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Assessing Social Compatibility in Captive Brown Bears *(Ursus arctos)*: Development and Application of a Standardised Ethogram for Behavioural Observations and Social Evaluation.

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SUMMARY

The brown bear (*Ursus arctos*), classified as a species of least concern by the International Union for Conservation of Nature (IUCN), faces significant challenges in captivity due to varied and often inadequate living conditions. One critical issue is the social compatibility of individuals housed together. Captive environments necessitate close quarters and interactions that can lead to stress and behavioural problems, especially for a species naturally inclined toward solitary living (Smith & Clark, 2018; Swaisgood and Shepherdson, 2005).

This study focuses on the social behaviour of captive brown bears, aiming to assess their suitability for cohabitation through the development and application of a standardized working ethogram, a crucial tool for behavioural observations and social evaluations. The research, in collaboration with the global animal welfare organisation FOUR PAWS, was conducted on two brown bears housed at the BÄRENWALD Müritz sanctuary, Germany. Behavioural observations were carried out using fifteen-minute continuous focal sampling sessions, employing a working ethogram specifically tailored to brown bear behaviour with an emphasis on social dynamics. Data collected was used to produce an activity budget and to identify space usage and aspects of social behaviour. Although the study originally planned three phases of socialization—housing in adjacent enclosures, introduction, and post-cohabitation—the bears were ultimately deemed unsuitable for cohabitation and the plan was adapted based on to the animals´ behaviour.

Findings underscore the challenges in assessing and managing social compatibility among captive brown bears, highlighting the need for detailed behavioural evaluations to optimize their welfare. By developing a standardized working ethogram, this research contributes insights into the complexities of bear social dynamics and provides a vital tool for animal caretakers, researchers, and wildlife managers to objectively assess and enhance social compatibility in captive environments. Furthermore, the insights gained will aid in refining enclosure designs, social grouping strategies, and overall management practices, ultimately improving the welfare of captive brown bears (Kreger et al., 2000).

1. INTRODUCTION

1.1. **Captive animal management**

The brown bear (*Ursus arctos*), classified as a species of least concern by the International Union for Conservation of Nature (IUCN), faces significant challenges due to shrinkage or local extinction of home ranges (H. ad Ghoddousi, 2018). According to the Zoological Information Management System (ZIMS), as of 2017, there are 713 *Ursus arctos* housed in 197 zoological institutions worldwide, either as individual animals or in groups. However, many bears are kept in facilities not recorded in this system, including bile farms, circuses, sanctuaries, rehabilitation centres, unregistered or mini zoos and private collections. This situation raises significant welfare concerns as captivity often subjects brown bears to varied and frequently inadequate living conditions (Montaudouin and Pape, 2004). Captive conditions impose numerous environmental and management restrictions that can negatively impact the welfare of these animals. For example, bear species are notably prone to developing stereotypical behaviours under such conditions (Montaudouin and Pape, 2005).

One critical issue is the social compatibility of individuals housed together. Ensuring the welfare of captive animals is a fundamental responsibility of modern zoos and wildlife sanctuaries. For species like the brown bear, which are usually solitary by nature, the challenges of maintaining social compatibility are particularly pronounced (Smith & Clark, 2018). In several facilities, where space and resources are limited, the interest in housing multiple individuals together often arises. Behavioural conflicts emerging from forced cohabitation can lead to stress, aggression, and other welfare issues (Mason et al., 2019). However, socialization provides rescued bears the opportunity to experience social structures that meet their species-specific and individual needs. Successfully introduced animals benefit from larger enclosures and the ability to display social behaviours. Additionally, sharing space with conspecifics can help reduce stress (FOUR PAWS, 2022). Understanding and assessing social compatibility in these scenarios is crucial to improving brown bears´ living conditions and ensuring their psychological well-being.

The increasing importance of ethology in wildlife management has led to the development of various tools and methods for observing and evaluating animal behaviour. An ethogram, a catalogue of behaviours exhibited by an animal, is a tool used to make more standardized observations, thereby enhancing the reliability and validity of the data gathered. Ethograms provide a systematic way to document and interpret animal behaviours, enabling more effective management strategies (Martin and Bateson, 2007).

A standardized working ethogram specifically tailored for brown bears under human care has been developed during a FOUR PAWS project aimed to assess their welfare (Stagni et al., 2024), but the social interactions are only broadly described. A working ethogram to answer to social compatibility question has yet to be developed and applied. This research aims to fill this gap by creating and implementing a standardized working ethogram to explore social dynamics among captive brown bears, facilitating more precise and reliable behavioural assessments, and enhancing our understanding of social interactions and compatibility in captive brown bears.

1.2. **Brown bears, social behaviour and reproduction**

The brown bear is a solitary carnivore and non-territorial species, occurring at low densities (Bellemain et al., 2005; Dahle and Swenson, 2003). Rather than strict territories, bears have home ranges that fluctuate based on geographical range and food availability (Schenk, Obbard, and Kovacs, 1998; Hawkins and Racey, 2009). Studies show that brown bears, among other bear species, exhibit a wide range of sexual dimorphism, from none to males being twice the size of females. The largest bear species can be up to ten times heavier than the smallest. They have evolved to occupy specialized niches as carnivores, herbivores, and myrmecophages, while retaining the capability to function as omnivores (Stirling and Derocher, 1990). Males typically have larger home ranges that overlap with those of several females (McLoughlin, Ferguson, and Messier, 2000; Dahle and Swenson, 2003; Støen, 2005; McLellan and Hovey, 2001). However, territorial behaviour has been observed in female brown bears within certain populations, such as in Scandinavia, where related females exclude unrelated females from shared areas (Støen, 2005; Puchkovskiy, 2024). Social interactions are generally limited to the breeding season, with social groups being limited to females with cubs (Stirling and Derocher, 1990). Despite this, bears exhibit various social roles within their populations, including dominance hierarchies and affiliative behaviours (Støen, 2005). Comparatively, other bear species, such as the polar bear (*Ursus maritimus*), also known for their solitary nature, still engage in social interactions, including play behaviour such as wrestling, chasing, and mock fighting, particularly in non-breeding seasons or when resources are abundant (Stirling, 2011).

The mating system of brown bear populations can generally be classed as promiscuous or polygamous, and they are subject to pronounced reproductive seasonality (Steyaert et al., 2012; Schwartz et al., 2003; Puchkovskiy, 2024). Female brown bears experience delayed implantation, where fertilized ova remain dormant in the uterus for approximately five months before implantation in November–December, resulting in cub births during winter denning (Schwartz, Miller, and Haroldson 2003; Mano

and Tsubota 2002). Natal dispersal is typically male-biased and considered a mechanism to avoid inbreeding (Bellemain et al., 2005; Zedrosser et al., 2007). The philopatry of female brown bears can lead to the formation of matrilineal assemblages, where genetic relatedness is spatially autocorrelated (Puchkovskiy, 2024; Støen, 2005).

While traditionally classified as solitary (Støen, 2005; Steyaert et al., 2014; Bellemain et al., 2005; Stirling and Derocher, 1990), there is evidence showing that brown bears can form social groups under certain conditions (Fagen and Fagen, 1996; Puchkovskiy, 2024), and they are characterized by many manifestations of sociality, such as extreme tolerance of conspecifics, physical communication and play-fighting (Stonorov and Stokes, 1972; Stirling and Derocher, 1990; Fagen and Fagen, 2009).

This social plasticity allows bears to adapt to different situations (Mattiello et al., 2014). Bear social behaviour can vary in response to several factors, such as individual genetic factors, season, or environmental conditions. Resource distribution, for example, significantly influences social behaviour: where resources are scarce, bears are likely to be more solitary, whereas in environments with abundant high quality food (e.g. in captivity), they may show tendency to aggregate with other individuals (Stirling and Derocher, 1990; Egbert, Stokes, and Egbert, 1976; Puchkovskiy, 2024; Sorum et al., 2023; Stonorov and Stokes, 1972). Other forms of aggregation may be observed in females with cubs and littermates that continue to associate, playing and feeding together (Masatomi, 1964; Bellemain et al., 2005; Zedrosser et al., 2007).

In captivity, brown bears can form dominance/subordination relationships even as yearling bear cubs (Pazhetnov et al., 1999). When housed together, with a satisfactory food supply, especially siblings or male-female pairs, bears can exhibit a range of social behaviours from tolerance for living together in a limited area, to strong positive associations and affection, in particular when caring for bear cubs (Koene and Ipema, 2014; Puchkovskiy, 2024; Sorum et al., 2023). For example, Egbert et al. (1976) classified non-agonistic encounters as “amicable”, involving brief interactions in which two or more bears pawed, mouthed, rubbed, or otherwise lightly contacted each other in the head and neck region, or “play”, consisting of mock fighting and, more rarely, sexual mounting. Sometimes bears can display play fighting behaviours lasting up to fifteen minutes, or more (Masatomi, 1964). Changes in social environment significantly impact their behaviour, highlighting the need for comprehensive understanding to ensure their well-being (Koene and Ipema, 2014). For example Mattiello et al. (2014) studied a captive sterilized male brown bear before and after the death of his female sibling, finding that when the bear was alone, the percentage of time he spent alert and inactive almost tripled, and the time spent sleeping was less than one-third compared to when the female was present.

Because brown bears are usually solitary animals and are typically difficult to observe, their communication methods and behaviours in the wild are not well understood (Stirling and Derocher, 1990). In contrast, the captive environment provides more opportunities to study their social interactions and housing conditions, which differ significantly from the wild. In zoos, bears are commonly kept in pairs or sometimes larger groups (Partridge and Association of British Wild Animal Keepers, 1992). In sanctuaries housing rescued bears, it is common to find large numbers of bears within a single enclosure. Montaudouin and Le Pape (2005) recorded more playful and less agonistic relationships when a maximum of two bears were housed together. A larger group size is therefore considered a potential source for social conflict. Shontelle (2009) suggested that when forming a new group of bears in a zoo, the bears should be of similar ages, with the male perhaps being older. Additionally, when adding to the group, introducing two young bears simultaneously is preferable to introducing one bear alone, as they can support each other during the introductory period. Understanding the complexities of bear social behaviour is crucial for their welfare in captivity. Therefore, great care is required when forming groups and adding new bears in sanctuaries. The physical and mental status of the bears should be considered in deciding which bears can be housed together (Shontelle, 2009).

1.3. **Research Setting and Objectives**

The primary objective of this study is to develop a comprehensive and standardized working ethogram for behavioural observations of social interactions between captive brown bears and record their behaviour. This ethogram will then be applied to assess the suitability of individuals for introduction to one another and their compatibility for long-term cohabitation in captivity. The specific objectives are as follows:

- To compile a detailed list of behaviours exhibited by captive brown bears, with a main focus on social dynamics.
- To standardize these behaviours into a functional ethogram for use in behavioural observations to evaluate a possible social introduction between two brown bears.
- To apply the ethogram in observing captive brown bears, and assess their social interactions and compatibility for cohabitation.
- To provide a source of potential comparison with similar studies conducted at the same facility, involving other animals.

- To provide recommendations for enhancing the welfare of captive brown bears by managing social compatibility based on the findings.

The materials and methods were discussed and developed in collaboration with FOUR PAWS specialists.

FOUR PAWS is a global animal welfare organisation based in Vienna, Austria. It focuses on improving the living conditions of animals under direct human influence, by revealing suffering, rescuing animals in need, and protecting them. Today, with offices in Australia, Austria, Belgium, Bulgaria, France, Germany, Kosovo, the Netherlands, Switzerland, South Africa, Thailand, Ukraine, the UK, the USA and Vietnam as well as sanctuaries for rescued animals in eleven countries, FOUR PAWS provides rapid help and long-term solutions. The organization's sustainable campaigns and projects focus on companion animals including stray dogs and cats, farm animals and wild animals – such as bears, big cats, orangutans and elephants – kept in inappropriate conditions as well as in disaster and conflict zones ('FOUR PAWS', n.d.). In FOUR PAWS sanctuaries wild animals are housed individually, in pairs or groups based on their behavioural responses. The goal is to improve animals´ welfare, by enriching their life and provide companionship when is desired. Social grouping is not forced on animals to free up enclosures.

2. ANIMALS; MATERIALS and METHODS

2.1. **Animals**

Behavioural observations were conducted on two brown bears, Luna and Michal, housed at BEAR SANCTUARY Müritz, Germany (53.3871° N, 12.3271° E).

Table 1. Animals involved in the study.

Name	Sex	Weight *(kg)	Length (cm)	Born	Born in
Luna	Female	95-135	160	2014	Wild
Michal	Male	200-270	220	2003	Captivity

**Physiological seasonal changes*

Luna (Figure 1) is a female brown bear (*Ursus arctos*) born in 2014, originally from Albania. She arrived at BEAR SANCTUARY Müritz in June 2017 after being rescued from the "Aulona Amusement Park" in Vlora, Albania. At the amusement park, Luna was confined in a small, inadequate cage and exposed to constant sunlight, atmospheric

Figure 1. Luna

precipitation, visitors, loud music, and noises. She was brought to the park at an age when bear cubs typically remain with their mothers. In November 2016, local authorities, with assistance from FOUR PAWS, confiscated and rescued Luna, and temporarily housed her at Tirana Zoo before transferring her to BÄRENWALD Müritz.

Luna is known to engage in abnormal behaviours including stereotypies, often with a specific pattern, such as circling with head tossing, and self-directed behaviours, which consist in repetitively biting, licking, or sucking parts of the body without any obvious purpose of self-maintenance (Vickery and Mason, 2003). In some cases, she can bite the upper part of her front limb. These behaviours can be accompanied by a "humming" vocalization and are often indicators of stress or psychological distress, especially in captivity, where they are seen as comfort behaviours but indicate underlying behavioural issues (Carlstead and Seidensticker, 1991). In the wild, similar self-directed behaviours can be observed in bear cubs when they are alone and waiting for their mothers, serving as a self-soothing and relaxing mechanism (Peters, Owen, and Rogers, 2007). To mitigate these behaviours, when the study was conducted, a behaviour modification plan was set up for Luna, consisting of behavioural medication (3 tablets of Clomipramine 75 mg daily) and supplements (500 mg Zylkene® daily) supported by positive reinforcement training and enrichment.

In 2021, animal caretakers, in collaboration with FOUR PAWS specialists, attempted to socialize Luna with Rocco, another male bear at the sanctuary, during the mating season. Luna had no prior direct contact with other bears. Initially housed in adjacent enclosures, Luna and Rocco exhibited positive affiliative behaviours and were subsequently allowed to share the same enclosure. They were frequently observed eating, sleeping, and playing together. However, after a month of cohabitation, quarrels, particularly during feeding times, became more frequent. Sometimes they would also chase each other through the enclosure. For this reason, the caretakers decided not to feed Luna and Rocco close to each other. Despite various management attempts, food-related agonistic interactions increased, leading to their separation in September 2021 to avoid unnecessary stress. In June 2022 Luna was sterilized due to recurrent pseudo pregnancies.

Michal (Figure 2) is a male brown bear born in 2003. He arrived at the sanctuary in September 2011 from Braniewo Zoo, Poland, where he was kept in poor housing conditions. Michal lived in a small 60-square-meter pit and lost his right forelimb in a fight with another bear at the age of three. He was known to limp around in circles all day long. Upon arrival

Figure 2. Michal

at BEAR SANCTUARY Müritz, Michal's behavioural issues significantly improved. The sanctuary provided him with a species-specific environment and care, which significantly reduced his stereotypic behaviours. Nowadays, Michal enjoys a more fulfilling life, often seen resting near visitors, swimming, and exploring the forested areas of his enclosure (FOUR PAWS, 2021).

Due to the absence of his right front limb, Michal places an unphysiological load on his contralateral leg. Veterinary check-ups have indicated that this abnormal load will lead to irreversible, progressive, and painful osteoarthritis in the affected joints. Optimal seasonal weight management and supplementation with Chondroitin and Glucosamine Sulphate were recommended to slow the progression of this condition. To date, only minor osteophytic and enthesophyte lesions have been observed in the X-Rays, and analgesic management is not yet required but will be implemented upon signs of reluctance to move or more abnormal weight bearing. Regular radiographic joint assessments, recommended at least every five years, are conducted to monitor the condition's progression or performed in case of symptoms. At the time of behavioural observations, Michal was receiving three tablets of Glucosamine (500 mg) per day. From 2013 to the summer of 2022, Michal shared an enclosure with a female bear: Tapsi. They showed affiliative behaviours and performed many activities together. For example, they even hibernated together. Tapsi was approximately 13 years older and in the last years of her life she suffered from severe arthrosis of the femoral articulation. Therefore, the couple had to be separated in 2022 to protect Tapsi's health and welfare. In 2023 she was euthanised as the pain management was not effective anymore.

2.2. **Study Area**

As defined by Pierce and Bekoff (2018), a sanctuary is a place where wild animals can live under human protection in conditions that resemble their natural habitats as closely as possible. The BEAR SANCTUARY Müritz, a FOUR PAWS animal welfare project, is Western Europe's largest bear sanctuary, at the time of the study, was home to thirteen brown bears rescued from zoos, circuses and private homes.

Situated near Stuer in the north-east of Germany, the sanctuary comprises 16 ha, of which 12 ha are built up with large outdoor enclosures that offer a varied landscape with mixed woodland, grasslands, forest glades, hillsides, rocks, a natural water course, artificial dens and various enrichment. The sanctuary provides an alternative living environment for brown bears that cannot be reintroduced to the wild, addressing their physical and psychological needs.

The size and structure of the sanctuary offer the bears an ideal environment, with approximately 5000 square meters per animal or socialised pair. If this space requirement is not met, additional enrichment is increased.

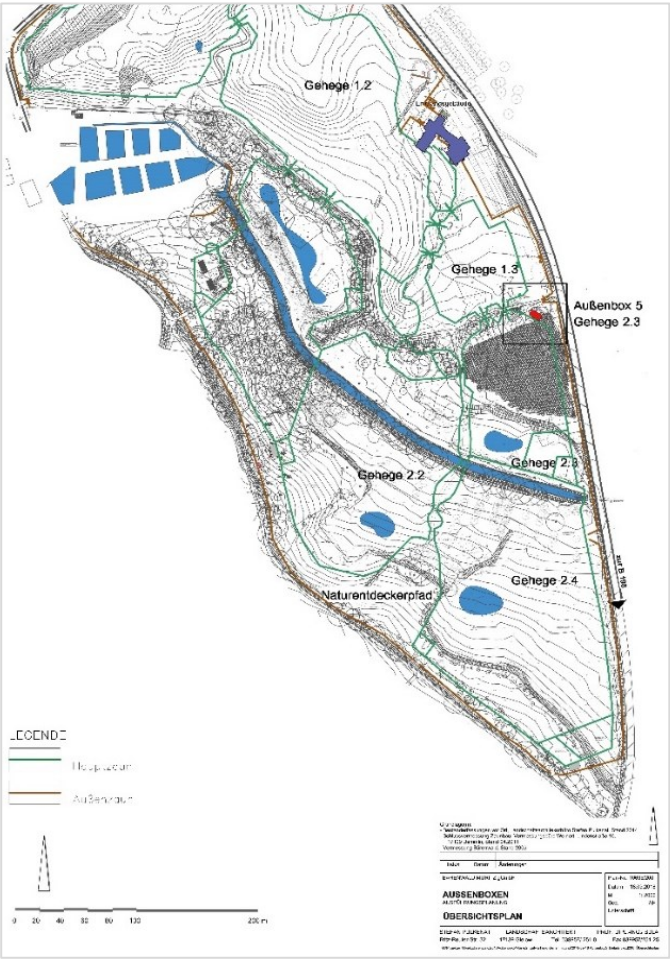

Figure 3. An overview map of the sanctuary featuring water bodies, enclosure perimeters, vegetation zones, and artificial structures. Key elements such as the main fence (green), outer fence (orange), and specific enclosures (Gehege) are clearly marked. The "Naturentdeckerpfad" (nature discovery trail) path is also indicated, providing an essential topographical context for the sanctuary.

The bears can fulfil their natural behaviours, such as wandering, withdrawing into their own space to be in seclusion, digging dens and rediscover their natural winter state of hibernation. Multiple artificial ponds and a natural watercourse allow for intensive bathing and coat care. The bears' diets are adjusted seasonally, and the food is scattered in the enclosure or presented in enriching ways to stimulate foraging behaviours. Additionally, the sanctuary adheres to a strict non-purchasing and non-breeding policy, with all male bears being neutered.

Michal was housed in an enclosure designed as an outdoor paddock with access to artificial dens. One side of this enclosure was exposed to visitors. The majority of the enclosure consisted of dense forest, particularly concentrated in the centre, with the remaining areas comprising open grassy fields, a natural watercourse, and an artificial lake, providing a varied and enriching environment. Luna was housed in one of the separation enclosures within Michal's enclosure, which was not exposed to the public. This was done to lower her threshold for coping behaviours in response to visitors. This separation enclosure was designed as an outdoor paddock with access to a small inner enclosure, referred to as the bear house.

The area featured a grassy landscape with minimal shrub vegetation, an artificial den, and a small shallow pool for drinking and bathing. To provide a stimulating environment for Luna, despite the confined space, the animal caretakers placed various stones and log piles, which encouraged foraging and explorative behaviour.

For the purpose of conducting behavioural observations and social evaluations, the enclosure identified as 2/4 (Figure 4) was further subdivided into ten distinct areas, based on the sanctuary management's requirements and the potential resources of interest to the animals.

Throughout the majority of the study, Luna was predominantly housed in areas B and D, whereas Michal had access to the remaining areas (R, N, L, T, S, F, G). Michal's access to area Y in enclosure 2/3 was restricted to June 3rd and 4th due to management reasons. During this period, the bears were physically separated into different areas, precluding any possibility of social interaction.

Figure 4. Overview of the sanctuary map, highlighting water bodies, enclosure perimeters, and separation zones. An enlarged view of enclosure 2/4, where brown bears Luna and Michal are housed, is provided. Specific locations within enclosure 2/4 and 2/3 (R; N; L; T; S; B; D; F; G; Y) are marked for the purpose of conducting behavioural observations and social evaluations.

2.3. **Experimental Design and Working Ethogram**

The project was originally designed to conduct behavioural observations over a three-month period, encompassing three distinct phases of the socialization process: housing in adjacent but separate enclosures, introduction, and post-cohabitation. This was strategically planned to coincide with the mating season for brown bears, after waking up from hibernation. The initial phase involved observing social interactions between the two bears, Luna and Michal, along the fence and gates to assess the feasibility of their introduction. Additionally, the caretakers set up some cooperative feedings. A cooperative feeding consists of feeding the two bears close to the sliding gate, in between the enclosures, through which they can interact, to support the familiarisation process between the individuals. However, due to ethical concerns, it was decided not to proceed with the remaining phases to avoid unnecessary stress or potential injuries. The interactions observed did not indicate positive influences on the single animal or acceptance of each other, as will be detailed in the results section of this paper.

Had the introduction taken place, the subsequent observations would have focused on detecting the presence of social affiliative interactions or agonistic interactions within the same enclosure, possibly allowing for a wider range of interactions. These interactions would have significant implications for

the welfare of the bears in a positive or negative manner. Importantly, the occurrence of agonistic behaviours, depending on context and intensity, would have necessitated immediate separation. For example, if one bear growled while eating to deter the other from approaching, this would indicate clear communication and be considered acceptable. Conversely, more severe conflicts, such as fights, chases, or resource limitation, would have elicited immediate intervention. Additionally, during the first phase, before the introduction phase, Luna was supposed to have access to the remaining areas of enclosure 2/4, whereas Michal would have been moved to the separation enclosure of enclosure 2/3 (area Y of Figure 4). This setup aimed to observe any changes in Luna's response toward Michal when housed in a broader and more varied environment. However, due to external factors, such as sudden toxicity of the natural water sources inside the enclosure that are fed by a stream outside of the premises, this plan was not possible (see limitations section of the paper).

To conduct the observations, a working ethogram was created in collaboration with FOUR PAWS specialists. This involved revising video footage of bear behaviour, reviewing literature, and comparing ethograms from other studies to familiarise with brown bear ecology and behaviour. A working ethogram serves as a systematic catalogue of behaviours observed in a specific species, providing a structured framework for recording and analysing animal behaviour (Lehner, 1996).

The purpose of a working ethogram is to ensure consistent and comprehensive documentation of behaviours, which is essential for accurate behavioural assessments and comparisons across studies. In particular, the ethogram was developed to understand and select behaviours of interest concerning the social behaviour of brown bears, and the visual signals they use to establish and maintain a social structure (Stonorov and Stokes, 1972).

The initial ethogram was developed based on ethograms established in other studies (Stagni et al., 2024; Stagni, Normando, and de Mori, 2017; Zarzo-Arias et al., 2018; Stonorov and Stokes, 1972; Montaudouin and Pape, 2005; Ross 2006; Renner and Lussier, 2002). The finalized ethogram, following preliminary observations of Luna and Michal at the sanctuary, included 33 distinct behaviours categorized into eight major categories: activity; inactivity; visibility; maintenance; affiliative social interactions; agonistic social interactions without contact; agonistic social interactions with contact and abnormal behaviours.

Table 2. Categories of behaviours (states and events) exhibited by the bears during observations. Adapted from the working ethogram developed in the framework of the BearWell project (Stagni et al., 2024). Modifiers are included in the description of the behaviour.

Behavioural Category	Behaviour Code	Description
Activity	Bathing	"Bears sit, walk, or swim in the water of a pool or pond. They can show maintenance behaviours (e.g. self-grooming), playful explorative behaviours".
	Locomotion	"Bears move forward or in any direction, with no repetitive pattern and not running. They might sniff and investigate the environment at the same time, including foraging".
	Running	Bears move in any direction at a speed faster than a walk. This behaviour is not caused by fear of any stimulus, and might be performed towards humans, heterospecific or conspecific.
	Digging	Bears break up or move earth, dirt or other substrate/surfaces with their paws and claws.
	Flight	Bears suddenly "run away from something or from someone (human, conspecific or other species). In the case of a conspecific, the latter has not shown any sign of aggression or threat (otherwise would be R of an agonistic social interaction)".
	Other	Bears perform any other behaviour not included in this working ethogram.
	Aggression towards object	"Bears have a sudden and violent reaction directed to an item inside the enclosure. They shake, charge and strike the object and growl loudly". The subject of this reaction could also be the gate or the bars of the enclosure.
	Play Alone	Bears interact with objects present in the enclosure, "they may manipulate, snap or throw objects around (including enrichments)". Includes pulling, pushing, nosing, batting, mouthing, rubbing, shaking, pawing, holding or biting a movable object or permanent surfaces such as ledges or rockwork. The object used to play could be an enrichment item, another object or there is no object involved. If there is no object involved, bears may play with their own paws or with the surrounding environment, such as digging. "They might paddle and splash in the water, run, climb, jump and/or roll".
Inactivity	Resting	Bears lie or sit down. The eyes might be open or closed and they may be sniffing the air and observing the surrounding environment. Bears might be resting alone or in company of other bears, the latter is considered if the distance between the bears is (0) in contact, (2) within 2 body lengths of distance, (4) within 4 body lengths, (6) within 6 body lengths and (8) within 8 body lengths of distance.
	Standing Still	Bears remain on their four paws, neither moving forward nor backwards. They may be sniffing the air and observing the surrounding environment.
Visibility	Out of Sight	"Bears cannot be seen or they can be seen only partially, hindering behaviour recognition. They might become out of the visual during the 15 min observation or they cannot be seen from the beginning at any of the predefined observation points".
Maintenance	Self-Grooming	Bears use their powerful jaws and teeth to scratch and bite at their fur, removing any dirt, debris, or parasites that may have accumulated. They may also use their tongue to lick themselves or their claws to comb through their fur and remove any tangles or mats.
	Eating	"Bears chew and ingest food items, provided by the caretakers or found in the enclosure. They grab the food directly with the mouth or they bring the food to the mouth with the front paws. Body position and locomotion is irrelevant (e.g. they can move, sit or lie down)". Bears might be eating alone or in company of other bears, the latter is considered if the distance between the bears is (0) in contact, (2) within 2 body lengths of distance, (4) within 4 body lengths, (6) within 6 body lengths and (8) within 8 body lengths of distance.
	Rubbing	Bears may rub any part of the body against an object, usually repeated. This may be a sign of territory marking or an act of self-grooming. Transient contact while in locomotion is excluded.
Affiliative Social Interactions	Allogrooming	Bears use their paws, mouth, or other part of their body to touch the other animal; the mechanical motion of allogrooming resembles scratching, picking, stroking, rubbing, licking or nibbling directed towards the other bear. This type of behaviour can also happen through the gate.
	Play Together	Bears perform tactile interaction with each other, by wrestling, pawing, biting and chasing each other in a manner that is considered playful, not harmful and with no other

		agonistic intent. This could happen also through the gate. Vocalization if they happen, are soft.
	Arousal	Bears perform behaviours which may include increased respiration and vocalization like repetitive grunts, huffing and tongue clicking towards other bears.
	Mounting	One bear position themselves on top of another bear, typically placing its forelegs over the shoulders or back of the other bear. This action may involve pressing down or straddling the other bear's body. Mounting behaviour may be accompanied by vocalizations, such as growling or vocal displays, as well as physical gestures such as pawing or nuzzling. One bear should be identified as A (agent) and the other bear R (recipient)
	Interactions	Bears display positive interest towards conspecific, also through the fence, indulging in interactions which are not expressively described in this working ethogram. For example, one bear might show interest in another bear by looking at them, sniffing the air at a distance, stretching the neck or head towards the conspecific direction. They can also briefly touch or smell each other.
	Caretakers Interaction	Bears interact with the caretakers, displaying positive interest towards them, in response, for example, to a feeding or training section.
Agonistic Interactions Without Contact	Avoidance	Bears avoid interactions in response to social behaviours, both agonistic and affiliative, of other bears.
	Away From	Bears prevent closeness with other bears, by changing direction of their path, backing slowly away or turning their head away.
	Aggression towards human	“Bears have a sudden and violent reaction directed to a human (staff or visitor) or an heterospecific (e.g. a visitor's dog). They show threatening behaviours like mock charge, jawing or snorting. Define if staff (S), visitor (V) or heterospecific (H)”.
	Mock Charge	“Bears start the action of charging but stop after few steps without getting close to the recipient”. In case one of the subjects is the initiator of the agonistic interaction, by doing the charge or starting the fight, then it should be identified as A (agent) and the other bear R (recipient).
	Tension	Bears display general tensing of muscles, especially of front. Bears might be walking or staying still. Ears might be laying back or near head with the openings not conspicuous from the front. Vocalizations like growling or roaring may be performed.
	Vocalizations	Bear may produce sounds of huffing, growls, low or high roars and teeth clacking as a warning when approached by another bear or when approaching another bear.
	Jawing	“Bears open and close the jaws, repetitively, rapidly and loudly. Body positions is stiff”.
Agonistic Interactions with Contact	Pawing	Bears might try to reach another bear with their paws and/or claws. This could also happen through the gate. In case one of the subjects is the initiator of the agonistic interaction, then it should be identified as A (agent) and the other bear R (recipient).
	Charge	“Bears perform a short run, violently and rapidly against a conspecific, usually with vocalisation”. In case one of the subjects is the initiator of the agonistic interaction, by doing the charge or starting the fight, then it should be identified as A (agent) and the other bear R (recipient).
	Fight	“Bears have aggressive contact, characterised by loud growls, biting, swiping and striking”. In case one of the subjects is the initiator of the agonistic interaction, by doing the charge or starting the fight, then it should be identified as A (agent) and the other bear R (recipient). Put X if none of them can be clearly identified as agent or recipient of the action.
Abnormal Behaviours	Stereotypies	Bears perform the same behaviour in a repetitive, constant, exaggerated and often unvarying manner, without apparent purpose or obvious goal. Behaviours shown can be pacing (incl. circling), weaving, tongue playing, head swaying, head tossing, bars biting or licking.
	Self-Directed	“Bears bite, suck or lick part of their bodies (usually the same spot) repetitively, without any obvious purpose of self-maintenance. It might be accompanied by a "humming" vocalisation”.
	Re-Directed	Bears might redirect their frustration towards another target, which could be a conspecific or an object present within the enclosure. “Bears bite, suck or lick part of a

	conspecific´s body (usually the same spot) repetitively, without any obvious purpose of grooming. Might be accompanied by a "humming" vocalisation".

Definitions of behaviours included in the descriptions of the behaviours in the ethogram:

Pacing (incl. circling): "bears walk repetitively the same path, which can be from left to right in a straight line, eight shaped or circular". Most of the times bears place their feet in exactly the same position on each way;

Weaving: "Bears stand or sit and repetitively swap the weight load from one side to the other";

Tongue playing: "Bears might stretch the tongue out of the mouth and/or roll it. They might put the tip in the nostrils or in the mouth";

Head sway: "Bears stand or sit and repetitively move the head side to side, usually in front of a door or fence";

Head tossing: "Bears suddenly turn, twist or throw back the head, head-tossing might be combined with the end of a pacing path. The front legs might be lifted or staying on the ground".

Bears in captivity are highly susceptible to the development of stereotypies, which are repetitive behavioural routines that are invariant in style, and appear to have no obvious function or consequence (Wechsler, 1991; Kolter, 2002; S. Vickery and Mason, 2004). Until quite recently occurrence of stereotypies was only considered as an indicator of a boring, poor environment. Nevertheless they can appear in complex and varied enclosures (Montaudouin and Pape, 2004; Mason, 1991; Fischbacher and Schmid, 1999).

2.4. **Data Collection**

Preliminary observations were conducted to familiarise with the two brown bears, their environment, and the daily routine of the sanctuary. These initial observations allowed for slight adjustments to the working ethogram in the field and the identification of the different areas within the enclosure, ensuring accurate and relevant data collection (Altmann, 1974). The sanctuary operated from 9 AM to 6 PM for the public, while staff activities began at 8 AM. The behaviour of each bear was monitored through six fifteen-minute observation periods per day, five days a week, during the spring season, from April 25th to June 19th. To maximize the chances of observing a variety of behaviours and minimize biases related to time and routine, an alternating observation schedule was established, as shown in Table 3. This approach helps reduce the potential for time-of-day effects and observer-induced biases, providing a broader and more representative overview of bear behaviours (Martin and Bateson, 2007). However, it should be noted that not all observation periods were completed every day, indicating some gaps in the data collection.

	Mon	Tue	Wen	Thu	Fri	Sat	Sun
8:00-8:30							
8:30-9:00	Michal	Luna		Michal	Luna	Michal	Luna
9:00-9:30	Luna	Michal		Luna	Michal	Luna	Michal
9:30-10:00							
10:00-10:30							
10:30-11:00	Michal	Luna		Michal	Luna	Michal	Luna
11:00-11:30	Luna	Michal		Luna	Michal	Luna	Michal
11:30-12:00	Michal	Luna		Michal	Luna	Michal	Luna
12:00-12:30	Luna	Michal		Luna	Michal	Luna	Michal
12:30:13:00							
13:00-13:30							
13:30-14:00	Michal	Luna		Michal	Luna	Michal	Luna
14:00-14:30	Luna	Michal		Luna	Michal	Luna	Michel
14:30-15:00							
15:00-15:30	Michal	Luna		Michal	Luna	Michal	Luna
15:30-16:00	Luna	Michal		Luna	Michal	Luna	Michal
16:00-16:30							
16:30-17:00	Michal	Luna		Michal	Luna	Michal	Luna
17:00-17:30	Luna	Michal		Luna	Michal	Luna	Michal
17:30-18:00							

Table 3. Observation Schedule for Monitoring Brown Bear Behaviour. Observation schedule outlining the specific times and alternation patterns for observing two brown bears, Michal and Luna, over the course of a week. Each bear was observed for 15 minutes within a 30-minute time span, six times per day, from 8:30 AM to 5:30 PM, five days a week, to ensure a comprehensive assessment of their behaviours while minimizing routine bias. Blank cells represent designated breaks or periods when behavioural recording was not occurring.

2.4.1. Continuous focal sampling and technical support

Observations were conducted at fixed intervals to maintain flexibility and minimize disturbances to the bears. Each observation session involved 15 minutes of continuous focal sampling, following the methodology outlined by Altmann (1974), However, a 30-minute time span was allocated for each bear per observation session. This additional time accounted for the large enclosure size, which required extra time to locate the bears or switch between focal subjects. During each 15-minute observation session, the location of the bears was sampled at 2-minute intervals, resulting in a total of eight scans per session. This method allowed for systematic and frequent documentation of the bears' locations and activities. Breaks between observation sessions were scheduled to recharge equipment and to minimize the stress caused by constant human presence, a consideration particularly important for more sensitive bears like Luna (Margulis, Hoyos, and Anderson, 2003).

All occurrences of behaviours of social interest observed outside the designated observation times were also recorded. These additional observations ensured comprehensive data collection on socially relevant behaviours that might not occur within the fixed observation periods. A detailed breakdown of these behaviours is provided in Table 7. Direct observations of the bears were complemented by video recordings using a Nikon D3200 camera. During each observation session, the camera was positioned on a tripod near the enclosure fence and adjusted as necessary to ensure optimal viewing of the bear. The camera's positioning was crucial for capturing clear and comprehensive footage of the bears'

behaviours. Information related to the observations was documented in a notebook, noting variables such as the location of the bears, distance from the observer, weather conditions, and other relevant environmental factors. This detailed documentation provided context for the behavioural data and helped account for any external influences on the bears' behaviours. The time spent by bears on each behaviour was measured using BORIS, a free software that allows for precise quantification of behaviours defined in an ethogram (Friard and Gamba, 2016).

2.4.2. Analysis

Data collected through behavioural observations were categorised into activity budgets, space usage, and social interactions´ frequency for each individual. The BORIS software was employed to code behaviours, though occurrences related to bears not part of the study were excluded from the analysis. All data, including notes on date, time, bear identity, weather conditions, relevant variables, location, and distance, were exported to Microsoft Excel. Social interactions with bears other than the primary subjects of the study, Luna and Michal, were recorded and coded as "*behaviour name_other*."
The frequency and duration of behaviours for each bear were calculated based on the total observation time, providing insights into behavioural changes over the observation period (Martin and Bateson, 2007). The spatial dispersion of behaviours throughout the enclosure was also analysed. Data were grouped into two periods for comparative analysis: the first 15 days (Period I) and the last 15 days (Period II). Unfortunately, for Period I, the data on the 27th of April is incomplete, missing observations for both Luna and Michal. On the 30th of April, there are eleven observations, because the third observation for Michal is absent. In Period II, the 9th, 16th, and 19th of June have only ten observations, with the first two on the 9th and the last two on the 16th and 19th missing for both bears. Behavioural categories with low or null occurrence were excluded from statistical analysis. For the remaining behaviours, the following metrics were calculated for each observation: duration, frequency, and presence/absence. Descriptive statistics were then performed. Due to the limited number of individual bears, the aim of the test, and the distribution of the data (including a significant number of zero entries), inferential statistical tests focused on the presence/absence of behaviours. Each single observation was treated as a sample unit (Grisa et al., 2013). Generalized Estimation Equations (GEE) were used to analyse the target variable, which was considered binomial (presence/absence). The following behaviours were included in the analysis: Eating (total) and Eating ≤ 8 body lengths, resting (total), locomotion, standing, and abnormal behaviour (including stereotypies and self-directed behaviours). Data distribution did not allow GEE for resting ≤ 8 body lengths. Chi-square test was

performed. The potential predictors for these behaviours in the GEEs were animal, period, time of day, and the interaction between period and animal.

2.5. **Ethical Approval**

This study was conducted within a FOUR PAWS sanctuary, adhering to FOUR PAWS policies and animal welfare standards. Therefore, ethical approval was not required, as the observational nature of the study did not involve any modifications to husbandry routines or manipulation of the animals. The animals had the ability to withdraw from the observer's view and video camera at any time.

3. RESULTS and DISCUSSION

3.1. **Behavioural time budget**

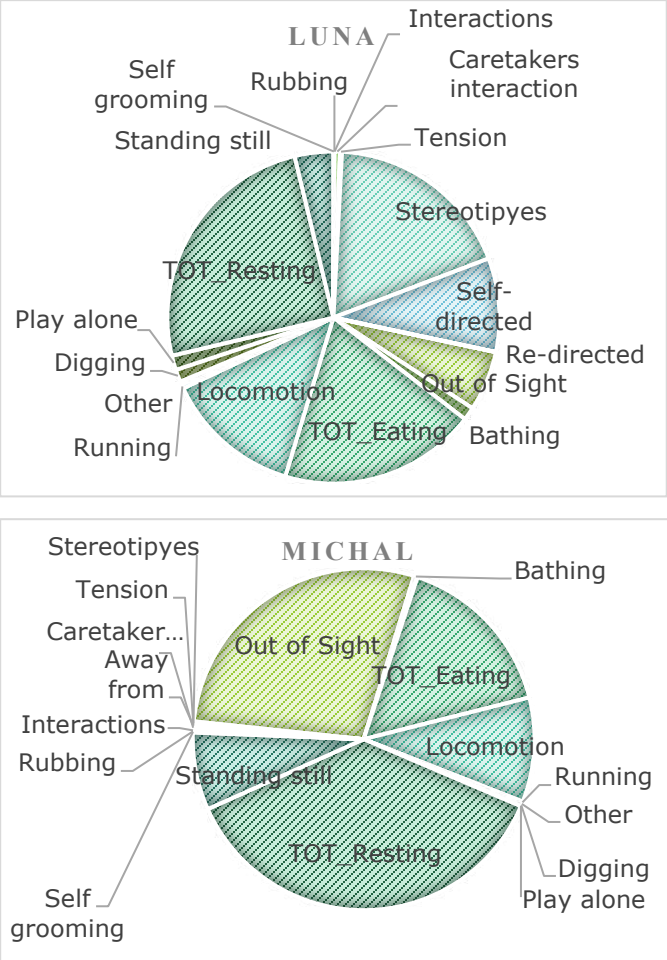

Figure 5. The charts show the amount of time dedicated to each individual behaviour. The values are calculated as follow: total seconds per behaviour/total seconds of observations (including OOS, but excluding events behaviour).

Activity budgets for each bear were created using the observational data, standardized by expressing the data as percentages, over the total time of observation. For this analysis, resting and eating behaviours were calculated without differentiating the behaviour according to the proximity modifiers.

Luna spent approximately 25.94% of her time resting and 13.84% in locomotion. She was out of sight for 6.10% and played alone for 1.47% of the observation period. Both Luna (19.99%) and Michal (16.22%) exhibited eating behaviours within the range observed in other captive bears (Mattiello et al., 2014; Koene 1998), suggesting that their feeding schedules are comparable to those of other captive bears.

Michal spent 10.05% of his time in locomotion, 28.57% out of sight, 37.50% resting, and 7.46% standing still. This pattern suggests a potentially more relaxed and confident disposition compared

to Luna, who is also a younger bear. Furthermore, it is important to note that Michal has only three legs, and the environmental conditions during the study, e.g. an enclosure with a dense forest, may have facilitated his tendency to be out of the sight of the observer.

When comparing the activity levels of both bears to previous findings for free-ranging and captive bears, free-ranging brown bears are active 45-60% of the day and night (Carlstead et al., 1991). The combined activity levels (locomotion, eating, playing) for Luna and Michal fall within this range. However, captive bears typically spend 12-20% of their activity in locomotion, exploring, or foraging, and up to 60% in stereotypic pacing or sitting (Carlstead et al., 1991). As previously mentioned, the observation period encompassed the time from post-hibernation through the mating season. This time is characterized by changes in behaviour patterns and a gradual increase in activity levels.

Luna exhibited 19.13% of stereotypical behaviours and 9.49% of self-directed behaviours, indicating potential stress or boredom, totalling 28.62% spent on abnormal behaviours. In comparison, Michal exhibited significantly fewer stereotypical behaviours (0.38%, $p < .001$). The differences in their enclosures could be a contributing factor. The caretakers have not been surprised by these findings, as they are actively exploring strategies to improve Luna's welfare. Through careful risk/benefit analysis, they have considered measures such as separating the female bear from public view—acknowledging that this constant exposure is a significant stressor. However, this approach poses challenges, as Luna's enclosure is relatively small and lacks natural environmental variety. To address these concerns, at the time of the study efforts were underway to boost Luna's confidence through targeted training and enrichment activities. These interventions aim to reduce her stress and encourage more natural behaviours, ultimately improving her overall well-being.

3.2. **Zone Usage and Proximity**

The zone usage of each animal was noted during the observations. Bias in zone usage and proximity of the bears can be attributed to management practices for the maintenance of the park. At times, bears were physically separated into different zones, precluding any possibility of social interaction. At other times, they were confined to adjacent areas, usually of smaller size, which might have affected their behaviour, as certain interactions might not have occurred otherwise.

Table 4. Table shows the distribution of zone usage and proximity for bears Luna and Michal over a series of 15-minute observations. The zones are categorized as R (River), N (Nest), L (Lake), T (Training), S (Socialisation), B (Bear house), D (Den), F (Forest), G (Gate), and Y (Yard). Proximity measures how close the bears were to each other, with 0 = In contact; 1 = ≤ 2 body lengths; 2 = ≤ 4 body lengths; 3 = ≥ 6 body lengths; 4 = other bear not visible. The data is calculated as the

proportion of the total number of occurrences for each category. Note: Scans during which the bears were out of sight were categorized separately (not shown in the table).

Bear	Zone										Proximity				
	R	**N**	**L**	**T**	**S**	**B**	**D**	**F**	**G**	**Y**	**0**	**1**	**2**	**3**	**4**
Luna	0	0	0	0	0	1401	755	0	0	0	0	2	8	245	1902
Michal	534	296	161	230	133	0	77	64	147	40	0	0	5	162	1518

Luna spent the majority of her time in the Bear-house (65%) and Den (35%) zones. Michal had a more varied zone usage, spending most time in the River (31.7%), Nest (17.6%) and Training (13.7%) zones. Results are limited by enclosure design. The data on social distance between Luna and Michal is particularly valuable in assessing their compatibility. However, the two bears were never in contact during the scans and were not in proximity to each other for most of the time (≥ 6 body lengths = 10.6%; other bear not visible = 89%). Specifically, they were very close—within 2 body lengths—only 0.05% of the time, and within 4 body lengths only 0.34% of the time. Michal was also observed the least in the Socialisation (7.91%) zone.

This limited proximity suggests a lack of social interaction between Luna and Michal, which may further indicate their incompatibility for close socialization.

3.3. **Individuals' variability and social evaluation**

The frequency of observed behaviours, including both states and events, was calculated to provide insights into the activity patterns, social interactions, and stress-related behaviours of each bear.

Luna showed higher locomotion frequency (0.31/min) compared to Michal (0.24/min) and exhibited more stereotypies (0.14/min) and self-directed behaviours (0.08/min) compared to Michal (0.08/min). Both bears showed similar resting patterns, though Michal rested more frequently (0.37/min) than Luna (0.26/min). Luna was slightly more often out of sight (0.07) than Michal (0.04), but Michal was out of sight for more time (28.57%) compared to Luna (6.10%).

Regarding social compatibility, affiliative behaviours were nearly absent, with low interaction frequencies for both Luna (0.0007/min) and Michal (0.0025/min).

Agonistic behaviours, such as tension, mock charges, and pawing, were recorded, with Luna being more frequently the agent of these behaviours compared to Michal, who tended to avoid these interactions more.

Table 5. Table reports the total number of occurrences for each behaviour that was recorded during the observation period. Based on these values the frequency was calculated as follow: total number of occurrences of a behaviour/total observation time.

Behaviours	Number of Occurrences	
	Luna	**Michal**
Out of Sight	278	173
Bathing	16	8
Eating (total)	457	288
Locomotion	1258	989
Running	101	34
Other	48	22
Digging	42	10
Play alone	44	7
Resting (total)	408	357
Standing still	621	787
Self-grooming	20	26
Rubbing	6	3
Interactions	3	10
Caretakers interaction	35	19
Away from	0	9
Tension	29	9
Stereotypies	587	128
Self-directed	337	0
Re-directed	4	0

Behaviours	Number of Occurrences	
	Luna	**Michal**
Flight	24	8
Aggression towards object (Gate)	16	3
Avoidance	0	7
Aggression towards human (S)	4	0
Mock charge (A)	6	1
Mock charge (R)	1	1
Mock charge_other (A)	2	0
Vocalization	3	2
Vocalization_other	9	0
Jawing_other	0	1
Pawing (A)	4	3
Pawing (R)	0	4
Pawing_other (A)	6	0
Pawing_other (R)	1	0
Fight_other (A)	1	0
Fight_other (R)	1	0
Fight_other (X)	2	1

No fights were observed between Luna and Michal, though more intense agonistic interactions occurred with other bears in the sanctuary, often following enclosure changes or feeding times.

Table 6. Number of occurrences of agonistic social interactions throughout the whole observation period (TOT), the first 15 days (I) and the last 15 days (II). Where (A) agent indicates the initiator of the behaviour, and the recipient is always the other bear.

Animals	Mock Charge (A)			Pawing (A)			Vocalisation			Avoidance			Fight	Charge
	I	**II**	**TOT**	**I**	**II**	**TOT**	**I**	**II**	**TOT**	**I**	**II**	**TOT**		
Luna	3	4	7	5	4	9	-	3	3	-	-	-	-	-
Michal	-	1	2	1	-	3	1	1	2	-	3	7	-	-

The frequency of agonistic behaviours (Table 6 and Table 7), particularly mock charges and pawing, though low, raised concerns about the compatibility of the bears.

Table 7. Table used to sample all currencies of social behaviours external to the observation schedule, such as agonistic interactions without contact (AW), agonistic interactions with contact (AC) and affiliative social interactions (AS). With their respective modifiers: (A) agent; (R) recipient and (X) None.

Animals	**Data**	**Time**	**AW (A/R/X)**	**AC (A/R/X)**	**AS (A/R/X)**	**Notes**
Luna; Michal	Sat 27.05	14:36			X	
Luna	Sat 27.05	14:38	A			
Luna	Tue 30.05	14:32	A			
Luna	Sat 03.06	10:29	A			
Luna; Michal	Tue 06.06	17:57	X		X	

Even when comparing the initial period (I) of observations with the final one (II), as seen in **Error! R eference source not found.**, the data does not suggest important improvements. Tolerance alone does not indicate positive social interactions or increased welfare, as social interactions should positively impact animals and not trigger abnormal behaviours (Mattiello et al., 2014).

Overall, Luna seems to display a higher tendency in engaging in social agonistic behaviours.

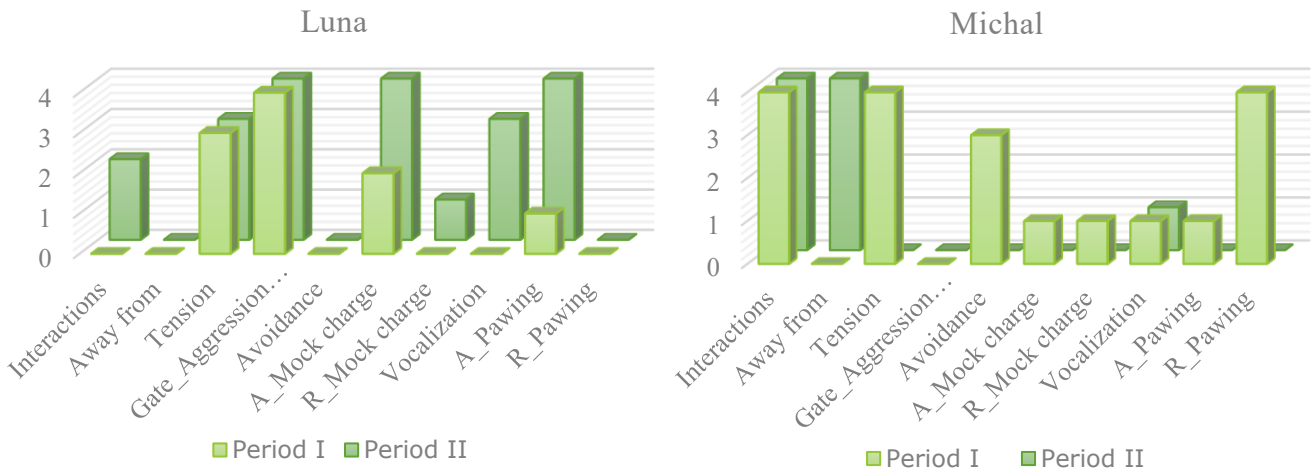

Figure 6. Graphs reporting occurrences of behaviours of social interest over Period I and Period II for Luna and Michal.

3.3.1. Frequency Analysis of Eating and Resting Behaviours Relative to Proximity

In this study, we examined the frequency of eating and resting behaviours of Luna and Michal at varying proximities, as indicated by the modifiers in **Error! Reference source not found.**.

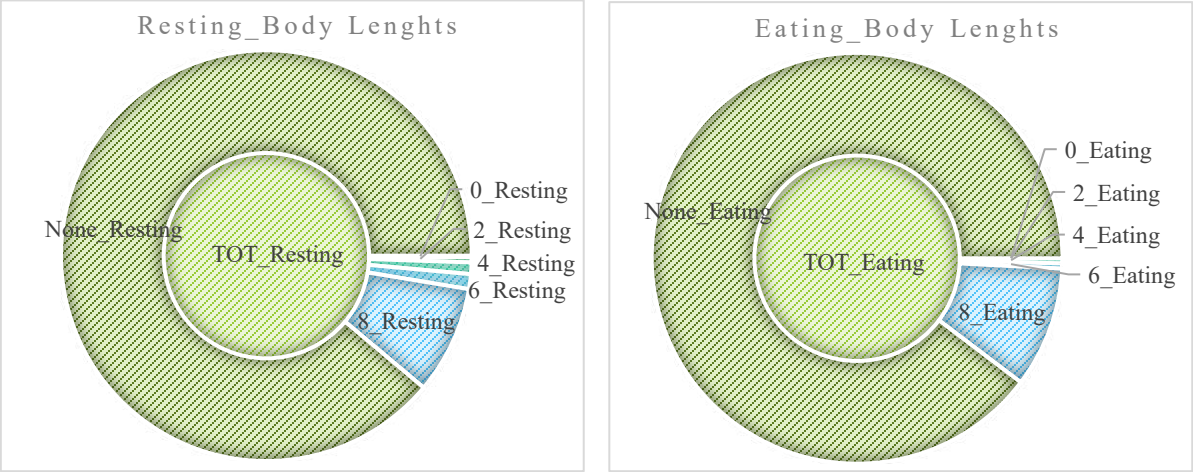

Figure 7. The numeric values preceding behaviours (e.g., 2_Eating) denote the number of body lengths (≤) between the bears, providing a measure of their social interaction distance during these activities.

The distance between the two bears during these behaviours could indicate tolerance or affiliation. Eating involves valuable resources and is often a motive for disputes between brown bears (Koene et al. 2002; Egbert, Stokes, and Egbert, 1976), while resting involves a more relaxed or vulnerable state, indicating that the animal is not alert or tense when in the presence of other animals (Lima et al., 2005).

Table 8. Number of occurrences for eating and resting throughout the whole period of observation. Proximity measures how close the bears were to each other, with 0 = In contact; 2= ≤ 2 body lengths; 4 = ≤ 4 body lengths; 6 = ≤ 6 body lengths; 8 = ≤ 8 body lengths.

Bear	Eating							Resting						
	0	**2**	**4**	**6**	**8**	**None**	**TOT**	**0**	**2**	**4**	**6**	**8**	**None**	**TOT**
Luna	0	0	1	2	49	405	457	0	0	5	7	34	362	408
Michal	0	0	2	1	22	263	288	1	3	2	2	31	318	357

Luna showed a higher total frequency of eating behaviour (0.11/min) compared to Michal (0.07/min). Both bears predominantly performed these behaviours when more than 8 body lengths apart, indicating a tendency to avoid close physical interaction during feeding and resting times. These patterns suggest that both bears prefer maintaining a considerable distance from each other during eating and resting, which may indicate a preference for personal space or could be a result of the enclosure design.

3.3.2. Inferential statistics

Inferential statistics were used to analyse the impact of different variables on behaviours.

A significant difference ($p < 0.001$) in the occurrence of resting behaviour within 8 body lengths across different periods can be observed. With period II having a higher frequency of eating and resting behaviours in proximity, as seen in *Figure 8*.

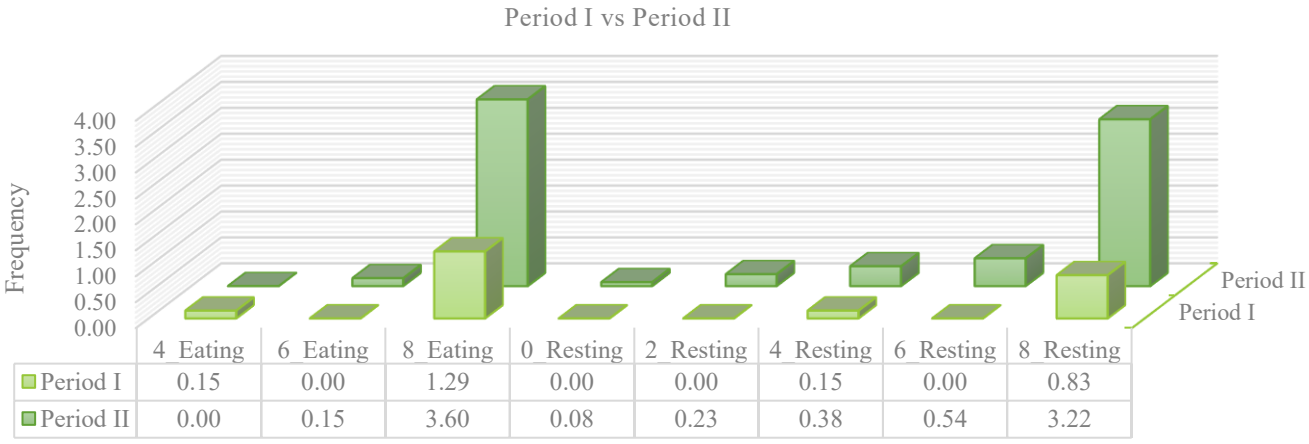

Figure 8. Graph representing changes of resting and eating frequencies over time.

However, different periods, bears and observation time do not significantly affect (Table 10) proximity while eating.

Table 9. chi-square calculated with online calculator (fisher). Data distribution did not allow GEE.). Terms with significance values ($p < 0.05$) are highlighted in bold. With Period I indicating the first and Period II the last 15 days.

Resting (all obs)	**Period I**	**Period II**
≤ 8 body lengths	3	18
≥ 8 body lengths	174	156
Two-tailed P value	**0.0006**	

Table 10. GEE Results. Dependent Variable is a binary variable indicating whether there is any eating distance recorded (1) or not (0). Terms with significance values ($p < 0.05$) are highlighted in bold. Focus was not used in the model as the proximity refers to both bears simultaneously.

Dependent Variable	**Effect**	**Test of model effects**		
		Wald Chi-square	**df**	**Sign.**
Eating ≤ 8 body lengths	(Intercept)	77.287	1	<0.001
	Period	2.571	1	0.109
	Bear	2.406	1	0.121
	Observation time slot	4.819	5	0.438
	Period * Bear	0.439	1	0.508

Additionally, factors associated with the presence of at least one episode of behaviours such as stereotypies, eating, resting, locomotion and standing still during the observation period were analysed.

Table 11. GEE results. Dependent Variable is a binary variable indicating whether there is any behaviour recorded (1) or not (0) during the observation. Terms with significance values (p < 0.05) are highlighted in bold.

Dependent Variable	Effect	Test of model effects		
		Wald Chi-square	**df**	**Sign.**
Stereotypies + Self Directed	(Intercept)	15.493	1	<.001
	Period	1.559	1	0.212
	Bear	59.715	1	**<.001**
	Observation time slot	12.019	5	**0.035**
	Period * Bear	2.689	1	0.101
Eating (TOT)	(Intercept)	0.034	1	0.854
	Period	2.318	1	0.128
	Bear	12.243	1	**<.001**
	Observation time slot	20.367	5	**0.001**
	Period * Bear	1.260	1	0.262
Locomotion	(Intercept)	45.563	1	<.001
	Period	1.088	1	0.297
	Bear	25.037	1	**<.001**
	Observation time slot	13.972	5	**0.016**
	Period * Bear	0.002	1	0.967
Resting (TOT)	(Intercept)	27.483	1	<.001
	Period	1.425	1	0.233
	Bear	0.849	1	0.357
	Observation time slot	8.556	5	0.128
	Period * Bear	0.471	1	0.493
Standing still	(Intercept)	3.223	1	0.073
	Period	0.044	1	0.834
	Bear	10.709	1	**<.001**
	Observation time slot	14.676	5	**0.012**
	Period * Bear	3.100	1	0.078

Stereotypies and self-directed behaviour

The analysis indicated that the period alone did not yield statistically significant differences in stereotypies and self-directed behaviour (Chi-Square = 1.559, p = 0.212). However, the bears (Luna vs. Michal) significantly influenced these behaviours (Chi-Square = 59.715, p < 0.001), highlighting individual variability. Observation time slot also had significant impact (Chi-Square=12.019, p=0.035). Specifically, there was an increased chance of the presence of the behaviour in slots 2, 3, 4, and 5, as compared to slot 6, with p-values of 0.006, 0.008, 0.020, and 0.003, respectively.

Eating behaviour

The period alone did not statistically affect eating behaviour (Chi-Square=2.318, p=0.128). Highly significant differences were found based on the bear (Chi-Square = 12.243, p < 0.001), indicating distinct eating patterns between the two bears. Observation time slots, in particular the fourth observation, also significantly influenced eating behaviour (Chi-Square = 20.367, p <0.001). In particular, there was a lower chance of the behaviour being recorded in the observations carried out during the fourth observation than in the sixth one. This could be attributed to variations in feeding schedules.

Locomotion

The observed bear had a highly significant impact on locomotion (Chi-Square = 25.037, $p < 0.001$). Observation time slots 2 and 3 show significantly lower probabilities of locomotion compared to the reference slot (Slot 6), with p-values of 0.004 and 0.009, respectively. Slots 1, 4, and 5 do not show significant differences from Slot 6, implying that the timing of observations plays a crucial role in the outcome. The period alone did not significantly affect locomotion ($p = 0.420$).

Resting behaviour

Neither period ($p = 0.233$) nor bear ($p = 0.357$) significantly influenced resting behaviour. Most observation time slots, except for the first one ($p = 0.010$, higher chance), did not significantly differ from the sixth one.

Standing still

Which bear was observed had a highly significant impact ($p < 0.001$) on the probability to record standing still. Observation time slot was associated with a different likelihood of observing the behaviour at least once during the observation. In particular, there was a different likelihood to observe at least one episode of the behaviour in the observations done in the second ($p=0.007$) and third slot ($p=0.039$) than in the sixth slot (set as reference in the analysis). For instance, Luna was more likely to be recorded standing still during the third time slot (0.18) compared to the sixth (0.15). Michal demonstrated a higher probability of exhibiting this behaviour during the first, second, fourth, and fifth time slots (0.17) when compared to the third (0.16) and sixth (0.15) time slots.

3.4. **Limitations, Environmental and Management Considerations**

The observations conducted in this study aligned with its objectives, focusing primarily on documenting social interactions and relevant behaviours to assess compatibility and social dynamics, including factors like inter-individual changes. Comprehensive records of other behaviours were also maintained.

The observed interactions between Luna and Michal did not demonstrate positive influences or mutual acceptance. As a result, sufficient data were collected to suggest that the potential outcomes of the introduction phase and eventual cohabitation would have not been positive. The sanctuary prioritized ethical considerations, opting to avoid unnecessary risks and minimize stress for the bears, leading to the decision not to proceed with the socialization project. For the same reason cooperative feeding sessions were discontinued, potentially influencing the results of the observations, as they would have been a good opportunistic situation to witness more interactions between the bears.

Additionally, an intended enclosure exchange between Michal and Luna did not occur, which would have provided insights into how Luna might have adapted behaviourally in a larger enclosure with increased opportunities for retreat and enrichment, potentially impacting her socialization dynamics. Differences in enclosure characteristics likely influenced the bears' behaviours and spatial distribution within the sanctuary. This highlights the critical importance of strategic enclosure positioning during initial socialization phases, particularly when bears are housed in adjacent enclosures. Additionally, challenges arose during the observation period due to water toxicity issues in the river, which necessitated restricting the bears' access to natural watercourses to mitigate health risks. These environmental concerns posed significant management challenges, resulting in delays to sanctuary operations and ongoing projects.

Luna exhibited higher levels of stereotypical and self-directed behaviours, which may indicate an unsuitable environment or insufficient enrichment. Implementing enrichment activities, improving the diet, and making structural modifications to the enclosures could potentially reduce stress-related behaviours and enhance welfare (Forthman et al., 1992; Vickery and Mason, 2003). Other effective strategies in alleviating stereotypic behaviours are medication, especially long-term and low-dosage Fluoxetine, unpredictable feeding schedules (Shih, Yu, and Wang, 2016) and the use of positive reinforcement training (Coleman and Maier, 2010). However, certain behaviours can become “installed” or “fixed” patterns, continuing independently from the original cause or current situation, which may compromise rehabilitation efforts. For instance, Mason (1991) discusses that established stereotypies can become emotionally neutral, manifesting as “pure motor automatisms” that are not inhibited by tranquilizers. These entrenched behaviours are much more difficult to discourage or interrupt, even outside of the original eliciting situation or in the absence of any apparent conflict. This contrasts with developing stereotypies, which are repetitive behaviours that emerge in response to stress or conflict and are more susceptible to intervention (Duncan and Wood-Gush, 1974).

Furthermore, the impact of Luna's sterilization on her behaviour towards male bears is of interest. Understanding how this factor affects her interactions and social behaviours could provide important insights into managing her welfare and social dynamics within the sanctuary.

4. CONCLUSION

Based on the findings of this study, Luna and Michal may not be suitable candidates for socialization due to the infrequent occurrence of affiliative social behaviours (**Error! Reference source not found.**) a

nd potential disinterest displayed by Michal towards Luna (Table 4). Luna, in contrast, exhibited a higher frequency of agonistic social behaviours without physical contact.

Nevertheless, the development and application of the ethogram proved to be a useful tool in assessing compatibility. By integrating behavioural observations with environmental and management practices, significant insights can be gained into enhancing the welfare of captive brown bears.
Although effective, the methodology used in this study demands considerable time and effort from animal caretakers. Simplified versions, as exemplified in Table 7, could be employed.
In terms of management strategies, an approach that accommodates both solitary territoriality and social clustering may be optimal for minimizing conflicts and injuries. However, the current space available might still limit the bears' ability to roam, avoid, or escape each other. Effectively addressing brown bear welfare often requires maintaining low bear density and providing sufficient space per individual (Koene and Ipema, 2014). For instance, a more effective strategy might involve setting up the more insecure and reactive bear, in this case Luna, for success. This could be achieved by creating situations where Luna can initiate interactions, rather than being approached with limited options for retreat.
Additionally, enhanced welfare can be achieved through targeted enrichment, animal training, strategic management of social interactions, and an in-depth understanding of each bear's unique behavioural needs. The study underscores the importance of tailored care and the intricate dynamics of social compatibility among these animals.

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