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Assessing the affiliative behaviors of captive ghost bats (Macroderma gigas) at Perth Zoo, Western Australia

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https://perthzoo.wa.gov.au/animal/ghost-bat

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Abstract

The ghost bat (*Macroderma gigas*) is the largest microchiropteran and only carnivorous bat species endemic to Australia. Since European settlement, habitat loss from activities such as mining have limited the ghost bat's preferred roosting sites, causing the species to contract its range northward. Through captive breeding programs, Perth Zoo has successfully maintained a colony of ghost bats since 1977 with recent intent for re-introduction to the wild in the future. Perth Zoo wanted to monitor the affiliative behaviors of *M. gigas* prior to the upcoming breeding season and assess any aggressive interactions between the bats. The current study found that both male and female bats exhibit a majority of time hanging, with the females in proximity to each other more than the males. Although rarely observed, the males exhibited more negative affiliative behavior than the females. The males exhibited territorial establishment whereas the females exhibited a more consistent spatial use of their enclosure. Both sexes preferred roosting sites with mock rock or wire substrates, in the upper level of the enclosure and in close proximity to heat lamps or cave entrances. During day-light, both sexes showed positive affiliative behavior towards the "colony" however, this behavior was decreased in hours of darkness. No negative affiliative behavior was observed for both sexes while feeding, suggesting that there was no resource competition for food. Findings of the current study suggest that the overall welfare of *M. gigas* is good prior to the breeding season. The current study provides baseline data to compare bat behavior throughout the coming seasons. Ghost bats are endemic to Australia, and with populations at risk in the wild it is important that Perth Zoo continues to monitor and maintain its captive breeding programs for possible re-introduction of this species in the future.

Keywords: Bats, behavior, *Macroderma gigas*, Perth Zoo

List of Figures

Table of Contents

1. Introduction

1.1 Natural history

Bats are one of the most speciose mammalian orders and greatly contribute to mammalian biodiversity. They are capable of many behavioral and physiological adaptations and hold pivotal ecological roles (Burland and Wilmer, 2001). Bats are an important component for natural systems and agriculture, acting as pollinators and seed dispersers and predators of agricultural pests (Burland and Wilmer, 2001). The ghost bat (*Macroderma gigas*) is in the family Megadermatidae (false vampire bats) and is one of the largest microchiropteran species (Wilmer et al., 1994). *M. gigas* is the only carnivorous species endemic to Australia, residing in the northern tropical region (Hutson et al., 2001; Wilmer et al., 1999). The species was once widely distributed across Australia, and sub-fossil records suggest that the range has contracted northwards following European settlement. The bats have since been restricted to cavernous areas and abandoned mines across tropical and subtropical northern Australia (Wilmer et al., 1994).

1.2 Ecology, habitat and roosting

M. gigas can adapt to many habitats, including the rainforest, however, arid zones in caves, old mines and rock crevices are preferred (Hudson and Wilson, 1986; Hutson et al., 2001). The bats have a high specificity in roost use and roost selection is dependent on several factors: temperature, humidity, air flow, light intensity as well as safety from predators, proximity to foraging areas and whether a site is conducive for reproduction (Avila-Flores and Medellin, 2004; Spanjer and Fenton, 2005). It may be because of this preferred warm and humid microclimate why *M. gigas* has retracted so far north in Australia (Armstrong and Anstee, 2000).

Although roosts are specifically chosen, there are different uses for different types of roosts. The structure of a roost is indicative of the type of use it receives by the bats. Rock crevices and shallow caves are more temporary and may be used strictly for feeding or to house a small number of individuals (Armstrong and Anstee, 2000). More complex caves and roosts may be used for more permanent occupation, such as maternal colonies when females are rearing their young (Armstrong and Anstee, 2000; Spanjer and Fenton, 2005).

In addition to roost specificity, *M. gigas* can have high fidelity to a specific roost (Spanjer and Fenton, 2005). Roost structure can influence roost availability and thus roost fidelity, as well as the assemblage of bats found at that site (Fenton, 1997). Short term movement between roosts can be potentially costly and can disrupt social bonds and lower familiarity with foraging sites (Lewis, 1995). There are differences between the sexes in site fidelity, where males are more territorial and therefore more site faithful than females (Lewis, 1995). Female bats weigh the roost costs and benefits with reproductive condition, and it may be advantageous for females to become familiar with several roosts (Lewis, 1995). However, fidelity to a specific roost may also facilitate the maintenance of territorial borders and thus decrease aggression between territory holders (Lewis, 1995). That being said, individuals may be more likely to cooperate with those whom they interact repeatedly.

Macroderma gigas are carnivores and feed on insects, reptiles, frogs, small birds and mammals and other bat species (Hudson and Wilson, 1986; Ghost Bat Fact Sheet, 2012). The bats are opportunistic and have been observed using a sitting and wait method of hunting, while participating in bursts of foraging (Boles, 1999). *M. gigas* has few known predators, however owls have been known to compete with them for food and some instances bat remains have been found in owl pellets (Hudson and Wilson, 1986; Kaita 2012 Unpublished).

1.3 Social structure

Macroderma gigas are gregarious and have been observed roosting individually or in small groups within a colony (Kaita 2012 Unpublished). Colonization may vary seasonally, but most bats form colonies during at least some of their life cycle (Burland and Wilmer, 2001). In the wild, many individuals may aggregate together in a colony and share common resources such as food, warmth, shelter and suitable roosting sites (Burland and Wilmer, 2001; Kaita 2012 Unpublished). Overall, the social behavior of bats is strongly influenced by their roosting sites and reproduction (Fenton and Ratcliffe, 2010). Bats possess a strong social unity and share information and communicate about various resources, ensuring that survival is maximized for all individuals (Fenton and Ratcliffe, 2010; Kaita 2012 Unpublished).

Within *M. gigas* males are polygamous, and mate with a few females. The bats exhibit strong maternal care, where the females form maternal colonies in which they care for their pups (Kaita 2012 Unpublished). The information learned during this time is essential for the development of the pups, and further enhances their social and communication skills (Fenton and Ratcliffe, 2010). It is this social learning and behavioral flexibility that makes bats adaptable to various environments, however, low reproductive rates leave them vulnerable to sudden changes (Fenton and Ratcliffe, 2010).

1.4 Threats

Since European settlement, *M. gigas* has drastically altered its previously widespread distribution to inhabit a small range in northern tropical Australia (Wilmer et al., 1994). The bats are considered vulnerable under the IUCN Red List, and they are protected in Australia by the *Environment Protection and Biodiversity Act 1998* (Kaita 2012 Unpublished). *Macroderma gigas* is currently faced with threats of habitat loss due to drilling and mining, mine collapse and

human disturbance (Armstrong and Anstee, 2000; Hoyle et al., 2001). Human land development has a huge impact on *M. gigas* which already has a limited availability of preferred roosting sites (Armstrong and Anstee, 2000). In the wild, *M. gigas* is living in fragmented remnant distributions, where there are large concentrations of bats around a few disjunct maternity sites, leaving some colonies vulnerable to extinction on a regional basis (Wilmer et al., 1994).

1.5 Present study aims

Zoos are an important resource for conservation, and maintain viable stocks of species that are faced with challenges such as habitat loss and extinction in the wild (Kaita 2012 Unpublished; Wayre, 1969). Perth Zoo plays an active role in animal conservation through captive breeding programs, with the long-term goal for this species of re-introduction into the wild (Kaita 2012 Unpublished). *Macroderma* gigas has been successfully held at Perth Zoo since 1977, and the zoo is one of few in the world with ghost bats (Kaita 2012 Unpublished). Perth Zoo wishes to assess the affiliative behavior of *M. gigas* prior to the breeding season, which commences in May-June. The behavior of the male and female bats will be compared, as well as the roosting behavior and habitat use within the male and female enclosures. Interactions between individuals in light, dark, while feeding and while non-feeding will also be considered in this study. It is hypothesized that the male bats will exhibit greater aggression towards each other in all aforementioned categories than the females. The long term goal of this study is to assess the behavior of *M. gigas* over the course of the year: prior to breeding, during breeding and post breeding, and to see if there are any seasonal changes in behavior for both the male and female bats.

2. Methods

2.1 Study site

Research was conducted within the Nocturnal House at Perth Zoo in Perth, Western Australia. The male and female ghost bats are held in separate exhibits within the Nocturnal House. The Nocturnal house is on a reverse lighting regime such that the lights are turned on during our night and turned off during the day. The bats were observed for 30 minutes during each session, with the behavior recorded on each minute mark. Observations were recorded for both male and female bats during the "light" schedule and the rest of the observations occurred during the "dark" schedule. Feeding times varied and whenever the bats were observed feeding it was recorded, but the rest of observation sessions were considered non-feeding times. A total of 100 observation sessions were recorded. Observations took place between 7:30 am and 5 pm for 13 days, including both week and weekend days.

2.2 Enclosure map and ethogram development

A map of each enclosure was created and sections of the exhibit were partitioned based on elevation, substrate and area (see Appendix). Each partition was assigned a numeric and alphabetic code, which allowed the bats' roosting preferences to be categorized in relation to other components of the enclosure, such as enrichment. This code was recorded each minute. A behavior ethogram was provided to categorize the behaviors into groups prior to observation (see Appendix). The groups included Resting, Exploratory, Stereotypic and Other. Positive and Negative Affiliative behaviors were also included. The groups were coded with a letter and recorded each minute.

2.3 Male Bat Data Collection

There were three bats in the male exhibit and observations were focused on one dominant male, named Green, and his behavior. The behavior of the other two subordinate males, named Yellow and Orange, was also recorded but behaviors could not be reliably assigned to each of these two individuals. Each bat was previously marked with a colored visible implantable elastomer (VIE) in their ear. This unique marking was viewed from a distance under a black light and allowed for easier tracking of individuals. Positive and negative affiliative interactions between the bats that occurred within each minute were also recorded (See Appendix). A total of 10 observation sessions were recorded in the light and 60 were recorded in the dark.

2.4 Female Bat Data Collection

There were nine bats in the female exhibit and the behavior of the majority of the group was recorded as well as the behavior of the outliers. Positive and negative affiliative interactions between the bats that occurred within each minute were recorded. Interruptions due to human interactions, such as camera flashes and tapping on the glass, were also recorded along with the bats' responses to those stimuli (see Appendix). A total of 10 observation sessions were recorded in the light and 20 were recorded in the dark.

Observations were collected as part of a baseline research project for Perth Zoo and because of this, more data was collected than was actually reported on throughout this paper. The methods sections reflects the research as a whole but analysis is focused on a few key findings.

3. Results

3.1 Overall behavior

The male bats were observed a majority of the time resting (67%). The remaining time was spent mostly out of sight, which is accounted for in the "other" category (24%). No negative affiliative behavior was observed over the course of 2100 data samples (Figure 1). Within each minute, the male bats exhibited neutral behavior with no (nil) interactions (77%). Vocalizing, an exploratory interactive behavior, was observed within the minute (22%). Negative affiliative behavior was also observed within the minute, but made up only 1% of behaviors exhibited within the minute (Figure 2).

The female bats were observed almost exclusively resting (80%). Most of the remaining time was spent exhibiting positive affiliative behavior (12%). No negative affiliative behavior was observed over the course of 900 data samples (Figure 3).

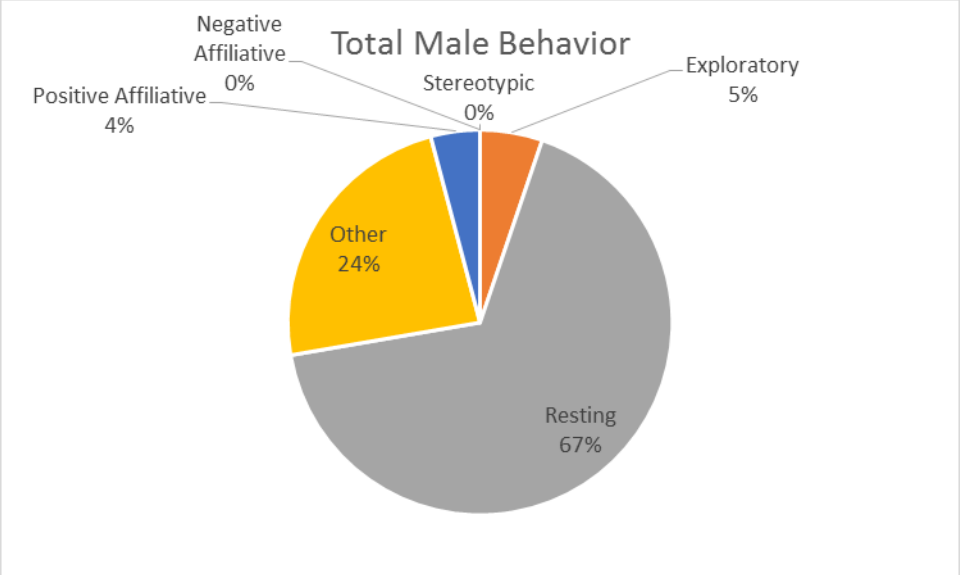

Figure 1. Percentage of behavior of male ghost bats (*Macroderma gigas*) over 2100 data samples. Behavioral categories include stereotypic, exploratory, resting, positive affiliative, negative affiliative and other.

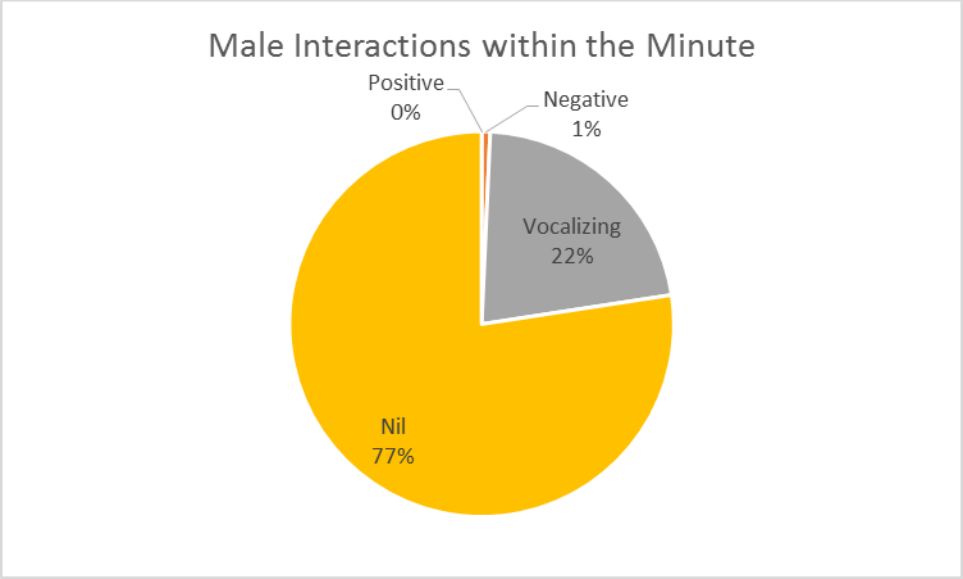

Figure 2. Percentage of behavior of male ghost bats (*Macroderma gigas*) within each minute over 2100 data samples. Behavioral categories include positive affiliative, negative affiliative, vocalizing and nil. It should be noted that for both males and females, positive affiliative behaviors were recorded as the bats behavior occurring on each minute mark and were not repeatedly marked for bat interactions within each minute.

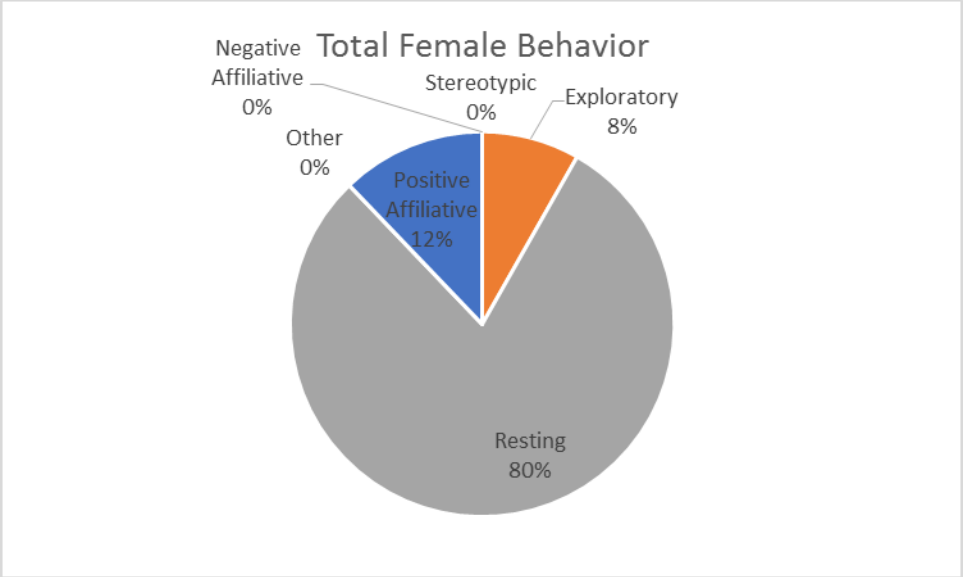

Figure 3. Percentage of behavior of female ghost bats (*Macroderma gigas*) over 900 data samples. Behavioral categories include stereotypic, exploratory, resting, positive affiliative, negative affiliative and other.

3.2 Spatial and enrichment use within enclosure

Over 2100 data samples, the male bats were observed in almost every area of the enclosure. The Dominant was observed heavily in Area 1. Subordinate 1 was observed the most in Area 6 and Subordinate 2 was observed the most in Area 5 (Figure 4). Second to these areas was Out of Sight—areas not visible by observation—where the Dominant and Subordinate 2 were also observed a majority of the time. Subordinate 1 consistently used other areas and was visible throughout most of observation (Figure 4).

In general, the female bats consistently used all areas of the enclosure over the 900 data samples, however, the majority of bats were observed almost equally in Areas 6 and 7. The outliers were observed heavily in Area 4 (Figure 7). Area 4 was the second preferred area for the majority and Areas 6 and 7 were second preferred for the outliers. Overall, the females preferred Areas 4, 6 and 7 slightly more than the other areas (Figure 7).

Within both the male and female enclosures there were several types of substrate and different forms of enrichment. In the male enclosure, the Dominant preferred mock rock walls whereas the Subordinates preferred wire meshing (Figure 5). In the female enclosure, both the majority and the outliers favored wire meshing, with mock rock walls as a close second choice (Figure 8). In addition to area partition and substrate, both the male and female enclosures were split into elevation levels. Overall, both the males and females were observed almost exclusively in the upper half of their respective exhibits (Figure 6, Figure 9).

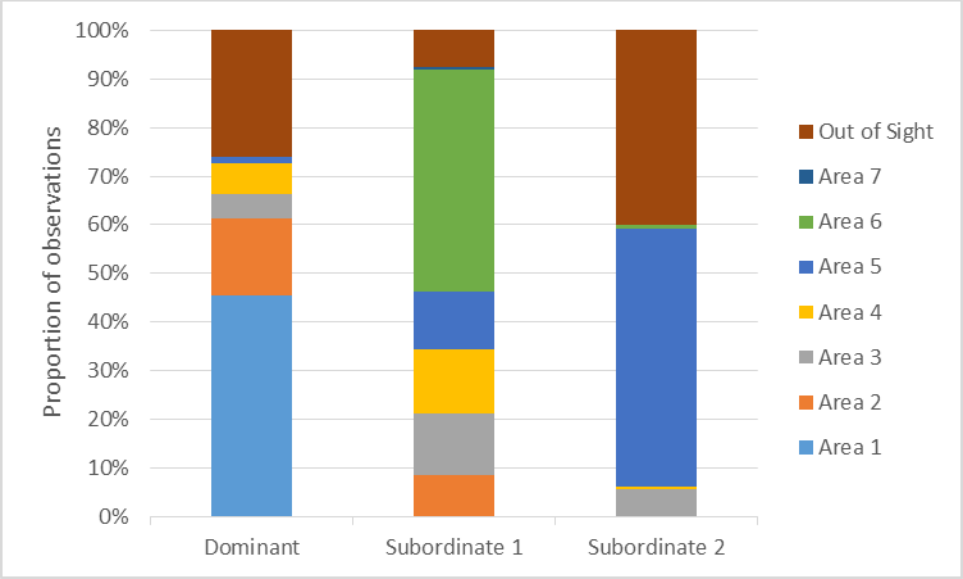

Figure 4. Male ghost bat (*Macroderma gigas*) spatial use of enclosure over 2100 data samples. Proportion of observations in each area category in relation to individual bat.

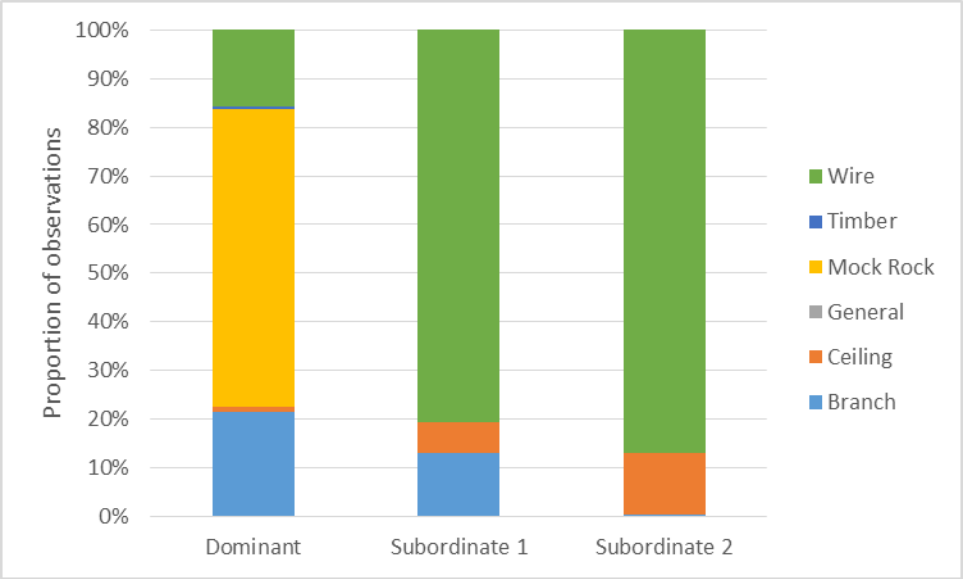

Figure 5. Male ghost bat (*Macroderma gigas*) use of substrate and furniture enrichment over 2100 data samples. Proportion of observations in each enrichment category in relation to individual bat.

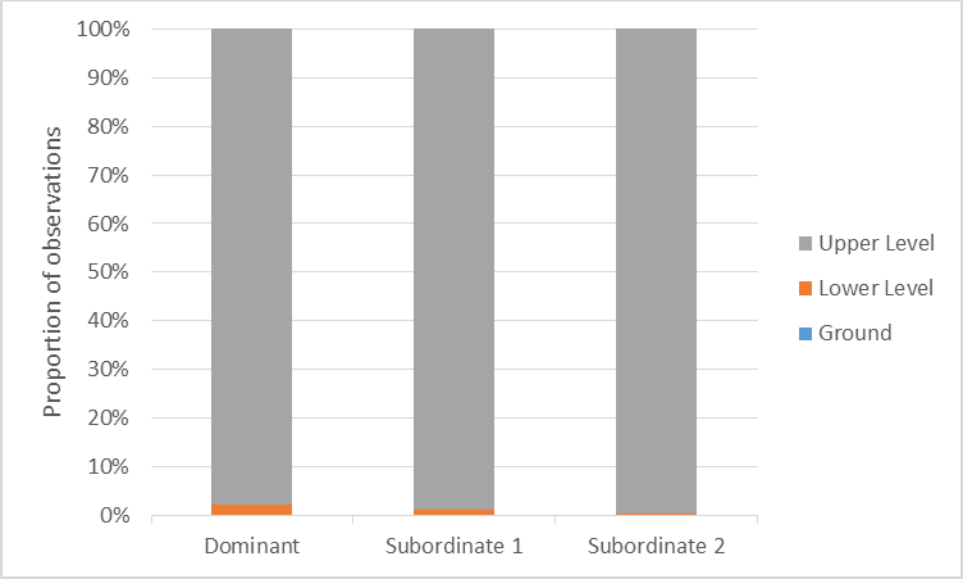

Figure 6. Male ghost bat (*Macroderma gigas*) use of elevation within enclosure over 2100 data samples. Proportion of observations in each elevation in relation to individual bat.

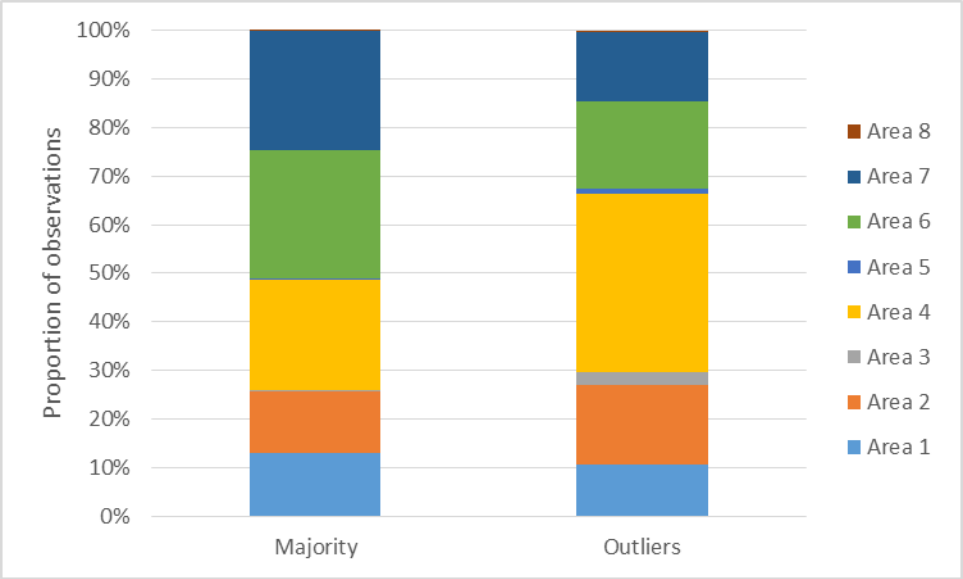

Figure 7. Female ghost bat (*Macroderma gigas*) spatial use of enclosure over 900 data samples. Proportion of observations in each area category in relation to the majority and outlier groups of bats.

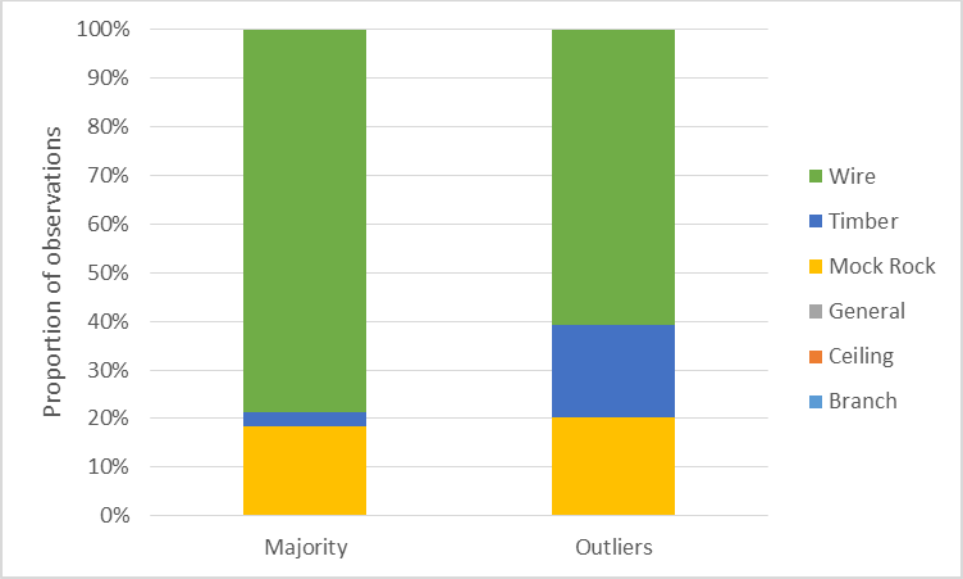

Figure 8. Female ghost bat (*Macroderma gigas*) use of substrate and furniture enrichment over 900 data samples. Proportion of observations in each enrichment category in relation to the majority and outlier groups of bats.

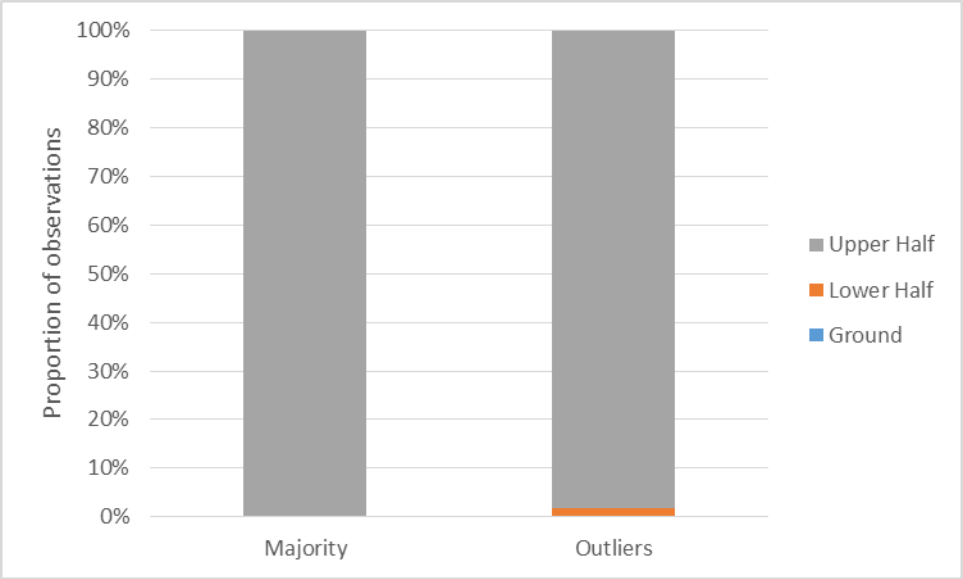

Figure 9. Female ghost bat (*Macroderma gigas*) use of elevation within enclosure over 900 data samples. Proportion of observations in each elevation in relation the majority and outlier groups of bats.

3.3 Light versus dark

When the lights were on in the male enclosure, the bats were observed a majority of the time hanging (57%). The males were also observed resting in proximity to each other (24%) and

out of sight (18%) (Figure 10). When the lights were off, the males remained hanging (68%), but spent less time in proximity (1%) and more time out of sight (24%) (Figure 11).

When the lights were on in the female enclosure, the bats were observed hanging (66%) and huddling (26%) (Figure 12). When the lights were off, the female bats were observed almost exclusively hanging (87%) and the remaining time was spent mostly feeding (10%) (Figure 13).

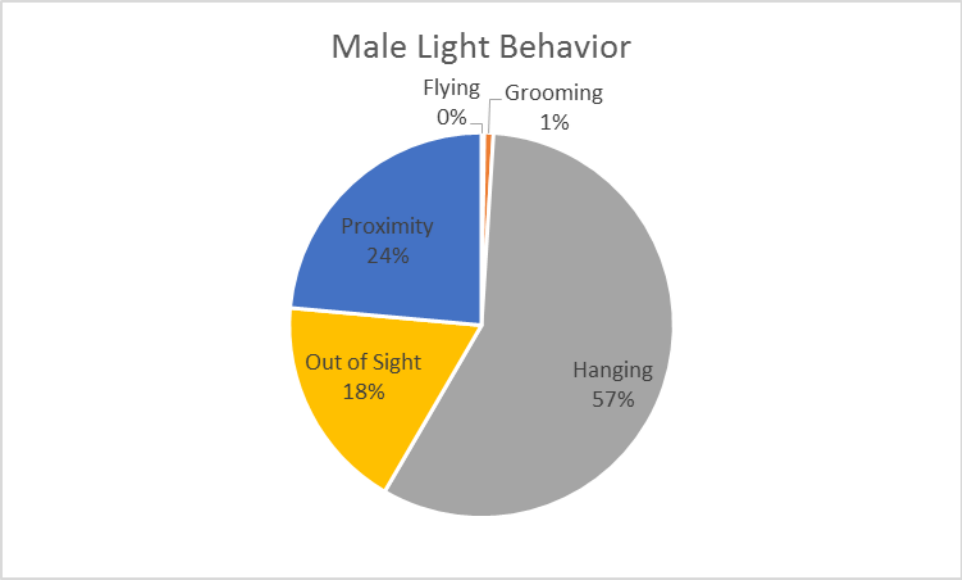

Figure 10. Percentage of behavior of male ghost bats (*Macroderma gigas*) from 7:30-8:30 am (lights on) over 300 data samples. Behavioral categories include flying, grooming, hanging, proximity and out of sight. Due to the nature of this pie chart (showing proportions of a whole), small values were rounded automatically and considered 0% of the whole.

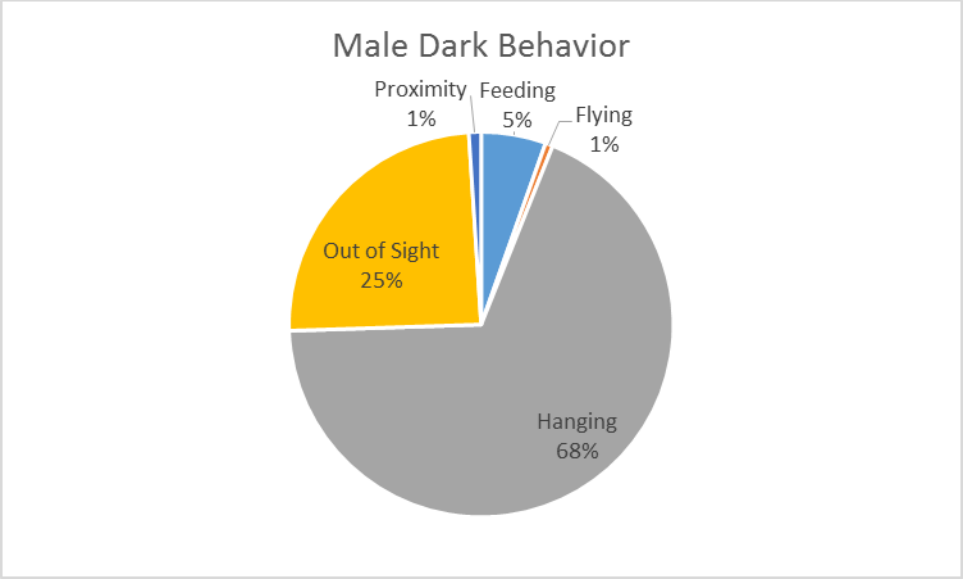

Figure 11. Percentage of behavior of male ghost bats (*Macroderma gigas*) from 8:30 am-5:00 pm (lights off) over 1800 data samples. Behavioral categories include feeding, flying, hanging, proximity and out of sight.

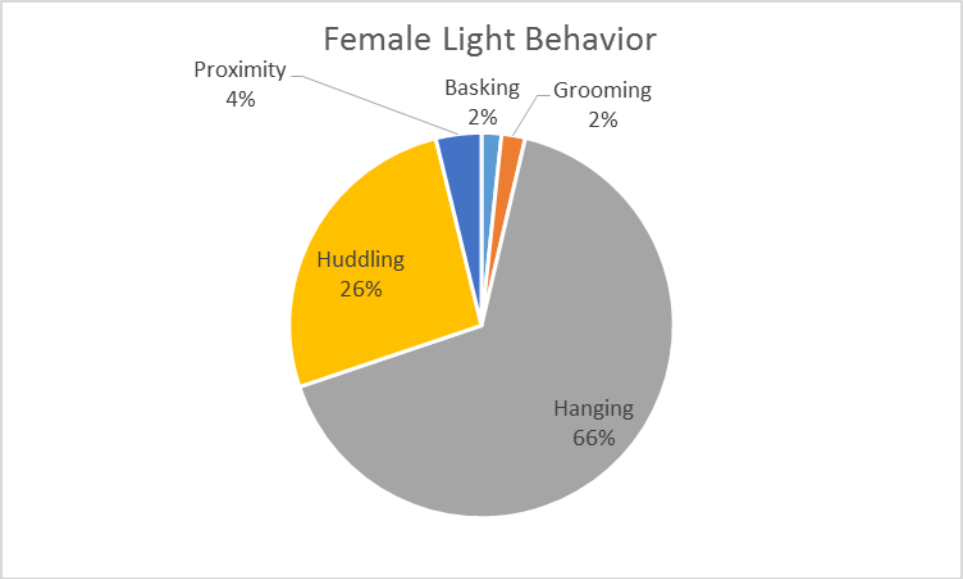

Figure 12. Percentage of behavior of female ghost bats (*Macroderma gigas*) from 7:30-8:30 am (lights on) over 300 data samples. Behavioral categories include basking, grooming, hanging, huddling and proximity.

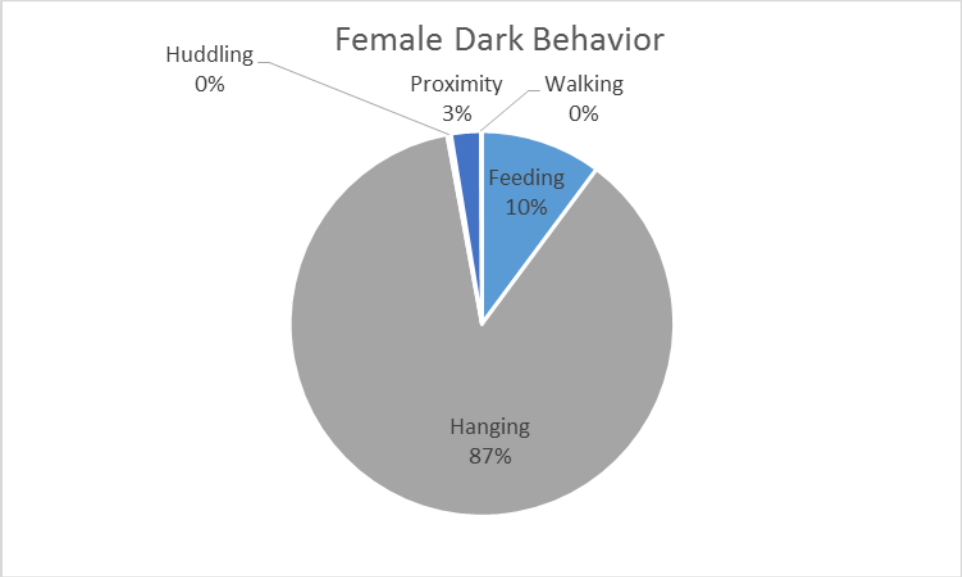

Figure 13. Percentage of behavior of female ghost bats (*Macroderma gigas*) from 8:30 am-5:00 pm (lights off) over 600 data samples. Behavioral categories include feeding, hanging, huddling and proximity and walking. Due to the nature of this pie chart (showing proportions of a whole), small values were rounded automatically and considered 0% of the whole.

3.4 Feeding versus non-feeding

The male bats showed no negative or positive affiliative behaviors during feeding and thus figures were not included. Feeding was defined as any bat having food in its mouth. Feeding was considered complete when the last bat had no remaining food in its mouth.

The female bats also showed no negative or positive affiliative behaviors during feeding and thus figures were not included. Feeding was defined as any bat having food in its mouth. Feeding was considered complete when the last bat in the outlier group had no remaining food in its mouth.

It should be noted that for both males and females, positive affiliative behaviors were recorded as the bats behavior occurring on each minute mark and were not repeatedly marked for bat interactions within each minute. Therefore, bats could have been feeding while also showing positive affiliative behaviors, but this was recorded solely as feeding time.

4. Discussion

4.1 Comparing male and female behavior

Overall, males and females spent a majority of their time resting. Roosting is a strong characteristic of bats, which spend a majority of their life cycle in colonies of either large or small groups (Kaita 2012 Unpublished). However, the female bats spent more time in proximity to each other than the male bats. In the wild, male ghost bats are polygamous and mate with several females during the breeding season, suggesting that they will defend their females and may not cooperate well with other males (Kaita 2012 Unpublished). After the breeding season, the female bats form maternal colonies. Within these strictly female colonies, strong maternal care is exhibited throughout the early life of the pups. Maternal groups also provide pups with important social skills, including learning and communication (Kaita 2012 Unpublished; Fenton and Ratcliffe, 2010). The maternal instincts and social bonding of the females after the breeding season may explain why the females exhibited more time in proximity to each other than the males. The males may be defensive and have a more difficult time cooperating with other males, and may explain why the males were rarely observed in proximity to each other.

Within each observation minute, the male bats rarely exhibited negative affiliative behavior. When negative affiliative behavior was observed, it was an instance of displacement or chasing between two individuals. However, because any negative behavior was rarely observed, it may be indicative of a common dispute between individuals. Vocalizing between the bats was common, however, there are differences in the frequencies of calls and this study did not differentiate between aggressive or social calls (Fenton, 2003). Aside from these behaviors, the male bats exhibited neutral behavior within the minute and maintained their calm resting behavior. Male ghost bats are territorial, which can lead to aggression between males.

However, individuals may be more likely to cooperate with those whom they interact repeatedly (Lewis, 1995). These findings combined with past research suggest that although there were some disputes (negative affiliative behavior) among the males, overall they were not aggressive. Over time, the males may have become more tolerant of each other's presence within the enclosure.

4.2 Spatial and enrichment use within enclosure

High specificity in roost selection is expected of bats, and is usually dependent on factors such as temperature, humidity and light intensity, as well as access to foraging areas and safety from predators (Avila-Flores and Medellin, 2004). Such factors are limited within the Zoo's exhibits, however, the males and females still showed roosting preferences within their enclosures. The male bats each had a section of the enclosure that they spent a majority of time in. The Dominant had preference over the visible cave area which was formed with mock rock, Subordinate 1 preferred the wire meshing under a heat lamp, and Subordinate 2 was observed on the wire meshing on the back wall of the enclosure, where it was dark and there was the entrance to a second cave. All of these areas were in the upper level of the exhibit, usually close to or on the ceiling.

In a study about the roost fidelity of bats, Lewis (1995) explained how there are differences between the sexes in site fidelity. Male bats are more territorial and are more site faithful than females, however fidelity may facilitate maintenance of territorial borders and therefore decrease aggression between territory holders (Lewis, 1995). This study supports the findings of the current study, where each individual male had his own preferred site within the enclosure, all of which were spaced evenly from each other. Combined with the lack of aggressive behavior found among the males, it is suggested that the males have established their

own territory distribution and have communicated that amongst each other, and have a mutual understanding about those territorial boundaries. However, this doesn't mean that each bat was strictly found in his own area. The bats shared the enclosure and occasionally were found in other established locations, but very little aggressive behavior was recorded.

The females were more consistent with their spatial use than the males, however still showed preferences within their enclosure. The majority preferred the wire meshing next to a heat lamp, which extended across one window of the enclosure. The outliers aggregated to the middle of the exhibit, on the mock rock cave opening directly above the feeding platform. Both of these areas are located relatively close to each other. The size and structure of a roost is indicative of the type of use by bats, with many bats will use granite crevices and shallow caves as temporary sites, and more complex areas for permanent occupation, including maternal colonies (Armstrong and Anstee, 2000). Short term movement between roosts is potentially costly for bats in the wild. Female bats weigh the costs and benefits of roost site in relation to reproductive condition, where it may be advantageous for them to become familiar with several roosts (Lewis, 1995; Spanjer and Fenton, 2005). These previous findings may explain why the females were observed consistently in many areas of the enclosure, instead of establishing one specific site, like their male counterparts.

Overall, both male and female bats preferred areas closer to heat lamps and cave openings. Thermoregulatory processes influence the ability of species to use different kinds of roosts, suggesting that areas with heat could have been more attractive to the bats and thus why the majority of females was observed near the lamp (Avila-Flores and Medellin, 2004). Caves made of sandstone or limestone are the natural habitat of ghost bats, providing protection from predators, preferred microclimate and seclusion from light and disturbances (Kaita 2012

Unpublished). Although in captivity, the instinctual comfort of heat and caves may be attractive to the bats, and may explain why both sexes showed preference to the caves and heat lamp enrichment in their enclosure.

4.3 Light versus dark

Within the Nocturnal House the lighting is reversed, which allowed the current study to assess behavioral interactions with the lights on and with the lights off. The male bats were observed mostly hanging in both the light and the dark, however in the light, the males exhibited considerably more proximity to each other than they did in the dark. The female bats overall exhibited more proximity to each other, however they were observed a majority of the time huddling in the light compared to the dark. Bats are nocturnal and are inactive during daylight hours. In the wild, most of their activity occurs during the night, when it is dark outside and they can hunt more effectively (Hudson and Wilson, 1986). When they are not hunting, the bats rely on their colony for warmth and safety, especially when roosting. It is this strong social unity that maximizes the chances of survival for all bats in the colony (Kaita 2012 Unpublished). These findings may explain why the male bats exhibited more proximity to each other during the light compared to the dark, suggesting that they rely on each other more when they are inactive. Female bats exhibit strong social interactions, especially when they are rearing pups in maternal colonies, suggesting that positive affiliative behaviors in proximity, such as huddling, are common among female bats regardless of the time of day (Armstrong and Anstee, 2000).

4.4 Feeding versus non-feeding

Neither the male or female bats exhibited positive or negative affiliative behaviors during feeding times. It was expected that the bats, especially the males, would exhibit greater negative affiliative behavior during feeding. However, the males were neutral when feeding and

maintained their territory throughout feeding. The findings suggest that there was no resource competition among food for the bats. The findings further suggest that the male bats may have previously established individual territories, while maintaining mutual understanding of those territories.

4.5 General welfare

After assessing the affiliative behavior of captive ghost bats, the current study suggests that both the male and female bats are in a good behavioral stage prior to their breeding season. Both males and females exhibited neutral and relatively normal interactions with each other and very little aggressive behavior was observed. The roosting preferences and enrichment use of the enclosure showed that both males and females were utilizing the upper level of their enclosures and were content with their preferred areas. There was also no sign of resource competition for food or heat lamps, suggesting that the bats were living harmoniously in their respective "colonies" prior to the breeding season. The current study provides good baseline data that Perth Zoo can utilize as the breeding season commences. Any data collected during the breeding season and after the breeding season can be compared against the stable behavioral data of the current study to gain an overall understanding of the ghost bats as they continue their life cycle.

5. Conclusion

The current study demonstrated that male and female ghost bats spend a lot of time resting, however females rest in closer proximity to each other than males. In the wild, the females form maternal colonies where they collectively rear their young and provide them with necessary resources to survive, which may explain why the females were in proximity more than the males (Armstrong and Anstee, 2000). Within each minute, males were exhibited more

negative affiliative behavior than females, however the number of observations was low and the males spent almost all of their time not interacting with each other. Male ghost bats are more territorial than females, however the maintenance of their territory may decrease aggressive interactions among individuals. In addition to this, individuals are less likely to show aggression towards individuals with whom they interact repeatedly (Lewis, 1995). Males and females exhibited preferences to roosting sites within their respective enclosures. The individual males had each established a territory separate from one another—Dominant in the mock rock cave, Subordinate 1 on the wire heat lamp and Subordinate 2 on the wire of the back wall—and were observed spending a majority of time in that established territory. The females were consistent in their enclosure usage, but preference was showed in central areas of the enclosure, consisting of mock rock and wire substrate. However, males are more site faithful than females, due to their strong territory defense (Lewis, 1995). Females prefer several roost options, where factors such as reproduction may play a role in roost choice (Spanjer and Fenton, 2005). In the light, both male and female bats exhibited more positive affiliative behavior (proximity, huddling) to their respective "colonies" but in the dark these behaviors were almost absent. No negative affiliative behaviors were observed while feeding, for both sexes, suggesting that there was no resource competition for food.

Limitations to this study include observer bias. The ethogram was helpful in defining key terms to record during observation, however differences in what is considered proximity, huddling and feeding could change the accuracy of data being collected. Also, identifying the Dominant from the Subordinates was challenging, especially when all three individuals were roosting in a similar areas or visiting each other in their established territories.

The current study suggested that the general welfare of the bats was good. The bats participated in seemingly normal behavior which is a positive sign as the bats soon go into their breeding season. The data collected during this study provides stable baseline data that Perth Zoo can use in the future if they wish to assess the behavior of the ghost bats in the coming seasons. Ghost bats are endemic to Australia, and with populations at risk in the wild it is important that Perth Zoo maintains its captive breeding programs for possible re-introduction of this species in the future.

6. References

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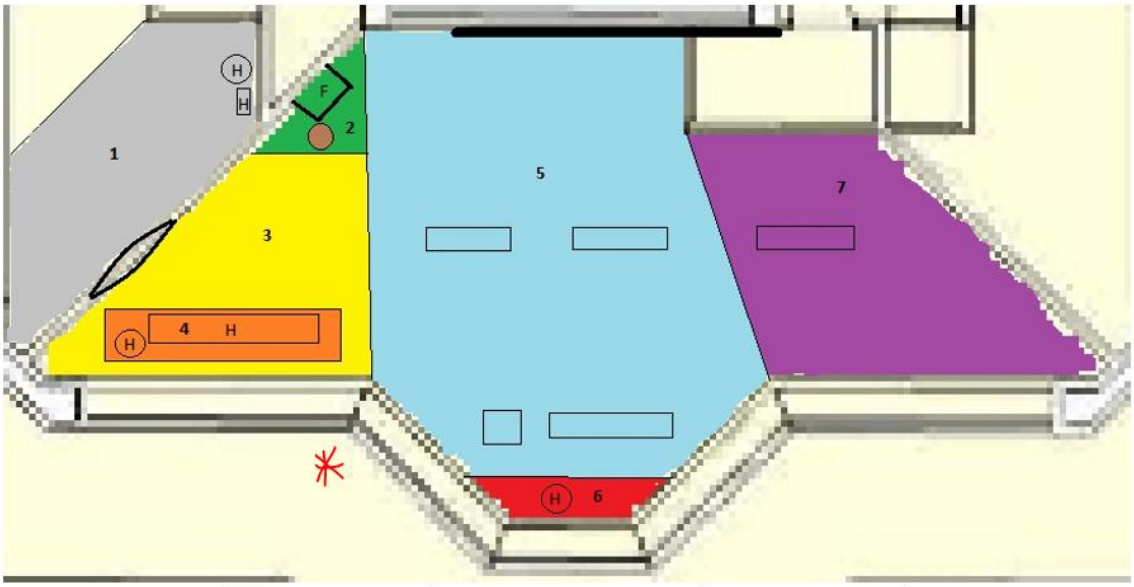
Appendix

Male Exhibit Map and Area Codes:

Male Ghost Bat Exhibit Map

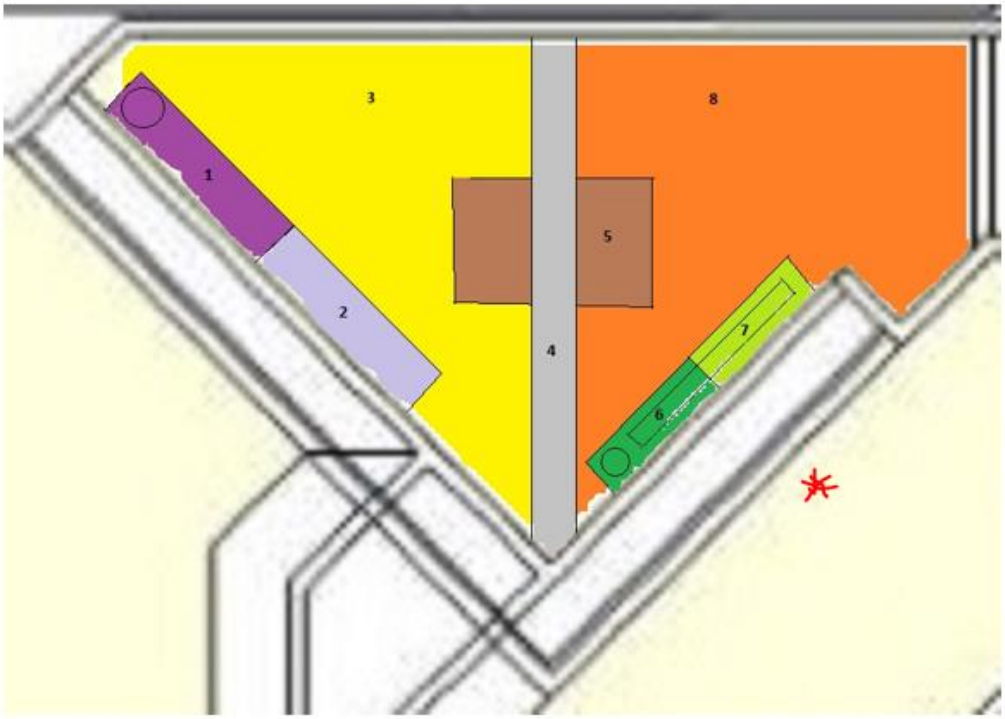


Area	Furnishing	Elevation
1	**G** - General	**U** - Upper Half
2	**W** - Wire	**L** - Lower Half
3	**M** - Mock Rock	**G** - Ground
4	**T** - Timber	
5	**B** - Branch	
6	**C** - Corner of Ceiling/Wall	
7		
8		

* denotes where observations took place

Female Exhibit Map and Area Codes:

Female Ghost Bat Exhibit Map



Area	Furnishing	Elevation
1	**G** - General	**U** - Upper Half
2	**W** - Wire	**L** - Lower Half
3	**M** - Mock Rock	**G** - Ground
4	**T** - Timber	
5	**B** - Branch	
6	**C** - Corner of Ceiling/Wall	
7		
8		

* denotes where observations took place

Male and Female Behavior Ethogram:

Ghost Bat Ethogram

Resting Group: **R**	**Exploratory** Group: **E**	**Stereotypic** Group: **S**	**Other** Group: **O**	**Positive/Neutral Affiliative Behaviour** Group: **P**	**Negative Affiliative Behaviour** Group: **N**	**Human Interactions** (Female bats only)	**Animal Response** (Female bats only)
Hanging	Flying	Pacing (same pathway is repeated 2 or more times)	Out of sight	Proximity (within 20cm, no negative behaviours)	Displace	Glass Bang	No Change in Behaviour
Self-grooming	Walking (feet only)	Turning in circles (2 or more times in a row)	Urinating	Huddle (within 2cm of each other)	Chase	Camera Flash	Evasive Response (retreats away from Human or seeks cover)
Basking Under Heat Lamp	Climbing (using wings)		Defecating	Copulate	Stationary Wing Flap	Calling to Animal	Social Response (approaches human)
Lying on Ground	Eating Food			Suckling	Aggression (foot grab or biting)	Keeper Interaction	Aggressive Response (hisses or lunges toward human)
	Drinking			Nil (did not occur)	Stare (Head orientated towards >5sec within 30 cm)	Nil (did not occur)	Attentive Response (pauses and listens)
	Vocalising				Nil (did not occur)		Nil (no human interaction)

Male Recording Sheet:

Minute	Dominant Male (Green)	Group	Area Code	Subordinate Male (Orange or Yellow)	Group	Area Code	Other Subordinate Male (Orange or Yellow)	Group	Area Code	First Bat Interaction within the minute (with ID's: D,S,S)	Group	Area Code
1												
2												
3												
4												
5												
6												
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30												

Information to be recorded for each **Male Ghost Bat** observation.

Exhibit Number	
Observer's Full Name	
Date	
Day	
Observation Start Time	
Observation End Time	
First Feed Time	
Second Feed Time	
Daily Zoo Visitors	

Notes:

Female Recording Sheet:

Minute	Majority Behaviour	Group	Area Code	Outlier Behaviour	Group	Area Code	First Bat Interaction within the minute	Group	Area Code	First Human Interaction within the minute	Animal Response	Area Code
1												
2												
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Information to be recorded for each **Female Ghost Bat** observation.

Exhibit Number	
Observer's Full Name	
Date	
Day	
Observation Start Time	
Observation End Time	
First Feed Time	
Second Feed Time	
Daily Zoo Visitors	

Notes: