Fall 2011

Animal Enrichment Strategies for Promoting Natural Behaviors in Captive Populations of Tasmanian Devils (Sarcophilus harrisii)

Tierney O'Neal
SIT Study Abroad

Animal Enrichment Strategies for Promoting Natural Behaviors in Captive Populations of Tasmanian Devils (*Sarcophilus harrisii*)

Tierney O'Neal
Project Advisors: Marissa Parrott, Ph.D., and Melanie Lancaster, Ph.D.
Threatened Species Department, Healesville Sanctuary
Healesville, VIC, AU

Academic Director: Tony Cummings
Home Institution: Franklin & Marshall College
Major: Animal Behavior

Submitted in partial fulfillment of the requirements for Australia: Rainforest, Reef, and Cultural Ecology, SIT Study Abroad, Fall 2011.

ABSTRACT

The population of Tasmanian devils (*Sarcophilus harrisii*) is in rapid decline due to Devil Facial Tumour Disease, and insurance populations have been created in captivity for potential future introduction into the wild. Many problems can arise within captive animal populations including loss of natural behaviors, and development of negative stereotypical (i.e. pacing) behaviors. These issues can decrease ecological fitness, potentially jeopardizing success of introductions of animals into the wild. By providing captive animals with enrichment, natural behaviors can be increased, and stereotypical behaviors can be decreased. Enrichment is defined as an activity or item that promotes the mental and physical well-being of an animal. In this study, ten different enrichment items were given to a group of captive devils to assess their effects on activity levels and behaviors. Data regarding items was also analyzed to see how long the enrichment was useful for, and how often it could be given to the devils for it to seem be conceived as novel. Results suggested that most enrichment items decreased stereotypical behavior and promoted natural behaviors.

ACKNOWLEDGEMENTS

First, I would like to thank Healesville Sanctuary and their staff for allowing me the opportunity to study using their resources and facilities. I most importantly give my thanks to Tammika McIvor who invited me into her home, and shared her ideas for the research project with me. I also have great thanks for my advisors Marissa Parrot and Melanie Lancaster, who have been instrumental in helping me conduct this study, and have taught me so much about scientific research and writing. I wanted to also thank the staff members that pulled me out of the office to have incredible encounters with the Sanctuary animals, and made sure that I took breaks while I was working on the project. The staff as a whole made my time so memorable and enjoyable, and I hope to someday make it back to the Sanctuary to visit all of the great friends I made. Finally, I would like to thank all of my family and friends for being so supportive and helping me make the trip to Australia.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

1. INTRODUCTION

1.1 Captive Animal Reintroduction into the Wild

A current goal of many zoo and aquarium facilities is to establish viable, long-term captive breeding populations of rare and endangered animals (Lyles 2001) as part of their conservation efforts. The hope for many of these breeding programs is the creation of an "insurance population," to maintain the species in captivity and for release into the wild to reestablish or supplement an existing wild population (Frankham et al. 2002). Reintroduction is a complex process that involves significant understanding of species' biology and ecology (Frankham et al. 2002), and involves an uphill battle against many factors. While reintroduction programs currently exist for many species, conditions for release of many captive-bred species are not suitable in the wild for many of these programs as wild habitats are unavailable or threats to their wild populations still exist (Kleiman et al. 1996). Regardless, captive breeding programs still exist with aims of retaining high genetic diversity and demographic viability through generations with eventual hope of reintroduction into the wild when the situation presents itself (Soulé et al. 1986).

Zoos working with affiliated universities, government wildlife departments and conservation organizations are prime locations for breeding programs of threatened species because they have the necessary knowledge and experience in animal care, veterinary medicine, animal behavior, reproductive biology, and genetics (Primack 2010). Zoos and their partners work to create facilities and develop the necessary technology to establish breeding colonies of threatened animals, and to develop new methods and programs needed to reintroduce species into the wild. (Conway et al. 2001).

As mentioned previously, wild conditions are often unsuitable for release of captive bred threatened species. At times, programs require that the individuals bred in captivity are managed in captive populations for several generations which can have detrimental effects. One of the most serious issues that can arise within a captive population is genetic adaptation to captivity and variability. Maintaining a captive population of an endangered species for conservation invariably leads to some degree of inbreeding, because population size in captivity is limited and is often founded by a small number of individuals (Kraaijeveld-Smit et al. 2006). Inbreeding can result in a loss of fitness amongst individuals as they adapt to conditions in captivity (Frankham et al. 2002). These inbred populations may also only represent a limited portion of the gene pool of the species as a whole (Primack 2010), and are thus not ideal for release in the wild. High genetic diversity is crucial for maximizing long-term viability in the wild (Frankham et al. 2002). Modern zoos now use global computerized databases provided by ISIS and special studbooks to carefully track genetic lineages of endangered captive animals to prevent pairing of related animals and avoiding inbreeding depression as part of a species survival plan to maximize genetic diversity in captive populations (Primack 2010).

Another problem with release from captive populations is that the individuals may not have the resources to learn how to survive in the wild. Captive conditions are very different to natural conditions, because individuals no longer have to evade predators or fight for their food, and they receive regular medical treatment (Lynch and O'Hely 2001). The predictable, often unchanging environment in captivity may encourage the loss of the range of behaviors required to survive in the variable, unpredictable natural environment (McPhee 2003).

Behavioral changes have also been observed in captive animals, often manifesting themselves in abnormal repetitive behaviors caused by motivational frustration, habit-formation, brain dysfunction, 'coping' effects (Mason et al. 2007) or unexpected human induced changes (McDougall et al. 2005). These behaviors may also indicate psychological changes (Clubb and Mason 2007) and are often exhibited through stereotypical behaviors such as pacing throughout enclosures. The amount of time spent in captivity is often positively correlated with an individual's level of stereotypy (Garner and Mason 2002, Vickery and Mason 2003). The constraints put on individuals in captivity can cause strong negative effects, especially on carnivores because of their naturally high activity levels in the wild (Clubb and Mason 2007, Jule et al. 2008). These negative behavioral changes can lead to deleterious effects on captive animals such as lower reproductive success, decreased health and lower behavioral variability which can compromise the aims of captive populations needed for reintroduction.

1.2 Population Decline of Tasmanian Devils

The Tasmanian devil (*Sarcophilus harrisii*) is integral to the ecology of Tasmania, Australia (Department of Primary Industries). It is the world's largest extant marsupial carnivore, and is endemic to Tasmania, after disappearing from mainland Australia around 430 years ago (Archer and Baynes 1972), thought to be a result of the arrival of dingoes. While the population of devils was considered stable and animals were common 19 years ago, the population is now considered Endangered at both a national level (*Environment Protection and Biodiversity Conservation Act 1999*) and state level (*Threatened Species Protection Act 1995*). The Tasmanian devil population has rapidly declined over the past decade due to devil facial tumour disease (DTFD), which is contagious and has a lethality rate of 100% (Department of Primary Industries). The disease was first reported in 1996 at Mount William National Park (north-east Tasmania) and has since spread to three-quarters of the state (Department of Primary Industries). From 1992 to 2009 there was an 80% decline in devil sightings across Tasmania (DPIPWE unpublished), and populations have declined by as much as 95% at sites where the disease was first encountered (Jones et al. 2007). Full extinction in the wild has been projected to occur within 25-35 years if decline continues at the same level (Department of Primary Industries).

After extinction from Australia's mainland, genetic diversity was lost and now remains low amongst individuals in Tasmania's population. This is consistent with an island population descended from a small founder group, along with island effects and population decline in the last 150 years (Department of Primary Industries). Although survival and reproduction do not seem to have been affected by the low genetic diversity thus far (Jones et al. 2007), genetic diversity can greatly reduce the disease resistance of a species (deCastro and Bolker 2004; Acevedo-Whitehouse et al. 2005), which is likely contributing to the rapid decline of devils from DFTD (Siddle et al. 2007). It is essential that the current genetic diversity is maintained and to ensure that any genes showing potential resistance to the disease are not lost. If the worst-case-scenario occurs and all devils in the wild become extinct in the wild, it is important that the captive populations contain the maximum level of genetic diversity possible to repopulate the wild (Department of Primary Industries).

1.3 Insurance Population

The current strategy for the recovery of Tasmanian devils is to develop an *insurance population* in captivity, while trying to manage them and the disease in the wild to retain the species' ecological function (Department of Primary Industries). The Australian and Tasmanian governments implemented the Save the Tasmanian Devil Program (STDP) in 2003 (STDP 2010). In 2005, the decision was made to start an insurance population because of the high probability of devil extinction in the wild determined by these factors:

- The existence of only two wild sub-populations of devils, neither of which is isolated from the other
- Lack of diagnostic tools, treatments, vaccines, or other preventions for the disease
- No recorded natural resistance to the disease
- The high risk of wild devils becoming extinct in the future, given the above factors, rate of spread of the disease and decline over 51% (Hawkins et al. 2006) of the devil population
- The small amount of time available to collect sufficient disease-free animals as potential founders from which to develop a genetically representative captive population (Department of Primary Industries)

The goal for these insurance populations is to have a 95% allelic heterozygosity for 50 years (Sinn et al. 2010) for potential release after 20 generations. The insurance populations are being established in captivity and on islands (Jones et al. 2007). Insurance populations consist of wild sourced founders and their progeny held at four breeding zoos on mainland Australia and at Tasmanian Wildlife Parks, and wild sourced founders in Tasmanian Government quarantine facilities (Jones et al. 2007). This program is advantageous because of the ability to manage and monitor genetic and demographic outcomes, high biosecurity, and the need for a smaller effective and thus actual population size (Jones et al. 2007).

1.4 Enrichment as a Management Tool

As mentioned previously, animals can adapt quickly to life in captivity due to a predictable environment. The reintroduction of devils into the wild after a potential 50 year period is not a simple matter (Sinn et al. 2010), especially if abnormal behaviors are established and wild behaviors are lost. To attempt to avoid negative behavioral change, environmental enrichment can be used to provide novel stimuli in a captive environment. Enrichment can be defined as a dynamic process that structures and changes an animal's environment in a way that provides behavioral choices and encourages species-appropriate behaviors and abilities (Van Metter et al. 2008). As with many other carnivorous species including large felids, it has been proposed that food-based enrichment based on species ecology would be beneficial (Kistler et al. 2009), but non-food related enrichment items can be useful to encourage curiosity and vary captive routines. In order to have greater success with reintroduction of Tasmanian devils into the wild, it is important to provide captive devils with enrichment to encourage natural behaviors and ensure they don't become too accustomed to captivity over several generations.

1.5 Project Aims

In this study, ten different types of enrichment were given to a captive population of Tasmanian devils that are part of the STDP program as an insurance population. As little is known about devils, their behaviors in captivity and the impacts of enrichment, my project seeks to answer the following questions:

1. Does introducing an enrichment item into devils' enclosures have an effect on their activity levels?
2. What types of enrichment are most effective at increasing activity levels?
3. How do activity levels and behaviors change over time following the delivery of an enrichment item, and after multiple exposures of the same item?
4. Which behaviors are elicited by different types of enrichment?

2. MATERIALS AND METHODS

2.1 Location

This project was conducted at Healesville Sanctuary in Healesville, Victoria, Australia. Their facilities house 87 Tasmanian devils, including 66 adults and sub-adults, with 21 joeys born in 2011. All devils are part of an insurance population for the Save the Tasmanian Devil Breeding Program, other than a few senescent individuals past breeding age. The Sanctuary has an allocated "Threatened Species" department dedicated to the research, management and breeding of several threatened species, including helmeted honeyeaters (*Lichenostomus melanops cassidix*), mountain pygmy possums (Burramys; *Burramys parvus*), platypus (*Ornithorhynchus anatinus*), a variety of frogs and Tasmanian devils.

2.2 Research Subjects

The Tasmanian devils (n=9) studied during this project were born in captivity at Healesville Sanctuary, and did not receive breeding recommendations in 2011. The group consisted of 5 females and 4 males, all 2 years of age. All individuals have had minimal contact with their keepers, with the exception of weighing and health checks. Each animal participated in a behavioral study ending within one week before this project began, held under the same conditions for this study. Participating individuals had never been exposed to the enrichments given for this project. No enrichment items had been given to the animals used in this study for over 3 months, prior to the commencement of this research.

2.3 Animal Enclosures and Diet

Each animal was housed individually in an enclosure measuring approximately; MHP 1-4: 15m x 7m ($105m^2$), MHP 5a-8b: 15m x 10m ($150m^2$). Enclosures contained a den site, shade, vegetation, a fort (manmade climbing structure) (see Figure 1) to climb on, and water available *ad libitum* from a self-filling water point. Males and females were housed in alternate enclosures as required by the current management protocol. This reduced variability amongst males as they were exposed to similar levels of pheromones from neighboring females. However, this study was conducted outside the devil breeding season so there should have been little to no influence from pheromones on behavior. The devil enclosures were arranged in two blocks of four and one row of four enclosures (see Appendix 1), situated in the staff-only threatened species precinct of Healesville Sanctuary. Each enclosure was surrounded by solid fences approximately 1.2m high, and devils were able to view outside their enclosures if climbing their forts. Enclosures were serviced at the same time daily by specialized devil keepers – feces were removed, water bowls were cleaned and refreshed, and any uneaten food was weighed and either left or removed based on the current protocol.

The devils at Healesville Sanctuary are on a feast/famine diet regime, which consists of a variety of large gorge feeds on “feast” days, with some small-scale scatter feeds in between (see Appendix 2 and 3 for schedule during study). The study conducted immediately before this research suggested that devils put on a perceived natural schedule where they are given variable food amounts and items, including large ‘gorge’ feeds followed by ‘starve’ days with little or no food, maintained better health and were exposed to more wild conditions. Between feast days the devils fast for 2-3 days before they are fed again. This mimics the natural diet of Tasmanian devils; in the wild, devils feed as infrequently as every 3-8 days, gorging on up to 44% of their body mass (Pemberton and Renouf 1993).

2.4 Enrichment Items

Ten different enrichment items were provided to each devil; 5 food-related items and 5 non-food related items. Each item was provided on two occasions, with 2 weeks between the first and second delivery of non-food items, and 1 week between the first and second delivery of food-related items (Appendix 4). The longer wait between non-food item delivery was to ensure that enough time had passed for the items to seem novel and exciting again to the animals, whereas food is always highly motivational and may not need as much time for animals to recover from the excitement upon first delivery.

Enrichment items were delivered on a set schedule in conjunction with their starve-gorge diet schedules. Because of this schedule, food-related items were arranged to accommodate this, i.e. carcass items were delivered on feast days.

2.4.1 Food-Related Items

The 5 food-related items used in this study were a pegged-down carcass, a carcass attached to a bungee cord, a meat smear, mulch piles with invertebrates, and a paper mache ball filled with dry dog kibble. The carcasses were both delivered in the morning because the devils are usually sleeping in their dens during that time. Entering the enclosures with a carcass while the devils were awake and alert was deemed dangerous for keepers, and were therefore impossible to deliver at the same time as the other items. The morning items will not be directly comparable to all of the other items for this reason, but are still important for the purpose of this study.

Pegged Down Carcass – for this item, a carcass was secured to the ground by hammering a peg through the meat, making food acquisition harder for the animal. This is meant to mimic social feeding in natural conditions, because the carcass cannot be removed immediately; in the wild a devil would have to compete with other devils to grab a carcass for itself. This item should promote behaviors that would strengthen muscles necessary for social feeding and tearing apart carcasses.

Bungee-Carcass – for this item, a carcass was secured to a bungee cord that was attached to the fort in the devils' enclosure (see Figure 1), and left dangling approximately 0.5m above the ground. This item mimics social feeding because as the devil tugs on the carcass the bungee provides tension and pulls back, imitating the feeling of another devil pulling on the carcass. This item should increase effort for food acquisition, and promotes behaviors strengthening muscles necessary for social feeding and carcass tearing.

Meat Smear – this item was a mixture of different meats, and had a gelatinous texture. It was separated and thrown into three different parts of the enclosure. This item should increase foraging and exploratory behavior, encouraging the devil to search around the enclosure and follow the smell of the smear.

Mulch Pile with Invertebrates – for this item, mealworms were mixed into a pile of mulch. The mulch was stored outdoors so scents from wild kangaroos or wallabies could have been present. The mulch pile with mealworms was split and placed in two different areas of the enclosure. In the wild, devils consume insects and small reptiles, which they would often need to dig and search for, but this is often not practicable in captivity. This item would make feeding more challenging, and should promote the natural behaviors of foraging and digging for food.

Paper Mache Ball – this item was thrown into the enclosure from the outer wall; each ball contained 10 pieces of dry dog kibble. As the devil grabbed the ball and started to tear it open, the kibble should have fallen out and been spread throughout the enclosure. As this happened, foraging and exploratory behaviors should have increased, as well as overall activity levels as they searched for food.

2.4.2 Non-Food Related Items

The 5 non-food-related items used in this study were kangaroo scats, koala scats, bedding from the burramys enclosures, change in orientation of fort ramps and a plain mulch pile.

Kangaroo/Koala Scats – the scats were freshly collected from animals in the Sanctuary, and placed in two different locations in the devil enclosures. Placing scats in their enclosure gives the illusion that another animal has come through and defecated in their territory. This can create a more 'natural' environment for the devils, as they would certainly come across scents from other animals on a nightly basis in the wild. This should increase exploratory behaviors and possibly foraging behaviors, and may also elicit defensive behaviors.

Burramys Substrate – the substrate (wood shavings and washed sea grass) was freshly collected from the burramys enclosures, and placed in two different locations in the devil enclosures. Placing the bedding from another animal in their environment provides new scents, although burramys are not an animal they would normally encounter in Tasmania. There should be increased curiosity around this item, and it should promote behaviors such as digging, sniffing, and potentially some defensive behaviors.

Fort Change – for this item, the ramp location leading up to the "fort" was changed so the access point was different for the devils (see Figure 1). The forts are extremely important as they provide the devils with 'aspect,' where they can see out of the enclosures and sniff the surrounding air, giving a greater perception of space. This has been said to increase breeding success (M Parrott personal comment), and is conducive to the animal's well-being. Changing the orientation of the fort should promote climbing behaviors and increase exploration.

Mulch Pile – for this item, mulch was placed in two different areas of the enclosure. The mulch was stored outdoors and may have contained scents from wild kangaroos and wallabies. By providing fresh mulch, the texture of the environment was temporarily changed. Placing mulch piles should promote activity and curiosity around the mulch piles, and devils may elicit digging, sniffing, and possibly defensive behaviors.

Figure 1 - Manmade fort in devil enclosure, with devil interacting with bungee carcass. Ramp leading up to fort is accentuated.

2.5 Experimental Equipment and Analysis

Each devil was monitored via video cameras and remote activity sensors in their enclosures from 8th September 2011 until 10th November 2011. The equipment was already present and had been successfully used in previous devil studies. Each enclosure contained identical cameras and sensors set up in the same manner so data was directly comparable amongst all enclosures.

2.5.1 Cameras

One motion detection triggered video camera (PACOM VN37C-W36-3M) was previously installed in each of the MHP neighboring enclosures with existing video and data collection equipment (GANZ Digimaster H.264 16 channel DVR). The cameras had been placed in optimum locations as determined by a previous researcher to view devil feeding and behavior. To ensure consistency, each camera had been mounted on the wall to the right of the den entrance. The cameras used for this study did not have infrared frequencies and therefore could only record activity during daylight hours. It has not been determined if high amounts of infrared light interfere with Tasmanian devil behavior and reproductive (photoperiod) cues, and therefore was ruled out for use in this study. The cameras began recording when motion was detected and stopped recording five seconds after motion ceased. Although devils are largely nocturnal, they are also active throughout the day, thus the recorded behaviors gave a snapshot of overall behavior. Enrichment items were also delivered during the day, making it the most important time for observations in this study.

After all video footage had been recorded for the study, the footage was reviewed and behaviors around items were analyzed using an ethogram developed for the study. Six crucial hours were identified for review of each item: the first 2 hours after the devils' first interaction with the item, 4-6PM the day after the item was introduced, and 4-6PM two days after the item was introduced. The hours of 4-6PM were chosen based on keeper knowledge of the devils most active time at Healesville Sanctuary. This time coincides with feeding time at the Sanctuary, and they have adapted to that schedule. During those 6 hours, the start and end time of behaviors identified as important by the ethogram were recorded, and amount of time spent interacting with each item was calculated. Findings from the study are presented as graphs and statistical analyses will be conducted shortly for publication.

The behavioral ethogram contained 11 behaviors, grouped and described below. This was developed with assistance from keepers at Healesville Sanctuary, through observation of captive and wild-born devils over a course of two and half years and adaptations appropriate for exhibited behaviors in this study.

Table 1 – Behaviors exhibited by Tasmanian devils around given enrichment items, grouped into behavioral classes.

Curious/play behaviors	
Sniff (Sn)	The animal is sniffing item or ground around item. This is primarily for non-food related items.
Scratch (Sc)	The animal's claws are used to scratch the item.
Pick up with paws (Pup)	The animal lifts item off ground with paws.
Nudge (N)	The animal nudges item with snout or open mouth.
Dig (Di)	The animal sifts through the item using paws.
Climb (Cl)	The animal climbs or standing atop the fort structure.
Carry (C)	The animal carries item in mouth.
Defensive behaviors toward item	
Scent Mark (SmI)	The animal squats with its hind legs, presses the perineal (anal) gland on the item or on the ground near item and drags whilst moving.
Urinate/Defecate (U/D)	The animal urinates or defecates on or around the item.
Feeding behaviors	
Tug (Tug)	The animal tugs on one of the carcass items.
Forage (F)	The animal is actively searching for food. The head will be down sniffing at ground. Distinguished from sniffing for non-food items if chewing is observed.

2.5.2 Sensors

All enclosures were outfitted with one infrared remote activity sensor (Trailmaster TM550) to monitor activity levels during the day and night. The activity sensors were attached to the enclosure walls via a magnet and secured with a wire bracket to ensure the sensors could not fall into the enclosure. The sensors had been mounted on the longest wall of each enclosure, with an access hole in the fencing so the sensor was accessible for data download from the outside of the enclosure. This reduced interactions between devils and keepers and helped avoid introducing foreign smells that could alter devil behavior. The base of each sensor was 90cm above the ground and angled in relation to the width of the enclosure to capture movement from approximately halfway through the enclosure. The settings of the sensors were P2, Pt 3.5, where two beams (P2) emitted by the sensor must be broken by the movement of the devil within 3.5 seconds (Pt 3.5) to record activity, and with an event delay of 1 minute, where by only one record of movement was recorded per minute. These settings ensured that small movements in the enclosures, i.e. vegetation moving in the wind, were not recorded as devil activity.

The raw sensor data was broken down into the number of sensor 'hits' (records) per hour for each devil for analysis. The sensor hits per hour were then more closely reviewed for each enrichment item by isolating activity levels within the first two hours of delivery of each enrichment, activity within 24 hours of enrichment delivery, and activity within 48 hours of enrichment delivery. The data was compared with baseline activity levels recorded for the same individuals gathered in the previous month during the prior study in which no enrichment items were provided. Findings from the study are presented as graphs and statistical analyses will be completed shortly for publication.

3. RESULTS

3.1 Activity Levels

Sensor data showed a significant decrease in activity after the first introduction of koala scats, kangaroo scats, fort change, mulch pile, and the bungee carcass. There was a significant increase in activity after the first introduction of the paper mache ball. There were no significant differences in activity for the first introductions of burramys substrate, mulch pile with mealworms, smear, or pegged down carcass. There were no significant changes after the second introductions of items except for a decrease in activity for burramys substrate, paper mache ball, smear, and pegged down carcass (Figure 2).

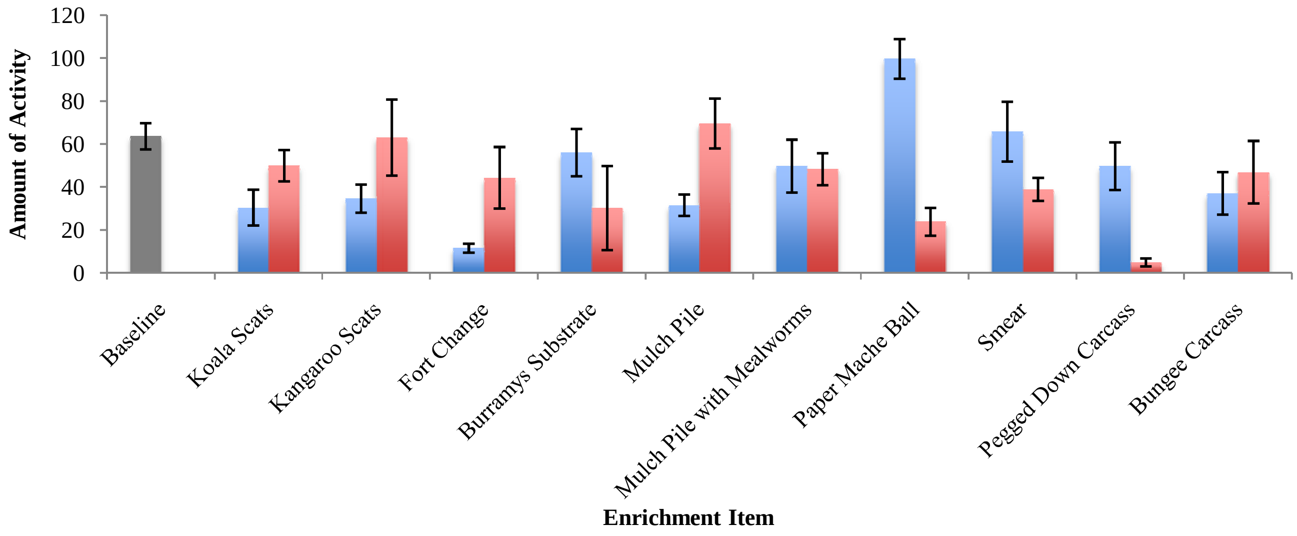


Figure 2 – Average activity levels within first two hours of introduction of enrichment item upon first (blue) and second (red) delivery. Baseline data was calculated from previous study using data from the hours of 4-6PM. Error bars represent ± S.E.

Sensor data showed significantly less activity than the calculated baseline data for the bungee carcass. Activity was significantly lower than baseline levels in the first 24 hours after koala scats, fort change, mulch pile, mulch pile with mealworms, pegged down carcass, and bungee carcass were given. All enrichment items less the bungee carcass had no overall significant differences in activity levels from baseline data in the second 24 hours after enrichment was given. There was a significant increase in activity from first to second 24 hours after delivery of koala scats, fort change, mulch pile, mulch pile with mealworms, and pegged down carcass, while there was a significant decrease in activity from the first to second 24 hours after delivery of the paper mache ball (Figure 3).

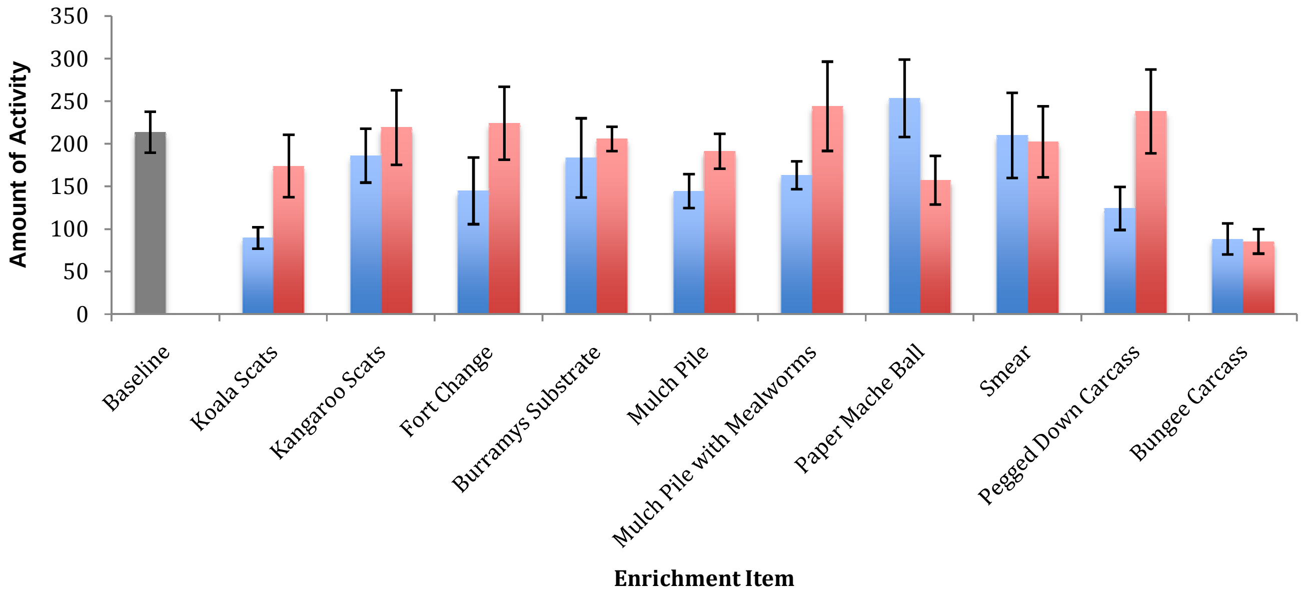


Figure 3 – Average activity levels within the first 24 hours (blue) and second 24 hours (red) after items first introduction. Error bars represent ± S.E.

3.2 Interactions with Enrichment Items

Extreme variations were observed in individual interest with the different enrichment items upon first delivery (Figures 4-13). Some level of interest amongst all devils was shown in the initial introduction of kangaroo scats (Figure 5), burramys substrate (Figure 7), mulch pile with mealworms (Figure 9), paper mache ball (Figure 10), smear (Figure 11), and both carcass enrichments (Figures 12 and 13). Some individuals were indifferent to the initial introduction of the fort change (Figure 6), mulch piles (Figure 8), and showed little to no interest in koala scats (Figure 4). These radical divergences are primarily responsible for large standard error calculations in the results found in this study, as well as small sample size.

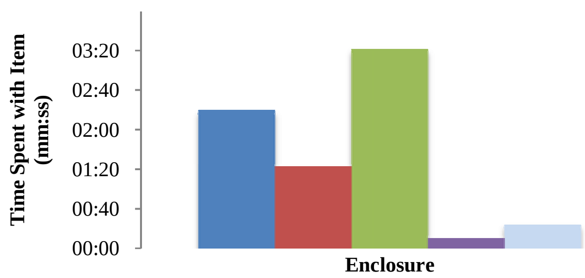


Figure 4 - Amount of time spent interacting with koala scats within 2 hours after first delivery for five different devils. Blue represents MHP1, red represents MHP2, green represents MHP3, purple represents MHP4, and light blue represents MHP6A.

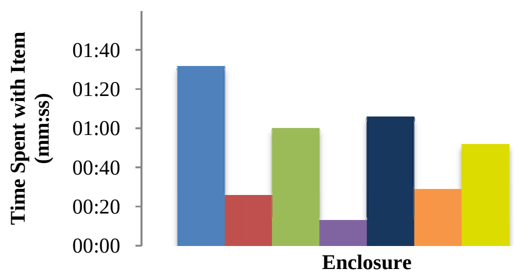


Figure 5 - Amount of time spent interacting with kangaroo scats within 2 hours after first delivery for seven different devils. Blue represents MHP1, red represents MHP2, green represents MHP3, purple represents MHP4, dark blue represents MHP5A, orange represents MHP6B, and yellow represents MHP7B.

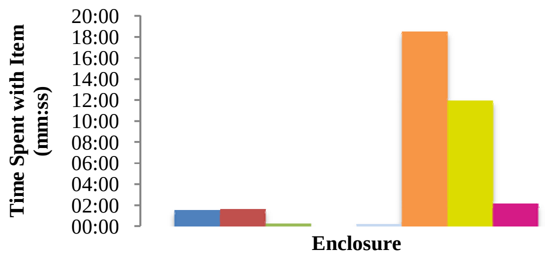


Figure 6 - Amount of time spent interacting with fort change within 2 hours after first item interaction for 8 different devils. Blue represents MHP1, red represents MHP2, green represents MHP3, purple represents MHP4, light blue represents MHP6A, orange represents MHP6B, yellow represents MHP7B, and pink represents MHP8B.

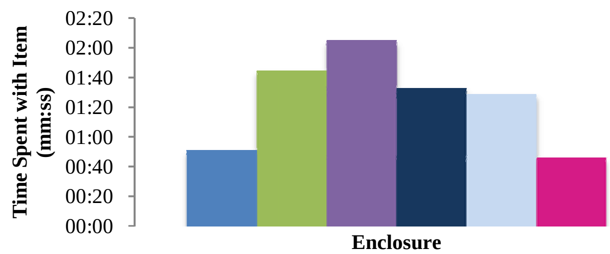


Figure 7 - Amount of time spent interacting with burramys substrate within 2 hours after first item interaction for 6 different devils. Blue represents MHP1, green represents MHP3, purple represents MHP4, dark blue represents MHP5A, light blue represents MHP6A, and pink represents MHP8B.

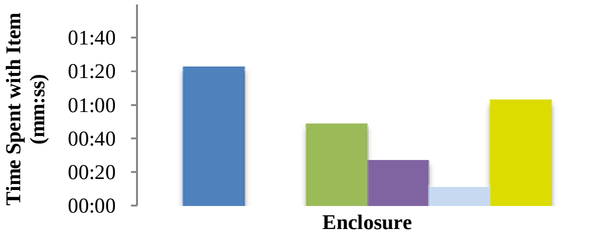


Figure 8 - Amount of time spent interacting with mulch pile within 2 hours after first item interaction for 6 different devils. Blue represents MHP1, red represents MHP2, green represents MHP3, purple represents MHP4, light blue represents MHP6A, and yellow represents MHP7B.

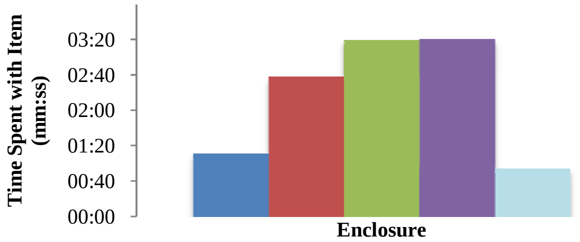


Figure 9 - Amount of time spent interacting with mulchpile with mealworms within 2 hours after first item interaction for 5 different devils. Blue represents MHP1, red represents MHP2, green represents MHP3, purple represents MHP4, and light blue represents MHP6A.

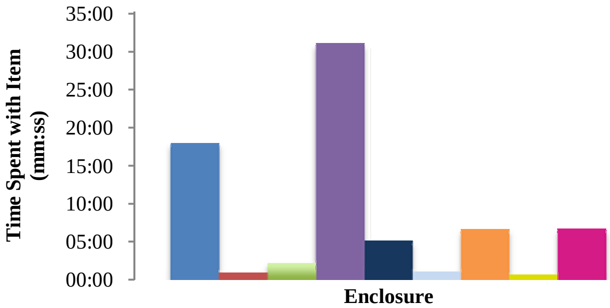


Figure 10 - Amount of time spent interacting with paper mache ball within 2 hours after first item interaction for 9 different devils. Blue represents MHP1, red represents MHP2, green represents MHP3, purple represents MHP4, dark blue represents MHP5A, light blue represents MHP6A, orange represents MHP6B, yellow represents MHP7B, and pink represents MHP8B.

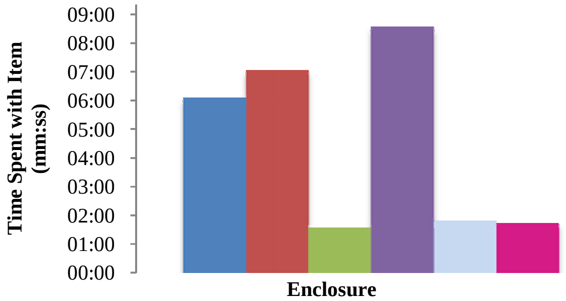


Figure 11 - Amount of time spent with smear within 2 hours after first item interaction for 6 different devils. Blue represents MHP1, red represents MHP2, green represents MHP3, purple represents MHP4, light blue represents MHP6A, and pink represents MHP8B.

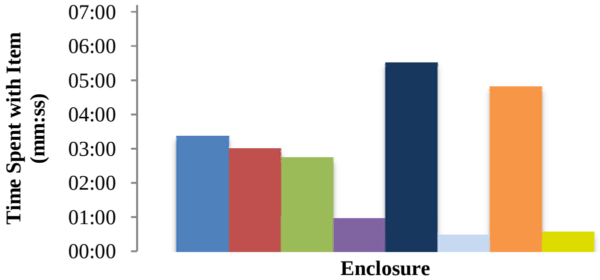


Figure 12 - Amount of time spent with pegged down carcass within 2 hours after first item interaction for 8 different devils. Blue represents MHP1, red represents MHP2, green represents MHP3, purple represents MHP4, dark blue represents MHP5A, light blue represents MHP6A, orange represents MHP6B, and yellow represents MHP7B.

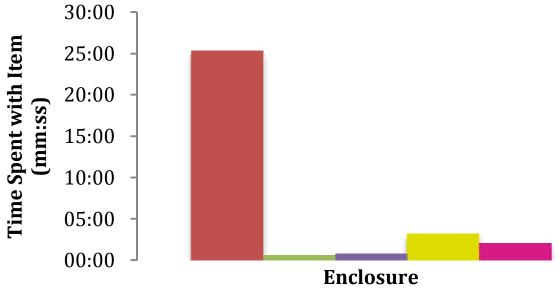


Figure 13 - Amount of time spent with bungee carcass within 2 hours after first item interaction for 5 different devils. Red represents MHP2, green represents MHP3, purple represents MHP4, yellow represents MHP7B, and pink represents MHP8B.

Upon first delivery the items that showed the most interest amongst the devils were all of the food-related items less the mulchpile with mealworms. The fort change, burramys substrate, and koala scats were the next most interactive items for the devils. Kangaroo scats and mulch piles were of least interest. Significant changes in initial 2 hours of interaction time with enrichment items from first to second deliveries were observed for the mulch pile with mealworms, and paper mache ball (Figure 14). On average, individuals showed much less interest in these items the second time they were delivered.

Trends in interest amongst devils for the different enrichment items continued over a 48 hours period for both the first and second delivery of enrichment items (Figure 15).

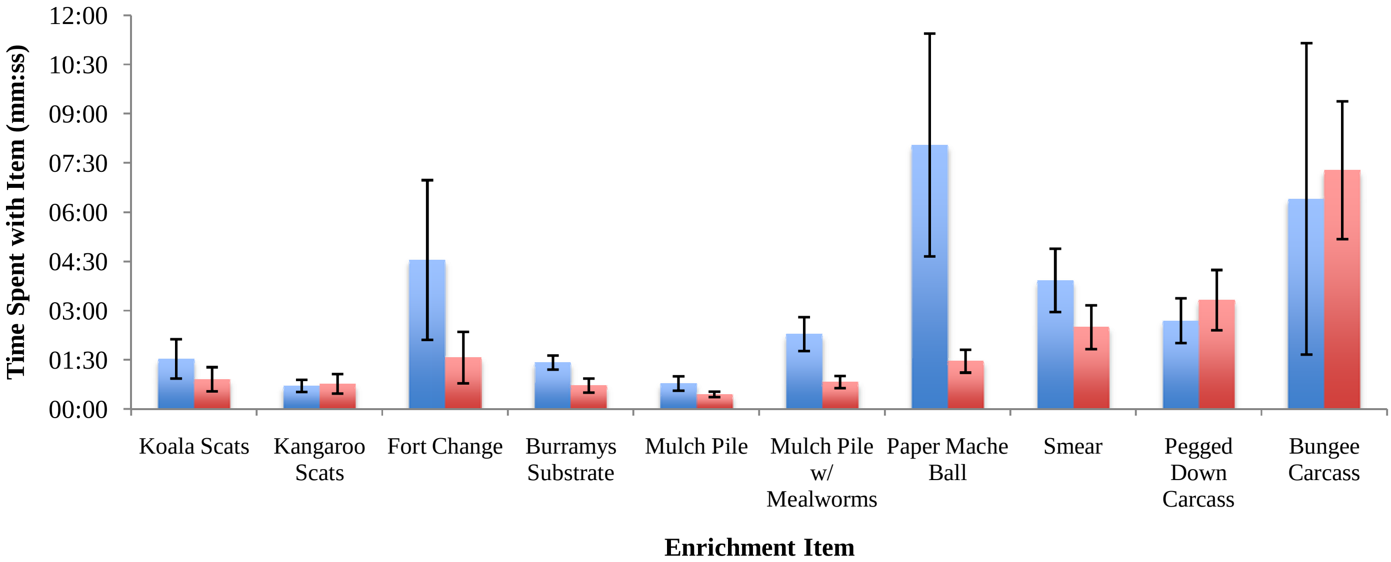


Figure 14 – Average amount of time spent amongst devils with enrichment within 2 hours after first interaction with item for first (blue) and second (red) deliveries. Error bars represent ± S.E.

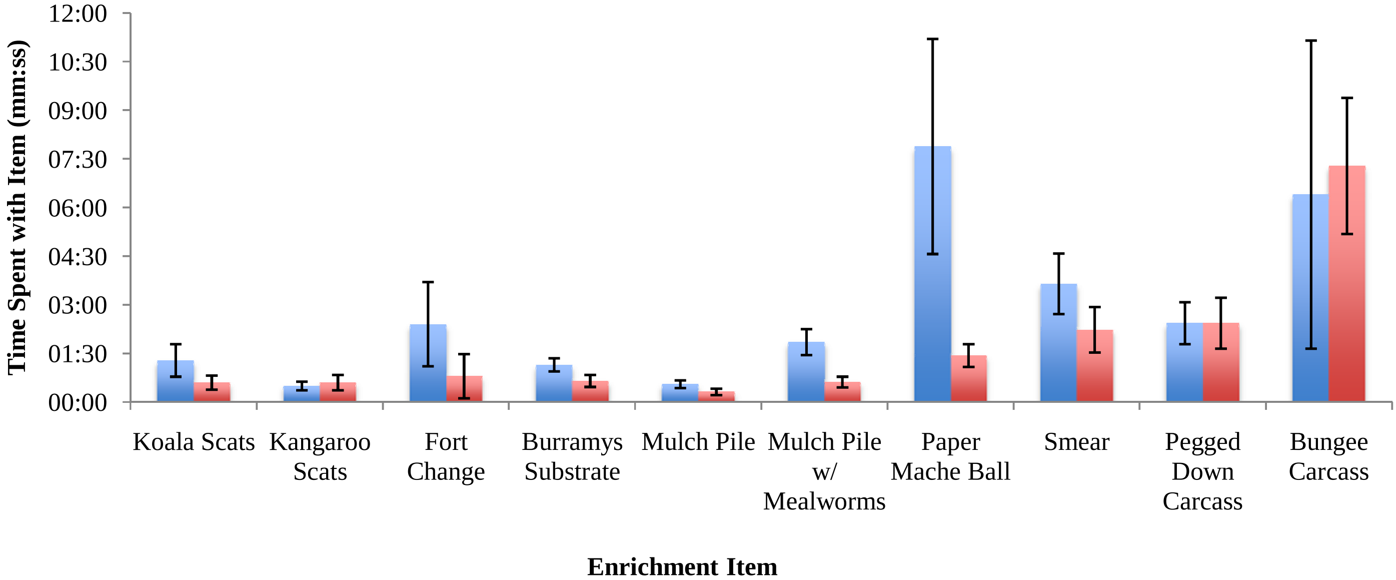


Figure 15 – Average amount of time spent amongst devils with enrichment over a 48 hour period after item was delivered for first (blue) and second (red) deliveries. Error bars represent ± S.E.

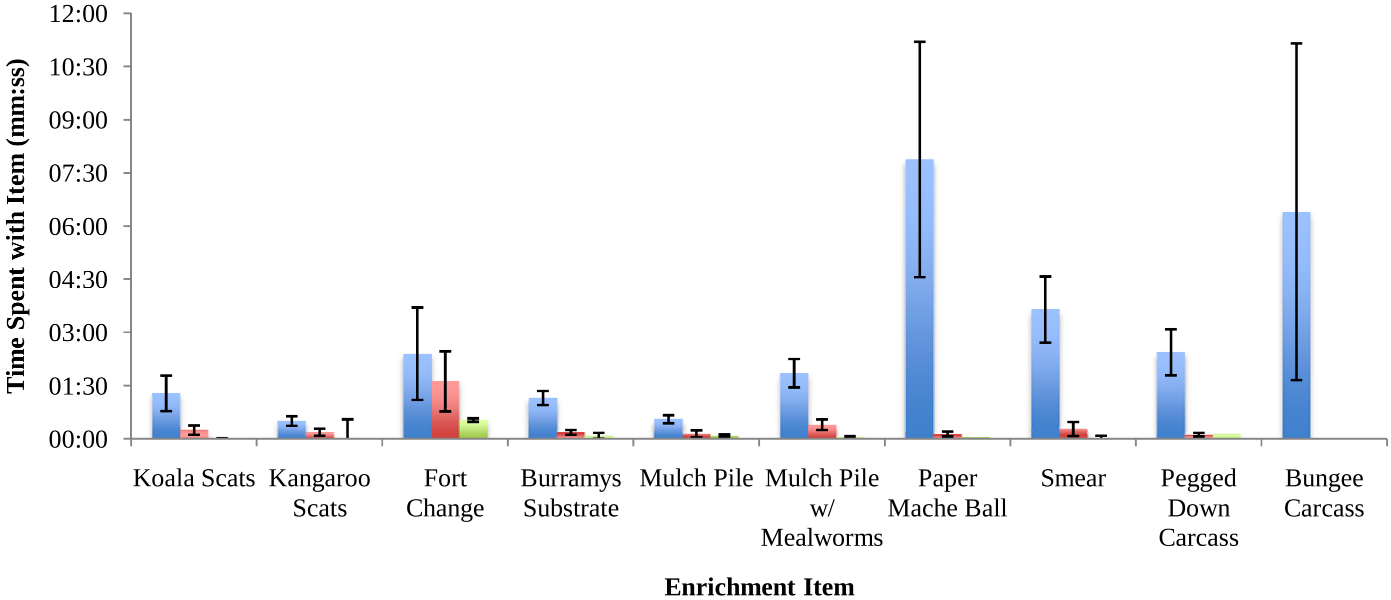


Figure 16 – Average amount of time spent amongst devils with each enrichment item within first 2 hours of interaction (blue), from 4-6PM 24 hours after introduction (red), and from 4-6PM 48 hours after introduction (green). Only first 2 hours of interaction with bungee carcass are pictured because item was removed after a 24 hour period. Error bars represent ± S.E.

Significant decreases in interactions were seen from initial interest in item to interest in item 24 and 48 hours after the item was introduced during the devils' most active times of day in all enrichment types except for the fort change. The fort change had no significant changes in interaction time from the initial interactions to the time span analyzed 24 hours later, however interactions did decrease 48 hours after introduction (Figure 16).

3.3 Behaviors Elicited from Enrichment Items

Sniffing was one of the most common behaviors observed as the devils investigated the different enrichment items. The second most common behavior was foraging, which is a variation of the sniffing behavior (Figures 17-26). Some defensive behaviors were observed in all of the non-food items besides the fort change (Figures 17-21). Very little to no defensive behaviors were observed in interactions with food-related items (Figures 22-26). Signficant decreases were seen in sniffing behavior from first to second introduction of items for the burramys substrate (Figure 20), mulch pile (Figure 21), and mulch pile with mealworms (Figure 22). There was also a significant decrease in foraging activity for the paper mache ball from first to second introduction (Figure 23).

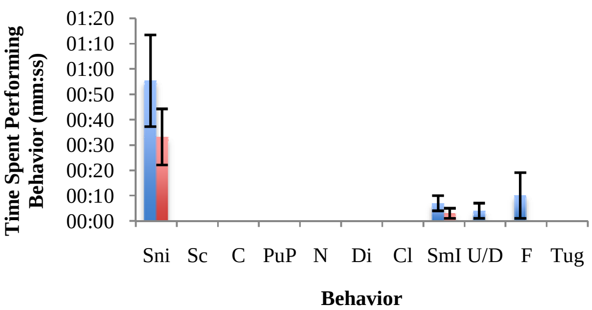


Figure 17 – Average amount of time amongst devils spent eliciting different behaviors toward koala scats upon first (blue) and second (red) introduction. Error bars represent ± S.E.

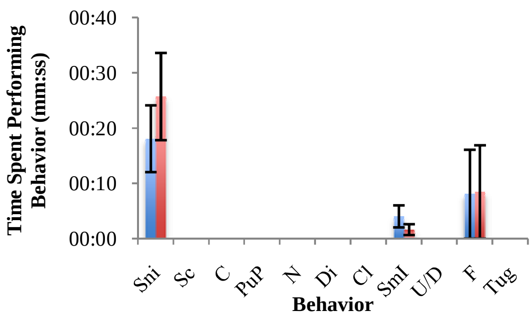


Figure 18 – Average amount of time amongst devils spent eliciting different behaviors toward kangaroo scats upon first (blue) and second (red) introduction. Error bars represent ± S.E.

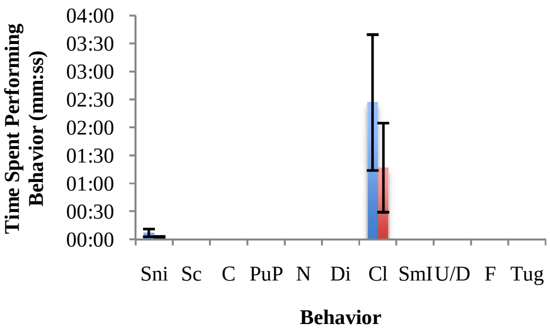


Figure 19 – Average amount of time amongst devils spent eliciting different behaviors toward fort change upon first (blue) and second (red) introduction. Error bars represent ± S.E.

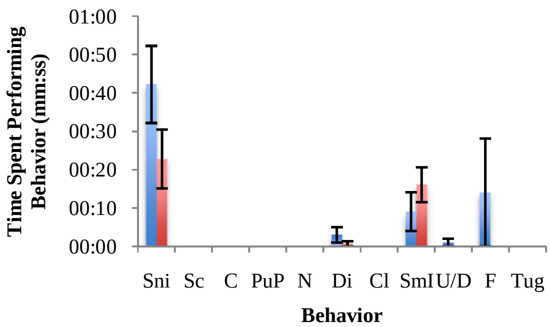


Figure 20 – Average amount of time amongst devils spent eliciting different behaviors toward burramys substrate upon first (blue) and second (red) introduction. Error bars represent ± S.E.

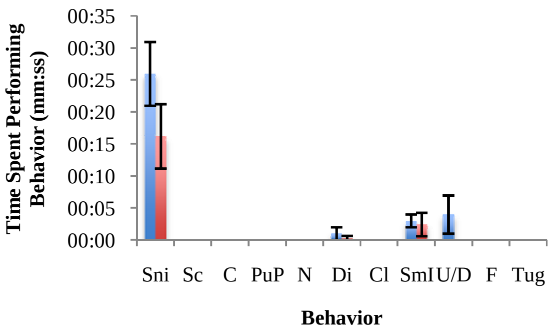


Figure 21 – Average amount of time amongst devils spent eliciting different behaviors toward mulch pile upon first (blue) and second (red) introduction. Error bars represent ± S.E.

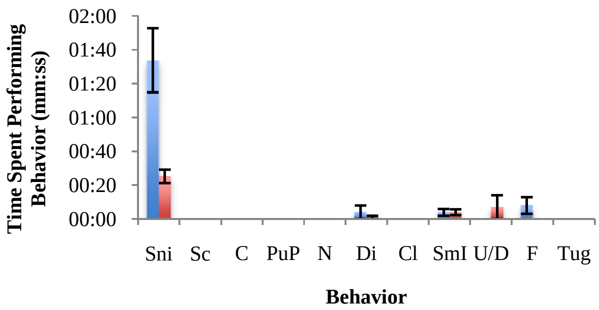


Figure 22 – Average amount of time amongst devils spent eliciting different behaviors toward mulch pile with mealworms upon first (blue) and second (red) introduction. Error bars represent ± S.E.

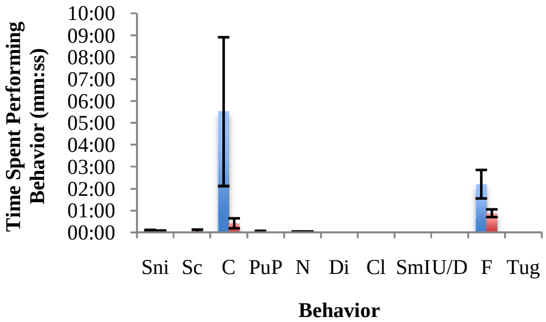


Figure 23 – Average amount of time amongst devils spent eliciting different behaviors toward paper mache ball upon first (blue) and second (red) introduction. Error bars represent ± S.E.

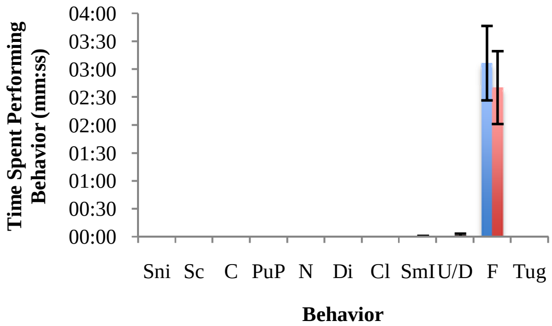


Figure 24 – Average amount of time amongst devils spent eliciting different behaviors toward smear upon first (blue) and second (red) introduction. Error bars represent ± S.E.

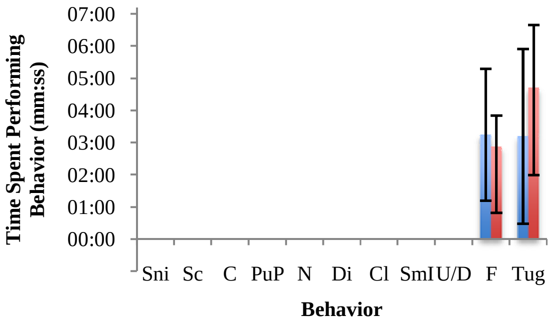


Figure 25 – Average amount of time amongst devils spent eliciting different behaviors toward pegged down carcass upon first (blue) and second (red) introduction. Error bars represent ± S.E.

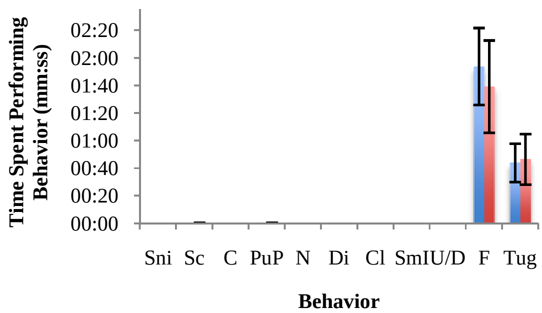


Figure 26 – Average amount of time amongst devils spent eliciting different behaviors toward bungee carcass upon first (blue) and second (red) introduction. Error bars represent ± S.E.

Overall, these were the behaviors elicited by each item (Figures 17-26):

Koala Scats – sniffing, scent marking, urinating/defecating, and foraging.

Kangaroo Scats – sniffing, scent marking, and foraging.

Fort Change – climbing and sniffing.

Burramys Substrate – sniffing, digging, scent marking, urinating/defecating, and foraging.

Mulch Pile – sniffing, digging, scent marking, and urinating/defecating.

Mulch Pile with Mealworms – sniffing, digging, scent marking, urinating/defecating, and foraging.

Paper Mache Ball – sniffing, scratching, carrying, picking up with paws, nudging, and foraging.

Smear – scent marking, urinating/defecating, and foraging.

Pegged Down Carcass – foraging and tugging.

Bungee Carcass – foraging and tugging.

4. DISCUSSION

4.1 Activity Levels

Almost all enrichment items given during this study had a significant overall effect on the activity levels of the devils. There was a significant decrease in activity after the introduction of koala scats, kangaroo scats, fort change, mulch pile, and bungee carcass after their first introductions (Figure 2). Because activity was measured in number of times a devil ran by the sensor in one given spot of their enclosure, this suggests that after these items were introduced, the devils spent their time focused in the area around the item and were not passing by the sensor, and/or had reduced levels of stereotypic behavior. After reviewing video footage it was clear that much of the devils' time in their enclosures is spent running along paths that they have worn into the ground, usually in a loop around the enclosure. While running their usual tracks they can generate a high number of sensor records, therefore these lower activity levels support the conclusion that stereotypic behavior was reduced, however this may require further investigation to confirm. Similar results were found in studies with other carnivores, like a large felid enrichment study, where providing food-based enrichment showed nonsignificant trends toward reduced pacing, and a trend toward increase in nonstereotypic activity (Bashaw et al 2003). Many forms of enrichment have been shown to reduce stereotypical behaviors and promote more natural behaviors, subsequently improving the welfare of captive animals (Quirke and O'Riordan 2011). Enrichment items are not effective across all species, but can be highly effective when tailored to the animal in question. These types of enrichment could be extremely useful when used for other captive carnivorous species or opportunistic feeders such as hyenas, felids, or wild dogs.

The sensor data also showed a significant increase in activity in the first 2 hours after the first introduction of the paper mache ball (Figure 2). The video analysis revealed that most of the time spent interacting with the paper mache ball was spent carrying the item (Figure 23). As the devils carried the paper mache ball, most ran around the enclosure with the item. Devils can be extremely possessive, most likely resulting in this act, which would have appeared as a high amount of activity in the sensor data. This item may be good for promoting higher activity levels, however it may be important to investigate if there is stress associated with the devil trying to protect and prove ownership items that can be picked up and carried around. On the other hand, devils in a natural environment must compete with other devils over food sources, and this protective behavior may not be negative in a wild environment. It is extremely important that wild behaviors are continued in the devil insurance populations in case of the necessity for future release.

Significant decreases in the first 2 hours upon second introduction of items were only seen for burramys substrate, the paper mache ball, smear, and pegged down carcass (Figure 2). This suggests that all non-food related items aside from the burramys substrate may need more than 2 weeks time before reintroduction to maintain a sense of novelty to the devils. Food-related items seemed to be fairly successful after just one week of absence. The bungee carcass showed no significant changes in activity from baseline levels upon first or second introduction (Figure 2), possibly because of the work required to interact with this item. Based on sensor data alone, the devils may have left and come back to work on consuming this item several times. These findings are important because they show that habituation is more likely to occur with non-food related items. All of the non-food related items were all presented around the same time of day, and other studies have suggested that a randomized schedule of enrichment can provide a greater degree of novelty (Quirke and O'Riordan 2011).

Review of activity levels showed that activity was significantly below baseline levels in the first 24 hours after enrichment delivery for the bungee carcass, pegged down carcass, koala scats, fort change, mulch pile, and mulch pile with mealworms. All items had activity around baseline levels, less the bungee carcass, in the second 24 hours after they were given (Figure 3). This proves that the effects of these enrichment items were not potent after a 24-hour period. These findings are also supported by the data collected from the video analysis which showed a significant decrease in interation time from initial 2 hours of interaction, to 24 and 48 hours later (Figure 16). Although the activity effects were not long lasting, these items still served their purpose shortly after delivery.

4.2 Individual Interests

Graphs for time spent with items amongst the different individuals in this study showed that there was high variation in interest for fort changes (Figure 6), mulch piles (Figure 8), and koala scats (Figure 4). Because some individuals showed little to no interest in these items, they may not be an effective form of enrichment for this particular species. To confirm this, a larger sample size should be tested. Fairly equal, high interest was shown in the initial introduction of kangaroo scats (Figure 5), burramys substrate (Figure 7), mulch pile with mealworms (Figure 9), paper mache ball (Figure 10), smear (Figure 11), and both carcass enrichments (Figures 12 and 13), supporting the quality of those specific enrichment items for this species.

On average, the paper mache ball, smear, bungee carcass, and pegged down carcass were the most effective in holding the interest of the devil within 2 hours of first interaction. These items had high standard deviations however, representative of the differences in individuals as earlier described. The next most effective items were the fort change, burramys substrate, and koala scats. Kangaroo scats seemed to be of insignificant interest in comparison to the other enrichments provided. Significant changes were seen from first to second deliveries in immediate interest for the mulch pile with mealworms and paper mache ball (Figure 14). On average, individuals showed much less interest in items upon second delivery, as a result of habituation. As mentioned previously, this issue may be resolved through a randomized enrichment schedule.

4.3 Behaviors Elicited by Enrichment Items

All non-food related items were successful in eliciting sniffing and exploratory behaviors, as well as some defensive behaviors such as scent marking and urinating or defecating. These are all natural behaviors that should be promoted, although items that elicit defensive behaviors may not be delivered during sensitive times such as their breeding period, in order to avoid stress. Scent marking behaviors have been observed in other studies using olfactory enrichment such as scats, where results showed decreased levels of pacing with greater amount of time spent investigating novel odors (Quirke and O'Riordan 2011).

Changing the orientation of the devils' forts showed high variation in interest amongst the devils. There were noticeable differences between individuals – it seemed that devils that normally used the fort frequently continued to do so after its structure was altered, however individuals that did not normally utilize the fort did not use it more often when it was altered. Because of this, I do not think that changing the orientation of the fort is necessary nor positive for the devils. It does not seem to have a negative effect on behavior either. Climbing is an important skill for devils to have in the wild, and further strategies to promote this behavior should be explored.

Items involving some type of substrate (i.e. mulch pile items, burramys substrate) elicited some digging behaviors, which can be positive for increasing leg strength for the devils, however these behaviors were minimal. To increase this behavior, it may be important to provide larger amounts of substrate than were given in this study.

All food-related items promoted a high degree of foraging behavior, encouraging exploration of the enclosure and making food acquisition more difficult. Under natural conditions, most animals spend a majority of their time searching for food (Kistler et al 2009), and it is crucial that a population of captive animals intended for future release not acclimate to being fed without effort involved. This is especially relevant for scavengers such as the Tasmanian devil, who are opportunistic and have to search for carcasses to feed on in the wild.

The pegged down carcass and bungee carcass were highly important items for the devils because they promoted tugging behaviors, which are necessary for devil survival. Tugging behavior would strengthen their jaw muscles as they worked on the carcass. Feeding of processed foods instead of whole carcasses has shown negative physiological and behavioral consequence in other studies. For example, Duckler (1998) found that compared to wild individuals, captive-reared tigers showed that the principle muscles operating their jaws and neck had a greatly reduced influence on the shape of the skull during development. The purpose of this study and this insurance population is to keep wild morphologies and behaviors in devils, and severe consequences as such are not an option.

5. CONCLUSION

To our knowledge, no publications are available providing information on Tasmanian devil behavior in captivity, let alone the effects of enrichment on devil behavior. My study showed the effects of enrichment on the activity levels of devils, as well as outlined how long enrichment is successful for, how long of a resting period they need before reintroduction, and showed which behaviors were elicited by different types of items. A further topic I intend on exploring for publication are whether or not these items promote nocturnal behavior in captive Tasmanian devils. I will also be conducting statistical analyses to further confirm or disprove the results put forth in this study. Overall, enrichment seems to be an important tool to utilize for this insurance population if they are intended for future release in the wild. Without these opportunities, behaviors could be lost that are necessary for survival in a natural environment, as the devils will most likely adapt to captive conditions.

REFERENCES

Acevedo-Whitehouse K., J. Vicente, C. Gortazar, U. Hofle, I.G. Fernandez de Mera and W. Amos (2005) Genetic resistance to bovine tuberculosis in the Iberian wild boar. Molecular Ecology **14**:3209-3217.

Archer M. and A. Baynes (1972) Prehistoric mammal faunas from two small caves in the extreme southwest of Western Australia. Journal of the Royal Society of Western Australia **55**:80-89.

Clubb R, Mason G. 2007. Natural behavioral biology as a risk factor in carnivore welfare: How analyzing species differences could help zoos improve enclosures. Applied Animal Behavior Science **102**:303-328.

Conway, W.G., M. Hutchins, M. Souza, Y. Kapentanakos & E. Paul. 2001. *The AZA Field Conservation Resource Guide*. Zoo Atlanta, Atlanta Georgia.

de Castro F. and B. Bolker (2005) Mechanisms of disease-induced extinction. Ecology Letters **8**:117-126.

Department of Primary Industries, Parks, Water, and Environment (2010) Recovery Plan for the Tasmanian Devil (*Sarcophilus Harissii*). Department of Primary Industries, Parks, Water, and Environment, Hobart.

Duckler GL. 1998. An ususual osteological formation in the posterior skulls of captive tigers (*Panthera tigris*). Zoo Biology **17**:135-142.

Frankham R, Hemmer H, Ryder O, Cothran E, Soulé M, Murray N, Snyder M. 1986. Selection in captive populations. Zoo Biology **5**:127-138.

Frankham, Richard, David A. Briscoe, and J. D. Ballou. *Introduction to Conservation Genetics*. Cambridge, UK: Cambridge UP, 2002.

Garner J, Mason G. 2002. Evidence for a relationship between cage stereotypies and behavioral disinhibition in laboratory rodents. Behavioral Brain Research **136**:83-92.

Hawkins C.E., C. Baars, H. Hesterman, G.J. Hocking, M.E. Jones, B. Lazenby, D. Mann, N. Mooney, D. Pemberton, S. Pyecroft, M. Restani, and J. Wiersma (2006) Emerging disease and population decline of an island endemic, the Tasmanian devil *Sarcophilus harrisii*. Biological Conservation **131**:307-324.

Jones M, Jarman P, Lees C, Hesterman H, Hamede R, Mooney N, Mann D, Pukk C, Berfeld J, McCallum H. 2007. Conservation Management of Tasmanian Devils in the Context of an Emerging, Extinction-threatening Disease: Devil Facial Tumour Disease. EcoHealth **4**:326-337.

Jule K, Leaver L, Lea S. 2008. The effects of captive experience on reintroduction survival in carnivores: A review and analysis. Biological Conservation **141**:355-363.

Kistler C, Hegglin D, Wurbel H, Konig B. 2009. Feeding enrichment in an opportunistic carnivore: The red fox. Applied Animal Behavior Science **116**:260-265.

Kleiman D.G., Allen M.E., K.V. Thompson & S. Lumpkin (eds) 1996. *Wild Mammals in Captivity: Pricipals and Techniques.* University of Chicago Press, Chicargo, IL.

Kraaijeveld-Smit FJL, Griffiths RA, Moore RD, Beebee TJC. 2006. Captive breeding and the fitness of reintroduced species: a test of the responses to predators in a threatened amphibian. Journal of Applied Ecology **43**:360-365.

Lyles, A.M. 2001. Zoos and Zoological Parks. In S.A. Levins (ed), Encyclopedia of Biodiversity, vol. 5, pp. 901-912. Academic Press, San Diago, CA.

Lynch M, O'Hely M. 2001. Captive breeding and the genetic fitness of natural populations. Conservation Genetics **2**:363-378.

Mason G, Clubb R, Latham N, Vickery S. 2007. Why and how should we use environmental enrichment to tackle stereotypic behaviour? Applied Animal Behaviour Science **102**:163-188.

McDougall P, Reale D, Sol D, Reader S. 2005. Wildlife conservation and animal temperament: causes and consequences of evolutionary change for captive, reintroduced, and wild populations. Animal Conservation **9**.

McPhee M. 2003. Generations in captivity increases behavioural variance: considerations for captive breeding and reintroduction program. Biological conservation **115**:71-77.

Primack, Richard B. *Essentials of Conservation Biology*. 4th ed. Sunderland, MA: Sinauer Associates, 2010.

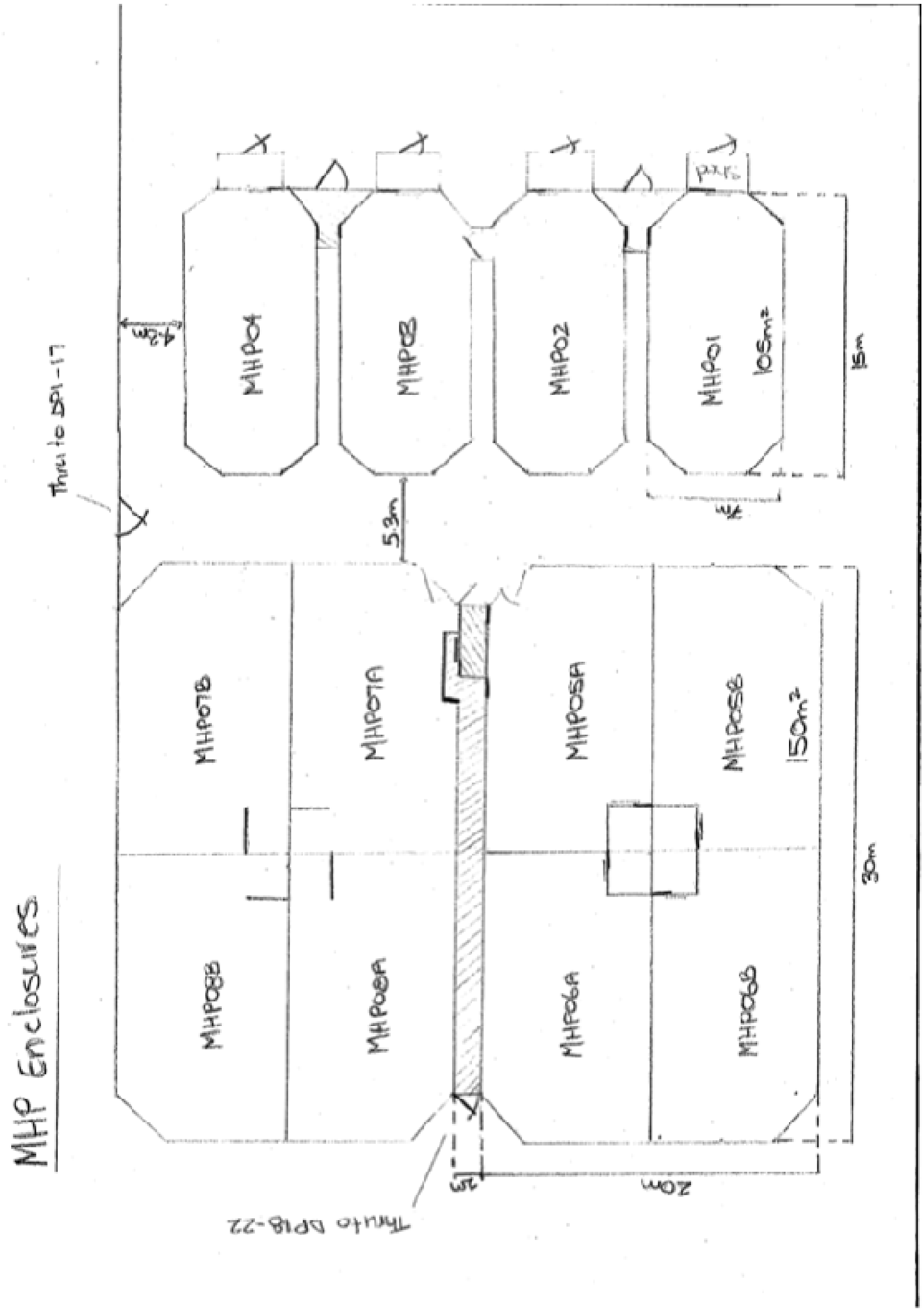
Siddle H.V., A. Kreiss, M.D. Eldridge, E. Noonan, C.J. Clarke, S. Pyecroft, G.M. Woods and K. Belov (2007) Transmission of a fatal clonal tumour by biting occurs due to depleted MHC diversity in a threatened carnivorous marsupial. Proceedings of the National Academy Sciences USA **104**:16221-16226.

Sinn D.L., K. Macnab and A. Sharman (2010) Free-Range Project Annual Report January-December 2009: Initial results from the first year's breeding season and recommendations for future planning. Save the Tasmanian Devil Program, Tasmania. Available at http://tassiedevil.com.au Accessed September 2010.

Quirke T, O'Riordan RM. 2011. The effect of a randomized enrichment treatment schedule on the behavior of cheetahs (*Acinonyx jubatus*). Applied Animal Behavior Science **135**:103-109.

Van Metter JE, Harriger MD, Bolen RH. 2008. Environmental Enrichment Utilizing Stimulus Objects for African Lions (*Panthera leo leo*), and Sumatran Tigers (*Panthera tigris sumatrae*). Bios **79**:7-16.

Appendix 1. Diagram of MHP enclosures utilized during this study.



Appendix 2. Male dietary schedule during this study.

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
5-Sep *C/E = 400*	6-Sep *P = 1200*	7-Sep *STARVE*	8-Sep STARVE	9-Sep W = 1200	10-Sep STARVE	11-Sep STARVE
12-Sep F/C = 600	13-Sep W = 400	14-Sep R = 1200	15-Sep STARVE	16-Sep STARVE	17-Sep W = 1200	18-Sep STARVE
19-Sep STARVE	20-Sep P = 1200	21-Sep STARVE	22-Sep STARVE	23-Sep W = 1600	24-Sep STARVE	25-Sep STARVE
26-Sep STARVE	27-Sep C = 700	28-Sep STARVE	29-Sep R = 1200	30-Sep STARVE	1-Oct STARVE	2-Oct F/I/E = 350
3-Oct P = 1200	4-Oct STARVE	5-Oct STARVE	6-Oct C = 300	7-Oct W = 1200	8-Oct STARVE	9-Oct STARVE
10-Oct R = 1200	11-Oct STARVE	12-Oct STARVE	13-Oct F/C = 600	14-Oct W = 400	15-Oct P = 1200	16-Oct STARVE
17-Oct STARVE	18-Oct W = 1200	19-Oct STARVE	20-Oct STARVE	21-Oct C = 700	22-Oct STARVE	23-Oct W = 1600
24-Oct STARVE	25-Oct STARVE	26-Oct STARVE	27-Oct C = 300	28-Oct F/I/E = 350	29-Oct P = 1200	30-Oct STARVE
31-Oct STARVE	1-Nov R = 1200	2-Nov STARVE	3-Nov STARVE	4-Nov W = 1600	5-Nov STARVE	6-Nov STARVE
7-Nov STARVE	8-Nov P = 1200	9-Nov STARVE	10-Nov STARVE	11-Nov	12-Nov	13-Nov

Appendix 3. Female dietary schedule during this study.

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
5-Sep *C/E = 350*	6-Sep *P = 1050*	7-Sep *STARVE*	8-Sep STARVE	9-Sep W = 1050	10-Sep STARVE	11-Sep STARVE
12-Sep F/C = 400	13-Sep W = 350	14-Sep R = 1050	15-Sep STARVE	16-Sep STARVE	17-Sep W = 1050	18-Sep STARVE
19-Sep STARVE	20-Sep P = 1050	21-Sep STARVE	22-Sep STARVE	23-Sep W = 1400	24-Sep STARVE	25-Sep STARVE
26-Sep STARVE	27-Sep C = 700	28-Sep STARVE	29-Sep R = 1050	30-Sep STARVE	1-Oct STARVE	2-Oct F/I/E = 300
3-Oct P = 1050	4-Oct STARVE	5-Oct STARVE	6-Oct C = 350	7-Oct W = 1050	8-Oct STARVE	9-Oct STARVE
10-Oct R = 1050	11-Oct STARVE	12-Oct STARVE	13-Oct F/C = 400	14-Oct W = 350	15-Oct P = 1050	16-Oct STARVE
17-Oct STARVE	18-Oct W = 1050	19-Oct STARVE	20-Oct STARVE	21-Oct C = 700	22-Oct STARVE	23-Oct W = 1400
24-Oct STARVE	25-Oct STARVE	26-Oct STARVE	27-Oct C = 350	28-Oct F/I/E = 300	29-Oct P = 1050	30-Oct STARVE
31-Oct STARVE	1-Nov R = 1050	2-Nov STARVE	3-Nov STARVE	4-Nov W = 1400	5-Nov STARVE	6-Nov STARVE
7-Nov STARVE	8-Nov P = 1050	9-Nov STARVE	10-Nov STARVE	11-Nov	12-Nov	13-Nov

Appendix 4. Schedule of enrichment item delivery during study.

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
5-Sep *Tanya projects last day*	6-Sep *Works dep to finish forts*	7-Sep *Works dep to finish forts*	8-Sep Scats - Koala	9-Sep	10-Sep	11-Sep Mulch pile - with mealworms
12-Sep	13-Sep	14-Sep Fort change	15-Sep	16-Sep	17-Sep Mulch pile - with mealworms	18-Sep
19-Sep	20-Sep Scats - Koala	21-Sep	22-Sep	23-Sep Carcass - peg down	24-Sep	25-Sep
26-Sep Fort change	27-Sep	28-Sep	29-Sep Carcass - peg down	30-Sep	1-Oct	2-Oct Scat - Kangas
3-Oct	4-Oct	5-Oct Smear	6-Oct	7-Oct	8-Oct Mulch pile	9-Oct
10-Oct	11-Oct Smear	12-Oct	13-Oct	14-Oct Scat - Kangas	15-Oct	16-Oct
17-Oct Paper mache ball	18-Oct	19-Oct	20-Oct Mulch pile	21-Oct	22-Oct	23-Oct Paper mache ball
24-Oct	25-Oct	26-Oct Burramys bedding	27-Oct	28-Oct	29-Oct Carcass - Bungee	30-Oct
31-Oct	1-Nov	2-Nov	3-Nov	4-Nov Carcass - Bungee	5-Nov	6-Nov
7-Nov Burramys bedding	8-Nov	9-Nov	10-Nov **End Study**	11-Nov	12-Nov	13-Nov