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Research article

Is stereotypic behaviour in polar bears heterogenous in nature?

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Abstract
Stereotypic behaviours may be heterogenous in nature for some species and thus have different causes or motivations. The current study examined stereotypic behaviour in two polar bears *Ursus maritimus*, one male and one female, at Brookfield Zoo Chicago. Data were collected at four different times throughout an approximate one-year period. Results suggest that stereotypic behaviour in polar bears may be heterogenous in nature as has been documented in other species. Pacing behaviour typically occurred in locations best suited to watch for the presence of animal care staff. However, the main location the male engaged in route tracing was near a window where the female could be visually observed but not physically interacted with during the spring which is the breeding season. In addition, principal components analysis reveals pacing and route tracing do not co-occur providing additional support that stereotypic behaviours in polar bears may be heterogenous in nature. Only through research and understanding the motivations for these behaviours will zoos be able to have a positive impact on the animals' welfare. Information gained from this study can assist future studies in ensuring stereotypic behaviours are scored separately during behavioural data collection.

Is stereotypic behaviour in polar bears heterogenous in nature?

The polar bear *Ursus maritimus* is a large carnivore found in the circumpolar Arctic (Stirling and Archibald 1977; Stirling and Derocher 2012). In this region, sea ice is critical for bears to successfully forage on their main prey item, the ringed seal *Pusa hispida*. Long-distance movements by polar bears are associated with seasonal changes in sea ice coverage (Ferguson et al. 1999; Johnson et al. 2017). In fact, home range size for polar bears have been found to range between 19,400 km^2 and 353,557 km^2 depending on the region (Ferguson et al. 1999; McCall et al. 2015). Previous research has shown that long-ranging carnivores, such as polar bears, are highly susceptible to developing stereotypic behaviours under human care (Kroshko et al. 2016). There may be some internal motivation to travel long distances and being restricted may result in stereotypic behaviour (Kroshko et al. 2016). However, habitat dynamics strongly influence space-use strategies for polar bears in the wild, with stable and predictable resources allowing restricted areas, and changing environments requiring migrations (Mauritzen et al. 2001). Motivation to travel long distances may be dependent on lack of stable distribution of resources, such as in seasonal environments. Thus, when resources are stable and consistent this motivation would likely be absent for polar bears.

Stereotypic behaviours are repetitive behaviours that have no obvious goal or function (Mason 1991a). These behaviours are thought to occur either due to current environment (Mason 1991b; Swaisgood and Shepherdson 2005) or central nervous system dysfunction (Lewis and Hurst 2004). In addition, these behaviours are also looked upon unfavorably by zoo visitors (Miller 2012). Within zoological facilities, polar bears are quite prone to stereotypic behaviour, with 85.4% of the 55 polar bears observed engaged in some form of stereotypic behaviour (Shepherdson et al. 2013). While there was great variability observed across bears, the average duration of time spent engaged in stereotypic behaviour was 14%. Variables that correlated with lower levels of stereotypic behaviour included environmental enrichment, number of bears in the group, and having a view out of the habitat (Sheperdson et al. 2013).

Previous research has linked stereotypic pacing in carnivores with the size of their home range (Clubb and Mason 2003; Kroshko et al. 2016). Specifically, carnivores with larger home

Figure 1. Aerial views of the east, south and west polar bear habitats at the Brookfield Zoo.

ranges engaged in more stereotypic behaviour. However, another study examining carnivores did not find the same outcome (Miller et al. 2019). This may suggest that how carnivores are managed at different facilities may impact if carnivores with large home ranges engage in more stereotypic behaviour. Alternatively, the difference in findings could be due to the larger sample size utilizing a literature review approach to build the dataset as opposed to direct observation of animals at two different facilities. Additional research has found that stereotypic behaviour in polar bears can be reduced through environmental enrichment (Forthman et al. 1992; Canino and Powell 2010), and providing access to off-exhibit areas (Ross 2006). Alternatively, an increase in stereotypic behaviour has been observed in polar bears during introduction to a novel smell (Linder et al. 2020), on starve days (Ames 1993; Cremers and Geutjes 2012), and during times of loud noise (Cremers and Geutjes 2012).

Whilst other case studies have tried to identify factors related to stereotypic behaviour in polar bears (Cless and Lukas 2017), there remain many unanswered questions regarding the motivation or cause behind stereotypic behaviour in polar bears. Specifically, there is little information on how to effectively reduce or eliminate stereotypic behaviour in polar bears. The first step in trying to achieve this would be to identify if the motivations or triggers for stereotypic behaviours in polar bears are heterogenous or homogenous in nature. If stereotypic behaviours are heterogenous in nature, they would have different triggers or motivations. However, if stereotypic behaviours are homogenous in nature, multiple forms would have the same trigger or motivation. If the former is true, analyzing these behaviours under the assumption that they have only one root cause would be ineffective.

Recent work would suggest that stereotypic behaviours are heterogenous in nature with different requirements needed to reduce or eliminate the different behaviours (Polanco et al. 2017; Polanco et al. 2018). This research evaluated the triggers for two forms of stereotypic behaviour in American mink *Neovison vison*, a model carnivore. In this study, environmental enrichment was better at mitigating whole body and head only stereotypic behaviour while removing neighbouring conspecifics was more effective at reducing scrabbling (Polanco et al. 2018). Additionally, more recent research suggests that stereotypic behaviours are also likely heterogeneous in nature for chimpanzees *Pan troglodytes* (Whitham et al. 2025). The authors found that the two different forms of stereotypic behaviour did not co-occur suggesting different underlying motivations. The purpose of the current study was to examine stereotypic behaviour in two polar bears over the course of approximately one year. The type of stereotypic behaviour (e.g., pacing versus route tracing) and the location of the behaviour were monitored for both bears during the four different seasons. Information gained from this study will provide evidence as to whether stereotypic behaviour is heterogeneous in nature for polar bears and thus help guide future research to ensure meaningful results.

Materials and Methods

Ethical Statement

There were no changes made to the care and management of the polar bears as a result of this research project. All work during the current study was completely observational and did not require Institutional Animal Care and Use Committee (IACUC) review.

Methods

The subjects of the study included a 15-year old male polar bear and a six-year-old female polar bear at Brookfield Zoo Chicago (Brookfield, IL, USA). The bears were recently introduced to one another just before the start of the study as the female arrived to Brookfield Zoo Chicago in early 2021. Depending on the time of year, the bears either lived together during breeding season (30 March 2021 to 7 May 2021), or lived individually in one of three habitats (Figure 1). During breeding season, the bears were located in the East Habitat. During non-breeding season the bears were rotated through the three habitats based on animal care staff choice (Table 1). All habitats consisted of both natural and artificial substrates and Table 2 contains a list of the main differences between the three habitats. Throughout the study, the bears were fed a variety of foods including herring, capelin, Nebraska Premium Canine, Nutrisource Lamb and Rice, beef fat, lettuce, carrots, and beef shanks. In addition, the animal care staff also has a robust enrichment and training program to try and engage the bears in species-specific behaviour and allow them to participate in their own care.

Data were collected by a single observer during four different time periods throughout 2021 to have data from each of the different seasons. This included 29 March to 5 May (Spring; 76 hours of data; 307 observation sessions), 6 July to 9 August (Summer; 52 hours of data; 205 observation sessions) 4 October through 27 October (Autumn; 34 hours of data; 136 observation sessions) and 1 December to 23 December (Winter; 39 hours of data; 154 observation sessions). Differences in data collection amounts was simply due to the observer not being available at

Table 1. Differences between the three polar bear habitats

East Habitat	South Habitat	West Habitat
Classroom with viewing window and feeding chute into habitat	Animal care staff training panel	Animal care staff training panel
Visual access to South Habitat	Visual Access to East and West Habitats	Visual access to South Habitat and Wolf Habitat
One timed feeder	Two timed feeders	Two timed feeders
Animal care staff door window when bears have access to quarantine habitat	Animal care staff door window	Animal care staff door window
690.50m^2	803.36m^2	761.93m^2

different times. The number of times each bear was in different habitats can be found in Table 2. Data were collected typically five days a week in the morning from 1000 to 1330 hrs and in the afternoon from 1330 to 1700 hrs. Time of day for observations was alternated each day to have approximately equal representation of times.

Focal follows were 15 minutes in duration utilizing instantaneous sampling at one-minute intervals for both behavioural states and location. Although additional behavioural data were collected, for the purpose of this study, the focus will be on the behavioural states of pacing and route tracing. Pacing was defined as the focal animal locomoting the same path at least 3 times on land or in water. Animals could perform this behaviour in any gait pattern. Route tracing was defined as the focal animal locomoting a circular path at least twice in any gait pattern. The two behaviours observed were mutually exclusive. All data were collected utilizing ZooMonitor, a behavioural monitoring application developed by the Lincoln Park Zoo (Chicago, IL, USA). All behaviour was corrected for time visible for consistency across observations. Locations of both stereotypic behaviours for the male and female were visualized using heatmaps. Additionally, a Principal Components Analysis (PCA) was utilized to identify if any underlying relationship (i.e., co-occurrence) exists between the two behaviours. A significance value of $P<0.05$ was used for the PCA.

Results

The average percentage of time and standard deviations for pacing and route tracing per habitat can be found in Table 2. The location of the pacing behaviour (warm colours) and route tracing behaviour (cool colours) for the female polar bear can be seen in Figure 2. The location of the pacing behaviour (warm colours) and route tracing behaviour (cool colours) for the male polar bear can be seen in Figure 3. Results from the principal components analysis resulted in one component accounting for 51.35% of the variance in results. Factor loadings for the two stereotypic behaviours onto the one component can be found in Table 3.

Discussion

Both forms of stereotypical behaviour, pacing and route tracing, were observed in polar bears in this study. Given the differences

Table 2. Number of times each bear was located in the different habitats during observations.

		Spring	Summer	Autumn	Winter
Female	East	100%	20%	31%	0%
	South	0%	55%	48%	46%
	West	0%	25%	21%	54%
Male	East	82%	47%	44%	0%
	South	18%	34%	13%	51%
	West	0%	19%	43%	46%

Table 3. Average and standard deviation for pacing and route tracing per habitat

	Pacing			Route tracing	
Animal	Habitat	Mean	SD	Mean	SD
Female	East	1.5%	7.7%	8.2%	17.7%
	South	12.7%	22.7%	1.7%	6.5%
	West	19.3%	35.2%	0.0%	0.0%
Male	East	16.2%	20.7%	1.4%	3.9%
	South	18.3%	25.0%	0.0%	0.0%
	West	8.6%	18.0%	8.4%	15.2%

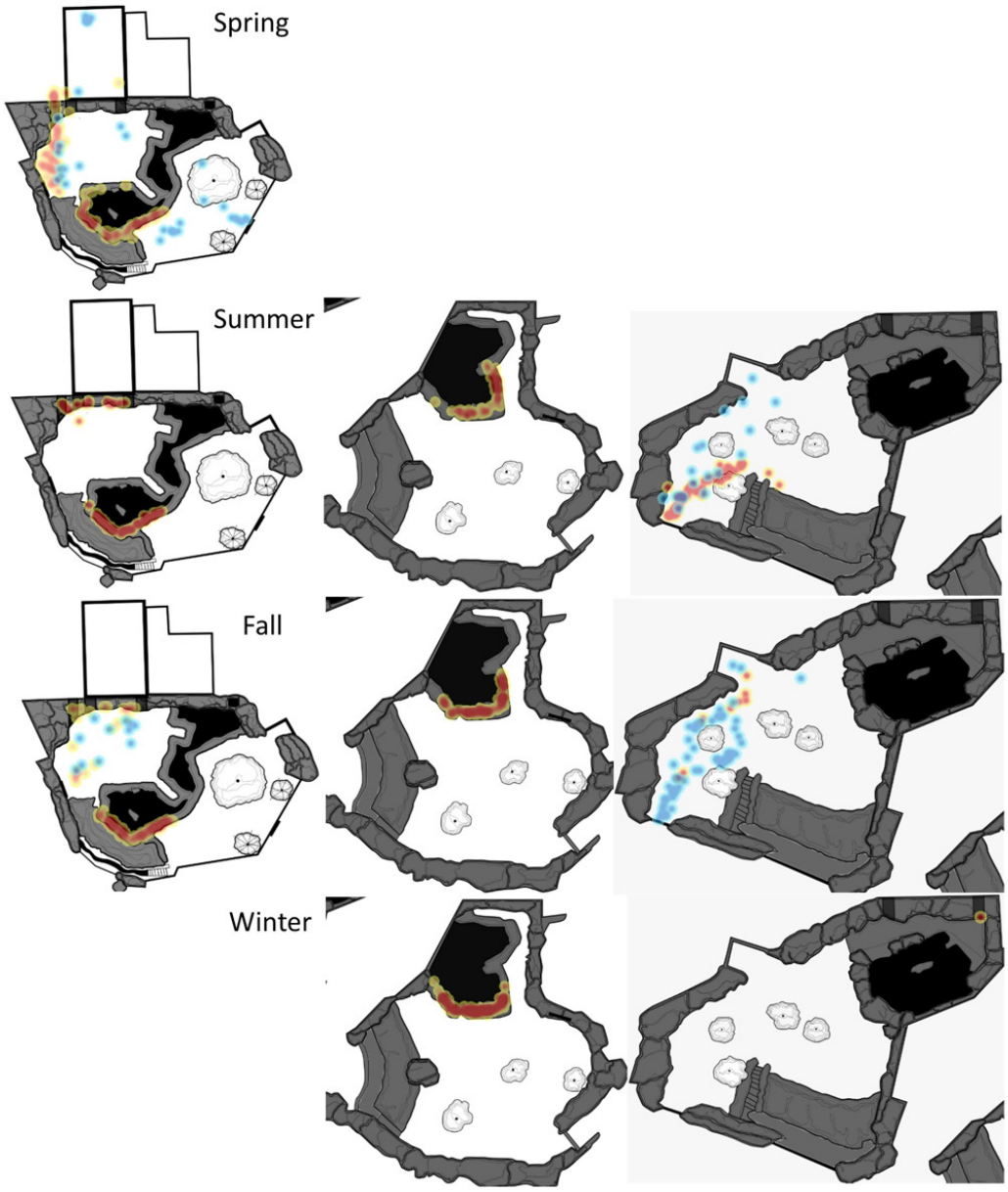

Figure 2. Location of pacing and route tracing behaviour for female polar bear in the east, south and west habitats during each season. Note. White areas are natural substrate except for the quarantine area attached to the east yard, grey areas are shotcrete artificial rock, and black areas are water. The warmer colours depict locations of pacing where the cooler colours depict the locations for route tracing. The female polar bear was not in the south or west habitats during the spring or the east habitat during the winter.

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Table 4. Factor loadings for stereotypic behaviour in Principal Components Analysis.

	Stereotypic behaviour
Pacing	-0.717
Route Tracing	0.717

observed in location of pacing and route tracing, combined with the lack of co-occurrence of the behaviours within observational periods, stereotypic behaviour is likely heterogenous in nature for polar bears. This includes varying locations both between habitats as well as within habitats. For both polar bears, route tracing occurred in the habitat where pacing occurred the least. In the case of the male this was the west habitat, and for the female, the south. This may suggest that the individuals have different motivations or triggers. In addition, while the motivation or trigger for the route tracing behaviour is less clear in most locations, it appears that the majority of the pacing behaviour occurs in locations where the bears can view or have the opportunity to view animal care staff. The male bear spent the most time pacing in the west habitat in a location between the animal care staff door window and the animal care holding shift door. This type of pattern has been observed before in other polar bears (Cless and Lukas 2017).

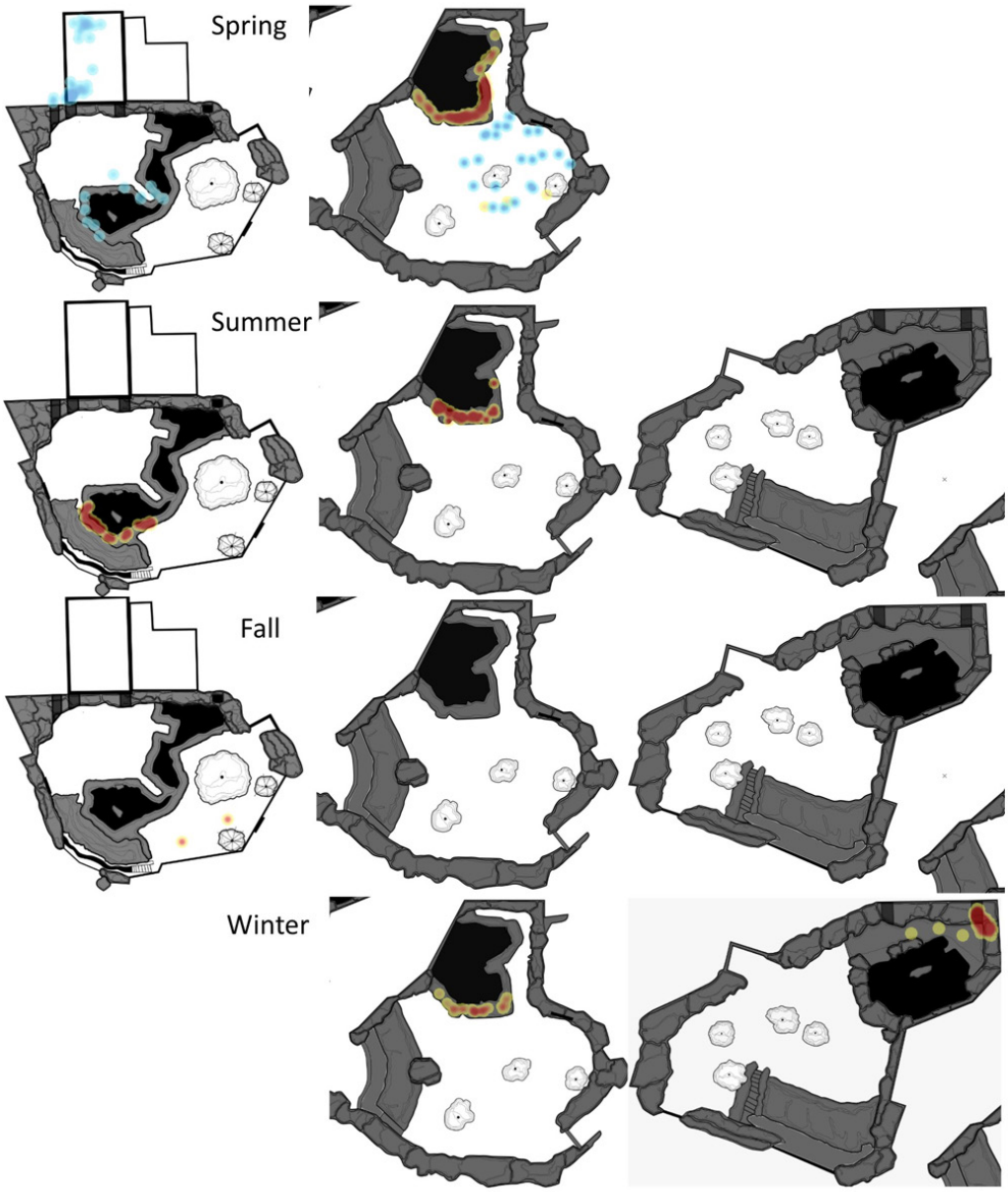

Figure 3. Location of pacing and route tracing behaviour for female polar bear in the east, south and west habitats during each season. Note. White areas are natural substrate except for the quarantine area attached to the east yard, grey areas are shotcrete artificial rock, and black areas are water. The warmer colours depict locations of pacing where the cooler colours depict the locations for route tracing. The male polar bear was not in the west habitat during the spring or in the east habitat during the winter.

The main pacing location for both bears in the south habitat was along the rockwork edge of the pool. This is an ideal location for the bears to watch for animal care staff that provide food and enrichment from the roof above. Previous research has also shown that feeding regime and location can have an impact on pacing behaviour in carnivores (Gilbert-Norton et al. 2009; Lyons et al. 1997). Specifically, the level of predictability of feeding events and the location of those events can impact pacing behaviour similar to what was observed in the south habitat. Similarly, the majority of the pacing in the east habitat also occurred on the rock work which is a prime location to watch for animal care staff on the roof of the building.

While the motivation or the root cause for the route tracing behaviour is less clear, it occurs in different locations and does not co-occur with the pacing behaviour. The male only engaged in route tracing behaviour in the spring and the location in the south yard was closest to a window where the female could be observed. Having visual access to her without physical access could be frustrating and displaced in the form of route tracing. Previous research has shown that the location of a stereotypic behaviour may be due to the trigger. For example, tigers at one facility paced at a window where they could see but not interact with neighbouring conspecifics (Miller et al. 2008). When the view of the neighbouring conspecifics was blocked, there was a significant decrease observed in the amount of stereotypic behaviour. However, in the current study, the location and trigger for the majority of the female's route tracing is less clear. Identifying the root cause or motivation is the key to reducing or eliminating these behaviours. Increasing enrichment may not always be the best solution depending on the behaviour observed (Polanco et al. 2017; Polanco et al. 2018).

Overall, the current study suggests that stereotypic behaviour in polar bears may be heterogenous in nature and that different individuals may have different motivations or triggers. The ability to view staff from specific locations where pacing is observed would suggest the potential cause for this behaviour. That the male only engaged in route tracing during the spring near the window where the female can be observed may explain this motivation as spring is when breeding would occur. The fact that stereotypic behaviours may be heterogenous in nature suggests that future studies with polar bears should make sure to not combine these behaviours into one category, but to score them independently. Increased efforts to examine when and where the different behaviours occur across multiple facilities may give greater insight as to the root cause of these behaviours for polar bears. Only through continued research will the likely heterogenous nature of stereotypic behaviour in polar bears and their potential root causes be better understood. Additionally, is would be interesting to examine the heterogeneous nature of stereotypic behaviour in other species to focus on the continuous improvement in animal welfare.

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