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Change in the behaviors and spatial use of Canada lynx (*Lynx canadensis*) over time at

John Ball Zoo

By Hailee Cederquist and Jodee Hunt

Introduction

Felines are popular attractions at zoos across the country, even more so when young animals are involved. As such caretakers strive to ensure that their animal's needs are met, and individuals display healthy behaviors and activity levels in comparison to their wild counterparts (Mcphee & Carlstead, 2010). However, cats, being wide-ranging carnivores, are known to be prone to stereotypical behaviors which can be detrimental to an animal's health (Clubb & Mason, 2003). Watching animals partake in potentially harmful behaviors can also damage guest views of zoos, which rely deeply on the public to endure.

For these reasons, it is important to ensure that animals in captivity are happy and healthy. Observing their behaviors and spatial use can provide a glimpse into the well-being of cats along with the relationships between behaviors and environmental factors. For example enrichment has been known to reduce stereotypy in captive animals (Swaisgood & Shepherdson, 2006). Visitor abundance is another factor which has been associated with low activity and stress in felines and is important to consider when evaluating the welfare of an animal (Suárez et al., 2017). Unusual occurrences which disrupt the daily routines of animals, such as construction, also may affect an animal's behavior (Chosy et al., 2014).

Our goal was to observe the Canada lynx (*Lynx canadensis*) at John Ball Zoo in Grand Rapids, Michigan, to determine the state of their well-being amongst these and other variables including time of day, weather, changes in their enclosure, and the birth of a lynx kitten.

For three consecutive summers we observed the lynx using the cloud-based program *ZooMonitor*. *ZooMonitor* is a program which allows the user to track the location and behavior of animals in an enclosure, as well as various environmental factors.

ZooMonitor allows researchers to continually assess the well-being of animals and visualize their behaviors, making it more simple to ascertain an animal's routines and pick out any deviations from that routine (Wark et al., 2019).

The two Canada lynx (a male 7 years of age and a female 3 years of age) at John Ball Zoo were introduced to the zoo and their enclosure in the summer of 2018 after which observations commenced and continued during summers 2019 and 2020. Both animals' behavior and movements throughout the enclosure were recorded along with environmental data.

In June of 2020, the female lynx gave birth to a live, female kitten. This disrupted the usual behavior of the lynx, as the male was out in the enclosure alone instead of with the female as in years past. The female lynx remained separated from the male in the indoor den and out of sight from guests with the kitten until August of 2020. This change in social structure significantly altered the behavior and activity levels of the lynx.

It is vital that the lynx remain healthy and happy despite these changes, and it is the state of their well-being which we attempted to establish through our observations.

Methods

A male and female Canada lynx (*Lynx canadensis*) were observed at John Ball Zoo in Grand Rapids, Michigan. The lynx were introduced both to the zoo and the enclosure in 2018. Data collection occurred the summers of 2018, 2019, and 2020. In June 2020, the female lynx gave birth to a live, female kitten. The female lynx remained in the indoor den, out of sight from visitors with the kitten until August of 2020. The male lynx was observed throughout the summer, and the female was observed along with the kitten after their introduction to the enclosure in August. No sessions were recorded of all three lynx in the same enclosure.

Data was collected using the same method each year. The cloud-based program *Zoomonitor* was used to collect spatial, behavioral, and environmental data during observation sessions. All research assistants were trained and tested for inter-observer bias testing prior to data collection.

Observations consisted of 30-minute sessions. Environmental data (e.g. temperature, wind, weather, enrichment presence) was collected at the start of every session. Additional notes could be taken before and after sessions for unusual occurrences (e.g. nearby construction, shortened session). During observation sessions, an individual animal's state behavior (e.g. walking, lying down, playing) and location within the enclosure was recorded every 30 seconds. Estimate of visitor abundance was also recorded during the 30 second intervals. All-occurrence behaviors (e.g. vocalizations, glance, jump) were recorded as soon as they occurred throughout the session.

Heat maps were generated from the data using the *Zoomonitor* program. Time budgets and chi-square contingency tests were used to compare behavioral data between years and between individual animals.

Results

Both adult lynx showed significant changes in their overall activity levels and spatial use over the course of the three summers. The most significant change occurred during the summer of 2020 when the male lynx was separated from the female after the birth of the lynx kitten, removing the social aspect of the lynx's routines. In 2019, the enclosure was also changed when vegetation was removed, and an elevated rock outcrop was fenced off and made mostly inaccessible to the lynx. The animal's spatial use and activity levels from 2018-2020 were compared using time budgets and heat maps, however due to the impacts of COVID-19 much less data was able to be collected in 2020.

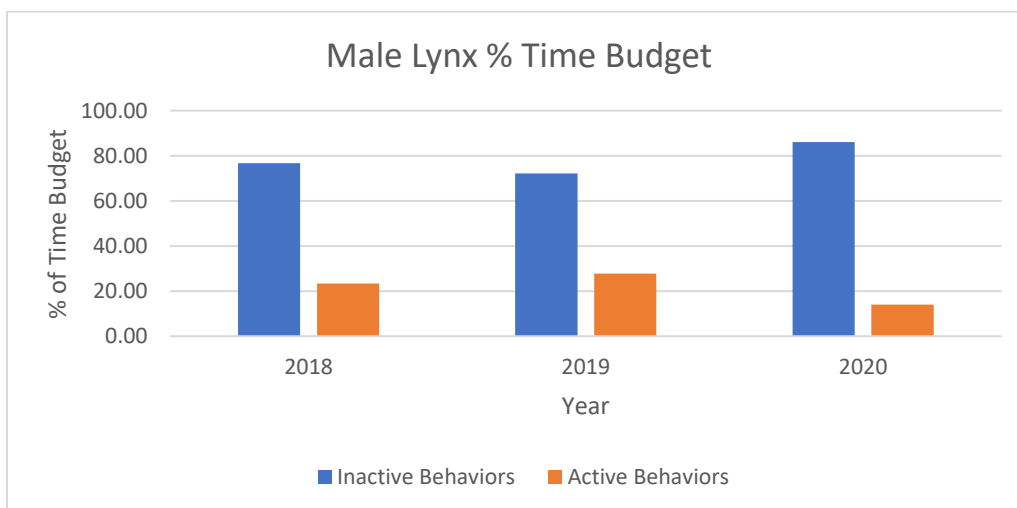


Figure 1. Graph depicting the male lynx's time budget divided between active (walking, route tracing, climbing/jumping, ingesting, social play, solitary play, and trotting) and inactive behaviors (lying down/sleep, grooming (self), grooming (social), and sitting/standing) over the course of 3 seasons of study.

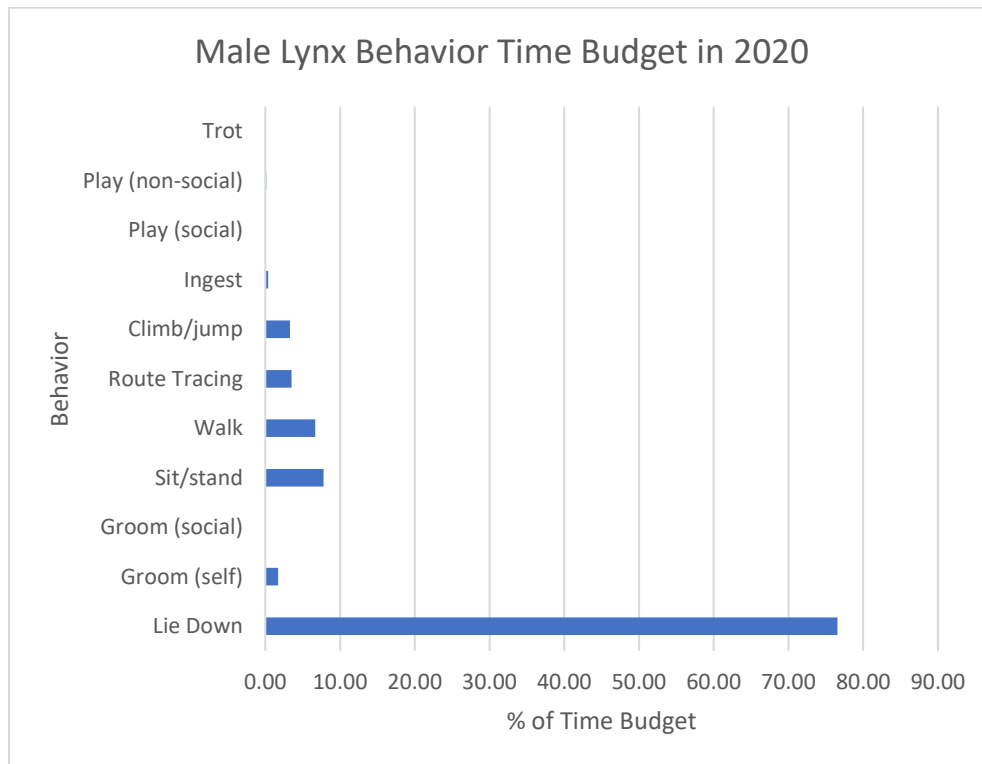


Figure 2. Graph depicting the time budget of the male lynx in 2020.

From 2018 to 2019, the male lynx increased the amount of time spent engaging in active behaviors (walking, route tracing, climbing/jumping, ingesting, social play, solitary play, and trotting) and decreased inactive behaviors (lying down/sleep, grooming (self), grooming (social), and sitting/standing) (Figure 1). However, from 2019 to 2020, the male lynx decreased the amount of time engaging in active behaviors from 27.82% to

13.97%. The most common behavior observed in 2020 was lying down at 76.55% followed by sit/stand, then walking (Figure 2). Lying down was also the most observed behavior in 2018 and 2019 at 51.46% and 69.47% respectively.

After performing a chi-square test it was determined that the change in levels of activity was significant with $0.001 > p$ ($\chi^2 = 66.33$).

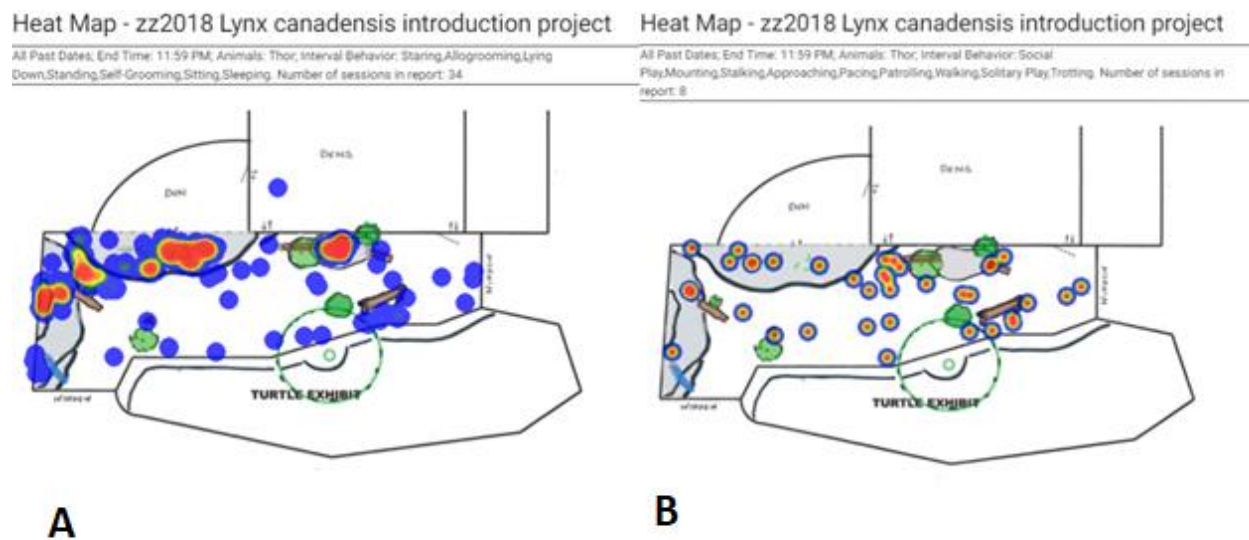
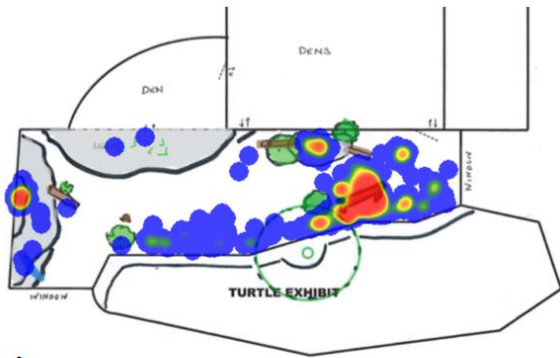


Figure 3. Heat maps depicting the areas in which the male lynx performed certain behaviors in 2018. Warmer colors indicate areas used more frequently (hot spots) while cooler colors indicate areas used less frequently. Figure 3A shows the locations of inactive behaviors and Figure 3B shows the locations of active behaviors.

Heat Map - z2019 Lynx canadensis introduction project

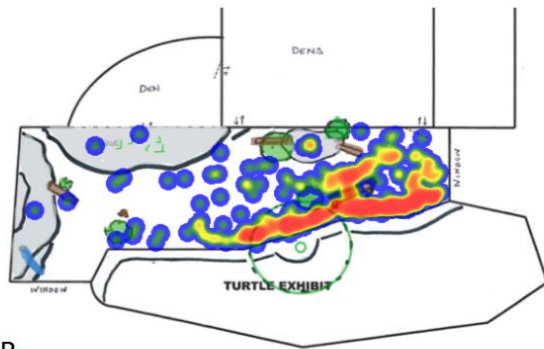
All Past Dates; End Time: 11:59 PM; Animals: Thor; Interval Behavior: Staring,Allogrooming,Lying Down,Standing,Self-Grooming,Sitting,Sleeping. Number of sessions in report: 58



A

Heat Map - z2019 Lynx canadensis introduction project

All Past Dates; End Time: 11:59 PM; Animals: Thor; Interval Behavior: Social Play,Mounting,Stalking,Approaching,Pacing,Patrolling,Walking,Solitary Play,Trotting. Number of sessions in report: 24

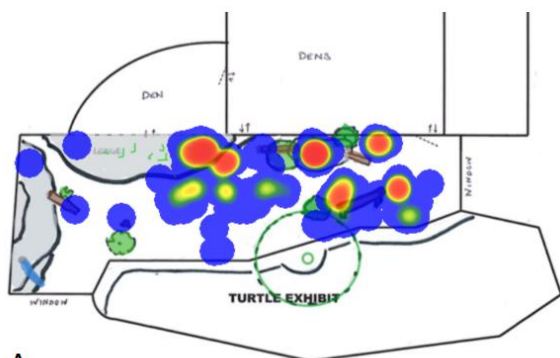


B

Figure 4. Heat maps depicting the areas in which the male lynx performed certain behaviors in 2019. Warmer colors indicate areas used more frequently (hot spots) while cooler colors indicate areas used less frequently. Figure 4A shows the locations of inactive behaviors and Figure 4B shows the locations of active behaviors.

Heat Map - 2020 Lynx

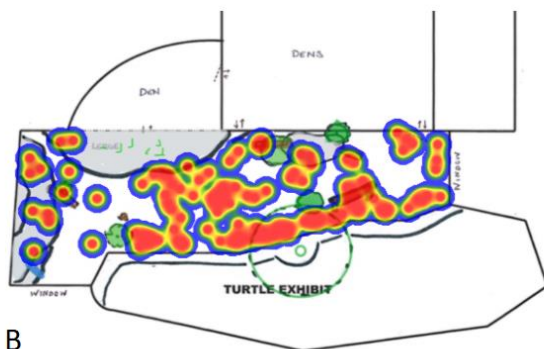
All Past Dates; End Time: 11:59 PM; Animals: Thor; Interval (state) behaviors: Lie down (recline),Sit or stand,Groom (self),Groom (social). Number of sessions in report: 14



A

Heat Map - 2020 Lynx

All Past Dates; End Time: 11:59 PM; Animals: Thor; Interval (state) behaviors: Swim/submerge in water,Trot,Walk,Climb/jump (ascending or descending),Ingest,Play (social),Play (non-social),Predator behavior,Route tracing,Pace. Number of sessions in report: 7



B

Figure 5. Heat maps depicting the areas in which the male lynx performed certain behaviors in 2020. Warmer colors indicate areas used more frequently (hot spots) while

cooler colors indicate areas used less frequently. Figure 5A shows the locations of inactive behaviors and Figure 5B shows the locations of active behaviors.

During 2018, the male lynx focused most of his inactive behaviors on the elevated rock ledges throughout the enclosure (Figure 3A). The rock ledges in the top left corner of the enclosure are approximately 10 ft off the ground and offer a space for the lynx to observe visitors while hiding from view. The elevated rock space in the back middle of the enclosure is approximately 2-3 feet off the ground but in 2018 had enough vegetation growing on top of it to hide the lynx while they rested there. The male lynx's active behaviors were sporadically performed in small areas throughout the enclosure (Figure 3B).

At the beginning of the season in 2019, the enclosure was changed when a large amount of vegetation which the lynx often hid in was removed, and the rock ledge near the back left of the exhibit was partially fenced off (fence ran through middle of it, leaving only a small space accessible). The male subsequently shifted his preferred resting spots and instead focused his inactive behaviors beneath a log near the middle right of the enclosure (Figure 4A). In 2019 the male's active behaviors formed a path along the fence adjacent to the turtle enclosure (Figure 4B). The male was often observed pacing and route tracing in this area.

In 2020 the male's inactive behaviors were less focused in a single area. He still made use of the lower rock outcrop and the space beneath the log but could also be found beneath the blocked off elevated rock ledge (Figure 5A). Overall, the areas in which he

performed his inactive behaviors were more spread out than in previous years. The areas in which he performed his active behaviors were also more spread out than previously recorded (Figure 5B). The male was observed performing active behaviors in nearly every area of his enclosure.

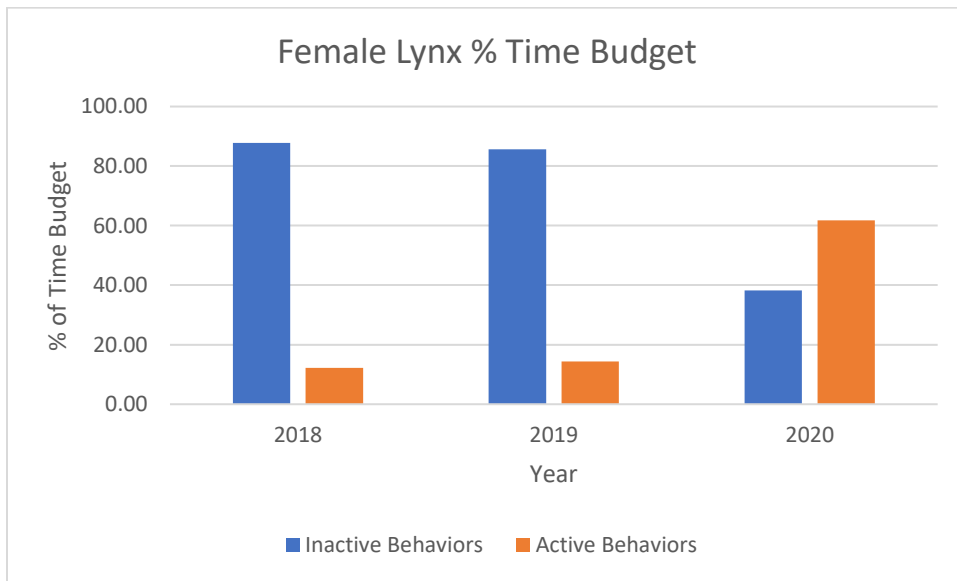


Figure 6. Graph depicting the female lynx's time budget divided between active (walking, route tracing, climbing/jumping, ingesting, social play, solitary play, and trotting) and inactive behaviors (lying down/sleep, grooming (self), grooming (social), and sitting/standing) over the course of 3 seasons of study.

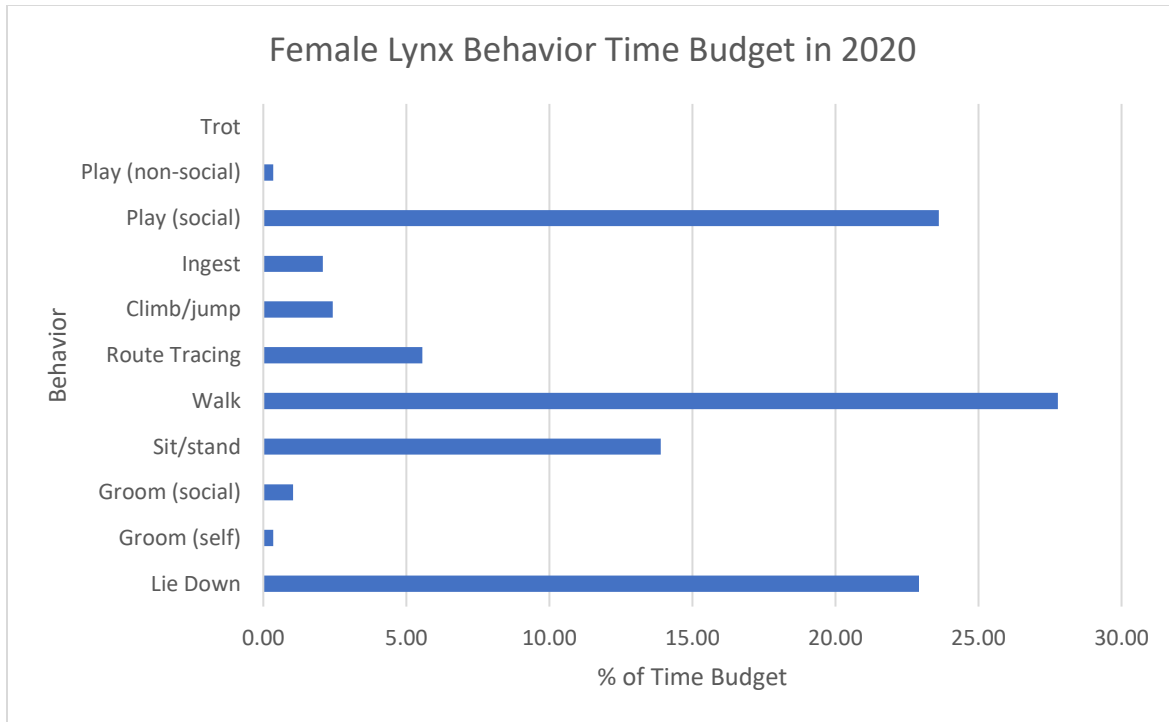


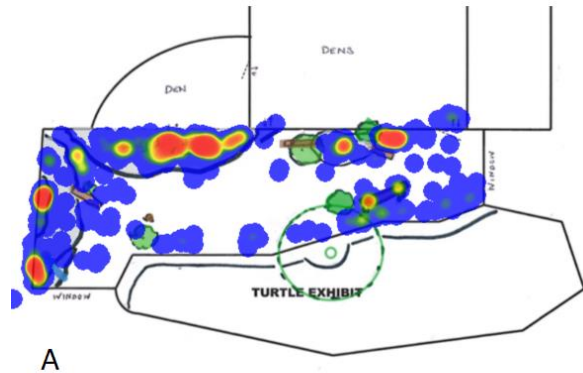
Figure 7. Graph depicting the time budget of the female lynx in 2020.

The female lynx increased the time spent engaging in active behaviors each season from 12.26% in 2018, 14.41% in 2019, and then a significant jump to 61.81% in 2020 (Figure 6). The female lynx dedicated the most time to walking in 2020, which made up 27.78% of her time budget, followed by social play and lying down.

The chi-square indicated that our data was significant $0.001 > p$ ($\chi^2 = 457.37$).

Heat Map - zz2018 Lynx canadensis introduction project

All Past Dates; End Time: 11:59 PM; Animals: Norrie; Interval Behavior: Staring,Allogrooming,Lying Down,Standing,Self-Grooming,Sitting,Sleeping. Number of sessions in report: 40



Heat Map - zz2018 Lynx canadensis introduction project

All Past Dates; End Time: 11:59 PM; Animals: Norrie; Interval Behavior: Social Play,Mounting,Stalking,Approaching,Pacing,Patrolling,Walking,Solitary Play,Trotting. Number of sessions in report: 25

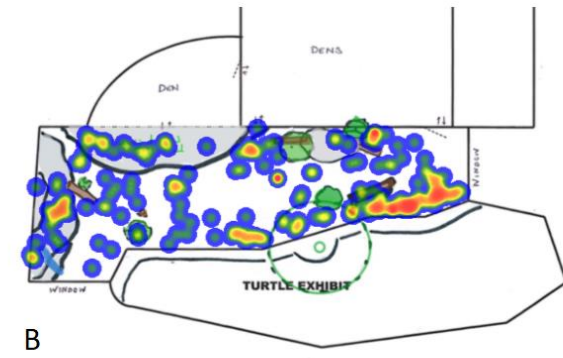
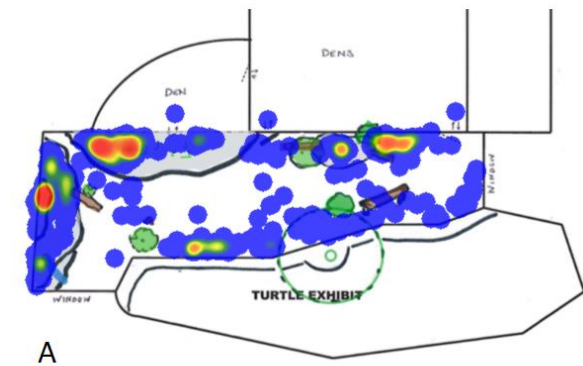


Figure 8. Heat maps depicting the areas in which the female lynx performed certain behaviors in 2018. Warmer colors indicate areas used more frequently (hot spots) while cooler colors indicate areas used less frequently. Figure 8A shows the locations of inactive behaviors and Figure 8B shows the locations of active behaviors.

Heat Map - z2019 Lynx canadensis introduction project

All Past Dates; End Time: 11:59 PM; Animals: Norrie; Interval Behavior: Staring,Allogrooming,Lying Down,Standing,Self-Grooming,Sitting,Sleeping. Number of sessions in report: 49



Heat Map - z2019 Lynx canadensis introduction project

All Past Dates; End Time: 11:59 PM; Animals: Norrie; Interval Behavior: Social Play,Mounting,Stalking,Approaching,Pacing,Patrolling,Walking,Solitary Play,Trotting. Number of sessions in report: 25

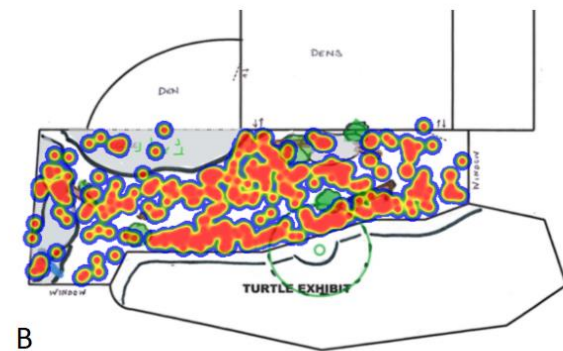
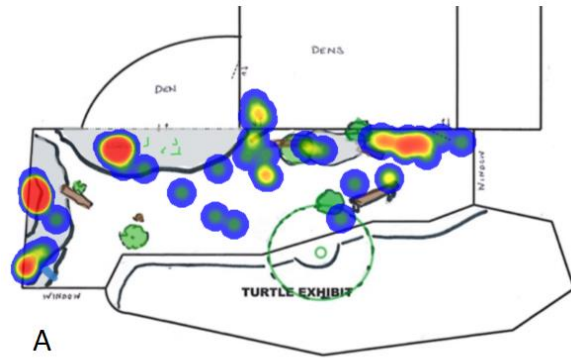


Figure 9. Heat maps depicting the areas in which the female lynx performed certain behaviors in 2019. Warmer colors indicate areas used more frequently (hot spots) while cooler colors indicate areas used less frequently.

cooler colors indicate areas used less frequently. Figure 9A shows the locations of inactive behaviors and Figure 9B shows the locations of active behaviors.

Heat Map - 2020 Lynx

All Past Dates; End Time: 11:59 PM; Animals: Norrie; Interval (state) behaviors: Lie down (recline), Sit or stand, Groom (self), Groom (social). Number of sessions in report: 5



Heat Map - 2020 Lynx

All Past Dates; End Time: 11:59 PM; Animals: Norrie; Interval (state) behaviors: Swim/submerge in water, Trot, Walk, Climb/jump (ascending or descending), Ingest, Play (social), Play (non-social), Predator behavior, Route tracing, Pace. Number of sessions in report: 5



Figure 10. Heat maps depicting the areas in which the female lynx performed certain behaviors in 2020. Warmer colors indicate areas used more frequently (hot spots) while cooler colors indicate areas used less frequently. Figure 10A shows the locations of inactive behaviors and Figure 10B shows the locations of active behaviors.

In 2018 the female's inactive behaviors were concentrated on the elevated rock ledges, not unlike the male lynx, where she could remain hidden from view (Figure 8A). Hot spots for the female lynx's active behaviors are apparent on the right side of the enclosure along the fence-line between the lynx and turtle enclosures, and on and near the rock ledges to a lesser degree (Figure 8B).

The heat map for the female's inactive behaviors in 2019 remains similar to that of 2018. Despite the elevated rock ledge being partially fenced off, she was still able to

jump up and rest there. She also continued to rest on the other 2 rock outcrops (Figure 9A). The female's spatial use when performing active behaviors changed significantly. The female made use of the entire enclosure instead of only a few concentrated areas (Figure 9B).

In 2020, again the female performed inactive behaviors in roughly the same spaces as in the previous 2 seasons (Figure 10A). The female still made use of most of the closure when carrying out active behaviors (Figure 10B). However, in 2020 the active behaviors are not performed as heavily in the far left of the exhibit.

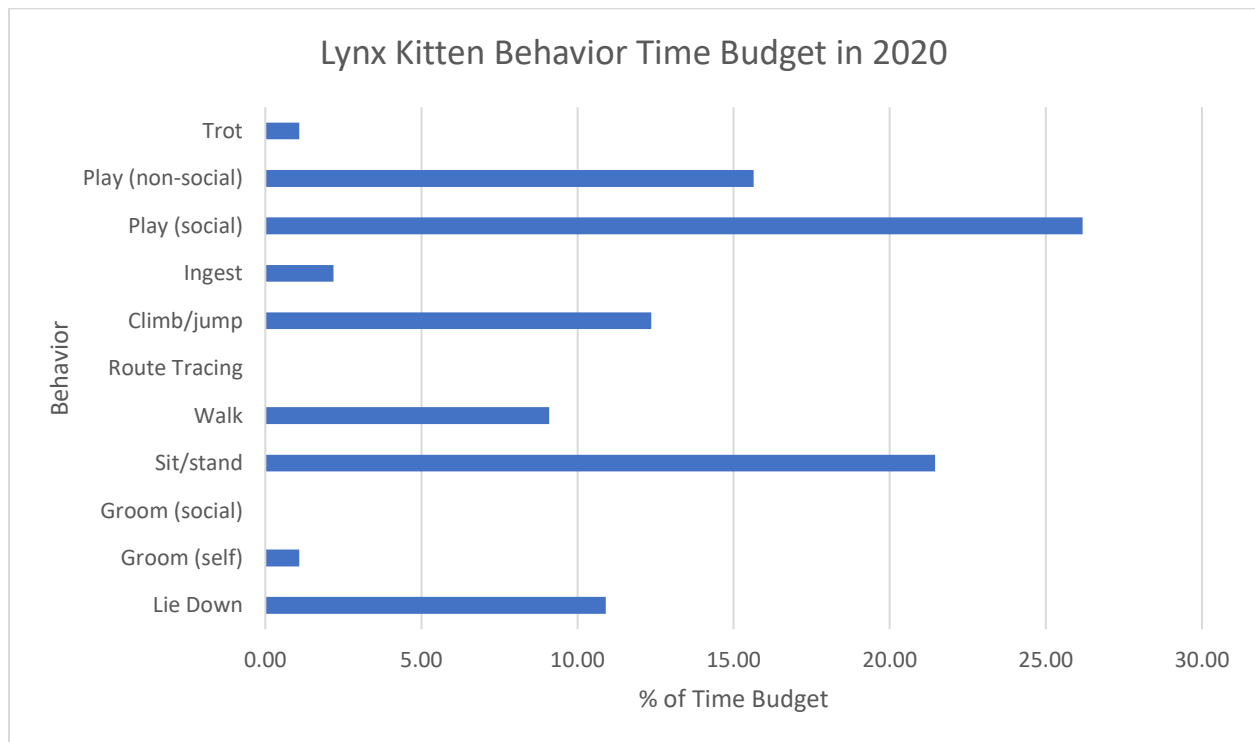


Figure 11. Graph depicting the time budget of the lynx kitten in 2020.

The lynx kitten was more active than either adults, as can be expected of a young animal. The kitten spent the largest amount of time engaged in social play at 26.18%, followed by sitting/standing and non-social play. The kitten was also the most active of all 3 individuals and was the only one to be more active than inactive.

Heat Map - 2020 Lynx

All Past Dates; End Time: 11:59 PM; Animals: Lynx kitten; Interval (state) behaviors: Lie down (recline), Sit or stand, Groom (self), Groom (social), Swim/submerge in water, Trot, Walk, Climb/jump (ascending or descending), Ingest, Play (social), Play (non-social), Predator behavior, Route tracing, Pace. Number of sessions in report: 5

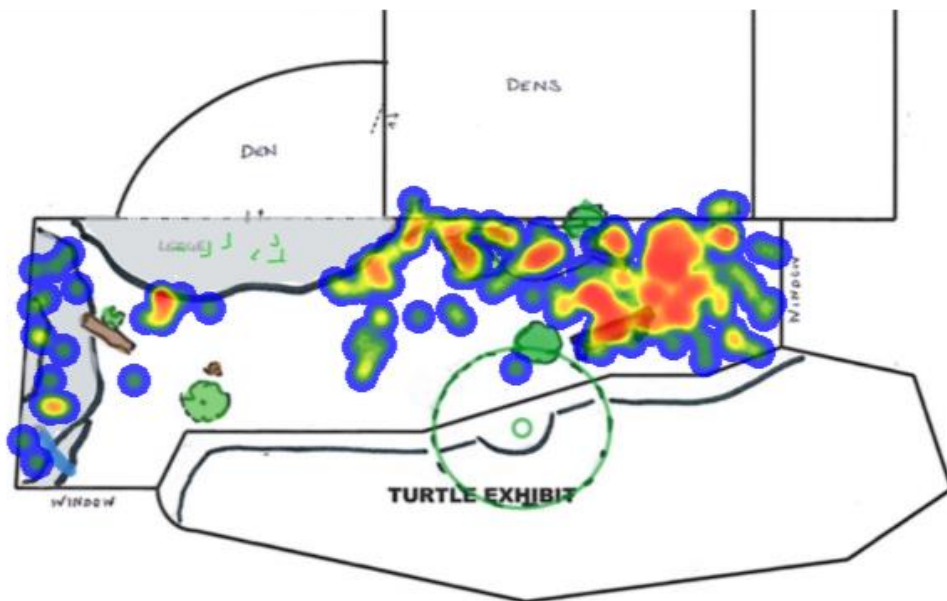


Figure 12. Heat maps depicting the areas in which the lynx kitten performed behaviors. Warmer colors indicate areas used more frequently (hot spots) while cooler colors indicate areas used less frequently. The locations of all behaviors are shown.

The kitten used most of the enclosure except for the front of the habitat nearest to the observation glass, but concentrated activities near the log near the right side of the enclosure, as well as the small rock outcrop on the right side. It is also notable that the young kitten was able to access the rock shelf on the left side of the enclosure.

Discussion/Conclusions

Both the male and female lynx were more inactive in 2018, the year of their introduction, and became more active in 2019. This is most likely due to the animals becoming more comfortable both with the enclosure and becoming comfortable with one another.

Throughout 2018 and 2019 the male showed higher levels of activity than the female lynx. However, in 2020 the male lynx went from spending 27.82% of his time engaged in active behaviors to only 13.97% of his time budget being active. We observed a large jump in the female's activity levels from only 14.41% time spent participating in active behaviors to 61.81% engaging in active behaviors. This significant change is due to the change in social structure after the birth of the lynx kitten in 2020. The male lynx was solitary throughout the entire season. He was unable to engage in social play and thus instead spent time engaging in more active and social behaviors resting. On the other hand, the female lynx spent all time with her kitten. As a young animal, the kitten is far more active than an adult and encourages play from her mother on a regular basis. This led to the large increase in the adult female's activity.

The spatial use of the enclosure by both adult Canada lynx also changed from 2018 to 2019. The male lynx dramatically shifted where he chose to rest. Because the hidden

areas he had used in previous years- the rock ledges and vegetation covered areas- were altered and physically blocked off in a way that made them less desirable as hiding spots, the male instead chose to rest hidden beneath a large log near the right side of the enclosure. From 2019 to 2020 the male shifted away from resting almost exclusively beneath the log to once again making more use of the rock outcrop behind the log and resting beneath the rock ledge at the left of the enclosure in the shade. He also made use of a larger area in the enclosure when performing active behaviors in 2019 compared to 2018 where there were many small hot spots of activity. This could be another result of the male becoming more comfortable in the enclosure and actively accepting the area as his territory and spending more time patrolling and route tracing, since the hot spots in Figure 4B indicate his most frequently used patrolling path. In 2020 the male lynx made use of the entirety of the enclosure, and no dominant pathways used for patrolling or pacing were apparent.

The female lynx resting areas remained largely the same between all 3 years, indicating the enclosure changes affected her spatial use when engaged in inactive behaviors very little. Regarding the female's active behaviors, from 2018 to 2019 the female moved from making use of only small areas to using the entire space within the exhibit. This change we found to be like that of the male- more than likely the female became more comfortable in the enclosure and with the male, and thus made use of a larger part of the enclosure. The difference between the male's use of the enclosure, with a prominent trail he used for patrolling, and the female's use of the entire enclosure, could be due to differences in the types of active behaviors they tended to perform. The female engaged in ore play behaviors, including social and solitary play, and stalking,

while the male tended to do more patrolling and walking. The reason for this difference in behaviors is most likely due to the age difference between the individuals. The female is younger than the male and as a younger animal is more inclined to play than an older individual. In 2020 the female lynx still made use of most of the enclosure when engaging in active behaviors.

The lynx kitten primarily used the upper right portion of the enclosure, where it is most difficult for guests to view the animals, perhaps suggesting that the young animal preferred to stay out of sight of the public.

Our dissemination plans for this data include presenting at Student Scholar Day at Grand Valley State University. We have already presented this data at the 2020 Animal Behavior Society conference and the 2020 Association of Zoos & Aquariums conference.

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