enclosure for signs of illness/injury, e.g. Blood on walls/furniture, bats fallen onto ground, abnormal guano. 'Flush' bats each day with a catch net to ensure claws/feet are not stuck in roosting sites. This also provides an opportunity to observe bats in motion and any abnormalities in the whole body. Daily checks may be done whilst cleaning or feeding bats.

Any physical examination of Ghost Bat should always include:

- ***Coat condition:*** Is the coat smooth and well groomed? Should not look 'scruffy'.
Is coat the right colour? (White to silver/blue grey)
It should not be dirty.
Are there any bald patches (Alopecia)?
Are there any parasites in the coat? Parasites are visible at close range.
- ***Injuries:*** Are there any noticeable scratches, bites, chunks out of the bats?
Is there any blood on bats/enclosure furnishings?
This may indicate injury.
Any tears/fractures to wings? Pertagium should be intact and bat able to fly easily.
Do feet grasp/climb properly? Bats should be able to roost easily.
Bats should be alert and bright. Bats should follow visual, noise and light cues.
- ***Appetite:*** Are the animals leaving whole, uneaten carcasses regularly? As the Ghost Bat is unable to go into a state of torpor, they do not fast and must continue to eat regularly to regulate body heat. Food should not be consistently left uneaten. Any fluctuations in diet must be monitored and recorded
- ***Face and Head:*** Is there any unusual discharge coming from the ears, eyes, nose/nose-leaf, or mouth? They should be free of discharge, dry and clean.
Do the eyes open/close normally? Eyes should be bright, alert and able to follow visual cues.
The face should be easy to see as the bats look down upon keepers in enclosure.
Are there any tears/injuries to ears or nose-leaf?
- ***Anus/Cloaca:*** Is there any discharge coming from the anus?
They should be clean and free of any waste particles as Ghost Bats are particularly well groomed animals. There should be no discharge.

- **Feaces:** Check consistency, feces should be small, cylindrical pellets, dark brown and dry. Concentrations of guano under the roosting sites/preferred feeding sites should be found. There should be no blood found in fecal matter.
- **Behavioural Changes:** Is there any sudden aggression from the bats? This may indicate illness or injury.
Are the bats suffering from lethargy? This may indicate illness or injury.
Are there any other abnormalities that need recording and/or treatment?

See Chapter 8.2 Detailed Physical Examination.
(Pers Comms. K.Jones, Nov, 2007. & Jackson.-2002)

8.2 Detailed Physical Examination

8.3.1 Chemical Restraint

Chemical restraint or immobilization of bats is rarely used unless required for surgery. Physical restraint is sufficient as bats become quiet and docile when in the hand (pers. Comms. K.Jones and P. Davies-March 2008) See 7.3 Capture and Restraint Techniques

Pre anesthetic fasting is not required for Ghost Bats.

Injectable anesthetic agents are rarely used for Ghost Bats although the following can be used: Ketamine (10- 20mg/kg) plus xylazine (2- 4 mg)
Ketamine hydrochloride (5-15 mg/kg)
Pentobarbital sodium (30-50 mg/kg) administered intraperitoneally.

Mask induction is the standard form of anesthetic delivery being rapid and smooth. (Vogelnest-1999) Isoflurane (4%) with oxygen or Halothane may be administered this way. The use of Halothane induces anesthesia but recovery can be prolonged.

Intubation with an endotracheal tube may be used and is straightforward in larger species. (Vogelnest-1999)

When chemically restraining the Ghost Bat take care to observe any excess salivation and/or catatonia. Acepromazine can assist in reducing catatonia. xxi

8.3.2 Physical Examination

- I.D on animal is confirmed. Also confirm sex of animal.
- A general physical is performed to monitor the following:
- Eyes, ears, teeth, body, wings, legs and coat are checked for condition and abnormality/injury. (See 8.1-Daily Health Checks) Eyes and ears should be clean and dry with no discharge, body should be checked for muscle tone and abdomen gently palpitated to score body (Palpitation may also confirm signs of pregnancy). Wings, legs and feet should move freely with no fractures or hole/tears in pertagium. Wear on teeth can indicate age of animal. General condition of teeth is observed. Coat should be smooth and well groomed with no parasites or waste stuck to coat.
- Bright, eyes and alert behavior/rapid movement and vocalizations should be observed when disturbed.
- Temperature
- Pulse rate – A resting heart rate of 235 beats per minute (at 35° C) is normal. (Animal Diversity Website)
- Respiratory rate – A mean breathing average of 55 breaths per minute is normal. (Animal Diversity Website)
- Measurements may be taken (particularly in young bats)/ Weight is measured (See 3.1.1 Mass and Body Measurements) Weight can be measured monthly for assessing trends (such as diet/feeding patterns and seasonal activity budget)
- Genitals are assessed in male bats. Testes should feel firm to touch. Size should be measured and recorded. Extrude penis and assess. (Jackson-2002)
- Feecal samples are regularly taken (Once every 6 months) to check for parasite loads (gastrointestinal helminths)
- Any treatments required are administered (including prophylactic treatments)
- All results are recorded before bat is released to enclosure (if healthy)xxii

8.4 Routine Treatments

Prophylactic worming/parasite treatments-Ivermectin or Fipronil (Frontline spot not spray) Once per month.

Feaces collected for feecal float every 6 months to check parasite loads. xxiii

8.5 **Known Health Problems**

Ghost Bats are self grooming animals that will keep themselves impeccably clean. They are a very robust and healthy captive species. There are a number of parasites that Ghost Bat may carry but when held in captivity under controlled conditions these numbers are negligible and they cause the bat no harm. Most known health problems occur of bats in wild populations. (pers.comms.K.Jones and P.Davies- March-2008)

The Ghost Bat is a possible asymptomatic vector (carries disease yet shows no signs) of three confirmed diseases within Australia. These diseases are rare in bats/animals that are managed in captivity, but the diseases are all zoonoses and affect other animals. There are confirmed deaths caused by these diseases in both humans and livestock. Risk of infection is low and usually found in Flying Foxes (Megachiroptera) but should not be ruled out of other bat populations. The controlled, indoor conditions of a nocturnal house can assist in preventing the spread of disease as it is a self contained environment where pest control is made easier (See Warnings and OH&S). More research must be undertaken in the study of diseases in both wild populations and captive bat collections.xxiv

Alopecia-non infectious disease:

- Aetiology: Stress/over grooming, ectoparasites or poor diet.
Signs: Fur loss, causing bald patches on animal. Pay particular attention to eye area.
Diagnoses: Visual/clinical signs.
Treatment: Support treatment: Mycex wash, reduce stress in animal, review diet.
Prevention: Daily visual checks. Ensure ample flight space, provide enrichment or remove interspecific species to reduce stress and over grooming. Do not house males together. Also look at light, noise and temperature and keep at optimum levels. Prophylactic parasite treatment. Nutrient load food (mice and insects) before feeding to animals to ensure a vitaminand mineral rich diet.

Trauma/Broken bones-non infectious disease:

- Aetiology:** Aggression and fighting, collisions or falls, mishandling (poor capture and restraint techniques). The severity of the break depends on the success of treatment. Severe breaks may render animal incapable of flight. Broken bones are rare.
- Signs:** Broken bones-look for: Lack of free movement of wings or legs (one wing may move more freely than another). Reluctance/difficulty moving/flying. Bones protruding from pertagium.
- Diagnoses:** Visual/clinical signs, radiography/x-ray.
- Treatment:** Support treatment-Confine animal to reduce movement/flight. Use Vetbond® (adhesive used for tissue repair) apply sparingly to dorsal surface of wing membrane in correct area on wing. Vetbond® can be used in place of splints to ‘glue’ wing to body to reduce movement. Check wing daily and reapply adhesive as required. Note: Avoid adhesive contact between hands and animals skin. Avoid applying adhesive to open wound or broken bone. Swab any open wound daily with Betadine® or Nolvasan® (10%) remembering to keep the bat dry. Apply an antiseptic ointment to prevent infection. Apply with an eyedropper. Look for signs of animals self mutilation (common when using Vetbond®). Surgical treatment-Compound fractures are generally pinned and often surgical items such as IV needles are used to pin small, fragile wing bones. Check for signs of self mutilation after treatment. An Elizabethan collar may be required to prevent this. If using an Elizabethan collar give Valium (diazepam) 0.5mg/ml for 2-3 days to reduce stress induced from collar.
- Prevention:** Separate males to prevent aggression. Check all grills/perching sites in enclosure for integrity to prevent falls. Do not provide branches more than 2 metres high to ensure free flight path and prevent falls. Remove dead/dry browse from enclosure that bats may become caught on. Correct capture handling technique to prevent injury due to mishandling. Correct design of enclosure
- Note:** Always use gauze to swab any excess liquid on bat until dry. Never leave bats wet. (Jackson-2002)

Torn ears/Pertagium (wing membranes)/Abrasions-non infectious disease:

- Aetiology:** Aggression/fighting, rough/abrasive surfaces with enclosure, dry, sharp browse, nails, wires or other protrusions in the enclosure. Healing and regaining flight is dependant on the severity of the tear/abrasion.
- Signs:** Visible holes or tears in the pertagium, ears, noseleaf. Also look for signs of abrasion on the wrists/fingers.
- Diagnosis:** Obvious visual and clinical signs.
- Treatment:** Treatment is similar to broken bones. Holes/tears may take weeks to months to heal. Some small tears/holes will not hinder flight and will heal without treatment. Holes generally heal more quickly than tears. Swab any larger open wound or abrasion daily with Betadine® or Nolvasan® (10%). Lotagen may also be used. Apply an antiseptic ointment to prevent infection using an eyedropper to apply. Vetbond® may be used to adhere larger tears in wings (use sparingly) Some larger tears that have extended through the edge of the wing may not heal if not re-adhered correctly. Ensure there is no necrotic tissue or inflammation/infection in wing. Check for signs of self mutilation after treatment. An Elizabethan collar may be required to prevent this. If using an Elizabethan collar give Valium (diazepan) 0.5mg/ml for 2-3 days to reduce stress induced from collar.
- Note:** Always use gauze to swab any excess liquid on bat until dry. Never leave bats wet. (Jackson-2002)
- Prevention:** House males separately. Correct enclosure design. Ensure that climbing/roosting sites are smooth (non abrasive) as bats will land on them to roost and feed. Remove old, dry browse and check regularly for any sharp obstructions in enclosure. Ensure bats have a free flight path around browse.

ABL (Australian Bat Lyssavirus) Other Names: Ballina virus-infectious disease: See Appendix 1.

- Aetiology:** Serotype #7 in the Rhabdovirus (rabies) family. ABL is the only rabies like virus found in Australia. It is a fatal zoonoses affecting both animals (bats) and humans. Transmission from bites, scratches and contamination of open wound with infected body fluids.
- Signs:** Rabies like symptoms including: Lethargy, weakness and loss of condition, inability to fly/navigate, paralysis in hindquarters in early stages. As virus progresses, confusion and sudden bursts of aggression, increased vocalization and dysphagia (inability to swallow) can be seen as nuerological pathways become infected

and break down. Frothing at the mouth, muscle spasms (back arching) and sudden death are seen in final stages.

- Diagnosis: Diagnoses is usually confirmed after death during Post Mortem. Similar tests to Rabies are conducted including histological examination and immunofluorescence antibody testing. Viral culture (brain), serology and immunoperoxidase staining are also diagnostic methods. Australian Animal Health Laboratories (Geelong) confirm infection with diagnostic testing on live bats.
- Treatment: No Treatment available. Immediately euthanase any infected/suspected infected bats. Have diagnostic testing done immediately.
- Prevention: Regular testing for the disease is the only prevention. Euthanasia of infected animals to prevent further infection. Thoroughly disinfect any infected enclosure with strong detergents/disinfectants. Handlers are at potential risk and should take due precautions. *See 1-Introduction, Warnings and OH&S*

Hendra Virus-Other Names: Bat paramyxovirus #1, Equine morbillivirus (in horses):

Generally found in Flying Fox populations, but cannot be ruled out in other bat species. More research required about this disease in bats. Is not considered highly contagious.

- Aetiology: Paramyxovirus first found in horses. Flying Foxes a probable host. Extent unknown in *Ghost Bat*
- Signs: Asymptomatic. No signs have been detected in bats that carry the disease. Potentially fatal to horses and humans.
- Diagnosis: As with ABL, Hendra virus can only be diagnosed during Post mortem via histological examination and immunofluorescence test.
- Treatment: Unknown. Vaccine development continues, to inoculate cats, horses and Flying Foxes.
- Prevention: Regular testing if captive collection and quarantine of infected animals. (Again aimed at Flying Foxes)

Menange virus: Bat paramyxovirus # 2:

Generally found in Flying Fox populations, but cannot be ruled out in other bat species. More research required about this disease in bats.

- Aetiology: Paramyxovirus. Cause unknown in bat populations, although some species of bat have tested positive to Menenge virus in NSW and Flying Foxes in Nth QLD. Extent unknown in found in horses. Flying Foxes a probable host. Extent unknown in *Ghost Bat*
- Signs: Currently unknown
- Diagnosis: Blood testing to show antibodies to the virus.
- Treatment: Currently unknown.
- Prevention: Currently unknown.

Ectoparasites-species and host specific (will stay on one individual only):

- Aetiology: Can include: fleas, mites, lice and ticks, although most bat parasites are species (host) specific. Most common parasite is the bat fly (nycteriibid and streblids flies) which live their life cycle on a single bat. Nycteriibid and streblids flies are potential vectors of other diseases. Mites may cause alopecia, poor coat condition and irritation. Generally parasites are considered harmless to bats and low in numbers in a captive situation.
- Signs: Visual signs. Can be easily seen in the bats pale coat.
- Diagnosis: Visual/clinical signs. Skin scrapings under microscopic examination.
- Treatment: Flea powder, Pyrethrin sprays, Frontline® (spot on-not spray) (fipronil) applied topically (back of neck, 1x small drop per bat). Ivermectin may also be used.
- Prevention: Daily visual check of all animals. Separation of infected animals. Prophylactic treatment using Frontline® (as above) or Ivermectin once a month. Enclosures can be treated using Low irritant Pea Beau or Mortein. Regularly clean and disinfect enclosure. Treat any new animals before introducing to enclosure/other bats. It is unlikely that bats will suffer from parasitic infection in a clean captive environment. Infected bats usually show few signs after a few weeks in captivity as parasite numbers drop.

Endoparasitic Worms:

Aetiology:	Cause few/no known health problems in bats. Endoparasites can include nematodes and cestodes. Mostly found in captive Flying Fox populations. Unlikely that harmful outbreaks of intestinal worms will occur in a captive population of <i>Ghost Bat</i>
Signs:	Clinical signs. Visual signs may be seen in fecal matter
Diagnosis:	Faecal floatation is used to diagnose gastrointestinal helminths.
Treatment:	See prevention. Treatment and prevention are the same.
Prevention:	Clean/disinfect enclosure and furniture regularly. <i>See 5.1 Hygiene and Cleaning.</i> Ensure that food source is known to be free of any parasitic disease prior to ingestion. Maintain regular pest control regime to prevent bats from ingesting infected food (pest cockroaches, flies, slugs, etc.) Worm all bats on arrival (before introduction to enclosure/other animals). Prophylactic treatment can include: Paste: Pyrantel pamoate-115mg/g (Pfizer) Applied as a paste-1ml/kg to the fur that is licked off when grooming. Injection: Praziquantel (Droncit® - Bayer) as an injectable cesticide can be administered by intramuscular injection (0.2 ml). Fenbendazole- 100mg/ml at 10 mg (Panacur 100®) may also be used successfully.

8.6 Quarantine Requirements

Animals will be required to undergo a quarantine period of 30 days. After import (onshore)

Paperwork for Quarantine includes:

- Veterinary paperwork outlining sex, age, diet, history, test results on last fecal examinations, physical examinations, current vaccinations, current treatments
- Contact details from dispatching institution.
- IATA guidelines and standards for transportation must be met. *See Appendices 6 – IATA Guidelines.*
- A cage card should be easily seen on the enclosure and contain all information required for the bats in care (classification, number of animals, sex, age, feeding regime, veterinary notes and husbandry notes).

9. Behaviour

9.1 Activity

Physical:

Shy, secretive and easily disturbed the Ghost Bat is nocturnal, carnivorous and the largest bat in the order microchiroptera. Endemic to Australia, the Ghost Bat is also the only carnivorous bat found in Australia. Flight is the only locomotion used by the Ghost Bat. Evolutionary changes have streamlined bats to become the only mammals with true and superb flight capabilities. Although some species of bat are able to crawl along the ground, the Ghost Bat is unable to walk or crawl due to the back legs being unable to support the bat for walking. They are so discreet and silent that humans have occupied mines and caves with no awareness that they were surrounded by a colony of the Ghost Bat. (Churchill. S.-1998)

Unlike other bats Ghost Bats are unable to enter torpor seasonally as they are endothermic: absorbing heat from outside sources, with core body temperature remaining relatively low. As result Ghost Bats must have an available heat/food source to maintain body temperature. Ghost Bats occupy a large hunting range. Should food become scarce Ghost Bats will move to warmer areas in search of a food source, failing this, Ghost Bats are able to enter a short daily hibernation period to overcome a food shortage. Physically active flying, grooming, vocalizing, socializing, hunting and consuming prey Ghost Bats can be found in colonies from 1- 1500 bats in the wild. Apart from being nocturnal, little is known about the wild time budgets for Ghost Bats. (Jackson. S.M.-2002)

Location/environment:

In the wild, the Ghost Bat covers a wide but patchy distribution across northern Australian regions including: Pilbara region (W.A.) Arnhem Land/Kimberley region (N.T.) and Rockhampton/Mt Etna region (QLD) (Gleen.W. et al-1997) Preferred habitat includes caves, mines and rock fissures in arid, desert conditions, savannah/spinifex grasslands through to rainforest habitat. *See 3.2 Distribution and Habitat.*

In captivity Ghost Bats are usually found within nocturnal houses with reverse cycle lighting to ensure maximize public viewing opportunity. *See Chapter 4-Housing Requirements.*

Dietary:

Ghost Bats are known to swoop on prey, taking birds and other species of bat from behind whilst in flight, or snatching whilst on tree branches. (Encyclopedia of Australian Wildlife-1997) The Ghost Bat swoops upon the prey, catching it up in its powerful claws and enveloping the prey in its wings. The prey will then be killed with powerful bites around the head. After making the kill, the Ghost Bat will then return to a temporary feeding roost, will eat its prey, dropping larger unpalatable pieces to the ground (generally heads and feet). (Straughn. R (Ed.)-2002)

Radio tracking studies have shown they forage 2 km from roost cave and use the same forage areas, (about 60 ha ea night). Within this area the Ghost Bat will hunt from tree roosts, moving to a new vantage point every 15 minutes. Foraging areas are not exclusive and up to 20 bats have overlapping ranges. Wild feeding roosts will be found by the heavy concentration of guano found under feeding roosts.

Ghost Bats use the following forms of hunting behaviour:

- Gleaning/ hunting on the wing. This includes skimming insects from cave walls and snatching prey from behind in midair (including other bats).
- Passive sit and wait hunting using eyesight and passive hearing.
- Active hunting with echolocation, (generally inaudible to the human ear)
- ‘Whispering’ echolocation, is used to avoid alerting potential prey. Whispering echolocation means that echolocation is ‘turned off’ intermittently (a form of ‘silent running’) to aid in a more successful hunt. (Churchill.S.-1998) *See Chapter 6-Feeding Requirements*

Human interaction/Conditioning:

Staff should try to minimize time spent within enclosure as Ghost bats are extremely sensitive to their environment and excessive noise/action in the enclosure can cause stress.

Since Ghost Bats cannot be handled by non inoculated staff any conditioning requiring handling is difficult and not recommended due to stress and potential zoonoses.

Ghost Bats will become conditioned to regular husbandry routines, sounds and actions around them. They are generally active during feeding times. Try not to encourage anticipation for food by changing daily feeding times and using regular activity feeds.

Ghost Bats will observe humans within the enclosure.

They cannot be conditioned to be caught, but if capture is carried out correctly the Ghost Bat is easy to handle, usually becoming quite placid when restrained. (Pers. Obs. K.Jones-2007/2008)

Sensory stimulation: See 9.7-Behavioural Enrichment

Include the following forms:

- Locomotive-how the animal moves
- Olfactory-smells
- Tactile-touch
- Visual-sight
- Auditory-sounds/listening
- Taste-what the animal will consume

The enclosure and environment should be created to provide for all forms of sensory stimulation. Consider UMWELT. (Behavioural Enrichment Table-TAFE NSW-WSI-2008)

9.2 Social Behaviour

Generally, Ghost Bats is a social animal that can be found in colonies of both sexes, usually numbering between 1- 400 although colonies of up to 1500 have been recorded in the wild. Ghost Bats rely on colonies to provide warmth and safety when roosting. They hunt independently but return to a temporary feeding roost that is occupied by many animals at one time. Aggression is observed in males within close proximity. Social structure is polyandrous with males siring offspring from multiple females. Males and females occupy separate roosts after mating (when females become pregnant and form maternity roosts or shift young to 'creche' caves). Females hang in warmest part of caves during pregnancy. Whole colony regroups in early winter and disperses in July. (Churchill.S.-1998)

9.3 Reproductive Behaviour

- Ghost Bats are viviparous with internal fertilization, development and nourishment occurring in the females' body. (Online: Animal Diversity Website, 2007)
- Sexually maturity occurs at approx 1 year old with males of the species sometimes reaching sexual maturity at 2 years of age.
- Social structure is poloyandrous with males siring offspring from multiple females.
- Mating occurs from July to August with young being born between September and November, after a gestation period of 3 months. Have been known to give birth in captivity in January, April and July therefore breeding out of season must not be excluded in captivity. (Gleen.W. 1997)

- Ghost Bats are dioecious: the sexes separate into gender specific colonies after mating, with females forming a maternity group throughout the winter months. They will not separate from each other until after the young have been weaned. Weaning occurs after 4 weeks suckling on milk produced from teat/nipple in armpit. Females have a set of ‘false teats’ that can be found within the pubic region. These teats do not produce milk. Their function is to give the pup easier grip when clinging to the mother during flight. (Online: Animal Diversity Website, 2007) Females hunt for pups after weaning returning to colony roost with food. When old enough, (after 7 weeks), pups will hunt with mothers to learn hunting behaviour.
- Young fly independently after 7 weeks after weaning in March following births in November.
- Ghost Bats have a reasonably strong parental investment in offspring, with females undertaking parental care, young are altricial, (relatively underdeveloped, cannot care for self or locomote separately).

Captive Breeding Notes:

- A single male may be introduced to females during captive breeding seasons as males are known to show aggression to others during breeding season.
- Breeding out of season must not be excluded in captivity. (Gleen.W.-1997)
- When breeding, or if pregnancy is suspected increase activity feeds and food in general. (Taronga Zoo diet).
- Ensure that any males are removed from enclosure if pregnancy is suspected due to aggression and wild breeding behavior.
- Ensure that any interspecific species are removed from enclosure if pregnancy is suspected as it may cause stress/risk to pregnant females and pups.
- Pregnancy can be detected by gently palpating the abdomen of the bat. Increase in size and weight is also a sign of possible sign of pregnancy.
- Wendy Gleen, (Former Studbook keeper, Keeper Taronga Zoo), Sue Churchill, and Jessica Worthington – Wilmer, (DNA Analyst), have all carried out research into *Macroderma Gigast* including population analysis and interim recommendations for captive management of *Macroderma Gigas*.

NOTE: “The last pups born at Taronga died. It seemed that “bashing “was the cause, possibly when bats flew down to ground, Bilbies may have attacked them. We think the Bilbies may have had something to do with it as they are opportunistic creatures. In the future the Bilbies will be removed from enclosure along with male Ghost Bat to ensure a successful maternity colony may be established.” (quote, Davies.P. pers. Comms. Dec-2007)

9.4 Bathing

Do not bathe Ghost Bats.

Whilst the enclosure may be regularly misted to maintain humidity levels and optimum environmental conditions the animals themselves should not be wet at any time. Ghost Bats (and bats in general) are very clean animals and will regularly groom themselves to maintain condition and as part of social interaction throughout the day.

If a Ghost Bat should become wet there is a risk that they could contract hypothermia.

9.5 Behavioural Problems

There are few behavioural problems observed in Ghost Bats and any problems noted are usually easy to manage if husbandry is reviewed as problems are usually stress related.

Aggression:

Is frequently seen in males if housed together. Aggression is sometimes observed in males towards females (particularly during the breeding season). Males usually become aggressive towards older /weaker females. This may be due to these specimens not being viable breeding stock.

Aggression from both sexes can be observed during feeding due to lack of feeding stations. 1x feeding station per 2x animals should overcome any aggression over food. There is little to no aggression towards keepers, with bats becoming surprisingly docile and quiet once captured and in the hand. (Jackson 2002)

Stereotypic Behaviour:

Overgrooming - May be observed in animals that have a lack of flight space/enrichment. In severe cases this may lead to Alopecia and further complications.

Lack of movement – Constant hanging may be due to lack of enclosure space, lack of enrichment and/or injury. Bats should move, fly and groom regularly. Ensure bats can fly and are feet/claws are not caught in wire. (Flush bats each day with a net during rounds or check movement when feeding)

Refusal of food:

Monitor food consumption of *Ghost Bat* (daily when cleaning enclosure). The table below shows potential problems and actions associated with food.

POTENTIAL PROBLEM WITH FOOD	POSSIBLE ACTION TO TAKE
FOOD ITEMS BEING TOO LARGE TO GRASP AND EAT	REDUCE FOOD SIZE AND NOTE ANY CHANGES
FOOD IS NOT FRESH/INSECTS HAVE BEEN FROZEN BEFORE FEEDING	CHECK QUALITY AND FRESHNESS PRIOR TO FEEDING. DO NOT USE FROZEN INSECTS. BATS WILL NOT EAT THEM AND THEY DECAY QUICKLY. COULD MAKE BATS SICK
ANIMALS ARE BEING OVERFED	OBSERVE TIME OF YEAR AND CONDITIONS. PERHAPS REDUCE FOOD PORTIONS
ANIMALS ARE SIMPLY NOT HUNGRY	FEED AS PER NORMAL ROUTINE AND NOTE ANY FURTHER CHANGES

(Pers. Obs./Comms. K.Jones-2007/2008)

9.6 Signs of Stress

Care must be taken when working with Ghost Bats as they are easily disturbed and very sensitive to their surroundings. Noise and human contact must be kept to a minimum within the enclosures (max 5-10 mins. at any one time). Signs of stress are listed below and immediate action should be taken to remedy any stressful situation.

- Overgrooming – Can lead to Alopecia and other secondary complications
- Lack of appetite/refusal of food
- Weight loss-May be due to lack of appetite /refusal of food
- Extreme vocalizations
- General poor condition/grizzled coat- May mean animals are not grooming properly.
- Inactivity/lack of movement/constant roosting-Ensure there is adequate flight space for bats. Ensure they are not stuck in wire grills or roosts. *See Chapter 8-Health Requirements 9.5-Behavioural Problems 9.7-Behavioural Enrichment.* (Jackson.S.M.-2002)

9.7 Behavioural Enrichment

Light levels, temperature and humidity may determine activity levels (including feeding and breeding behaviour).

Enrichment is a necessity for successful captive management of Ghost Bats as they are generally found in Nocturnal houses where light is minimal. Animals must move and display natural, active behaviour to be an interesting display. Without enrichment, animals will be likely to remain within roosting areas /visual barriers or hang high out of public display.

Behavioural enrichment can be achieved in many ways. One enrichment activity should be applied each day for the animals to provide the following:

- Simulation of a wild environment which in turn encourages the following:
- Encourage instinctive behaviour in the animals
- To provide sensory stimulus for the animals (hunting, physical, dietary, exploratory, social)
- To create activity and movement, creating an active display for the public
- To create new and varied activities each day for the animals

When providing enrichment, consider UMWELT (what is important in the animals' world)

The table below can be used to provide enrichment activities for the Ghost Bat.

Enrichment devices/Activities	Advantages/Enrichment value	Disadvantages/Cautions
Flat rocks – <ul style="list-style-type: none"> • Place food upon rocks. • Move rocks around enclosure regularly • Mock rock is a great choice • If using real rock use smaller rocks for ease of handling 	<ul style="list-style-type: none"> • Provides visual interest for animals and public • Encourages hunting instinct • Mock rock is easy to clean (hygienic) and lightweight (easy to move around enclosure) • A quick, easy way to provide enrichment during feeding times 	<ul style="list-style-type: none"> • Ensure rock is smooth and has no sharp edges or points that can damage feet, claws and pertagium (wing membrane) • Rock will need regular disinfection to maintain hygiene • Remember OHS when moving large rocks
Offer variation in food – <ul style="list-style-type: none"> • Pinkies or weaners instead of adult mice • Activity feeds (see below) 	<ul style="list-style-type: none"> • Provides different textures, shapes and sizes for sensory stimulus • A quick, easy way to provide enrichment during feeding times 	<ul style="list-style-type: none"> • Nil
Activity feeds- <ul style="list-style-type: none"> • Scatter feed mealworms/cockroaches 	<ul style="list-style-type: none"> • Encourages hunting instinct • Encourages exercise and 	<ul style="list-style-type: none"> • Cleaning will need to be thorough to remove dead insects

<ul style="list-style-type: none"> in enclosure Place locusts/crickets/moths on cave walls Place a cricket feeder in enclosure to stagger the release of live insect food throughout the day 	<p>movement around enclosure</p> <ul style="list-style-type: none"> Provides active visual display Offers variation in diet Offers bats a continuous food supply throughout the day Crickets, locusts provide auditory stimulation 	<ul style="list-style-type: none"> Offer extra insects if housed with Bilbies as there may be competition for food Ensure there is at least one insect for each animal to minimize aggression Do not use frozen insects-bats will refuse them. Decay too quickly, bat may become sick.
<p>Gorge and starve days –</p> <ul style="list-style-type: none"> Increase food portions to all animals (mice and chicks) Increase activity feeds (see above) Ensure all bats have consumed more than usual Next day do not feed bats 	<ul style="list-style-type: none"> Simulates natural environment and feeding behaviour Breaks normal feeding routine Can trigger breeding behaviour 	<ul style="list-style-type: none"> Bats must be carefully monitored to ensure they are not hungry Enough food must be consumed on gorge days prior to a starve day Heat must be monitored to ensure animals temp. is consistent when not hunting/eating (Endothermic)
<p>Vary feeding times –</p> <ul style="list-style-type: none"> Feed main meals twice a day Activity feed between main meals Feed a.m. and p.m. with an activity feed in the middle of the day 	<ul style="list-style-type: none"> Simulates natural environment and feeding behaviour Breaks normal feeding routine Spot cleaning can be done throughout the day Not all animals are hungry at the same time. Gives all bats a chance to feed at leisure 	<ul style="list-style-type: none"> Multiple feeds take more time than a single feed Ensure that there are multiple feed platforms to minimize aggression Increases disturbance to bats. Must be done with minimal disruption Try not to be feeding out in enclosure for more than 5 mins. at any one time
<p>Browse –</p> <ul style="list-style-type: none"> Ideally, species should be native (local to wild populations if possible) Soft shrubbery is recommended (less likely to injure animals) Offer browse of different heights (soft tussocks and larger, taller branches- under 2 metres to leave flight path above) Species that can be used successfully include: Grasses/tussocks Banksia Lillypilly 	<ul style="list-style-type: none"> Creates a natural environment Provides additional perching areas Provides shelter for bats Provides varied microclimates Provides visual barriers for animals Provides good areas for activity feeds Provides adequate climbing opportunities of different height with branches/apparatus from ground to climb should they fall down Branches of different 	<ul style="list-style-type: none"> Ensure browse is smooth and has no sharp edges or points that can damage feet, claws and pertagium (wing membrane) Browse will need regular changing. All dried browse must be removed (see above) Ensure that plants are not toxic Shrubbery/furniture must be matched to suit the theme of the enclosure. Do not mix environments. E.g. Arid only, not Arid mixed with Rainforest)

<ul style="list-style-type: none"> • Lomandra • Westringea • Ptosperum • Acacia • Eucalypt. 	<p>height offer multiple areas to hide, roost, hunt and fly around (navigate)</p>	<ul style="list-style-type: none"> • Do not place browse near any heat sources, including lamps, (fire danger) (Davies-2007)
<p>Large logs –</p> <ul style="list-style-type: none"> • Can be used in the same manner as flat rocks (see flat rocks) 	<ul style="list-style-type: none"> • Provides interesting public display • Offers another opportunity for hunting instincts 	<ul style="list-style-type: none"> • Ensure logs are smooth and have no sharp edges or points that can damage feet, claws and pertagium (wing membrane) • Regular disinfecting required when feeding onto logs to prevent disease Can be heavy to move (consider OH&S)
<p>Simulated caves /minshafts–</p> <ul style="list-style-type: none"> • Mock rock is a good choice, lightweight and easy to clean • Timber can be used for surrounds if creating a mock mineshaft 	<ul style="list-style-type: none"> • Simulates natural environment • Can create a visual barrier if required • Creates an interesting public display • Gives animals multiple areas/levels to hang, perch and roost 	<ul style="list-style-type: none"> • Walls roosts must be non - abrasive to avoid injury to animal and to withstand regular cleaning • Do not use treated timber (it may be toxic to animals)
<p>Substrate/sand –</p> <ul style="list-style-type: none"> • Red sand is found in wild regions and recommended if it can be sourced. Sydney sand and compacted dolaride also work well • Heat pad can be buried under substrate for extra warmth 	<ul style="list-style-type: none"> • Sand simulates natural habitat • Sand is easy to clean with a shovel and sieve (hygienic) • Provides a soft area to land when animals hunt on ground 	<ul style="list-style-type: none"> • Aromatic wood (pine, cedar chips) should not be used/stirred up due to respiratory distress in animals (Jackson-2002) • Substrate will need changing every few months
<p>Water –</p> <ul style="list-style-type: none"> • Hoses on a fine mist should be used • Briefly spray enclosures to raise humidity and temperature for bats • Small pools can be used in the enclosure with caution • Monitor heat and humidity in enclosure when using water (mist or pool) 	<ul style="list-style-type: none"> • Maintains temperature/humidity in enclosure • Keeps browse fresh/longer lasting • Simulates natural rainfall/environment • Creates climate changes for animals 	<ul style="list-style-type: none"> • Do not wet bats due to risk of Hypothermia (Jackson-2002) • Do not spray bats directly • Control spray duration to avoid great temperature fluctuations • Ensure pools are plumbed in and cleaned out properly to prevent stagnation (especially discarded food) Consider hygiene (Davies-2008) • Provide pebbles/rocks in bottom for bats to climb

		out if they fall in
<p>Nestboxes/roosts – <i>see section 4.8-Nestboxes or Bedding Material</i></p> <ul style="list-style-type: none"> • Can be boxes or cloth • Hang in high and low positions for public viewing and behavioural interest 	<ul style="list-style-type: none"> • Provides visual barrier • Provides warmth and shelter • Provides a resting place away from public view 	<ul style="list-style-type: none"> • Ensure there are no tears or fraying that animals can become tangled in • Ensure there are multiple roosts to minimize aggression
<p>Visual barriers –</p> <ul style="list-style-type: none"> • Can be nestboxes • Roosting areas (including cloth roosts) • Browse • Walls/(cave walls) • Other furniture 	<ul style="list-style-type: none"> • Provides safety, shelter, rest and warmth for animals • Provides somewhere comfortable for animals to socialize • Bats generally roost high in the enclosure, therefore minimal visual barriers are required 	<ul style="list-style-type: none"> • Ensure that barriers cannot cause bats any injury • Ensure that public viewing is not restricted by visual barriers • Ensure adequate flight path is maintained.
<p>Sensory stimulus –</p> <ul style="list-style-type: none"> • <u>Everything</u> in the enclosure should be geared around behavioural enrichment for the animal • Consider UNWELT and following stimulus: tactile, visual, auditory, olfactory, hunting, social, locomotive, conditioning 	<ul style="list-style-type: none"> • Crickets and locusts provide auditory stimulation • Different textures in enclosure (rocks, sand, etc) to provide tactile stimulation • Ample flight room to provide physical stimulation (exercise) • Use faeces from other species for olfactory stimulation 	<ul style="list-style-type: none"> • Nil
<p>Interspecific Housing –</p> <ul style="list-style-type: none"> • House with other species including: • Bilby • Ring Tailed Possum • Potoroo • Bettong 	<ul style="list-style-type: none"> • Offers extra social stimulation for animals • Creates an interesting display for public • Increases general movement/action in enclosure 	<ul style="list-style-type: none"> • Do not overcrowd enclosure • More cleaning will be required • May hinder breeding activity of bats • Bats will rarely come to ground to hunt
<p>Smells/Olfactory Stimulation –</p> <ul style="list-style-type: none"> • Use other animal faeces from different animals and scatter throughout enclosure • Lay scent trails around enclosure using food 	<ul style="list-style-type: none"> • Provides olfactory stimulation • Animals may become more active 	<ul style="list-style-type: none"> • Ensure the faeces contains no diseases (only collect from healthy animals) • More cleaning/disinfection will be required
<p>Ample Flight Space</p> <ul style="list-style-type: none"> • Check EAPA for <u>minimum</u> enclosure requirements • Provide a high roof for ease of flight/multi level perching 	<ul style="list-style-type: none"> • Provides opportunities for flight and natural locomotion • Provides exercise opportunities • Keeps animals in healthy condition 	<ul style="list-style-type: none"> • Ensure there are no obstacles/sharp items that could cause injury to bats • Enclosure may need to be larger if housing large groups or multiple

	<ul style="list-style-type: none"> • Offers increased public viewing/action in enclosure 	species
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(Pers. Obs./Comms. K.Jones-2007/2008) (Jackson. S.M.-2002)

9.8 *Introductions and Removals*

Introductions of new bats or reintroductions of familiar bats can be achieved with minimal disturbance, aggression or changes in behaviour. Keepers must note any changes in behaviour and take action if necessary. The following methods can be used to make introduction stress minimal.

- Introduce primary reinforcers that will keep the bats interested in other activities.
- Introduce into enclosure early in the morning to give the bats maximum time to adjust. Gives keepers all day to note any changes.
- Rearrange furniture in enclosure to provide new/different stimulus to occupy animals and minimize aggression.
- Unscheduled feed to occupy animals (food will be the primary reinforcer, minimizing aggression)
- Provide a new enclosure so animals can organize a new hierarchy.
- Hang bat in a cage close to the enclosure to become accustomed to one another.
- Talcum powder to confuse scents of animals.

Removals: Remove females in groups to minimize stress. Only remove a single female if necessary (veterinary, quarantine etc.) Males can be removed individually. Provide roost site immediately.

9.9 *Intraspecific Compatibility*

There are social differences between male and female Ghost Bats. In captivity, females should be housed in groups numbering 2-3+ where possible to encourage social activity. Males are known to show aggression towards one another and should not be housed together. A single male may be introduced to females with little problems, although signs of aggression from male to female must be watched for. Below is a table outlining how a Ghost Bat may be housed in captivity:

SEX OF SPECIES	HOUSED SEPARATELY	HOUSED TOGETHER	DURING BREEDING
FEMALE	NOT RECOMMENDED	2+ DEPENDING ON SPACE	2+ DEPENDING ON SPACE
MALE	RECOMMENDED	NOT RECOMMENDED	1 ONLY WITH FEMALES

Note: The removal of any older, weaker females during breeding season may be a precaution against aggression from males. (Pers. Obs./Comms. K.Jones.-2007/2008)

9.10 Interspecific Compatibility

The Ghost Bat may be suitably matched with the Bilby (*Macrotis lagotis*). These species are commonly housed together in captivity as in they occupy the same areas in the wild and create a very attractive display together. Observe the following when housing these species together.

PROBLEMS WHEN HOUSED WITH BILBY	POSSIBLE ACTIONS TO TAKE
BILBY WILL FORAGE FOOD SCRAPS FROM ENCLOSURE FLOOR, POSSIBLE DISEASE RISK. BILBIES BECOME OVERWEIGHT	REGULAR TWICE DAILY CLEANING OF ANY DISCARDED FOOD. REMOVE DISCARDS EACH TIME FOOD IS FED OUT.
BILBIES CAN BE AGGRESSIVE TOWARDS BATS DURING BAT BREEDING SEASON. FALLEN PUPS CAN BECOME PREY OF THE BILBY. GHOST BAT MAY NOT BREED WITH OTHER SPECIES IN ENCLOSURE	REMOVE BILBIES FROM ENCLOSURE BEFORE INTRODUCING MALE GHOST BAT FOR BREEDING.
ENCLOSURES WILL BECOME SOILED MORE QUICKLY	ENCLOSURES WILL REQUIRE MORE REGULAR CLEANING

There is a possibility of housing species such as Bettong, Potoroo, Ring Tailed Possum but possible behavioural problems will need monitoring (aggression, breeding problems, changes in feeding patterns etc.)

Known diseases between species may include ectoparasites but is minimal in captive management species. (Pers.Cons. K.Jones & P.Davies-2007)

9.11 Suitability to Captivity

The Ghost Bat is a well suited addition to a captive collection. In addition to being a spectacular display for public viewing, the Ghost Bat is:

- Easy to feed (food is easily sourced)
- Easy to manage with low maintenance husbandry and cleaning.
- Very active (given correct conditions and husbandry)
- A robust and healthy species with a captive lifespan of 18+ years.
- Species has both interspecific and intraspecific compatibility.

For these reasons, the Ghost Bat is highly recommended as a captive managed species. (Jackson.S.M.-2002)

10 *Breeding*

The Ghost Bat is not related to rodents or birds as is commonly thought. The Ghost Bat is a placental mammal and more closely related to primates than either rodents or birds. Pups are born fully formed and suckle milk from the female.

Ghost Bats have been successfully held and bred in captive institutions since 1977 from wild caught founders, although little is known about the reproduction of Ghost Bats in general. Wherever possible the copulation and/or birth of Ghost Bats should be recorded using audio and/or visual media including video recording. Infrared cameras may be installed into roosts with minimal disturbance to the animals. Recording may be reviewed for future study and captive management. (Gleen.W. 1997)

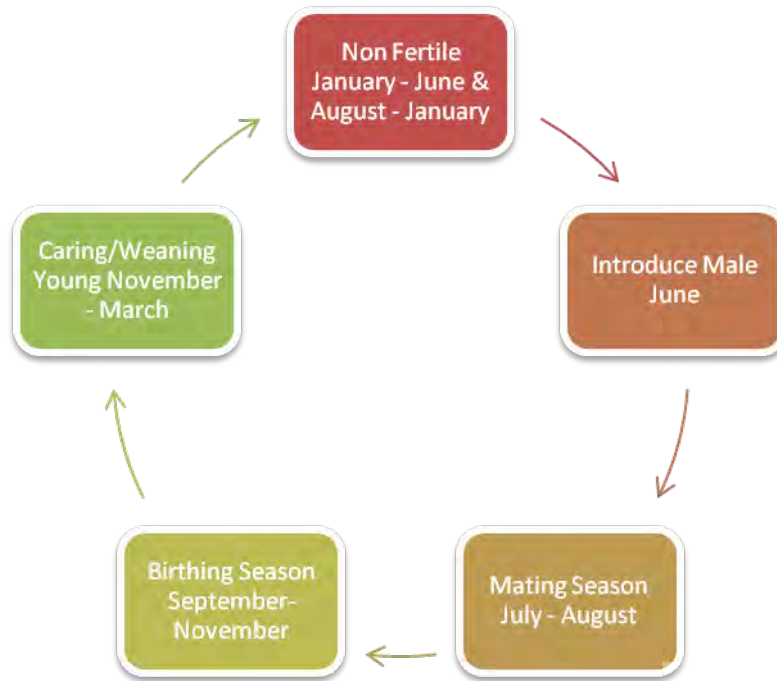
Whilst this chapter outlines general breeding conditions for the Ghost Bat please see the following for detailed information prior to breeding within a captive institution: Institutional Captive Management Plan (CMP), studbook (and studbook keeper) and Population analysis and Interim Recommendations for the Captive management of the Ghost Bat.

Wendy Gleen (former Studbook keeper – Taronga Zoo), Jessica Worthington Wilmer (DNA Analyst), Dee Dee Woodside (current Studbook keeper) may all be of assistance in the captive management of this animal. (Pers. Obs./Comms. K.Jones-2008)

Ghost Bat Reproductive Information at a Glance

SPECIES	SEXUAL MATURITY	NO.OF YOUNG	MATING	BIRTH SEASON	GESTATION DAYS	WEANING
Ghost Bat	Females – 1 year Males - 2 years	1 x pup per bat per season	July-August	Sept. – Nov.	Exact days unknown – approx. 3 months	2 months from Dec – Mar. (depending on DOB)

Ghost Bat Reproductive Cycle



(Pers.Comms. K.Jones-2008)

10.1 Mating System

- The Ghost bat roosts alone or in small groups with larger colonies found seasonally (during the breeding season). The largest group in the wild only thought to have approx. 500-600 maximum animals to a roost. (Gleen.W. 1997)
- The Ghost Bat has a polygynous mating system with males of the species siring offspring from multiple females during a single breeding season.
- In the wild the Ghost Bat is dioecious: The sexes separate into gender specific colonies after mating, with females forming and primarily inhabiting a maternity group throughout the winter months. They will not separate from each other until after the young have been weaned. In captivity this should occur artificially: The male should be separated from the group once pregnancy is positive in females.
- Maternity groups are valuable to the Ghost Bat for various reasons including: providing warmth, shelter, babysitting (Females are known to mind the crèche whilst others hunt), and learning behaviours including social, hunting and communication.

- In captive breeding plans males should only be grouped together with caution (whether in breeding season or not) due to aggression that may be displayed. Keepers must monitor behaviour.
- Sensate females (beyond reproductive age) may be left with the maternity colony with caution. Keepers must monitor the group daily to ensure that aggressive behavior is not displayed. If aggression is shown older females may be grouped with any females that return negative pregnancies.

10.2 Ease of Breeding

Unlike other species of microchiroptera the Ghost Bat is relatively easy to breed in captivity given correct husbandry practices and breeding triggers. These triggers include:

<i>Light</i>	Should mimic natural seasonal conditions – particularly in Nocturnal Houses. Light cycles may need to be altered to accommodate this.
<i>Heat/Humidity</i>	Ideally between 26c -30c to accommodate breeding. Regular misting to keep humidity at approx 80% may be required. Keepers to check temperature and humidity daily.
<i>Diet/Feeding Routine</i>	Increase insects (Crickets, locusts, mealworms, cockroaches and moths (if available). Gorge and starve days may also be a trigger – see Diet and Feeding.
<i>Noise</i>	Must be kept to a minimum – may require off exhibit holding if too noisy.
<i>Shelter</i>	Must be provided in the form of solid roosting boxes or suspended cloth roosts see Housing Requirements. Provide multiple roost sites (1 roost per 2 x bats)
<i>Intraspecific Compatability</i>	Remove other species from enclosure prior to breeding attempt to minimize disturbance/danger to pups.
<i>Age of Animals</i>	Juveniles under the age of one will not reproduce. Older bats <u>may</u> be sexually sensate – too old to breed see – 10.7 Age at 1 st and last breeding
<i>Husbandry Routine</i>	Should be minimal. Keepers in enclosure for 5-10 min spot clean each day + feeding once per day – (Perth Zoo minimal husbandry 5-10 mins 3 times per week + feeding once per day for 6 days per week only).
<i>Weight</i>	Must be at optimum weight as obesity may result in negative pregnancies.
<i>Exercise</i>	Should be considered with scatter feeding and ample room for flight. Obesity may occur if exercise is limited.

It is also noted that whilst this species breeds well in captivity when housed as a group, the results of single pairing is as yet unknown and will require further study. (Pers.Cons. K.Jones & P.Davies-2007/2008)

10.3 Reproductive Condition

Within captive animal populations that hold the Ghost Bat, reproductive condition/history is generally ascertained from studbook records. In cases where studbook information is not available (wild caught bats, assumptions made in records or individuals or groups not accounted for in studbooks) the following signs may be observed to ascertain reproductive condition:

Ghost bats reproduce after the age of 1-2 yet it has been noted that after the age of 3+ ability to breed successfully usually increases.

10.3.1 Females

Internal features of the female Ghost Bat include:

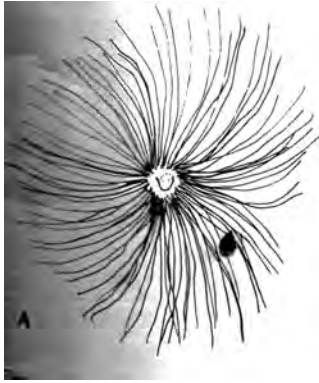
- Eutherian (placental mammal)
- Viviparous: internal fertilization, development and nourishment occurring in the females' body. Being a eutherian the Ghost Bat gives birth to live young (Online: Animal Diversity Website, 2007)
- Seasonal ovulations whereby the environmental conditions must be viable/abundant for the Ghost Bat to reproduce. If the conditions are not viable the female is able to store the males sperm until conditions are more suitable for breeding.
- The female Ghost Bat has a single estrus cycle during the breeding season.
- Have a reasonably strong parental investment in offspring, with females undertaking parental care, young are altricial, (relatively underdeveloped, cannot care for self or locomote separately).

Whilst these internal features cannot be seen they are important to know when considering breeding in captivity.

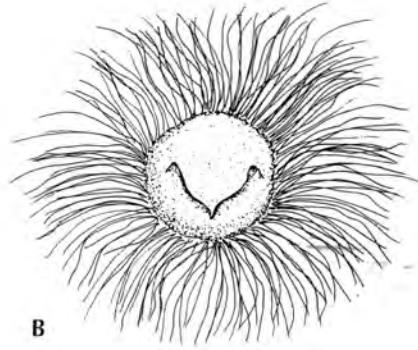
External features of the Ghost Bat that can be seen include:

- A set of 'false teats' or nipples that can be found within the pubic region (near the backlegs). These teats do not produce milk. Their function is to give the pup easier grip when clinging to the mother in flight to the mother. (Online: Animal Diversity Website, 2007) (Nipples in females will be enlarged if the bat has previously given birth)
- Pregnancy may be apparent if Female bats seem overweight, lethargic or changes in diet become apparent. The female's abdominal area may be gently felt to check for any abnormal fullness taking into consideration bats that may have a full stomach. (after eating)

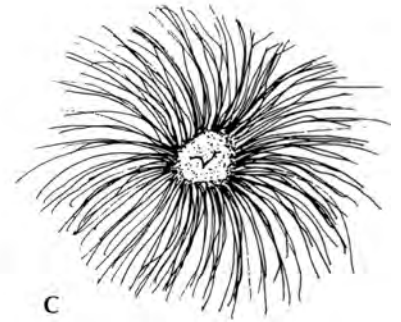
- When giving birth, the female Ghost Bat will remain hanging upside down with wings spread in such a way to catch the newborn pup. The pup will then climb onto the mothers' belly clinging to the false set of nipples that can be found near the back legs.
- Nipples: Images of nipples at various stages of reproductive development may be seen below (Images-Jackson.S.M.-2002):



A
Nulliparous – Pre birth female.
Birth Nipple.
Notice the small dome shape and thick triangular shape and hair regression.
Hair surrounding the nipple.
wrinkled and deeply



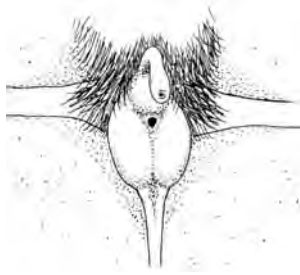
B
Lactating – During Weaning.
Notice the enlarged nipple and
hair regression.
Nipple produces a milky substance.



C
Regressed – Post
Notice the
Surrounding skin is
Pigmented.

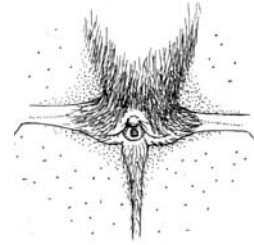
10.3.2 Males

- Males show aggression during the breeding season and have been known to display aggression particularly toward older females.
- The size of the testes and epididymal sac can be used to assess reproductive condition in males. The epididymal sac stores sperm increases in size as the testes increase. These should be easy to locate and will be easily visible as they descend from the abdomen unlike some species where the testes remain abdominal even during the breeding season. Experience may be required when looking for the testes.
- It is unknown if the male shows courtship displays in the form of vocalization, scent marking or mating displays.
- Images of the genitals in the male and female Ghost Bat can be seen below (Images-Jackson.S.M.-2002) and are a good indication of differentiating between genders.



Male genitalia is clearly visible in the male Ghost bat.

Size of testes is a clear indication of reproductive condition.



Genitalia of the Female Ghost Bat.

Note that nipples are a more easily visible cue of the reproductive condition in the female.

10.4 Techniques Used to Control Breeding

In captivity breeding is controlled by the separation of sexes. Males are removed from the enclosure with females being left as a group.

New techniques are being developed at present in the form of Melengestrol acetate contraceptive implants. Whilst they have been used successfully in Rodrigues Flying Foxes there is no evidence to suggest that this technology can be adapted to the Ghost Bat. Further study into alternate forms of contraception for the Ghost Bat is required.

Surgical or other forms of contraception are not required as gender separation is sufficient. (Jackson.S.M.-2002)

10.5 Occurrence of Hybrids

Hybridisation of the Ghost Bat is unlikely in captive institutions due to the Ghost Bat being the only member of the megadermatidae family in Australia. Hybridisation will not occur in Ghost Bats in captivity if stock is known and individual groups are housed separately. As each individual group is classified by region determination of Northern and Southern groups should be confirmed.

Macroderma gigas saturata is classified as distinct taxonomic unit See 2.2 Subspecies therefore there is risk of integration if founding stock and genetic lineage is unknown. Intergration between *Macroderma gigas* and *Macroderma gigas saturata* is not recommended as it would weaken the gene pool of both species. It is unlikely that wild populations would produce intergrades due to distance between colonies and subspecies.

Studbooks must be reviewed along with the population analysis and interim recommendations for captive management of Ghost Bats.

The current captive population of Ghost Bats primarily descended from founding stock from Pine Creek, N.T. with the exception of the Perth Zoo population having individuals from Port headland W.A. Adelaide Zoo holds individuals from Winnellie. The Winnelli stock may be classed as a distinct taxonomic unit.

Taronga stock were DNA tested in 1994 and Winnelli in 1996 so the pedigree of these populations is completely known. Although some pedigree assumptions had to be made when analysing the studbook data it is highly recommended that the studbook keeper be contacted prior to breeding. All wild caught animals are assumed unrelated.

The inbreeding coefficient in the current captive population is fairly low as there was approximately 93.8% of gene diversity found in the wild in the NT group. The WA group in Perth only retained 75% genetic diversity in 1997 Due to calculation through GENES analysis it was found that there has been a loss of 5.7% of genetic diversity since the founding generation. (1997-1996). Since founders have contributed unevenly to the current population there is a risk of loss of genetic diversity. (Gleen.W.-1997)

10.6 Timing of Breeding

Whilst timing of breeding is important for the Ghost Bat in the wild, in captivity the Ghost Bat breeds well therefore timing of breeding is not imperative, particularly within Nocturnal Houses where conditions may be controlled. If in a controlled environment adapt light cycles to mimic natural seasonal conditions. A group consisting of 1x male with a larger group of females can be left in most cases excluding when aggression is displayed or pregnancy is positive in females. If groups are usually separated the male should be introduced to the female group no later than June. As the breeding season is usually between July- August introducing the male in June ensures that general behaviour may be monitored to check compatibility prior to the copulation period. Since Ghost Bats in captivity have been recorded breeding outside of the known seasonal cycles timing of breeding requires further study.

10.7 Age at First Breeding and Last Breeding

Ghost Bats become sexually mature at approx 1 year old with males of the species sometimes reaching sexual maturity at 2 years of age. Following sexual maturity, first breeding can take place. Data for Age specific fertility must be treated with a great deal of caution as the Captive sample sizes are small with total number less than 20 ($n < 20$). Female fecundity is thought to peak at age 14 (with data taken from a single animal only). Male fecundity is thought to peak at age 12 (with data taken from two animals only).

Captive breeding in females has been recorded from 1 to 14 years of age and males from 3 to 13 years of age. One female was 16 years of age at last breeding at Taronga in 1995. Overall trends are extremely hard to calculate due to the data only indicating the ages of which captive breeding has been recorded to date. Given the lack of data for later age classes true reproductive limits are as yet unknown and further study will be required. Wild populations reflect similar trends to date.

In interim population analysis conducted in 1996 all bats over the age of 16 were omitted as it was assumed to be post reproductive.

The maximum reproductive age in the Ghost Bat is poorly known but Taronga Zoo has successfully bred Ghost Bats at the age of 16-18 yrs. This breeding occurred in 2005 but unfortunately the pups did not survive past weaning. (Gleen.W.-1997)



Age-specific fertility in the Australasian captive population of *Macroderma gigas* (unsmoothed data)

(Table-Gleen.W.-1997)

10.8 Ability to Breed Every Year

The Ghost Bat seems capable of breeding every year from all available information but it has not been recorded in captive populations although breeding in captivity is generally successful. This may be for various reasons. Further study into captive reproduction every year is required.

Taronga Zoo are currently using the same bats that bred successfully in 2005 to hopefully breed again. The male was introduced into the group in August of 2007 and has resided in the group ever since yet no positive pregnancies are confirmed to date. Due to ease of captive management the male will be left in the enclosure indefinitely and monitored by keepers.

Exercise and optimum weight is a must when breeding as lack of exercise and resulting obesity may result in negative pregnancies.

10.9 Ability to Breed More than Once Per Year

The Ghost Bat does not have the ability to breed more than once per. This is due to the fact that fertilization takes place between June and August with the embryo being stored in the female. After a 3 month gestation period pups are born between September and November. There is no time within the breeding cycle for another fertilization to take place.

Whilst there is no evidence to suggest that Ghost Bats will breed more than once a year it has been acknowledged that bats in arid or tropical regions in the wild that have generous food availability year round may breed more than once per year. Further study in this area may be required.

The fact that Ghost Bats are seasonal breeders and the female is able to store sperm until conditions prove most viable for breeding may negate the need to breed more than once a year.

10.10 Nesting, Hollow or Other Requirements

Shelter must be provided in the form of solid roosting boxes or suspended cloth roosts (see Housing Requirements – Chapter 4.) Provide multiple roost sites (1 roost per 2 x bats).

As Ghost Bats are a highly sensitive animal and even minimal disturbance may cause poor breeding, appropriate roosting sites must be provided.

As Ghost Bats are a cave dwelling species in the wild and females form maternity colonies, it is best to remove males into bachelor groups or individually during the lactation season. Specific roosting requirements are unknown but a quiet, dark and sheltered place will definitely be required away from disturbance.

10.11 Breeding Diet

Large dietary changes are not necessary when breeding the Ghost Bat but the following should be taken into consideration. An increase of insects into the diet when attempting to breed increases both the amount of food and exercise the bats get and may assist in triggering breeding. Mealworms may be free fed (scattered or set into bowls). Crickets, locusts or cockroaches may be fed 3-4 times per week (1-2 per bat) and moths when available. General diet should be monitored by keepers along with food consumption. Gorge days may be followed by 1 starve day per week to trigger wild conditions and breeding.

Diet/Feeding Routine	Increase insects (Crickets, locusts, mealworms, cockroaches, moths if available). Gorge and starve days may also be a trigger – see feeding.
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10.12 Oestrous Cycle and Gestation Period

Mating occurs from July to August with young being born between September and November, after a gestation period of 3 months.

Ghost Bats have been known to give birth in captivity in January, April and July therefore breeding out of season must not be excluded in captivity. (Gleen.W, 1997)

The exact figures of gestation in days are unknown. The gestation period for most species of bats is generally poorly known. Further study in this area is required.

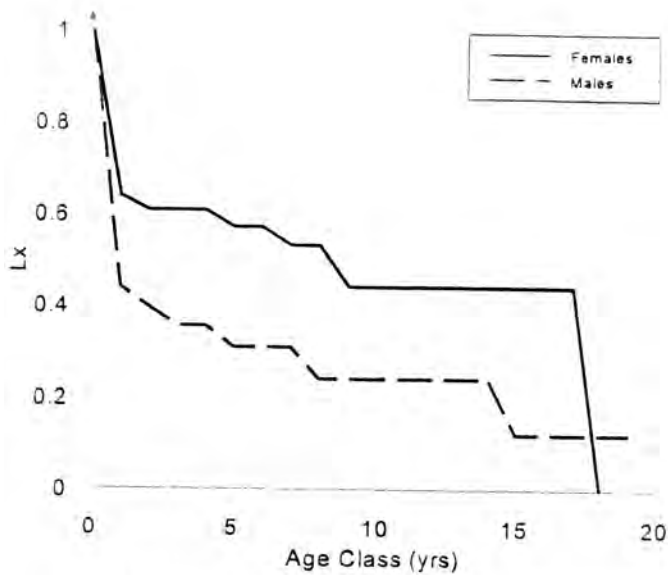
Current captive populations of the Ghost Bat show a skewed male/female sex ratio of around 1:2.5 Of the young born in captive institutions until 1997 there is a definite female bias with 12 males having been born compared to 27 females.

10.13 Litter Size

Both wild and captive litter sizes are the same with only a single pup being born to a female each breeding season. An increase in litter size has never been recorded in captivity.

Ghost Bats in captivity tend to show a pattern of ‘type 3’ survivorship: high rates of juvenile mortality but survive well in later years. Female survival in first year 65% and 45% in males (under half). The oldest known Ghost Bat in captivity is a male, 20 years of age. Many of the original founding stock is still alive to date.

Current data is being collected on captive births to date (including institution, DOB, sex) to add to this manual.



Age-specific mortality in the Australasian captive population of *Macroderma gigas* (unsmoothed data)

(Table-Gleen.W.-1997)

10.14 Age at Weaning

The young whilst altricial (requiring parental care including lactation and learned hunting skills), are well formed and able to reach independence after a period of approximately 7-8 weeks.

Young fly after 7 weeks and are weaned after a period of 8 weeks (2 months) in February following births in November.

After weaning mothers teach juveniles the skills required to hunt until total independence is achieved at approximately 8 weeks. (Straughn.R.-2002)

10.15 Age of Removal from Parents

Offspring may be removed from parents after the age of 8 – 10 weeks (earliest) when they are fully weaned, capable of independent flight and feeding (ensure juveniles are feeding well).

There is no requirement to separate offspring from parents as Ghost Bats live and thrive in colonies. Reasons that removal may become necessary in captivity include:

- Transfer to another institution.
- Aggression within group
- Illness or injury (in which case hand rearing may be necessary.)

- Skewed gender ratios – Surplus males will require removal as they reach maturity as males can be aggressive when grouped together.
- Captive Management Plans (CMP) – May require that young are removed prior to first breeding at age 1 (females) and 2 (males) if there is a risk of loss of genetic diversity amongst the group (inbreeding). Inbreeding is not recommended as captive stock must maintain genetic diversity.

Note: The above reasons may not require that juveniles be removed at the earliest age (8-10 weeks) and must be reviewed in conjunction with the CMP, Studbook keeper or others. (with aggression or illness/injury being the only exception).

If removal is required for breeding purposes the young may be left with the mothers until just prior to the reintroduction of the male for the next breeding season.

10.16 Growth and Development

- Ghost Bat pups weigh approx. 20 grams at birth and measure approx. 4.5cms. in length.

Developmental stages of Ghost Bat juveniles:

- Eyes open
- Fur visible
- Appearance of teeth
- Self hanging
- Feeding on solid food
- Self feeding/hunting
- Stretching/flapping of wings
- Ability to fly independently
- Independent

See Chapter 3.2.2 Mass and Morphometrics which include size and measurements of bats.

- Note: If measurements are taken of a Ghost Bat it is recommended that plastic calipers be used, not metal, as a struggling bat may damage/ break the delicate patagium, (wing membrane) or wing bones, against the metal. Plastic calipers may not be as accurate as metal, but for the small difference it is a safer alternative for the animal. (Churchill.S, 1998)

JUVENILE:

- Juveniles are smaller than adults or sub adults and have dark grey fur as opposed to the lighter shades of the adults.
- Possibly will be attached to the mother, (hanging on to the ‘false teat beneath the armpits of the mother).
- Wing joints have very large bands of cartilage surrounding the wing joints. (Churchill.S, 1998 and Pers.coms, Davies.P 26-7-07)
- The testes that have yet to descend into the scrotum in males.

Wendy Gleen, (Former Studbook keeper, Keeper Taronga Zoo), Sue Churchill, and Jessica Worthington – Wilmer, (DNA Analyst), have all carried out research into the Ghost Bat including population analysis and interim recommendations for captive management of *Macroderma gigas*.

NOTE: A growth chart including body weight, developmental stages, and age is currently being created to add to this manual. Correct information to create this chart is currently being sourced.

“Last pups born at Taronga died, seemed that ‘bashing’ was the cause, possibly when bats flew down to ground, Bilbies may have attacked them. They may have been beaten up or harassed by Bilbies, we think the Bilbies may have had something to do with it as they are opportunistic creatures” (Pers comms. P. Davies.)

Next breeding season if results are positive Bilbies will be removed from enclosure along with Male Ghost Bat to ensure a successful maternity colony may be established. Females have second set of nipples they are false and do not produce milk, but are there for the pup to cling to when being carried in/out of flight.

11 Artificial Rearing of Mammals

Introduction

Any carers involved in the artificial rearing of the Ghost Bat must be inoculated against Lyssavirus (See 1 Introductions - Warnings and OH&S). Under no circumstances should a non inoculated keeper attempt hand raising any bat species.

Tetanus vaccinations are also highly recommended due to small bites or scratches that may be incurred through regular handling and feeding.

Artificial rearing techniques of Microchiropterans is little known, with more study required in this area both generally and with specific relation to the Ghost bat. Any carer involved in artificially rearing a microchiropteran must be willing to experiment with various techniques (Jackson- 2002) and record all successes, failures and other relevant data as it must be assumed that there will be varying degrees of success. Record keeping may assist other carers in the future.

When deciding to artificially rear a keeper should always ask the following questions:

- Why does the bat need to be artificially reared? It is always best that a pup be left to be raised by its' mother. If so, leave it to be parent raised.
- If this is not appropriate can limited care be offered to **assist** the parent raise the young? If limited care will work the pup should be returned to the mother as soon as possible to decrease imprinting and reliance on humans.
- As fostering is unknown in Microchiropterans in general or Ghost Bats a carer would need to experiment with this option.
- If the young must be completely artificially reared it must have a destination. That destination may be as part of the collection, to another institution or for wild release, but do consider that if there is no destination for the bat that artificial rearing would be cruel to the animal. If a person is artificially rearing to gain experience only the options of destination must be considered, including euthanasia. (Pers. Cons. K.Jones and G. Phipps-2008)

If hand rearing any animal the carer should always have a hand rearing kit available that can be used if the carer is called away for any reason. With a 'take away' kit the carer can be assured that appropriate care can be offered anywhere and at any time. The kit should include all items required for artificial rearing including a record sheet for recording data. (Pers. Cons. K.Jones and B. Walker-2008)

11.1 Housing

Ghost Bat pups may be housed in any of the following ways:

- 1) Incubation – Incubators are controversial in the artificial rearing of microchiropterans due to the potential of dehydration within the incubator, although it must be noted that incubators have been used with success to artificially raise various microchiropterans. If so, be sure to record and monitor humidity levels within the incubator as there may be a risk of dehydration.
- 2) Styrofoam containers – Styrofoam coolers or eskys work well for temporary housing and are easy to transport the bat in. Place a small Styrofoam cooler inside of a slightly larger one to create adequate insulation for the bat. The space between the two walls may also be used to place a heat pack or extra toweling in to provide extra warmth. Only use non coloured containers as dyes may be harmful to pups. Ensure there is a perch inside the cooler to let the pup hang if it prefers. Always tape the box lid to ensure escape is not possible. Only use this option for pups (adults may claw at, tear and ingest the foam or make holes large enough to escape)
- 3) The bat may be wrapped in a cloth and pinned to the carers shirt with extra outer coverings when temperatures are cool, although this option must be tested with individuals as Ghost bats may stress if kept in cloth bags.
- 4) A small box or basket lined with cloths may be placed in a larger heated box with a damp sponge at its base to provide humidity for the bat.

The outer container for Styrofoam coolers or boxes should measure approximately 30 cm D x 50 cm L x 35 cm H to be suitable for holding pups until weaning occurs. Ensure that adequate ventilation is provided regardless of the method of housing. If using Styrofoam containers or boxes, punch holes from the outside in at 10cm intervals around both of the coolers with a pencil, hot nail or similar. (Jackson- 2002)

When the bat begins to outgrow this arrangement or not require intensive care, a small holding or flight cage can be used to adjust the bat to a captive environment. This can be useful for training the bat to fly and free feed as these opportunities will be limited if using methods 1-4 above. The cage should have the following features:

- Be small enough to capture the bat easily for hand feeding (if required) and weighing. If the cage is too large catching time and stress levels are increased.
- Room to fully stretch the wings (one at a time is preferred to lessen the likelihood of injury).
- 1 covered wall of wire mesh, (1cm grid with cloth covering). Wire provides adequate ventilation and covering provides shelter from draughts, noise and sudden movement.

- Only a single bat should be housed in this way to avoid possible injury from another stressed or startled bat in the same cage.
- This method is used until the bat can feed from bowls independently by which time introduction to the regular captive enclosure or release may be possible.
- This is also an appropriate way to transport Ghost Bats as some do not do well in cloth bags, becoming stressed and anxious, (unlike other Microchiropterans). (Care and Handling of Australian Native Animals).

11.2 Temperature Requirements

Ghost Bat pups must be artificially reared in conditions similar to those of the natural roosting environment, most commonly caves. As pups cannot regulate their own body temperature it is essential that the carer maintain a constant temperature of between 32° C and 38° C with a humidity level of approximately 80% to prevent dehydration.

Heat pads or well wrapped hot water bottles may be used to maintain temperatures but must never be placed directly next to the pup due to the risk of overheating and burns. (See 9.6 Housing, 2) Styrofoam containers)

It is also important for the carer to maintain a constant temperature for the bat and limit any sudden temperature fluctuations due to the risk of hypothermia. This may be achieved by ensuring that the artificial housing and bat are not left in temperature extremes, in the open elements or in draughts. Unless required the bat should generally remain undisturbed to also help control temperature in the artificial housing.

All bats, including Ghost bats need to be warmed before any food is offered (approximately 35°C). Bats can be warmed gently in the hand until they do not feel cold or temperature slightly raised in the housing before feeding to ensure milk is not inhaled causing pneumonia and death. Only feed solid food at room temperature-never cold.

Temperatures can be measured by a thermometer with a plastic coated probe next to the bats skin to ensure correct temperature regulation (Jackson- 2002). Alternatively, temperature guns may be used. Temperature guns can be used within 6cm of the animal and give a reliable temperature to 0.1°C. They are an easy to use, accurate and inexpensive way to check temperature regulation. (Pers. Cons. K.Jones and B.Walker.)

Never let bats become cold (particularly overnight)

Never use radiators, heaters, blow dryers or other direct heat sources to heat bats as this can cause dehydration and can severely affect wing membranes. (Jackson-2002)

11.3 Diet and Feeding Routine

When hand rearing Ghost bats the future of the bat will become evident in the first few days of feeding as the pup must learn/relearn how to feed individually in a captive environment. Ensure before feeding that the species is confirmed as providing care to a bat whose feeding group is not identified can compromise the effectiveness of the care and be harmful to the animal.

Ghost bats become very subdued when in a captive environment and may be anxious and stressed. As a result bats may refuse food at first, dropping to an alarmingly low weight. In this case forced feeding may be required. Up to 3 days forced feeding may be required in which time the bat should begin to feed itself. Hand feeding ensures the bat is taught what is and is not edible. (Care and Handling of Australian Native Animals). The following consideration should be made when feeding:

- Wrap the bat in cloth with wings folded gently against the body and the feet protruding from the end, allowing the bat to grasp if desired.
- The bat should be awake and lively before food is offered.
- Ghost Bats must be warm (approximately 35°C) before food is introduced, due to the risk of inhalation pneumonia.
- Bats must be hydrated **prior** to feeding. Dehydration is the most common problem and cause of death in artificially reared bats.
- As the natural posture for bats is to hang upside down Ghost Bats must be inverted when feeding to ensure that milk does not aspirate into the lungs when learning to feed.
- Hearing the sounds of other bats nearby may encourage the bat to feed. Feeding the bat near a Ghost bat enclosure or playing a tape with Ghost bat calls may help.
- Learn how to distinguish when a pup needs feeding/is full. (see below)
- If only slightly furred once fed, milk can be seen within the stomach of the pup and digestion of milk can also be gauged visually. The stomach should never be seen empty. Feed pup until milk can be seen and the stomach is slightly extended but not overfull.
- Gently palpitate the abdomen with a fingertip to understand how the stomach feels when full. This is necessary as when the pup is furred you will no longer be able to see the milk in the stomach and will have to rely on feeling the abdomen.
- Do not over feed the pup due to the risk of bloat (a common cause of death).
- Pups should be checked each hour after feeding to this may assist carers in ascertaining when a pup requires feeding or is full. (Jackson-2002)

- Ghost Bat pups will require stimulation to defecate and urinate. This may be achieved by softly wiping a warm, damp cloth over the genitals, although pups may not defecate after every feed. Stools should be firm and dark, although cream stools may be seen while the pup adjusts to the milk formula.

Captive diets should include at least some components of the wild diet which is easy to source for Ghost bats. Seasonal supplementation may be required and every effort should be made to ensure that a wide variety of food is offered after the pup has been weaned. (Care and Handling of Australian Native Animals)

Formulas:

There are currently 3 known milk formulas that may be used for the hand rearing of various microchiropterans, including Ghost Bats:

- Wombaroo Insectivorous Bat Milk – Appropriate from birth to weaning.
- Biolac Puppy Milk – 20ml milk formula to 100ml sterile water.
- Ghost Bat Milk – Created and used successfully by Territory Wildlife Park. Ghost Bat milk consists of: 100ml cow's milk, 1 egg yolk, and 1 teaspoon of glucose powder e.g. Glucodin. This is heated in the microwave until it forms a custard like consistency, stirred again and heated for a further 20 seconds. This formula is to be made up daily.
- Wombaroo artificial colostrum may also be used for neonates. (Jackson-2002)

Other Foods:

- Soft tissues can be offered. Brain or cut mealworms can work and bats can be weaned onto mealworms by 'cutting off the insects head and squeezing its viscera into the pup's mouth like a tube of toothpaste allowing them to chew on the exoskeleton when willing to strengthen the jaws. (Jackson-2002) Alternatively, mealworms can be blended and offered the same way as milk formula or cooled in the fridge to reduce movement and make it easy for the bat to eat.
- Day old chicks, mice. Neonate mice or 'pinkies' are best offered to a pup due to the soft texture and minimal fur. Chicks and adult mice may be cut into small pieces to accommodate the size of the bat in care ensuring that they are at room temperature prior to feeding.
- Supplements can include: Boiled eggs, Dry mix of powdered milk substitute and high protein baby cereal, e.g. Farax. 10 parts powdered milk to 100 parts cereal.
- Vitamins (especially vitamin D) can be given in the water or in a powder form incorporated into the dry mix above.
- If bats do not readily consume the dry mix it can be used as a substrate for mealworms being fed to the bat with a sprinkle added over the mealworms when feeding the bat. (Care and Handling of Australian Native Animals)

Feeding apparatus:

Feeding Ghost Bat pups may prove a challenge due to the small size of the animal although the following apparatus may assist in the artificial feeding of Ghost bats (particularly pups):

- Small eyedroppers – From which the bat can lap milk one drop at a time.
- 1ml syringes - From which the bat can lap milk one drop at a time.
- 3ml syringes – Which can be used to feed any blended food (mealworms)
- Surgical tubing - From which the bat can lap milk one drop at a time.
- Eye make up sponges - From which the bat or pup can suckle on should it refuse to lap.
- Milk can be placed in the hand to be lapped in the initial stages.
- Spoons from which milk can be lapped.
- Forceps – To offer solid food pieces. Forceps will protect hands from bites and scratches.
- Rubber catheters.
- Specially designed artificial feeding devices.
- Syringes may be required to introduce fluids intravenously if the bat is dehydrated and refuses to drink water.

Below is a recommended feeding chart on the Ghost bat from 1 week to weaning:

Pups age (weeks)	Developmental stage of pup	Foods required for pup	Amount required and feeding intervals	Conditioning or training regime
1 week	Newborn	Artificial milk formula (See 9.8 Diet and Feeding Routine – Formulas)	Until milk can be seen in the stomach and is full (not overfull) – Check pup every 1-2 hours. Do not let stomach become empty. (see points above 9.8 Diet and Feeding Routine))	Keep pup warm. Minimal interference to maintain optimum temperature.
2 weeks	Dependant solely upon carer	Artificial milk formula (See 9.8 Diet and Feeding Routine – Formulas)	As above	As above
3 weeks	Dependant solely upon carer	Artificial milk formula (See 9.8 Diet and Feeding Routine – Formulas)	As above	As above
4 weeks	Dependant solely upon carer/showing signs of independence.	Artificial milk formula (See 9.8 Diet and Feeding Routine – Formulas)	As above	Gently stretch wings one at a time after each feeding to exercise so muscles do not atrophy.
5 weeks	Dependant solely upon carer/ showing signs of independence.	Artificial milk formula	As above	As above.
6 weeks	Still dependant but becoming increasingly independent	Artificial milk formula, mealworms, other insects (blended) (See 9.8 Diet and Feeding Routine – Other foods)	Semi solid food 10-20% of body weight if in flight cage plus regular formula feedings.	As above. Short periods in small flight cage (See 9.6 Housing). Hand feeding over bowls. Flight training (See 9.2 Behavioural Considerations)

7 weeks	Pup is only dependant now for training in eating solid foods. Weaning is occurring.	Artificial milk formula, mealworms, other solid food (See 9.8 Diet and Feeding Routine – Other foods)	2.5ml half strength Vitrate/milk formula, 10-40 mealworms and small mouse (pinkies)/chick pieces. Feed up to 20ml milk overnight + 3x feeds of solid food per day.	As above. If pup is eating readily cage space may be increased. Offer limited enrichment in cage
8 weeks	Weaning finished (pup returned to adult enclosure)	Reduced milk formula feedings. Standard adult diet (monitored to ensure pup receives enough food)	2.5ml half strength Vitrate/milk formula, 10-40 mealworms and small mouse (pinkies)/chick pieces. Feed up to 20ml milk overnight + 3x feeds of solid food per day.	If pup is strong and eating independently consider introducing to adult enclosure and monitor.

By 7-8 weeks of age the pups should be feeding well from bowls which both milk and solid food may be left in for the pup to feed without artificial assistance. For the next few weeks the pup can be ‘meated off’ the milk formula and the size of solid food peices may be gradually increased to a standard adult diet. (See Weaning 9.14)

This table is an approximation only of artificial rearing and conditioning techniques designed for easy reference from the limited data currently available. (Pers.Coms. K. Jones 2008)

11.4 Specific Requirements

- Any carers involved in the artificial rearing of the Ghost Bat must be inoculated against Lyssavirus (See 1 Introductions - Warnings and OH&S). Under no circumstances should a non inoculated keeper attempt hand raising any bat species.
- Tetanus vaccinations are also highly recommended due to small bites or scratches that may be incurred through regular handling and feeding.
- Check bats for any signs of dehydration upon arrival into care. (See 9.15 – Rehabilitation and Release Procedures)
- Ghost Bat pups will require stimulation to defecate and urinate. (See 9.8 Diet and Feeding Routine)
- Ghost Bat pups must be warm before feeding (See 9.7 Temperature Requirements)
- Wings must be exercised after feeding the bat by very gently extending the wings one by one a few times each to ensure that flight muscles do not atrophy.

- Flight training should be encouraged. (See 9.12 Behavioural Considerations)
- When training to feed or fly in a flight cage always use towels, hung under the bowls and on walls in case of falling. The enclosure floors in the initial stages should also be padded and all sharp objects (browse) removed from the enclosure in case of injury when learning to fly.
- Ghost bats should be introduced into an enclosure with other Ghost bats as soon as possible to encourage observational learning, natural behaviours and minimize imprinting.

11.5 Data Recording

Data recording is paramount in the artificial rearing of pups. This ensures a complete history of the bat is recorded along with health related records for veterinary checks (of particular use if the bat becomes sick, weak, or does not thrive). Records also indicate successes, failures, and other important data for any keepers working with the animal. Records should always include:

- Date
- Time of information recording
- Sex
- Approximate age
- Body weight (to the nearest 0.1 g) – See Developmental Stages 4.3 and continue using this regime to weigh bats
- General activity levels and behaviour
- Characteristics
- Frequency of urination/defecation
- Amount of food being fed/consumption rate
- Type of food being fed
- Veterinary examinations and results
- Where the pup was found and any history or details in relation to the finding (may assist with wild release)
- Why the pup is in artificial care

11.6 Identification Methods

- Nail polish (in various colours) may be used on a single claw of each pup to determine ID
- Microchipping
- PIT tags
- Small finch band placed on thumb of pup
- Weight
- Visual determination (size, colours, specific visual characteristics).

11.7 Hygiene

Good hygiene and husbandry are essential to the overall success of artificially rearing Ghost bats. The following must always be maintained to prevent illness and death in the bat and/or any illness in the carer:

- Always wash hands before and after any interaction with a bat. Also wash hands between feeding different bats.
- Correct use of PPE (gloves, sleeves)
- Never allow a pup to become too close to the face, do not attempt to kiss or cuddle the pup or let it lick you.
- Always sterilize all feeding equipment (Halasept or Milton) or Boil in water for 10 minutes. Rinse in cold water after sterilizing. Always sterilize feeding equipment between meals. (teats and bottles must be kept in the fridge)
- Always use sterile water for mixing formulas (at least in the early stages – first few weeks)
- Only ever heat milk once and always discard left over milk formula or feed to other animals.
- Always clean left over food, faeces, urine or other waste from the bat with warm water and a soft cloth as soon as it becomes soiled. Always dry the bat well and never leave damp or wet.
- A cloth with warm water is sufficient for cleaning Ghost Bats-do not use soaps or other detergents or chemicals on the bat.
- Pups must be toileted after all feedings. (See 9.8 Diet and Feeding Routine)
- Always maintain a clean bedding area, carry case and roosting site at all times, free of faeces, urine, milk formula, other food and any other waste.
- Ensure bats are quarantined until they are cleared by a veterinary for introduction into the collection.

11.8 Behavioural Considerations

- At the time of weaning pups should be trained to fly by placing on the hand and gently raising and lowering the hand. Ensure that there is plenty of soft material for the pup to fall on or crash into. If flying is not trained at this age it may result in the pup never learning to fly.
- Before reintroduction into the enclosure takes place any male Ghost Bats must be removed due to potential aggression. Male bats should also be checked for paternity prior to any further breeding due to the chance of inbreeding and limited genetic diversity.
- Before reintroduction of pups any conspecific species should be removed from the enclosure (Bilbies, Bandicoots, Potoroos, etc.) due to the risk of attack. Should a pup fall to the ground it may not have the strength to climb to safety before it is attacked by other animals, particularly foragers.

- Ghost Bat pups should preferably be reintroduced into the enclosure no later than 8 weeks of age as this would be the natural stage of weaning in the wild and may lessen the impact of human imprinting at the early stages of development. The Ghost Bat pup must be given the opportunity to be able to learn basic skills from the older individuals in the enclosure (including communication, grooming, hunting/feeding techniques).
- The carer should monitor food intake and signs of aggression from other bats after reintroduction and whilst hand feeding within the enclosure may be problematic, if the pup is not receiving enough food or is being aggressed by others a smaller flight cage may be put into the enclosure where the pup can both interact with other bats and eat enough without any threats.
- Excess light, noise and human interference should be kept to an absolute minimum within and around the enclosure to ensure the pup becomes accustomed to the new enclosure. Ghost bats are susceptible to interference and stress may be caused to the bats.

11.9 Use of Foster Species

There are no known foster or cross foster species for the Ghost Bat. As each bat gives birth to a single pup it is unlikely that a Ghost Bat mother would take on a second infant that is not her own biologically as it would lessen the likelihood of her own to thrive.

Due to the Ghost bat being the only known carnivorous bat endemic to Australia there are no other known species that share enough similarities to successfully rear a Ghost Bat pup to adulthood. (Pers. Coms K.Jones)

11.10 Weaning

Occurs at approximately 8 weeks of age at which time the pup should be reintroduced into the enclosure if pup is feeding well independently. The weaning of Ghost bats requires that the pup readily accepts food from the hand and associates and seeks out food within the food dishes.

Foods to be offered include:

- Soft tissues can be offered. Brain or cut mealworms can work and bats can be weaned onto mealworms by ‘cutting off the insects head and squeezing its viscera into the pup’s mouth like a tube of toothpaste allowing them to chew on the exoskeleton when willing to strengthen the jaws. (Jackson-2002). Alternatively, mealworms can be blended and offered the same way as milk formula or cooled in the fridge to reduce movement and make it easy for the pup to eat.
- Day old chicks, mice. Neonate mice or ‘pinkies’ are best offered to a pup due to the soft texture and minimal fur. Chicks and adult mice may be cut into small pieces to accommodate the size of the bat in care ensuring that they are at room temperature prior to feeding.
- Supplements can include: Boiled eggs, Dry mix of powdered milk substitute and high protein baby cereal, e.g. Farax. 10 parts powdered milk to 100 parts cereal.

- Vitamins (especially vitamin D) can be given in the water or in a powder form incorporated into the dry mix above.
- Should bats do not consume the dry mix it can be used as a substrate for mealworms being fed to the bat with a sprinkle added over the mealworms when feeding the bat. (See 9.8 Diet and Feeding Routine) (Care and Handling of Australian Native Animals)

To begin the weaning process a mixture of the food listed above may be introduced into the diet with fewer formula feedings.

The following guidelines may assist the carer in weaning or force feeding solids and will assist in training the pup to feed independently from bowls and seeking out its own food.

:

- Hearing the sounds of other bats nearby may encourage the pup to feed. Feeding the pup near a Ghost bat enclosure or playing a tape with Ghost bat calls may help.
- Soft tissues can be offered. Brain or cut mealworms can work and bats can be weaned onto mealworms by ‘cutting off the insects head and squeezing its viscera into the pup’s mouth like a tube of toothpaste’ (Jackson-2002), allowing them to chew on the exoskeleton when willing to strengthen the jaws.
- When food is taken in the mouth but is not being chewed the carer can gently pull the food away from the bat. The bat may then learn to chew when grabbing the food back. The threatened removal of the food can spur the bat to action. (Care and Handling of Australian Animals).
- Forceps feeding (to prevent injury to hands) of the pup may be done over a bowl of mealworms so the pup learns to associate the food with the bowl.
- Observational learning has been observed in the Ghost Bat and housing with other bats for short periods can condition the pup to captive feeding (what the food is and how to get it)
- Always offer a few drops of fresh water after feeding solids until independent.
- Gently exercise wings following each feeding to stimulate bat into digestion and movement.
- When the Ghost Bat accepts food readily it should immediately seek food and feed itself from bowls independently from that time on. (Care and Handling of Australian Animals).
- Bats can be housed and fed as adults when 10-40 whole mealworms are consumed regularly without assistance. (Jackson-2002)

11.11 Rehabilitation and Release Procedures

Rehabilitation Procedures and Emergency Care for Bats:

- 1) Ensure the bat is not dehydrated by using the 'pinch test' - When skin is **gently** pinched at the back of the neck it should bounce back within a second. If the skin takes any longer to bounce back the bat is probably dehydrated. If so (5g-10g maximum glucose or 1g of electrolyte replacer to 100ml sterile water, alternatively 20ml Vytrate to 250ml sterile water) may be used immediately. If the bat refuses this intravenous fluid injections (0.9% sodium chloride or 4-5% dextrose solution) may be required before feeding initially. The carer must also be aware that intravenous injections may be required at any time during hand rearing.
- 2) Stabilize the bats temperature – very important in juveniles as they cannot regulate their own temperature. (See Temperature Requirements 9.6)
- 3) Check for signs of extreme old age - Worn teeth and old scars on peritragium may indicate age as well as joint swelling. In the case of extreme old age use well blended food to accommodate feeding. Euthanasia may need to be considered as an option. In any case, approximate age of bat should be determined where possible.
- 4) Check for any broken bones, joint swelling in the bat – The following figure can be used as a guide to determine the bones within the wings.
- 5) Check for open wounds and/or secondary infections – If open wounds are present Amoxil or Clavulox may be prescribed for infections.
- 6) Check for torn or punctured membranes – In wings, noseleaf, ears, legs, etc. The membrane is very likely to self heal if the bat is kept in small housing with smooth walls and no objects to further injure membranes. Vetbond may be used (See Health Requirements-)
- 7) Check for signs of Pneumonia- The bat may suffer from anorexia (reluctance to feed), labored breathing and fluid in nostrils. Keep the bat warm and hydrated and have the correct antibiotic prescribed by a veterinarian.
- 8) Check for conditions found in wild bats – such as mite infestations etc. that would not readily occur in captive stock – Keep quarantined – Treat alopecia with Vitamin D or calcium – Seek veterinarian advice.
- 9) Hold in treatment/quarantine cage – Away from captive stock, in quiet, warm, dark housing whilst appropriate treatment is administered.
- 10) Feed bat – After determining age use the feeding guides (See Diet and Feeding Regime 9.8 and Weaning 9.14) to attempt first feeding.
- 11) Weigh bat and confirm identification of species – Weighing can be carried out after emergency care has been provided. Confirmation of species is paramount to provide the most appropriate long term care and management of the bat.
- 12) Seek advice on long term care and housing arrangements for the bat- All microchiropterans are protected by law throughout Australia and the appropriate authorities must be contacted in regards to long term care for the individual and the species as a whole.

13) Place the bat with the same species if at all possible – This will assist the bat to become independent and is of great benefit from a behavioural point of view.

Release Procedure :

In Captivity:

Ghost Bat pups should be introduced to other Ghost Bats at the time of weaning or before in short intervals, (approximately 6-8 weeks).

If possible pups should be placed with others of a similar age and/or size. This greatly increases the chance for social and flight development. As Ghost Bats are a social species, recently weaned Ghost Bat pups should not be housed alone as adults due to stress. (Only adult males should be housed alone).

Keepers must closely monitor the pup but must be aware that contact and interaction should be kept to a minimum as any imprinting resulting from hand rearing must now be minimized. The best way for a pup to lose any imprinting is for the pup to socialize with other Ghost bats. Bats should be placed into the enclosure with the other bats and monitored for any discouraging signs. Talcum powder may be used to dust bats prior to introduction to confuse the foreign odours that bats may detect. A small flight cage may be required for the rehabilitated bat within the main enclosure to let bats become accustomed to one another without being able to damage one another. Monitor health, food consumption and social interaction with other bats and remove bat if it is unable to thrive.

If the bat is unable to thrive in the environment the following decisions will need to be made: Could the bat be used for educational purposes? Will the bat thrive in captivity? Could the bat be sick or unable to fly? If a destination cannot be created for the bat euthanasia may be the only solution.

In the Wild:

Any bats being released into the wild should be released in the same location as the pup was originally found due to the familiar surroundings. Warm, dry weather is most appropriate for successful release. Bats should be fed prior to release but not overfed as bats must be alert when released. Bats should always be released when they are warm and should be released at dusk to increase the chances of successful release.

Ensure that any cats, dogs or other animals are not in the immediate area. Low trees, branches, and any other obstacles must be removed prior to flight as the bats will need a clear take off to minimize injury. Place the bat on a tree trunk and watch from a distance to ensure that you can observe the bat familiarize itself with its surroundings. Bats should fly within 5 to 30 minutes of release.

If the Bat refuses to fly or is struggling after several attempts the bat should be recaptured and returned to captivity. If after several attempts at release the bat will not fly, the following decisions will need to be made: Could the bat be used for educational purposes? Will the bat thrive in captivity? Could the bat be sick or unable to fly? If a destination cannot be created for the bat euthanasia may be the only solution.

12 Acknowledgements

I would like to acknowledge the following people, for their assistance in the compilation of this Husbandry Manual:

Graeme Phipps, Brad Walker and Jackie Salkeld (lecturers at TAFE WSI) they are the reason that this manual has been created.

Paul Davies (Head Keeper, Nocturnal House, Australian Mammals Division, Taronga Conservation Society Australia) Wendy Gleen (Ex Studbook Keeper for *Ghost Bat*, Keeper, Nocturnal House, Australian Mammals Division, Taronga Conservation Society Australia) Evelyn Weston (Unit Supervisor, Australian Mammals Division, Taronga Conservation Society Australia)

I would also like to thank the Australian Mammals Division of Taronga Conservation Society Australia). Working within this division is a great pleasure and something that I will always cherish.

I also need to thank the unsung heroes of this manual: My family. At the beginning of this manual they knew nothing about the Ghost Bat but now at the end of it they could all be Ghost Bat Keepers in their own right.

Thank You All.

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PERSONAL OBSERVATIONS.

All personal observations have been made by Kathryn Jones whilst undertaking husbandry duties for *Ghost Bat* at Taronga Park Zoo between January 2007- March 2008.

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15 Glossary

Terminologies used in this manual that may not be easily understood without explanation/definition include:

Aesthetically-	Inoculated-
Assumptions-	Insectivorous-
Atrophy-	Intermittently-
Carcasses-	Interscapular-
Carnivorous-	Intraspecific-
Cartilaginous-	Inverted-
Census-	Juvenile-
Characteristic-	Lacerations-
Contamination-	Liberally-
Copulation-	Lyssavirus-
Corrosion-	Maternity-
Crèche-	Membrane-
Differentiate-	Microchiropteran-
Diffused-	Microclimates-
Dioecious-	Morphological Variation-
Dowel-	Mortality-
Echolocation-	MSDS (Material Safety Dadt Sheets)-
Elongation-	Necrosis-
Endothermic-	Nulliparous-
Estrus-	Odiferous-
Eutherian-	Pertagium-
Excrement-	Placental-
Extinction-	Polygynous-
Fertilization-	PPE-
Founders-	Primarily-
Gauze-	Propagation-
Genus-	Protrusions-
Gleaning-	Proximity-
Gorge-	Respiratory-
Guano-	Scrotum-
Hazardous-	Sensate-
Hibernation-	Simulating-
Hierarchy-	Skewed-
Husbandry-	Sputum-
Immaculately-	Substrate-
Immunity-	Synonym-
Imprinting-	Taxonomic-
Innocuous-	

Tertiary-
Testes-
Thermo-regulate-
Torpor -
Vivaparous-

Ventral Surface-
Vertical-
Viable-
Weaning-
Zoonoses-

NOTE: Definitions are being completed to add to final draft.

