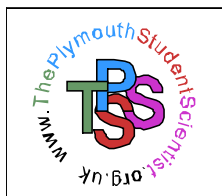


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Anti-predator responses of a group of black lion tamarins (*Leontopithecus chrysopygus*) in reaction to a terrestrial and an aerial predator

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Abstract

Anti-predator training was conducted on a free-ranging group of black lion tamarins at the Durrell Wildlife Conservation Trust, in July 2007. The study aimed to investigate the anti-predator behaviours exhibited in response to different predators, and determine if a predatory threat in the morning influenced behaviour later in the day. The tamarins were exposed to three treatments; a terrestrial predator, an aerial predator, and the aerial predator coupled with an adverse tamarin scream. The tamarins gave alarm calls and exhibited piloerection in response to both predators. A stronger reaction was perceived in response to the aerial threat; however this may have been influenced by the lack of previous experience. Vigilance was significantly altered towards the predator and remained changed throughout the day, showing a high state of awareness for all treatments. The results indicated that there was no significant change in behaviour over the day. This is a positive outcome, as it shows that the captive-bred tamarins are able to recover quickly from a predator threat. In the wild this would be essential, due to the high costs involved with anti-predator behaviour.

Keywords: anti-predator behaviour; anti-predator training; black lion tamarin; *Leontopithecus chrysopygus*.

1. Introduction

The black lion tamarin (BLT) is a critically endangered primate (IUCN 2007a) indigenous to the Atlantic Forest of Brazil (Anon 2002). The Morro do Diabo State Park in São Paulo, is the last stronghold of the species and is a site of extensive deforestation (Fig. 1.2) (Anon 2002). BLTs are threatened by anthropogenic factors, such as habitat destruction and hunting for the pet trade, as well as natural disasters (Kleinman & Rylands 2002). Currently BLTs are found in only nine fragmented forest patches (Kleinman & Rylands 2002) with no opportunity for dispersal (Holst & Ballou 2006). Eight of these patches are too small to be viable in the foreseeable future (Kleinman & Rylands 2002). The lack of additional habitat for BLTs to disperse into and the scarcity of appropriate conservation strategies (Holst & Ballou 2006) are causes for concern among conservationists.

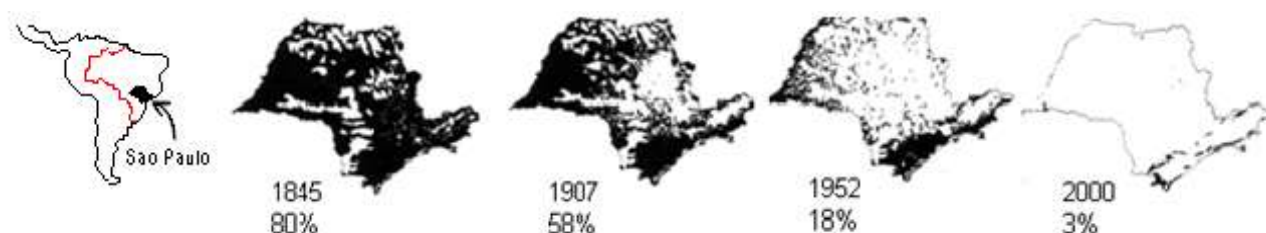


Figure 1.2 The disappearance of BLT habitat in São Paulo, Brazil. The black areas show the ranges of BLTs (after Anon 2002).

These problems are being combated by focusing conservation efforts on a metapopulation management plan (Anon 2002), involving; translocation, managed dispersal, reintroduction, habitat preservation and education (Kleinman & Rylands 2002). Valladares-Padua and Cullen (1994) applied an approximate density value of 3.72 individuals/km² to fragmented habitat patches and estimated that there was a total wild population of only 1004 individuals remaining. The study concluded that the survival of the species would be greatly improved by metapopulation management. This strategy includes captive populations (Feistner 2003), which are maintained at approximately 500 individuals (Kleinman & Rylands 2002), and can be used to augment wild populations (Ostermann *et al.* 2001). Ballou and Valladares-Padua (1997 In: Martins 1999) advised that the management strategy should aim to sustain 95% genetic diversity in the next 100 years. This can be maintained through reintroductions of captive-bred individuals (Rambaldi *et al.* 2006).

Reintroduction is the ultimate goal of many captive-breeding programmes and reintroduction attempts often fail due to a lack of appropriate experiences in captivity (Shier & Owings 2006). For reintroductions to be successful the animal must have an appropriate behavioural repertoire prior to release, including adequate navigation, locomotion and foraging skills, an ability to acquire suitable shelter, species-specific behaviours and predator avoidance skills (Box 1991). A lack of predator recognition has been the failing point of many reintroduction programmes (Griffin *et al.* 2000; Wallace 2000). Few of these essential behaviours are innate (Box 1991); however they can be developed through captive experiences (McLean *et al.* 1996; Shier & Owings 2006). Snowdon (1989) recommended that “animals should be maintained in captivity so that they can retain their ability to survive if they are reintroduced into the wild”.

For small mammals, such as tamarins, it is essential to respond efficiently to a predator threat, due to the high metabolic rate of the species and the high energy costs involved with anti-predator behaviour (Caine 1998). Tamarins and marmosets (Callitrichidae, Campbell & Snowdon 2007) are predated by a number of species, including boa constrictors (*Boa constrictor*), ocelots (*Leopardus pardalis*) (Kinzey 1997), coatis (*Nasua* spp.) (Franklin & Dietz 2001) and raptors, such as burrowing owls (*Athene cunicularia*) (Stafford & Ferreira 1995). Predation attacks are common occurrences (Caine 1998). Typical reactions to predators include alarm calling, mobbing, freezing or fleeing (Gautier-Hion & Tutin 1988 In: Caine 1998).

Reintroduction has already proved to be a successful conservation tool for the golden lion tamarin (*Leontopithecus rosalia*) (Kleinman & Rylands 2002) and population numbers are now increasing (IUCN 2007b). In 2006 the reintroduced populations contributed to approximately 40% of the total wild population (Rambaldi *et al.* 2006). For BLTs, reintroductions are still a relatively new strategy, with the first in 1999 (Kleinman & Rylands 2002). This reintroduction involved a male BLT from the free-ranging environment at the Durrell Wildlife Conservation Trust (DWCT). The male survived for over three months before being predated. Although this male had developed locomotory, foraging and navigational skills whilst in the free-ranging environment, predation was still a major threat once released. (Valladares-Padua *et al.* 2000).

The BLTs at the DWCT are part of a genetically healthy population that aims to interact with wild individuals (Feistner 2003). The free-ranging environment encourages species-specific behaviours to be displayed, such as movement through spindly branches and foraging skills (Price *et al.* 1989). The environment cannot, however, teach individuals to avoid predation. As captive-bred BLTs have not experienced evolutionary isolation, but have suffered ontogenetic isolation from predators, the likelihood of anti-predator training being successful is heightened (Griffin *et al.* 2000).

In previous years, the free-ranging tamarins at the DWCT have been subjected to anti-predator training. In 2003, Heigl investigated the different responses to three stimuli - a cat, a plain snake and a striped snake. It was found there were significantly more vocalisations during the presentation of the predators, showing a level of recognition. No significant change in the use of the enclosure was found. In 2005, Bacon conducted a similar study, whereby the model predator was presented singularly and then coupled with an adverse stimulus. The stimulus was seen to intensify the anti-predator reactions.

The current investigation aimed to extend this research by assessing the reactions of the free-ranging BLTs at the DWCT to different predators – a cat, a bird and a bird coupled with an adverse tamarin scream. Due to the need for practical conservation measures, such as reintroduction, the investigation aimed to show how the presence of a predator caused specific essential behaviours, such as foraging and vigilance, to change over a period of time. If a significant change in behaviour is seen, this could highlight potential problems with reintroductions, as recovery from exposure to a predatory threat needs to be rapid (Caine 1998).

2. Materials and Methods

2.1 Study Subjects

The investigation was conducted at the DWCT in July 2007. The study subjects were a family group of seven free-ranging BLTs, consisting of a dominant pair and five of their offspring (Appendix 1). During the day the tamarins were free to range throughout the zoo. At night they were securely housed in huts (Plate 2.1). The wood was also shared with a group of silvery marmosets (*Mico argentatus*) (DWCT 2006), however these will not be discussed in this study.

The free-ranging broad-leaved wood (Plate 2.1) measured approximately 1,350m², with an additional 3,350m² of surrounding woodland and included a range of species, such as sweet chestnut (*Castanea sativa*), oak (*Quercus robur*) and sycamore (*Acer pseudoplatanus*) (Bacon 2005).



(Source taken by Author 2007)

Plate 2.1 Tamarin Wood. The photograph on the left shows the BLT shed with ropes connecting to surrounding trees. The second hut with perches and connecting ropes is seen on the right.

The study timetable needed to integrate with the daily routine (Table 2.1). The zoo is open to the public from 0930 until 1800. Visitors were not allowed access to the wood, but were able to view the wood from the paths and viewing areas.

Time	
0830	Huts opened Breakfast of soaked pellets and banana smoothie containing vitamin supplements
1100	Fed wax moths for the visitor talk
1230	Lunch of mixed fruit, vegetables and a protein source
1700	Supper of wax moth larvae, locusts and bread soaked in honey Shut away for the night

(Author 2008)

Table 2.1 The BLT daily routine

2.2 Pilot Study

Initial observations allowed the observers to become skilled at identifying each individual (Appendix 2) and to become familiar with group activity patterns. The tamarins were visited three times a day: during the morning, midday and in the afternoon. This also allowed the tamarins to become habituated to the observers, thus removing observer bias (Martin & Bateson 2007). Ethograms were constructed to define specific behaviours and vocalisations (Appendix 3).

When individuals could be easily identified, observations using the 2005 check sheet began (Bacon 2005). A focal sampling technique was used (Martin & Bateson 2007) to record; behaviour, vigilance, height and cohesion. One individual was observed every 30 seconds. Observations were taken at different times during the day to gauge when the tamarins were most active and when there were periods of rest. Observations were taken over twenty minutes to allow practise of recording behaviour. After the pilot study it was decided to modify the check sheet (Appendix 4).

Reliability tests were conducted to ensure that the difference in data collectors did not affect the reliability of the results. It was found that there was an 87% accuracy rate. The differences found were discussed, compromises agreed upon, and the ethograms altered accordingly (Appendix 3). To further increase reliability between observers, markers were placed in the wood at distances of 2, 5 and 7m from both of huts (Appendix 5) and heights of 1, 2 and 3m from the ground.

During the final study; behaviour, vigilance, height, distance from the huts and vocalisations were recorded. Due to the daily routine (Table 2.1) observations were limited to 10 minute blocks. An observation timetable was devised to ensure there was no bias towards certain individuals (Appendix 6).

2.3 Control Week

To collect baseline data the tamarins were observed for seven days before a predator was shown using a focal sampling method (Martin & Bateson 2007). Observations on four focal individuals were collected simultaneously. Each observer recorded the behaviour of two individuals at thirty second intervals. This allowed time for the focal individual to be found, identified and data collected.

2.4 Predators

During training days the predator was presented at 0940. An additional observation was taken at 1000. During exposure to the predator, behaviours were recorded using a scan sampling method (Martin & Bateson 2007) (Appendix 7). Behaviour was documented every 15 seconds. Vocalisations were recorded using a Sony TCM-5000EV cassette recorder and a Sennheiser ME66 shotgun microphone with a MZW66 windscreen and a K6 powering module, to allow later analysis.

2.4.1 The Cat

To simulate a terrestrial predator a toy tiger was dragged along the forest floor between the two huts (Plate 2.2), as both were used by the tamarins throughout the day. To prevent anti-predator behaviour being displayed before observations started, the cat was concealed by one observer whilst taking it into the wood. Observations began when that observer was ready to pull the cat along the ground.



(After Bacon 2005)

Plate 2.2 Aerial map of tamarin wood with the cat run shown in yellow; the cat was placed next to the second hut (blue dot) and pulled towards the BLT hut (green hut) and then out of the wood. The run took approximately 5 minutes.

2.4.2 The Bird

A painted wooden model of a bird, with a wing span of 100cm, was used to simulate an aerial predator. A length of fishing wire was tied between two trees, so that it crossed an open space in the middle of the wood. A second line was tied in the same way. The bird was then hooked to the first line and connected to the second by the head and tail, allowing the bird to be 'flown' in either direction. The run was repeated twice. To avoid causing extra stress to the tamarins with ladders, the bird was stored in the tree, underside down, so that only the plain wood could be seen.



(After Bacon 2005)

Plate 2.3 Aerial map of the tamarin wood with the bird run shown in white; the bird was 'flown' from a tree below the BLT hut (green dot) up to a tree next to the second hut (blue dot) and back again. This took approximately 7 minutes.

During the second and third presentation, the model was coupled with a 'death scream' of a BLT and a cotton-top tamarin (*Saguinus oedipus*) (M. Hauser pers. comm. 2007). The two screams were paired, as the BLT vocalisation was not a full

scream, however it was deemed important to use as it was from the same species. The scream was played through a laptop and a loud speaker system whilst the bird was in flight. This was repeated twice. The bird was shown four times in total, twice with the adverse stimuli and twice without.

2.5 Data Analysis

Data was formatted in Microsoft Office Excel 2007™. Averages for each of the recorded behaviours were calculated over the control week and for the different treatments.

Behaviours were analysed as a group, as BLTs are social primates (Carroll 2002) and individual behaviour may have been influenced by the dominance hierarchy, as well as the level of previous experience, which varied within the group.

Due to the small sample size (N = 7) results were analysed using a non-parametric test (Martin & Bateson 2007). SPSS™ was used to conduct a Friedman's test to determine whether behaviour over the day changed significantly between the different treatments. When a statistical difference was found (P < 0.05) results were analysed in a pairwise manner using a Wilcoxon signed-ranks test to determine where the difference occurred. For vigilance only the direction of gaze during stationary behaviour was analysed, as during the other behaviours attention is not solely directed at monitoring surroundings.

Due to the limited number of predator presentations, statistical analysis was not possible for behaviours or vocalisations during the predator presentation. Observations were made to allow a descriptive analysis of the anti-predator behaviour that occurred.

For this study, heights and distances have not been statistically analysed. However, this is an area that could give a greater insight into anti-predator behaviour and deserves further investigation.

3. Results

3.1 Locomotion

There was no significant difference between the amount of locomotion observed during the different treatments (Friedman test: $\chi^2_3 = 5.261$, P = 0.145).

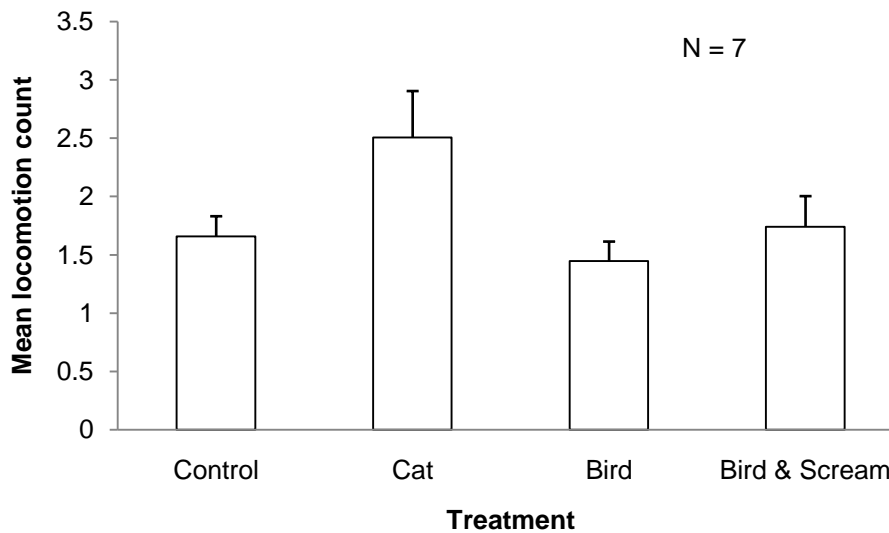


Figure 3.1.1 Amount of locomotion observed during the control week and the days the predators were presented.

Most locomotion was observed during the cat treatment (Figs 3.1.1 & 3.2.1). Least locomotion occurred during the bird treatment. During the control, locomotion was greatest during the 'post' period; however, in the predator treatments most locomotion took place in the 'during' period (Fig. 3.2.1).

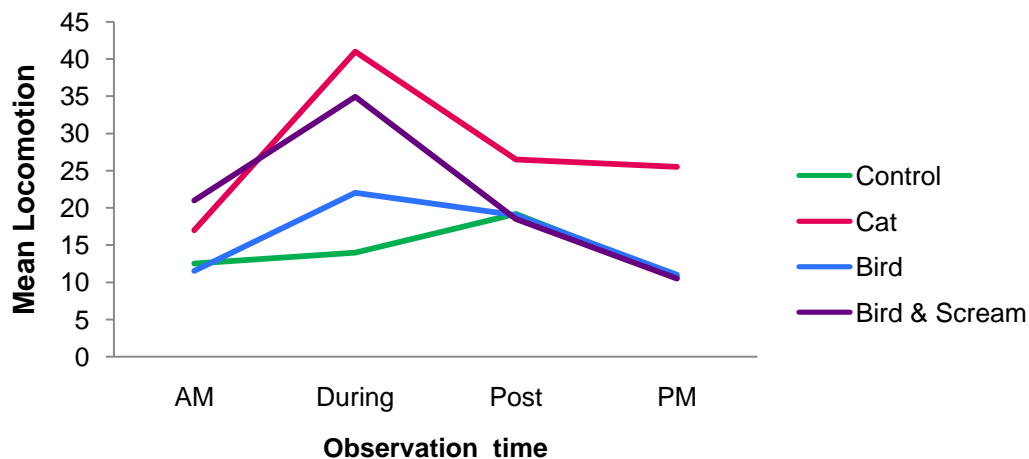


Figure 3.1.2 Change in locomotion throughout the day, during the control week and days that the predator was shown.

3.2 Foraging and Feeding

No significant difference in the amount of foraging behaviour observed was found over the different treatments (Friedman test: $\chi^2_3 = 0.771$, $P = 0.856$).

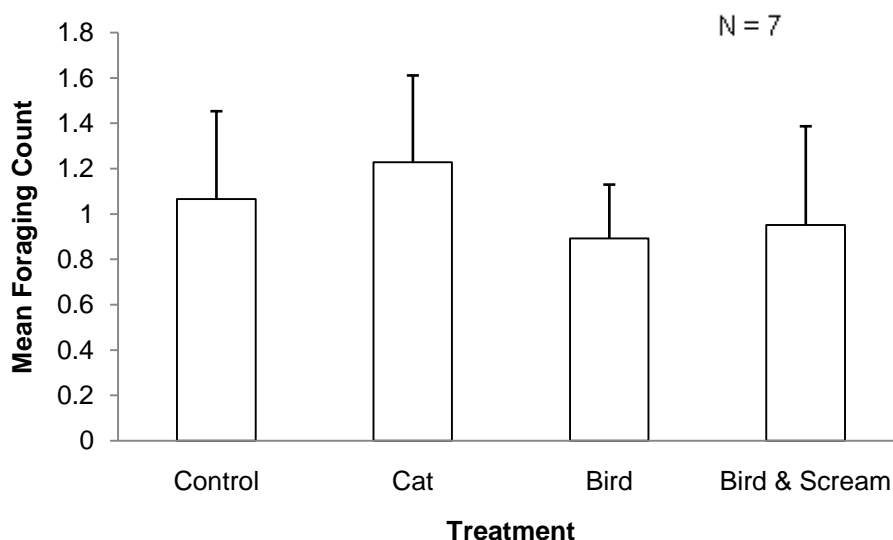


Figure 3.2.1 Amount of foraging observed during the control week and the days the predators were presented.

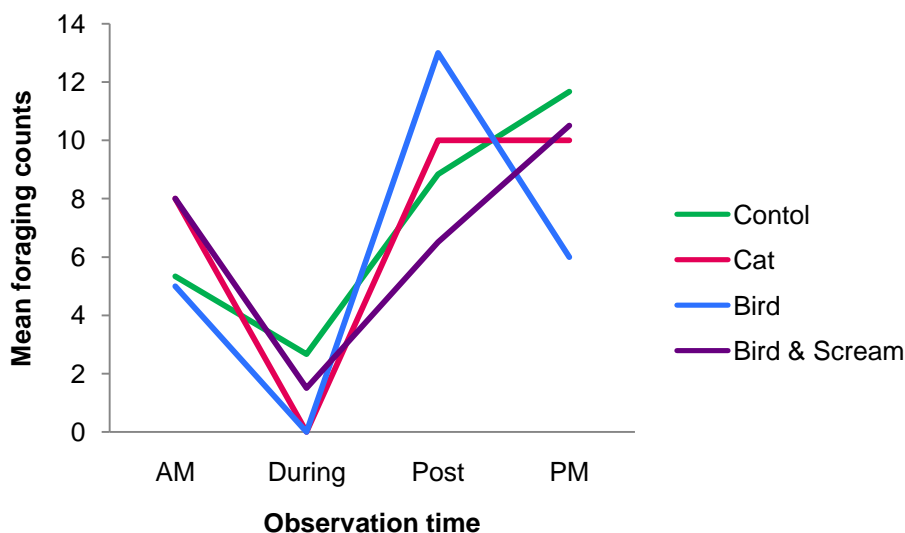


Figure 3.2.2 Change in foraging frequency throughout the day during the different treatments.

A similar foraging pattern was observed for all treatments. During the cat and bird presentations no foraging was observed, and very little foraging occurred during the bird and scream treatment. A much lower level of foraging occurred during the 'PM' period under the bird treatment, compared to other treatments.

No significant difference in the amount of feeding was seen during the different treatments (Friedman test: $\chi^2_3 = 1.632$, $P = 0.652$).

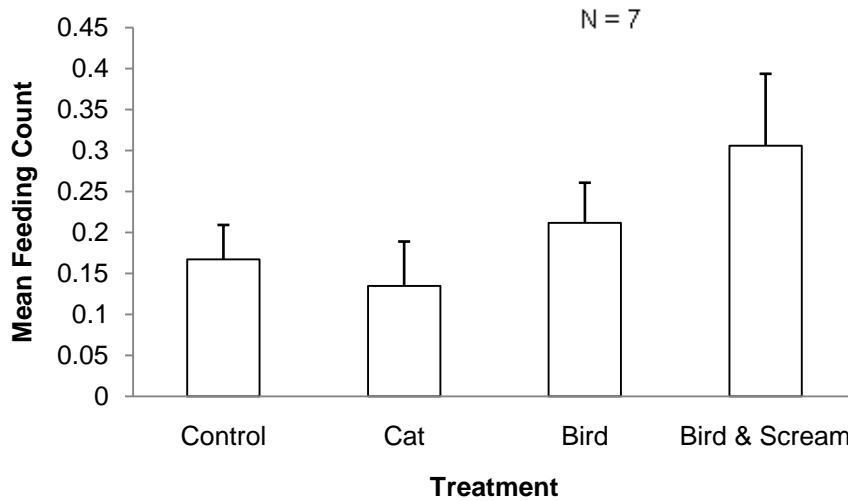


Figure 3.2.3 Amount of feeding observed during the control week and the days the predators were presented.

3.3 Social

No significant difference in the amount of social behaviour was found between the different treatments (Friedman test: $\chi^2_3 = 2.186$, $P = 0.535$).

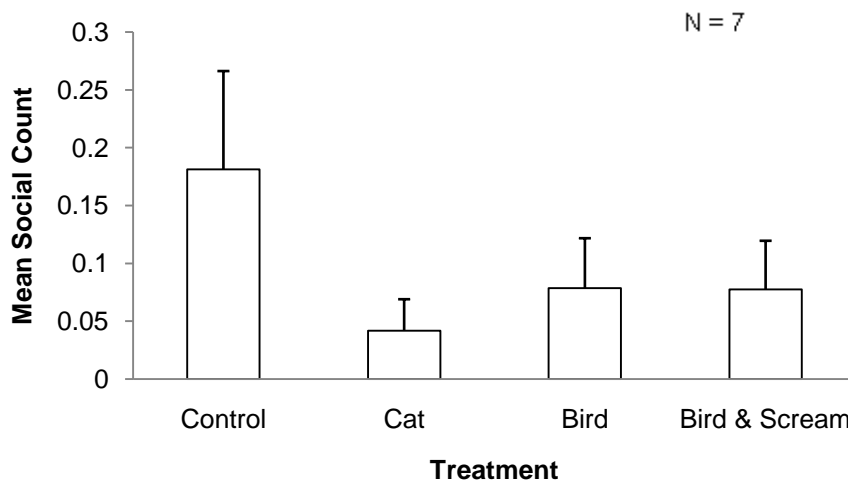


Figure 3.3.1 Amount of socialisation observed during the control week and the days the predators were presented.

3.4 Stationary

No significant difference in the time spent stationary was found between the different treatments (Friedman test: $\chi^2_3 = 5.571$, $P = 0.134$).

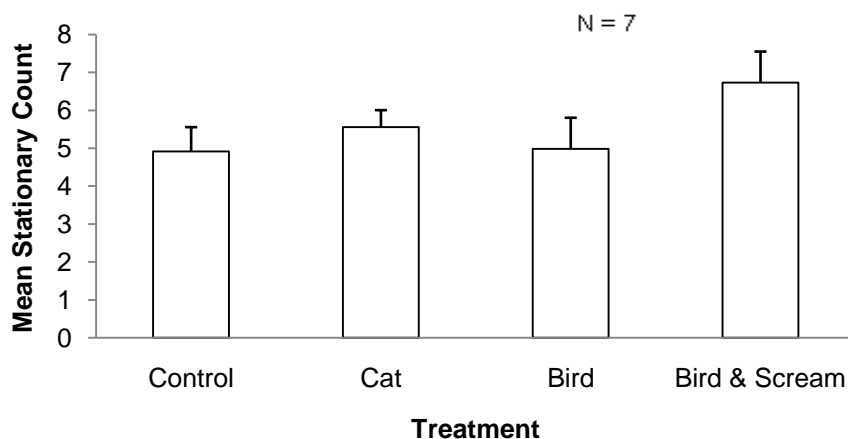


Figure 3.4.1 Amount of stationary behaviour observed during the control week and the days the predators were presented.

3.5 Not Visible

No significant difference in the amount of time spent out of sight was recorded over the different treatments (Friedman test: $\chi^2_3 = 0.771$, $P = 0.856$).

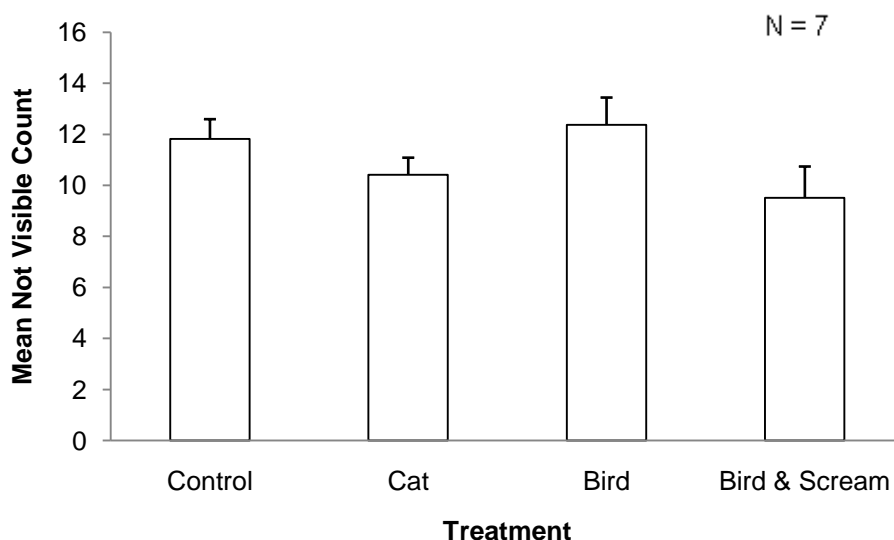


Figure 3.5.1 Amount of time spent out of sight during the control week and the days the predators were presented.

3.6 Vigilance

The tamarins were observed directing their gaze upwards significantly more during the presentation of the aerial predator (with and without the scream) when compared to the control week (2-tailed Wilcoxon signed-ranks test: $Z = -2.366$, $N = 2$, $P = 0.018$) (Fig. 3.6.1).

Significantly more downwards gaze was observed during the presentation of the terrestrial predator, when compared to the control week and the bird and scream treatment ($Z = -2.366$, $N = 7$, $P = 0.018$) and when compared to the bird (2-tailed Wilcoxon signed-ranks test: $Z = -2.371$, $N = 7$, $P = 0.018$) (Fig. 3.6.1).

There was significantly more downwards gaze during the control week compared to the bird and scream treatment (2-tailed Wilcoxon signed-ranks test: $Z = -2.197$, $N = 7$, $P = 0.028$) (Fig. 3.6.1).

No significant differences were found between the amount of horizontal vigilance observed in the different treatments (Friedman test: $\chi^2_3 = 2.912$, $P = 0.405$) (Fig. 3.6.1).

Under all treatments horizontal vigilance was most highly used (Fig. 3.6.1). During the control week, upward and downward vigilance were seen at very similar levels.

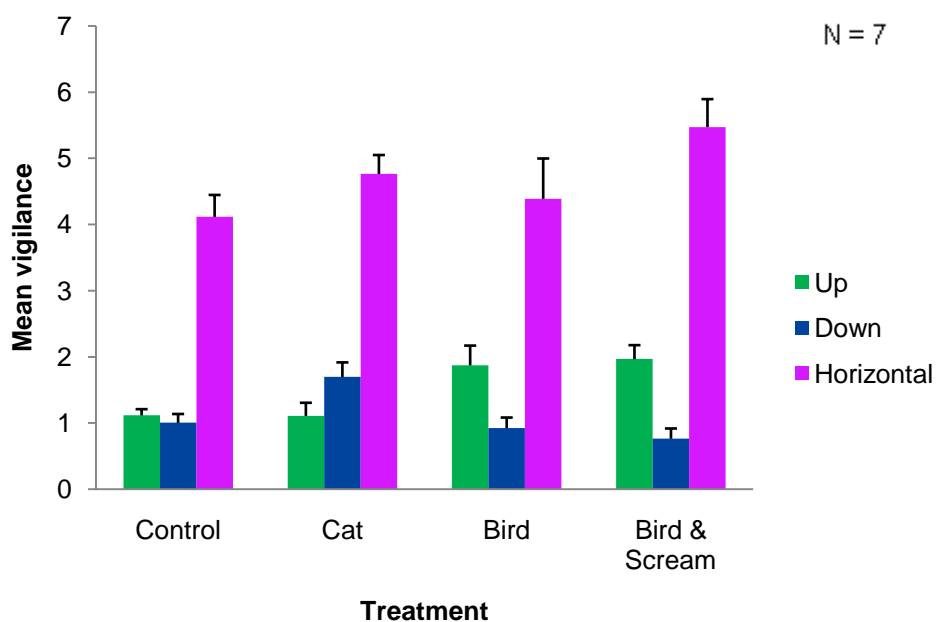


Figure 3.6.1 Amount of upward, downward and horizontal vigilance observed over the different treatments.

3.7 Vocalisation

More trills, whines and alarm calls were heard during the presentation of the model predators, compared to the control week. In all cases whines were the most frequent vocalisation. The bird predator caused the most alarm calling. The bird and scream resulted in the least amount of vocalisation when compared to the bird and cat treatments. (Figure 3.7.1).

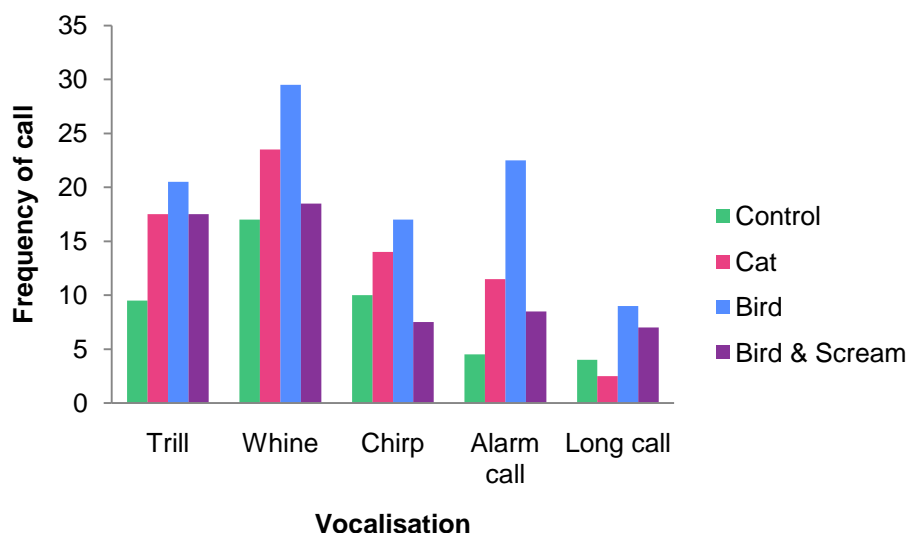


Figure 3.7.1 Frequency of vocalisations heard in the 'during' period.

4. Discussion

This study aimed to show whether the daily time-budget of BLTs was significantly altered due to a predatory threat. It also considered the different anti-predator behaviours exhibited in response to terrestrial and aerial predators.

This study involved a small sample size (N=7) and this must be considered when interpreting the results as the behaviours observed may not be reflective of larger populations.

4.1 Observations of anti-predator behaviour in reaction to predatory threat

In reaction to the terrestrial and aerial predator presentations, strong anti-predator responses were displayed, particularly for the aerial threat. During the presentations essential behaviours, such as foraging (Fig. 3.2.2), were suspended, showing the majority of attention and energy is directed towards anti-predator behaviour.

In response to the model cat, individuals were observed to mob the predator. Mobbing is an intrinsic part of Callitrichid anti-predator behaviour (Campbell & Snowdon 2007) and is designed to drive the predator away from the group (Caine 1998). Callitrichids predominantly engage in mobbing behaviour in response to terrestrial and terrestrial-arboreal species, but attacks have been reported on perched raptors (Campbell & Snowdon 2007). The observed mobbing behaviour in this study is comparable to a group of wild golden lion tamarins reacting to a tayra (*Eira barbara*) (Stafford & Ferreira 1995). This observation is encouraging for conservationists, as it shows captive-bred tamarins reacting in a similar way to their wild counterparts.

Piloerection (the standing of hair, Meek *et al.* 2007) was observed in response to each presentation of the predators and was observed more frequently on days between predator presentations than during the control week. The response was greater during the aerial predator threat, where piloerection lasted for the entire

scanning period. Piloerection has been observed in bonnet macaques (*Macaca radiata*) in response to a model Indian python (*Python molurus*) (Coss *et al.* 2007) and has been noted by Campbell and Snowdon (2007) during the mobbing behaviour of cotton-top tamarins. Ruiz-Miranda *et al.* (2002) observed piloerection in golden lion tamarins after playbacks of unfamiliar conspecific calls, showing piloerection is not always an anti-predator behaviour.

Alarm calls were given in response to the predators. These may function to warn conspecifics, or to encourage the predator to abort the predation attempt (Blumstein & Armitage 1997). The frequency of all vocalisations, especially alarm calls and whines, were highest during the bird treatment (Fig. 3.7.1). It was perceived that whines were made at times of uncertainty. It has been hypothesised that certain calls used during a predator threat may be stimulated by fear (Campbell & Snowdon 2007).

The tamarins were quietest when the aerial predator was coupled with the scream (Fig. 3.7.1). Price *et al.* (1991) observed that when tamarins were in an exposed position, for example exiting nest holes, they were less vocal and more vigilant. The aim of the scream was to represent the threat aerial predators pose. By increasing the feeling of vulnerability, this may have been achieved.

Observation of a successful attack by a burrowing owl on a group of white tufted-ear marmosets (*Callithrix jacchus*) showed the group scattering after the captured individual screamed (Stafford & Ferreira 1995). This was not seen in this study. The scream used consisted of a cotton-top tamarin coupled with a BLT vocalisation. Cotton-top tamarins do not inhabit the same regions as BLTs (Campbell & Snowdon 2007). The results may indicate that the BLTs did not associate the cotton-top tamarin scream with a capture. Future work should aim to use a BLT scream and investigate if this affects the strength of the anti-predator response.

Studies have shown that Callitrichids react to aerial predators by rapidly moving to a safe place and freezing (Caine 1998; Searcy & Caine 2003). In this study individuals remained near the huts during the aerial presentations. Individuals were observed to stand on top of the huts, looking up. This behaviour was unexpected, but was also observed in long-tailed macaques (*Macaca fascicularis*) and bonnet macaques in response to a python (Coss *et al.* 2007). It was suggested this allowed a better view of the predator, and the function may be the same in this case.

In previous years, anti-predator training using terrestrial predators had been conducted on this family group (Heigl 2003; Bacon 2005). This could explain the perceived stronger reaction observed in response to the aerial predator.

4.2 Variations in behaviour throughout the observation periods

With the exception of vigilance, no significant differences were found in the frequency of behaviours over the treatments (Figs 3.1.1, 3.2.1, 3.2.3, 3.3.1, 3.4.1, 3.5.1). The non-significant results of behaviours, such as foraging and feeding, show that the tamarins are able to continue with normal activity once a threat has passed. This assumption is supported by Caine (1998), who stated that to avoid the costs involved with anti-predator behaviour marmosets were able to accurately

determine the threat posed and rapidly recommence essential behaviours once the threat had passed.

Although not significant, the amount of locomotion observed was highest during the days the terrestrial predator was shown (Fig. 3.1.1). This could be due to the mobbing behaviour observed during the predator presentation; however, locomotion frequency was also observed to be strongly affected by weather, with greater distances travelled on warm, dry days. Bacon (2005) acknowledged that the tamarins behaviour during the 2005 anti-predator training was influenced by the weather.

Figure 3.1.2 shows locomotion rates were higher during the predator presentations. On days the aerial predator was shown, locomotion rates returned to baseline levels soon after the presentation. This further supports Caine (1998), who showed that the behaviour of Geoffroy's marmosets (*Callithrix geoffroyi*) rapidly returned to normal rates after the predator (model owl) had been removed. This return to baseline levels did not occur after the cat was shown. This inconsistency could be due to changing weather conditions.

In response to the predators, in particular the aerial predators, locomotion became very rapid and remained at an elevated level during later observations. As the ethogram (Appendix 3) only accounted for locomotion, and not the manner in which movement occurred, this was not apparent in the statistics. For other similar studies the ethogram may need to be modified to account for this.

Figure 3.2.2 clearly shows that foraging frequency returns to normal levels soon after the predator threat has disappeared. BLTs are frugivorous and insectivorous, with non-mobile prey contributing to 72% of their diet in the wild (Keuroghlian & Passos 1999). Foraging for live prey is costly, as it involves concentration on one small space (Caine 1998). Due to the inability to conduct vigilant behaviour whilst foraging (Hardie & Buchannan-Smith 1997), it is essential to postpone foraging activity whilst a predatory threat is present; however, it is fundamental to survival to resume foraging once the threat has passed, thereby reducing the costs of anti-predator behaviour (Caine 1998).

Foraging and feeding behaviours were observed to be strongly influenced by the weather. This could explain the low levels of foraging observed during the 'PM' period in the bird treatment. During days of high foraging activity, feeding behaviour was less observable (Figs 3.2.1 & 3.2.3) due to individuals foraging high in trees. On days of low foraging, food was obtained from meals placed in the huts, making the behaviour more visible. For future studies the ethogram should be altered to either combine feeding and foraging behaviour, or specify feeding as the consumption of keeper given food items.

The results of a previous anti-predator training of these BLTs have shown a reduction in foraging and an increase in stationary behaviour as a result of a predatory threat (Bacon 2005). Bacon (2005) proposed that these results show that the predator would have a long-term affect on the subjects. These results are contrasting with those found in this study. The lack of significant changes in foraging (Fig. 3.2.1) and stationary (Fig. 3.4.1) behaviour suggest that there is no long term affects on these behaviours.

There was no significant change in the amount of social behaviour between the treatments (Fig. 3.4.1). On the 12/07/07 Telva, the dominant female, had her contraceptive implant removed. Following removal, Telva elicited more social activity with Pinon, the dominant male. An increase in socialisation was also observed between Telva and her eldest daughter, Tavo. This influence on the normal socialisation levels between the three individuals could have caused a higher variation than usual in the results. Only a small amount of play behaviour was observed between the younger tamarins. This is unsurprising, as in the wild, play occupies a small amount of the total time-budget (3.8% in wild juvenile golden lion tamarins, de Oliveira *et al.* 2003).

It has been documented (e.g. Moodie & Chamove 1990) that introducing a brief stressor causes an increase in social affiliation. This was not shown in the results of this study, however, at certain times, social behaviour was observed inside the hut, for example, social grooming following the first bird presentation. This behaviour was unable to be recorded as it was not possible to identify individuals.

It was deemed important to include the proportion of time spent out of sight as behaviour was unknown. BLTs are arboreal primates and spend the majority of their time in the upper understory, at 4-6m high (Albernaz 1997). On fair weather days individuals spent more time foraging high in the trees, where they were not visible. When the weather was poor, more time was spent inside the huts.

Vigilance is important for prey animals (Caine 1998; Searcy & Caine 2003) and plays an important role in the behavioural repertoire of tamarins, as many predators rely on surprise attacks (Hardie & Buchanan-Smith 1997). After a predatory threat there was increase in vigilance towards where the predator had been observed (Fig. 3.6.1). This result was expected. The results showed a high level of horizontal vigilance for all treatments and increased levels during the predator treatments, compared to the control (Fig. 3.6.1). Bacon (2005) also found that horizontal vigilance increased in response to a model terrestrial predator. Price *et al.* (1991) showed that cotton-top tamarins became generally more vigilant in response to a disturbance, and that the increased vigilance was not solely directed towards the disturbance. This is reflected in the change in the BLTs vigilance.

The vigilance results could have been bias by the sloped topography of the wood, as observations were conducted from the higher levels. Due to the slope, the tamarins gaze will not be level to the ground; when gazing horizontally, they may in fact been looking at a higher or lower level. This may have caused the elevated levels of horizontal vigilance during the bird and scream treatment, as the scream was played from a path at the top of the wood.

A comparison between a group of cotton-top tamarins before and after relocation from enclosed housing into a free-ranging environment, showed vigilance was altered according to the new surroundings (Price *et al.* 1991). Specifically, levels of upward vigilance significantly increased. This was thought to reflect the increased predation risk from raptors. The results from this study have also shown that BLTs are able to significantly alter vigilance according to the threat posed. Further investigation would be needed to assess how long vigilance remains altered;

however these results are encouraging for conservationists regarding reintroductions.

During this study five vocalisations, each with a different function, were recorded. Long calls, for instance, are used to communicate over long distances (Ruiz-Miranda *et al.* 2002). Ruiz-Miranda *et al.* (2002) found that the golden lion tamarins could distinguish between long calls from their own and neighbouring groups. During the study, individuals were heard to alarm at real potential threats, such as great black backed gulls (*Larus marinus*) and common kestrels (*Falco tinnunculus*). This behaviour was also observed in free-ranging cotton-top tamarins (Price *et al.* 1991). This may show that anti-predator behaviour is innate, as naïve individuals are able to detect potential threats and respond accordingly. After the first training the tamarins were perceived to be quieter and more nervous. Alarm calls were given to stimuli that would not normally provoke a response, for example, a call on the handheld VHF radio.

Vocalisations also varied with the weather. On warm, dry days the tamarins foraged further away from the huts. BLTs often forage singularly or in pairs (Keuroghlian & Passos 1999). This spatial separation of the group resulted in more long calls. During wet weather the tamarins tended to stay in or near the huts and very few vocalisations were heard.

To prevent habituation the tamarins were only exposed to each treatment twice, however it is not possible to know whether they were exposed enough to have a lasting impact on memory without future studies. Bacon hypothesised that the decrease in vigilance throughout the 2005 anti-predator training may have been a result of habituation. It is also not know how adverse the stimulus needs to be to train the tamarins about predator avoidance. This is closely related to how innate anti-predator behaviour is. In certain species it has been proven that anti-predator behaviour is not forgotten, despite being separated from predators. For instance, Californian ground squirrels (*Spermophilus beecheyi*) can distinguish between poisonous rattlesnakes (family: Viperidae, Cooke *et al.* 2004) and harmless snakes 300,000 years after isolation occurred (Blumstein 2000). In this study the tamarins were observed to react strongly to each presentation, so it can be assumed that habituation had not occurred; however, in any further studies, the possibility of habituation occurring needs to be carefully considered.

One question that still requires an answer is what is causing the tamarins to show anti-predator behaviour? Is it the shape or pattern of the predator? In this study a toy tiger used and was successful in eliciting anti-predator behaviours; however, tigers do not inhabit Brazil (Cooke *et al.* 2004) and although cats are potential predators, a striped cat is unlikely to be encountered. For future work it is necessary to establish to what degree the tamarins can distinguish between predator shapes or coat patterns and how this affects the reaction. This could lead to dramatic improvements in the preparation of animals for release and the success of reintroduction programmes.

5. Conclusion

For all the behaviours and vocalisations that were observed in this, and other similar studies, it is difficult to tell whether the response is natural and complete, or if the behaviour presented is a modified version of the wild behaviour, caused by

adaptation to captivity (Campbell & Snowdon, 2007). It is made harder to distinguish due to the lack of observations of wild predation events (Searcy & Caine 2003). For reintroduction to be successful the subjects need to be able to recognise predators and respond appropriately. Behaviour training has been successful in other species, such as black-footed ferrets (*Mustela nigripes*) (Vargas *et al.* 1998) and black tailed prairie dogs (*Cynomys ludovicianus*) (Shier & Owings 2006) and improved post-reintroduction survival of both.

Simply being able to respond appropriately to predators is not adequate enough to guarantee post-release survival. In a comparative study of captive-born golden lion tamarins and their wild-born offspring, it was found the captive-born individuals lacked foraging and locomotory skills. Captive individuals were observed to be less agile and utilised lower areas. (Stoinski *et al.* 2003). These behavioural problems can be solved by providing captive animals with a complex environment. It is possible to keep Callitrichids in a free-ranging exhibit. Free-ranging environments have been utilised successfully for cotton-top tamarins (Price *et al.* 1989) and golden lion tamarins (Bronikowski *et al.* 1989 In: Price *et al.* 1989).

This study has shown that animals that have bred in captivity for many generations are still able to show anti-predator behaviour and react efficiently to predators with no long term implications. For conservationists' considering reintroductions, this is a positive outcome, as it proves there is a potential for captive individuals to be able to respond appropriately when a predator is encountered.

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Appendices

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