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Improving our knowledge of snow leopard behaviour (*Panthera uncia*) through close encounters and enclosure utilisation

A thesis presented
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Abstract

There is currently limited information on the behaviour of snow leopards (*Panthera uncia*) in wild or captive environments, or on the influence of close encounters on behaviour in captivity. This limits the ability of facility managers to design and evaluate habitats that fulfil the behavioural needs of captive animals, or to design and evaluate appropriate close encounter or enrichment strategies. The present study aimed to evaluate the behaviour of two snow leopard sisters (Asha and Manju) at Te Nukuao Wellington Zoo in response to the introduction of close encounters (Chapter 2) and to develop detailed behavioural time budgets and characterise habitat utilisation (Chapter 3). To evaluate the effects of encounters on behaviour, continuous video recordings from 12 encounter days (three per week over four consecutive weeks) were analysed according to a pre-defined ethogram, for the periods 1 hour before (immediately before guests' arrival), during (while guests were present), and 1 hour after (immediately after guests left) encounters. Behavioural time budgets were calculated from continuous video recordings over 12 separate days (four days per week from weeks 1, 3, and 5, including 2 encounter and 2 non-encounter days per week) using the same pre-defined ethogram. In addition, the cat's location in the habitat was recorded (based on pre-defined grids). The cats' behaviour differed during and after encounters, and with different enrichment presentations. Both cats spent more time interacting with hanging enrichments than with other presentation types. The percentage of time spent inside the dens (where enrichment was presented) before and after the encounters differed between cats, possibly reflecting differences in response to/anticipation of guest presence. Furthermore, Asha's time spent interacting with the enrichment increased over the four weeks, whereas Manju showed no such trend. The behavioural time budgets and habitat utilisation were similar among both cats. Both cats spent a large proportion of time inactive, which is consistent with previous data from wild and captive felids, with the largest proportion of their time spent in the flat, elevated sections of the habitat. This research is the first to characterise snow leopard behaviour in response to the introduction of close encounters. Presenting food enrichment in hanging format increased the time spent interacting, possibly mimicking natural hunting behaviours. Future research should evaluate behaviour over a longer period to account for any acclimation effects. Although there were broad similarities between the cats in their behavioural time budgets and habitat utilisation, the identification of individual

differences in some behaviours highlights the importance of considering and characterising behaviour at the individual level when designing and evaluating enrichments and close encounters.

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Chapter 1: Literature Review

1.1 Introduction

Snow leopards (*Panthera uncia*) are listed a vulnerable species on the International Union for Conservation of Nature (IUCN) Red List, with wild population estimates between 4,000 and 7,465 (McCarthy et al., 2024). Many of the threats faced by snow leopards such as, habitat loss/fragmentation, prey loss, and persecution from human-animal conflicts, along with their declining population number, mean that the need for captive management has become increasingly important (Tetzloff and Schwartz, 2024). E*x-situ* snow leopard populations are a part of the European Endangered Species Program (EEP) as well as the Species Survival Plan (SSP), which both focus on the sustainability and genetic diversity across both programs (Tetzloff and Schwartz, 2024). Despite this, very little is known about their behaviour and welfare within a captive environment.

Understanding the welfare of snow leopards in captivity and how they interact with their environment is essential to optimising *ex situ* conservation strategies (Bateson and Martin, 2021). Understanding their behaviour will contribute to our current knowledge of this under-studied species. To date, little data is available on snow leopard behaviour in captivity (Freeman, 2005; Burgener et al., 2008; Rosandher, 2009; Gartner and Powell, 2012; Gartner et al., 2016). This thesis aims to increase our knowledge of snow leopards' behaviour, focusing on the effect of close encounters on behaviour and how the snow leopards utilise their habitat. The data generated from this research will be the foundation for future studies aiming to evaluate the welfare and behaviour of captive snow leopards.

1.2 Snow leopard overview

1.2.1 Morphometrics

Snow leopards are elusive cats that live in high-altitude mountain ranges in Central and South Asia (Figure 1.1). They have a stocky, low-profile body-to-tail and a shoulder height of 0.6 metres (Johansson et al., 2022a) with short muscular legs. Their long tail (0.8 to 1 metre) is adapted for balance and keeping their centre of gravity low in the steep terrain in which they live (Fox et al., 2024). The mean body weight for adult females is 36 kg and 42 kg for adult males, with males being 15% heavier than the females (Johansson et al., 2022a).



Figure 1.1 Snow leopard captured on a camera trap in Mongolia (Snow Leopard Trust).

1.2.2 Conservation Status

Snow leopards are currently listed as vulnerable on the IUCN Red List as of 2016 (McCarthy, 2017). In 2024 the wild population was estimated to be 4,731 to 7,465 within their historic home range (Table 1.1) (McCarthy et al., 2024), The global Snow Leopard and Ecosystem Protection Program (GSLEP) population was estimated to be between 4,000 and 6,500 individuals (McCarthy et al., 2024). Snow leopards' range across 12 countries (Afghanistan, Bhutan, China, India, Kazakhstan, Kyrgyzstan, Mongolia, Nepal, Pakistan, Russia, Tajikistan, and Uzbekistan), extending from southern Siberia in the north across a broad arc including the mountains of Central Asia and the Tibetan Plateau, and ending in the Himalayas in the south and east (McCarthy et al., 2024). It is estimated that snow leopards inhabit an area of 1.8 million km^2 with elevations ranging from 540 to over 5000 m (Sharma et al., 2024b). Their long-term home range has been reported to be 225 ± 33 km^2 (mean ± SE) and 133 ± 23 km^2 for male and female snow leopards, respectively (Johansson et al., 2018). The monthly home ranges are 88 ± 4 km^2 (mean ± SE) and 59 ± 4 km^2 (mean ± SE) for males and females, respectively (Johansson et al., 2018). Due to the large natural home ranges and elusive nature, relatively little is known about the behaviour of this species.

Table 1.1 Snow leopard population estimates (showing the low and high range) and trends as derived from country updates (McCarthy et al., 2024)

		Estimate range		
Country	**Estimate provided**	**Low**	**High**	**Population trend**
Afghanistan	Yes	189	224	May be declining in some areas
Bhutan	Yes	79	112	Stable in Jigme Dorji NP, elsewhere unknown
China	Yes	2500	4500	Not stated
India	Partial	(155)	(217)	Not stated
Kazakhstan	Yes	141	183	Recovering, but not uniformly across country
Kyrgyzstan	Yes	150	250	Not stated
Mongolia	Yes	806	1127	Not stated
Nepal	Yes	300	400	Increase in Kanchenjunga 2009–2013, overall unknown
Pakistan	No	–	–	Not stated
Russia	Yes	65	65	Two subpopulations stable, others declining
Tajikistan	Yes	250	280	Not stated
Uzbekistan	Yes	96	107	Not stated
Total		**4731**	**7465**	

1.2.3 Behavioural Research in Snow Leopards

Knowledge about snow leopard behaviour is limited, with the literature to date focusing mainly on their population/conservation status (Bhatnagar et al., 2024; Davletbakov et al., 2024; Esipov et al., 2024; Khanal et al., 2024; McCarthy et al., 2024; Moheb et al., 2024; Munkhtsog et al., 2024; Shi et al., 2024; Grachev, 2026), habitat and home ranges (Jackson and Ahlborn, 1989; Johansson et al., 2018; Maurya et al., 2026), diet (Johansson et al., 2022b; Mallon et al., 2024; Akber et al., 2025; Ghoddousi et al., 2025; Hong et al., 2025; Johansson et al., 2025), human and livestock interactions/coexistence (Mishra et al., 2024; Suryawanshi et al., 2024; Akber et al., 2025; Ghoddousi et al., 2025; Hong et al., 2025), and genetic diversity (Hacker et al., 2024; Solari et al., 2025; Wang et al., 2025; Yang et al., 2025). This is largely because the behaviour and activity of wild snow leopards is difficult to study (Johansson et al., 2022b; Ma et al., 2024). Due to this difficulty, much of our understanding of snow leopard behaviour comes from studies of captive cats (Freeman, 2005; Burgener et al., 2008; Macri and Patterson-Kane, 2011; Gartner and Powell, 2012). Snow leopards are top predators and primarily hunt cliff-dwelling species using ambushing and stalking strategies while using cover to get closer to the prey (Yachi, 2000; Chetri et al., 2017; Johansson et al., 2025). Activity has been reported to peak at both 06:00 and 16:00, indicating crepuscular behaviour pattern (Johansson et al., 2022b; Akber et al., 2025). Dusk and dawn are optimal times for increased activity and hunting due to low light conditions, which allowing cats to ambush prey that does not have the same ability to see in these conditions (Johansson et al., 2022b; Akber et al., 2025). With hunting being a large part of

their activity, snow leopards have been reported to travel between 0.1 km and 10 km in a 5-hour period (Johansson et al., 2022b). They display territoriality within-sex, with male territories usually overlapping with adult females (Johansson et al., 2018). They have been observed to change their prey preferences seasonally, and it has been suggested that this was due to the variation in prey vulnerability by season (Johansson et al., 2025). Recent studies have investigated the maternal behaviour of snow leopards. The activity patterns of female snow leopards were altered by their reproductive state, showing a move away from crepuscular activity with peaks less defined and higher evening activity (Larsson, 2025). Females also reduced their distance and activity from dens when they had young cubs (Pålsson, 2022). While research is increasing, there is limited knowledge on the daily time budgets of snow leopards in the wild.

Stanton et al (2015) developed a standardised ethogram to be used across felid behavioural research, including domestic and exotic felids. After a large literature review of felid behavioural research and books, the behaviour described showed similarities across species and therefore, the behaviours described were collated and categorised to develop the ethogram. 15 main categories of felid behaviour were decided on: active, affiliative, aggressive, agonistic, calm, exploratory, fear, feeding, inactive, locomotion, maintenance, marking, reproductive, stereotypic and vocalisations (Stanton et al., 2015). Within these categories, base behaviours were included, and an ethogram with all behaviours and definitions was also created. These behaviours demonstrated the shared similarities across felid species and the ability to make a standardised felid ethogram.

1.3 Significance of Captive Management of Snow Leopards for Conservation

1.3.1 Conservation Concerns

Snow leopards have been listed as Endangered (EN) from 1986 to 2008 due to an estimated population of less than 2,500 mature individuals (Jackson, 2008). However, assessors later determined that snow leopards should have been listed as Vulnerable (VU) at this time due to the effective population size being used as a substitute for “mature individuals", leading to a figure of 2,040, which was 50% of the estimated adult population of 4,080 (McCarthy et al., 2024). Accordingly, snow leopards were then downlisted to VU as they met the criteria of having more than 2,500 but less than 10,000 mature individuals, with an estimated 10% population decline within three generations (McCarthy et al., 2024).

The main threats to snow leopard populations include habitat loss and fragmentation, illegal poaching, persecution from herders due to killing of livestock, and humans moving deeper into the mountains (Nygren et al., 2024). Conservation depends on the local people living within the range of snow leopards valuing this species and wanting to save them. Many conservation organisations work alongside the local people and, with the help of zoo partnerships, continue to promote coexistence and limit livestock predation by snow leopards (Suryawanshi et al., 2019). To gather a statistically robust estimate of the global snow leopard population, a standardised sampling method was subsequently introduced across the 12 countries snow leopards inhabit (Sharma et al., 2024a).

1.3.2 Captive Population

With snow leopard populations declining in their native range, the need for captive management has become increasingly important (Tetzloff and Schwartz, 2024). Snow leopards became a part of the European Endangered Species Program (EEP) in 1987, which involved breeding programs for many threatened species managed in captivity across Europe (Nygren et al., 2024). The goal of the EEP was to maintain high genetic diversity to allow populations to adapt to environmental changes and resist diseases and various stressors (Nygren et al., 2024). In North America in 1981, the Association of Zoos and Aquariums (AZA) developed the Species Survival Plan (SSP) due to the decline of several wild species; the Snow Leopard SSP was developed in 1982, overseen by the Felid Taxon Advisory Group (TAG) (Tetzloff and Schwartz, 2024). The goal of the snow leopard SSP was to implement strategies to maintain a sustainable, genetically diverse, demographically stable and behaviourally competent population (Tetzloff and Schwartz, 2024). Nowadays, snow leopard conservation is a global effort, with both the EEP and SSP exchanging snow leopards across the programs to allow for new genetics to be passed on and assist in the sustainability of the populations within both programs (Tetzloff and Schwartz, 2024).

The EEP currently has 187 individuals, making it the largest subpopulation globally, and contains 94.9% of the genetic diversity that makes up the other subpopulations (Nygren et al., 2024). Currently, the total *ex situ* population is 357 individuals, including 152 males and 179 females, located within 160 institutes across 30 countries (Species360, cited in IUCN, 2026). There are three population management programs governing snow leopard management

across these regions: the Association of Zoos and Aquariums (AZA), the Japanese Association of Zoos and Aquariums (JAZA) and the World Association of Zoos and Aquariums (WAZA).

Having a sustainable, diverse snow leopard *ex situ* population may be crucial in saving this vulnerable species in the wild (Tetzloff and Schwartz, 2024). While the need for a reserve population of snow leopards is important, spreading awareness and education is a key role of zoos, as well as assisting in research, funding and technical support for the conservation of wild counterparts (Tetzloff and Schwartz, 2024). Many zoos have partnerships with snow leopard conservation organisations, including Snow Leopard Trust, Snow Leopard Conservancy, Wildlife Conservation Society, and Mountain Spirit (Tetzloff and Schwartz, 2024). Te Nukuao Wellington Zoo has had a conservation partnership with Mountain Spirit, a non-profit grassroots organisation from Nepal, since 2021 (Zoo, 2022/23). Their goal is to protect mountain communities, cultures and biodiversity, including protecting the snow leopard population and habitats within the mountains of Nepal (Zoo, 2022/23). "*This partnership has strengthened community engagements and stewardship for snow leopard conservation through education and outreach programs, as well as small-scale income generation and wildlife deterrent measures. The partnership has provided an important platform for Mountain Spirit to network with international organizations and learn from the Zoo's long and rich conservation initiatives and practices*." (Wellington Zoo, 2022/2023, p. 6).

For the sustainability of captive populations, Global Species Management Programs (GSMPs) have been established for many species, including Amur tigers (*Panthera tigris altaica*) and red pandas (*Ailurus fulgens*) (Nygren et al., 2024). These GSMPs involve the management of a specific taxon with globally set goals while working alongside the regional processes (WAZA, 2025). If the multiple snow leopard programs were brought together into a GSMP, this would allow for a larger effective population size, increased genetic diversity and opportunities for cooperation between zoos for both the exchange of animals, as well as practices for management and promoting conservation (Nygren et al., 2024). Maintaining snow leopard's *ex situ* also means there is a self-sustaining insurance population, which can be utilised for improving or restabilising genetic diversity in wild populations of snow leopards and help prevent extinction (Nygren et al., 2024).

Species reintroduction is the deliberate release of captive animals into the wild. Reintroduction is used in conservation to recover vulnerable animal populations, although this method is controversial and involves a large amount of collaboration between experts from different fields (Miquelle et al., 2024). Animals for reintroduction can come from multiple sources, including rehabilitation programmes, captive rearing, wild caught and rescues (Miquelle et al., 2024). Small populations of wild snow leopards quickly lose their genetic diversity, which leads to breeding limitations and therefore a dismantling of age structure (Nygren et al., 2024). Reintroduction allows for new genetic diversity to enter the population; however, reintroduction comes with many obstacles.

Quantifying the success of reintroduction is usually done only at a specific time point, not long after release, as long-term monitoring is restricted (Jule et al., 2008). Project outcomes often look at "habitat suitability, long-term food availability, the season of release, type of release (soft or hard) and the source (wild-caught or captive-born) of released animals" (Jule et al., 2008). Therefore, the true success of reintroduction is difficult to evaluate without long-term monitoring.

Carnivores with large ranges have been found to have low breeding success and high levels of stereotypical behaviour in captivity; this is a behavioural deficiency that may influence survival during reintroductions (Vickery and Mason, 2005). A review of the effects of captive experience on reintroduction survival supported previous reports that captive-born carnivores have a lower success rate and lower survival rate for reintroduction than their wild-caught counterparts (Jule et al., 2008, p. 356). While further research is needed to improve our understanding of the effects of captivity on reintroduction for snow leopards, there are multiple examples of promising reintroductions of large felid populations, such as the jaguar (*Panthera onca*) in Argentina, Iberian lynx (*Lynx pardinus*) in Spain and Portugal, Florida panther (*Puma concolor coryi*) in Florida and Amur tiger (*Panthera tigris altaica*) in the Russian Far East (Miquelle et al., 2024). Miquelle et al. (2024) reported successful reintroductions with both wild-caught and captive-born individual Iberian lynx (Miquelle et al., 2024), which is promising in the context of using captive-bred animals to supplement wild populations.

In addition to immediate conservation efforts, captive snow leopard populations can be used to educate the public and raise awareness of conservation projects for this species. Snow leopards are elusive in the wild, making research into this species difficult; however, captive

populations allow researchers to gather information they would not be able to otherwise. Zoos are a part of many research projects, some involving testing technology on captive cats before taking it to the wild, as well as gaining biological information that cannot be acquired from their wild counterparts. An example of research conducted on captive snow leopards assisting in wild research involved zoos across Europe, where researchers used the captive snow leopards to test the accuracy of camera traps used to identify wild snow leopards (Slight and Lind, 2024). This research showed that identifying wild individuals through camera traps may not be as reliable as previously thought, and therefore, population estimates from camera traps may be an overestimation (Johansson et al., 2020). This research was only possible due to the collaboration between researchers, conservationists and zoos.

The most prominent example of *ex-situ* snow leopards having a direct contribution to conservation is at Woodland Park Zoo (Seattle, Washington, USA) (Mallon and McCarthy, 2024), when the first two snow leopards were introduced to the zoo, zookeeper Helen Freeman established the Snow Leopard Trust (SLT) in 1981 (Mallon and McCarthy, 2024). The trust continues to engage in conservation, education and research for snow leopards, including supporting the Snow Leopard Foundation of Kyrgyzstan (Koontz, 2024). Currently, there are several *ex-situ* conservation programmes established for this species (Nygren et al., 2024; Tetzloff and Schwartz, 2024).

The Global Snow Leopard and Ecosystem Protection Program (GSLEP) was developed to bring together the 12 snow leopard range countries with the goal of conserving snow leopards and their high-mountain ecosystems (Sharma et al., 2024b). GSLEP developed individual National Snow Leopard and Ecosystem Protection Priorities (NSLEPs) as well as Global Support Components (GSC) to assist in cross-national boundary issues, aiding countries to work together to address these issues (Sharma et al., 2024b). The Population Assessment of the World's Snow leopards (PAWS) was an initiative launched by GSLEP (Sharma et al., 2024a) to provide a scientifically strong estimate of the global snow leopard population size (McCarthy et al., 2024). Previous global population estimates were shown to be unreliable (Sharma et al., 2024a), for example, the study areas used to assess snow leopard density were too small to be accurate and were biased towards the better habitats (Suryawanshi et al., 2019). Furthermore, only six out of 12 countries were used across the studies and are estimated to cover only 0.3-0.9% of the snow leopard's global range. These factors may have led to a density overestimate of up to five times (Suryawanshi et al., 2019). Based on these findings, it was recommended that the sampling and analytical protocols for global

population estimates be refined and standardised to ensure that larger and underrepresented areas of the global range are included (Suryawanshi et al., 2019).

1.4 Importance of Animal Welfare for Zoo Animals

1.4.1 Importance

Understanding how animals interact with the environment is essential to optimising the welfare of animals in human care (Bateson and Martin, 2021). Welfare assessments and routine monitoring are crucial for providing insight into the quality of life of the animals, as well as improving and maintaining standards of welfare within zoos (Morrison and Novikova, 2022). Stress adversely affects reproduction between mates; therefore, monitoring of behaviour and welfare can be instrumental for captive breeding programmes (Tetzloff and Schwartz, 2024). Animal carers can then use this information to make informed decisions about animal care and management.

1.4.2 Five Domains of Animal Welfare for Captive Animals

Animal welfare is a subjective term that represents the mental experiences of an animal (Littlewood et al., 2023). While welfare cannot be directly measured, models have been formulated to assess animal welfare, such as The Five Freedoms (Council, 1993) and the Five Domains Model (FDM) (Mellor, 2017). In the context of zoo populations, the Five Freedoms, which focuses on negative welfare, has largely been replaced by the FDM as it aims to both promote positive animal welfare and prevent negative animal welfare (Australasia, 2025). The FDM is now widely used in zoos and aquariums, with governing bodies such as the World Association of Zoos and Aquariums (WAZA) and the Zoo and Aquarium Association Australasia (ZAA) supporting this model (Mellor et al., 2015). In the most updated version of the model, the domains are designated as (1) nutrition, (2) physical environment, (3) health, (4) behavioural interactions and (5) mental state/experiences (Mellor et al., 2020). The requirements for the five domains are that animals (1) receive proper nutrition and an engaging, pleasurable diet, (2) live in an environment that promotes comfort, (3) experience good physical health and are safe from injury and disease, (4) can express choice and control over their interactions with the environment and other animals and engage in species-appropriate behaviours in ways that the animal finds rewarding, and (5) based on the outcomes of domains 1–4 have lives where positive mental experiences are occurring, while negative mental experiences are minimal (Mellor and Beausoleil, 2015). In some

circumstances, it may be desirable to represent an animal's welfare status using a single score or grade, for example, when evaluating the impact of an intervention designed to improve welfare. Using the FDM, overall welfare status is assessed by grading welfare enhancement and welfare compromise in domains 1–4; these separate grades are then combined to create a final grade indicating the overall degree of compromise and enhancement (Mellor et al., 2020) (Figure 1.2). For grading welfare compromise, the objective is to identify welfare compromise and then put in place measures to minimise or eliminate the negative effects (Mellor and Reid, 1994). Welfare compromise is graded based on the degree of negative effects animals may experience, ranging from mild to severe suffering (Mellor et al., 2009).

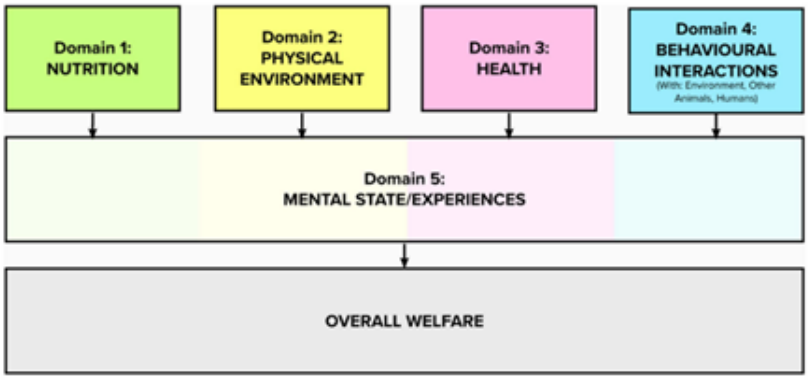


Figure 1.2 The 2020 Five Domains of animal welfare (Littlewood et al., 2023).

Domains 1 through 3 focus on internal physiological and pathophysiological disturbances due to nutritional, environmental and health-related problems. Domain 4 focuses on the external physical, biotic and social conditions within the animal's environment which prevent or promote behaviours or pose opportunities or challenges (Mellor et al., 2009). This domain has been more recently updated to include animals' capability to self-select goal-directed behaviours when interacting with other non-human animals, humans, and features of the environment (Mellor et al., 2020). These internal and external factors are then assessed and their consequences, in terms of the likely associated mental experiences, are assigned to Domain 5, which then determines the animal's welfare state (Mellor et al., 2009). In an example used by Mellor and Beausoleil (2015), water deprivation (Domain 1) causes dehydration, which leads to osmoreceptor-stimulated neural impulses passing to the brain and generating the affective experience of thirst (Domain 5). The FDM is a flexible tool that is regularly updated to reflect the latest scientific knowledge, and all assessments of welfare

undertaken using the model should be interpreted in terms of the current scientific knowledge (Mellor, 2017).

Under the WAZA Code of Ethics 2023, members must ensure animals under their care have opportunities to have positive experiences in their daily lives (WAZA, 2023). While ensuring animals have opportunities for positive experiences, it is also a requirement to address inadequacies that may prevent an animal from reaching positive outcomes (WAZA, 2023). The FDM functions in animal welfare assessments by looking at both internal physical and functional states as well as external circumstances that may impose a positive or negative affective experience on the animal(s) (Mellor, 2017). Evaluation of an animal's welfare state can be used to inform strategies for welfare enhancement, which supports 'positive affective engagement' and represents an animal's ability to engage in natural behaviours they find rewarding and specifically responding to motivators to undertake these behaviours and exercising their agency (Mellor and Beausoleil, 2015). The overall aim of the FDM is to evaluate the amount of time an animal spends in a positive and a negative welfare state, a concept which is demonstrated in Figure 1.3. This information can then be used to enhance animal welfare.

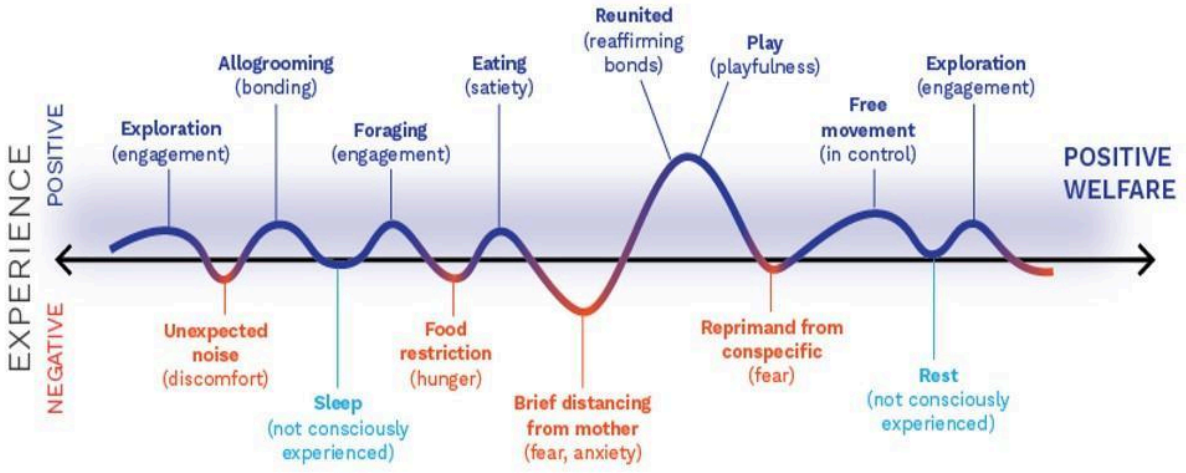


Figure 1.3 Conceptual Model of an Animal's Affective Experience (Zoo and Aquarium Association Australasia, 2025).

One of the WAZA recommendations for the care of animals within Zoos and Aquariums is to implement animal monitoring practices. These monitoring methods should align with the animal's physical/functional states as well as their behavioural activities (Mellor et al., 2015). Monitoring behaviour allows insight into how animals perceive and engage with their external environment and the associated negative or positive experiences (Mellor et al.,

2015). For example, without regular monitoring of animal behaviour in zoos, observed behaviours may be assumed to be normal but may in fact be an indication of a health-related issue. However, without a baseline understanding of species' (or individual animals') normal behaviour, these indicators may not be picked up on, leading to poor welfare.

1.5 Value of Monitoring Animal Behaviour in Zoos

Monitoring animal behaviour allows insight into animal wellbeing and welfare. Having a baseline of the normal behaviour of an individual allows for any changes that arise to be observed (Watters et al., 2009). The most common method for monitoring animal behaviour is visual observation, which includes scan sampling and focal sampling. Scan sampling involves scanning a group of subjects at specific regular intervals and recording the behaviour of each individual at that time (Donát, 1991), while focal sampling refers to continuous monitoring and recording of the behaviour of a single individual for a specific amount of time (Donát, 1991). Focal sampling is typically preferred, as scan sampling usually only collects a restricted range of behaviour to save time spent on observations and can miss behaviours that are outside of the observation periods (Donát, 1991). These methods can be intensive and time-consuming as well as biased, due to the complexity of behaviour (Bateson and Martin, 2021). Bias can also be introduced due to human presence and interaction if sampling is carried out in person (Bateson and Martin, 2021). Due to these biases and time constraints, new methods have been introduced, including video-based pixel-tracking software (e.g., Ethovision (Aitken et al., 2017)), pedometry (e.g. physical activity in dogs (Chan et al., 2005)), and accelerometery (e.g. categorising cheetah behaviour (McGowan et al., 2022)).

When monitoring animal behaviour, it is important to develop a clear ethogram, which catalogue and description of the behaviours expressed by the species or animal of interest. Published ethograms are used when selecting behavioural categories for research, when available (Bateson and Martin, 2021). It is also important to determine the type of data that are needed. The types of metrics used in behavioural observations include latency (e.g. time from the start of observation or presentation of a specific stimulus to the onset of a behaviour), frequency (number of occurrences of a behaviour per unit of time), duration (length of time for a single behaviour, total length of time for all occurrences of a behaviour over a specific period or percentage of time spent doing said behaviour) and intensity (typically used to describe strength or amplitude of a behaviour) (Bateson and Martin, 2021).

To ensure relevant data, careful behavioural selection is an important aspect of this type of research.

Stereotypical behaviour is a repetitive behaviour that has no obvious goal or function (Odberg, 1978). While stereotypies are widely thought to arise through restrictions to the animal's agency, they are often poorly understood, and the exact cause for the behaviour is unclear. There are many hypotheses as to the cause and reason for its occurrence. Among predator species the absence of a pre-hunting phase that occurs in the wild is lost in captivity, which can lead to frustration expressed in the form of stereotypies (Clubb and Mason, 2007). Animals such as bears and small carnivores, which are territorial and display high activity levels in the wild, are thought to be more at risk of stereotypical behaviour in captivity. In the wild, they naturally spend large portions of their day foraging or marking territories; however, this is restricted in captivity, causing them to develop stereotypical behaviours (Clubb and Mason, 2007). There has been evidence both against and for this hypothesis, with individual differences thought to be the cause of this (Clubb and Mason, 2007). Body weight and home-range size are risk factors for stereotypical behaviour; therefore, wide-ranging carnivores are at high risk due to their larger body weights and restrictions on natural ranging behaviour (Clubb and Mason, 2007). Snow leopards exhibit one of the largest home ranges of all felid species (Johansson et al., 2018), so are at risk of stereotypical behaviours and welfare challenges in captivity. It also means that there is a need to carefully consider methods for improving welfare of captive snow leopards, primarily through habitat design and enrichment strategies.

1.6 Strategies for Improving the Welfare of Captive Cats

Environmental enrichment involves adding something new to an animal’s environment to promote the use of their senses and provide opportunities for them to express natural or highly motivated behaviours (Young, 2003). This may include changing the structure of the zoo habitat, providing opportunities for interactions with conspecifics, and adding natural or artificial devices (Shepherdson, 2003). The main goal is to improve welfare by providing animals with opportunities to express agency (Mellor and Beausoleil, 2015). Enrichment strategies are often introduced to discourage unwanted behaviours and prevent welfare compromise, for example, the occurrence of stereotypical behaviour (Swaisgood and Shepherdson, 2006).

Reported that implementing enrichment programmes reduced stereotypies by between 50% to 60% in carnivores, primates and other species (a review of enrichment zoo-based studies between 1990 and 2003) (Swaisgood and Shepherdson, 2006). This finding was supported by a meta-analysis that demonstrated a reduction in the frequency of stereotypical behaviour in mammals provided with environmental enrichment (Shyne, 2006). However, both reviews found that environmental enrichment did not eliminate the expression of stereotypical behaviours (Shyne, 2006; Swaisgood and Shepherdson, 2006). This is thought to be due to the enrichment not targeting the main causes of welfare compromise or because they are not being used as a preventative strategy but instead are being introduced after the stereotypies have started (Clubb and Mason, 2007).

While environmental enrichment does not eliminate stereotypical behaviour, it reduces stereotypies and is therefore thought to improve animal welfare within zoos (Shyne, 2006). There are multiple types of enrichments, which include sensory enrichment, physical enrichment, enrichments that encourage exercise, cognitive enrichment, feeding-based enrichment and social enrichment (Bloomsmith et al., 1991). Enrichment can include training (e.g. training for voluntary blood draws). These enrichments are not mutually exclusive, and one enrichment can be a part of multiple categories; for example, puzzle feeders are both food- and cognitive-based (Bloomsmith et al., 1991). The type of enrichment used is dependent on the species/individual and should be biologically appropriate, as well as where and how they are managed.

1.7 A Role for Close Encounters in Both Enrichment and Awareness for Conservation Goals

Close encounters within zoos allow for visitors to learn about animals as individuals which has been shown to create empathy for the species as a whole (Akerman, 2019). Visitor knowledge and interest in conservation of species was reported to improve when they were able to connect on a more personal level with the animals (Duffy, 2008). One of the goals of close encounters is to teach the visitors about the conservation work that zoos are involved in and how they can also be involved or support this work (Duffy, 2008). Similarly small, guided tours alongside a close encounter have been shown to improve the knowledge of visitors for the specific species (Whitehouse-Tedd et al., 2021). Concerns with close encounters include the illusion that wild animals may be seen as tame and thus encourage the public to approach or interact with their counterparts in the wild (Szokalski et al., 2013b).

Enrichment has shown to increase activity, foraging and decrease stereotypical behaviour in captive cats and has been used as a welfare indicator in many (Chan et al., 2025), however, literature on the effects of close encounters on the behaviour and agency of snow leopards is lacking.

1.8 Snow Leopards at Te Nukuao Wellington Zoo

Te Nukuao Wellington Zoo is a non-profit charitable trust operating since 2003 as a subsidiary of the Wellington City Council (Zoo, 2025). This was the first zoo in New Zealand, opening in 1906, and is now a Toitū carboNZero certified zoo. The zoo is also a member of the WAZA and the ZAA for Australasia (Zoo, 2025) .

Te Nukuao Wellington Zoo, Wellington, New Zealand (-41.319403, 174.784501) acquired two female snow leopard sisters in 2023 from Melbourne Zoo, with the zoo habitat opening to the public in April 2023 (Figure 1.4). Their habitat was purpose-built, featuring *"steep rock faces, caves, climbing poles, fallen perching logs, and different substrates"* (Wellington Zoo, 2023, p. 9), as seen in Figure 1.5. The substrates within the habitat include a grass, dirt, wood, rocks and shrubs.. Shrubs and grasses planted at the time of building will grow and change over time. The cat's outdoor habitat is divided into two separate areas, each with its own inside den and a cave in the outdoor area (Figure 1.6). The habitat and dens are serviced daily by keepers, with different levels of cleaning (e.g., scrubbing, full hosing) depending on the needs. Enrichment is offered following a schedule which includes different types, such as cognitive, physical environment, social, sensory and food, as well as specific approved items that are rotated, to provide different enrichment types daily.



Figure 1.4 Digital rendering of the snow leopard habitat at Te Nukuao Wellington Zoo (Wellington Zoo, 2025).

Te Nukuao Wellington Zoo offer close encounters with the following animals: Ring-tailed lemur (*Lemur catta*), Red panda (*Ailurus fulgens*), Asian small-clawed otter (*Aonyx cinereus*), Black-and-white ruffed lemur (*Varecia variegata*), snow leopards, Giraffe (*Giraffa*), Kororā Little Penguin (*Eudyptula minor*), Capybara (*Hydrochoerus hydrochaeris*), Meerkat (*Suricata suricatta*), Sun bear (*Helarctos malayanus*), Lion (*Panthera leo*), Minibeasts (invertebrates) and Sumatran Tigers (*Panthera tigris sondaica*). All close encounters offered by the zoo are voluntary for the animals, meaning that they decide if and for how long they will interact during the encounters. While some encounters involve feeding the animals or the animals interacting with visitors by walking on their laps, most are hands-off for both keepers and visitors. In September 2024, the zoo introduced a non-contact close encounter experience with the snow leopards.

Close encounters involved bringing up to four guests into the back of house of the snow leopard habitat; the cats were then locked out of the dens for the guests and keepers to place enrichment into the dens. The guests then stand behind a designated line, and the cats called in. They voluntarily chose whether they wanted to participate by coming into the dens when guests were present. The enrichment was not removed after the guests left. Further detail is provided in section 2.2.3 (Experimental Design).



Figure 1.5 Images of the snow leopard habitat at Te Nukuao Wellington Zoo (Wellington Zoo, 2025).

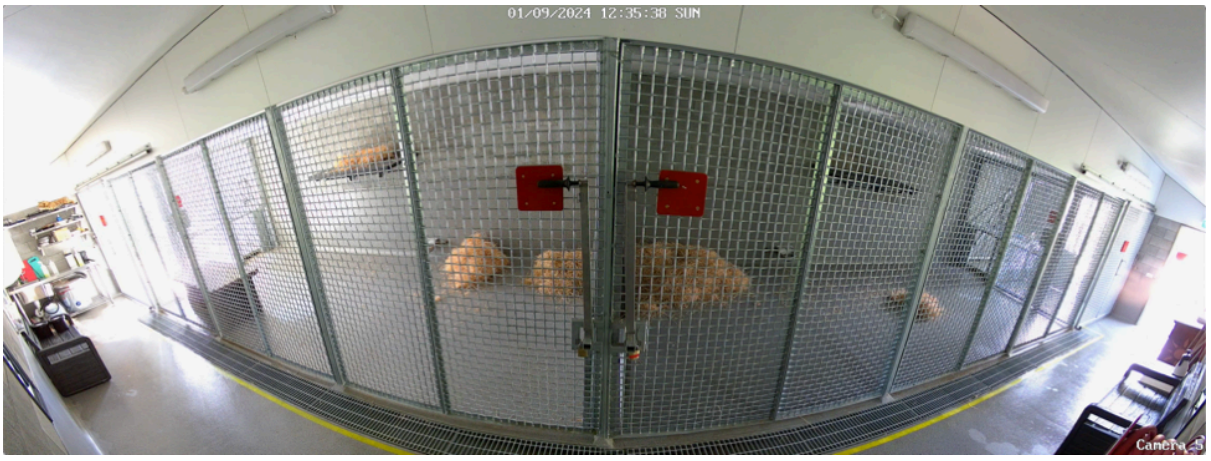


Figure 1.6 Indoor den of snow leopard habitat at Te Nukuao Wellington Zoo, viewed from the 180-degree camera.

1.9 Aims and Objectives

This thesis initially intended to collect two weeks of concurrent acceleration and video data from snow leopards at Te Nukuao Wellington Zoo. These data were to be used to develop a behavioural algorithm for this species using machine learning. The aims were (1) to develop a remotely releasing collar (i.e., a collar that detaches at the press of a remote button to avoid the need for any general sedation to remove the devices) and conduct preliminary testing on dogs from which the collars could be manually removed at any point; and (2) to collect concurrent acceleration and video (recording) data from snow leopards at Wellington Zoo and apply the machine learning approach to develop behavioural algorithms to model behaviour for this species. Unfortunately, due to unforeseen circumstances this was not possible.

Objective (2) was therefore changed to the following: to evaluate how the snow leopards respond to the close encounters that started in September of 2024. We were especially interested in how and when they engaged with the enrichment items and whether they entered the dens during the encounters. The research also aimed to evaluate the effects of weather, keepers, and other environmental factors on the behaviour of cats around encounters. A further objective (3) was to provide Te Nukuao Wellington Zoo with information on the zoo habitat utilisation by the snow leopards. Specifically, a behavioural time budget with locations of specific behaviours are displayed within defined areas of the zoo habitat. The effects of hour of the day, day of the week and location were assessed.

The primary outcome of this research was to evaluate and provide the zoo with information to allow them to optimise the welfare of the two snow leopards, Asha and Manju. All findings reported to the zoo to be used to enhance zoo habitat design and/or management practice for cats. This thesis is also intended to contribute to the limited literature on snow leopards and snow leopard behaviour to help further understand and conserve this keystone species.

Chapter 2: Evaluating the Effects of Close Encounters on the Behaviour of Snow Leopards (*Panthera uncia*)

2.1 Introduction

Over the last decade the role of zoos has changed, with an increased focus on education and building a connection between visitors and endangered animals. Close encounters, either through animal contact or behind-the-scenes tours, have been shown to improve visitor interest and motivation in conservation, due to the personal connection they gain with the animal(s) (Newsome and Rodger, 2008; Acaralp-Rehnberg et al., 2020). However, ensuring that the welfare of animals is not compromised by the encounter is of utmost importance. Specifically, participation in encounters should be voluntary and support a positive interaction for the animals as well as visitors (Duffy, 2008).

The iconic nature of felids makes them a popular choice for close encounters (Szokalski et al., 2013a). Servals (*Leptailurus serval*) at Werribee Open Range Zoo (Victoria, Australia) showed a reduction in stereotypical pacing during three weeks of interactions, which included a mixture of behind-the-scenes encounters and presentations with keeper interactions with the animals to the public (Acaralp-Rehnberg et al., 2020). While the servals showed a reduction in stereotypical behaviour during interactions, there was also a reduction in behavioural diversity. While this may have been due to the encounters, it is not clear whether this was a negative welfare impact, but something to be monitored long term (Acaralp-Rehnberg et al., 2020).

Cheetah (*Acinonyx jubatus*) at Cheetah Outreach's Western Cape facility in South Africa, were involved in hands-on encounters and showed no positive or negative states; however, the proportion of time spent lying with their head down increased while being stroked by guests, suggesting a relaxed state during the encounters, however, one out of four cheetahs showed tail-licking behaviour while being stroked by guests (Whitehouse-Tedd et al., 2021). This decreased when stroking stopped and may therefore represent a stress behaviour (Whitehouse-Tedd et al., 2021). This specific individual also purred during over half of the observations while being stroked, but purring only increased 8% when stroking stopped (Whitehouse-Tedd et al., 2021). This shows the importance of individual animal monitoring when looking at the welfare impacts of encounters. One Sumatran tiger (*Panthera tigris sumatrae*), three African lions (*Panthera leo leo*) and three cheetahs were observed in behind-the-scenes tours at Zoos South Australia (Szokalski et al., 2013a). The cheetahs were involved in a hands-on visitor experience, while the tiger and lions were involved in protected contact tours. The tiger and lions showed an increase in feeding during the tours but

also an increase in pacing which was suggested to be in response to feeding rather than a stress response (Szokalski et al., 2013a). The cheetah showed a decrease in pacing during their interactions and exhibited a variety of species-typical behaviours (Szokalski et al., 2013a). These results show that although behaviour may be altered due to encounters, this may not represent a negative impact on welfare.

There is currently no standardised way to measure the effects of encounters on animal welfare (Spooner et al., 2021). Any standardised method needs to be flexible enough to account for individual differences in animals' behaviours in response to encounters and may need to be species-specific. With limited research available on animals involved in encounters, there has been a call for more in-depth research on the potential welfare impacts (Spooner et al., 2021). There has been an increase in felid encounters (Szokalski et al., 2013a), and while a lot of literature focuses on the impact on guests, there needs to be more research on the welfare effects on the animals involved (Szokalski et al., 2013a).

Te Nukuao Wellington Zoo (New Zealand) is globally renowned for its welfare-focused management and runs close encounters with several of its animals (e.g. meerkats (*Suricata suricatta*) and capybaras (*Hydrochoerus hydrochaeris*)). In September of 2024, the zoo began close encounters with its two snow leopards, Asha and Manju, which were the only snow leopards in Aotearoa New Zealand. The encounters provide an experience for guests to gain more knowledge and understanding about these animals while also contributing to conservation. 10 percent of proceeds from the close encounters are donated to conservation projects the zoo supports, including a non-profit organisation (Mountain Spirit) in Nepal, which aims to protect the snow leopard habitat, and Snow Leopard Conservancy (Zoo, 2026). To date, however, there is little quantitative data available on how encounters impact the welfare and behaviour of the snow leopards.

Research into the behaviour of snow leopards and other zoo-held animals in response to close encounters is essential to ensuring that close encounter programs support positive animal welfare. Therefore, this study aimed to describe Asha and Manju's behaviour and determine how their engagement with close encounters at Te Nukuao Wellingon Zoo changed over the first few weeks following their introduction. This study explored how the behaviour of the snow leopards before, during, and after a close encounter event. Finally it investigated whether engagement during encounters was associated with external factors, including keeper identity and enrichment format.

2.2 Methods

2.2.1 Animals

Two captive-born snow leopards (*Panthera uncia*) at Te Nukuao Wellington Zoo (Wellington, New Zealand) were used for this research. At the start of the study, the two four-year-old sisters, Asha and Manju, weighed approximately 31 kg and 33 kg, respectively. The cats were fed according to standard operating procedures at the zoo with *ad libitum* access to water. As this study was purely observational, animal ethics approval was not required.

2.2.2 Enclosures and Video Surveillance

Each cat was housed individually in one of two structurally similar enclosures consisting of an indoor den and outdoor habitat separated by a wire fence (Figure 2.1). Each outdoor habitat was fitted with two Reolink Duo 2 surveillance cameras (Reolink Technology Co., Wilmington, Delaware, USA). These cameras offered a 180^{o} panoramic view with a 4K resolution set to 30 Hz. Another Reolink Duo 2 camera was positioned to monitor both the indoor dens (Figure 2.1a). Video footage was continuously recorded from all cameras from the 22nd of August 2024 through to 3rd October 2024 and stored on a Network Video Recorder (NVR) system that was kept in the back of house of the snow leopard habitat.

2.2.3 Experimental Design

The snow leopard close encounters ran from approximately 12:45 to 13:30 on Sundays, Mondays and Fridays. Initially, the cats were excluded from the dens while a keeper brought the guests into the back-of-house area and gave a health and safety briefing. Guests prepared different types of food-based enrichment items (Figure 2.2; Table 2.1) and placed them in the dens, supervised by the keepers. The guests then left the dens and were positioned in a safe location (behind the yellow line in Figure 2.1). The snow leopards were allowed to re-enter the dens, should they choose to, and the guests were able to observe the cats' responses to the enrichment items. The encounters could also include watching a training session between the cats and keepers. The encounter lasted from approximately 13:00 to 13:30, beginning when the cats were let back into the dens and visitors were behind the safety line. After 13:30, the encounter finished, the guests were escorted back into the public zoo area, and the cats were left alone with the enrichment items. For the purpose of this research, the encounter consisted of three clear time points: Before (the hour prior to guests entering), During (guests entering to guests leaving, including the short period where cats were locked out of dens while enrichment was placed) and After (the hour following the guests leaving). The cats had access to the habitat and dens during all timepoints, unless locked out for cleaning of the dens

prior to encounters. The observations were from the first day the cats were introduced to the encounters.

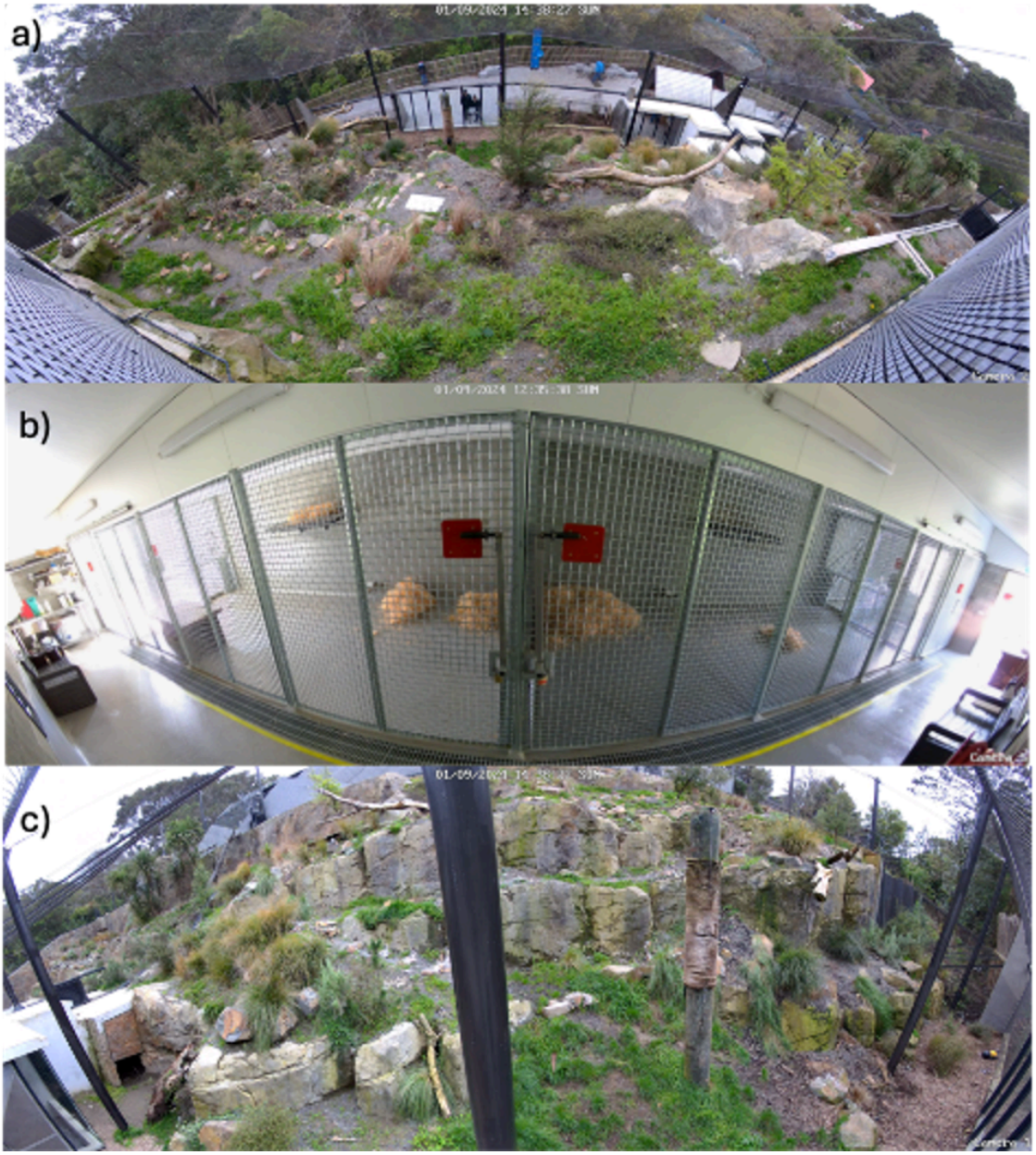


Figure 2.1 (a) A frame from video footage of the indoor dens and **(b)** outdoor enclosures of the two snow leopards at Te Nukuao Wellington Zoo and **(c)** outdoor enclosures showing the two snow leopards from the bottom view (guest side). The yellow lines represent the camera wiring, and the black dashed lines with letters indicate the grid sections used for each enclosure.

Table 2.1 Enrichment items and their corresponding letter code and description. All enrichment items were placed inside the snow leopards' indoor dens for the close encounters at Te Nukuao Wellington Zoo.

Code	Enrichment Item	Description
B	Browse	Tree branches and leaves inside the dens alongside a food item placed in-between or elsewhere
C	Cardboard	Cardboard placed on the ground with food enrichment throughout/under
G	Ground	Food item placed on the ground
H	Hanging	Food item hanging from a platform or fencing
K	Kennel	Food item placed on top of the kennels
T	Towel	Towel with food item inside
W	Water buoy	Food item placed inside the water buoy; this may also include hay within the buoy. The buoy may be hanging or placed on the ground

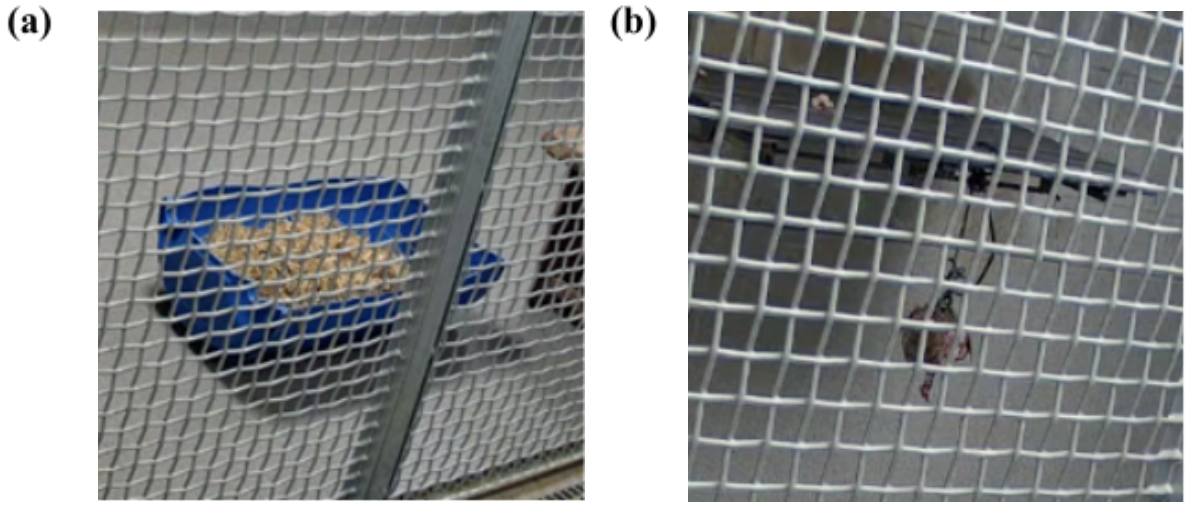


Figure 2.2 (a) Example of a food enrichment placed within a buoy (W) with straw inside the indoor den for snow leopards during a close encounter at Te Nukuao Wellington Zoo. **(b)** Example of a hanging (H) food enrichment placed off the platform inside the indoor den for the snow leopards during a close encounter at Te Nukuao Wellington Zoo.

A total of 12 encounters were evaluated for this research, three per week during September 2024. Using the recorded video footage and BORIS (Friard and Gamba, 2016), the cats' behaviours were scored continuously (1-second focal sampling interval) before, during, and after each encounter according to a pre-defined ethogram (Table 2.2). The ethogram consisted of a total of 35 behaviours (Table 2.2). 'People present' was defined as the period when keepers and guests entered the back-of-house (BOH) area. 'Den in' was defined as the snow leopards entering their inside dens, with either most or all of their body inside the den (this excluded the tunnel enter the den). The percentage of time the cats spent exhibiting each of these behaviours and the proportion of time spent in the den were determined for each period (Before, During, and After). The frequency and duration of interactions with the enrichment items were also assessed for the During and After time periods.

Table 2.2 Ethogram of snow leopard behaviour scored during close encounters with guests at Te Nukuao Wellington Zoo. The ethogram was adapted from Rosandher et al. (2009) and Stanton et al. (2015).

Title	Definition
Aggression mild	All types of threats: striking with paws, showing of teeth without action contact with conspecific
Aggression serious	Contact with either teeth or paws with the conspecific
Approaching	Cat moves toward enrichment item while looking at it
Body rub	Cat slides along the body or head of another animal, rubbing its body against parts of the other animal in the process
Carrying	Cat picks enrichment item up off the ground and moves it to another location
Cheek rub	Cat rubs cheek against an object many times
Climb	Cat ascends and/or descends an object or structure
Defecate	Cat releases faeces on the ground while in a squatting position
Drinking	Cat ingests water (or other liquids) by lapping up with the tongue.
Eating enrichment	Cat ingests food (or other edible substances) by means of chewing with the teeth and swallowing.
Groom	Cat cleans itself by licking, scratching, biting or chewing the fur on its body. May also include the licking of a front paw and wiping it over one's head
Head rub	Cat rubs its cheek or forehead against the other animal's cheek or forehead
Jump	Cat leaps from one point to another, either vertically or horizontally
Lay - head down	Cats body is on the ground in a horizontal position, including on its side, back, belly, or curled in a circular formation with its head down
Lay - head up	Cats body is on the ground in a horizontal position, including on its side, back, belly, or curled in a circular formation with its head up
Lift	Cat uses one or both front paws to lift an enrichment item above the ground
Manipulate object	Cat uses any part of body to touch, hold, move, or pick up an object
Object rear	Cat stands up on its hind legs with forelegs toward or against enrichment item
Other	Any behaviour that does not fit into one of the descriptions provided
Out of Sight	Cat not visible to the observer
Parkour	Jumping erratically onto and off parts of the enclosure, including jumping erratically into the air not onto an object
Play	Cat interacts with something in a "non-serious" manner (i.e. where there is no intention of harm)
Roll	While lying on the ground, cat rotates body from one side to another. During the roll, the back is rubbed against ground, the belly is exposed, and all paws are in the air. Cat may continue rolling repeatedly from side to side
Run	Forward locomotion in a rapid gait, which is faster than walking or trotting
Scrape	Cat scrapes hind feet on the ground in a backwards direction, shuffling one foot after the other.
Scratch	Cat scratches its body using the claws of its hind feet
Sit	Cat is in an upright position, with the hind legs flexed and resting on the ground, while front legs are extended and straight
Sniff/Lick enrichment	Cat smells modifier by inhaling air through the nose. Cats tongue protrudes from mouth and strokes modifier
Social Roll	Cat rolls on the ground in proximity of another cat* *within one or two body lengths of each other
Stand	Cat is in an upright position and immobile, with all four paws on the ground and legs extended, supporting the body
Stretch	Cat extends its forelegs while curving its back inwards
Taking food via tongs	Cat takes food from tongs put through fencing by staff/guests
Tunnel	Sitting, laying or standing in tunnel for longer than 5 seconds (excludes walking through tunnel into den)
Urinate	Cat releases urine on the ground while in a squatting position
Urine Spray	While standing with tail raised vertically, cat releases a jet of urine backwards against a vertical surface or object. The tail may quiver as urine is discharged.
Walk	Forward locomotion at a slow gait
Yawn	Cat opens its mouth widely while inhaling, then closes mouth while exhaling deeply

Table 2.3 Ethogram (Table 2.2) behaviours categorised into active, inactive, enrichment, maintenance, social and out of sight/other for behavioural scoring during close encounters with the snow leopards at Te Nukuao Wellington Zoo.

Active	Inactive	Enrichment	Maintenance	Social	Out of Sight/Other
Cheek rub	Lay - head down	Approaching	Defecate	Aggression mild	Other
Climb	Lay - head up	Carrying	Drinking	Aggression serious	Out of Sight
Jump	Sit	Eating enrichment	Groom	Body rub	
Object rear		Lift	Taking food via tongs	Head rub	
Parkour		Manipulate object	Urinate	Social Roll	
Play		Sniff/Lick enrichment			
Roll					
Run					
Scrape					
Scratch					
Stand					
Stretch					
Tunnel					
Urine Spray					
Walk					
Yawn					

2.2.4 Statistical Analyses

All statistical analyses were performed using RStudio (Posit, 2026) with a significance level of $P < 0.05$. A trend or tendency was described as $0.05 < P < 0.10$. Descriptive statistics (mean, standard deviation, and standard error) for the percentage of time spent exhibiting each behavioural category were calculated (Table 2.3). The normality of all continuous data was checked using a Shapiro-Wilk normality test. Wilcox tests were performed to test the differences between cats across the behavioural categories (interaction with enrichment, active, inactive, social, maintenance, and time spent inside). Wilcox tests were also performed to compare between and within cats for the different periods (Before, During and After). General Linear Models (GLM) were used when significance was found. Kruskal tests were performed to evaluate the effects of other variables on the behavioural categories, including temperature humidity index (THI), head keeper identity, day of the week, rain presence (yes or no; obtained from the video footage) and enrichment presentation, where relevant. All data are presented as mean ± SEM unless otherwise stated.

2.3 Results

2.3.1 Overview of Encounters

A total of 12 close encounters were analysed, consisting of 30.9 hours of footage per cat and 61.8 hours of footage total. The average duration of an encounter was 34.6 ± 2.0 minutes. An average of 3.9 visitors participated in each encounter, with an average of 2.7 staff present. Of the 12 encounters, interactions with the enrichments were recorded in which cats used the

browse (n=1), cardboard (n=2), ground (n=1), hanging (n=7), kennel (n=1), towel, (n=1) and water buoy (n=5) forms of enrichment, respectively. Both cats received the same enrichment with minimal differences.

Overall, the amount of time spent exhibiting active (P = 0.09), inactive (P = 0.15), interacting with and/or approaching enrichment items (P = 0.37), social (P = 0.99) and maintenance (P = 0.24) behaviours did not differ between the cats (Table 2.4).

Table 2.4 Mean ± SEM percentage of time snow leopards Asha and Manju spent exhibiting active, inactive, enrichment, social, maintenance, and other behaviours within each time point (1 hour before, during and after close encounters) during September 2024. Out of sight has been removed from this table, and therefore the values do not add to 100%.

Timepoint	Active	Inactive	Enrichment	Social	Maintenance	Other
Asha						
Before	0.36 ± 0.14	43.58 ± 4.03	N/A	0.04 ± 0.03	0.84 ± 0.38	3.51 ± 3.50
During	2.34 ± 0.58	33.95 ± 4.78	1.52 ± 0.51	0.16 ± 0.11	1.09 ± 0.49	0.73 ± 0.51
After	2.25 ± 0.32	21.82 ± 4.77	6.51 ± 0.51	0.35 ± 0.17	1.45 ± 0.38	1.88 ± 0.84
Mean	1.65 ± 0.46	33.44 ± 5.10	2.68 ± 1.40	0.18 ± 0.12	1.13 ± 0.42	2.04 ± 2.07
Manju						
Before	1.59 ± 0.46	36.90 ± 3.37	N/A	0.03 ± 0.03	1.54 ± 0.37	2.11 ± 1.63
During	2.53 ± 0.65	30.19 ± 4.63	2.33 ± 0.92	0.08 ± 0.06	0.97 ± 0.46	0.19 ± 0.08
After	2.99 ± 0.46	22.43 ± 4.53	3.05 ± 1.10	0.24 ± 0.10	2.05 ± 0.54	4.53 ± 3.58
mean	*2.37* ± 0.54	29.84 ± 4.44	*1.79* ± 0.89	*0.12* ± 0.07	*1.52* ± 0.46	*2.28* ± 2.27
Overall mean	2.01 ± 0.51	31.61 ± 4.77	2.23 ± 1.17	0.15 ± 0.10	1.32 ± 0.44	2.16 ± 2.15

Of the variables tested, THI and rain were shown to impact the percentage of time the cats spent inactive (P = 0.02 and P = 0.002, respectively). THI also influenced time spent active (P = 0.02), and rain influenced time spent performing social behaviours (P = 0.03). There was a negative correlation between activity and THI (rho = -0.359, P=0.002). While significant, the effects of THI and rain were not investigated further due to insufficient variation in weather for formal analysis. The only variable that showed a significant effect on the percentage of time the cats spent in maintenance was day (P = 0.05), with the median being highest on Sunday (compared to Monday or Friday). Due to only analysing encounter days, this was not explored further.

2.3.2 Time Spent Inside the Dens

The amount of time spent inside the dens did not differ between the cats (P = 0.91), with an average of 20.5 ± 23.26 minutes spent inside during the entirety of each encounter event. In the hour before the close encounters Manju spent more time inside the den than Asha (P = 0.048), whereas Asha tended to spend more time inside the den after the close encounters (P

= 0.08; Figure 2.3). Asha spent less time inside before (P = 0.008) or during (P = 0.002) compared to after the encounter, but time inside did not differ during compared with after the encounter (P = 0.16). Overall, Asha spent the least amount of time indoors before the encounters and spent the most amount of time indoors after the encounters. The amount of time Manju spent inside the den did not differ between time points (P = 0.65). Enrichment type was found to significantly affect time spent inside (P = 0.01).

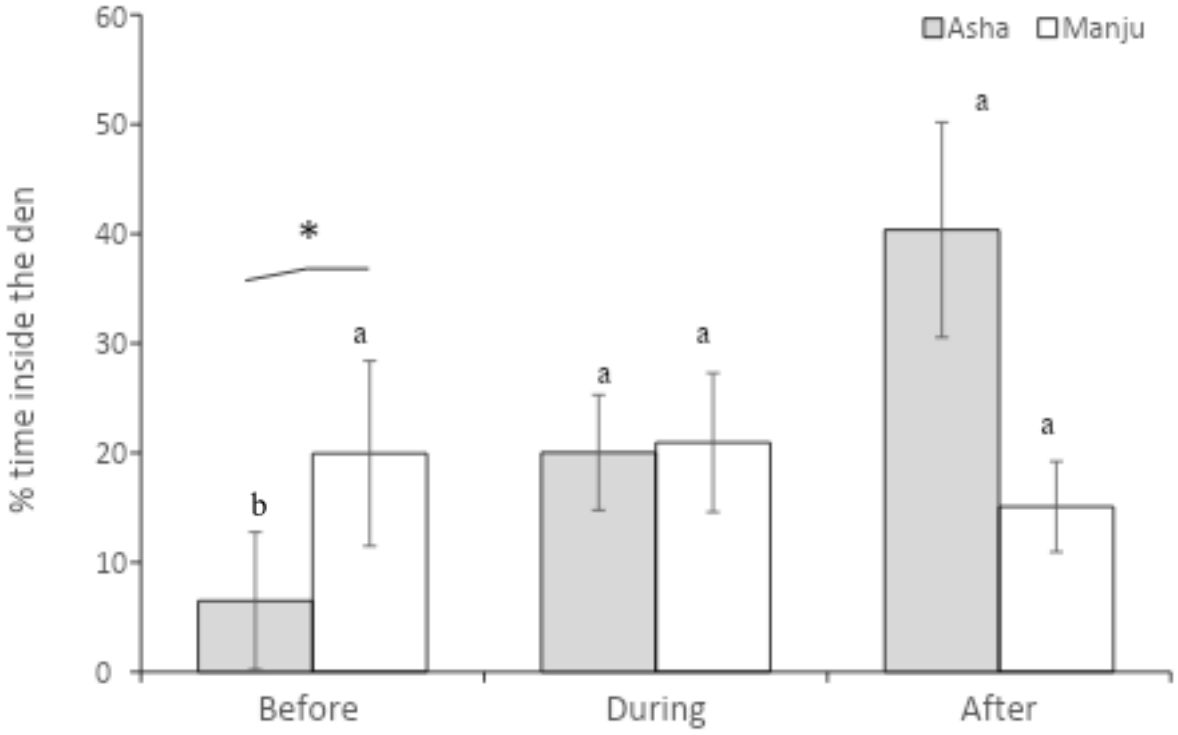


Figure 2.3 Comparison of the percentage of time snow leopards Asha (grey bar) and Manju (white bar) spent inside the den before (1 h prior), during (while **guests are** present), and after (1 h after guests leave) close encounters that involve the provision of food enrichment. *Indicates statistical difference between cats. Different superscripted letters indicate statistical differences within a cat over time.

2.3.3 Time Spent Interacting with the Enrichment

There was no difference between cats in the time spent interacting with enrichment across all timepoints (P = 0.37) (Table 2.4). Therefore, data from both cats were combined for subsequent analysis. The combined data showed that the mean percentage of time spent interacting with the enrichment items was similar during (13.45 ± 1.81) and after (19.86 ± 3.44) the encounter event. However, while Manju spent a similar amount of time interacting with the enrichments during and after the encounter, Asha spent significantly more time interacting with the enrichment after the encounter compared to during (P = 0.049) (Figure 2.4).

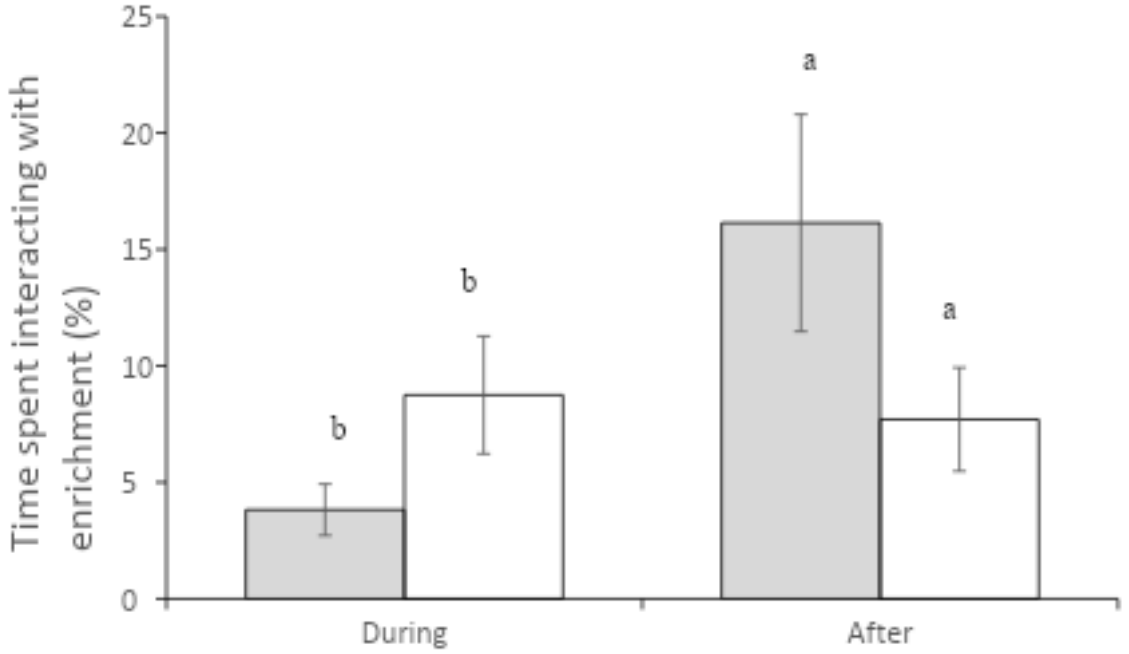


Figure 2.4 The percentage of time snow leopards Asha (grey bar) and Manju (white bar) spent interacting with the food enrichment during the close encounters (while guests were present), and after (1 h after guests leave). Different superscripted letters indicate statistical differences within a cat over time.

Asha showed a clear trend of increasing time spent interacting with the enrichment from week 1 to week 4, with a preference for after the encounters (Figure 2.5 a). While Manju showed no clear trend across the 4 weeks (Figure 2.5 b). Enrichment type and THI were shown to have statistically significant effects on time spent approaching and interacting with enrichment ($P = 0.02$ and $P = 0.01$, respectively).

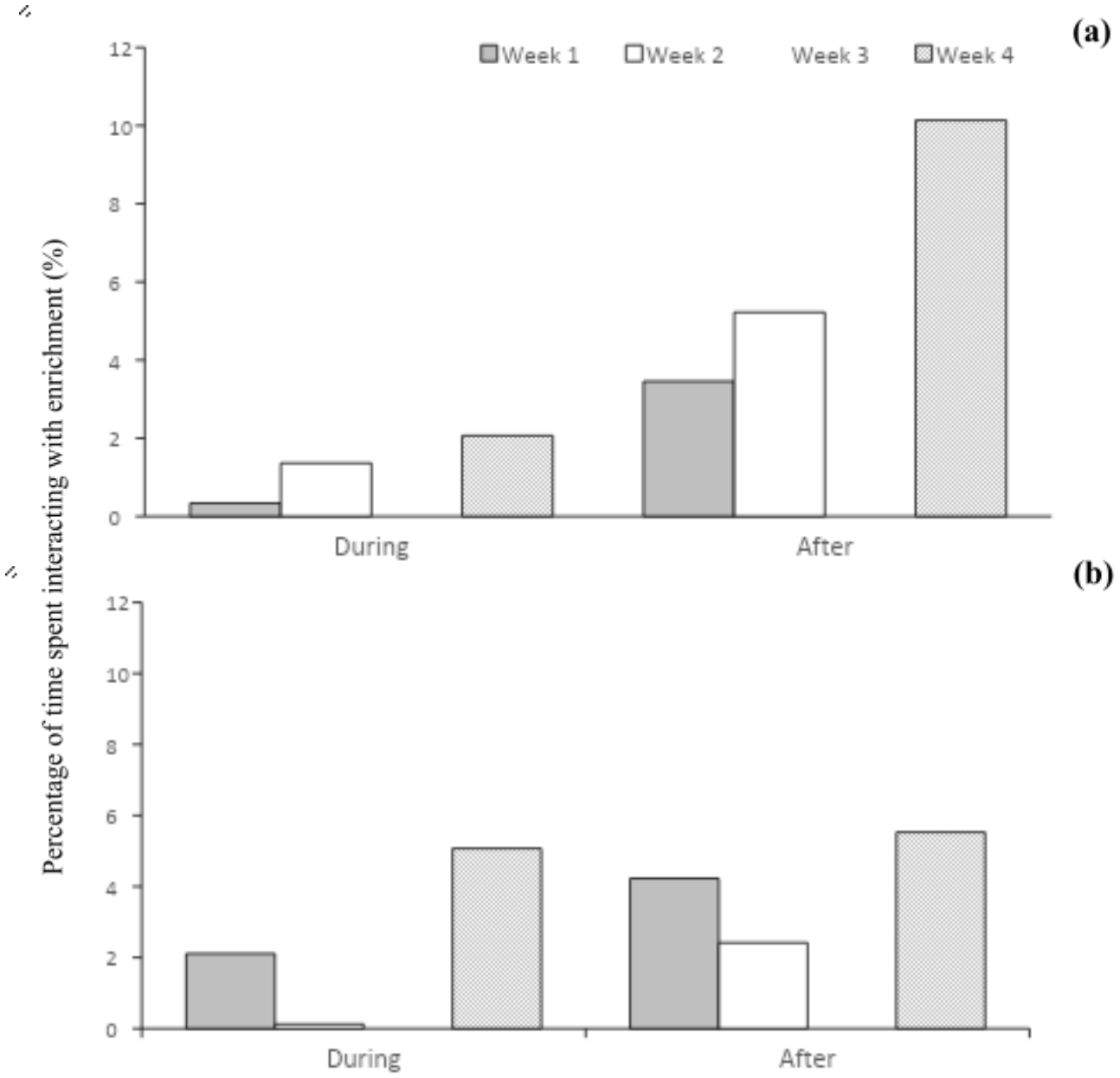


Figure 2.5 Mean percentage of time snow leopards Asha **(a)** and Manju **(b)** spent approaching and interacting with enrichment objects during the snow leopard close encounter and the 1 h after the encounter finished across the 4-week study period at Te Nukuao Wellington Zoo.

2.3.4 Enrichment Types

Enrichment type had a significant effect on time spent approaching and interacting with the object ($P = 0.02$) (Table 2.1). Hanging enrichments (H) were the most interacted with (Figure 2.6). Enrichment type also significantly influenced the percentage of time spent inside the den ($P = 0.01$) and performing social behaviour ($P = 0.003$) (Table 2.4).

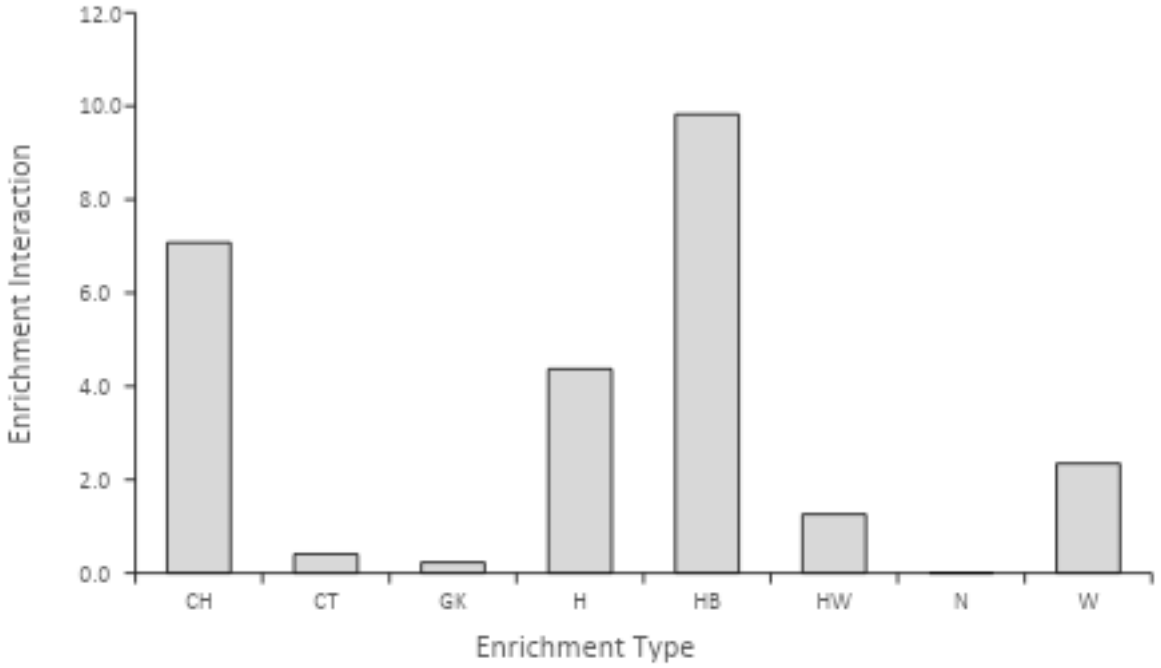


Figure 2.6 Comparison of the mean percentage of time spent approaching and interacting with different enrichment types across both time points (during and after) for both snow leopards (Asha and Manju) combined during the study period at Te Nukuao Wellington Zoo. B = browse, C = cardboard, G = ground, H = hanging, K = kennel, T = towel and W = water buoy; some are combined due to a mix of both types within one enrichment session. See Table 2.1 for an explanation of enrichment types.

2.3.5 Keeper Effects

Overall keeper had a statistically significant effect on the time spent showing active ($P > 0.001$) and social ($P = 0.001$) behaviours when all timepoints combined. The mean percentage of time spent active was highest when Keeper 4 was present (3.03%), followed by Keeper 1 (2.40%), then Keeper 3 (2.39%) and Keeper 2 (1.46%) (Figure 2.8). Keeper also significantly influenced the time spent performing social behaviours ($P = 0.008$). The mean percentage of social behaviour was highest when Keeper 3 was present (0.65%), followed by Keeper 4 (0.53%), with Keeper 1 (0.24%) and Keeper 2 (0.08%). The head keeper was used for analysis; however, multiple keepers may have been present during each encounter, thus confounding the results.

2.4 Discussion

Research of the behaviour of snow leopards and other zoo-held animals in response to close encounters is essential to ensuring that close encounter programs support positive animal welfare. This study focussed on the effects of enrichment and close encounters on the

behaviour of two snow leopards at Te Nukuao Wellington Zoo. The encounters were introduced on the 1st of September 2024; due to the timing of the study, this was also the first day that behaviour observations commenced. As cats were new to encounters, this may have influenced the results.

There were no significant differences in behaviour between the cats when all time periods are combined (before, during and after the close encounters). However, Asha tended to engage with the enrichment item more after the encounters had finished, 1.52% ± 0.51 during, 6.51% ± 0.51 after. Whereas Manju engaged equally during and after the encounter, 2.33% ± 0.92 during, 3.05 ± 1.10 after. A possible explanation for Asha's preference is that the presence of unfamiliar people before and during the encounter discouraged her from engaging with enrichment until the visitors left. Therefore, she may have been anticipating the guest's presence in the 'before' period, spending less time inside the den and avoiding them during the encounters. While no comparable data are available for snow leopards, Whitehouse-Tedd et al. (2021) found that individual cheetah involved in hands-on tours were observed to display more tail-licking (a stress-related behaviour) when being patted by visitors, with a reduction once patting had stopped, suggesting that contact with unfamiliar people was stressful. In contrast, individual cheetah, being walked by keepers, showed affiliative behaviour towards keepers and visitors (Szokalski et al., 2013a), highlighting individual differences in responses.

In the present study, the time spent inside the den, where the enrichment was presented, differed between cats. Manju spent more time in the den than Asha in the hour before the encounter began, whereas Asha spent more time inside than Manju in the hour after the encounter ended (after the guests had left the back-of-house area). This may suggest that Manju was anticipating the appearance of enrichment as she had become accustomed to the schedule. Pacing observed in lions prior to encounters involving feeding was suggested to be food anticipation and not a stress response to visitor interactions (Szokalski et al., 2013a). Servals have also been found to show an increase in pacing prior to encounters, which was attributed to anticipatory behaviour (Szokalski et al., 2013a; Acaralp-Rehnberg et al., 2020). Pacing prior to encounters may be due to a lack of something within the cat's environment, making them more interested in participating in the encounters (Spooner et al., 2021). Snow leopards across five facilities were observed to pace in the evening which was suggested to be anticipatory, due to their evening feeding schedules (Macri and Patterson-Kane, 2011). While this did not relate to a close encounter, it does show that captive snow leopards have

shown anticipatory behaviour around food. This supports the notion that Manju was likely anticipating the food enrichment.

Whether the encounters had prolonged effects on snow leopards' daily behavioural time budgets was beyond the scope of this chapter and is addressed in Chapter 3. However, Szokalski et al. (2013a) found that the behaviour of both tigers and lions differed when comparing days with protected contact tours and non-tour days, with less inactive behaviour observed on tour days. This was explained by the increase in feeding and pacing behaviour observed during the tour days (Szokalski et al., 2013a).

The enrichment presentation influenced the time spent interacting with the enrichment. This is not surprising, as some presentations, such as hanging, required more time and effort to obtain the reward than others. Snow leopards stalk and ambush their prey in the wild and therefore are likely to be motivated to express hunting behaviours. As well as interacting with their prey once caught, due to its typically large size, such as the Siberian ibex (*Capra sibirica*) (Veissier et al., 2024). Therefore, enrichment presentation that requires the cats to spend time trying to access the food item allows them to express some of their natural exploratory behaviours. This may explain why environmental enrichment has been shown to reduce stereotypical behaviour (Veissier et al., 2024). Live fish as a food presentation for a female fishing cat (*Prionailurus viverrinus*) reduced sleeping by 60%, as well as increasing behavioural diversity, and habitat utilisation (Shepherdson et al., 2005). Similarly additional types of hidden food increased, exploratory behaviour by almost 10% and pacing decreased (Shepherdson et al., 2005). In the wild, snow leopards can spend a large portion of their time walking their home range (133 ± 23 km^2 for female snow leopards) (Johansson et al., 2018). As this is limited within captivity, other behaviours need to be encouraged to allow the cats to express the energy they would usually use for travel. Enrichment allows the cats to spend time displaying active and exploratory behaviours and possibly reduces stereotypical pacing.

A limitation of the present study was that the enrichment types and presentations, guest numbers, and zookeepers present were outside the control of the researchers. There were often multiple types of enrichment provided within a single encounter; therefore, analysing the effect of specific enrichment types was difficult. It would be beneficial for future studies to use a single type per encounter to determine the effects on behaviour. Similarly, while the amount of time spent performing active and social behaviours varied depending on the specific head keeper present, it is important not to overinterpret this, as more than one keeper

was present for each encounter, as well as different combinations of keepers. There was insufficient data to statistically evaluate the effects of each keeper combination. Despite this, further research into the effects of keepers on the snow leopards is warranted, as research in other felid species has shown that the number of keepers can impact stress levels (as indicated by faecal glucocorticoid metabolite concentrations) (Koester et al., 2015). Indeed, it is well known that captive animals can display preferences for certain keepers (Hosey and Melfi, 2012). A non-encounter control period was not included in this chapter; however, this is covered within chapter 3. Chapter 3 results showed that encounter days compared to non-encounter days had a significant effect on time spent active for their daily time budget, with a mean of 10.73% on encounter days, and 7.29% on non-encounter days. It also showed a trend towards lower maintenance levels on encounter days; 3.21% on encounter days, 4.17% on non-encounter days.

Collectively, these results show that snow leopards had individual preferences and responded differently to the presence of people and objects. Therefore their behaviour in response to interactions with guests and enrichment should be individually monitored. A previous study of eleven snow leopards at the Wildlife Conservation Society's Bronx Zoo in New York City (New York, United States) identified a variety of personality traits, including Active/Vigilant, Curious/Playful, Calm/Self-Assured, Timid/Anxious, and Friendly to Humans (Gartner and Powell, 2012). With two types of tests (keeper assessment and novel object tests), individual differences were observed, as well as age and sex differences (Gartner and Powell, 2012). This study adds to the literature demonstrating individual differences within captive snow leopards (Gartner and Powell, 2012). Asha's trend of interacting more with enrichment over the 4 weeks shows that cats can become more accustomed to encounters and enrichment, and therefore behaviour may change over time. This demonstrates that cats may acclimatise to encounters over time, and judgment of welfare impacts may need to be over an extended period of time as well as at the individual level (O'Connor et al., 2022).

2.5 Conclusion

In conclusion, the two cats in this study differed in the time they interacted with enrichment and time spent inside the dens. The cats had preferred enrichment types, with certain types (i.e. hanging) allowing them to spend more time inside the dens interacting with the enrichment. Enrichment allows cats to display exploratory behaviours they may not get to

express often. This data helps to expand their behavioural diversity, and while not addressed in this study, it may help lessen stereotypical behaviour. This would be beneficial for future studies to investigate further, as well as the anticipatory behaviour displayed. Due to this study focusing on the first month that encounters began, it would be beneficial to understand the long-term impact of the encounters on the cats and how this impacts their welfare. The cats showed differences in effects from the encounters means that the cats should be independent in any further analysis of their effect on welfare.

Chapter 3: Determining Habitat Utilisation and Behavioural Time Budgets of Captive Snow Leopards (*Panthera uncia*)

3.1 Introduction

In the wild, snow leopards inhabit very large areas (greater than 100 km^2), with use of specific areas varying over time (Johansson et al., 2018). A snow leopard's wild habitat typically ranges from 540 to 5,000 m in elevation (Sharma et al., 2024b). Throughout this habitat, features include rugged mountainous terrain, with the cats using both ridgelines and gullies (Fox et al., 2024; McCarthy et al., 2024). Rocky and fragmented steep terrain is often selected for sleeping, with ridgelines and cliffs being used primarily for daytime activities such as resting or travelling (Jackson and Ahlborn, 1989). With such a large home range, they scent-mark and scrape within the main core areas, and not specifically the boundaries, suggesting marking relating more to communication (Jackson and Ahlborn, 1989; Fox et al., 2024). Snow leopards show overlapping neighbouring territories in order to mutually avoid each other to stay solitary while still utilising the area and communicating through scent marking (Krofel et al., 2025). Due to having large home ranges and long distances travelled to hunt and mark their territory, snow leopards are highly motivated to move for long periods. Captive environments therefore need to consider ways to meet this biological need, due to the limitations placed on the animal by the captive environment (Ross et al., 2009).

Habitat design can influence how animals use their environment and help us understand their needs and preferences in captivity (Brereton et al., 2025). There may be preferred areas they spend more time in and areas they tend to avoid or spend less time in. Habitat utilisation studies allow this to be quantified and for management decisions to be made to ensure an appropriate and effective design, with all areas contributing to the biological needs of the animal and optimising positive welfare (Ross et al., 2009; Rendle et al., 2018). Behavioural diversity and the presence of stereotypical behaviour have been used to evaluate habitat utilisation (Brereton, 2020).

This study aimed to characterise habitat utilisation by snow leopard sisters Asha and Manju at Te Nukuao Wellington Zoo. This was done by calculating their behavioural time budgets, as well as identifying locations within the habitat where behaviours were expressed, relating this back to the specific features found within the defined locations.

3.2 Methods

3.2.1 Animals

Two captive-born snow leopards (*Panthera uncia*) held at Te Nukuao Wellington Zoo (Wellington, New Zealand) were used for this research. At the start of the study, the two four-year-old sisters, Asha and Manju, weighed 31 kg and 33 kg, respectively. The cats were fed according to standard operating procedures at the zoo with *ad libitum* access to water. As this study was purely observational, animal ethics approval was not required. Further details regarding the cats can be found in Chapter 2 (section 2.2.1 Animals).

The cats engaged in non-contact close encounters where guests enter the back-of-house area ('encounters' hereafter) three days a week (Mondays, Fridays and Sundays). There is a rotating enrichment schedule, where different types are used (e.g., cognitive, physical, environmental, social, sensory and food) but never the same combinations of enrichments two days in a row. Different types of enrichment items were used within the different types. The cats' enclosures were serviced daily when possible. Ranging from a full hose and scrub to smaller upkeep tasks. The outdoor habitats were only to be cleaned when the cats are recalled into the indoor dens and therefore may be left for a maximum of 2 days. The encounters were as described in section 2.2.3, but for the current study, scoring was continuous. Environmental factors were noted, including dusk and dawn times (timeanddate.com, 41°17'S / 174°47'E), visitor hours and whether it was an encounter day or not.

3.2.2 Enclosures and Video Surveillance

Enclosure video surveillance was the same as in study 1 (See section 2.2.2). In short, the cats were housed separately in adjoining habitats, each fitted with two Reolink Duo 2 cameras with 180^{o} panoramic view at 4K resolution (20 FPS). The adjacent indoor dens were monitored using a single Reolink Duo 2 viewing both sides (Figure 3.1, a). The cameras were connected to a Reolink RLN36 36 Channel NVR (Reolink, Hong Kong, China) and video footage was continuously recorded from 22nd August through to 3rd October 2024 (i.e., a total of six weeks).

3.2.3 Experimental Design

The focus of this study was to determine how the cats utilised their enclosure and to identify factors that influenced their behaviour. Therefore, the outdoor and indoor habitats were sectioned into virtual grids (Figure 3.1). The outdoor habitats were sectioned by tier and

number in a manner that accounted for specific features within the exhibit (Table 3.1; Figure 3.1b, c). Tier one was at the front of the habitat, closest to the visitors, while tier four was the very back of the habitat, furthest from visitors' view. The habitat is flat at tier one and inclines up to tier four. Each habitat is split in half with two grid sections per tier, excluding tier one, which includes the platform on top of the caves and therefore has three sections. The inside den has five sections, including the tunnel from the habitat into the dens (Figure 3.1, a).

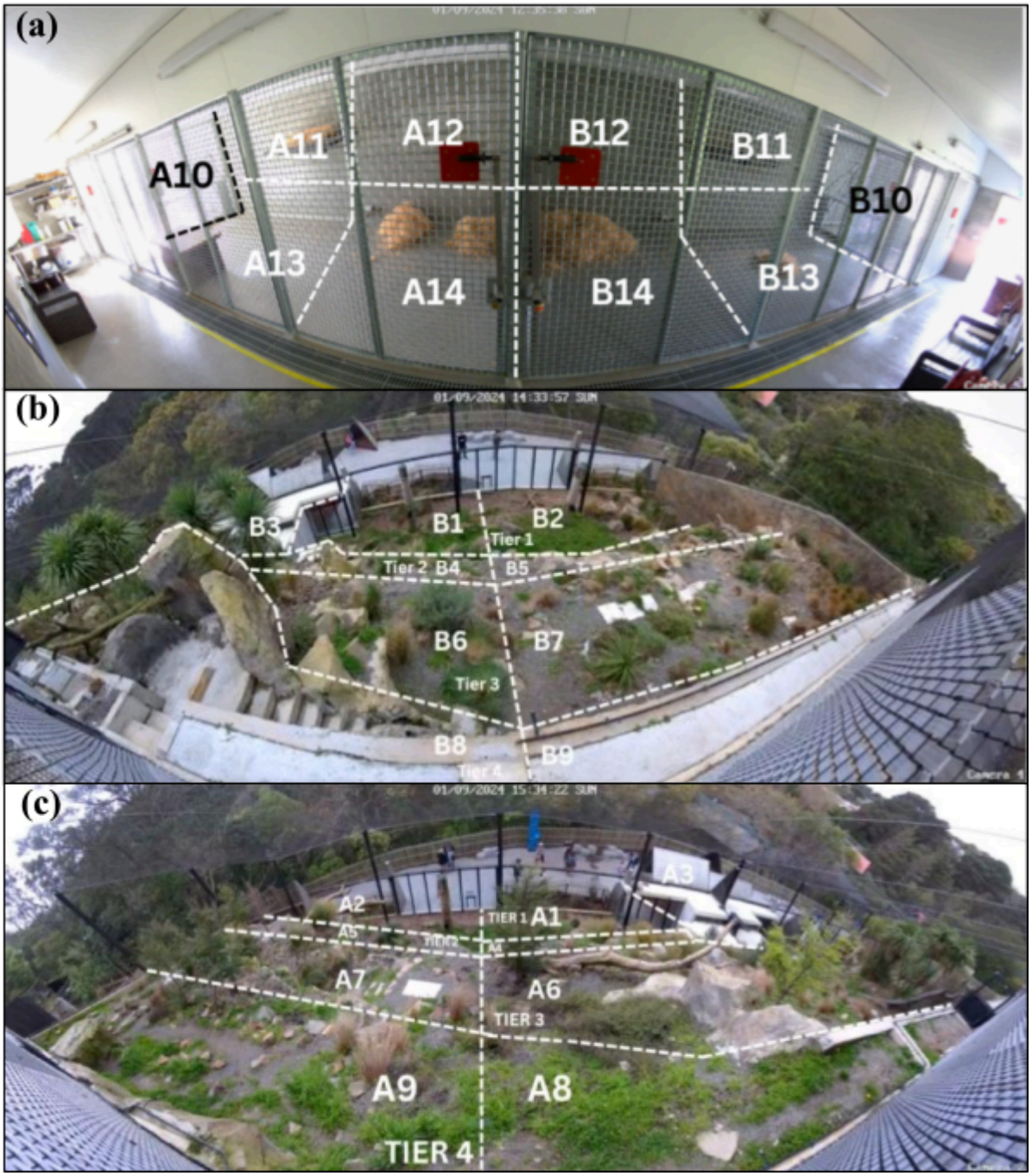


Figure 3.1 The grid sections used for the indoor dens **(a)** and outdoor habitats for behavioural scoring of snow leopards Asha **(b)** and Manju **(c) at Te Nukuao Wellington Zoo.**

Table 3.1 Grid sections and their signifiers for the habitats of the snow leopards at Te Nukuao Wellington Zoo.

Tier	Habitat A		Habitat B	
Tier 1 – Flat area	A1	Includes cave, window for guests	B1	Includes cave, window for guests, big cat tree – wrapped partly with rope
	A2	Big cat tree – wrapped partly with rope, window for guests	B2	Big cat tree – wrapped partly with rope, window for guests
	A3	Platform on top of cave	B3	Platform on top of cave
Tier 2 – start of incline to back of habitat – path from top to bottom	A4	Vertical cliff faces	B4	Vertical cliff faces
	A5	Large log extending off the cliff, vertical cliff faces	B5	Large log extending off the cliff, vertical cliff faces
Tier 3 – Fairly flat	A6	Log and tree, partly flat	B6	Tree, partly flat
	A7	Trees, partly flat	B7	Mostly flat area
Tier 4 – very back of habitat	A8	Flat with part ledge	B8	Ledge, boulder platform, log between platform and path, stairs down to B6 and B7, entrance into B10
	A9	Flat, boulder platform, entrance to B10	B9	Ledge at top of habitat
Inside Dens	A10	Tunnel from habitat to inside dens	B10	Tunnel from habitat to inside dens
	A11	Elevated platform	B11	Elevated platform
	A12	N/A	B12	N/A
	A13	Kennel (not the whole time)	B13	Kennel (not the whole time)
	A14	Straw/hay pile, drinking fountain	B14	Straw/hay pile, drinking fountain

Habitat use was evaluated over 12 days, with four sample days from each of weeks one, three and five. Two of the four days monitored each week were close encounter days (Sundays and Mondays), and two were non-encounter days (Thursdays and Saturdays). The encounters are described in detail in Chapter 2 (section 2.2.3). In brief, the encounters included up to four guests entering the back of house of the snow leopard habitat and placing enrichment items inside the dens for the snow leopards. The cats were then allowed access to the dens and could voluntarily decide to come and interact with the enrichment while the guests watched and listened to keeper talks about the snow leopards, the keepers' roles, and their conservation in the wild.

Daylight saving began on the 29th of September 2025; however, the time stamps on the cameras did not update. Unfortunately, this was not noticed until after behavioural scoring was complete. As a result, only 23 hours per day were analysed from the four sampling days in week five. As this was not expected to impact the results, no effort was made to retrieve the missing hour. A minimal expected effect on results meant this missing hour was not included. For the duration of each sample day (00:00 – 23:59 (24 hours)), the cats' behaviour

and location within the exhibit (i.e., grid section) were scored from video recordings using 5-minute focal sampling. Behaviour was scored according to the ethogram presented in chapter 2 (Table 2.2), with enrichment interaction behaviours now grouped under 'Enrichment interaction' (manipulating enrichment items, including lifting, carrying, holding, eating and sniffing/licking), and the inclusion of behaviours; investigate (cat moves around attentively while sniffing ground and/or objects or shows attention towards a specific stimulus by sniffing and/or pawing at it), pacing (repetitive locomotion in a fixed pattern, such as back and forth along the same route. Can include walking, trotting and running. Movement seems to have no apparent goal or function. Must be performed at least two times in succession before qualifying as stereotypic) and training (Engaging with keepers in a training manner). These behaviours were then grouped into eight categories, as outlined in Table 3.2.

Table 3.2 Snow Leopard Ethogram behaviours split into categories: active, inactive, marking, social, pacing, maintenance, other and out of sight. Refer to Table 2.2 for definitions.

Category	Behaviours included
Active	Climb; Enrichment interaction; Investigate; Jump; Object rear; Parkour; Play; Roll; Run; Stand; Walk
Inactive	Lie – head down; Lie – head up; Sit
Marking	Cheek rub; Scrape; Urine spray
Social	Aggression mild; Head rub; Social roll
Pacing	Pacing
Maintenance	Defecate; Urinate; Drinking; Eating; Groom; Scratch
Other	Yawn; Stretch; Other
Out of sight	Used when animal was out of view

3.2.4 Statistics

All statistical analyses were performed using RStudio (Posit, 2026) with a significance level of $P < 0.05$. A trend or tendency was described as $0.05 < P < 0.10$. Descriptive statistics (mean, standard deviation, and standard error) for the percentage of time spent exhibiting each behaviour in each grid section were calculated. Wilcox tests were performed to compare Asha and Manju across the behavioural categories and habitat utilisation and overall time budgets, as well as comparing behaviour on encounter days to non-encounter days. Friedman tests were performed to compare the hourly time budgets with specific behaviours comparing the cats. Kruskal test was performed to compare cats for time spent in specific areas. All data are presented as mean ± SEM unless otherwise stated.

3.3 Results

Video footage consisted of 144 hours per cat, with a total of 288 hours of footage observed and analysed. This included six encounter days and six non-encounter days.

3.3.1 Daily Time Budget

The amount of time spent exhibiting each category of behaviours is shown below (Table 3.4) There were no differences between the cats except for "Other" (Table 3.4). Encounter day had a significant effect on time spent active ($P<0.05$), with the cats displaying more active behaviour on encounter days than non-encounter days (Table 3.4). There was also a trend toward lower levels of maintenance behaviour on encounter days ($P=0.08$). Otherwise, encounter day had no other statistically significant effect on behavioural time budget in the cats.

Table 3.4 Mean daily time budget (%) on encounter days and non-encounter days for the two snow leopards at Te Nukuao Wellington Zoo for the study period. Maint = Maintenance; OOS = Out of Sight.

Day	Active	Inactive	Maint	Marking	Pacing	Social	Other	OOS
Encounter day								
Day 1	11.98	80.21	2.26	0.52	2.43	0.35	0.35	1.91
Day 2	12.85	78.65	3.13	0.00	1.91	0.35	0.35	2.78
Day 3	10.94	79.34	3.99	0.35	3.47	0.17	0.35	1.39
Day 4	8.85	53.47	3.99	0.17	2.43	0.00	0.00	31.08
Day 5	10.42	68.92	2.78	0.35	5.21	0.17	0.69	7.29
Day 6	9.38	70.31	3.13	0.35	1.22	0.52	0.17	10.76
Total mean	*10.73*	*71.82*	*3.21*	*0.29*	*2.78*	*0.26*	*0.32*	*9.20*
Non-encounter day								
Day 1	6.94	65.45	1.91	0.69	0.87	0.35	0.35	4.69
Day 2	8.68	77.95	4.86	0.35	2.43	0.00	0.35	5.38
Day 3	6.08	68.06	4.69	0.35	11.98	0.17	0.69	8.33
Day 4	7.47	70.83	4.69	0.87	14.06	0.17	0.69	1.56
Day 5	7.64	67.19	5.56	0.69	2.95	0.52	0.17	11.11
Day 6	6.94	75.52	3.30	0.00	1.39	0.00	0.87	7.81
Total mean	*7.29*	*70.83*	*4.17*	*0.49*	*5.61*	*0.20*	*0.52*	*6.48*
Overall mean	9.01	71.33	3.69	0.39	4.20	0.23	0.42	7.84

3.3.2 Daily Behaviour Patterns

Whilst the Wilcoxon test showed no statistically significant difference in hourly activity between the cats ($P=0.54$), the Friedman test showed that time did affect activity levels ($P=0.01$). There was a tendency toward a difference in time spent pacing between cats ($P=0.05$), with Friedman's test also indicating that the hour of the day affected pacing levels ($p=0.007$). While no statistical differences were found between the cats, qualitative differences in behaviour were observed (Figures 3.2 and 3.3).

Asha was more active at sunrise, including some periods of pacing (Table 3.2). She then decreased in activity through the mid-morning with a peak of almost no activity around midday. Her activity levels then increased after midday, including periods of pacing. Her activity decreased around sunset and into the late hours and early morning (Figure 3.2). No obvious patterns were observed during visitor hours for Asha (Figure 3.2).

Manju showed an increase in activity at sunrise, with this continuing until around midday, followed by a decrease in activity for a short period before increasing again around sunset. Her activity then decreased again and remained low during the night and early morning. Manju paced periodically throughout the day, with the lowest levels occurring late night and early morning (Figure 3.3). A possible trend of increased activity during visitor hours was observed (Figure 3.3).

3.3.3 Enclosure Utilisation

No difference was found between the cats for time spent in different areas of the habitat (P=1.0) (Table 3.5). Both cats spent an overwhelming majority of their time on the platform above the cave (Table 3.5), followed by the raised platform inside their dens and along the far back of their habitat, furthest from guests (Table 3.5). All three of these grid sections are areas where the cats spent a large portion of their time inactive (personal observation). Grids 5 and 7 were along the non-shared fence line and were the least used by the cats (both used under 1% of the time; Table 3.5). These areas were mainly used for maintenance behaviour (defecating and urinating) and sometimes marking (scraping) (personal observation) (Table 3.5).

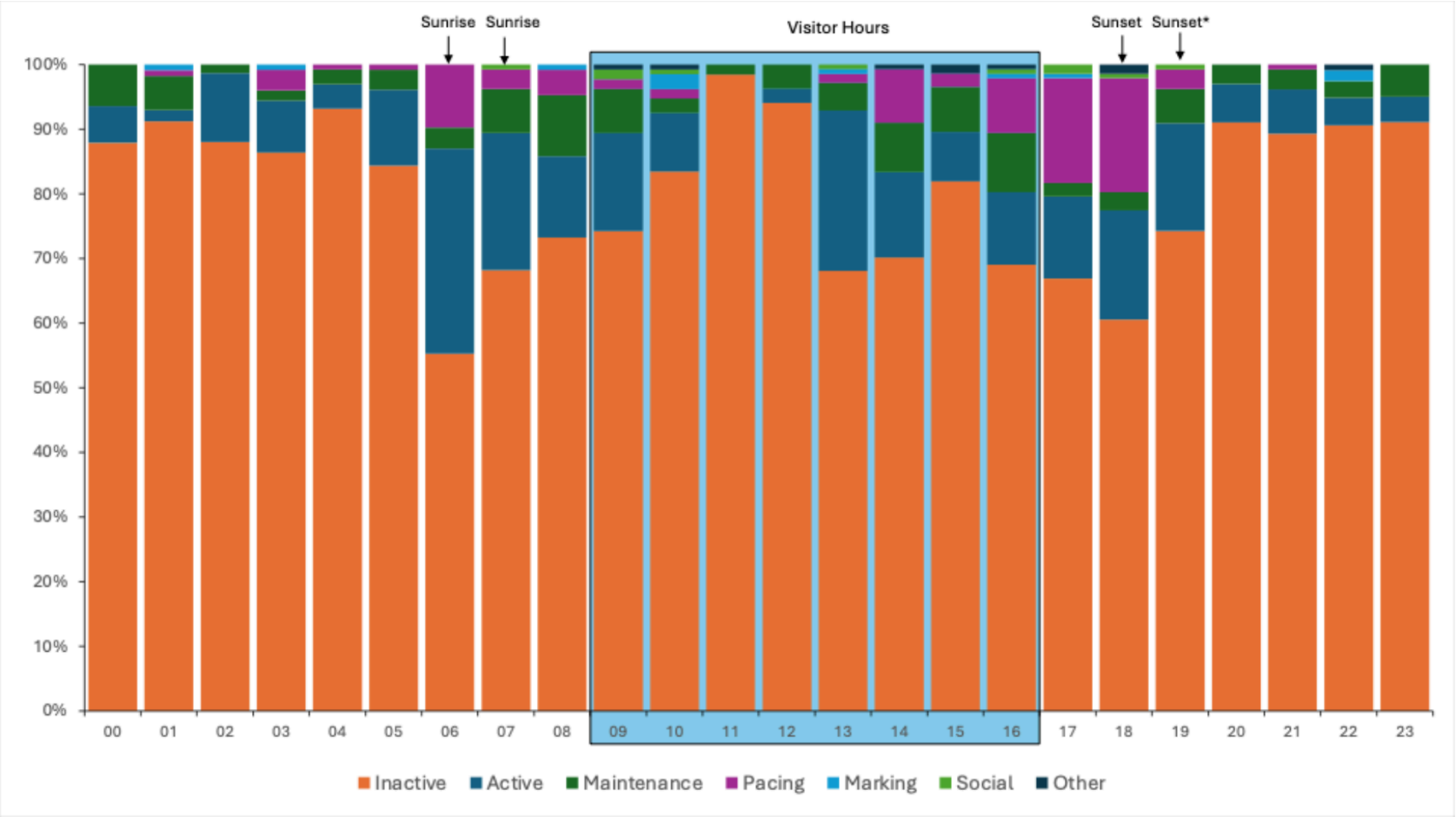


Figure 3.2 Hourly time budget for snow leopard Asha at Te Nukuao Wellington Zoo for the study period. Visitor hours are 09:30 – 17:00 (Due to the data being shown hourly, the hour (09:00) including 09:30 is included in the area highlighted as visitor hours). * Represents daylight savings sunset, sunrise was between 06:00 and 07:00; however, only one sunrise during the study period was at 07:00 including during daylight savings.

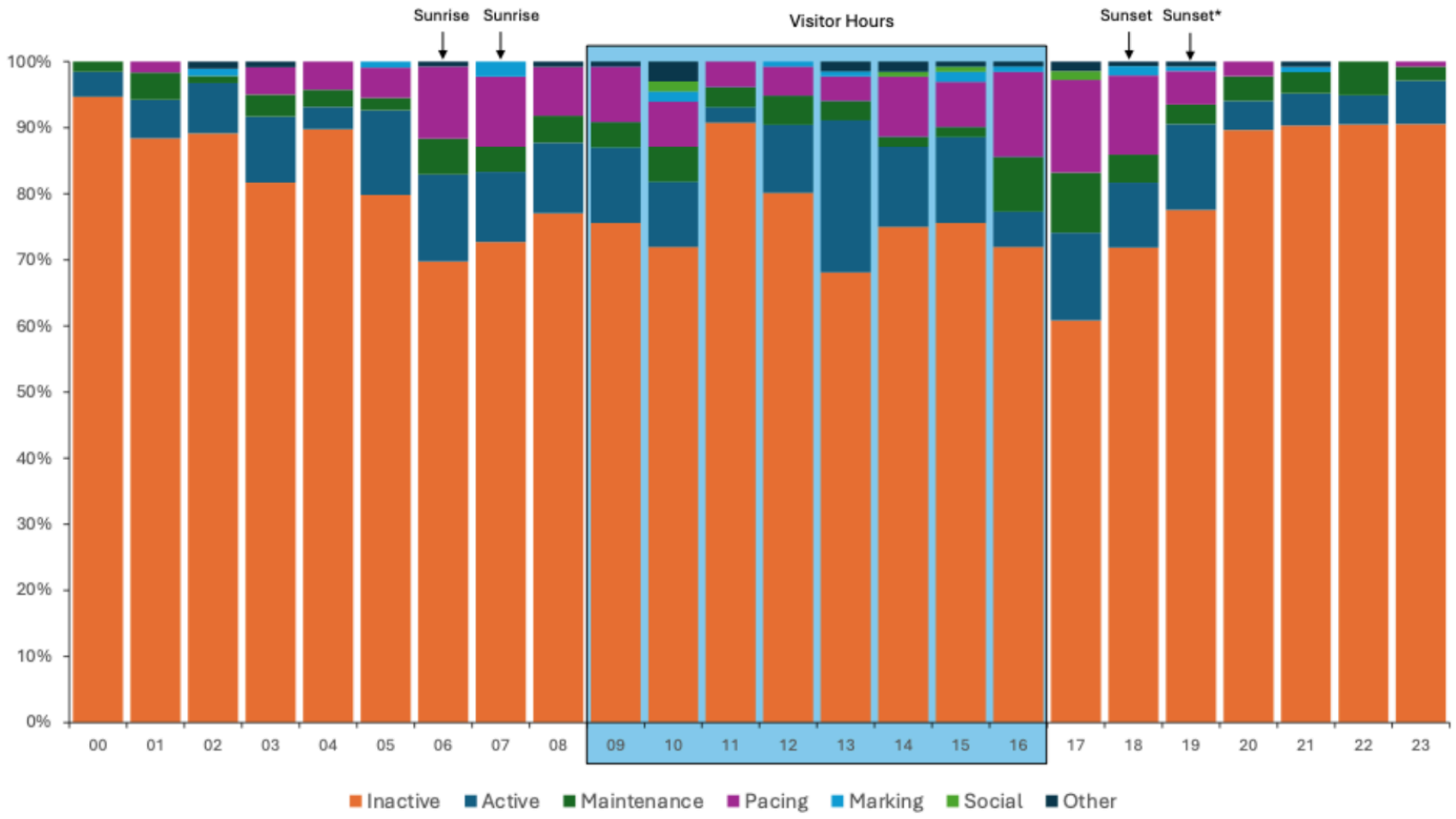


Figure 3.3 Hourly time budget for snow leopard Manju at Te Nukuao Wellington Zoo for the study period. Visitor hours are 09:30 – 17:00 (Due to the data being shown hourly, the hour (09:00) including 09:30 is included in the area highlighted as visitor hours). * Represents daylight savings sunset, sunrise was between 06:00 and 07:00; however, only one sunrise during the study period was at 07:00 including during daylight savings.

Table 3.4 The mean percentage of daily usage in each region of the habitat, and the mean percentage of time exhibiting specific behaviours within each region overall by snow leopards Asha and Manju at Te Nukuao Wellington Zoo. Detailing the specific Active behaviours. Abbreviations: Maint = Maintenance, OOS = Out of Sight, Enrich/invest = Enrichment interactions and investigate combined. Due to each numbered grid section having similar features in both habitats (A and B; Table 3.1), utilisation data have been combined for clarity

Grid section	Description	% Time in Grid	Active (%)									Inactive	Scent Mark	Social	Maint.	Other	OOS
			Run	Walk	Pace	Jump/ Parkour	Climb	Play	Roll	Stand	Enrich /invest.						
A/B 1	By guest windows	7.34	-	5.31	24.90	0.41	-	-	-	2.86	0.20	2.86	-	-	-	0.61	62.86
A/B 2	By guest windows	4.04	0.37	8.15	50.37	-	0.74	0.37	0.74	6.67	1.85	17.04	-	-	5.56	1.48	6.67
A/B 3	Platform on top of cave	41.17	0.04	0.73	-	0.07	0.04	0.04	0.15	1.53	0.11	90.87	0.22	0.44	3.82	0.40	1.56
A/B 4	Along shared fence line	1.06	4.23	23.94	-	-	1.41	-	-	22.54	1.41	38.03	2.82	-	2.82	-	2.82
A/B 5	Along non-shared fence line	0.55	-	29.73	-	-	2.70	-	-	24.32	2.70	37.84	-	-	-	-	2.70
A/B 6	Along shared fence line	1.60	-	18.69	3.74	2.80	1.87	-	-	23.36		26.17	0.93	3.74	0.93	2.80	14.95
A/B 7	Along non-shared fence line	0.78	1.92	36.54	-	-	3.85	-	-	5.77	17.31	23.08	5.77	-	3.85	1.92	0.00
A/B 8	Top back of habitat	3.38	-	17.70	1.77	0.88	6.64	-	-	12.39	0.44	49.12	2.65	-	0.88	0.44	7.08
A/B 9	Top back of habitat	13.97	-	4.18	1.71	0.21	0.21	-	0.32	2.47	0.32	85.96	-	-	2.79	0.43	1.39
A/B 10	Tunnel	2.35	-	10.83	0.64	-	-	-	-	10.19	1.27	22.29	3.18	-	1.27	0.64	49.68
A/B 11	Den - Platform	14.57	-	0.21	-	0.10	-	-	-	0.82	4.21	89.83	0.10	-	4.62	-	0.10
A/B 13	Den	2.07	-	19.57	2.90	-	-	-	0.72	5.80	5.07	43.48	0.72	-	12.32	-	9.42
A/B 14	Den	7.11	-	1.68	0.63	-	-	-	0	2.11	1.05	85.89	0.42	-	8.00	0.21	0.00
Average		NA	0.55	14.33	5.15	0.34	1.45	0.0	0.16	9.83	2.98	50.80	1.40	0.35	3.91	0.69	8.03

3.4 Discussion

Calculating behavioural time budgets and associated locations allows us to characterise habitat utilisation and assist in further understanding the behaviour of captive snow leopards. This will also assist captive facilities, to optimise animal welfare and encourage highly motivated behaviours within their habitat. Overall, the behaviour time budgets for both Asha and Manju did not differ between the cats (apart from category 'other'). Inactive behaviour was the most commonly observed, which is not unexpected for felines (Kitchener, 1991). The second highest behavioural category was active, followed by maintenance and pacing. The cats spent most of their time resting (lying head up/head down). Activity mainly consisted of walking and standing, with a smaller percentage of time standing on their hind legs against an object and investigating their habitat. Alongside the behavioural time budget, the locations of the specific behaviours were recorded, providing information on habitat utilisation. While the two cats' habitats were not exact replicas, they have the same overall layout with many of the same physical features. Therefore, grid numbers were allocated in accordance with the features of the section, which allowed a comparison of cats' use of their habitats. No difference was found between cats in their time spent in different areas within their habitats.

The cats were most active on the platform on top of the cave and the two far rear areas of the habitat (A/B 3, 8 and 9). This is where the cats spent a lot of time walking, either to reach the indoor dens or to access other areas of the habitat. When looking at specific behaviours in these three sections, walking and standing had the highest frequency of occurrence. The most used area of the habitat was the platform on top of the cave (A/B 3). This platform is where the cats spent the most time inactive, mainly lying down. This was most likely because these areas had the largest elevated flat space in the habitats. Snow leopards prefer to rest along elevated linear areas such as ridgelines and edges of the topographic landscape (Jackson and Ahlborn, 1989). This is consistent with the two other areas where the cats were most inactive: the back of the habitat, where the cats have a view of the whole habitat and a smaller flat area to lie down, and the elevated platform inside their dens where they spent time resting. Felids (such as cheetah, jaguar, and snow leopards) at Edinburgh Zoo (UK), used predominantly elevated locations for resting and observation, as well as using the back of habitats for observation (Lyons et al., 1997). This suggests that elevated locations can be a simple enrichment for cats, allowing them to watch, hide and observe their surroundings and as they would in the wild, as they use the elevation to their advantage when hunting prey (Fox et al., 2024).

The areas the cats used the least were the two sections of the non-shared fence line (A/B 5 and 7). Active and inactive were the most common categories of behaviours seen in these sections, with a small amount of maintenance and marking in section seven (A and B). From personal observation, these areas were mainly used as a pathway to other sections and therefore involved a lot of walking and a small amount of maintenance (defecating, urinating, or scraping). Spray marking was directed (personal observation) mainly towards the other cat's habitat and therefore is consistent with research that suggests marking is used as a form of communication between snow leopards (Jackson and Ahlborn, 1989). Scraping usually occured along travel paths in the wild, and therefore this result is in agreement with the natural behaviour of snow leopards (Fox et al., 2024). Sections A/B 5 and A/B 7 are the sides of the habitat that do not share a fenceline with the adjoining habitat; had a few features for the cats to interact with. These results suggest these areas are underutilised and mainly used as paths between other sections and to perform maintenance and marking behaviours.

Pacing behaviour was most frequently observed by the guest viewing area (A/B 1 and 2). The features of this area allow the cats to move in a repeated pattern along a relatively flat area without any obstructions. The areas where both cats shared pacing behaviours was along the guest viewing area into the habitat, as well as where they sometimes received food/enrichment. Manju also paced at the top back of her habitat (B9), where a ledge spanning the whole width of the habitat allowed her to repeat a similar pattern to that observed in the viewing area. In contrast, Asha's habitat had no ledge, and she did not exhibit pacing in this area. A study on captive felids found that of 15 individuals that were observed to pace, the edges of the habitat were specifically used (Lyons et al., 1997). A study of leopards (*Panthera pardus*) also found that all eight of the on-exhibit leopards showed a preference for pacing along the edges of their habitat (Mallapur et al., 2002). Lyons et al. (1997) suggested that the edges of habitats were an enforced territorial boundary, as well as a form of stimulation, due to the view of the public. Research has shown that snow leopards do not spend time walking their specific boundary in the wild, and spend time in specific areas for shorter periods, moving to new areas within their home range frequently (Jackson and Ahlborn, 1989). Therefore, pacing along the edges of the habitat may not relate to territorial behaviour. With snow leopards having large home ranges, it is unclear whether the distances covered in the wild need to be expressed in captivity, as travel in the wild may be due to the need to acquire resources (Watters, 2014). With feeding schedules shown to affect pacing in captive felids**,** pacing may be due to the anticipation of food rather than the need to move

over an extended period of time (Lyons et al., 1997). A small amount of pacing occurred within the den areas. This may have been anticipatory behaviour, due to enrichment and encounters happening within the dens. Anticipatory pacing has been observed in snow leopards prior to feeding (Macri and Patterson-Kane, 2011). However, no significant interaction was found between pacing and encounter days, although on two non-encounter days there was a higher percentage of pacing (Figure 3.4). Overall, non-encounter days had a slightly higher percentage of time pacing due to these two high days; however, no other obvious trends were seen.

The complexity of a habitat (addition of logs, platforms for sleeping, and sheds) has been shown to influence pacing in leopards, with increased habitat complexity associated with increased activity and resting and reduced pacing (Mallapur et al., 2002). While anticipatory pacing has been observed in other studies involving snow leopards and felids (Macri and Patterson-Kane, 2011; Acaralp-Rehnberg et al., 2020), it does not always represent a negative welfare state and can represent a positive experience (Watters, 2014). It has been described as an indicator of reward sensitivity, and it is thought that the importance of a 'reward' may be related to the frequency of the event, with lower occurrences linked to higher expression of anticipatory behaviour (Spruijt et al., 2001; Watters, 2014). Therefore, less anticipatory behaviour may represent better welfare due to positive events being a common occurrence (Watters, 2014). Among cheetahs, visual access to a conspecific in an adjoining habitat was associated with increased stereotypical behaviour (pacing) (Quirke et al., 2012). This may have been due to the inability to perform affiliative behaviours (Quirke et al., 2012). Due to their adjoining habitats, this may have influenced the snow leopard's pacing in the present study and should be investigated in further research.

A limitation of the present study was a lack of literature on snow leopard enclosure use and therefore comparison was not possible. Daylight savings (NZDT) occurred on the 29th of September; therefore, data collected during week 5 corresponded to the first week of NZDT. The keepers adjusted their schedule in accordance with NZDT, but the cameras did not change automatically, so some of the footage was changed manually to NZDT. Therefore, an hour of footage from the last four data collection days was deleted because it would have been collected from the following day. As this was discovered after behavioural scoring was completed, there were four days with only 23 hours of scored footage instead of 24, with the period from 23:00 to 00:00 missing. The cats were typically inactive during this time, so the absence of observations during this missing hour would likely have had minimal effect on

overall activity analysis or interpretations. Seasonal changes were unable to be investigated due to the lack of variability in weather during the study period.

3.5 Conclusion

In conclusion, gathering a behavioural time budget for Asha and Manju has provided further understanding into the behaviour of snow leopard's *ex-situ*. Demonstrating that cats spend a large portion of their time inactive and have preferred areas for resting (i.e. elevated, flat areas) and for pacing (i.e., relatively flat, unobstructed areas). The results have also identified areas where further research may improve our understanding, such as anticipatory behaviour, the connection between pacing and encounters and other variables, and further ways to encourage natural behaviours. Alongside this, habitat utilisation data have provided information on where behaviours are exhibited, the most frequented areas of the habitat, and areas that are currently underutilised at this specific site. The zoo can use this information to optimise specific areas, such as adding or removing features to encourage natural behaviours that the snow leopards are highly motivated to exhibit. This may help reduce any pacing that is occurring and optimise welfare. Due to the two cats showing some differences in their preferences, they should be treated independently when optimising the habitat and welfare.

Chapter 4: General Discussion

4.1 Discussion

The initial aim of this research was to validate a machine learning model to classify snow leopard behaviour from triaxial acceleration data obtained from a wearable sensor; the aim was then to use this method to monitor behaviour and habitat utilisation of the snow leopards at Te Nukuao Wellington Zoo. A purpose-built collar was developed (Figure 4.1) and piloted on dogs at the Centre for Canine Nutrition (Massey University, New Zealand), and animal ethics approval was obtained from the MUAEC (Protocol number 24/13) to fit the collars to the snow leopards for data collection.

Manju was initially removed from the study as she obtained a greenstick fracture injury and required sedation prior to the collar being ready. An attempt was made to fit a collar to Asha during a planned routine anaesthesia and health examination; however, this was unsuccessful due to the collar not being able to be made tight enough to be safely fit on her. There were no further opportunities to fit the collars to either snow leopard during the study period. As an alternative, and with the Zoo's approval, an attempt was made to fit the collar on one of the tigers at Wellington Zoo (Senya) during a scheduled procedure (Figure 4.1). While the fitment was successful, Senya removed the collar within a day and destroyed the unit, meaning no data was obtained (Figure 4.1).

Given the snow leopard exhibit was fitted with continuous surveillance equipment before the planned anaesthesia and collar fitment, the aim of this thesis was changed to using the video footage to conduct traditional observation-based behaviour research, with the aims of: (1) evaluating the behavioural responses of the snow leopards to enrichment and close encounters, including whether the engagement in encounters was impacted by other factors (keepers and enrichment format); and (2) providing Te Nukuao Wellington Zoo with information on habitat utilisation by the snow leopards and the effects of variables such as hour of the day, day of the week and location on snow leopard behaviour. Overall, this thesis aimed to provide further understanding of snow leopard behaviour in captivity (a species for which published data are lacking) and to provide Te Nukuao Wellington Zoo with information to aid management decisions for the two snow leopards in their care. To the authors knowledge, this is also the first report of continuous 24-hour video footage being used to determine the behavioural time budget of snow leopards in captivity.



Figure 4.1 Purpose-built remote releasing collar being fit onto Senya **(a)** and Asha **(c)** during a routine health exam at Te Nukuao Wellington Zoo. Remote releasing collar after Senya removed it herself **(b).**

When reviewing current literature on captive snow leopard behaviour, few studies have focused on habitat enrichment (Rosandher, 2009; Fernandes, 2017), and no literature could be found that assessed the effects of close encounters or guest interactions on snow leopard behaviour. While there was literature on the behaviour of snow leopards in captivity (Freeman, 2005; Burgener et al., 2008; Macri and Patterson-Kane, 2011; Gartner and Powell, 2012; Gartner et al., 2016), it was limited and only two studies included a behavioural time and/or activity budget (Freeman, 2005; Macri and Patterson-Kane, 2011). Freeman (2005) concentrated on adult pairs of snow leopards, with a specific focus on oestrus and sex differences in behaviour. Macri and Patterson-Kane (2011) focused on comparing the behaviour of solitary vs socially housed snow leopards, as well as assessing the effect of Feliway® (a pheromonal product designed to reduce stress in cats) as part of an enrichment program.

Chapter 2 of this thesis took a similar approach to Macri and Patterson-Kane (2011) by evaluating the effects of a treatment (i.e., close encounters) on the behaviour of snow leopards. This was the first study to date to assess the effects of close encounters on snow leopard behaviour and provides a basis for future studies. Close encounters have been evaluated in other species, such as servals (Acaralp-Rehnberg et al., 2020), tigers, African lions and cheetah (Szokalski et al., 2013a; Whitehouse-Tedd et al., 2021), koalas (*Phascolarctos cinereus*) (Webster et al., 2017), giraffes (*Giraffa camelopardalis*) (Dagg, 1970) and African elephants (*Loxodonta africana*) (Lacinak, 2024). Collectively, these studies showed that close encounters can impact the behaviour of a wide range of species.

The two snow leopards in this study show preferences for the type of enrichment, with hanging or buoy types encouraging them to spend more time expressing exploratory behaviours. While the behavioural time budget showed a low percentage of exploratory behaviour (e.g. investigation or hunting behaviours), the enrichment during close encounters encouraged these types of behaviours. This has also been observed in a clouded leopard and a fishing cat during an enrichment study (Das, 2026). With specific preferences in enrichment type being shown, those that take longer to obtain the reward (e.g. food) should be prioritised to promote the behaviours they are motivated to express (searching, pursuing, finding food, and hiding places) (Chan et al., 2025). However, these enrichment types should not be the only types included as enrichments should be changed often to prevent habituation and ensure they remain novel, as increasing environmental novelty is often a goal of enrichment activities (Shepherdson, 2003). Given the cats' engagement with the enrichments, it may be possible to increase the use of underutilised areas of the habitat, or perhaps enrichment novelty could be enhanced by changing location within the habitat. While this may not be possible for logistic reasons, it may be beneficial for enrichment outside of encounters.

Previous research has shown that encounters can have an effect on the expression of stereotypical behaviours (Das, 2026). The behavioural time budget showed that the cats in this study displayed pacing and possibly anticipatory behaviour. While no statistical significance was found between the encounters and pacing, this does not mean they do not play a part in influencing this behaviour, as well as their anticipatory behaviour. Given that this data was collected when encounters were first introduced, the possible effects of enrichment (during encounters or otherwise) on stereotypical behaviour should be investigated over a longer term. Previous studies have shown variable effects of enrichment on stereotypical pacing which was reduced during enrichment due to an increase in active

behaviour in a clouded leopard (not significant) and fishing cat (statistically significant) (Das, 2026), providing an example of how effective enrichment reduces stereotypical behaviour through targeting specific, highly motivated behaviours such as exploration. Pacing was found to take up similar amount of time across different studies investigating the behaviour of snow leopards under different captive management (Freeman, 2005; Macri and Patterson-Kane, 2011).

The two studies (Freeman, 2005; Macri and Patterson-Kane, 2011) investigating the behavioural time budgets of snow leopards showed that they spent the majority of their time in an inactive state, which aligns with the results of this study (Freeman, 2005; Macri and Patterson-Kane, 2011). A recent study has shown that female snow leopards in the wild spend 44.9% of their activity budgets travelling or exhibiting locomotive behaviour (Shrestha et al., 2025). While in the present study, the cats spent 13.21% of their time active or pacing. According to this data, wild snow leopards are 3.5 times more active than their captive counterparts. Therefore, enrichment promoting active behaviours would encourage more behaviours seen in the wild.

While there are similarities across captive snow leopard behaviour, as well as Asha and Manju specifically, individual differences have been noted, which may relate to personalities. Captive snow leopards have been classified into five different personality types, as discussed earlier (Gartner and Powell, 2012). This shows that there are ways to assess personality in snow leopards using novel objects. This may be useful in future studies in assessing Asha and Manju's individual differences, which can then be used to provide specific enrichment in accordance with personality type to ensure it is beneficial for both cats.

This study showed the importance evaluating snow leopards independently even when similarities are present. They each had preferences which include elevated flat platforms for resting and areas to be able to view their surroundings. While large flat areas, often around the edge of the habitat, are often used for pacing, therefore reducing large flat areas may assist in redirecting pacing behaviour to different behaviours.

4.2 Limitations

The major limitation within this study is the sample size. With only two animals in this study (n = 2), the results have limited statistical power and should be interpreted with caution. In addition, as an observational study conducted during normal zoo operations, many variables

(e.g., keeper presence, enrichment presentation, weather, and visitor numbers) were unable to be controlled. This introduces potential for confounding effects on the behaviour of the cats. For example, the combination of keepers present on a given day was inconsistent and changed regularly, thus limiting investigations into the effects of individual keepers or keeper combinations on cat behaviour. Similarly, the type and presentation of enrichment varied with each encounter, and multiple enrichments may have been offered within a single encounter. While greater standardisation may have enabled more detailed statistical analysis, enrichment variation is crucial to maintaining novelty and minimising the changes of habituation occurring.

It is also worth noting that the snow leopards had had no previous experience prior to this trial with scheduled close human encounters. While this allowed us to assess how the cats were affected by the introduction of the close encounters as a novel experience, as well as how they adapted to the encounters over the first month, it may not reflect the behaviour of snow leopards in response to more established encounter experiences.

4.3 Conclusion and Future Directions

4.3.1 Conclusion

The original aim of the study of using wearable technologies and machine learning to monitor snow leopard behaviour was not achieved. However, this is the first study to use traditional behavioural monitoring techniques were used to generate detailed data on snow leopard behaviour in response to close encounters (Chapter 2) and habitat utilisation (Chapter 3). The two sisters, Asha and Manju, responded differently to the close encounters over time: Manju did not show any specific trends, while Asha appeared to become more accustomed to them over time, spending more time inside the dens during encounters as the study progressed.

Interacting with enrichment varied with presentation format, with hanging enrichments being interacted with the most. While the large variation in enrichment formats limit the strength of this interpretation, these data can provide insights into the design of future enrichments. Habitat utilisation data did not differ between the cats either for specific behaviours or time spent in particular zones, suggesting similarities in how they interact with their environment. Both cats showed a preference for resting on elevated areas that provide a view of their surroundings.

Pacing behaviour was observed in both cats, with no relationship to encounter days. Instead, pacing was mainly displayed by the guest viewing area, suggesting a tendency to use habitat edges and flat areas for this behaviour. A behavioural time budget and spatial mapping of behaviours were also developed; these data provided comparative reference point for future studies aiming to evaluate the behaviour of snow leopards in captivity, although the small sample size may limit generalisability.

Overall, this thesis provides preliminary behavioural data on a species for which information is limited, contributing to the sparse literature on snow leopard behaviour in captivity and offering insights that may inform future research and efforts optimise animal welfare.

4.3.2 Future Research

- Long-term effects of encounters on behaviour: With this study assessing the effect of the close encounters on the snow leopards at the beginning of the encounters being introduced, exploring the effect of encounters over a longer-term would allow further understanding of acclimatisation and the effects on behaviour long-term.
- Impact of changes to habitat on behaviour and utilisation: This study gives further understanding and knowledge of the habitat utilisation by Asha and Manju. With this baseline knowledge, the zoo will be able to assess the impacts of any future additions or changes to the habitat on the snow leopard's behaviour, to optimise animal welfare.
- Relationship between pacing and close encounters: Due to pacing not being directly assessed in relation to the close encounters, this would be a beneficial area for future research. This could provide a greater understanding of anticipatory behaviour by the cats, as well as identifying any stress or coping behaviours being exhibited.

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