Summer Visitor Use and Resource Monitoring at Focal Attractions and Trails in Yellowstone National Park

Summer 2018 Youth Conservation Corps Data Collection Effort

August 31, 2019

Final Report by:

Susan Sidder, PhD Student

Ashley D'Antonio, PhD

Oregon State University
College of Forestry

Youth Conservation Corp Members collecting data during summer 2018.

(photo by YCC Crew Leaders and provided to OSU)

Table of Contents

Executive Summary iii

Key Findings iv

Acknowledgements vii

Introduction: Summer 2018 Data Collection Effort 1

Sampling Period & Study Sites 4

- Sampling Period 4
- Study Sites 4
  - Fairy Falls 5
  - Midway Geyser Basin 6
  - Norris Geyser Basin 7
  - Old Faithful 8

Methods 9

- Visitor Use Estimation 9
  - Parking Lot Counts 9
  - Automatic Trail Counters 9
  - Trail Counter Calibrations 10
- Visitor Use & Capacity Measures 11
  - People-at-one-time (PAOT) Counts 11
  - Visitor Encounters 12
- Visitor Spatial Behavior 12
  - GPS-Based Tracking of Visitors 13
  - Waypoint Mapping of Visitor Behaviors & Resource Impacts 14

Results 17

- Fairy Falls 18
  - Visitor Use Estimation 18
  - Visitor Use/Capacity Measures 26
  - Visitor Spatial Behavior 27
- Midway Geyser Basin 40
  - Visitor Use Estimation 40
  - Visitor Use/Capacity Measures 51
  - Visitor Spatial Behavior 53
- Norris Geyser Basin 66

Visitor Use Estimation 66
Visitor Use/Capacity Measures 76
Visitor Spatial Behavior 78
Old Faithful Geyser Basin 90
Visitor Use Estimation 90
Visitor Use/Capacity Measures 96
Visitor Spatial Behavior 100
All Sites Visitor Use Estimation Comparison 113
Recommendations 116
Next Steps 117
Appendices Lists 118
References 119

Executive Summary

During the summer of 2018, Youth Conservation Corps (YCC) Crews in Yellowstone National Park (YELL) assisted with a citizen science-based, visitor use monitoring project. This project was a continuation of work started in summer of 2017. The YCC Crews collected social science and resource-related data at four focal attraction sites in YELL: Fairy Falls trail and Grand Prismatic Spring Overlook, Midway Geyser Basin, Norris Geyser Basin, and Old Faithful Geyser Basin (focused mostly on the Upper Geyser Basin and Geyser Hill). These locations represent four of the five locations where data collection occurred in 2017. Repeat measures at these four locations allow for monitoring use at these focal attraction sites over time. Data collection methodologies included: visitor use estimations via parking lot counts and automatic trail counters, measures of visitor experience including counts of encounters on trails and people-at-one-time (PAOT), measurements of restroom use and wait times at restrooms, as well as measures of the spatial behavior and impacts of visitors using GPS-based methodologies. The YCC Crews successfully collected high-quality data via this citizen science project. The data is slightly limited in sample size and its generalizability. It was only collected on weekdays, Monday through Friday, between approximately 9:00 and 15:00. Despite these limitations the data can be used to monitor changes in visitor use over time and highlight potential visitor use issues at each focal attraction site. Additionally, in 2018, a continuous measure was incorporated into this project via the installation of semi-permanent trail counters at the four focal attraction sites. These automatic trail counters provide use estimation continually during the study period, including dates and times when the YCC Crews were not present at the locations. This report summarizes the data collected by the YCC Crews in 2018.

The data collected in 2018 highlights that across all focal attraction sites, visitor use begins to peak around 11:00 and remains high throughout the day and slowly decreases into the afternoon hours. Continuous data collection from the trail counter installation shows that use at some locations remains close to peak levels until 16:00 or 17:00. Parking lot infrastructure at Fairy Falls and Midway Geyser Basin are not sufficiently matched to the level of visitor use at these sites; thus, these parking lots fill early in the day. Undesignated and roadside parking were frequently observed at Fairy Falls, Midway Geyser Basin, and Norris Geyser Basin. Continuous trail counter data also indicated at many of these focal attraction sites, weekday use is slightly higher than weekend use. Littering and seeing litter (both in and outside thermal areas) was by far the most common resource impact observed and mapped by the YCC Crews across all focal attraction sites. On average, visitors spend between 30 minutes to 1.5 hours at these focal attraction sites. Overall these sites have high use levels—especially during periods of peak use—but visitors spend relatively little time at any given location. This creates relatively dynamic visitor use conditions at all focal attraction sites.

Key Findings

In general, the YCC Crews collected sound data at the four focal attraction sites with few issues or difficulties. In 2018, there did appeared to be some confusion regarding how to conduct PAOT and encounter counts, but points of clarification were added to the 2019 protocols to reduce this confusion in the future. Data from the 2018 PAOT and encounter counts are still usable but were not recorded as cleanly as they were in 2017. Despite these limitations, the data appear to be of high enough quality for monitoring purposes at these focal attractions over time and can be compared to the data collected in 2017. See the "Recommendations" section for ways to improve this monitoring effort. Overall, it is important to note the YCC Crews and YELL staff did an excellent job in this data collection effort—the hiring of the Geologists in Parks intern to work with the YCC Crews, as well as the installation of semi-permanent trail counters, resulted in higher quality data and data organization for 2018. It is important to note the findings from this monitoring project are based on data collected only on weekdays from the end of June through early August and between the hours of 9:00 and 15:00. Thus, the data is limited in that it may not be generalizable to weekend use, use early or late in the day, or early summer or late summer use. However, the level and quality of data collected by the YCC Crews is sufficient in quantity and quality for monitoring purposes.

Below are a few key findings from the YCC Crew data collected in the summer of 2018:

- There is a small increase in visitor use across all sites during the second half of July. But increased use around the Fourth of July holiday is also evident in some data collection methods from 2018 (including encounters and PAOT). For example at Fairy Falls, visitor counts in June ranged between approximately 2,000 counts and just below 6,000 counts. In July, visitor counts never dropped below 4,000 counts and maxed at approximately 6,500 counts at Fairy Falls. For context, total recreation visits to YELL in 2018 were 810,884 in June, 940,563 in July, and 813,970 in August (NPS 2019)

- In terms of overall visitor use at all the focal attraction sites, all sites appear to be busiest at approximately 11:00 with a slight, but often not substantial, drop in use around 14:00 or 15:00. Percent decreases in visitor use counts in the early afternoon hours (between 12:00 and 15:00) were consistently in the single digits across all focal attraction sites. Trail counter data indicate that at sites like Midway Geyser Basin and Old Faithful Geyser Basin, use remains high (compared to early or late day counts) well past the time YCC Crews end their data collection (into the 17:00 hour).

- At some of the focal attraction sites, average daily visitor use on weekdays is higher than average visitor use on weekends (Fairy Falls, Midway Geyser Basin, and Old Faithful Geyser Basin). However, daily average visitor use levels across the week at Norris Geyser Basin were more variable with some weekdays having lower use than weekend days, while other days of the week were higher.

- Parking lots at Fairy Falls (which has a total of 97 gravel and paved parking spots combined) and Midway Geyser Basin (which has 55 designated parking spots) were often full or close to full when YCC Crews arrived and began their counts (around 9:00). Undesignated and roadside parking at these destinations begins to peak around midday. At Fairy Falls the maximum average observed undesignated parking was 28 vehicles and the maximum average roadside parking was 50 vehicles (averaged across an entire day). At Midway Geyser Basin, the maximum average roadside parking observed was 117 vehicles and the maximum average undesignated parking was 16 vehicles (averaged across an entire day).

- Like 2017, most visitors tend to visit and spend more time at the main geothermal attractions at each study site (Grand Prismatic Overlook, Old Faithful Geyser, etc.) But GPS tracks show that visitors traveled beyond these main attractions at each site, especially in the Norris Geyser Basin and Old Faithful Geyser Basin trail systems.

- On average, visitors spend relatively little time (between 30 minutes to 1.5 hours) at these focal attraction sites. Average time at Old Faithful Geyser Basin was variable, with an average of approximately 1 hour and 20 minutes (SD of 1 hour and 10 minutes). This indicates relatively rapid turnover of visitors at each of these focal attraction sites.

- Visitor behaviors and resource impacts of interest tend to be associated with the locations that have the highest densities of visitor use. Litter was the most common resource impact observed by the YCC Crews. However, visitors were also frequently observed actively littering and seen short distances (< 1 m) off of boardwalks. Other behaviors of interest, such as interacting with wildlife or visitor conflict, were rarely observed by the YCC Crews (see Appendix H). At Midway Geyser Basin, litter was found throughout the trail system but observations of individuals littering were concentrated closer to the trailhead. For all other focal attraction sites, there does not appear to be any consistent patterns in the location of litter or the act of littering; littering related impacts were observed consistently throughout the trail systems.

- On average, during peak use time the Fairy Falls trail receives approximate 600 visitor counts/hour. Visitor encounters along the Fairy Falls trail average 250 people for the length of the trail to the Grand Prismatic Overlook. Use is relatively dispersed along this trail, but visitors concentrate at the Grand Prismatic Overlook platform and, on average, 50 visitors at one time are observed at the platform area.

- Midway Geyser Basin has the highest peak, hourly use levels on average with 1,400 visitor counts. Midway also has one of the most concentrated trail systems of all focal attraction sites resulting in high counts for trail encounters (586 encounters on average) and PAOT (approx. 40 to sometimes over 100 PAOT at Grand Prismatic).

- Norris Geyser Basin appears, on average, to be the next busiest focal attraction site after Midway Geyser Basin, with hourly peak use levels at approximately 800–900 counts/hour. However, due to the larger extent of the Norris Geyser Basin boardwalk system (compared to Midway Geyser

Basin), encounters and PAOT counts are lower on average. Visitor use is more diffuse at Norris Geyser Basin.

- YCC Crew data collection at Old Faithful is concentrated near Geyser Hill. At this location of the Old Faithful Geyser Basin boardwalk complex, visitors on average encounter approximately 400 other visitors and can experience 45–55 other visitors at the PAOT locations (Beehive Geyser and the "Z" Bridge). Overall, all visitor use level measures at Old Faithful Geyser Basin are dynamic and are often driven by the timing of eruptions of Old Faithful Geyser.

- Restroom wait times were measured in 2018 at Norris Geyser Basin and Midway Geyser Basin. At Norris Geyser Basin during peak use, the wait time in restroom lines ranges from 5 minutes to 12.5 minutes on average. At Midway Geyser Basin, during peak use, the wait time in restroom lines ranges from 15 minutes to 34.5 minutes on average. In 2019, the methods for restroom data collection by YCC Crews will be adjusted to allow for wait time calculations for individual restrooms (e.g., Comfort Station at Norris vs. the non-flush vault toilets at Norris).

- Overall, based on the visitor use data collected by the YCC Crews in 2017 and 2018 and an understanding of the level of facilities provided at each focal attraction site, some generalizations about visitor use can be made. Visitor facilities and infrastructure at Norris Geyser Basin and Old Faithful Geyser Basin appear to be better able to absorb the visitor use levels observed at these two sites. The larger trail networks and parking lots at Norris Geyser Basin and Old Faithful Geyser Basin result in lower PAOT and encounter counts as well as (for Norris Geyser Basin) fewer instances of roadside or undesignated parking compared to Midway Geyser Basin and Fairy Falls. Midway Geyser Basin, and to a lesser extent Fairy Falls, have infrastructure and facilities that may be mismatched to the high levels of use seen at these sites. Parking lots are often filled or close to full by 9:00, resulting in roadside and undesignated parking present throughout the day. Visitor encounters and PAOT counts also are higher, on average, due to the concentration of visitors in relatively short trail systems (compared to Norris Geyser Basin and Old Faithful Geyser Basin).

Acknowledgements

The data collection that is summarized here would not have been possible without substantial assistance, both in the field and during project development, and insightful input from Alicia Murphy in 2017 and 2018. Additionally, original support, assistance, and input from Ryan Atwell and Kyle Meakins during the 2017 data collection effort provided a solid foundation for the continued successful data collection effort in 2018. Ray McPadden and Christina White provided helpful comments on the 2017 YCC Reports that greatly improved the data collection in 2018. Ray and Christina have continued to provide wonderful insights and suggestions for revisions of this report and improvements to data collection for 2019. Additionally, many thanks to the YCC Crew participants and their crew leaders for the many hours they spent in the field collecting data. Ian Redding and Jenna Deibel at Oregon State University were responsible for data entry and QA/QC checks on entered data. Jenna Deibel and Allison Starkenburg also contributed to data analysis for this report. A special thank you to Claire Morris whose dedication to the project, enthusiasm for working with the YCC Crews, and attention to detail greatly improved the quality of the data collected in 2018 and ensured the timely transfer of the data to Oregon State University at the end of the data collection season. Her involvement in this project in 2018 greatly improved overall implementation of the project. Finally, thank you to Jenni Burr who has been incredibly helpful facilitating communication with the park after data collection wrapped up and helping us to continue to make progress on this project upon Claire's departure. Jenni has providing many helpful insights for the YCC project and provided substantial and incredibly helpful comments and revisions on this report. We look forward to continuing working with Jenni, Christina, Ray, the Geologist in Parks interns and the YCC Crews on data collection and data summaries from 2019.

Introduction: Summer 2018 Data Collection Effort

Beginning in 2017, Yellowstone National Park's (YELL) Yellowstone Center for Resources and Youth Conservation Corps (YCC) partnered with Oregon State University (OSU) to create a citizen science visitor use and resource impacts monitoring data collection initiative. This report serves as the final report summarizing the results from the second year of data collection in 2018. The citizen science initiative engages the park's YCC participants in a week of social science data collection during their YCC residence in YELL. In addition to generating high quality visitor use and resource impact monitoring data for the park's use in decision making, this initiative is also designed to provide YCC Crew members with hands-on experience participating in science-based, social science monitoring data collection. Monitoring protocols for various social science measures were developed by OSU and implemented by the YCC Crews with assistance from their crew leaders and coordination/logistical assistance from YELL staff.

This project was initiated in 2017 to help the park better understand visitor use and associated resource impacts at popular locations in YELL. Between 2014 and 2016 YELL saw a 21% increase in visitation. In 2018, YELL experienced its third busiest year on record—receiving over 4.1 million visits to the park (NPS 2019). This rapid increase in visitors over a short period of time has led to management concerns related to congestion (especially along roads and in parking lots), impacts to the visitor experience, and impacts to biophysical resources. Monitoring is an important component of understanding recreation resources and trends related to visitor use and impacts over time (Hammitt et al. 2015).

During the 2017 data collection season, YCC Crew members collected social science monitoring data at five focal locations in YELL: Artist Point, Fairy Falls, Midway Geyser Basin, Norris Geyser Basin, and Old Faithful Geyser Basin. These locations were chosen through collaboration with YELL staff and based on the following selection criteria: the sensitivity of biophysical resources to impacts from visitor use and levels of visitor use indicated from previous studies. In 2018, this list was reduced to include only Fairy Falls, Midway Geyser Basin, Norris Geyser Basin, and Old Faithful Geyser Basin (figure 1). This decision was made to increase the amount of data that could be collected at the remaining locations and based on a review of the 2017 results for Artist Point. As such, this report for the 2018 data collection only includes data collected at Fairy Falls, Midway Geyser Basin, Norris Geyser Basin, and Old Faithful Geyser Basin.

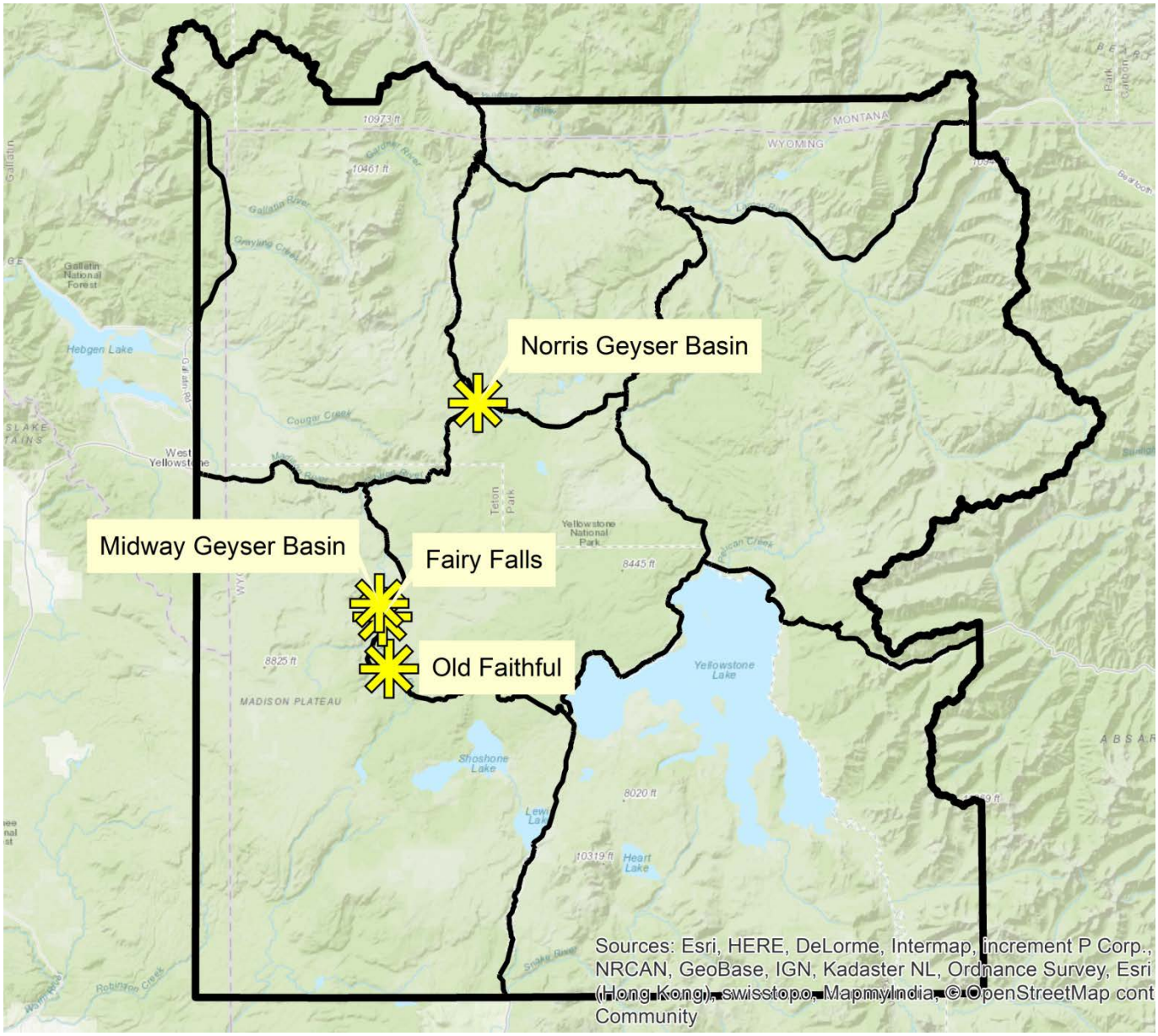

Figure 1. Base map showing general locations of focal attractions in Yellowstone where YCC Crews collected data during summer 2018 represented by yellow stars. The Fairy Falls trail is located in the Midway Geyser Basin area.

This report presents descriptive analyses of the 2018 data collected by the YCC Crews. The YCC Crews collected a variety of social science data on aspects of visitor use related to numbers and distributions of visitors, spatial behavior, and social and resource conditions at each focal attraction site. Specifically, the following types of data, organized by data type category, were collected by the YCC Crews in 2018:

- Visitor Use Estimation
    - Tallies of visitor counts recorded by automatic trail counters (Pettebone et al. 2010)
    - Hourly parking lot counts (Monz et al. 2014)
- Visitor Use Measures
    - PAOT counts (Manning 2007)
    - Visitor encounters along trails (Manning 2011)
    - Counts of restroom lines and restroom occupancy times
- Visitor Spatial Behavior
    - GPS-based tracking of visitor behavior (D'Antonio et al. 2010)
    - Waypoint marking of locations of visitor impact behaviors and resource impacts of interest

The data collection methods are reported in aggregate for each type of data collected. The same methods were used to conduct monitoring at the four focal attraction sites. The results are organized by each focal attraction site. Finally, the report ends with recommendations for continued citizen-science visitor use and resource impact monitoring efforts using YCC Crews.

Sampling Period & Study Sites

Sampling Period

Data collection occurred on weekdays between June 18, 2018, and August 10, 2018 (see Appendix A for data collection schedule). YCC Crews only worked on weekdays; therefore, no data collection occurred on weekend days. Data collection by the YCC Crews took place primarily between 9:00 and 15:00, with a few days extended to 16:00. Mondays and Fridays were half days of data collection (see Appendix A) to allow for crews to take care of weekly, logistical tasks. Data collection occurred at one site per day (see Appendix B). The YELL intern was responsible for organizing and scanning data sheets, downloading data , and transferring data to OSU for data entry, analysis, and reporting.

Study Sites

Figure 2. Example of a boardwalk-style Trail in Yellowstone National Park.

YCC Crews collected data at four study sites (referred to in this report as "focal attraction" sites): Fairy Falls, Midway Geyser Basin, Norris Geyser Basin, and Old Faithful Geyser Basin (figure 1). Three of the sites—Midway Geyser Basin, Norris Geyser Basin, and Old Faithful Geyser Basin—contain a large amount of sensitive hydrothermal features. The trails at these three hydrothermal locations are largely boardwalk-based trails (figure 2). The fourth site, Fairy Falls, is a relatively new trail which opened in July of 2017, providing an overlook of the Midway Geyser Basin Area. Fairy Falls has some hydrothermal features near the trailhead but the primary attraction at Fairy Falls is the viewing platform for Grand Prismatic Spring. A limited number of parking spots are available at all of these focal attraction sites except for the Old Faithful Geyser Basin area, which has a large series of parking lots. During summer of 2018, Norris Geyser Basin experienced ongoing construction, with periodic closures of boardwalks due to reconstruction and repair. Additionally, the parking lot at Norris Geyser Basin was often closed by YELL staff when parking demand exceeded capacity of the designated parking spots.

In the section to follow, each focal attraction site is briefly described and a map of the area where the YCC Crews focused their data collection efforts is provided. The maps also show trail counter locations (green stars), the extent of the trail where visitor encounters were recorded (brown trail segments), and where PAOT counts were conducted (orange circles). Additional maps and photos of these locations are provided in Appendix C. The monitoring protocols used to collect these data will be described in detail in the "Methods" section of this report.

Fairy Falls

The Fairy Falls trailhead is accessible via the Grand Loop Road and located just south of the parking area for the Midway Geyser Basin. The Fairy Falls trailhead provides access to Fairy Falls (a 2.5-mile hike) and the Imperial Geyser Basin (approximately 3-mile hike). During summer 2016, a new trail was built along the Fairy Falls trail to provide an overlook of Grand Prismatic Spring. Along with the new trail, the Fairy Falls parking area was expanded. The new Grand Prismatic Overlook Trail is located 0.6 miles from the Fairy Falls trailhead and provides a viewing platform at the top (see brown trail in figure 3). To replicate the 2017 data collection effort, the YCC Crews focused their 2018 data collection efforts on the Fairy Falls trailhead and the Grand Prismatic Spring Overlook Trail. This focus on the same areas in both 2017 and 2018 was done intentionally to allow for comparison of data between years and for trend analysis.

Figure 3. Fairy Falls focal attraction site. Symbols on map: trail counter locations (green stars), the extent of the trail where visitor encounters were recorded (brown trail segments), and where PAOT counts were conducted (orange circle).

Midway Geyser Basin

Midway Geyser Basin, located on the Grand Loop Road of YELL, is a popular location in the park for viewing hydrothermal features. Grand Prismatic Spring, the largest hot spring in YELL, is located here. The geyser basin is accessed from the Midway Geyser Basin parking area where visitors cross a bridge over the Firehole River to access a boardwalk trail. The boardwalks provide a less than 1-mile loop through the geyser basin (figure 4). During both the 2017 and 2018 data collection seasons, the YCC Crews focused their data collection efforts on the bridge and boardwalk system located on the west site of the Firehole River.

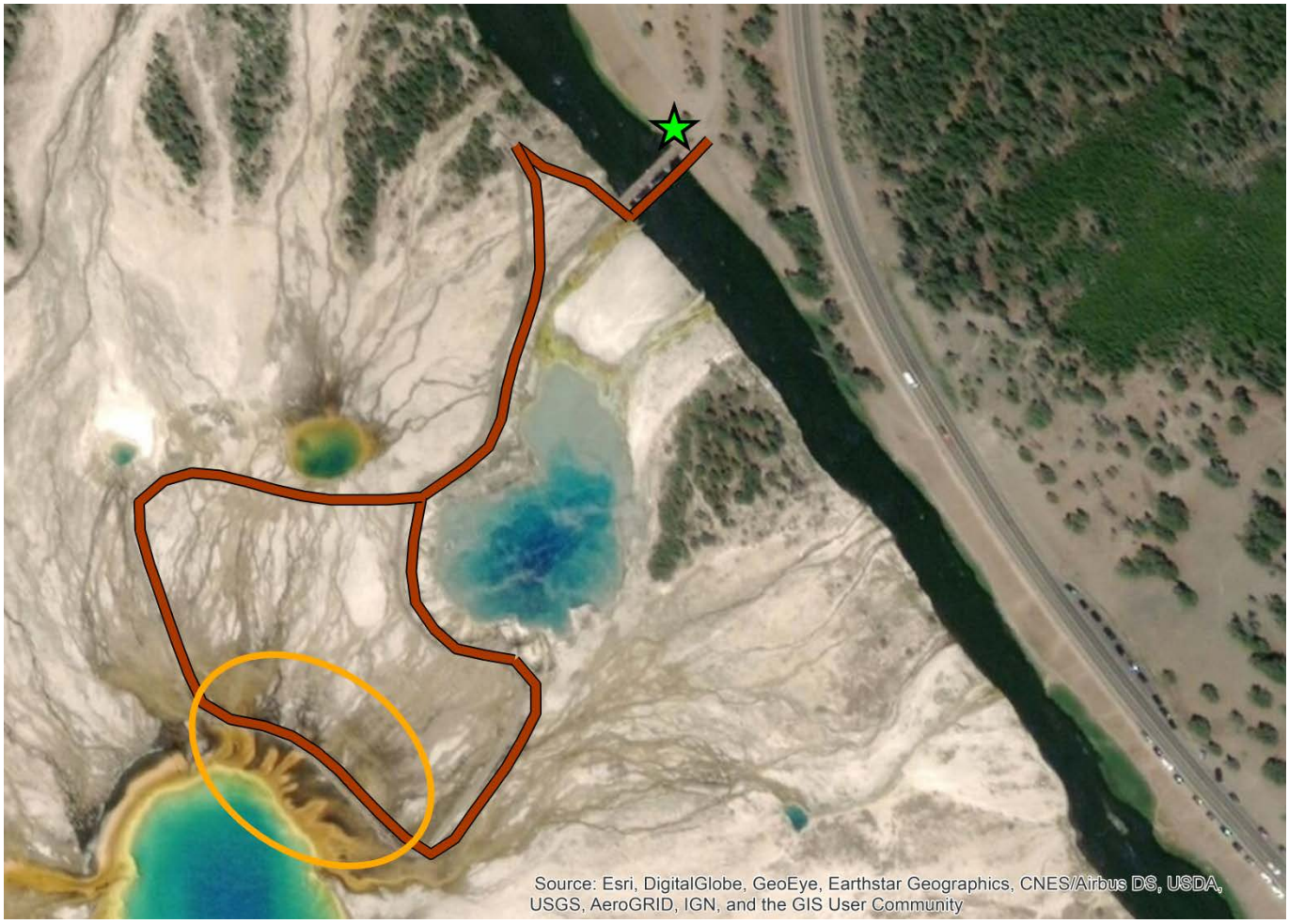

Figure 4. Midway Geyser Basin focal attraction site. Symbols on map: trail counter locations (green stars), the extent of the trail where visitor encounters were recorded (brown trail segments), and where PAOT counts were conducted (orange circle).

Norris Geyser Basin

The Norris Geyser Basin is another popular, hydrothermal feature-focused destination in YELL. The Norris Geyser Basin is accessed via a large parking area and has a trail system of paved, dirt, and boardwalk-style trails. The Norris Geyser Basin Museum is also located here. During the 2017 data collection effort, the YCC Crews focused on the Porcelain Basin loop, an approximately 1-mile loop trail in the Norris Basin made up of mostly boardwalks, with some paved and dirt sections, that can be accessed from the Norris Geyser Basin Museum. During the 2018 data collection effort, boardwalk construction on the western portion of the Porcelain Basin loop resulted in YCC Crews being unable to complete a loop of the Porcelain Basin. The PAOT and encounter monitoring locations were adjusted accordingly and are reflected in figure 5.

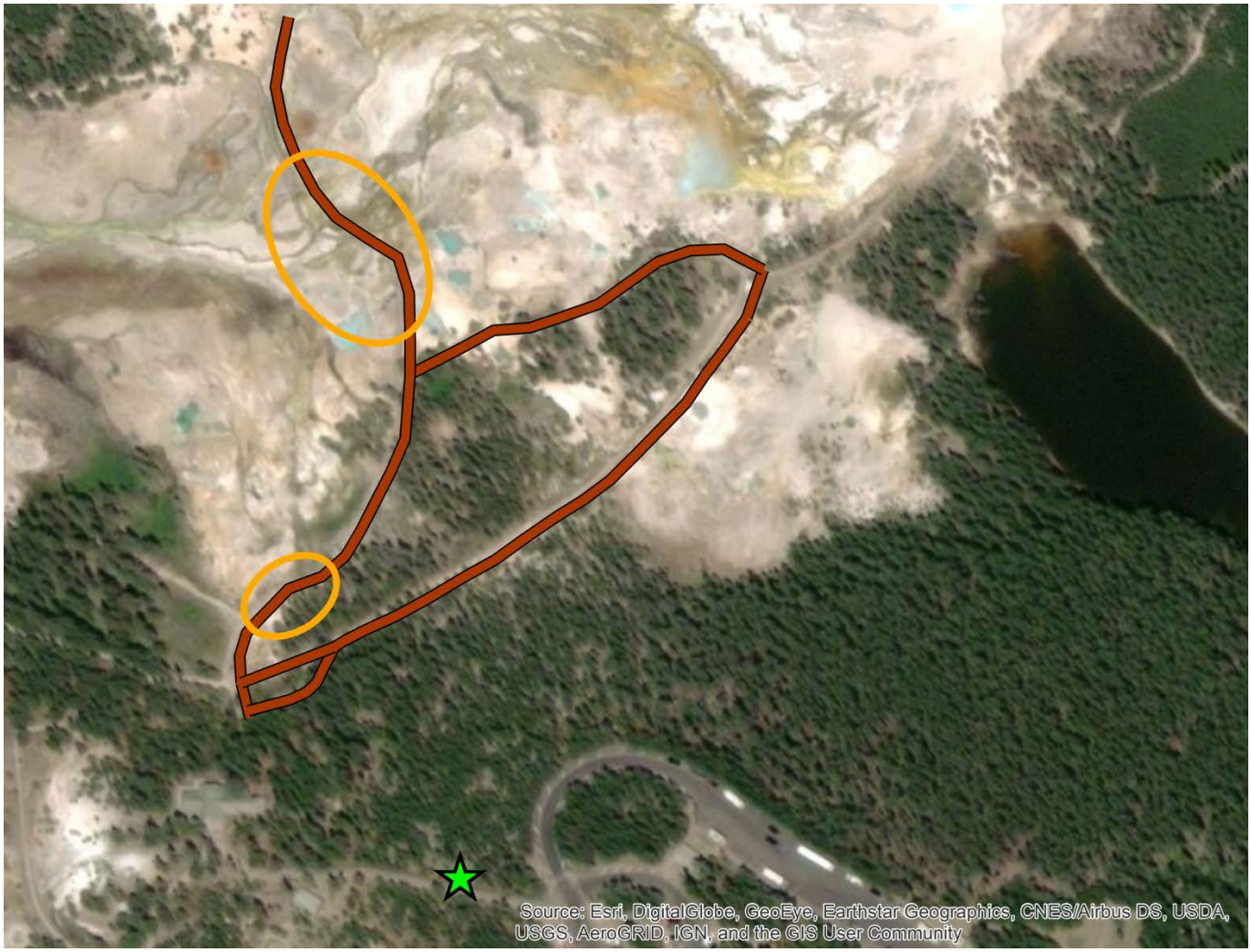

Figure 5. Norris Geyser Basin focal attraction site; data collection focused on Porcelain Basin (shown here). Symbols on map: trail counter locations (green stars), the extent of the trail where visitor encounters were recorded (brown trail segments) which was approximately 0.5 miles in 2018, and where PAOT counts were conducted (orange circle).

Old Faithful

The Old Faithful Geyser Basin area is one of the most popular destinations in YELL. Numerous hydrothermal features are found at this location as well as a visitor center, the Old Faithful Inn, and a variety of lodging, food and shopping locations. Due to the popularity of this location and the many amenities here, the Old Faithful area has the largest parking lot of the focal attraction sites in this study.

Geyser Hill is located just north of the Old Faithful Geyser and provides a boardwalk loop around many hydrothermal features including Beehive Geyser and Doublet Pool. To access Geyser Hill, visitors must walk around the Old Faithful Geyser area and cross the Firehole River via a bridge. The trails leading to Geyser Hill as well as the Old Faithful Geyser Basin area were the focus of the YCC Crew data collection efforts for 2018 (figure 6). YCC Crews focused on the same areas for PAOT and encounters data collection in both 2017 and 2018. However, it should be noted that the trail counter location in 2018 was moved from the trail leading from the parking lot into the trail system to the location depicted in figure 6. The decision to move the counter was made to simplify data collection at Old Faithful and to generate more accurate counts of visitors using the boardwalk/trail system than the 2017 placement generated.

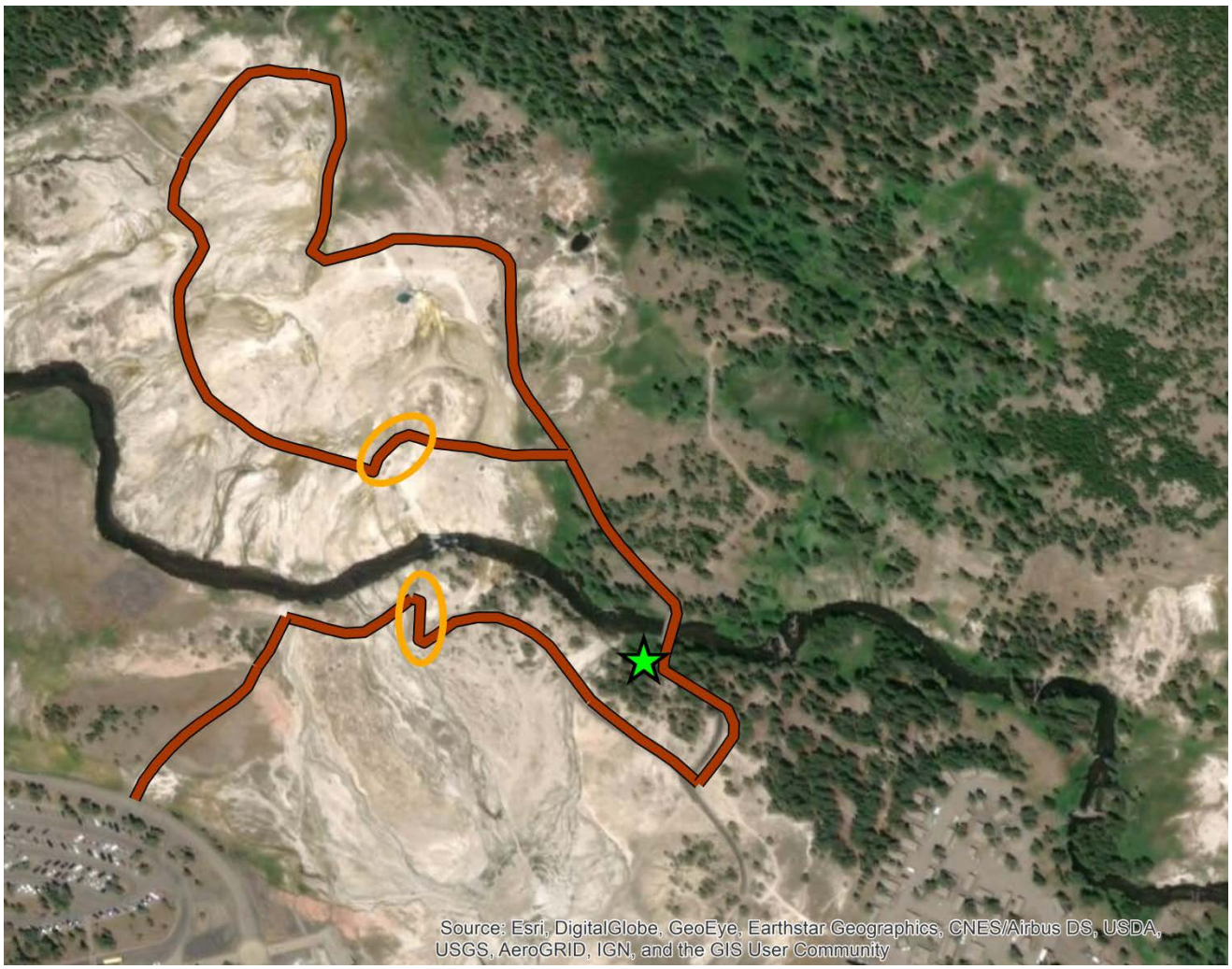

Figure 6. Old Faithful Geyser Basin focal attraction site; data collection focused on Geyser Hill (shown here). Symbols on map: trail counter locations (green stars), the extent of the trail where visitor encounters were recorded (brown trail segments), and where PAOT counts were conducted (orange circle).

Methods

The methods used to collect data in 2018 were comparable to those implemented by YCC Crews in 2017, with a couple of key modifications made from recommendations by both YCC Crew leaders and OSU researchers in 2017. Notably, the trail counter installation and calibration element of the 2017 protocols were improved upon. In 2018, additional counters were purchased by both YELL and OSU, and counters were deployed for the duration of the peak use season by the YELL intern. The YELL intern, NPS volunteers, and YCC Crews calibrated the trail counters. Artist Point was also dropped as a focal attraction site due to the desire to collect more data at fewer locations in 2018. Finally, parking lot count data collection evolved to include observations of restroom line lengths and restroom occupancy times. These restroom-related measures were added to the protocols for Midway and Norris Geyser Basins which have restrooms near the parking areas that could be monitored by the parking lot data collection crews. Each type of data collection method is described below. For full details on implementation of the data collection method, refer to the protocols and log forms for each type of data.

Visitor Use Estimation

Pedestrian and vehicle visitor use levels were quantified at the focal locations. Two different methods were used to collect these data: one focused on counting visitors on trails and one focused on counting parked vehicles. Parking lot counts were not conducted at Old Faithful Geyser Basin because the parking lot is too expansive and busy to be safely counted by the YCC Crews. Each of the two visitor use estimation data collection methods is described in detail below.

Parking Lot Counts

At Fairy Falls, Midway Geyser Basin, and Norris Geyser Basin the YCC Crews counted and recorded the number of vehicles in the trailhead parking lots on the hour for each hour they were collecting data (Monz et al. 2014). Recorded vehicles were categorized as parked in designated parking spots (striped or identified in another way as an appropriate place to park), undesignated parking spots (e.g., double-parked, parked on a curbside, or in grass within the parking lot), or parked along the roadside. Additionally, the number of vehicles of different types such as tour buses, RVs, and bicycles were also recorded. If a queue of cars was formed waiting for a parking spot the number of cars waiting in line was documented. Parking lot data is summarized by date and time of day, and average and standard deviations of total vehicles and other vehicles counts of interest are presented in this report.

Counts of restroom lines and restroom occupancy times were also recorded at Midway and Norris Geyser basins. YCC Crews were instructed to record the number of people in line at the time a person entered the restroom, the number of people in line at the time the same person exited the restroom, and the duration of the bathroom occupancy for the individual. These counts were done discretely through observation to provide a measure of congestion and wait times at the restrooms. Restroom counts were not conducted at Fairy Falls because that focal location does not have bathrooms, nor at Old Faithful Geyser Basin due to the complexity of the site.

Automatic Trail Counters

The semi-permanent installation of trail counters at the focal locations throughout the peak use season was a marked shift from the 2017 data collection. During the summer of 2017, the YCC Crews only had access to one automatic trail counter. This single counter was installed and uninstalled by YCC Crews each day of data collection, only recording data during the times when YCC Crews were collecting data at a site. The process of installing and uninstalling the counter daily resulted in high variability between days and error in use estimation counts. In response to the compromised count data quality experienced in 2017, OSU and YELL both purchased additional automatic counters to be installed semi-permanently during the summer months at the YCC focal attractions sites. Additionally, in 2018 YELL hired an intern to serve as an on-the-ground point of contact for both OSU and the YCC Crews for the project duration. To increase accuracy of count data collection and download, the YELL intern was

tasked with installing and downloading the counters rather than the YCC Crews as was the case in 2017. Trail counters were installed at the four focal locations from mid-June through late October, resulting in approximately five months of continuous count data collected, even on days when the YCC Crews were not collecting other visitor use data at the locations.

The counters were TRAFx (TRAFx, 2018a) infrared trail counters. See figure 3 through figure 6 for trail counter locations for each focal attraction site (shown as green stars). Data were periodically downloaded from the trail counters and uploaded to TRAFx's DataNet website (TRAFx, 2018b). Trail counter data is summarized by the average and standard deviation of counts (counts = total number of counter hits) by hour of the day and day of the week. Total daily counts are also reported. Automatic trail counters almost always underestimate visitor use as they undercount when large groups pass the counter at once or individuals walk shoulder to shoulder. Therefore, counter calibration techniques should always be used with automatic trail counter placement (see "Trail Counter Calibrations" for additional detail on calibration methods).

In addition to counter installation at the four focal locations, counters were installed at the following locations in the park: Boiling River (2 counters), Brink of Lower Falls (1 counter), Artist Point (1 counter), Castle (1 counter), Fountain Paint Pots (1 counter), West Thumb (1 counter), and Elephant Back (1 counter). These counters were installed to provide the park with baseline data on visitor use levels at other locations of interest. A map of all counter locations for 2018 can be found in Appendix G. As added value, the additional counter data have been analyzed and data summaries are included in Appendix G.

Trail Counter Calibrations

Trail counters, even when carefully placed, will have some level of error in their use estimates. Observational techniques can be used to calibrate the trail counters and calculate a measure of counter error (Pettebone et al. 2010). This error measure can be used to "correct" trail counter use estimates. To calibrate the trail counters in 2018, the YELL intern, YCC Crews, and NPS volunteers manually counted visitors as they passed the automatic trail counter at each focal location. These manual counts are then compared to the automatic counts from the trail counter.

Ten hours of calibration data, collected across the use season, was the target for robust calibration data collection in 2018. The total number of calibration hours are reported for each counter discussed in this report (table 1) and in Appendix G (for all other counters). The goal of ten hours is based on work by Pettebone et al. (2010). A minimum of five hours of non-zero calibration counts, that can be matched to full hours of data collection by the trail counter, are required to accurately calibrate an automatic trail counter. Up to ten hours, there is an improvement in the calculation of the calibration value used to correct the automatic counters. For the YCC data collection effort, ten hours was used as a target to provide a few extra hours of usable data beyond the minimum five-hour requirement. This was to account for unforeseeable data loss such as calibration counts that happened to be occur during an unexpected "zero hour" with no use or if data was lost from the trail counter during data download or processing.

Table 1: Summary of calibration coefficients and hours of calibration for counters installed at focal attraction sites.

Counter Location	Calibration Coefficient	Coefficient Standard Error	R Squared (R^2)	Hours of Calibration
Fairy Falls	1.84	0.12	0.96	10
Midway Geyser Basin	1.94	0.10	0.98	9
Norris Geyser Basin	1.85	0.05	1.00	5
Old Faithful Geyser Basin	2.05	0.28	0.93	5

Important note about visitor use estimations from automatic trail counters: Trail counters, even with calibration, do not count individual visitors. The automatic trail counter is activated as each visitor passes and thus records a total count of visitor "hits". The results presented in this report are total counts (or "hits") on the automatic trail counter at each focal attraction site. These results cannot be interpreted as the number of individual, unique visitors at the site. While some locations where the trail counters were installed are loop trails (such as Midway Geyser Basin), average hourly counts cannot simply be cut in half to estimate use as the flow of visitors in and out of a trail system is not consistent across a day. Calibration data from the trail counters confirms that use is not consistent across a day at any of these focal attraction sites (e.g., more people may enter a trail in the morning and exit later in the day). For true loop trails (like Midway Geyser Basin) daily total use or overall counts could be divided by two as an estimate of overall visitor use. But it is not recommended that this approach be used for more complex trail systems with multiple entrances and exits such as Old Faithful Geyser Basin or even Norris Geyser Basin (where individuals can enter from the campground). Due to the inaccuracy that can occur from dividing visitor use estimates in half to estimate total visitation, in this report all automatic trail counters data is reported as total counts.

Note about automatic trail counter analysis: Information about the representativeness of the visitor use measures collected at the focal attractions on weekdays can be derived from additional analysis of the continuously collected trail counter data. Specifically, data from the trail counters can be used to provide an indication of the extent to which the level of use at the focal extraction sites on days during which the data were collected can be considered typical use conditions on the dates during which data were not collected, including weekend days and other weekdays during the peak use season. The average use levels on weekdays on which data were collected and the average use levels on weekend and weekdays on which data were not collected can be calculated from the counter data for each focal location. Subsequently, these average use levels can be compared to determine whether use levels on days during which data were collected are comparable to days during which data were not collected. If use levels are determined to be comparable, then inference from the collected measures can be extended to weekend days and weekdays on which data were not collected. If measures are not comparable (higher or lower), then inference from the collected measures should be interpreted with the relative levels of use in mind. For example, if the average use levels on weekend days is higher than the average use levels on data collection days, then there is evidence to suggest that the measures of social and ecological conditions on weekend days may be higher in magnitude or frequency than the measures collected on week days.

Visitor Use and Capacity Measures

Visitor use estimates using trail counters and parking lot counts can provide a good understanding of the number of visitors entering a trail system. However, they do not provide a complete picture of what other visitors might be experiencing in terms of visitor use levels on trails or at destinations of interest, such as overlooks. In order to better understand visitor use within the trail system at the focal attraction sites and the level of use that may be experienced by visitors, the YCC Crews recorded visitor encounters on trails (Manning 2011) and conducted PAOT counts at key locations in the trail systems of each focal location (Manning 2007).

People-at-one-time (PAOT) Counts

At each focal attraction site, one or two key locations were selected for conducting PAOT counts. Figure 3 through figure 6 highlight these locations using orange ovals and Appendix C shows these locations in greater detail. At each of the locations highlighted in orange, the YCC Crews conducted an instantaneous count of the number of visitors occurring in the pre-identified space at that specific time. These PAOT counts occurred approximately every 20 minutes or as frequently as YCC Crew were able given the length of the trail system. The time that the PAOT count occurred was also recorded.

At Fairy Falls the PAOT location was the viewing platform for the Grand Prismatic Spring Overlook (figure 3; Appendix C). Midway Geyser Basin's PAOT location was the section of boardwalk trail close to Grand Prismatic Spring (figure 4; Appendix C). However, in 2018, it also appears as if the YCC Crews recorded PAOT counts at Excelsior Geyser Crater as well. At Norris Geyser Basin, the PAOT counts occurred on the stairs leading down to the Porcelain Basin boardwalk and on the curved portion of the boardwalk heading towards Whirligig Geyser (figure 5; Appendix C). Old Faithful Geyser Basin also had two locations for PAOT counts: one on the lower part of Geyser Hill in the "Z" section of the boardwalk and one on the "L" section of boardwalk near Beehive Geyser (figure 6; Appendix C). Old Faithful Geyser Basin is unique in that it also had a special PAOT count that occurred only during Old Faithful Geyser eruptions. If an eruption of the Old Faithful Geyser occurred during data collection and the YCC Crews were able, they also documented the estimated number of visitors found on the viewing platform at Old Faithful Geyser.

This count estimation at Old Faithful Geyser during eruptions was collected by having YCC Crew members head to the platform approximately 10 min before the predicted start of the eruption. One YCC Crew member would start at each end of the viewing platform and walk toward to middle; counting visitors as best as they could along the way. Once the YCC Crews met in the middle, they added together their counts for the total number of visitors estimated to be on the viewing platform prior to the eruption.

PAOT counts are summarized by the average and standard deviation of the number of visitors counted at the PAOT location(s). All counts are also presented on a graph, organized by the time of day when the count was taken. These graphs can show the minimum and maximum counts, when those counts where taken (in terms of time of day), and the variability in the PAOT counts.

Important note about PAOT counts: Because PAOT are instantaneous counts, even at very busy locations and during peak use, zero counts can be observed at PAOT locations. Zero or very low (single digit) counts were recorded at all focal attraction site PAOT locations, these are truly low counts and not data errors by the YCC Crews.

Unfortunately, during the 2018 implementation of the PAOT protocols, the YCC crews did not use consistent naming conventions or labeling the PAOT counts on the log forms. Additionally, sometimes counts were added together in advance of being recorded (at locations where multiple counts occurred) rather than recording the counts separately. The merging of the data between the two PAOT locations made using the data more difficult as the data were unable to be "unmerged" during data analysis and cleaning. For this reason, the PAOT results for Norris Geyser Basin, Old Faithful Geyser Basin, and the Old Faithful Geyser eruptions have some data that are missing and some data that only exist as summed counts.

Visitor Encounters

Alternating with PAOT counts, the YCC Crews hiked segments of the trail system at each of the focal attraction sites and counted the number of visitors they passed. The trail segments where visitor encounters were documented are shown as dark brown lines in figure 3 through figure 6. To provide context for these visitor encounter counts, YCC Crews also documented where the counts started, ended, and which direction they traveled while counting. The start and end time of these counts were also recorded. Visitor encounters are summarized by date with the average, standard deviation, minimum, and maximum counts represented in table format for each day of data collection.

Visitor Spatial Behavior

Visitor use estimation techniques and counts of visitors within a trail system provide an accurate picture of visitor use levels at a given site. However, these numbers do not provide information on the behavior of visitors. The YCC Crews employed two different, spatially explicit methods to collect data that can be used to understand visitor behavior at the focal attraction sites: GPS-based tracking of visitor behavior and waypoint mapping of observed resource impact behaviors and occurrences of resource impacts.

GPS-Based Tracking of Visitors

To better understand where visitors go while at the focal attraction areas, the YCC Crews randomly selected visitors to participate in a GPS-based tracking study during the sampling periods at each focal attraction site (D'Antonio et al. 2010). Visitors selected to participate in the GPS component were invited to voluntarily carry a small, handheld GPS unit with them while they visited the focal attraction site. If the selected visitor agreed to participate in the study, they were given a GPS unit set to record the visitor's location every 10 seconds.

GPS units were handed out at the most popular starting point for the trail system at Fairy Falls, Midway Geyser Basin, and Norris Geyser Basin. At Old Faithful Geyser Basin, the GPS units were handed out between the Visitor Center and Old Faithful Geyser. Because the GPS units were handed out at the trailheads, visitors may have hiked beyond or into different trail systems than the ones where PAOT counts, encounter counts, and the waypoint mapping (described below) occurred.

Upon completing their hike or visit to the location, the GPS unit would be returned to the YCC Crews. Visitors were instructed to return the GPS units to visitor centers if the YCC Crews were not at the focal attraction site when the visitors returned from their hike/visit. YCC Crews were instructed to save each GPS track with a unique identifier, following a naming convention included in the OSU protocols. When working with the GPS data during the analysis phase of this project, OSU discovered that the naming protocols were not properly followed consistently in 2018, with multiple tracks accidentally being saved under the same name. This did not result in any data loss, but rather additional time and effort required for sorting and analyzing the GPS tracks.

Once a week the YELL intern downloaded the visitor GPS tracks as point data. The point data was sent to OSU for processing. The point data was cleaned of erroneous points (e.g., points on the road when GPS units were not turned off at the end of the day, points collected at the trailhead while waiting for the GPS unit to be handed out to visitors) before completing any analysis.

Cleaned GPS tracks were analyzed in GIS using a kernel density procedure. The output of this procedure identifies spatially explicit areas where high and low densities of visitor tracking points occurred. These high-density areas can be interpreted as either locations where many visitors go during their visit to the focal attraction site and/or locations where visitors spend more time during their visit. Kernel density analysis provides an *estimate or prediction* of where most of the visitor use is occurring based on the data collected in the field. This approach was used to help reduce the impact of outliers in the dataset (meaning the behavior of one tracked visitor who did something unique does not impact the overall density map). The output from the kernel density analysis therefore produces a prediction of how many visitor tracking points would be found in given area given the input dataset.

Finally, also using the GPS-based tracking points, the average time visitors spent at each focal attraction site was calculated. The minimum and maximum amount of time spent at each location was also identified from the GPS data. Any times under 1 minute were dropped from the analysis as these times were likely due to GPS-based error. This is a very time intensive analysis process when the GPS-based tracking dataset is large (which it is in this study). Therefore, while the same analysis can be completed at key locations (such as time spent on the Old Faithful Geyser viewing platform or in proximity to Grand Prismatic Spring), no further detailed analysis of this kind was able to be performed for specific locations within each focal attraction site for this report.

Important note about GPS-based tracking analysis: In this case, a 30-meter radius was used as the analysis area for the kernel density analysis. This value is determined to be appropriate for GPS-based tracking as this is a reasonable radius for understanding social considerations such as crowding and visitor flow through boardwalks. In other words, a visitor is likely aware of the 30 meters directly around them and this radius is considered appropriate for a "human scale" analysis. For example, while hiking the Midway Geyser Basin boardwalk, visitors can likely see and experience the level of visitor use 30 meters ahead of them or reflect on their experience of walking 30 meters

of boardwalk. Since geyser basins also generally do not have vegetation or trees obstructing visitor view, visitors can experience the conditions of boardwalks across from them.

Because of the 30-meter radius that is used in the analysis to help understand overall density on the boardwalks, the analysis output will show results that appear off of the boardwalks. **It is important to note that the width of the density layer in the map is not necessarily reflective of off-trail use or visitors being off-boardwalk;** it is an artifact of the 30-meter radius around each "visitor" used to calculate the kernel density. Kernel density maps are best interpreted as a means of highlighting locations of potential management concern or further examination as they show where the majority of visitors are going and/or where visitors are lingering. The raw, cleaned GPS-based tracking points are provided in the report to help visualize off-trail or off-boardwalk behavior.

Additionally, the caption of each kernel density map for the GPS-based tracking and the overall data sets of waypoints (see next section) includes units for the low, medium, and high density areas. These units represent the *expected counts of GPS tracking points* for each density level. These units do not represent individual visitors. Because individual tracking points can be represented of one or many visitors, it is not a simple analysis to convert these expected counts (that are the default and logical kernel density output) to individual visitors per area. While it is possible to determine how many visitors go to a specific location or stop at a specific location (e.g., Excelsior Geyser Crater), this analysis was considered outside the scope of a monitoring project as it is incredibly labor and time intensive. An example of how this analysis could be conducted will be provided to YELL in the fall of 2019 for only Steamboat Geyser as an addendum to this report (see "Next Steps" section).

Waypoint Mapping of Visitor Behaviors & Resource Impacts

GPS-based tracking can document where visitors go as well as how long they may spend in a trail system or at a location. However, it does not document other behaviors of interest or impacts that may be related to visitor behavior. To better understand visitor behavior and resulting impacts from visitor use at the focal attraction sites, a waypoint mapping protocol was developed for the YCC Crews. Using small, handheld GPS units the YCC Crews systematically hiked the trail segments of interest (see the brown trail sections in figure 3 through figure 6) and marked a waypoint when they observed a behavior of interest or a resource impact of concern. Behaviors of interest and resource impacts of concerned were identified by YELL managers during initial project development and scoping in 2017. The same list of behaviors and impacts was monitored during the 2018 season.

Each waypoint was assigned a unique ID and a behavior or impact code was assigned to that waypoint ID on a separate data sheet. Resource impacts such as piece of trash or footprints in geyser basins were recorded and marked with a waypoint only once during each sampling period to prevent over sampling of these longer lasting impacts. Behaviors of interest, such as visitors hiking off-trail or off-boardwalks or blocking trails, were recorded and marked with a waypoint each time they were observed.

YCC Crews also took photos of behaviors or impacts that they found interesting or thought deserved extra documentation. Not many photo numbers were recorded during the 2018 data collection season. Once a week, the YELL intern downloaded the GPS units and emailed the waypoints to OSU. After data entry was completed for the behavior and impact codes data sheets, the codes were assigned to the waypoints and analyzed in GIS.

Behavior and impact waypoints were analyzed at each focal location and were further analyzed by type of point for each focal location (see Appendix H). First, a kernel density analysis was performed with all the points, regardless of point type collected at each focal location, to identify spatially explicit areas within the focal attraction where high and low densities of behavior or impact waypoints occurred. These high-density areas can be interpreted as locations where many waypoints occurred or where waypoints frequently occurred at the focal attraction site. Kernel density analysis provides an *estimate or prediction* of where most of the waypoints were collected in the field.

The waypoints for each focal location were further classified by waypoint type into one of six waypoint groups. Waypoints were grouped together to combine similar behaviors or similar resource impacts into mutually exclusive datasets within each focal location for kernel density analysis. Table 2 reports the six waypoint categories used for grouping and identifies the waypoint codes included within each category. Kernel density analyses were conducted on each of the six waypoint categories to further identify high-density and low-density areas within each focal location where many waypoints of a certain type occurred or where waypoints of a certain type frequently occurred.

Important note about waypoint mapping procedures: Some of the types of resource impacts that the YCC Crews documented may have remained on the landscape for hours or days (such as litter or carvings into hydrothermal mats). YCC Crews tried to minimize instances where they recorded the same impact item (ex: piece of trash, footprint in geyser basin) more than once by using their notes, memory of what they collected, and the memory of YCC Crew leaders. However, because the YCC Crews members changed each week, it is possible that less ephemeral resource impacts were recorded on multiple occasions. YELL is working on solutions using an in-house app and tablets for data collection to reduce repeated mapping of the same resource impacts for the 2019 YCC Crew data collection effort.

Table 2. Resource impact and behavior code categorization for kernel density analysis by category.

Category	Waypoint Code	Code Definition
Resource Impact Waypoint Categories		
Thermal Area Resource Impact	FOOT	Footprint observed in thermal area
	OBJ 2	Personal object observed in thermal area (e.g., hat, bottle)
	TH LIT 2	Litter observed in thermal area
	THROW 2	Object observed in thermal pool
	TH GRAF 2	Graffiti observed in thermal mat
Other Resource Impact	SOC 1	Social trail < 3m long
	SOC 2	Social trail > 3m long
	LIT 2	Litter observed in other area
	GRAF 2	Graffiti observed in other area
	OTHER 1	Please describe in detail
Resource Impact Behavior Waypoint Categories		
Thermal Area Impact Behavior	OB 1	< 1m off boardwalk in thermal area
	OB 2	> 1m off boardwalk in thermal area
	OBJ 1	Personal object dropped or blown into thermal area (e.g., hat, bottle)
	TH LIT 1	Visitor littering in thermal area
	THROW 1	Throwing object into thermal pool
	TH GRAF 1	Drawing graffiti in thermal mat
Other Impact Behavior	OB 3	Visitor observed in other closed area
	LIT 1	Visitor littering in other area
	NOISE 1	Excessive traffic noise (e.g., motorcycles, engines, honking)
	GRAF 1	Drawing graffiti in other area
	OTHER 1	Please describe in detail
Visitor Conflict/ Congestion Behavior	FLOW	Groups obstructing flow of others
	ROUGH	Roughhousing
	NOISE 2	Other excessive human noise (e.g., shouting, music, use of phones)
	CON 1	Non-verbal visitor conflict (e.g., tension observed as one visitor or group crowds or cuts in front of another)
	CON 2	Verbal visitor conflict (e.g., audible verbal conflict between visitors)
Wildlife Impact Behavior	PET 1	Pet on boardwalk
	PET 2	Pet off leash
	FEED	Feeding wildlife
	WILD 1	Visitor 5-25m from wildlife
	WILD 2	Visitor < 5m from wildlife

Results

The results in this report are summarized by focal attraction site. Unless otherwise noted, all data collection methods described above occurred at all focal attraction sites. For a full breakdown and the data collection effort at each focal attraction site by the YCC Crews, please see the "Data Summary from Summer 2018 Data Collection Effort & Repeat Photography Study" document delivered to YELL as part of this project on February 1, 2019 (Sidder & D'Antonio 2019). A condensed summary of the data collection effort is also provided in Appendix B and an overview of the YCC Crews 2018 data collection effort is provided in table 3.

Table 3. Overall data collection effort by the YCC Crews during the summer of 2018.

Focal Attraction Site	# Periods of Data Collection	Data Collection Effort (hh:mm)*
Fairy Falls	8	37:30
Midway Geyser Basin	7	38:30
Norris Geyser Basin	6	32:00
Old Faithful Geyser Basin	8	38:15

*Occasionally the start and/or end times of data collection were not recorded; therefore, the estimated hours of data collection effort are conservative.

While the results are presented by focal location, table 3 summarizes the overall GPS-based tracking effort from this study for all focal locations. The GPS-based tracking portion of the study is the only monitoring protocol that required voluntary participation by visitors to be included in the study. Overall, the YCC Crews had a high response rate for the GPS-based tracking portion of the study, with response rates ranging between 83% and 91%. These response rates are comparable to those achieved in 2017, which ranged between 83% and 93%. Group sizes in 2018 ranged from 3.1 visitors per group (Old Faithful Geyser Basin) to 3.5 visitors per group (Norris Geyser Basin). The number of useable GPS tracks for analysis is smaller than the number of GPS acceptances received in the field and recorded on the data collection forms (table 4). This is likely due to several factors including the removal of GPS tracks that had data errors, saving mistakes made during the data download phase, and GPS unit error. The number of "lost" tracks in this study was higher than expected. Despite this, the YCC Crews collected enough useable tracks for analysis of visitor behavior at the focal attraction sites.

Table 4. Summary of GPS-based tracking data collection effort and response rate for 2018 data collection.

Focal Attraction Site	Number of Acceptances*	Number of Rejections*	Response Rate	Number of Useable Tracks for Analysis	Group Size Average	Group Size ±Standard Deviation
Fairy Falls	267	35	88.4	172	3.4	2.2
Midway Geyser Basin	207	21	90.8	152	3.4	2.5
Norris Geyser Basin	193	40	82.8	162	3.5	2.7
Old Faithful Geyser Basin	215	39	84.6	132	3.1	1.8

*Number of acceptances and number of rejections are calculated from the daily contact log forms that the YCC Crews record in the field and may not match the actual number of useable GPS tracks due to recording errors onsite.

Fairy Falls

Visitor Use Estimation

Parking Lot Counts

The parking lot at Fairy Falls contains 74 gravel parking spaces and 23 paved parking spaces for a total of 97 designated parking spots. Figure 7 displays average hourly parking counts for Fairy Falls; meaning all 9:00 hourly counts were averaged across the summer, all 10:00 counts were averaged across the summer, etc. The percent change in the total number of vehicles parked is shown in table 5. See Appendix D for full summary tables of parking lot counts. Appendix E contains graphs of average, hourly vehicle counts for each focal attraction site parking lot by date. The percent change over hour provides a comparative metric for how rapidly the number of vehicles in the parking lot changes each hour.

At 9:00 there is an average of 66 vehicles parked at Fairy Falls. Between 9:00 and 10:00 there is, on average, an 82% increase in parking. This rapid increase in parking results in the Fairy Falls parking lot filling between the 10:00 and 11:00 hour. Peak vehicle use occurs at 11:00 with, on average, 105 vehicles parked in designated spots. The largest percent decrease in total vehicles occurs between 11:00 and 12:00, with a 14% loss in the number of vehicles. After 12:00, the number of vehicles parked in designated spots ranges between 80 and 85 vehicles on average throughout the rest of the sampling day. From 12:00 to 15:00, the direction of the percent change (either increase or decrease in total vehicles) varies, but overall, the magnitude of the change is small, ranging from a 2% change to a 5% change.

In terms of undesignated and roadside parking, as the parking lot fills in the morning, undesignated and roadside parking begins in increase at 10:00. The number of combined undesignated and roadside parked vehicles remains consistent between 30 and 35 vehicles from 11:00 through 15:00. Overall, the Fairy Falls parking lot is full between 10:00 and 12:00. Even when parking spots appear to be available in the gravel or paved lot after 12:00, roadside and undesignated parking is still present and constant from 10:00 to 15:00.

At Fairy Falls, the discrepancy between the number of vehicles recorded in designated spots versus the number of total designated spots (97) could be the result of the gravel lot. The gravel parking lot (or overflow lot) at Fairy Falls does not have clearly defined parking spaces. Therefore, creative or careful parking in the gravel lot could result in the total number of designated spaces varying slightly each day or hour. Meaning, depending the types of cars parked in the gravel lot or how closely cars are parked together, there could have been instances where more than 74 vehicles parks in the gravel lot resulting in a total designated parking count greater than 74 even though all cars were parked in a designated parking area.

Table 5. Average percent change over hour in total vehicles in the Fairy Falls parking lot.

Time	Percent Change in Total Vehicles
9:00 to 10:00	82 %
10:00 to 11:00	19 %
11:00 to 12:00	-14 %
12:00 to 13:00	4 %
13:00 to 14:00	-2 %
14:00 to 15:00	-5 %

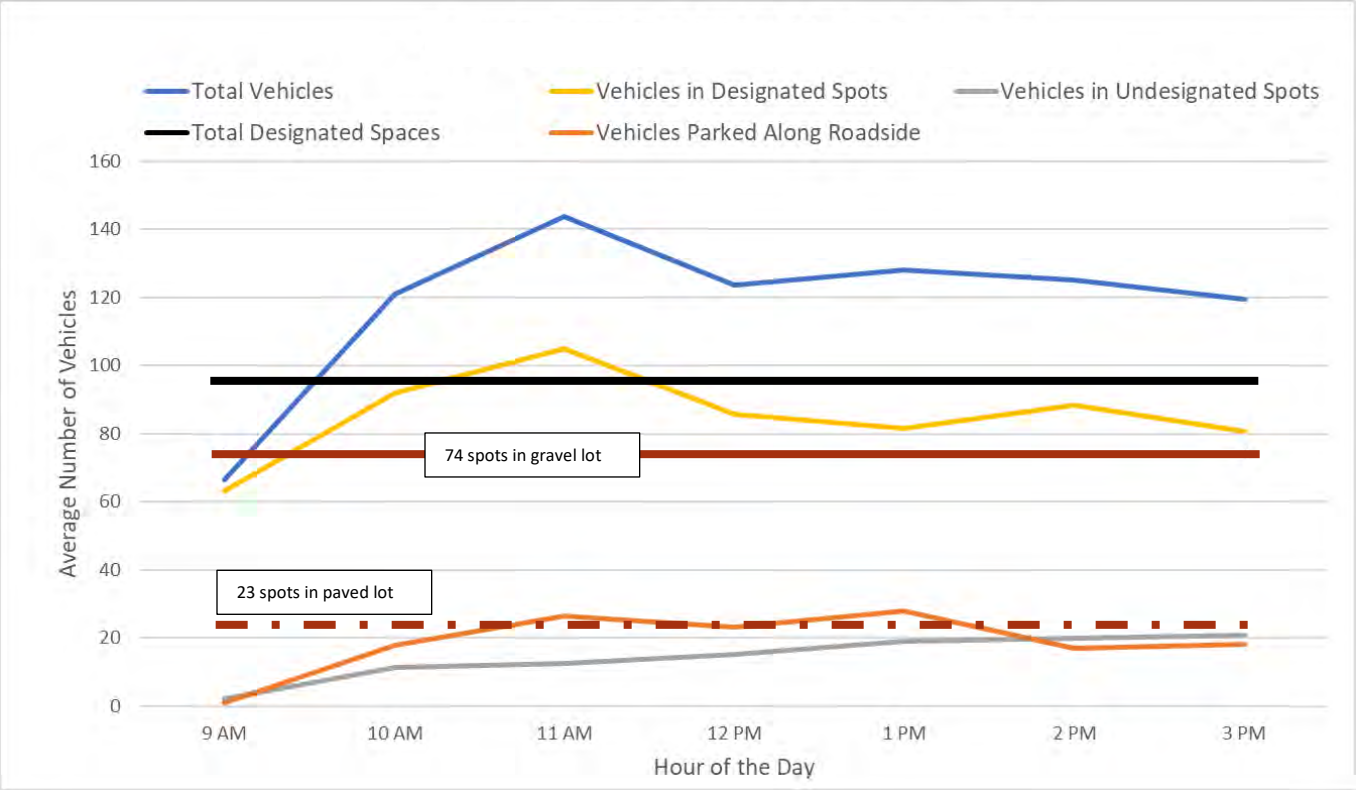

Figure 7. Average number of total vehicles parked at Fairy Falls (blue line). The total number of vehicles is the sum of the average number counted in designated spots in the Fairy Falls parking lot (yellow line), in undesignated spots (orange line), and parked along the roadside (grey line) by hour of the day. The Fairy Falls parking lot has a total of approximately 74 designated parking spots in the gravel lot (solid red line) and 23 designated spots in the paved lot (dashed red line). The black line represents total of gravel and paved parking spots.

Table 6 summarizes the average number of tour buses, RVs, and vehicles queued in the Fairy Falls parking lot observed during the sampling period by date of collection. Tour buses were observed on three dates during the data collection, and only one bus, on average, occurred on those dates. RVs occurred consistently on the data collection dates, with average numbers ranging from zero RVs (note standard deviation is one suggesting an RV was present on the date) to four RVs. Vehicle queuing occurred intermittently during the data collection dates, with few or no average vehicles queued on some dates and longer average vehicle queues (maximum average of 12 vehicles) on other dates.

Table 7 summarizes the average number of tour buses, RVs, and queued vehicles in the Fairy Falls parking lot by hour of the day. Tour buses tended to occur during the 10:00, 11:00, and 15:00 hours with one bus on average observed during those hours. Across other hours of the day at Fairy Falls, tour buses were not observed. RVs tended to occur consistently throughout the sample hours with on average one to two RVs present in the parking lot during each hour of the day. Vehicle queues tended to be longest during the 10:00 and 11:00 hours when vehicle parking is rapidly increasing (tables 5 and 7), with average queues of six to nine vehicles. Queues were shortest on average at the beginning of the day or toward the middle/late afternoon.

Table 6. Average number of tour buses, RVs, and vehicles queued in the parking lot at Fairy Falls summarized by sampling day. These counts were taken at the same time as the parking lot counts. SD = standard deviation, n = sample size.

		Tour Bus Counts		RV Counts		Vehicle Queue Counts	
Date	***n***	**Average**	**(±SD)**	**Average**	**(±SD)**	**Average**	**(±SD)**
6/18/2018	3	0	0	4	3	0	0
6/22/2018	4	1	1	1	1	1	1
6/28/2018	7	0	0	2	1	1	3
7/3/2018	5	0	0	0	1	6	4
7/23/2018	4	1	1	3	2	1	2
7/27/2018	3	0	0	1	1	0	0
7/31/2018	7	1	1	1	1	12	12
8/8/2018	5	0	0	1	2	3	8
Overall	**-**	**0**	**0**	**2**	**1**	**3**	**4**

Table 7. Average number of tour buses, RVs, and vehicles queued in the parking lot at Fairy Falls summarized by time of day. These counts were taken at the same time as the parking lot counts. SD = standard deviation, n = sample size.

		Tour Bus Counts		RV Counts		Vehicle Queue Counts	
Time	***n***	**Average**	**(±SD)**	**Average**	**(±SD)**	**Average**	**(±SD)**
9:00	6	0	0	1	2	0	0
10:00	5	1	1	1	1	6	7
11:00	5	1	1	2	1	9	14
12:00	4	0	0	2	1	1	1
13:00	6	0	0	2	1	4	6
14:00	5	0	0	2	2	5	6
15:00	6	1	1	1	3	1	1
Overall	**-**	**0**	**0**	**2**	**2**	**4**	**5**

Automatic Trail Counters

The trail counter at Fairy Falls was deployed from June 13, 2018, through October 24, 2018, collecting data continuously during that time period in hourly time bins. The data are summarized according to season of use, with data collected from June 13, 2018, through September 3, 2018 (Labor Day), being categorized as the peak use season and data collected from September 4, 2018, through October 24, 2018, being categorized as shoulder season data. Peak season data are reported here in the body of the report. The same graphical and tabular summaries are presented for the shoulder season data in Appendix F.

The count data included in this report are calibrated data; uncalibrated count data is not presented. Ten hours of calibration data collected across eight days throughout the peak use season were used to calibrate the Fairy Falls counter (see table 1). The calibration coefficient for the 2018 deployment of the Fairy Falls counter is 1.84. A calibration coefficient over a value of one indicates the counter was undercounting the number of passes in front of the counter. The calibration coefficient of 1.84 suggests the counter at Fairy Falls was under counting by almost a factor of two. The R^2 value for the regression equation used to generate the calibration coefficient is 0.96, suggesting that the counter consistently undercounted the number of passes. The high calibration coefficient, and

accompanying R^2 value, suggest the placement of the counter could be improved to reduce the amount of error in the originally collected count data. For reference calibration coefficients between 0.75 and 1.25 are usually considered within the normal range of counter error for well-placed counters. Despite the high calibration coefficient, the corrected trail counter data is considered an accurate estimate of overall visitor use/counts.

Across the peak use season, daily total counts ranged from approximately 2,000 counts to just over 7,000 counts (figure 8). A count is considered one pass by the counter; it cannot be interpreted as an individual. The counters record a tally each time an individual passes the count location regardless of direction of travel, so counts reported here correspond to either an entrance or an exit from the Fairy Falls trail system.

Looking across hours of the day, visitors tended to begin arriving at Fairy Falls in the 5:00 hour and continued until approximately the 23:00 hour (table 8; figure 9). Hourly counts begin exceeding an average of 100 counts per hour at 8:00, growing to a peak of an average of 596 counts per hour at 12:00 and declining to an average of 82 counts per hour at 20:00. The average hourly counts rise steadily in the morning during a four-hour period from 8:00 to 12:00 before declining less rapidly from 12:00 to 20:00 (table 9).

Table 8. Average number of hourly counts during the peak use season (June 13 through September 3, 2018) at the Fairy Falls trailhead. SD = standard deviation; N = sample size.

Hour	Average	±SD	N*
0:00	0	0	82
1:00	0	0	82
2:00	0	0	82
3:00	0	1	82
4:00	0	0	82
5:00	1	2	82
6:00	8	7	82
7:00	36	20	82
8:00	119	46	82
9:00	285	96	82
10:00	513	191	82
11:00	584	215	81
12:00	596	170	82
13:00	584	142	83
14:00	543	116	83
15:00	499	103	83
16:00	418	98	83
17:00	327	79	83
18:00	240	71	83
19:00	178	68	83
20:00	82	49	83
21:00	13	15	83
22:00	1	2	83
23:00	0	1	83

*N varies across hours of the day based on the hour of counter installation, the hours of data download, and the hour of counter removal.

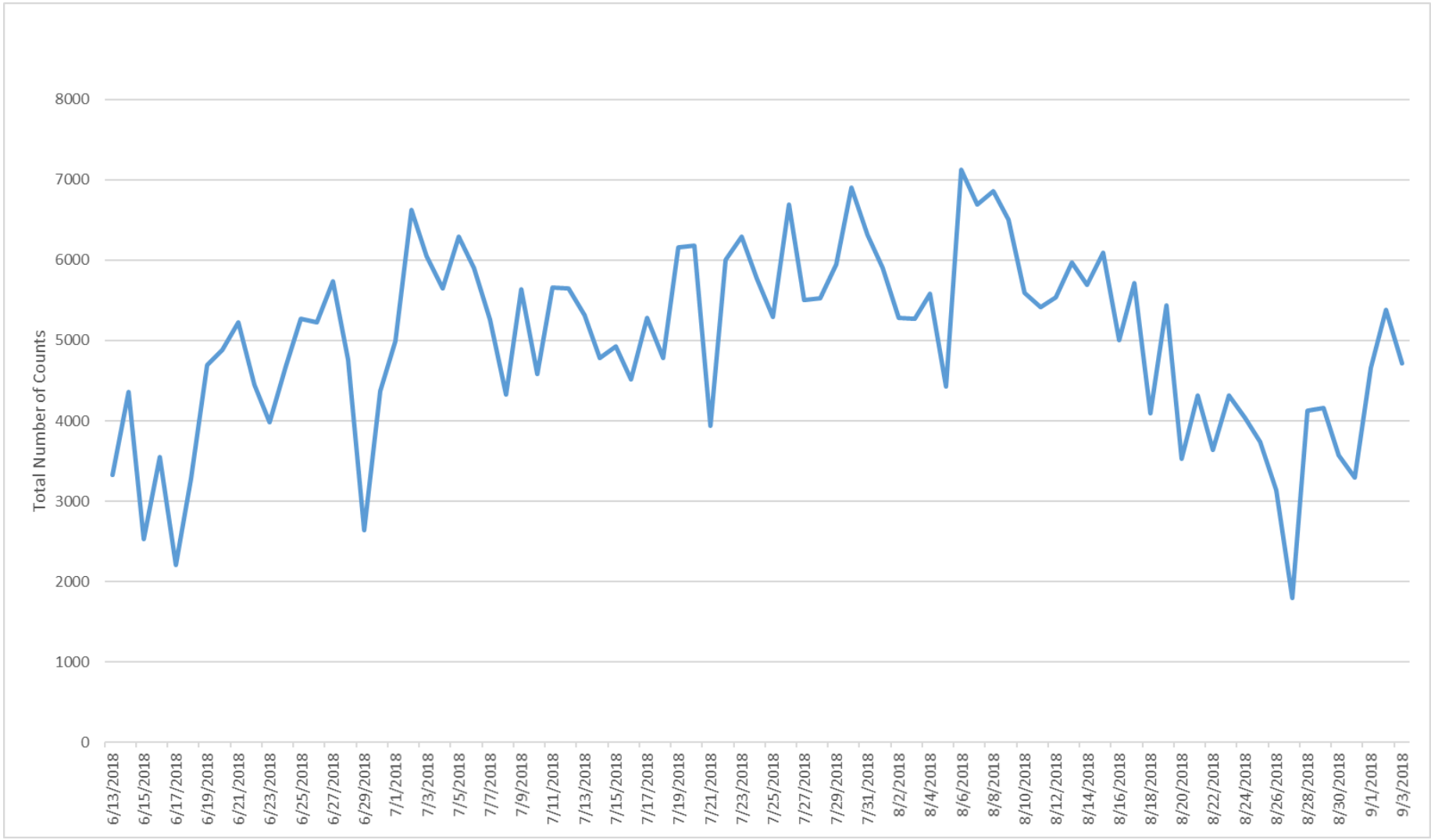

Figure 8. Daily total number of counts at the Fairy Falls trailhead during the peak use season from June 13 through September 3, 2018.

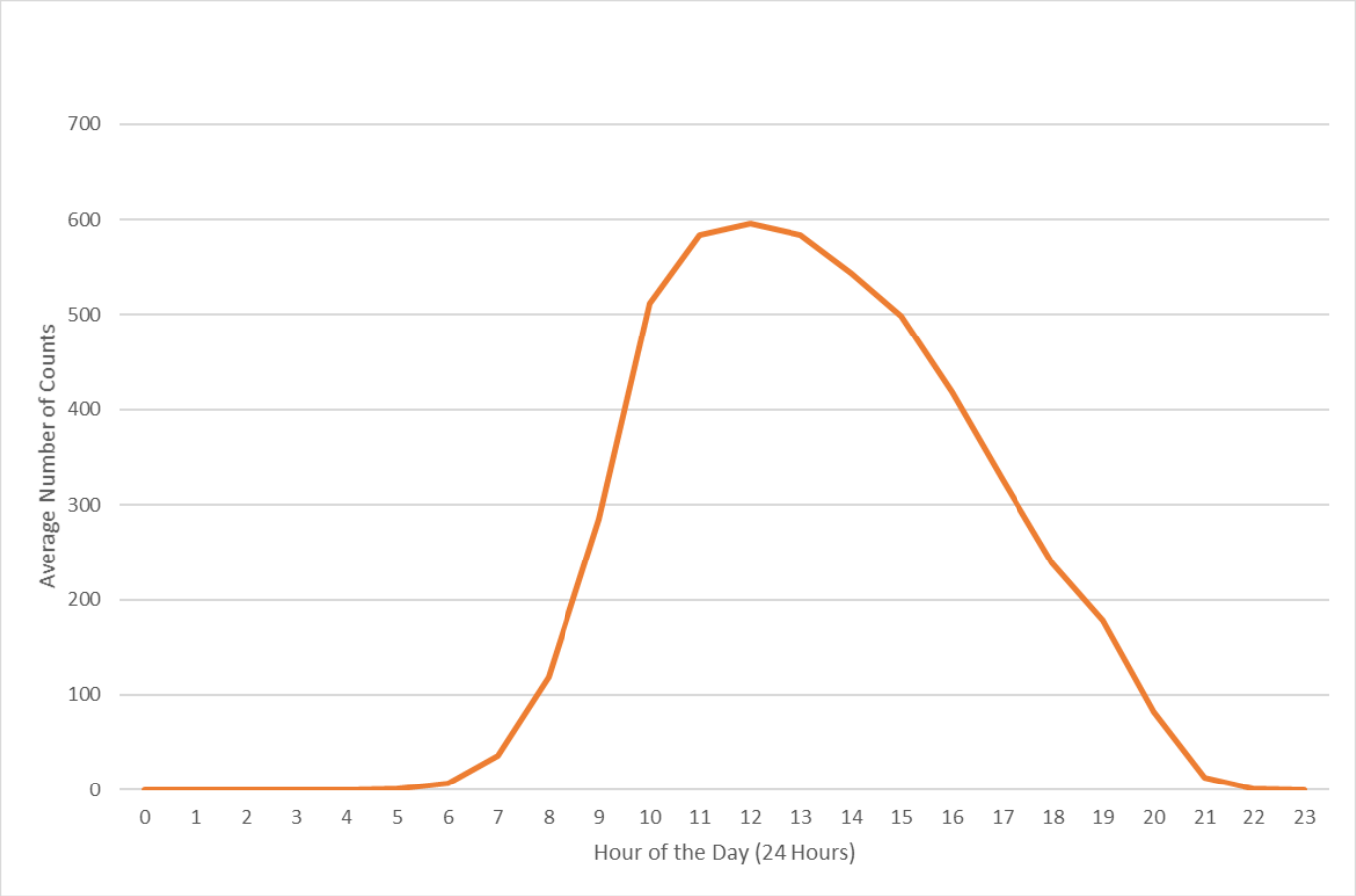

Figure 9. Average number of hourly counts at the Fairy Falls trailhead during the peak use season from June 13 through September 3, 2018.

Table 9: Percent change in average total counts across the day for Fairy Falls counter.

Time	Percent Change in Total Counts by Hour
6:00 to 7:00	350 %
7:00 to 8:00	231 %
8:00 to 9:00	139 %
9:00 to 10:00	80 %
10:00 to 11:00	14 %
11:00 to 12:00	2 %
12:00 to 13:00	-2 %
13:00 to 14:00	-7%
14:00 to 15:00	-8 %
15:00 to 16:00	-16 %
16:00 to 17:00	-22 %
17:00 to 18:00	-27 %
18:00 to 19:00	-26 %
19:00 to 20:00	-54 %
20:00 to 21:00	-84 %
21:00 to 22:00	-92 %
22:00 to 23:00	-100 %
23:00 to 24:00	0 %

Across days of the week during the peak use season, the average number of counts varied across days of the week (table 10; figure 10). Interestingly, the average number of counts Monday through Thursday exceeded the average number of counts Friday through Sunday. This pattern of weekday counts exceeding, on average, weekend day counts is not typical; traditionally, higher visitation is experienced on weekend days at recreation sites. Across the days of the week, counts on Saturdays was the most consistent, given it has the smallest standard deviation value. However, the magnitude of the standard deviation values across all days of the week suggests that visitation across days of the week varies by ± nearly 20% of the average across the peak use season.

Table 10. Average number of daily counts by day of week during the peak use season (June 13 through September 3, 2018) at the Fairy Falls trailhead.

Day	Average	±SD	N*
Sunday	4,749	1,124	12
Monday	5,137	1,632	12
Tuesday	5,341	841	11
Wednesday	5,165	1,045	12
Thursday	5,318	974	12
Friday	4,702	1,287	12
Saturday	4,576	733	12

*N varies across days of the week due to the day of counter installation and the day of counter removal.

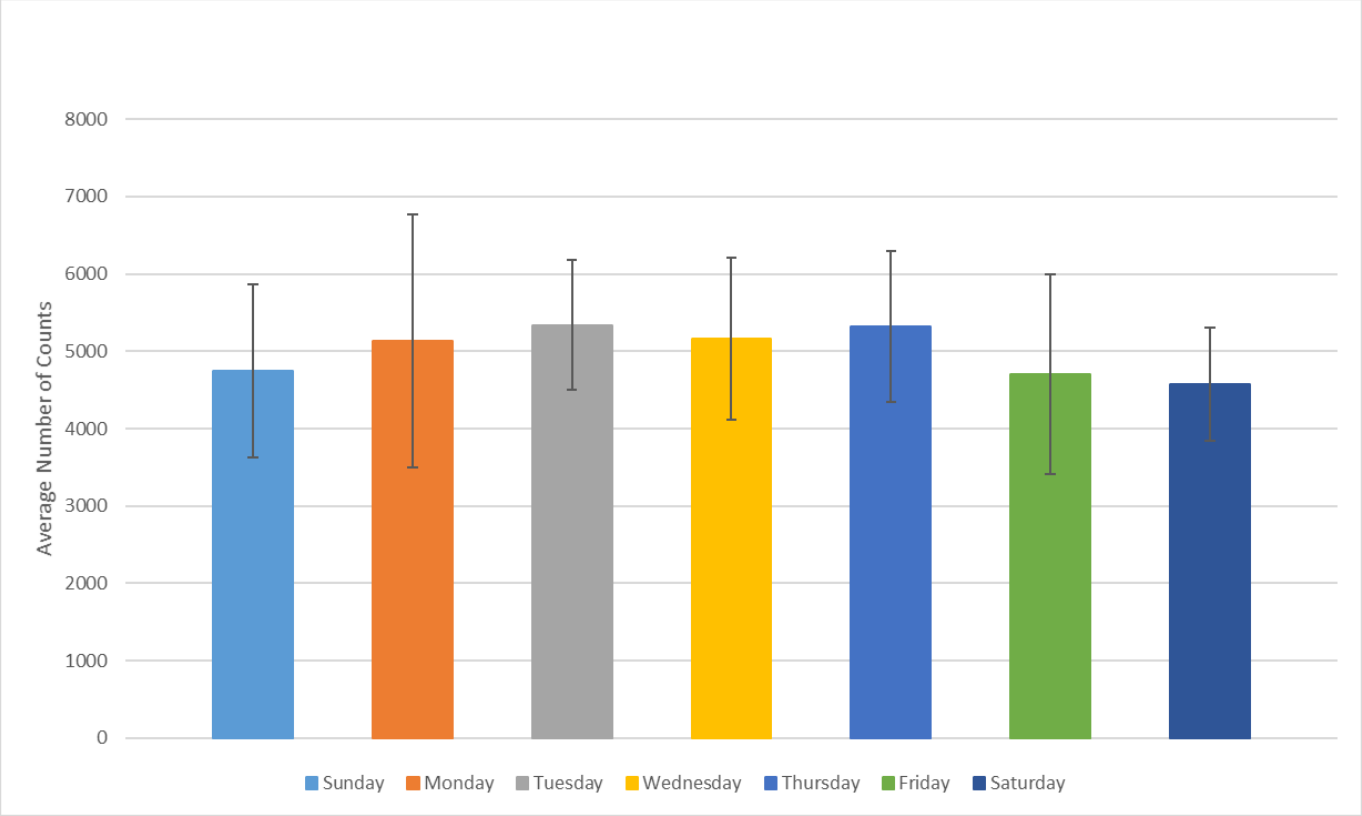

Figure 10. Average number of counts, by day of week, at the Fairy Falls trailhead during the peak use season from June 13 through September 3, 2018. The vertical black bars extending above and below the top of the colored bars represent the standard deviation for the estimate of the mean for each day.

Visitor Use/Capacity Measures

While hiking the new Grand Prismatic Spring Overlook trail, an approximately 0.4 mile trail which opened July 2017, YCC Crews encountered approximately 250 other visitors on average (table 11). The number of encounters observed by the YCC Crews on this trail ranged from 13 (recorded on 6/28/2018) to just over 500 visitors (recorded on 7/3/2018; table 11). Fewer visitors were observed at the Grand Prismatic Spring overlook viewing platform (table 12). On average, 49 visitors were observed on that platform at one time with a maximum observation of 203 visitors at or around the platform location (occurred on 8/8/2019, a date that experienced higher than usual use; see note on table 12). Temporally, visitor use on the platform remains relatively stable across the day with a few higher peaks recorded during later afternoon PAOT counts (figure 11). It is important to remember that PAOT counts are variable and occur at one instant in time, so low values can be observed during periods of overall high visitor use and higher counts can be observed during overall lower use times (e.g., high counts occurring in the afternoon even though overall use tends to be highest in the morning hours). PAOT and trail counters provide a more site-specific metric of how visitor experiences may vary at a location.

Table 11. Summary of trail encounters (number of visitors passed) for the approximately 0.4-mile Grand Prismatic Spring Overlook trail at Fairy Falls. SD = standard deviation; N = number of counts that equaled the entire trail length.

Date	Average	±SD	Min	Max	N
6/18/2018	253	65	187	335	6
6/22/2018*	NA	NA	NA	NA	NA
6/28/2018	188	74	13	270	17
7/3/2018	327	127	111	516	12
7/23/2018	252	108	135	403	7
7/27/2018	271	138	142	458	4
7/31/2018	274	82	135	407	13
8/8/2018	221	74	112	342	16
Overall	**248**	**100**	**13**	**516**	**76**

*YCC Crew notes indicate that Former Park Superintendent Dan Wenk visited Fairy Falls on 6/22/2018 and data collection was halted upon his arrival. Thus, no encounters data were collected that day.

Table 12. PAOT summary for PAOT location (Grand Prismatic Spring) at Fairy Falls. SD = standard deviation; N = sample size.

Date	Average	±SD	Min	Max	N
6/18/2018	26	9	15	37	6
6/22/2018	31	16	9	45	4
6/28/2018	51	18	21	85	15
7/3/2018	61	23	25	106	14
7/23/2018	32	7	25	42	5
7/27/2018	26	9	22	34	4
7/31/2018	37	15	13	57	17
8/8/2018*	146	39	11	203	4
Overall	**49**	**33**	**9**	**203**	**69**

* Note that this average is much higher than any other day of data collection, these values were double-checked in both the datasheets and calculations. All PAOT counts on 8/8/2018 were higher than normal for this location. YCC Crews indicated the presence of tour groups at Fairy Falls on 8/8/2018 which may have contributed to the higher than normal counts on this date.

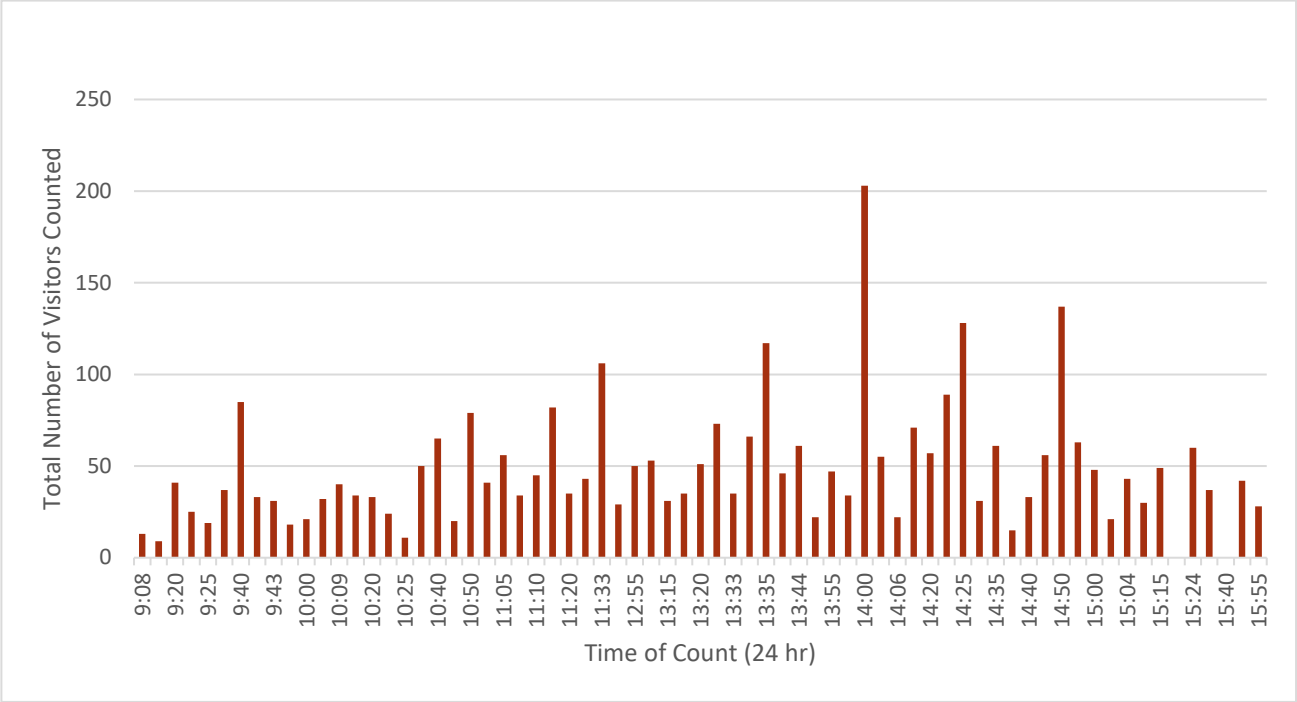

Figure 11. All individual PAOT counts organized by time at the Grand Prismatic Overlook platform at Fairy Falls.

Visitor Spatial Behavior

Note on density maps: For this section, on all kernel density maps, although the blue density layer may extend beyond the trail or boardwalk that does not necessarily mean use or impacts extend this far. The width of the blue density layer on the maps is an artifact of the analysis type. See "Methods" section for more detail.

GPS-based Tracking

Figure 12 and figure 13 show the extent and density of GPS study participants at Fairy Falls. The GPS tracks collected from participants at Fairy Falls are displayed in figure 12, with the blue dots representing collected GPS tracking data. On average, visitors to the Fairy Falls trail system spend approximately one hour recreating. The minimum visit duration was 10 minutes and the maximum visit duration was just over five hours (table 13).

Table 13. Average, minimum, and maximum amount of time spent in the trail system at Fairy Falls by GPS participants.

Measure	Time (h:mm:ss)
Average	1:03:00
±SD	0:51:00
Minimum	0:10:00
Maximum	5:09:00

Figure 12. Raw, cleaned GPS-based tracking point data collected from visitors at Fairy Falls. GPS units were handed out at the trailhead.

Figure 13. Density of GPS-based tracking points collected from visitors at Fairy Falls. Low densities were an estimated count of 18-271 points per 1 m^2 and high densities were an estimated 2,247-4,621 points per 1 m^2**.**

Looking at the pattern of use at Fairy Falls, most visitors who start their visit at the Fairy Falls trailhead are hiking to the Grand Prismatic Spring Overlook. This is evidenced by the darker and medium blue colors that lead from the trailhead to the Grand Prismatic Spring Overlook (figure 13). Additionally, a portion of visitors tend to continue further into the trail system to Fairy Falls (the waterfall feature itself), another popular stopping location. This area is also highlighted with a darker blue patch deeper into the trail system, indicating a higher density of points, in figure 13. A minority of visitors continue even further into the trail system, traveling both north and west on the trail network from the Fairy Falls trailhead. The absence of darker blue coloring on these sections of trail indicates that the density of points in these areas is smaller than experienced at the other, more popular locations.

Waypoint Mapping

In addition to GPS tracking of visitor travel patterns at Fairy Falls, two types of GPS waypoints were collected to mark where behaviors expected to cause resource impacts occur along the trail (hereafter impact behavior waypoints) and to mark where resource impacts have already occurred along the trail (hereafter resource impact waypoints). The focus of this data collection was from the parking lot trailhead to the Grand Prismatic Spring Overlook. Resource impacts were not mapped deeper into the Fairy Falls trail system. A total of 1,139 waypoints were collected at Fairy Falls across eight days of sampling (figure 14). The darker blue portions of the kernel density map in figure 14 indicate that a higher number of waypoints occurred at these locations. At Fairy Falls, the highest density of waypoints occurred on or around the observation deck for the Grand Prismatic Spring.

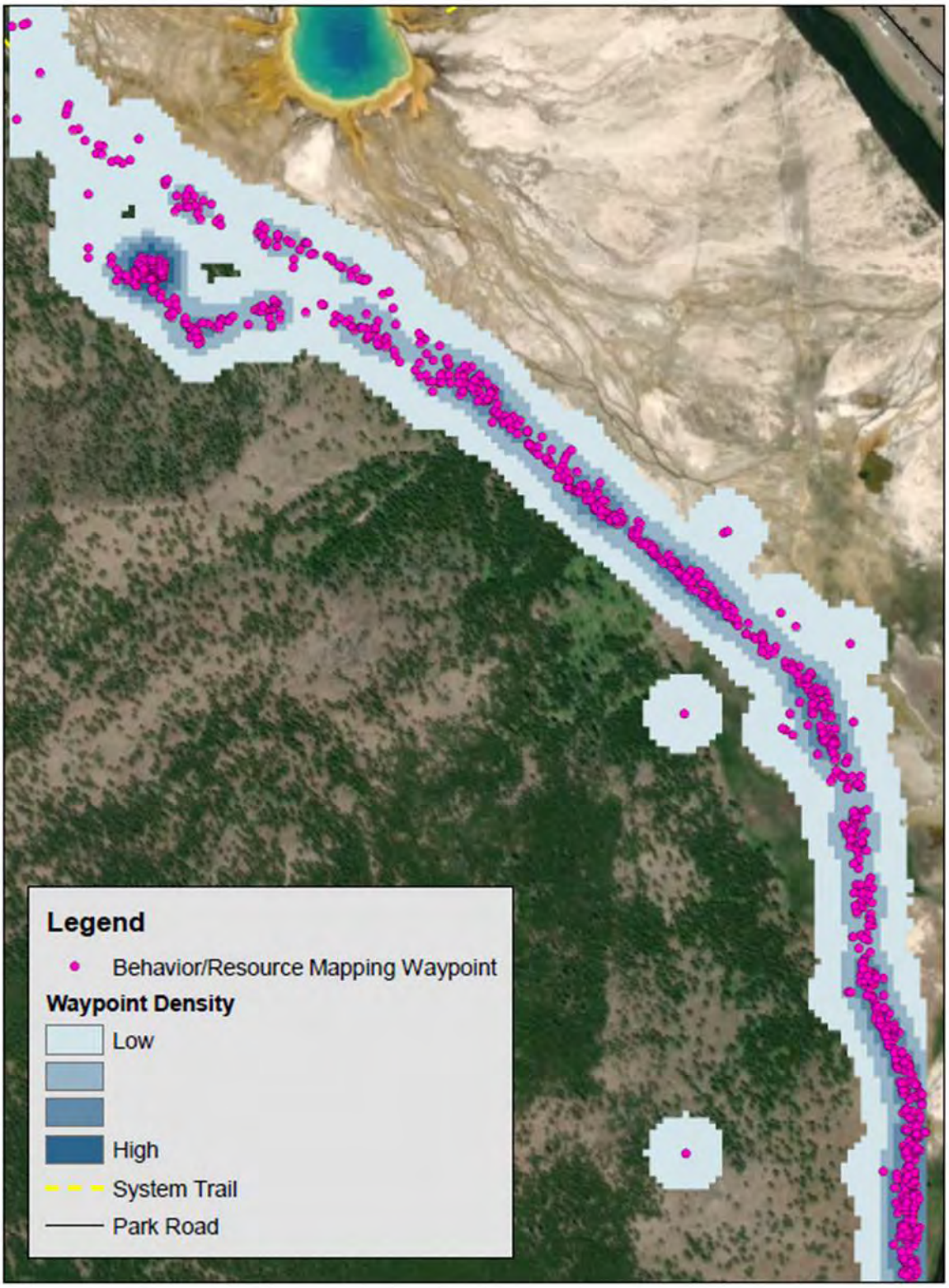

Figure 14. Density of impact behavior and resource impact waypoints along the trail to the Grand Prismatic Overlook at Fairy Falls trailhead. Low densities were an estimated count of < 1-6 points per 1 m^2 and high densities were an estimated count of 35-73 points per 1 m^2.

To generate a more detailed understanding of how specific resource impacts or impact behaviors are spatially distributed at Fairy Falls, the resource impact and impact behavior waypoints were separated for further analysis. Waypoints were matched to behavior codes using a spatial join. During the match process, 78 waypoints were unable to be matched due to missing behavior codes, resulting in a 93% match rate between recorded behavior codes and marked GPS waypoints. The results to follow are generated from the 1,061 matched waypoint and behavior code pairs.

Figure 15 shows the frequency distribution and number of observations for impact behavior waypoints at Fairy Falls. A total of 41 impact behavior waypoints were marked, with most of those waypoints being classified as visitors being observed in a non-thermal closed area, visitors being observed less than 1 m off a boardwalk in a thermal area, or another type of impact behavior without a code. Figure 16 shows the frequency distribution and number of observations for the resource impact waypoints at Fairy Falls. A total of 1,020 resource impact waypoints were marked, with the overwhelming majority of those waypoints marking locations where litter was observed in a non-thermal area. Refer to table 2 for detailed descriptions for each impact behavior and associated resource impact code. For waypoints labeled as “Other” please see detailed table in Appendix H listing the comment recorded by the YCC Crews for each “Other” waypoint.

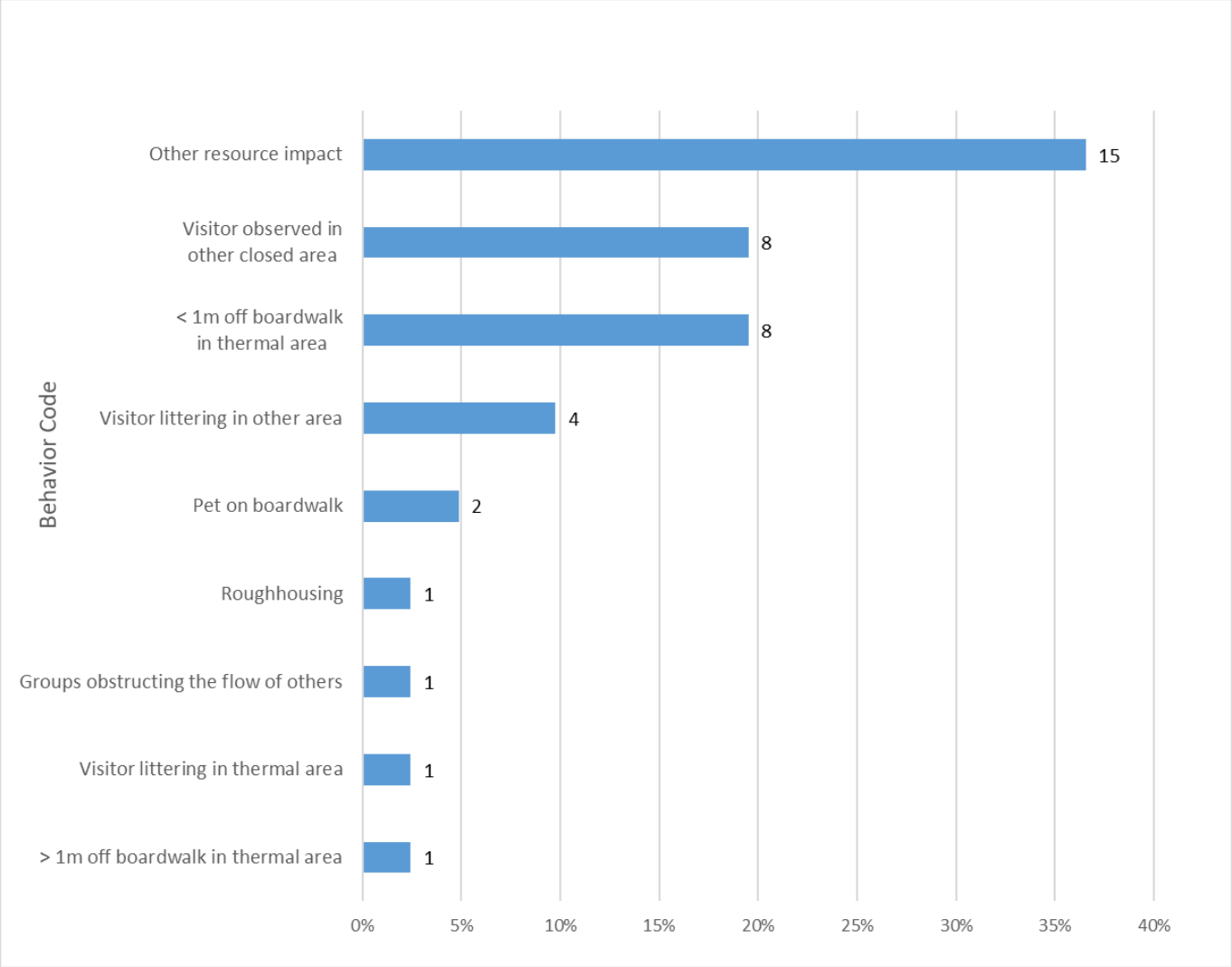

Figure 15. Frequency and counts of impact behavior code waypoints collected along the Fairy Falls trail. Number next to bar represents the "n" value or number of observations per category.

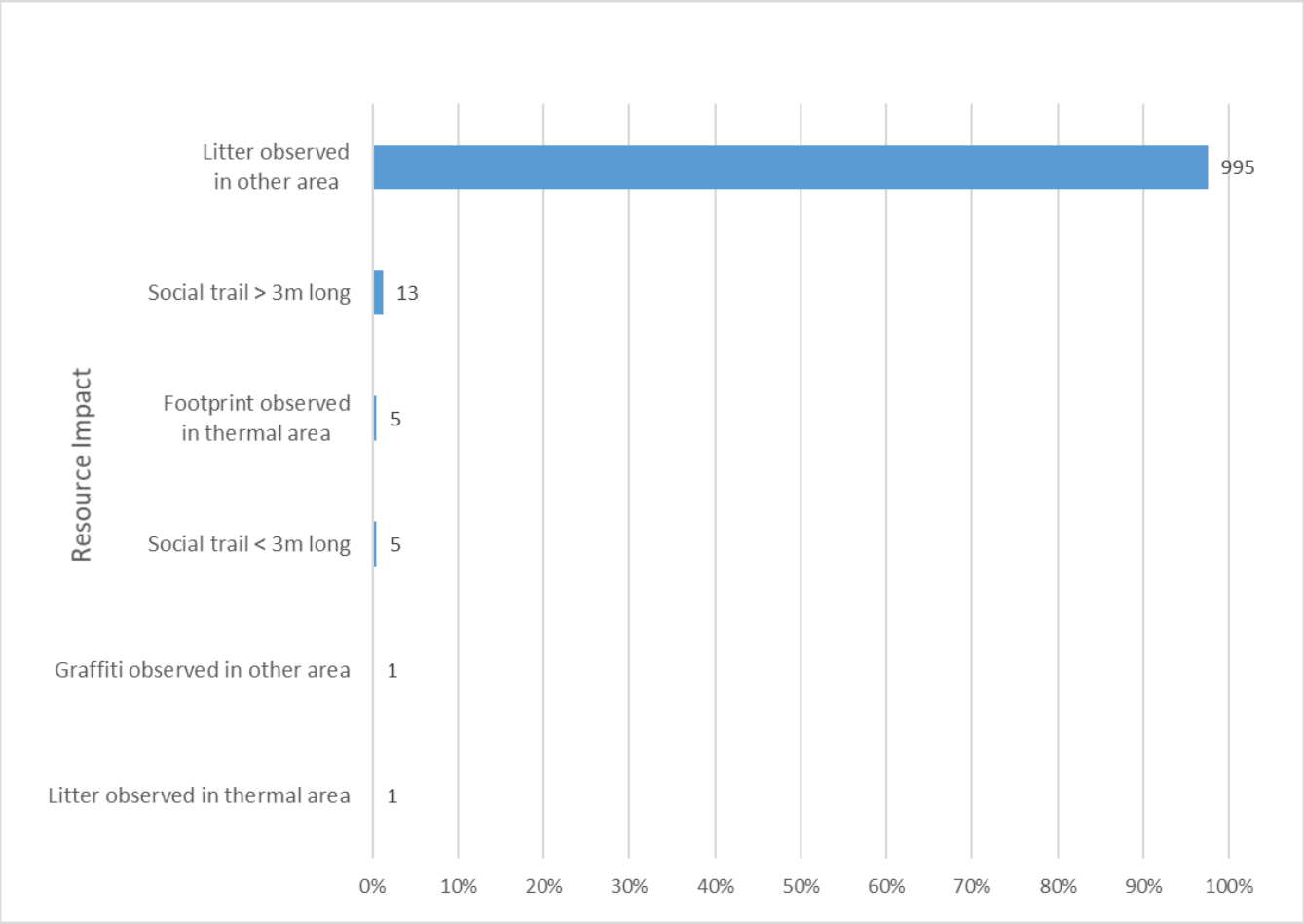

Figure 16. Frequency and counts of resource impact code waypoints collected along the Fairy Falls trail. Number next to bar represents the "n" value or number of observations per category.

Impact behavior and resource impact waypoints were further categorized into six groups for kernel density analysis. Impact behavior waypoints were categorized into thermal area/mat impact behaviors, other impact behavior, visitor conflict and congestion, and wildlife impact behavior. Resource impact waypoints were categorized into thermal area resource impact or other area resource impact. Kernel density analyses were performed on each of the six categories to identify where specific impact behaviors or resource impacts are likely to occur at Fairy Falls. Figure 17 through figure 22 display the results of these targeted impact behavior and resource impact analyses. For the most part, non-thermal resource impacts and impact behaviors were the most common along the Fairy Falls trail; this is expected as the Fairy Falls trail does not provide direct access to many thermal features in comparison to boardwalks in geyser basins like Norris and Midway. These behaviors and impacts were spread throughout the system, with increased density near the trailhead or at the Grand Prismatic Spring overlook area. Visitor conflict and congestion behaviors were infrequent, but when they did occur, they were located near the Grand Prismatic Spring overlook. Wildlife impact behaviors were also infrequent and occurred along the flat section of trail prior to taking the overlook cut off. For maps of each type of waypoint individually for Fairy Falls please see Appendix H.

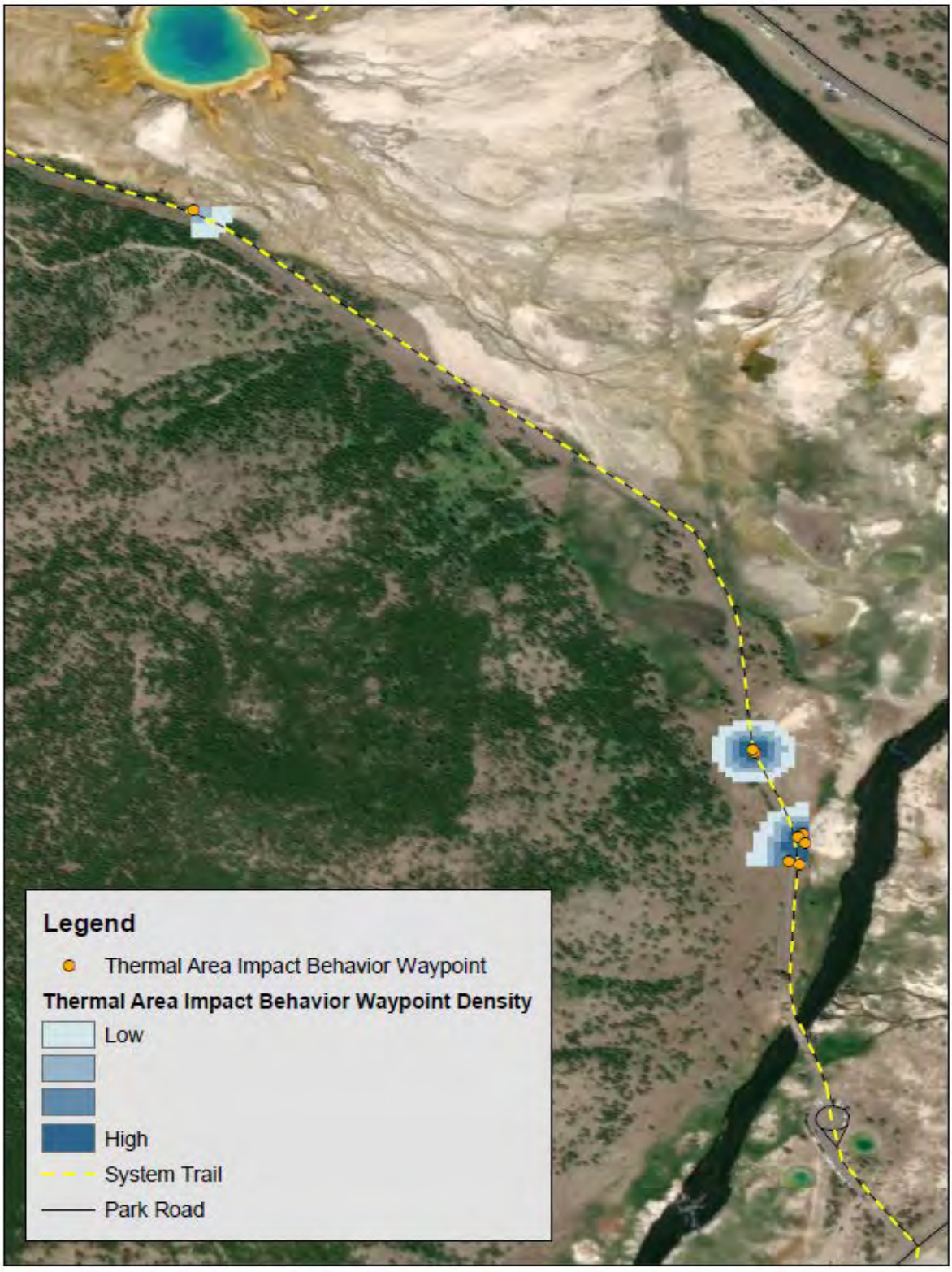

Figure 17. Thermal area impact behavior waypoint density analysis at Fairy Falls.

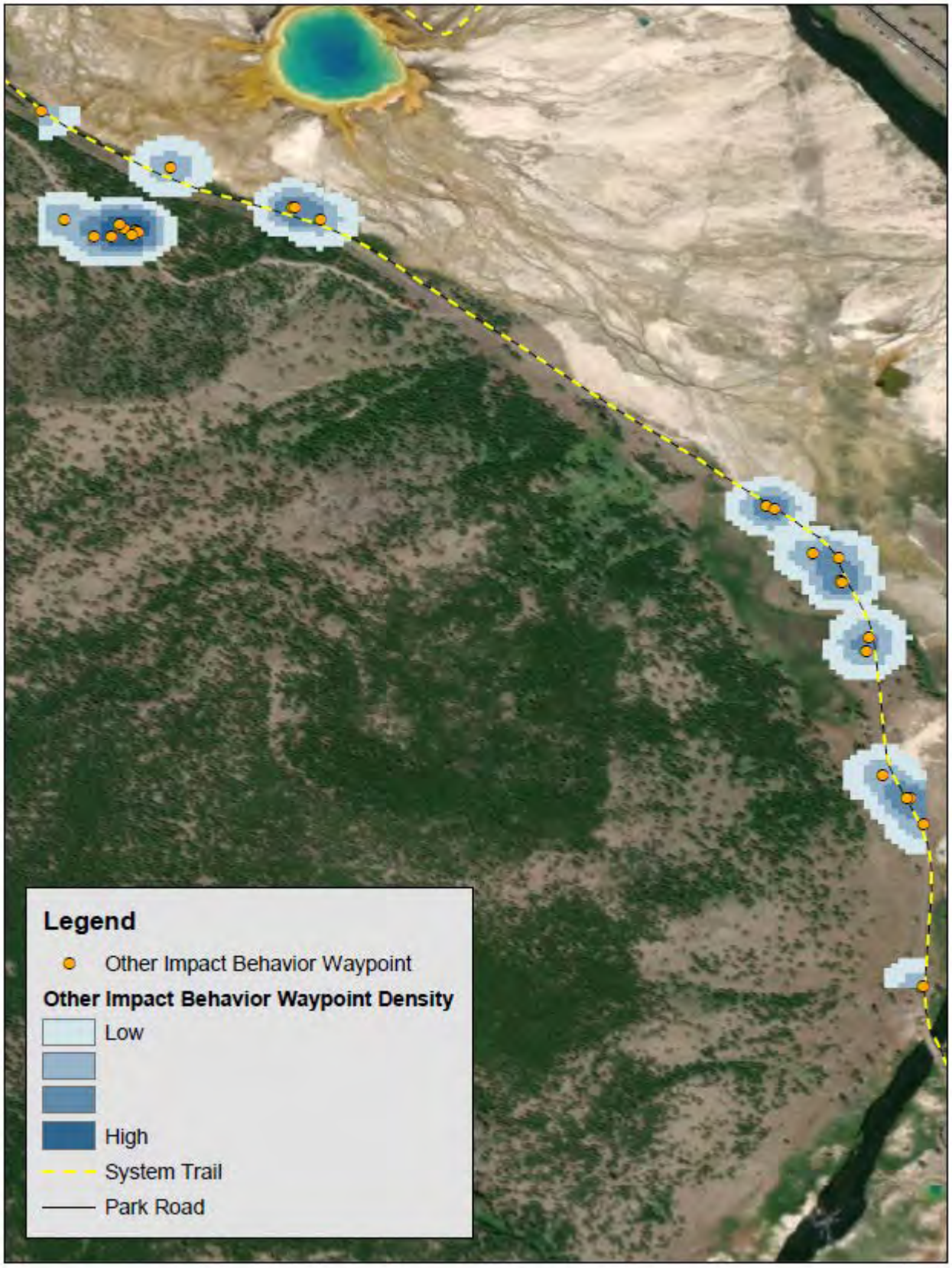

Figure 18. Other impact behavior waypoint density analysis at Fairy Falls.

Figure 19. Visitor conflict and/or congestion waypoint density analysis at Fairy Falls.

Figure 20. Wildlife impact behavior waypoint density analysis at Fairy Falls.

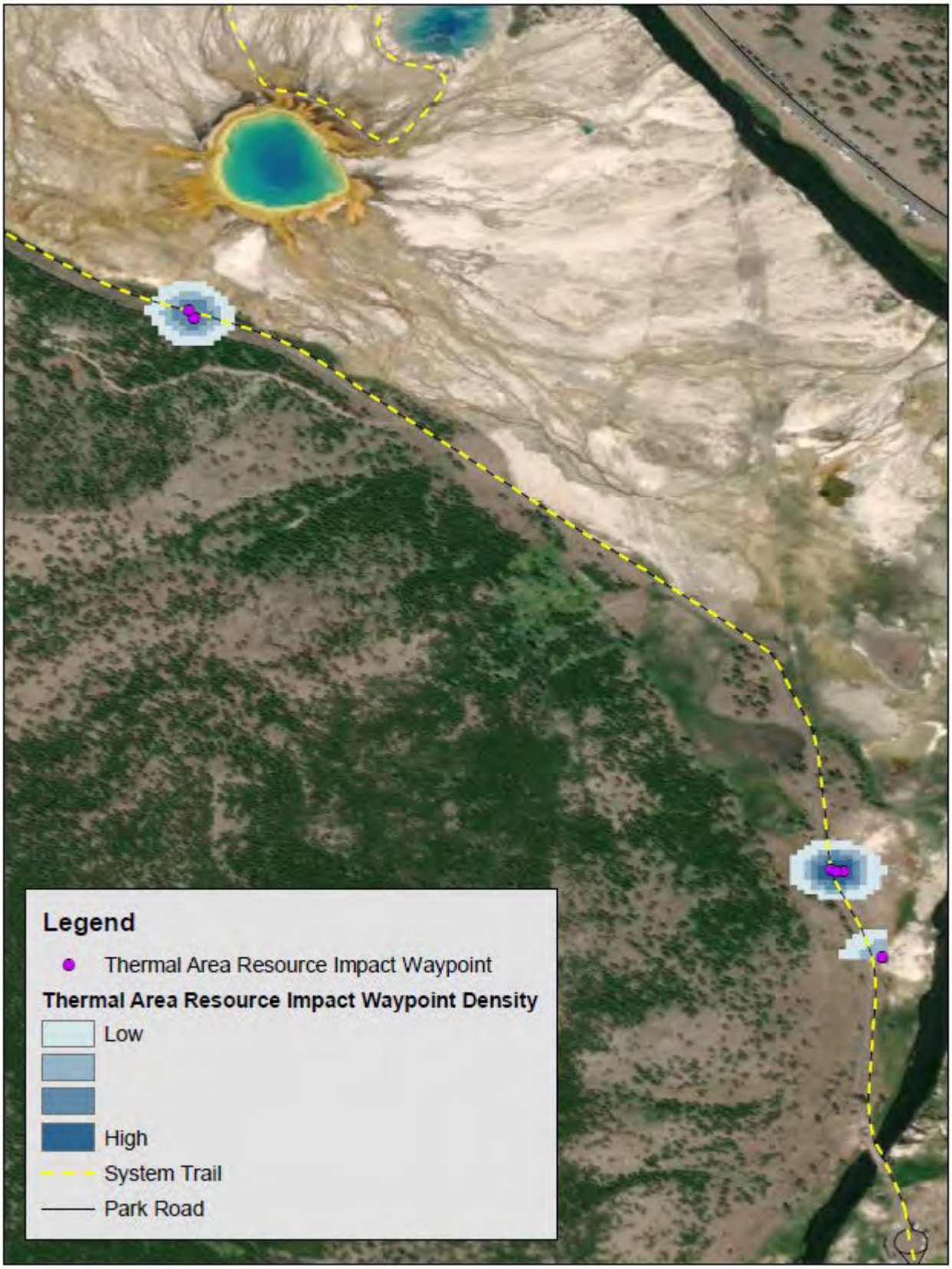

Figure 21. Thermal area resource impact waypoint density analysis at Fairy Falls.

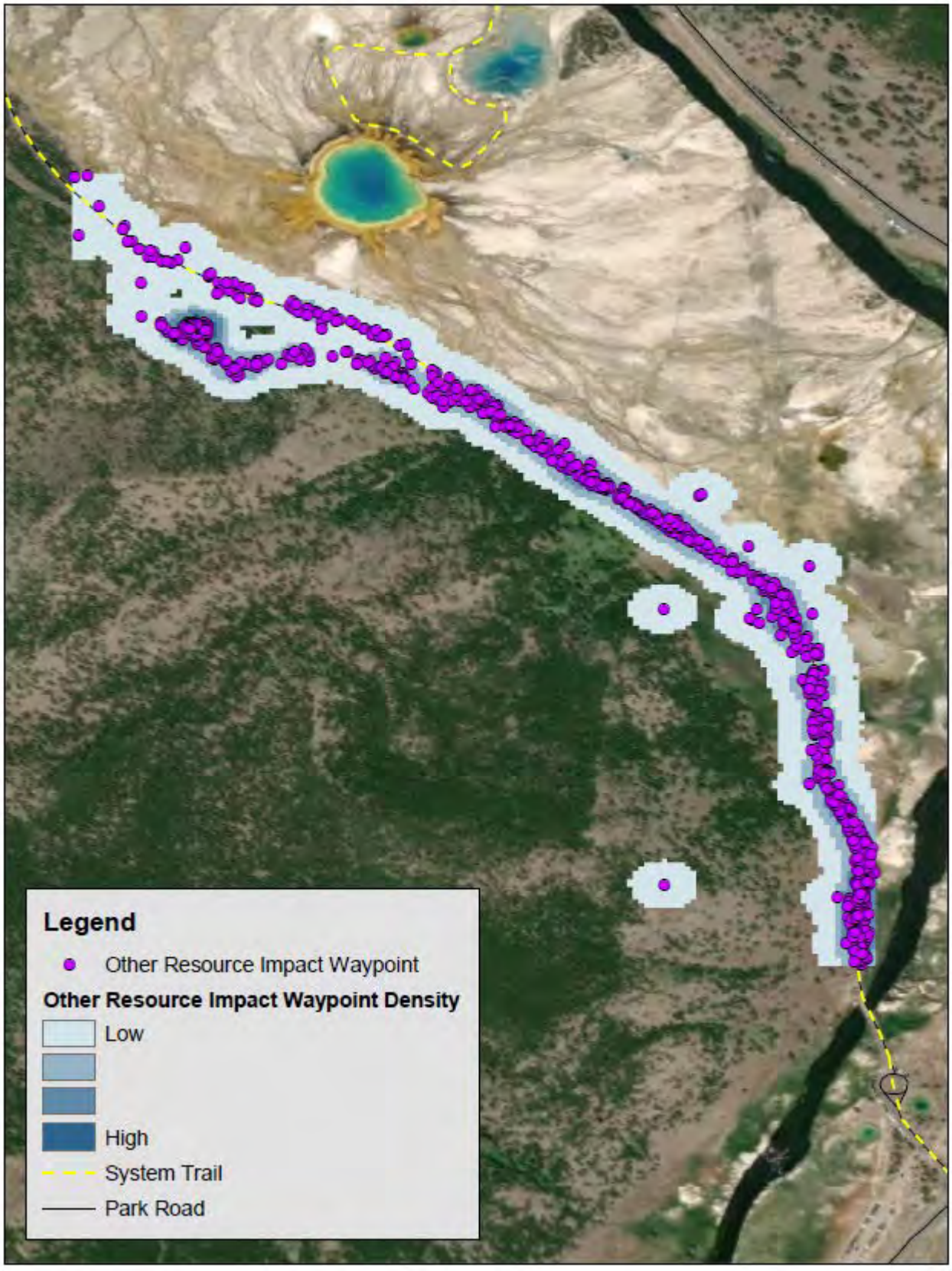

Figure 22. Other resource impact waypoint density analysis at Fairy Falls.

Midway Geyser Basin

Visitor Use Estimation

Parking Lot Counts

The Midway Geyser Basin parking lot has 55 designated parking spots. Figure 23 shows the average number of vehicles parked at Midway Geyser Basin each hour. These are hourly averages summarized for the entire data collection period (e.g., all 9:00 counts were averaged, all 10:00 counts were averaged, etc.). See Appendix D for full summary tables of parking lot counts. Appendix E contains graphs of average hourly vehicle counts for each focal attraction site parking lot by date. The magnitude of the patterns displayed in figure 23 and discussed in the accompanying text can be quantified through looking at the percent change in the total number of vehicles hour over hour in the Midway Geyser Basin parking lot (table 14). The percent change over hour provides a comparative metric for how the number of vehicles in the parking lot changes as the day progresses.

When YCC Crews arrive at 9:00 to begin data collection, the Midway Geyser Basin parking lot is full with an average 60 vehicles (5 vehicles above the counted designated spots) already parked and roadside and undesignated parking (parking within the parking lot but outside of striped or otherwise recognized parking spots) has already begun. Undesignated parking remains relatively low and consistent between 9:00 and 15:00. The number of vehicles recorded in designated spots increases slowly in the morning (table 14) with a slight (-7%) dip around noon (likely due to visitors eating lunch). The largest percent increase in the total number of vehicles occurs between 12:00 and 13:00 with a 56% increase in vehicles during this hour. The total number of vehicles parked at Midway Geyser Basin peaks at 13:00 with 154 vehicles, on average, parked in the parking lot and along the roadside (figure 23). Use decreases slowly after the 13:00 peak with decreases of smaller magnitude, the largest being an 8% decrease in vehicles between 13:00 and 14:00 (table 14). When the YCC Crews leave at 15:00, on average, there are still 78 vehicles parked in designated parking spots.

Roadside parking is prevalent at Midway Geyser Basin, with the number of vehicles parked along the roadside increasing dramatically from an average of between 10 and 30 vehicles from 9:00 until 12:00 to an average of 78 vehicles at 13:00. In fact, at 13:00 (peak use for parking at Midway Geyser Basin) the number of vehicles parked along the roadside exceeds the number of vehicles recorded in designated spots.

The discrepancy between the number of vehicles recorded in designated spots versus the number of total designated spots is likely a result of the difficulty in differentiating between designated and undesignated spots when the parking lot begins to fill. It also may be due to differences in interpretation of the protocols between YCC Crews from week to week. Finally, when parking lots begin to fill visitors may begin to double park or park in tour bus or RV spaces; it is likely the YCC Crews counted these vehicles as parked in designated spots when, in reality, these vehicles likely qualify as undesignated vehicles.

Table 14. Average percent change over hour in total vehicles in the Midway Geyser Basin parking lot.

Time	Percent Change in Total Vehicles
9:00 to 10:00	26 %
10:00 to 11:00	8 %
11:00 to 12:00	-7 %
12:00 to 13:00	56 %
13:00 to 14:00	-8 %
14:00 to 15:00	-3 %

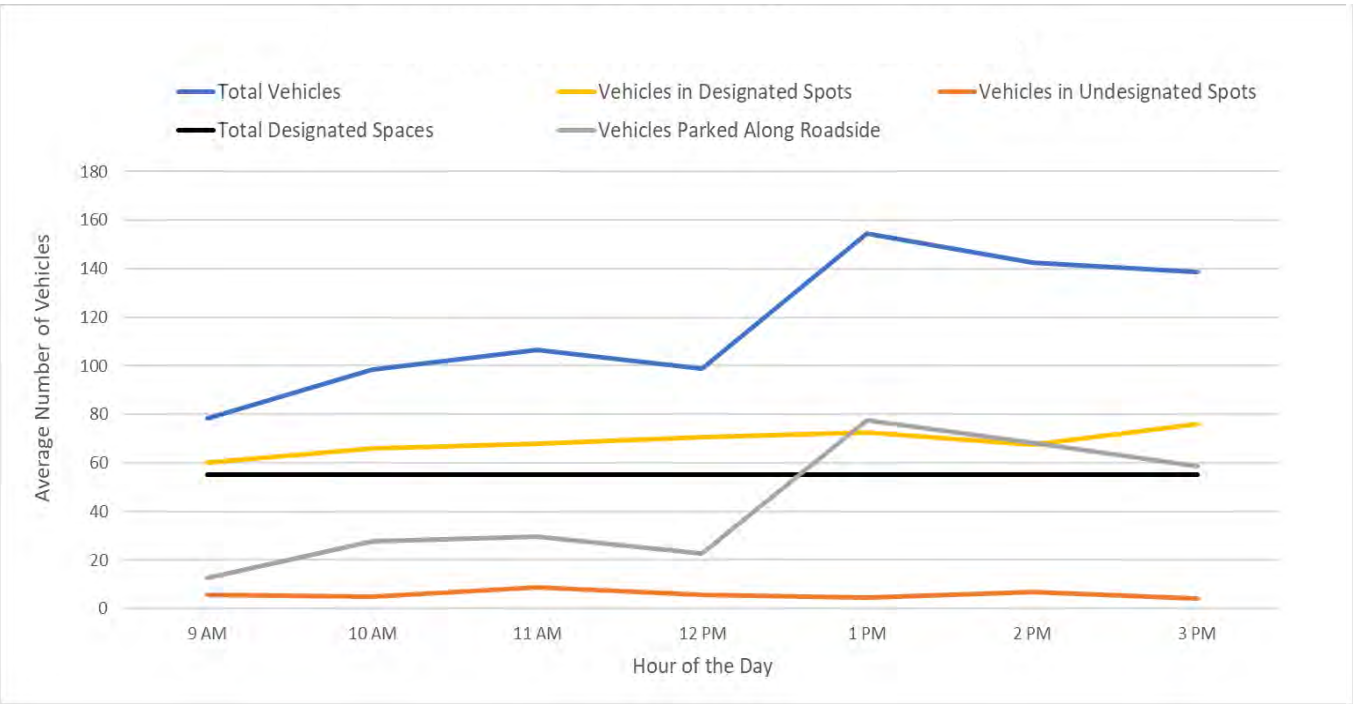

Figure 23. Average number of total vehicles parked at Midway Geyser Basin (blue line). The total number of vehicles is the sum of the average number counted in designated spots in the Midway Geyser Basin parking lot (yellow line), in undesignated spots (orange line), and parked along the roadside (grey line) by hour of the day. The total number of designated parking spaces in the Midway Geyser Basin parking lot is 55 spaces (black line; Otak 2017).

Table 15 summarizes the average number of tour buses, RVs, and queued vehicles in the Midway Geyser Basin parking lot by date. The average number of tour buses per day ranged from one to four, with the average being two tour buses. RVs occurred in higher frequencies, on average, than tour buses. The average number ranged from one to five RVs, with three per day being the overall average number. Queued vehicles occurred on every sample date, with average numbers ranging from 15 to 36 vehicles. The average number of queued vehicles per day was 28 vehicles, suggesting the demand for parking at Midway Geyser Basin consistently exceeds the supply of available parking across the use season.

Table 15. Average number of tour buses, RVs, and queued vehicles summarized by sampling day for Midway Geyser Basin. These counts were taken at the same time as the parking lot counts. SD = standard deviation, n= sample size.

		Tour Bus Counts		RV Counts		Vehicle Queue Counts	
Date	***n***	**Average**	**(±SD)**	**Average**	**(±SD)**	**Average**	**(±SD)**
6/21/2018	5	2	1	3	1	27	5
6/25/2018	3	2	1	4	3	31	5
6/29/2018	3	4	4	1	2	15	23
7/5/2018	5	1	1	5	3	24	14
7/20/2018	4	3	2	3	1	33	5
8/1/2018	7	2	1	3	3	36	9
8/7/2018	3	3	1	4	1	30	15
Overall	**-**	**2**	**2**	**3**	**2**	**28**	**11**

Table 16 summarizes the average number of tour buses, RVs, and queued vehicles in the Midway Geyser Basin parking lot by hour of the day. The average number of tour buses per hour ranged from one to four. Tour buses most frequently occurred during the 10:00, 13:00, and 15:00 hours of the day. The average number of RVs ranged from two to six per hour, with the average number peaking during the 15:00 hour. Queued vehicles occurred during every hour of the sample day (9:00 to 15:00) with average queue lengths ranging from 14 to 39 vehicles. The average number of vehicles queued was consistently above 30 vehicles from 11:00 to 13:00 in the Midway Geyser Basin parking area. The average number of queued vehicles suggests that across the hours of the sample day the demand for parking exceeds available parking in the Midway Geyser Basin parking lot.

Table 16. Average number of tour buses, RVs, and queued vehicles summarized by time of day for Midway Geyser Basin. These counts were taken at the same time as the parking lot counts. SD = standard deviation, n= sample size.

		Tour Bus Counts		RV Counts		Vehicle Queue Counts	
Time	***n***	**Average**	**(±SD)**	**Average**	**(±SD)**	**Average**	**(±SD)**
9:00	4	1	1	3	1	14	13
10:00	5	4	3	2	1	20	12
11:00	6	2	1	3	2	39	6
12:00	4	2	2	3	2	33	3
13:00	3	3	1	3	2	35	10
14:00	5	2	1	4	3	28	4
15:00	3	3	1	6	3	29	20
Overall	**-**	**2**	**1**	**3**	**2**	**28**	**10**

Restroom Line Counts

Restroom occupancy and restroom line length data were also collected for the restrooms in the Midway Geyser Basin parking area during the parking lot count data collection. Table 17 reports the three restroom line length measures collected by date: number of people in line when a person entered the restroom, number of people in line when a person exited the restroom, and the average restroom occupancy time. Across the sample days, average line lengths ranged from three to eight people at a person's entry and a person's exit from the restroom. The average occupancy time was two minutes across most sample days. These data suggest that across the sample period, visitors generally had to wait in line for the bathroom at Midway Geyser Basin.

Average restroom line lengths and occupancy times were also calculated across hours of the sample day (table 18). Line lengths at a person's entry and a person's exit ranged from 4 to 17 people. Line lengths peaked during the 12:00 and 13:00 hours of the day. Average occupancy times ranged from one to two minutes across hours of the day, with the overall average being two minutes. These data suggest that across hours of the day, restroom line lengths are inconsistent and peak during midday hours.

The restroom line and occupancy data were further explored to understand how the average length at time of entry and average length at time of exit varied across time. By looking at the concurrently collected data, trends in whether restroom lines were getting longer or getting shorter across time can be identified. Figure 24 graphs the average line length at entry and the average length line at exit, in 15-minute time bins, for the Midway Geyser Basin parking lot restrooms. The two lines track together closely throughout the day except during the 9:00 to 9:45 time period when restroom lines were growing, indicated by the average number of people in line at exit exceeding the

average number of people in line at entry. These data suggest, in general, across hours of the day, the length of the restroom line grew at the same rate as people were leaving the restroom line.

The average restroom occupancy times can be used to understand average restroom line wait times across the sample day. At Midway Geyser Basin, the average restroom line wait time ranged from one to two and a quarter minutes. At the average peak line length across the day (15 people), the average wait could range from 15 minutes to 34.5 minutes.

Table 17. Average restroom occupancy (in minutes) and restroom line length by date for Midway Geyser Basin. SD = standard deviation, n= sample size.

		Number in Line at Entry		Number in Line at Exit		Restroom Occupancy (minutes)	
Date	***n***	**Average**	**(±SD)**	**Average**	**(±SD)**	**Average**	**(±SD)**
6/21/2018	14	7	1	7	1	2	1
6/25/2018	12	4	1	5	1	2	1
6/29/2018	24	3	4	3	4	2	1
7/5/2018	33	4	4	4	3	2	1
7/20/2018	32	6	3	5	3	2	1
8/1/2018	44	5	5	7	5	2	1
8/7/2018	177	8	5	8	5	1	1
Overall	**-**	**5**	**5**	**6**	**5**	**2**	**1**

Table 18. Average restroom occupancy (in minutes) and restroom line length by hour for Midway Geyser Basin. SD = standard deviation, n= sample size.

		Number in Line at Entry		Number in Line at Exit		Restroom Occupancy (minutes)	
Time	***n***	**Average**	**(±SD)**	**Average**	**(±SD)**	**Average**	**(±SD)**
9:00	31	4	4	4	4	2	1
10:00	117	5	3	5	3	1	1
11:00	49	7	4	7	3	1	1
12:00	6	17	4	17	3	2	1
13:00	45	13	6	13	6	1	1
14:00	65	5	4	6	4	2	1
15:00	17	7	3	6	3	1	1
Overall	**-**	**8**	**4**	**8**	**4**	**2**	**1**

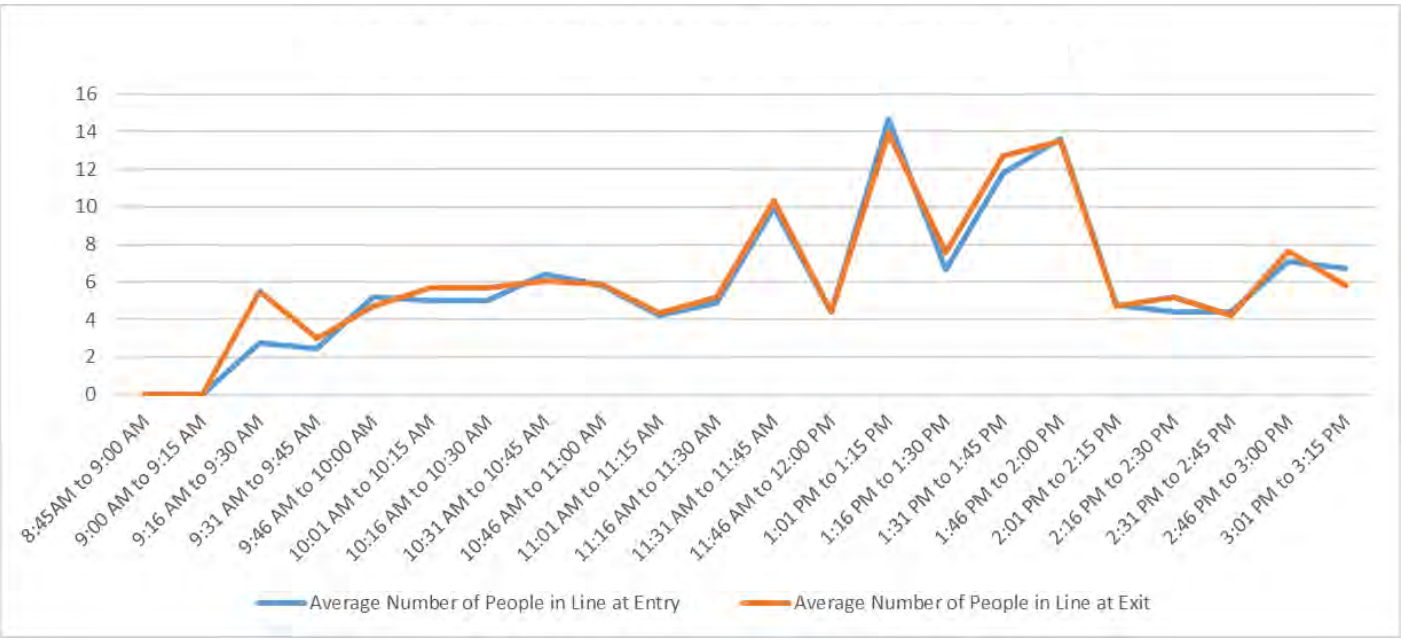

Figure 24. Graph of average restroom line lengths at entry and exit, organized by 15-minute time bins for Midway Geyser Basin.

Automatic Trail Counter

The trail counter at Midway Geyser Basin was deployed from June 19, 2018, through October 24, 2018. The counter collected data continuously, except during the time period from August 5 through August 21, 2018. During this time, the counter did not record data because it was not properly relaunched, or reset, after download. The data from the dates of counter failure were **NOT** included in the analysis of the counter data.

The counter recorded data in hourly time bins. Summaries of the data are reported according to season of use, with data collected from June 19, 2018, through September 3, 2018 (Labor Day), being categorized as peak use season data and data collected from September 4, 2018, through October 24, 2018, being categorized as shoulder season data. Peak season data are reported here in the body of the report. The same graphical and tabular summaries are presented for the shoulder season data in Appendix F.

The count data included in this report are calibrated data; no uncalibrated count data is presented. Nine hours of calibration data collected across seven days during the peak use season were used to calibrate the Midway Geyser Basin counter. Originally, eleven calibration sessions were conducted; however, two were conducted during the period of August 5 through August 21, 2018, when the counter was not recording data. Therefore, these data were unable to be incorporated into the calibration analyses.

The calibration coefficient for the 2018 deployment of the Midway Geyser Basin counter is 1.94. A calibration coefficient over a value of one indicates the counter was undercounting the number of passes in front of the counter and the recorded data should be upscaled to reflect actual visitation. The calibration coefficient of 1.94 suggests the counter at Midway Geyser Basin was under counting by a factor of two. The R^2 value for the regression equation used to generate the calibration coefficient is 0.98, suggesting the counter consistently undercounted the number of passes. The high calibration coefficient, and accompanying R^2 value, suggest counter placement was likely influential in generating a high calibration coefficient. Improving counter placement could be a strategy for reducing the amount of error in the originally collected count data. Specifically at Midway Geyser Basin, the counter was placed low, likely missing the torso section for most visitors passing the counter. This placement could have resulted

in missed counts. Additionally, the counter was placed on a wide section of the trail next to interpretative signs. The wide section of trail may have allowed visitors to pass by the counter unrecorded and the interpretative signs may have caused other visitors to stop in front of the counter, thus preventing passing visitors from being counted. For reference calibration coefficients between 0.75 and 1.25 are usually considered within the normal range of counter error for well-placed counters. The high calibration coefficient does not compromise the quality of the counter data that was collected once it has been corrected for counter error, but better trail counter placement results in higher quality data overall.

Across the peak use season, daily total counts ranged from approximately 1,200 counts to over 20,000 counts (figure 25). Daily total counts consistently exceeded 15,000 counts per day, with many days exceeding 20,000 counts per day. A count is considered one pass by of a visitor at the counter; it cannot be interpreted as an individual. The counters record a tally each time an individual passes the count location, regardless of direction of travel. Counts reported here correspond to either an entrance or an exit from the Midway Geyser Basin trail system.

Unexpectedly low counts were recorded from July 15 through July 23, 2018, due to a spider building a web in the counter sensor and that interfered with the accuracy of the counter (figure 25). These counts are inaccurate (and were not included in any summary analysis).

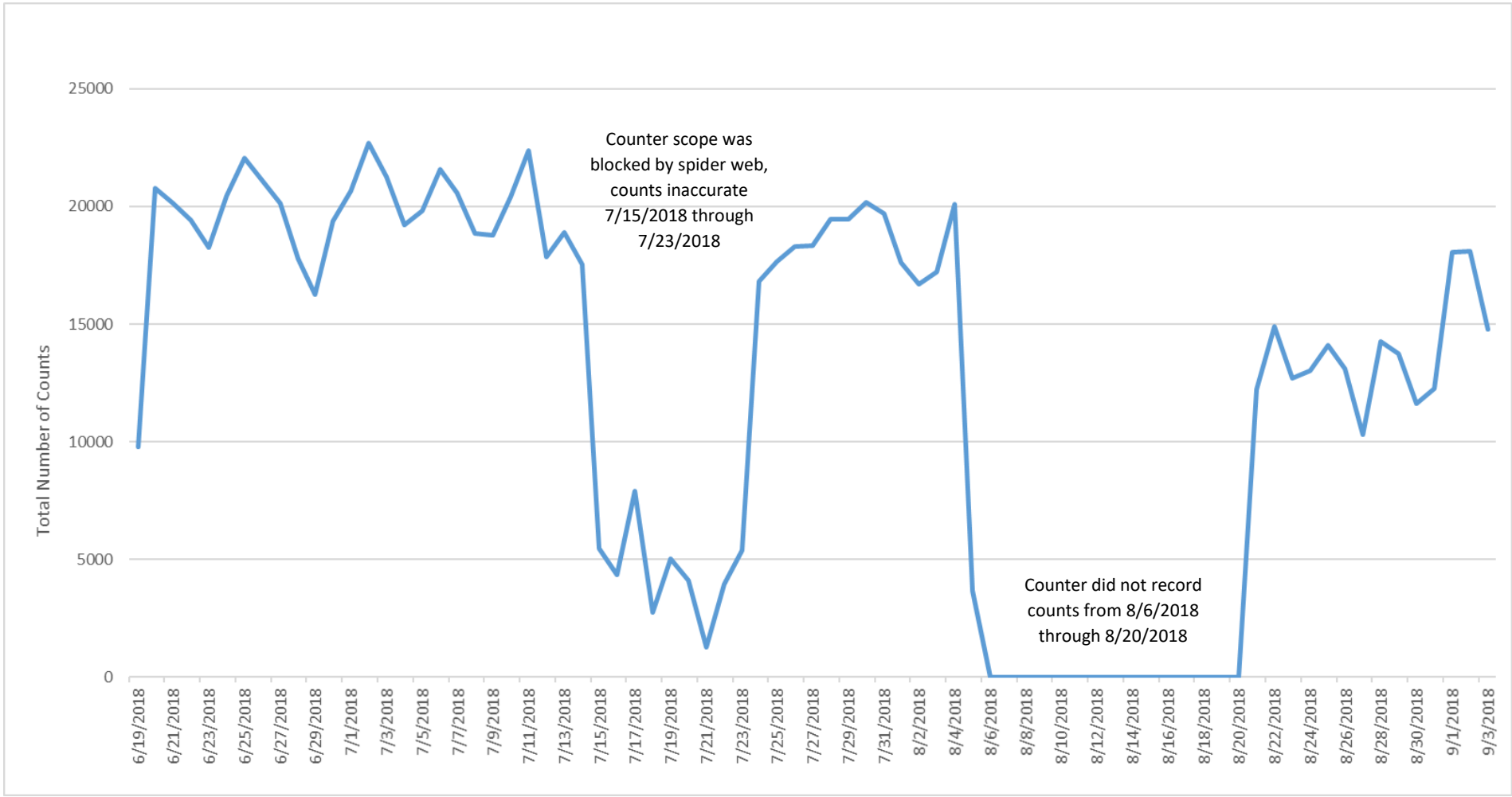

Figure 25. Daily total number of counts at Midway Geyser Basin during the peak use season from June 13 through August 5, 2018, and August 21 through September 3, 2018.

Average hourly counts at Midway Geyser Basin exceeded 1,000 counts from 9:00 through 18:00 during the peak use season (table 19, figure 26). Counts noticeably increased from single digits to an average of 59 counts at 6:00, continuing to increase throughout the day to peak at an average of 1,494 counts at 11:00 (see table 20 for a magnitude of this increase). Counts remain consistently high through the afternoon, but at 17:00 percent decreases in counts enter the double digits (see table 20). Counts dip below 1,000 at 19:00 but remain in the triple digits at Midway Geyser Basin until 21:00, with an average of 125 visits even later into the evening.

Table 19. Average number of hourly counts during the peak use season (June 19 through August 5, 2018, and August 21 through September 3, 2018) at Midway Geyser Basin. SD = standard deviation; N = sample size.

Hour	Average	±SD	N*
0:00	1	3	60
1:00	1	1	60
2:00	2	6	60
3:00	1	4	60
4:00	0	0	60
5:00	4	6	60
6:00	59	46	60
7:00	275	145	60
8:00	720	261	60
9:00	1,118	264	60
10:00	1,334	336	59
11:00	1,494	418	58
12:00	1,475	528	60
13:00	1,441	568	60
14:00	1,487	629	61
15:00	1,434	590	61
16:00	1,369	582	61
17:00	1,289	560	61
18:00	1,110	482	61
19:00	824	394	61
20:00	443	251	61
21:00	125	110	61
22:00	6	8	61
23:00	2	7	61

*N varies across hours of the day based on the hour of counter installation, the hours of data download, and the hour of counter removal.

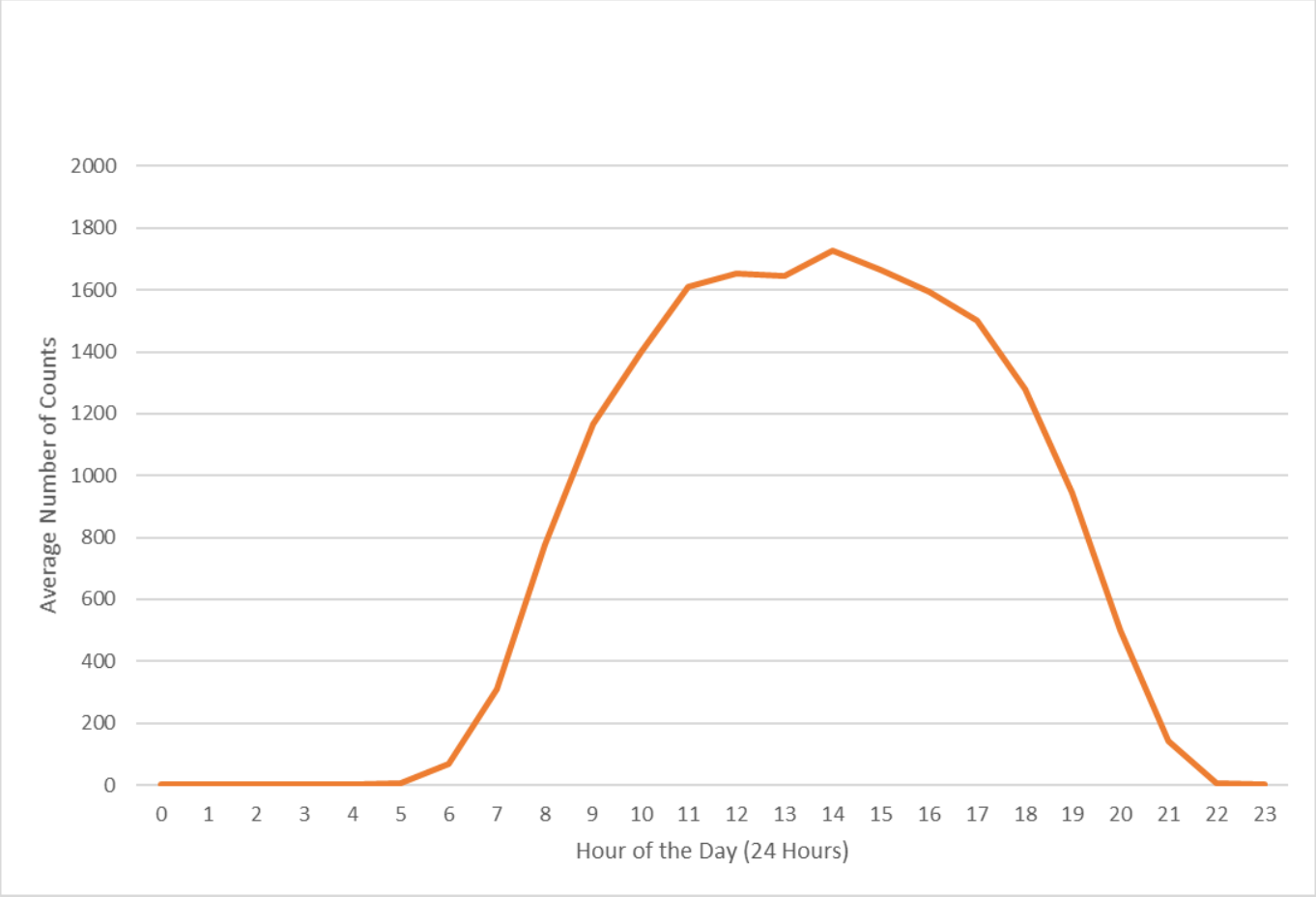

Figure 26. Average number of hourly counts at Midway Geyser Basin during the peak use season from June 19 through August 5, 2018, and August 21 through September 3, 2018.

Table 20: Percent change in average total counts across the day for Fairy Falls counter.

Time	Percent Change in Total Counts by Hour
6:00 to 7:00	366 %
7:00 to 8:00	162 %
8:00 to 9:00	55 %
9:00 to 10:00	19 %
10:00 to 11:00	12 %
11:00 to 12:00	-1 %
12:00 to 13:00	-2 %
13:00 to 14:00	3%
14:00 to 15:00	-4 %
15:00 to 16:00	-5 %
16:00 to 17:00	-6 %
17:00 to 18:00	-14 %
18:00 to 19:00	-26 %
19:00 to 20:00	-46 %
20:00 to 21:00	-72 %
21:00 to 22:00	-95 %
22:00 to 23:00	-67 %
23:00 to 24:00	-100 %

Across days of the week, average counts at Midway Geyser Basin ranged from a low of 13,747 counts on Sundays to a high of 16,573 counts on Wednesdays (table 21, figure 27). Interestingly, peak use days tended to occur on weekdays at Midway Geyser Basin, with average counts Tuesday through Saturday being higher than average counts Sunday and Monday. It is important to consider the magnitude of the standard deviation for each estimate of the average per day of week. Looking at the standard deviation values, they range from almost half of the average of Sundays and Mondays to closer to a third of the average during the rest of the week. This suggests that variation is large across days in the sample. Therefore, it is likely that for each day of the week counts were substantially higher and substantially lower than the averages.

Table 21. Average number of daily counts by day of week during the peak use season (June 19 through August 5, 2018, and August 21 through September 3, 2018) at the Midway Geyser Basin trailhead. SD = standard deviation, N = sample size.

Day	Average	±SD	N*
Sunday	13,747	7,390	9
Monday	14,818	7,342	8
Tuesday	15,929	5,117	8
Wednesday	16,573	5,867	8
Thursday	15,543	4,909	8
Friday	15,678	5,259	8
Saturday	16,523	6,034	8

*N varies across days of the week due to the day of counter installation and the day of counter removal.

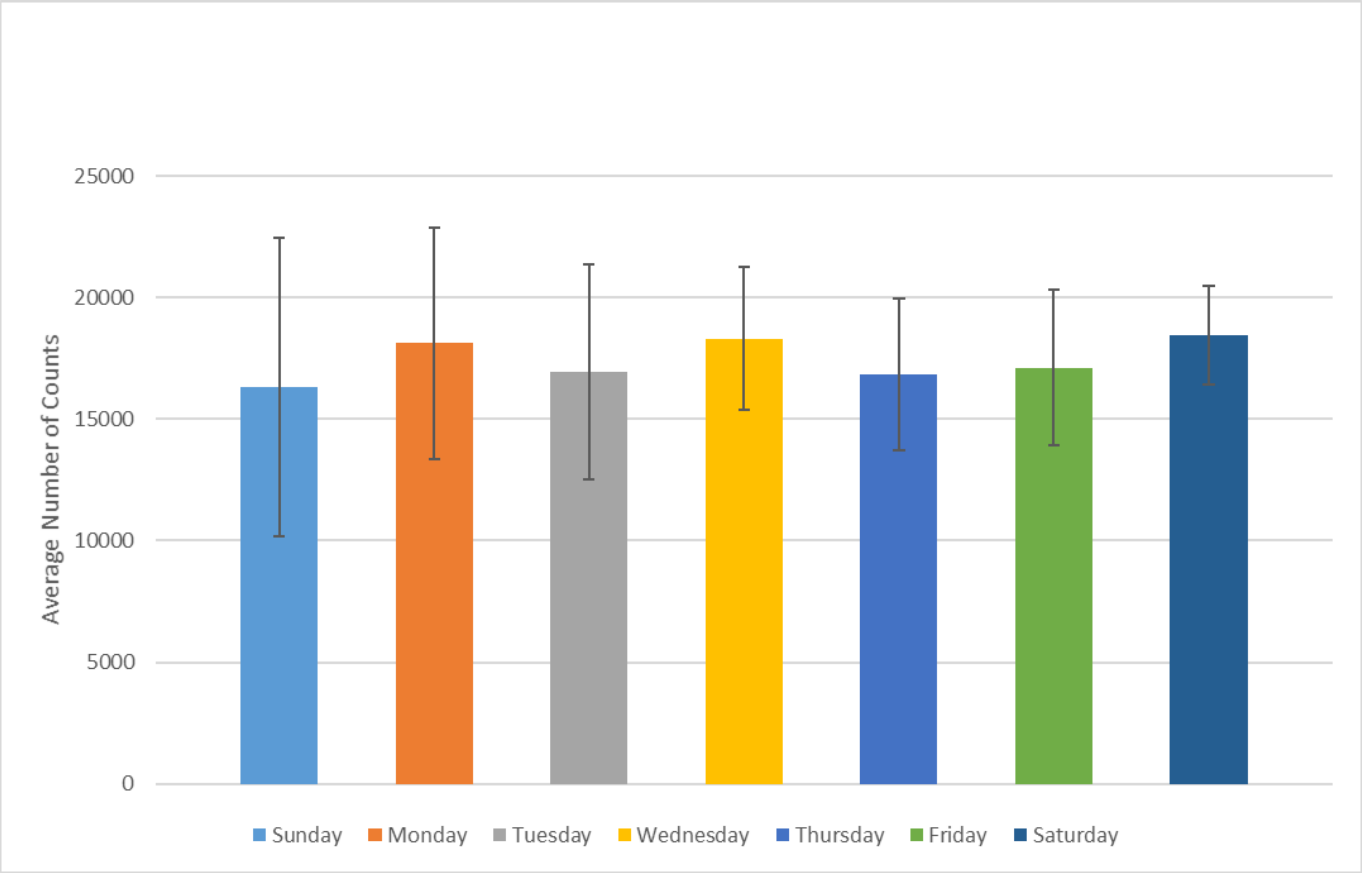

Figure 27. Average number of counts, by day of week, at Midway Geyser Basin during the peak use season from June 19 through August 5, 2018, and August 21 through September 3, 2018. The vertical black bars extending above and below the top of the colored bars represent the standard deviation for the estimate of the mean for each day.

Visitor Use/Capacity Measures

There were a few issues with the 2018 PAOT and encounter data at Midway Geyser Basin in 2018. For visitor encounters, it was not clear from the data sheets if/when the YCC Crews may have walked the loop multiple times, and thus the total encounters count could be inflated (see table 22 especially on 8/1/2018). Though the Grand Prismatic Spring viewing location was the assigned PAOT location for Midway Geyser Basin, PAOT counts were sometimes recorded for Excelsior Geyser Crater or for Excelsior and Grand Prismatic PAOT locations at one time (written as "Both" on the data sheet). When these "Both" counts occurred, it is not clear how the visitors were distributed between the two PAOT locations (table 23).

For encounters, when hiking the 1-mile boardwalk loop at Midway Geyser Basin, on average, YCC Crews would encounter between approximately 108 (recorded on 6/25/2018) and up to 1,000 other visitors (table 22, but see note for 8/1/2018). The overall average number of encounters recorded by the YCC Crews was 585 visitors in a loop hike of the Midway Geyser Basin boardwalk trail. At Midway Geyser Basin, PAOT counts occurred at the boardwalk overlooking Grand Prismatic Spring (see figure 28). On average, 109 visitors at one time were at this location (table 23). Average PAOT counts at Grand Prismatic Spring ranged from 5 to 293 visitors on the boardwalk at Grand Prismatic Spring. PAOT counts at this location showed a wide range of variability across time (figure 28). There is a noticeable increase in total PAOT at the Grand Prismatic Spring overlook boardwalk between 11:00 and on throughout the afternoon (figure 28). YCC Crews would occasionally conduct PAOT at Excelsior Geyser Crater and occasionally count "Both" locations which is assumed to be Grand Prismatic counts plus Excelsior Geyser Crater counts. These "Both" counts are summarized in table 23 but not included in any figures; the PAOT counts in figure 28 represent counts that were known to have only included people at the Grand Prismatic PAOT location. It is important to remember PAOT counts are variable and occur at one instant in time, so low values can be observed during periods of overall high visitor use and higher counts can be observed during overall lower use times (e.g., high counts occurring in the afternoon even though overall use tends to be highest in the morning hours). PAOT and trail counters provide a more site-specific metric of how visitor experiences may vary at a location.

Table 22. Summary of trail encounters (number of visitors passed) for the entire 1-mile boardwalk loop at Midway Geyser Basin. N = number of counts that equaled the entire trail length.

Date	Average	±SD	Min	Max	N
6/21/2018	391	145	181	654	16
6/25/2018	846	347	108	1326	9
6/29/2018	455	285	208	864	6
7/5/2018	606	202	286	931	14
7/20/2018	545	125	341	700	13
8/1/2018*	801	305	514	1582	11
8/7/2018	536	103	412	703	13
Overall:	**585**	**257**	**108**	**1582**	**82**

*Some values may be unusually high; it was not clear if the YCC Crew walked the trail multiple times.

Table 23. PAOT summary for PAOT location at Midway Geyser Basin. YCC Crews also occasionally took counts at Excelsior Geyser Crater and occasionally combined counts at Grand Prismatic and Excelsior. SD = standard deviation; N = sample size.

	Grand Prismatic Spring Boardwalk Overlook					Excelsior Geyser Crater					Both Grand Prismatic & Excelsior				
Date	**Ave.**	**±SD**	**Min**	**Max**	**N**	**Ave.**	**±SD**	**Min**	**Max**	**N**	**Ave.**	**±SD**	**Min**	**Max**	**N**
6/21/2018	145	51	75	293	16	-	-	-	-	-	-	-	-	-	-
6/25/2018	-	-	-	-	-	140	59	50	234	9	-	-	-	-	-
6/29/2018	39	29	5	87	10	21	13	5	34	12	-	-	-	-	-
7/5/2018	109	37	60	187	18	-	-	-	-	-	-	-	-	-	-
7/20/2018	-	-	-	-	-	-	-	-	-	-	102	36	37	158	13
8/1/2018	-	-	-	-	-	-	-	-	-	-	71	22	39	120	18
8/7/2018	102	29	55	150	15	-	-	-	-	-	-	-	-	-	-
Overall	**109**	**50**	**5**	**293**	**59**	**21**	**76**	**5**	**231**	**21**	**84**	**32**	**37**	**158**	**31**

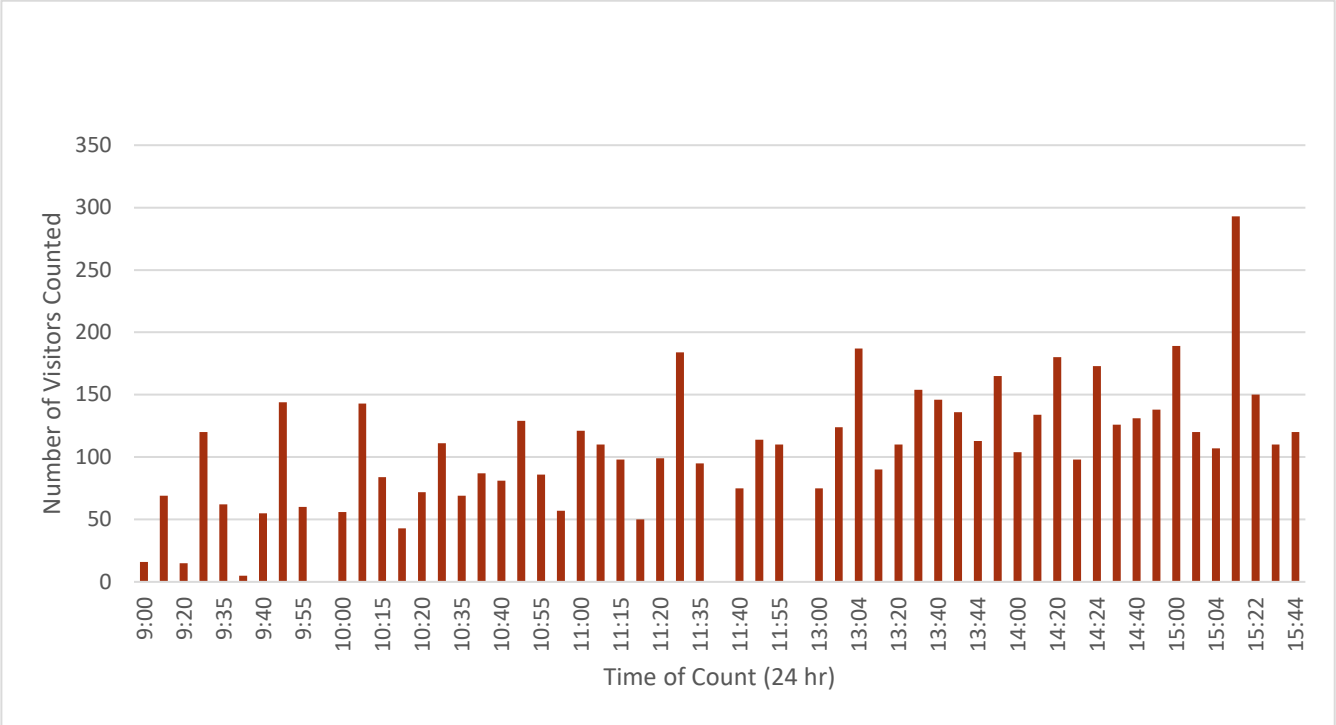

Figure 28. All individual PAOT counts organized by time at the Grand Prismatic Spring overlook on the boardwalk at Midway Geyser Basin.

Visitor Spatial Behavior

Note on density maps: For this section, on all kernel density maps, although the blue density layer may extend beyond the trail or boardwalk, that does not necessarily mean use or impacts extends that far. The width of the blue density layer on the maps provided in this section is an artifact of the analysis type. See "Methods" section for more detail.

GPS-based Tracking

Figures 29 and 30 show the extent and density for GPS study participants at Midway Geyser Basin. The GPS tracks collected from participants at Midway Geyser Basin are displayed in figure 29, with the blue dots representing collected GPS tracking data. On average, visitors to the Midway Geyser Basin boardwalk system spend approximately 28 minutes recreating. The minimum visit duration was five minutes and the maximum visit duration was just over one hour (table 24), which is a relatively quick turnover rate compared to other locations where the YCC Crews collected GPS tracks.

Table 24. Average, minimum, and maximum amount of time spent in the boardwalk and trail system at Midway Geyser Basin by GPS participants.

Measure	Time (h:mm:ss)
Average	0:28:00
±SD	0:10:00
Minimum	0:05:00
Maximum	1:06:00

Looking at the pattern of use at Midway Geyser Basin, most visitors walk the boardwalk loop around Midway Geyser Basin. Additionally, higher densities of GPS points (darker blue areas of figure 30) occur in the sections of boardwalk that provides the closest view to Grand Prismatic Spring and other thermal features in the geyser basin. The higher density of GPS waypoints located near the trailhead may be a function of YCC Crews handing out GPS units in this location; however, it also may be a function of visitors stopping to read the interpretive signs located at the entrance to the bridge leading to the geyser basin and enjoying the view from the bridge.

Waypoint Mapping

In addition to GPS tracking of visitor travel patterns at Midway Geyser Basin, two types of GPS waypoints were collected to mark where behaviors expected to cause resource impacts occur along the trail (hereafter impact behavior waypoints) and to mark where resource impacts have already occurred along the trail (hereafter resource impact waypoints). A total of 1,303 waypoints were collected at Midway Geyser Basin across eight days of sampling (figure 31). The darker blue portions of the kernel density map in figure 31 indicate a higher number of waypoints occurred at these locations. Interestingly, the highest density of waypoints occurred in the zigzag boardwalk section of the geyser basin boardwalk system. Examination of the individual waypoint maps founds in Appendix H suggest many of the waypoints along the zigzag are related to litter (visitors observed littering or litter observed). If appropriate, YELL may want to consider placing a trashcan at the switchback portion of the zigzag to reduce litter-related impacts at the beginning of the Midway Geyser Basin trail. Other areas of high waypoint density include the area where the boardwalk splits into a loop and overlook areas for the Grand Prismatic Spring and Excelsior Geyser Crater (figure 31).

Figure 29. Raw, cleaned GPS-based tracking point data collected from visitors at Midway Geyser Basin. GPS units were handed out at the trailhead. *Note: some of the GPS points located off-boardwalk in this map could be the result of consistent GPS error when the data was collected (the Garmin units used in this study have been known to have spatial error that ranges from less than 1 meter to up to 6 meters)*

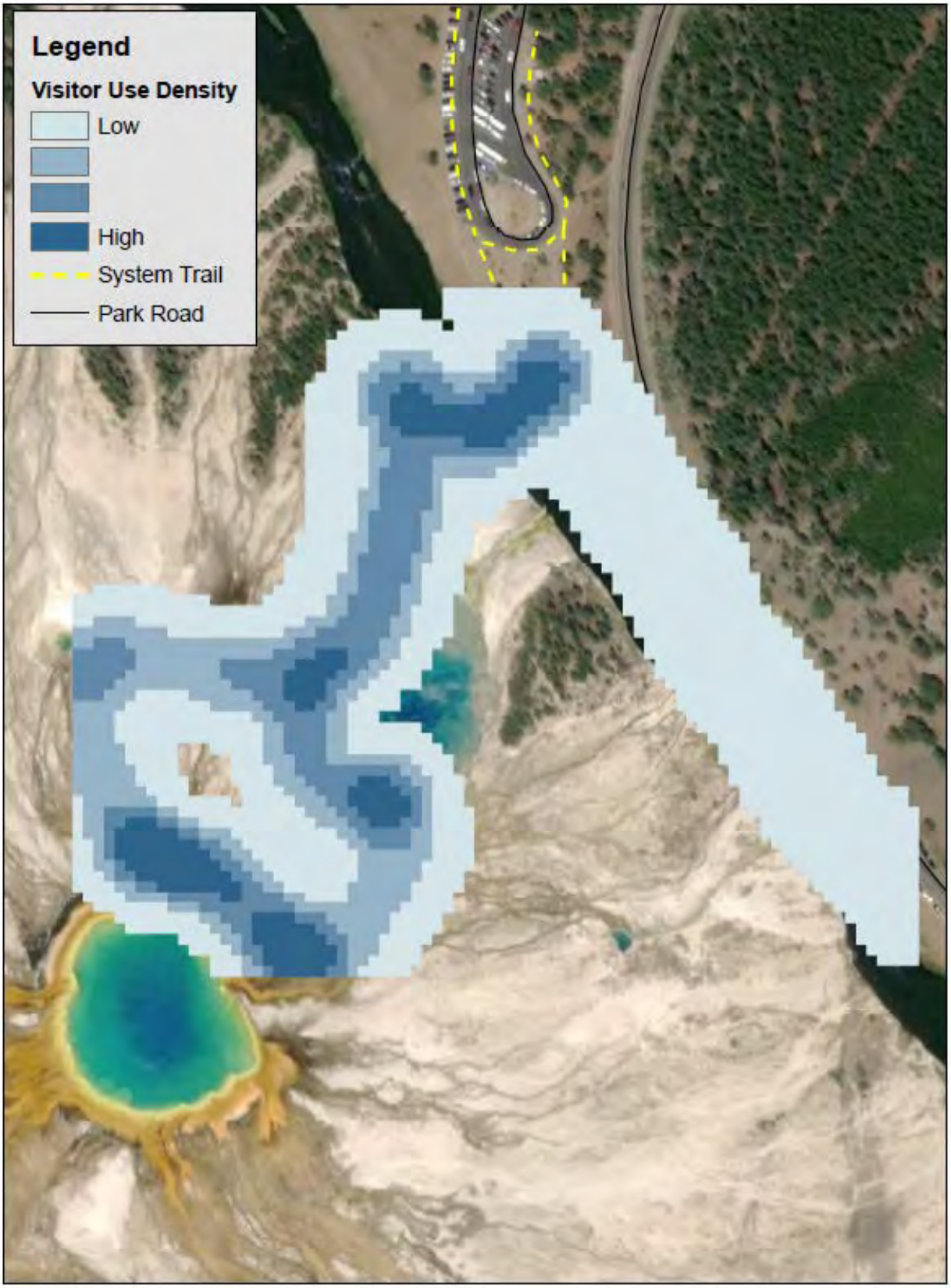

Figure 30. Density of GPS-based tracking points collected from visitors at Midway Geyser Basin. GPS units were handed out at the trailhead. Low densities are an estimated count of 6-193 points per 1 m^2 and high densities are an estimated count of 812-1,409 points per 1 m^2.

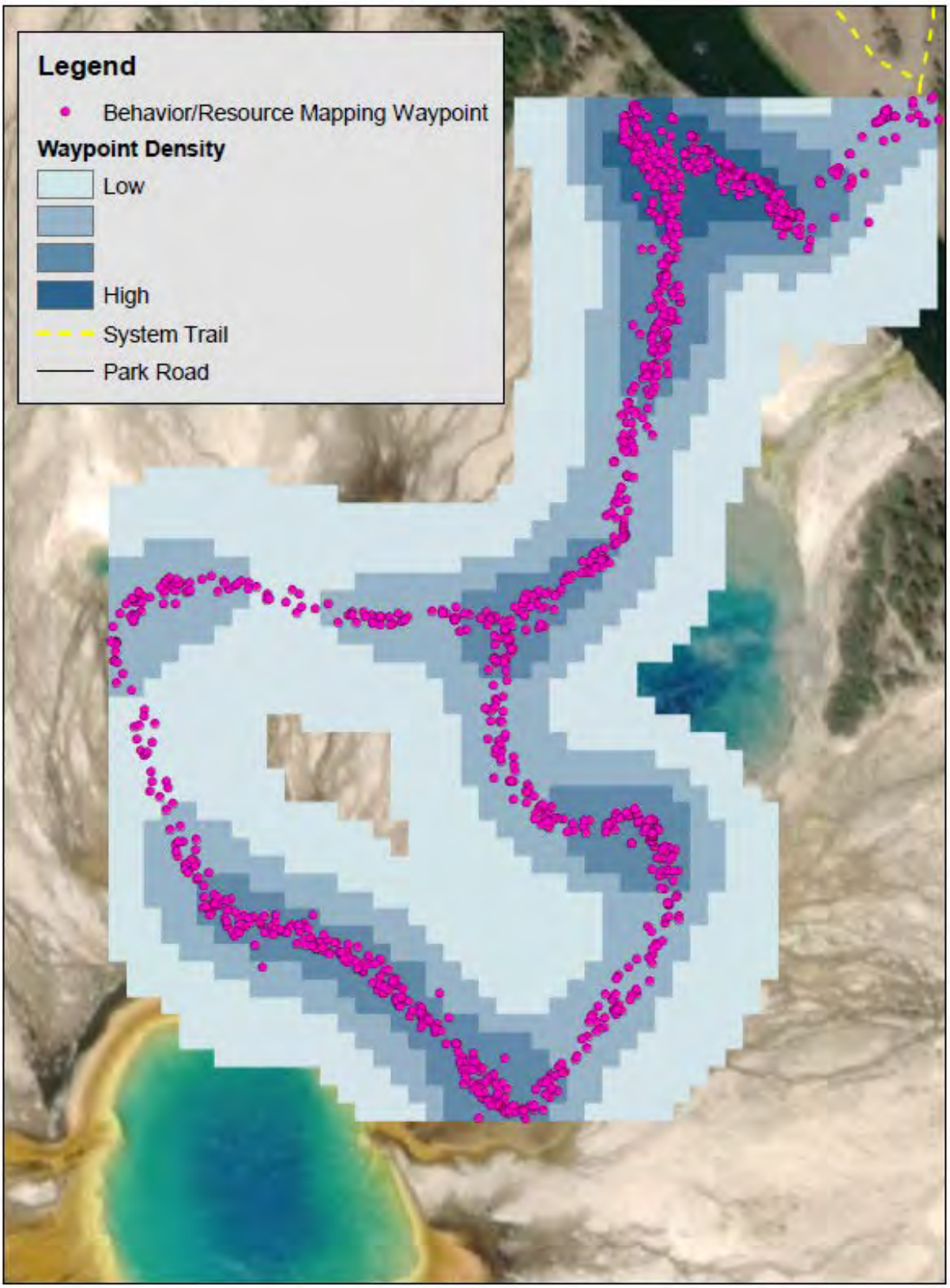

Figure 31. Density of impact behavior and resource impact waypoints at Midway Geyser Basin. Low densities are an estimated count of < 1-14 points per 1 m^2 and high densities are an estimated count of 64-113 points per 1 m^2**.**

To generate a more detailed understanding of how specific resource impacts or impact behaviors are spatially distributed at Midway Geyser Basin, the resource impact and impact behavior waypoints were separated for further analysis. Waypoints were matched to behavior codes using a spatial join. During the match process, 109 waypoints were unable to be matched due to missing behavior codes, resulting in an 86% match rate between recorded behavior codes and marked GPS waypoints. This match rate is lower than expected due to a missing data sheet from June 21, 2018 that blew away during data collection and could not be retrieved.

Figure 32 shows the frequency distribution and number of observations for impact behavior waypoints at Midway Geyser Basin. A total of 107 impact behavior waypoints were marked, with the majority of those waypoints being classified as visitors littering in other (non-thermal) areas, behaviors marked as “other” by data collectors, and groups obstructing the flow of other visitors. Refer to Appendix H for data collector provided comments assigned to each “other” behavior code.

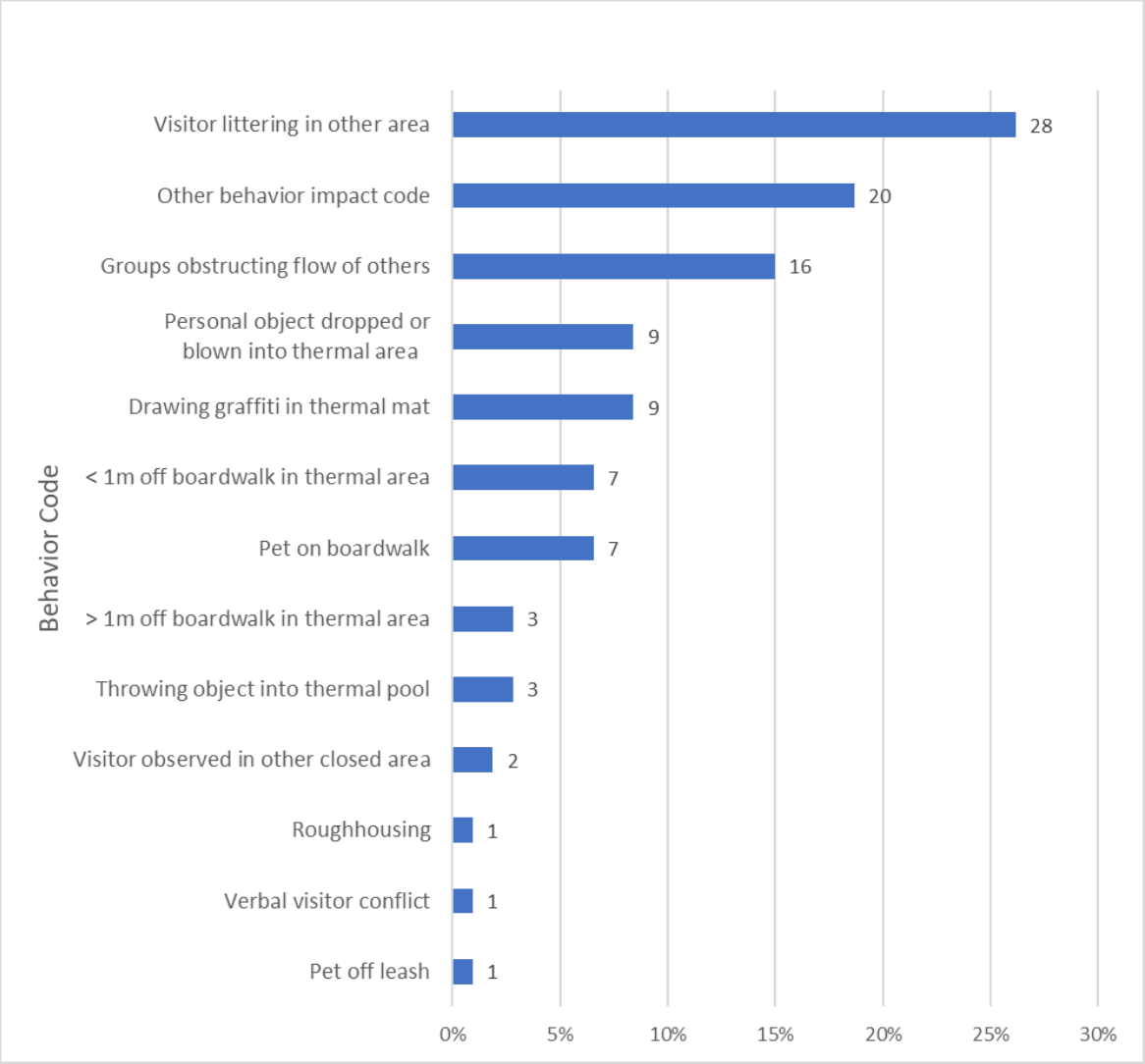

Figure 32. Frequency and counts of impact behavior code waypoints collected at Midway Geyser Basin. Number next to bar represents the "n" value or number of observations per category.

Figure 33 shows the frequency distribution and number of observations for the resource impact waypoints at Midway Geyser Basin. A total of 1,072 resource impact waypoints were marked, with the majority of those waypoints marking locations where litter was observed in thermal areas or litter was observed in other, non-thermal, areas.

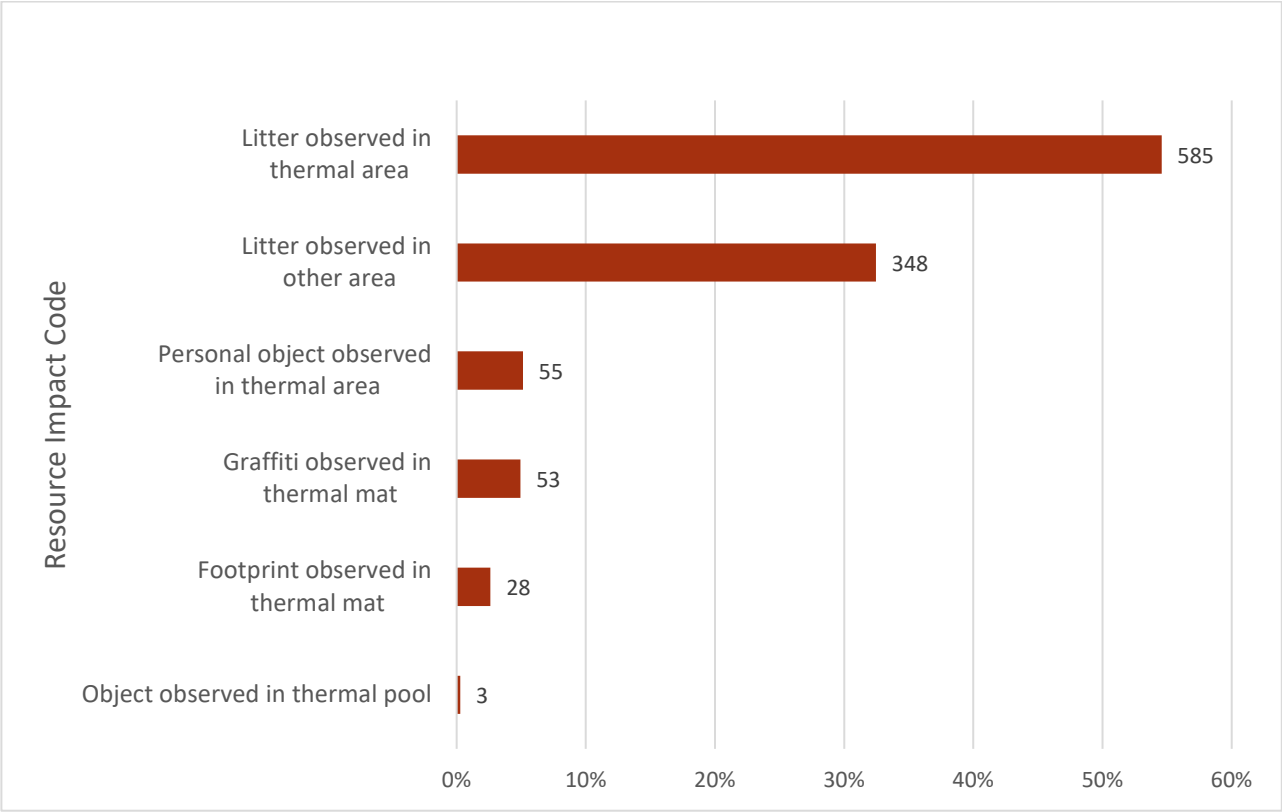

Figure 33. Frequency and counts of resource impact code waypoints collected at Midway Geyser Basin. Number next to bar represents the "n" value or number of observations per category.

Impact behavior and resource impact waypoints were further categorized into six groups for kernel density analysis. Impact behavior waypoints were categorized into thermal area impact behaviors, other impact behavior, visitor conflict and congestion, and wildlife impact behavior. Resource impact waypoints were categorized into thermal area resource impact or other area resource impact. Use of the term “other” in the above labels indicates the mapped behaviors or impacts were not considered be in thermal areas by data collection crews. As such, the term “other” can be considered to refer to other, non-thermal areas.

Kernel density analyses were performed on each of the six categories to identify where categorized impact behaviors or resource impacts are likely to occur at Fairy Falls. Figure 34 through figure 39 display the results of these targeted impact behavior and resource impact analyses. Among the four categories of waypoints marking observed behaviors, behaviors occurring in thermal areas and behaviors occurring outside of thermal areas arose most frequently. This suggests visitor behaviors such as littering in thermal and non-thermal areas, walking off boardwalks in thermal areas, and noise-related behaviors tended to occur most frequently from among the list of behaviors monitored. Additionally, these impacts occurred throughout the Midway Geyser Basin system (represented by the mapped waypoints being distributed throughout the trail system). In contrast, visitor behaviors related to conflict and congestion tended to only occur near the Grand Prismatic Spring viewing area rather than

throughout the boardwalk system. Additionally, wildlife-related behaviors (e.g., having pets on boardwalk or off leash) tended to occur away from the Grand Prismatic Spring viewing area. Resource impact waypoints occurred indiscriminately throughout the system and in larger numbers than the behavior waypoints. Thermal resource impacts were mapped throughout the entire boardwalk system. Resource impacts outside of thermal areas tended to be closer to the trailhead. Whether or not an impact was marked as occurring in a thermal area or in a non-thermal (other) area was influenced, in some respects, by the data collector's understanding and interpretation of the location of thermal areas. Nonetheless, the prevalence and distribution of resource impact waypoints suggests resource impacts occur in thermal and non-thermal areas along the entirety of the Midway Geyser Basin boardwalk system.

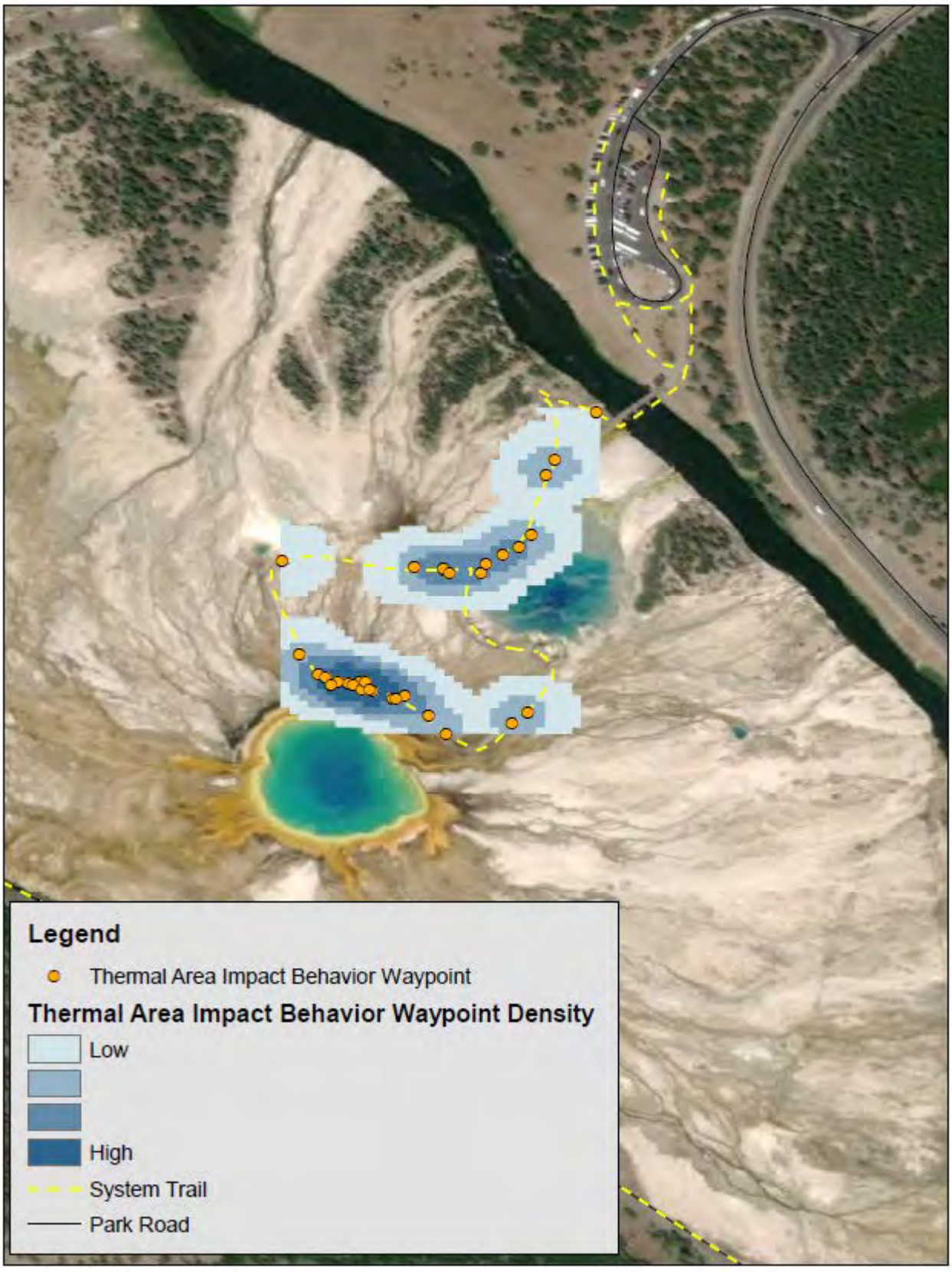

Figure 34. Thermal area impact behavior waypoint density analysis at Midway Geyser Basin.

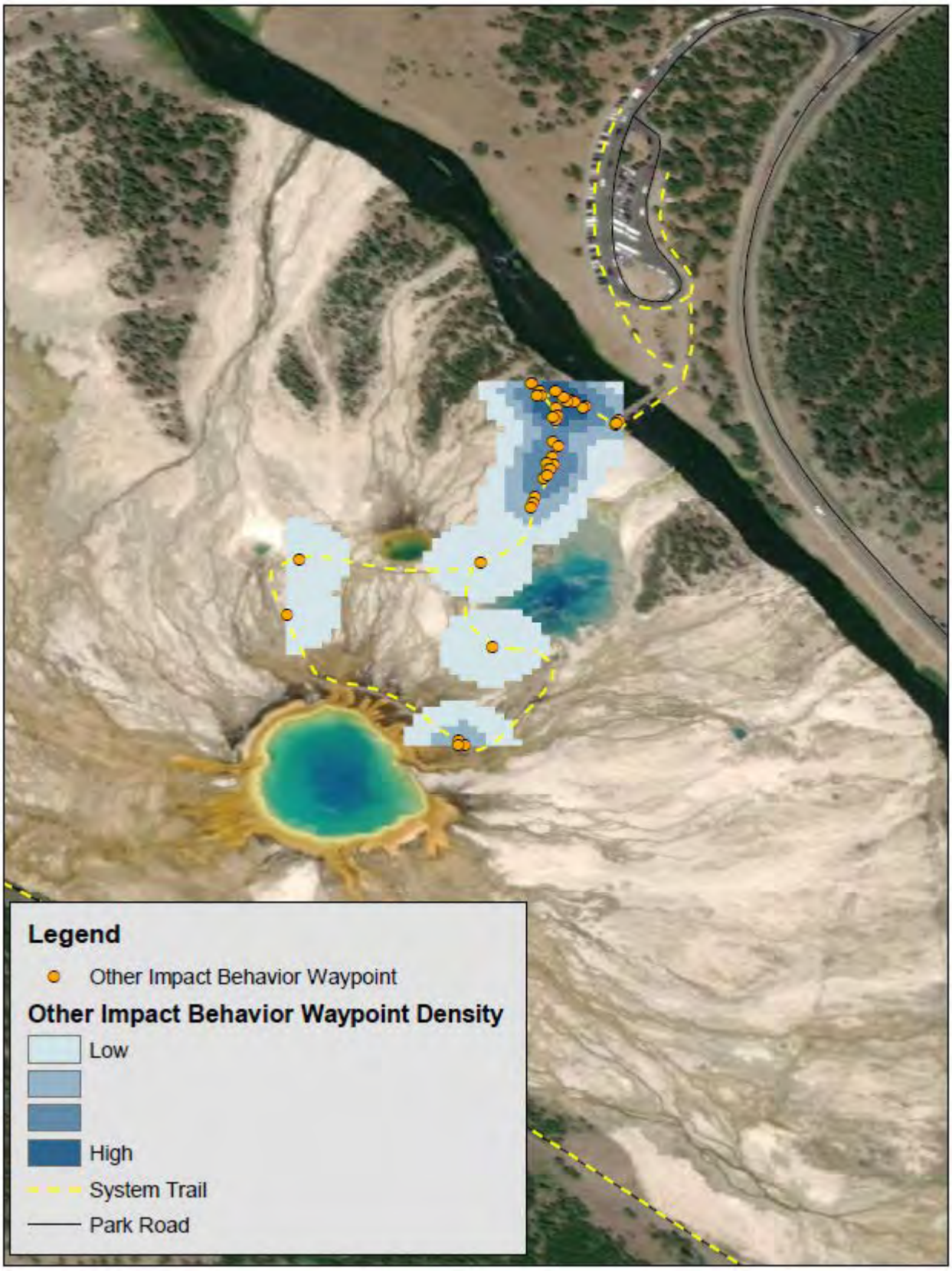

Figure 35. Other impact behavior waypoint density analysis at Midway Geyser Basin.

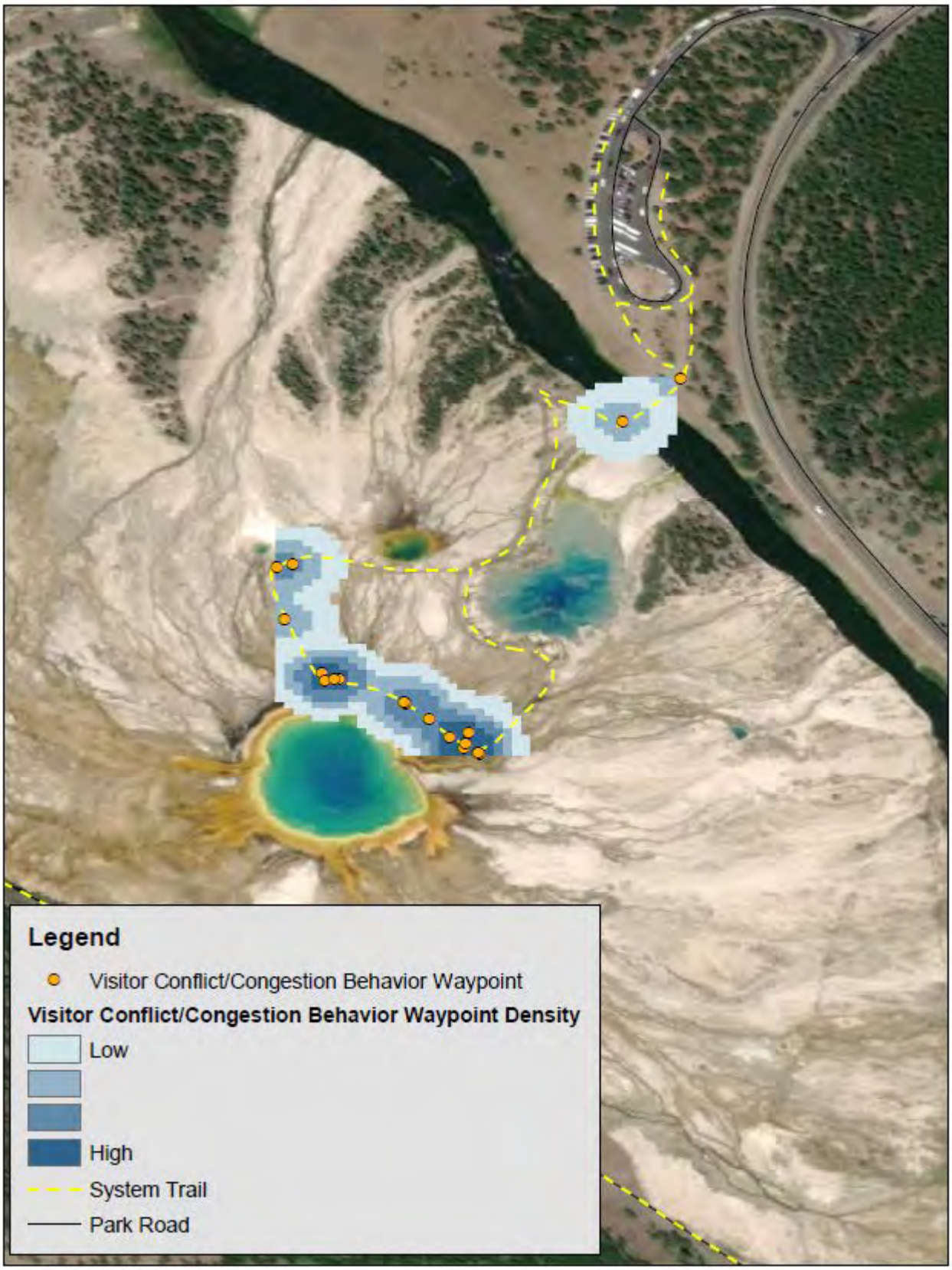

Figure 36. Visitor conflict and/or congestion waypoint density analysis at Midway Geyser Basin.

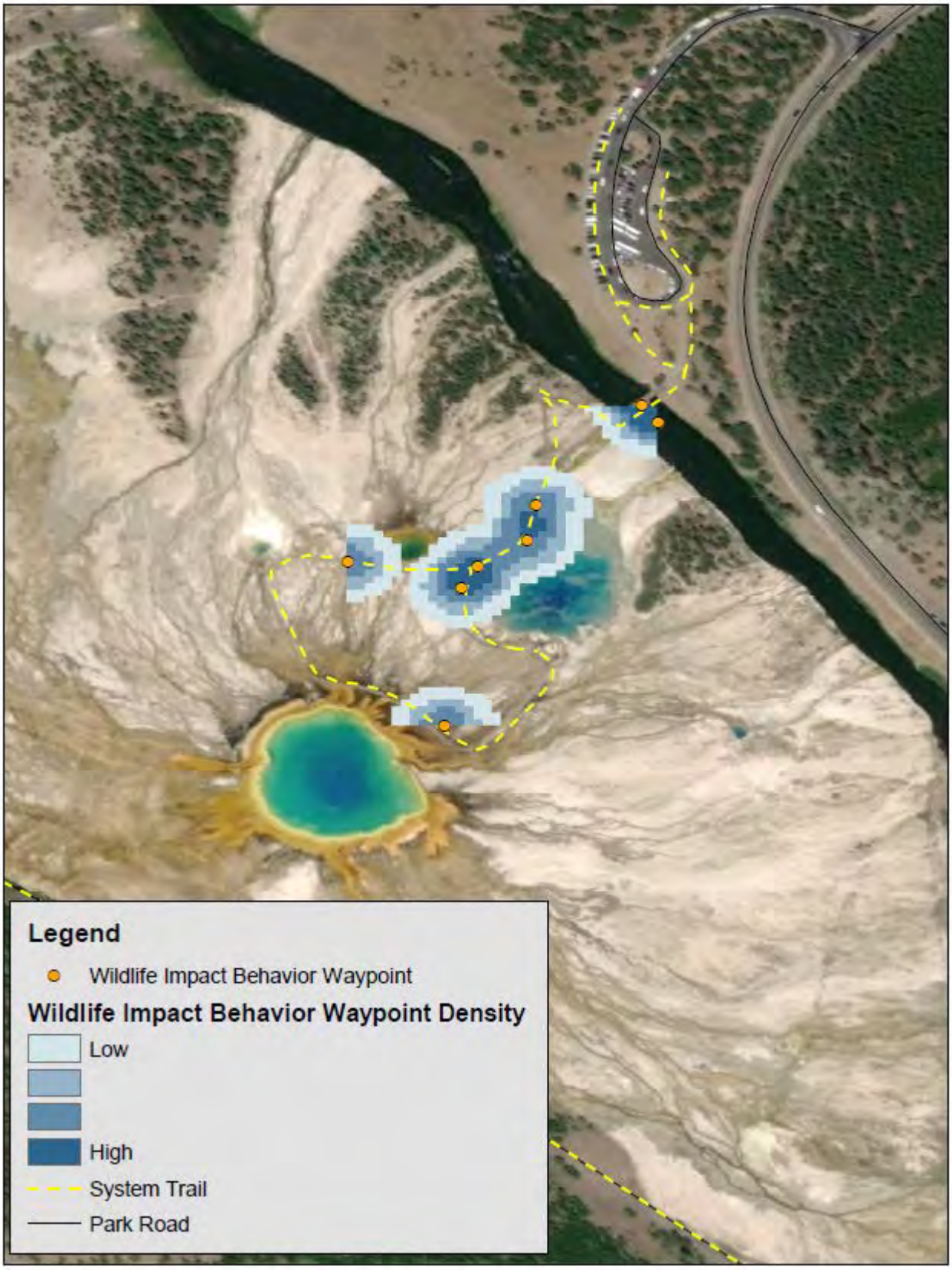

Figure 37. Wildlife impact behavior waypoint density analysis at Midway Geyser Basin.

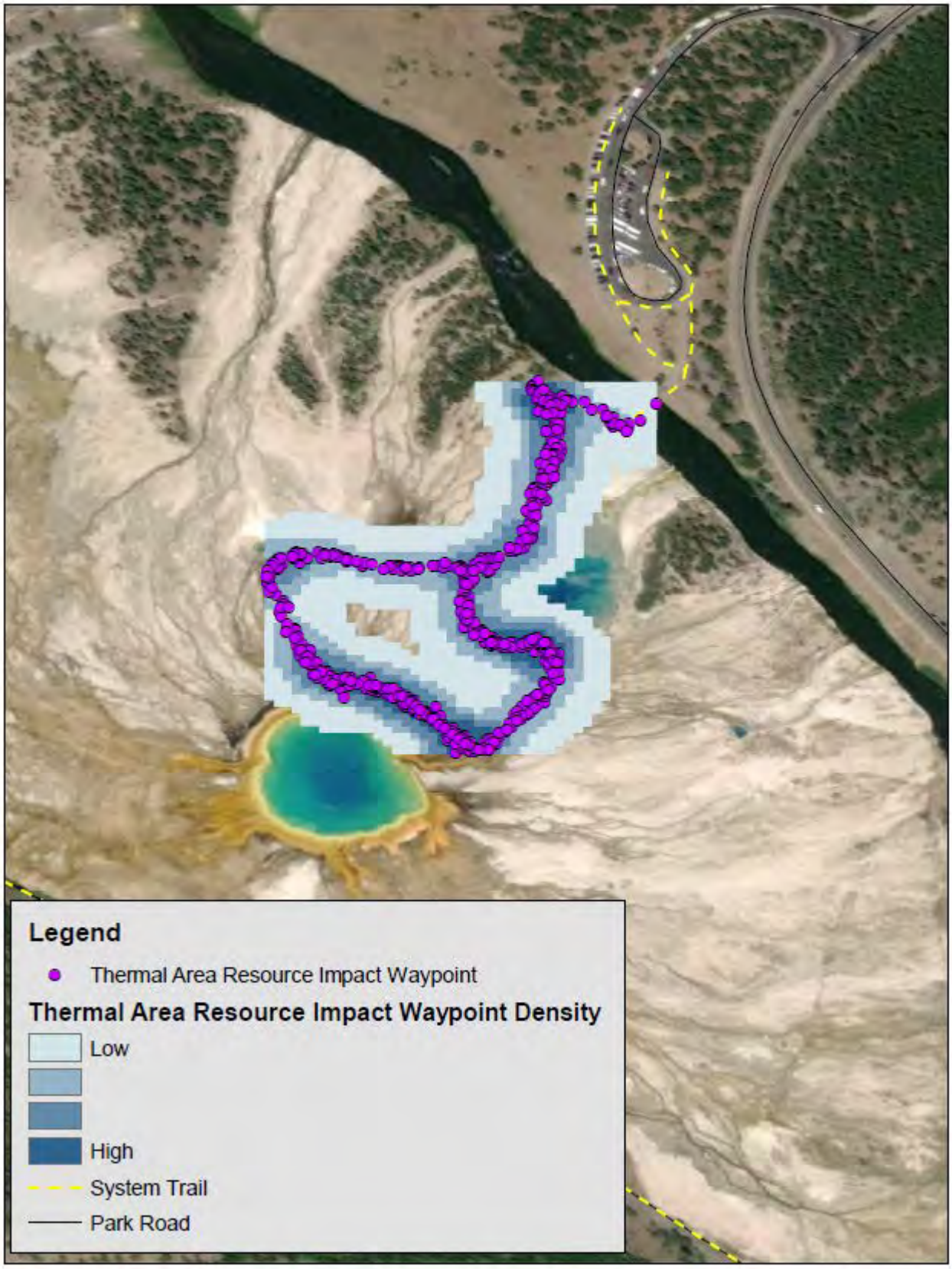

Figure 38. Thermal area resource impact waypoint density analysis at Midway Geyser Basin.

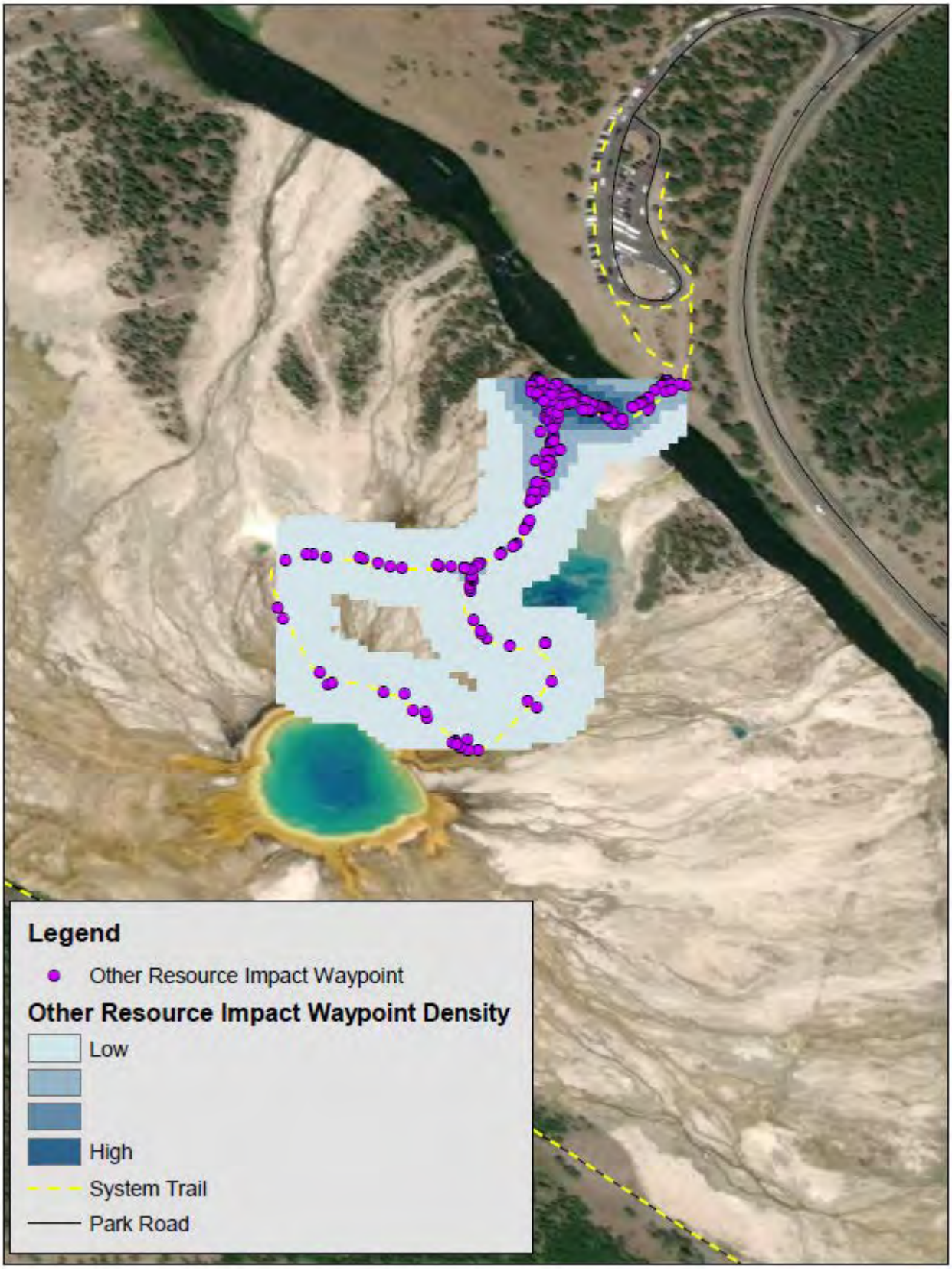

Figure 39. Other resource impact waypoint density analysis at Midway Geyser Basin.

Norris Geyser Basin

Visitor Use Estimation

Parking Lot Counts

The Norris Geyser Basin parking lot has 143 designated spots. Figure 40 shows the number of vehicles, on average, parked at Norris Geyser Basin (e.g., all counts at 9:00 are averaged together, all counts at 10:00 are averaged together for the whole data collection season). See Appendix D for full summary tables of parking lot counts. Appendix E contains graphs of average hourly vehicle counts for each focal attraction site parking lot by date. The magnitude of the patterns displayed in figure 40 and discussed in the accompanying text can be quantified through looking at the percent change in the total number of vehicles hour over hour in the Norris Geyser Basin parking lot (table 25). The percent change over hour provides a comparative metric for how the number of vehicles in the parking lot changes each hour.

When the YCC Crews arrive at Norris Geyser Basin, most days the parking lot is not yet full and an average number of 90 vehicles are in the parking lot. Between 9:00 and 10:00 there is a 62% increase in vehicles in the Norris Geyser Basin parking lot (table 25). After 10:00 parking remains relatively stable with only small percent changes either up or down (table 25). After 13:00 percent change in vehicles begins to reach double digits again and vehicle use at Norris Geyser Basin peaks with an average of 188 vehicles at 15:00 as the YCC Crews leave for the day (figure 40). At 13:00 there is an interesting change in where visitors are parking. Vehicles in designated spots begins to decrease, whereas roadside and undesignated parking increases (figure 40).

It is important to note the parking lot at Norris Geyser Basin was closed when deemed full by park staff (when park staff were available to enforce the closure). These closures were not consistent or regular but did occur throughout the sampling period of the YCC Crews. However, due to where the YCC Crews were collecting data, they were not always able to document when the parking lot was closed versus open. Therefore, some of the variability and patterns of use (such as the relatively flat increase in total vehicles combined with low numbers of roadside and undesignated parking from 10:00 to 13:00) at Norris Geyser Basin could be driven by the parking lot closures. There is no way to numerically examine the relationship between the data collected by the YCC Crews and these parking lot closures; however, looking at figure 40 it is clear that after 13:00, on average, total vehicles at Norris Geyser Basin increases steadily with roadside parking and undesignated parking appearing to drive the increase. This inflection point likely represents a change in the conditions at Norris Geyser Basin, such as the presence or absence of parking enforcement.

Table 25. Average percent change over hour in total vehicles in the Midway Geyser Basin parking lot.

Time	Percent Change in Total Vehicles
9:00 to 10:00	62 %
10:00 to 11:00	3 %
11:00 to 12:00	-2 %
12:00 to 13:00	-7 %
13:00 to 14:00	12 %
14:00 to 15:00	18 %

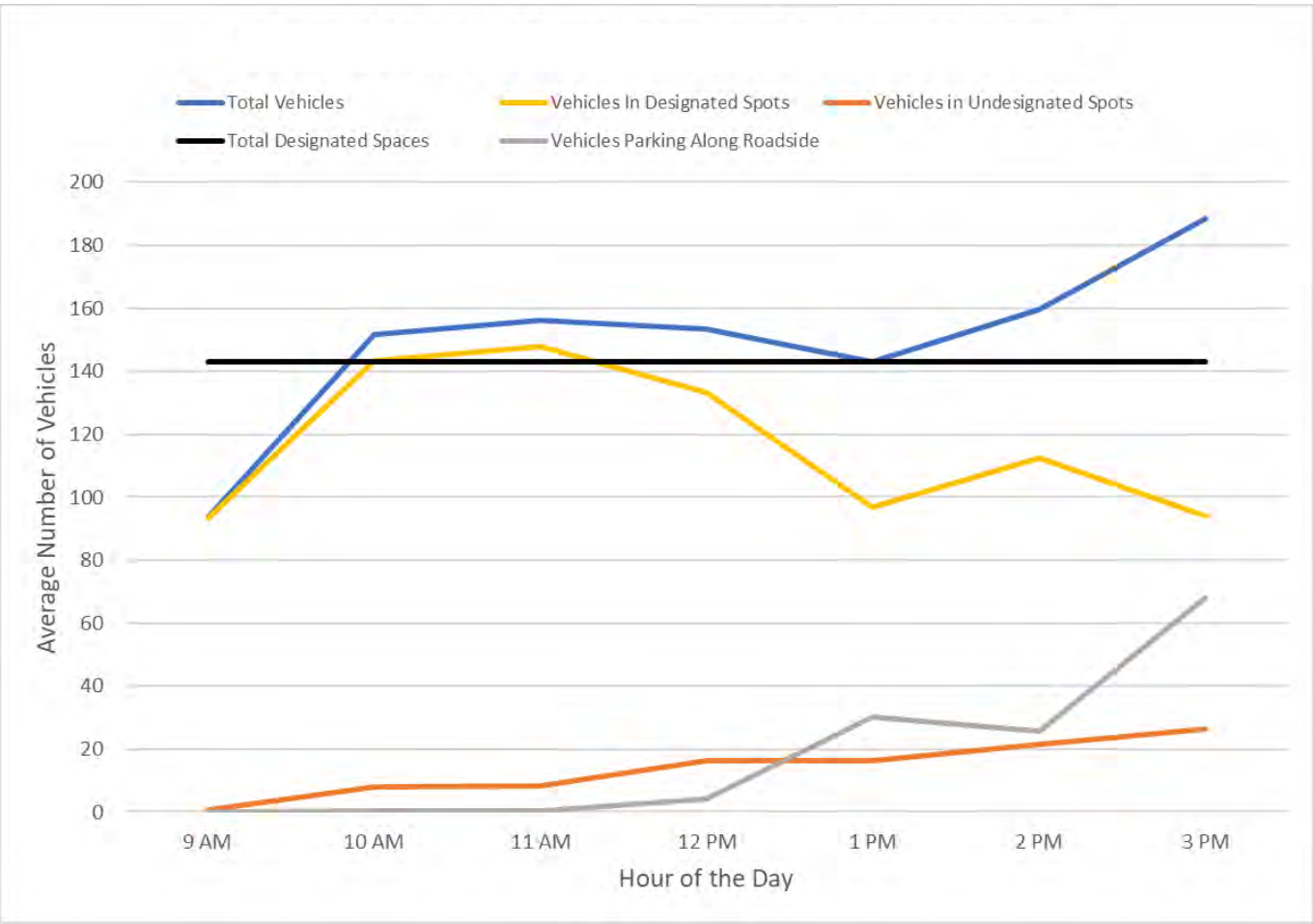

Figure 40. Average number of total vehicles parked at Norris Geyser Basin (blue line). The total number of vehicles is the sum of the average number counted in designated spots in the Norris Geyser Basin parking lot (yellow line), in undesignated spots (orange line), and parked along the roadside (grey line) by hour of the day. The total number of designated parking spaces in the Norris Geyser Basin parking lot is 143 spaces (black line; Otak 2017).

Table 26 reports the average number of tour buses, RVs, and queued vehicles in the Norris Geyser Basin parking area across the sample days. The average number of tour buses ranged from one to two buses, with the overall average being one. The average number of RVs ranged from 2 to 10 RVs, with the average being seven. These data suggest that across the sampling period, tour buses and RVs consistently occurred in the Norris parking area, with RVs occurring in greater magnitudes than tour buses. Queued vehicles also consistently occurred in the Norris Geyser Basin parking lot; however, the magnitude of queued vehicles varied across the sampling period. The average number of queued vehicles ranged from 3 to 26 vehicles, with an overall average of 13 vehicles. It should be noted that during some dates of the sampling period, the parking at Norris Geyser Basin was actively managed by park staff who limited the number of vehicles allowed to enter the parking area. The variability seen in the vehicle queuing data at Norris across the sample days may be a function of active parking management rather than actual fluctuations occurring in an unmanaged scenario.

Table 27 reports the average number of tour buses, RVs, and queued vehicles by time of day at Norris Geyser Basin. Across the hours of the day, the number of tour buses ranged from zero to two buses, with an overall average of one bus. Notably, the average number of tour buses was greater during the 9:00 and 10:00 hours and tended to be lower throughout the rest of the day, suggesting that tour buses may be stopping in the Norris Geyser Basin parking

lot at higher frequencies during the morning hours. The average number of RVs ranged from five to nine per hour, with the overall average being seven. The average number of queued vehicles ranged from 0 to 36 across hours of the day, with the highest average vehicle queues occurring between the 10:00 and 12:00 hours. It should be noted the sharp drop off in the average number of vehicles queued after 12:00 (from an average of 27 vehicles queued to an average of 0 vehicles queued) is likely a function of the active parking management that occurred in the Norris parking area during certain hours of the day during the 2018 season.

Table 26. Average number of tour buses, RVs, and queued vehicles by sampling day at Norris Geyser Basin. These counts were taken at the same time as the parking lot counts. SD = standard deviation, n = sample size.

		Tour Bus Counts		RV Counts		Vehicle Queue Counts	
Date	***n***	**Average**	**(±SD)**	**Average**	**(±SD)**	**Average**	**(±SD)**
6/20/2018	6	2	3	8	2	7	19
6/26/2018	5	1	1	6	3	3	3
7/23/2018	5	1	1	6	3	14	29
8/2/2018	7	1	1	8	5	26	2
8/6/2018	3	1	0	10	3	6	29
8/10/2018	3	1	1	2	2	24	1
Overall	**-**	**1**	**1**	**7**	**3**	**13**	**14**

Table 27. Average number of tour buses, RVs, and queued vehicles by time of day at Norris Geyser Basin. These counts were taken at the same time as the parking lot counts. SD = standard deviation, n = sample size.

		Tour Bus Counts		RV Counts		Vehicle Queue Counts	
Time	***n***	**Average**	**(±SD)**	**Average**	**(±SD)**	**Average**	**(±SD)**
9:00	5	2	2	5	3	2	3
10:00	5	2	3	8	4	24	18
11:00	4	1	1	9	6	36	34
12:00	3	0	1	8	3	27	23
13:00	4	0	0	7	1	0	0
14:00	5	1	1	7	4	2	3
15:00	3	1	0	6	5	8	8
Overall	**-**	**1**	**1**	**7**	**4**	**14**	**13**

Restroom Line Counts

Restroom occupancy and restroom line length data were also collected for the restrooms in the Norris Geyser Basin parking area during the parking lot count period. Table 28 reports the three restroom line length measures collected by date: number of people in line when a person entered the restroom, number of people in line when a person exited the restroom, and the average restroom occupancy time. Across the sample days, average line lengths ranged from one to three people at a person's entry and one to four people at a person's exit from the restroom. The average occupancy time was one minute across most sample days. These data suggest that across the sample period, visitors generally had to wait in line for the bathroom at Norris Geyser Basin, but average line lengths were relatively short.

Table 28. Average restroom occupancy (in minutes) and restroom line length by date for Norris Geyser Basin. SD = standard deviation, n = sample size.

		Number in Line at Entry		Number in Line at Exit		Restroom Occupancy (minutes)	
Date	***n***	**Average**	**(±SD)**	**Average**	**(±SD)**	**Average**	**(±SD)**
6/20/2018	51	3	2	4	2	1	1
6/26/2018	66	1	1	1	1	1	1
7/23/2018	42	1	2	1	2	2	1
8/2/2018	63	1	2	1	2	1	1
8/6/2018	-	-	-	-	-	-	-
8/10/2018	41	2	3	1	1	1	1
Overall	**-**	**2**	**2**	**2**	**2**	**1**	**1**

Table 29 reports the average restroom line length at entry and exit and the average restroom occupancy by hour of the day for the Norris Geyser Basin parking area restrooms. Average line length at entry and at exit ranged from zero to three people across hours of the day. Average occupancy ranged between one and two minutes, with average occupancy being longer in the afternoon hours between 13:00 and 14:00. These data suggest, across hours of the day, visitors must wait in line for the restroom at Norris Geyser Basin but average line lengths were not very long.

Table 29. Average restroom occupancy (in minutes) and restroom line length by hour for Norris Geyser Basin. SD = standard deviation, n = sample size.

		Number in Line at Entry		Number in Line at Exit		Restroom Occupancy (minutes)	
Time	***n***	**Average**	**(±SD)**	**Average**	**(±SD)**	**Average**	**(±SD)**
9:00	58	2	3	1	1	1	1
10:00	81	1	2	1	2	1	1
11:00	46	2	2	2	2	1	1
13:00	34	3	2	3	3	1	1
14:00	33	1	2	2	2	2	1
15:00	11	0	1	0	0	2	1
Overall	**-**	**2**	**2**	**2**	**2**	**1**	**1**

The restroom line and occupancy data were further explored to understand how the average length at time of entry and average length at time of exit varied across time. By looking at the concurrently collected data, trends in whether restroom lines were getting longer or getting shorter across time can be identified. Figure 41 graphs the average line length at entry and the average length line at exit, in 15-minute time bins, for the Norris Geyser Basin parking lot restrooms. The two lines track together closely from 9:00 to 13:00, after which the lines diverge. From approximately 13:15 to 14:00 and again from 14:30 to 15:00, the average number of people in line at entry is greater than the average number of people in line at exit, suggesting the line length is decreasing during this period. From 14:00 to 14:30, the opposite pattern occurs and the line length is growing. This variability in the pattern suggests that during the afternoon hours the restroom line lengths, and subsequent wait times, are more variable than during the morning hours at Norris Geyser Basin.

The average restroom occupancy times can be used to understand average restroom line wait times across the sample day. At Norris Geyser Basin, the average restroom line wait time ranged from one to two and a half minutes. At the average peak line length across the day (five people), the average wait could range from 5 minutes to 12.5 minutes.

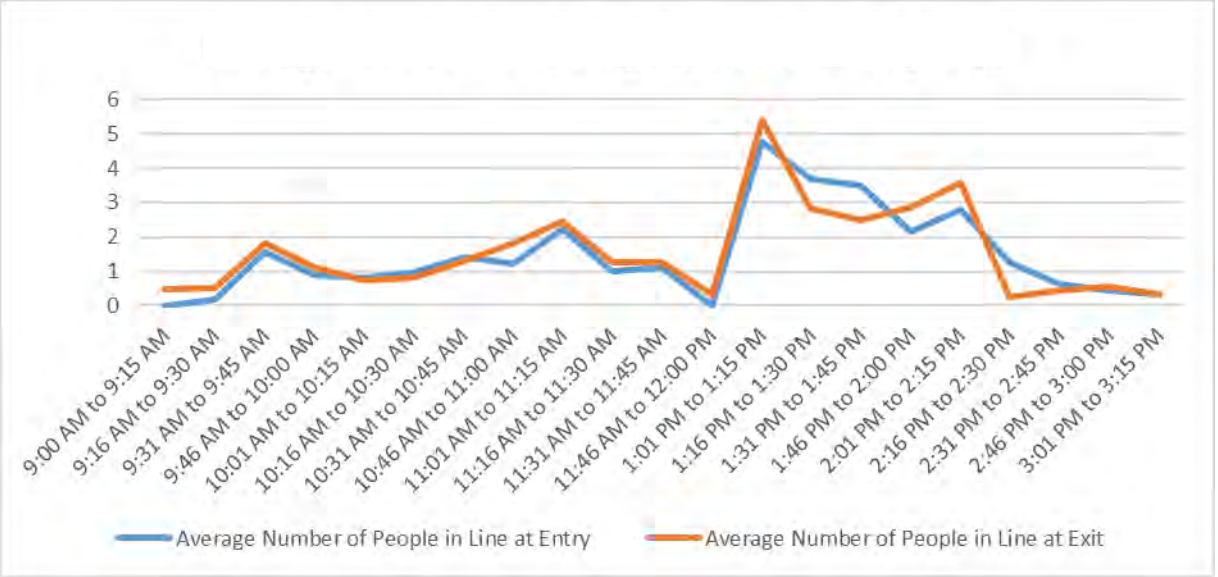

Figure 41. Graph of average restroom line lengths at entry and exit at Norris Geyser Basin, organized by 15-minute time bins.

Caution should be used when interpreting the Norris Geyser Basin restroom data collected for 2018. Norris Geyser Basin contains three clusters of restrooms in the parking area, one comfort station with flushing toilets and running water and two clusters of vault-style toilets. Discussion with park managers during the onsite presentation of results suggests restroom wait times may vary by the type and location of restroom available at Norris Geyser Basin. Data collected during the 2018 season were not labeled consistently by restroom type or location, so these suspected trends were unable to be explored empirically. The 2019 data collection forms have been modified to record distinct occupancy and line length data for each restroom cluster at Norris Geyser Basin to explore the potential for restroom line length and wait time differences by restroom location and type. The potential differences in restroom line lengths and wait times could have depressed the average wait times and line lengths if conditions varied widely by restroom type or location. Further, the comfort station style restroom at Norris Geyser Basin enables visitors to wait in line inside the restroom building itself prior to using the restroom. These visitors were not visible to YCC observers in 2018 and it is likely that restroom line lengths were artificially shortened by not being able to observe the full restroom line. Given this constraint, it is possible restroom wait times were longer than reported.

Automatic Trail Counter

The trail counter at Norris Geyser Basin was deployed from June 19, 2018, through October 24, 2018, collecting data continuously during that time period in hourly time bins. The data are summarized according to season of use, with data collected from June 19, 2018, through September 3, 2018 (Labor Day), being categorized as the peak use season and data collected from September 4, 2018, through October 24, 2018, being categorized as shoulder season data. Peak season data are reported here in the body of the report. The same graphical and tabular summaries are presented for the shoulder season data in Appendix F.

The count data included in this report are calibrated data; uncalibrated count data are not presented. Five hours of calibration data collected across five days throughout the peak use season were used to calibrate the Norris counter. The calibration coefficient for the 2018 deployment of the Norris counter is 1.85. A calibration coefficient over a value of one indicates the counter was undercounting the number of passes in front of the counter. The calibration coefficient of 1.85 suggests the counter at Norris was under counting by almost a factor of two. The R^2 value for the regression equation used to generate the calibration coefficient is 1.00, suggesting the counter consistently undercounted the number of passes. The high calibration coefficient, and accompanying R^2 value, suggest the placement of the counter could be improved to reduce the amount of error in the originally collected count data. For reference calibration coefficients between 0.75 and 1.25 are usually considered within the normal range of counter error for well-placed counters. The high calibration coefficient does not compromise the quality of the counter data that was collected once it has been corrected for counter error. However, better trail counter placement does result in higher quality data with less error.

Across the peak use season, daily total counts ranged from approximately 0 counts to a peak of nearly 14,000 counts (figure 42). A count is considered one pass by the counter; it cannot be interpreted as an individual. The counters record a tally each time an individual passes the count location regardless of direction of travel. Visits reported here correspond to either an entrance or an exit from the Norris Geyser Basin trail system.

The wide variability seen in the peak season use data at Norris Geyser Basin is unexpected, particularly the lower overall counts recorded during the July 2 through July 18, 2018, where total daily visits were consistently under 2,000 visits. During this time a piece of tape was obstructing the automatic counter sensor, and the resulting erroneous counts collected between July 2-18, 2018, were not included in any summary data analysis. Excluding this timeframe, daily total counts tended to fluctuate around 12,000 counts until the middle of August, when counts began to decrease toward 8,000 counts before peaking again over the Labor Day weekend with 12,442 counts on September 2, 2018.

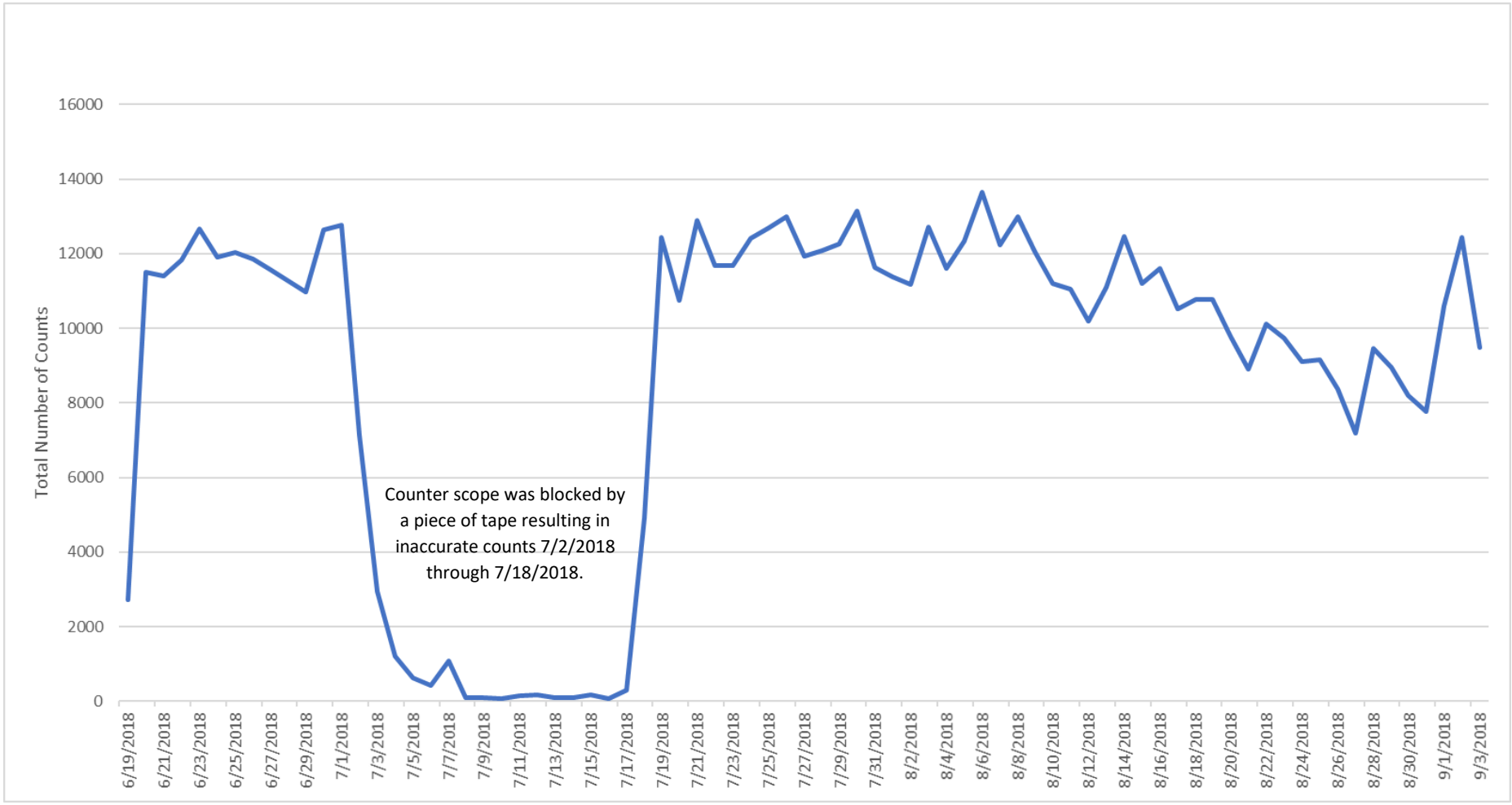

Figure 42. Daily total number of counts at Norris Geyser Basin during the peak use season from June 19 through September 3, 2018.

Looking across hours of the day, counts tended to start occurring at Norris Geyser Basin in the 6:00 hour and increased steadily until the 11:00 hour (see tables 30 and 31) where counts consistently exceed 800 counts per hour until 16:00 (table 30; figure 43). After this time, average hourly counts begin decreasing, with counts dropping out the triple digits after the 20:00 hour. The magnitude of standard deviations during the peak use hours of the day (11:00 through 16:00) at Norris Geyser Basin are approximately half of the average value for those hours, suggesting that throughout the use season the number of counts during these hours is likely to be variable with hours experiencing significantly more or significantly less visitation than the average values.

Table 30. Average number of hourly counts during the peak use season (June 19 through September 3, 2018) at Norris Geyser Basin. SD = standard deviation; N = sample size.

Hour	Average	±SD	N*
0:00	1	3	76
1:00	0	1	76
2:00	0	1	76
3:00	0	0	76
4:00	0	1	76
5:00	2	3	76
6:00	29	27	76
7:00	214	129	76
8:00	329	188	76
9:00	594	307	76
10:00	779	394	75
11:00	854	445	76
12:00	834	444	76
13:00	846	458	76
14:00	830	435	75
15:00	866	435	76
16:00	859	450	76
17:00	781	427	77
18:00	604	341	77
19:00	366	218	77
20:00	169	116	77
21:00	33	36	77
22:00	2	6	77
23:00	2	12	77

*N varies across hours of the day based on the hour of counter installation, the hours of data download, and the hour of counter removal.

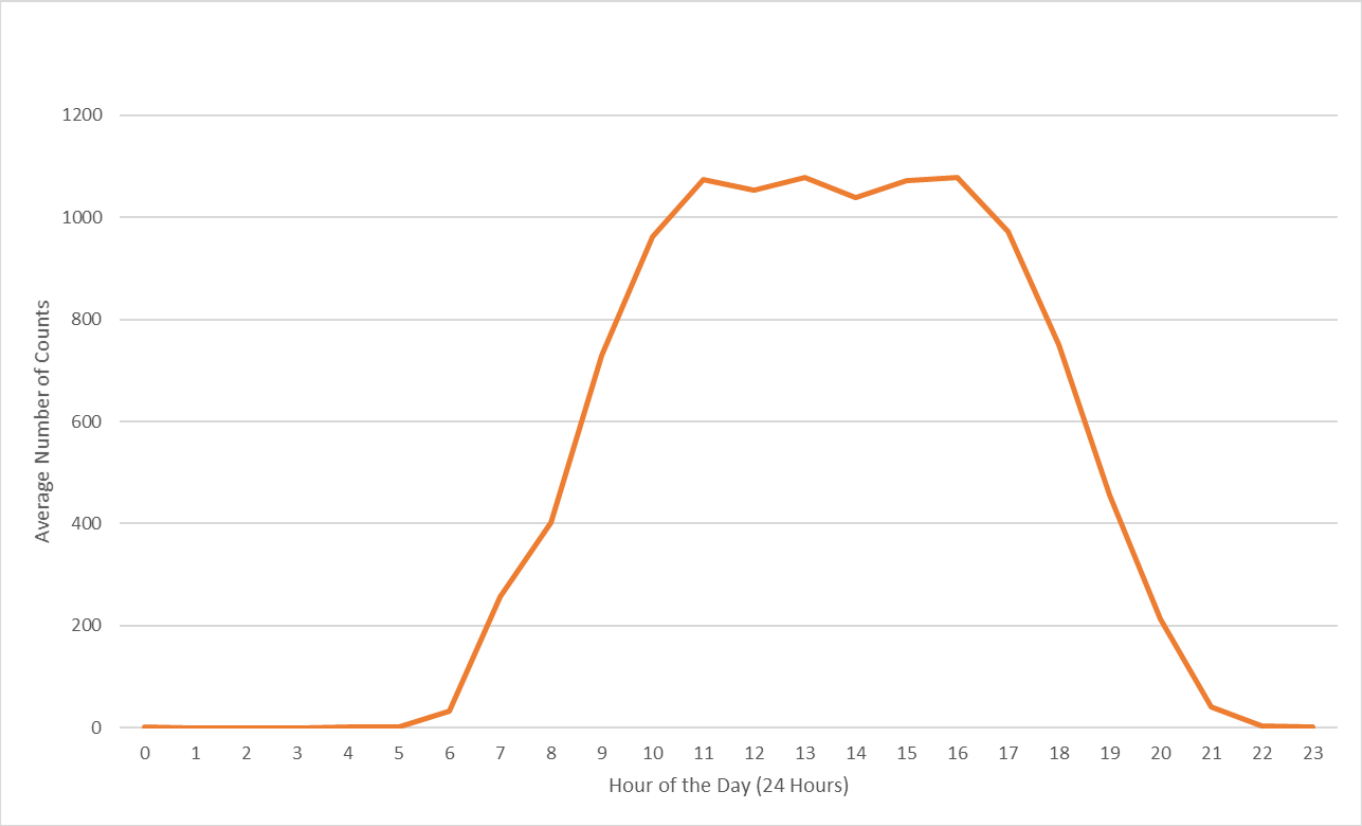

Figure 43. Average number of hourly counts at Norris Geyser Basin during the peak use season from June 19 through September 3, 2018.

Table 31: Percent change in counts by automatic trail counter per hour at Norris Geyser Basin.

Time	Percent Change in Total Counts by Hour
6:00 to 7:00	638 %
7:00 to 8:00	54 %
8:00 to 9:00	81 %
9:00 to 10:00	31 %
10:00 to 11:00	10 %
11:00 to 12:00	-2 %
12:00 to 13:00	1 %
13:00 to 14:00	-2%
14:00 to 15:00	4 %
15:00 to 16:00	-1 %
16:00 to 17:00	-9 %
17:00 to 18:00	-23 %
18:00 to 19:00	-39 %
19:00 to 20:00	-54 %
20:00 to 21:00	-80 %
21:00 to 22:00	-94 %
22:00 to 23:00	0 %
23:00 to 24:00	-100 %

Looking across days of the week (table 32 and figure 44), the average number of counts varies, with Tuesdays, on average, experiencing the lowest number of counts during the week and Saturdays, on average, experiencing the highest number of counts. The number of counts on weekend days tended to be higher than the number of visits on weekdays, except for Wednesdays which experienced a number of counts comparable to a weekend day visitation. The standard deviations for all average estimates are approximately 50% or more of the average estimate, so it is likely that visitation varies widely within days of the week across the peak use season.

Table 32. Average number of daily counts by day of week during the peak use season (June 19 through September 3, 2018) at Norris Geyser Basin. SD = standard deviation, N = sample size.

Day	Average	±SD	N*
Sunday	9363	4736	11
Monday	8670	4747	11
Tuesday	7730	5132	11
Wednesday	8790	4576	11
Thursday	9246	4560	11
Friday	8846	4457	11
Saturday	9517	4552	11

*N varies across days of the week due to the day of counter installation and the day of counter removal.

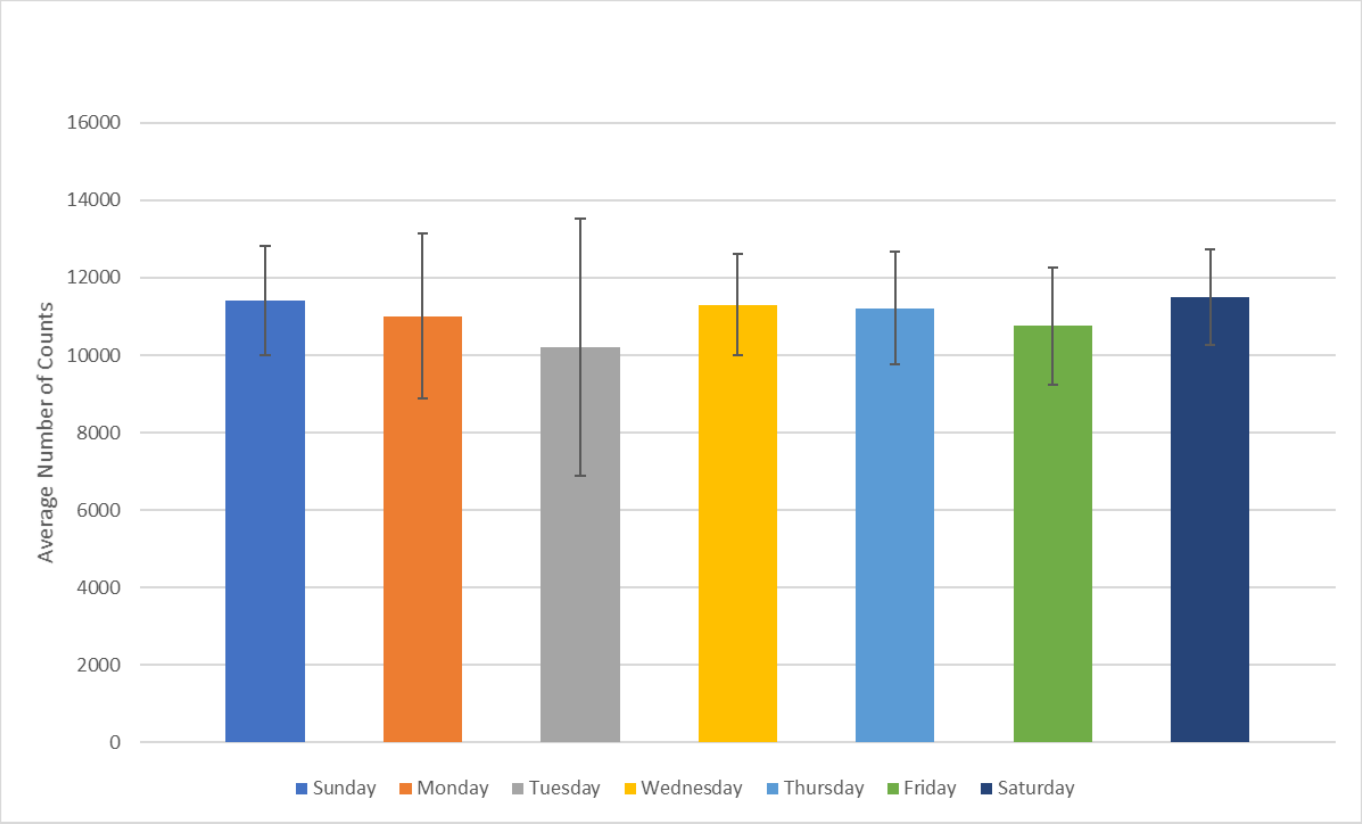

Figure 44. Average number of visits, by day of week, at Norris Geyser Basin during the peak use season from June 19 through September 3, 2018. The vertical black bars extending above and below the top of the colored bars represent the standard deviation for the estimate of the mean for each day.

Visitor Use/Capacity Measures

Visitor encounters along the Porcelain Basin trail (see figure 5) averaged 245 visitors per hike of the entire loop (table 33). Encounter counts conducted by the YCC Crews ranged from 97 visitors (recorded on 8/2/2018) to 454 visitors (recorded on 8/10/2018) in a single hike of the entire loop trail (table 33). The Norris Geyser Basin focal attraction site included two PAOT locations in Porcelain Basin: on the stairs down to the boardwalk and on the boardwalk trail where it curves on the way to Whirligig Geyser (see figure 5). On average, the boardwalk had higher PAOT counts (30 visitors) compared to the stairs area (24 visitors; table 34). At both PAOT locations counts were highly variable across a day (figures 45 and 46).

As occurred at Midway Geyser Basin, occasionally these two PAOT locations were counted together and summarizes of these "Both" counts can be found in table 34. Due to some counts being combined, the total sample size for each individual PAOT location (the stairs and the boardwalk) are lower in 2018 than they were in 2017. Only three days of data collection occurred for each PAOT location. Despite this, multiple counts of each location were taken each day, but the PAOT counts for 2018 may not be as accurate as those collected in 2017. It is also important to remember that PAOT counts are variable and occur at one instant in time, so low values can be observed during periods of overall high visitor use and higher counts can be observed during overall lower use times (e.g., high counts occurring in the afternoon even though overall use tends to be highest in the morning hours). PAOT and trail counters provide a more site-specific metric of how visitor experiences may vary at a location.

Table 33. Summary of trail encounters (number of visitors passed) for the entire 1-mile Porcelain Geyser Basin loop at Norris Geyser Basin. SD = standard deviation; N = number of counts that equaled the entire trail length.

Date	Average	±SD	Min	Max	N
6/20/2018	203	76	110	429	14
6/26/2018	241	54	113	344	16
7/25/2018	222	91	109	403	15
8/2/2018	252	98	97	453	14
8/6/2018	287	86	192	418	6
8/10/2018	331	109	171	454	8
Overall:	**245**	**90**	**97**	**454**	**73**

Table 34. PAOT summary for PAOT locations at Norris Geyser Basin. SD = standard deviation; N = sample size.

	Porcelain Basin Stairs					Porcelain Basin Boardwalk					Both Stairs and Boardwalk				
Date	Average	±SD	Min	Max	N	Average	±SD	Min	Max	N	Average	±SD	Min	Max	N
6/20/2018	-	-	-	-	-	-	-	-	-	-	18	7	7	29	15
6/26/2018	-	-	-	-	-	8	-	8	8	1	13	8	4	30	15
7/25/2018	37	27	8	105	16	15	14	1	43	14	-	-	-	-	-
8/2/2018	9	10	0	35	16	42	40	2	148	16	-	-	-	-	-
8/6/2018	-	-	-	-	-	-	-	-	-	-	64	20	35	102	9
8/10/2018	33	8	23	42	4	42	17	22	60	4	-	-	-	-	-
Overall	**24**	**23**	**0**	**105**	**36**	**30**	**31**	**1**	**148**	**35**	**27**	**24**	**4**	**102**	**39**

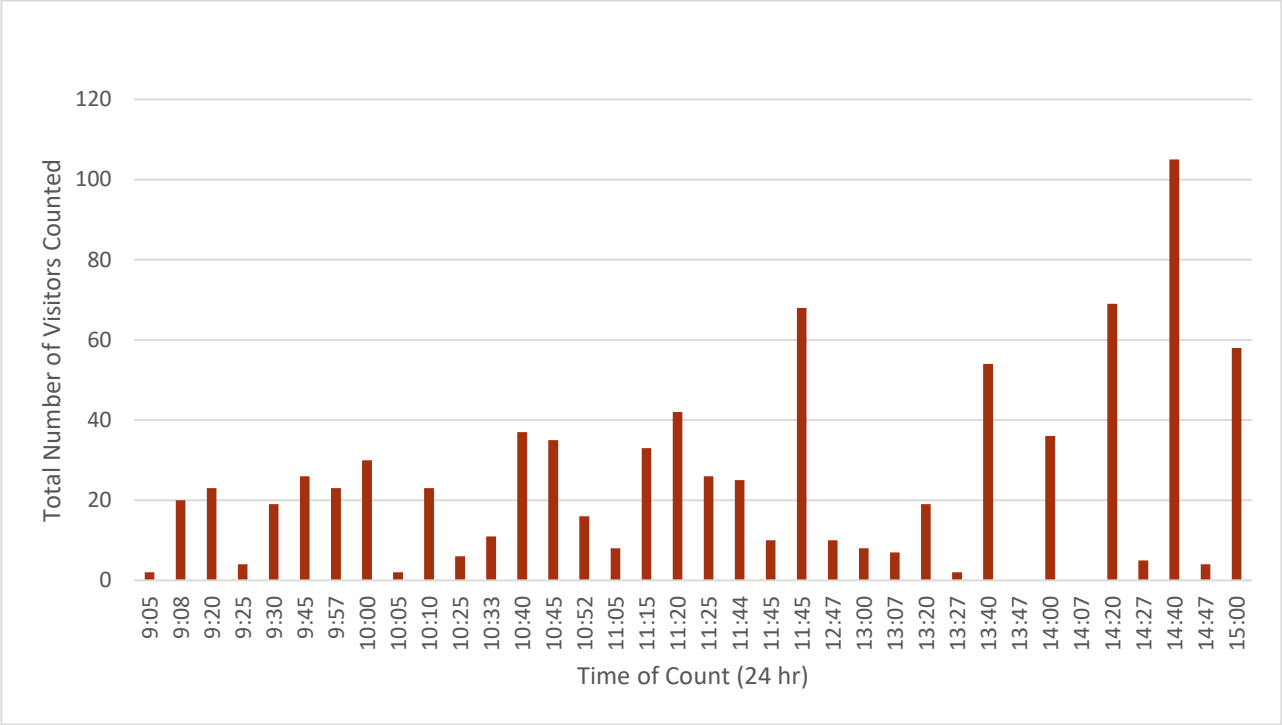

Figure 45. All individual PAOT counts organized by time at the stairs leading down to the Porcelain Basin boardwalk at Norris Geyser Basin.

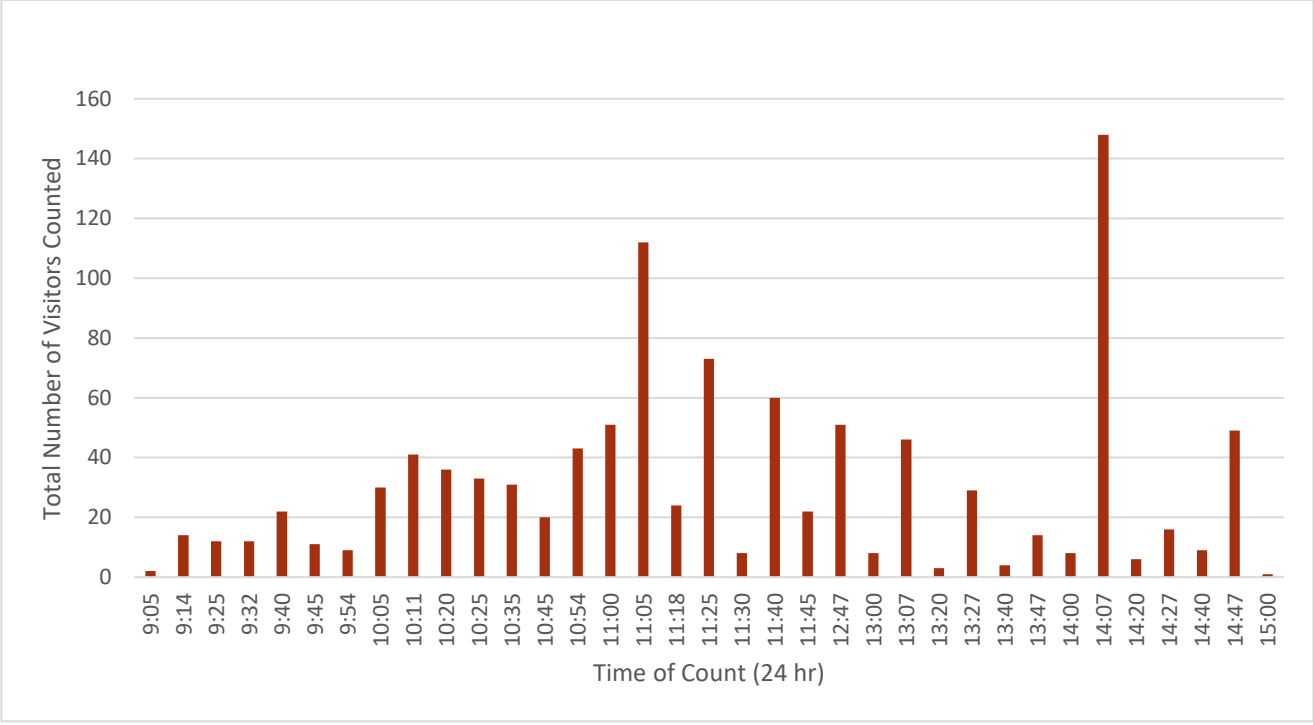

Figure 46. All individual PAOT counts organized by time at the boardwalk heading towards Whirligig Geyser at Norris Geyser Basin.

Visitor Spatial Behavior

Note on density maps: For this section, on all kernel density maps, although the blue density layer may extend beyond the trail or boardwalk, that does not necessarily mean use or impacts extends that far. The width of the blue density layer on the maps provided in this section is an artifact of the analysis type. See "Methods" section for more detail.

GPS-based Tracking

Figure 47 and Figure 48 show the extent and density for GPS study participants at Norris Geyser Basin. The GPS tracks collected from participants at Norris Geyser Basin are displayed in figure 47, with the blue dots representing collected GPS tracking data. On average, visitors to Norris Geyser Basin spend approximately one-hour recreating. The minimum visit duration was three minutes and the maximum visit duration was two hours and 44 minutes (table 35).

Table 35. Average, minimum, and maximum amount of time spent in the Norris Geyser Basin by GPS participants.

Measure	Time (h:mm:ss)
Average	0:59:00
±SD	0:33:00
Minimum	0:03:00
Maximum	2:44:00

Looking at the pattern of use at Norris Geyser Basin, use occurs throughout the trail system with all open boardwalks and trails receiving at least some level of use, as evidenced by the GPS track pattern and the kernel density map. The highest densities of use in Norris Geyser Basin occur right at the entry into the geyser basin, with the darkest blue patch of the kernel density map located near the Norris Geyser Basin Museum and "entrance" into the geyser basin from the parking lot trail. Other areas of high GPS point density include the area near Steamboat Geyser and portions of the trails leading to the Porcelain Basin. During the 2018 sampling season, portions of the Norris Geyser Basin boardwalk that allowed visitors to walk a complete loop around Porcelain Basin were under construction and closed for various durations during the season. Therefore, the use pattern observed in 2018 may be atypical of general patterns of use at Norris due to this disruption. Additionally, Steamboat Geyser was active during the 2018 data collection period, which also could have influenced visitor behavior. A supplemental report comparing visitor behavior related to the eruption activity of Steamboat Geyser from the 2017, 2018, and 2019 GPS-based tracking data will be provided to YELL as an addendum to this report in the fall of 2019.

Figure 47. Raw, cleaned GPS-based tracking point data collected from visitors at Norris Geyser Basin. GPS units were handed out at the trailhead.

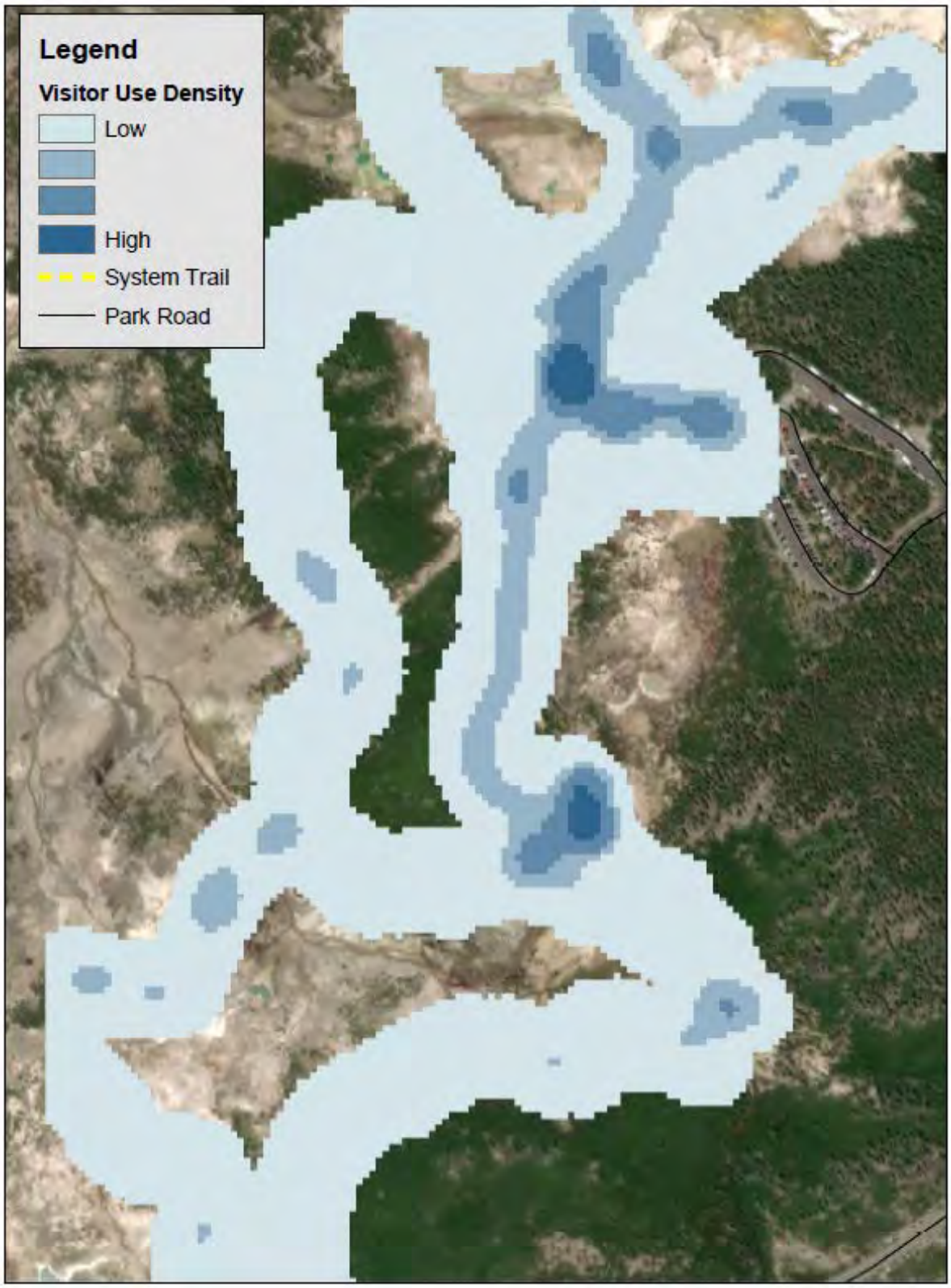

Figure 48. Density of GPS-based tracking points collected from visitors at Norris Geyser Basin. Low densities are an estimated count of 10-209 points per 1 m^2 and high densities are an estimated count of 1,288-2,671 points per 1 m^2**.**

Waypoint Mapping

In addition to GPS tracking of visitor travel patterns at Norris Geyser Basin, two types of GPS waypoints were collected to mark where behaviors expected to cause resource impacts occur along the trail (hereafter impact behavior waypoints) and to mark where resource impacts have already occurred along the trail (hereafter resource impact waypoints). For waypoints labeled as "Other" please see detailed table in Appendix H listing the comment recorded by the YCC Crews for each "Other" waypoint. A total of 912 waypoints were collected at Norris Geyser Basin across six days of sampling (figure 49). The darker blue portions of the kernel density map figure 49 indicate that a higher number of waypoints occurred at these locations. At Norris Geyser Basin, the highest density of waypoints occurred near the Norris Geyser Basin Museum where the parking lot trail meets the geyser basin network of trails and boardwalks.

To generate a more detailed understanding of how specific resource impacts or impact behaviors are spatially distributed at Norris Geyser Basin, the resource impact and impact behavior waypoints were separated for further analysis. Waypoints were matched to behavior codes using a spatial join. During the match process, 48 waypoints were unable to be matched due to missing behavior codes, resulting in a 95% match rate between recorded behavior codes and marked GPS waypoints. The results to follow are generated from the 912 matched waypoint and behavior code pairs.

Figure 50 shows the frequency distribution and number of observations for impact behavior waypoints at Norris Geyser Basin. A total of 124 impact behavior waypoints were marked, with most of those waypoints being classified as visitors actively littering in a non-thermal area (LIT1), visitors actively littering in a thermal area (THLIT1), and groups obstructing the flow of other groups (FLOW). Figure 51 shows the frequency distribution and number of observations for the resource impact waypoints at Norris Geyser Basin. A total of 742 resource impact waypoints were marked, with many of those waypoints marking locations where litter was observed in a non-thermal area (LIT2) followed by litter observed in a thermal area (THLIT2). Refer to table 2 for detailed descriptions for each impact behavior and resource impact code.

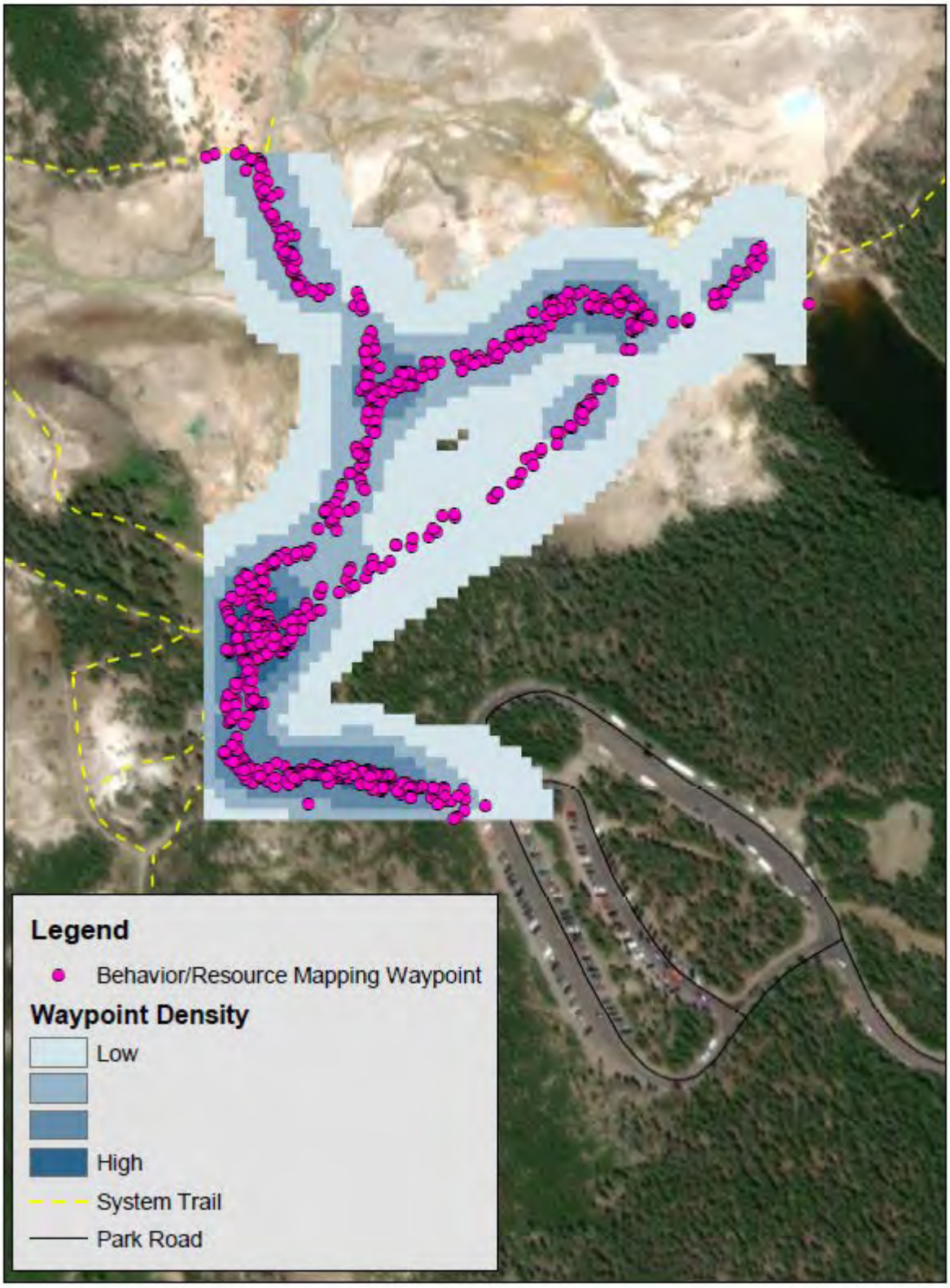

Figure 49. Density of impact behavior and resource impact waypoints at Norris Geyser Basin. Low densities are an estimated count of < 1-8 points per 1 m^2 and high densities are an estimated count of 36- 63 points per 1 m^2**.**

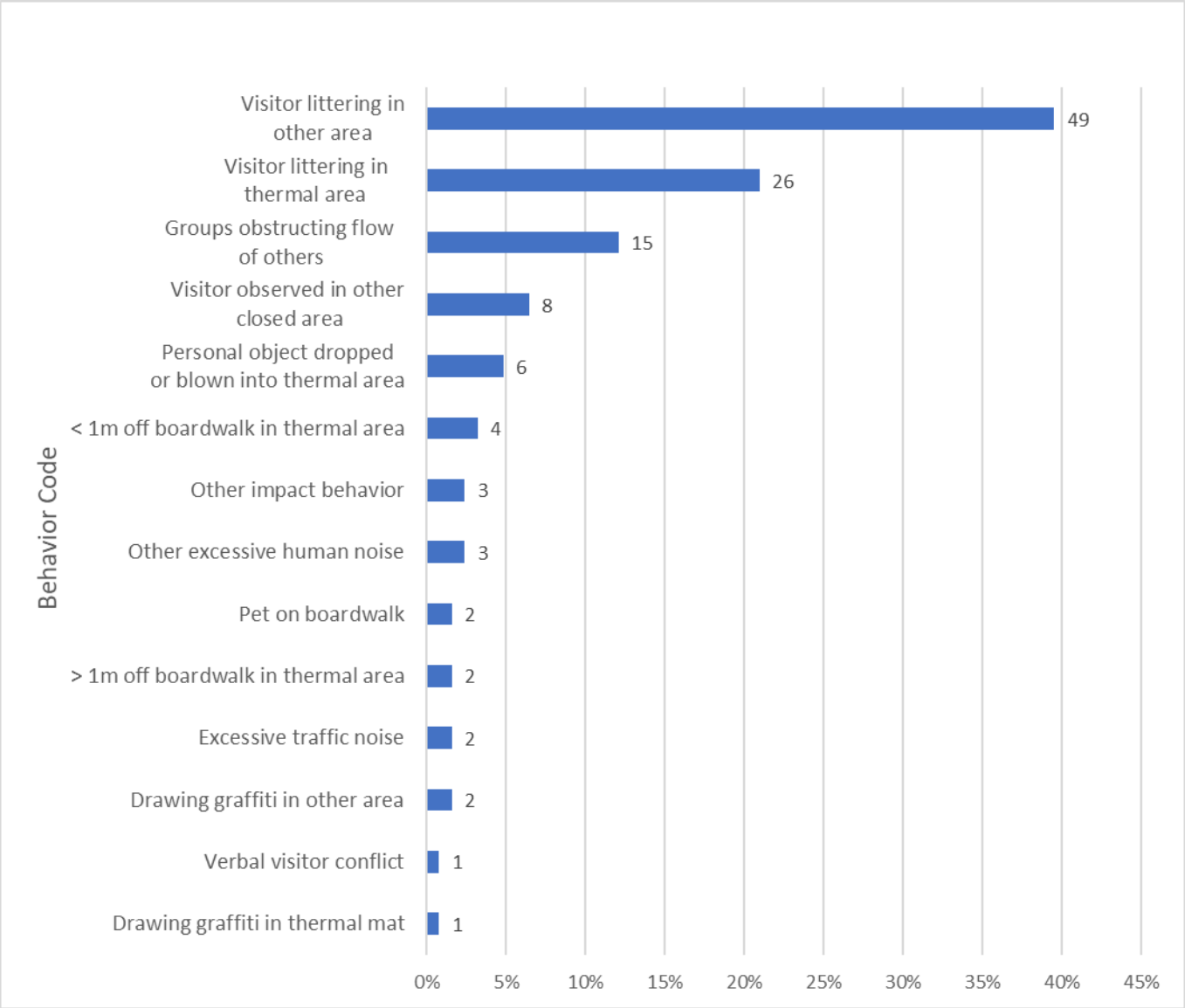

Figure 50. Frequency and counts of impact behavior code waypoints collected at Norris Geyser Basin. Number next to bar represents the "n" value or number of observations per category.

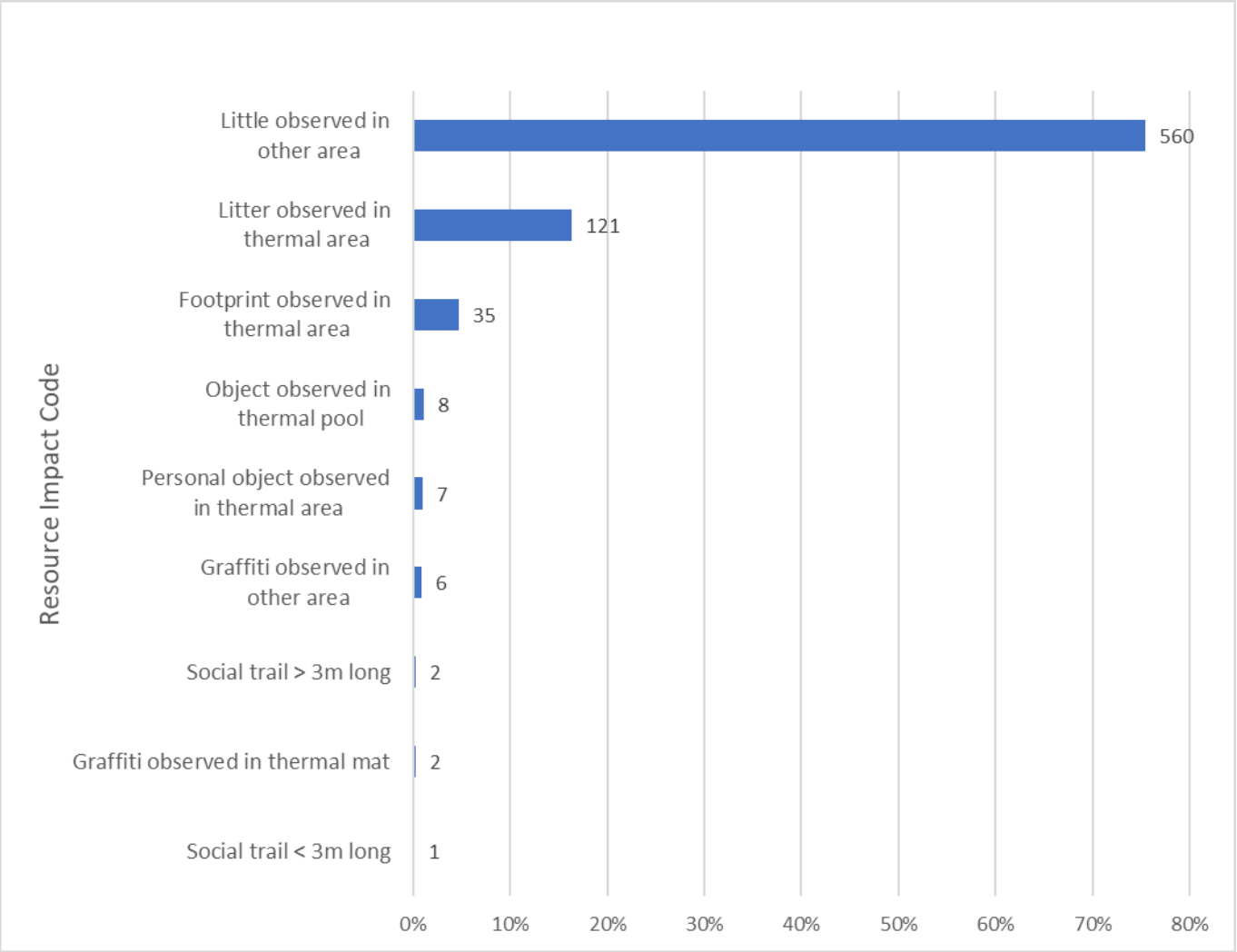

Figure 51. Frequency and counts of resource impact code waypoints collected at Norris Geyser Basin. Number next to bar represents the "n" value or number of observations per category.

Impact behavior and resource impact waypoints were further categorized into six groups for kernel density analysis. Impact behavior waypoints were categorized into thermal area/mat impact behaviors, other impact behavior, visitor conflict and congestion, and wildlife impact behavior. Resource impact waypoints were categorized into thermal area resource impact or other area resource impact. Kernel density analyses were performed on each of the six categories to identify where specific impact behaviors or resource impacts are likely to occur at Norris Geyser Basin. Figure 52 through figure 56 display the results of these targeted impact behavior and resource impact analyses. Thermal impact behaviors and thermal resource impacts were most likely to occur in the Porcelain Basin portion of the Norris Geyser Basin network, with highest densities of these waypoints occurring in this region. Generally, impacts and impact behaviors were concentrated in this northern section of Norris Geyser Basin, in and around the trails and boardwalks in the museum and Porcelain Basin areas. There is no wildlife impact behavior kernel density analysis for Norris Geyser Basin because there were too few points to conduct the analysis.

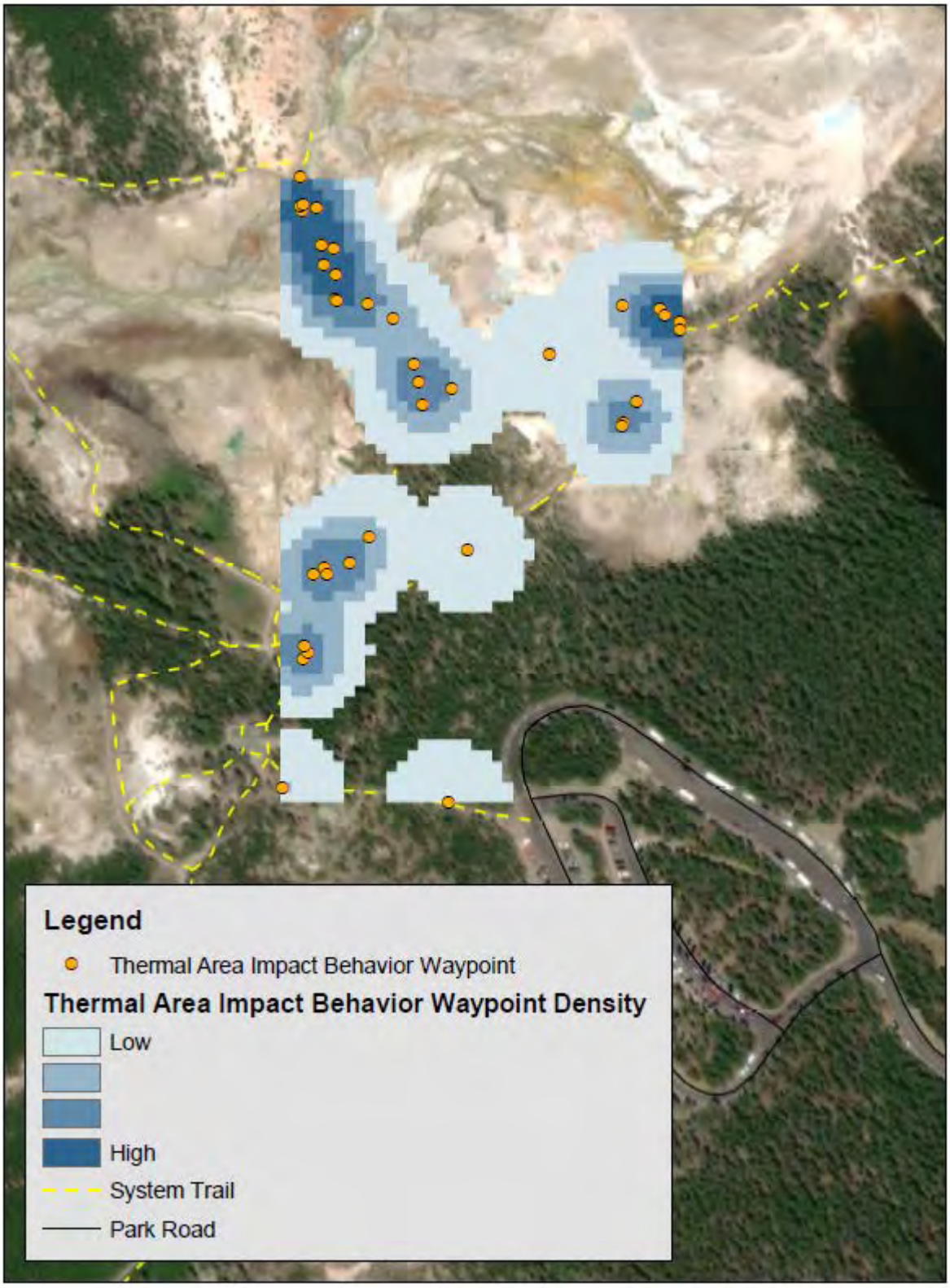

Figure 52. Thermal area impact behavior waypoint density analysis at Norris Geyser Basin.

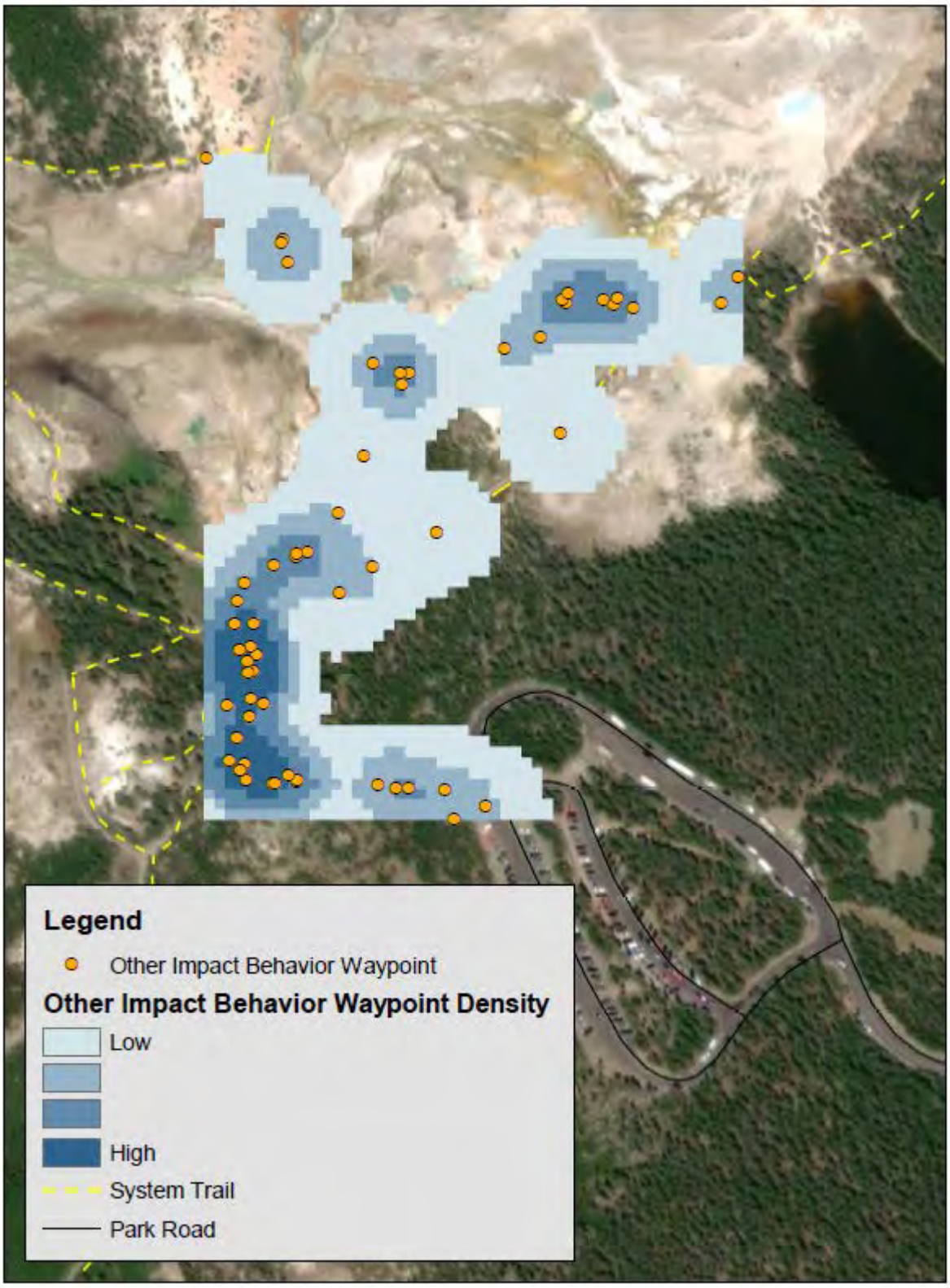

Figure 53. Other area impact behavior waypoint density analysis at Norris Geyser Basin.

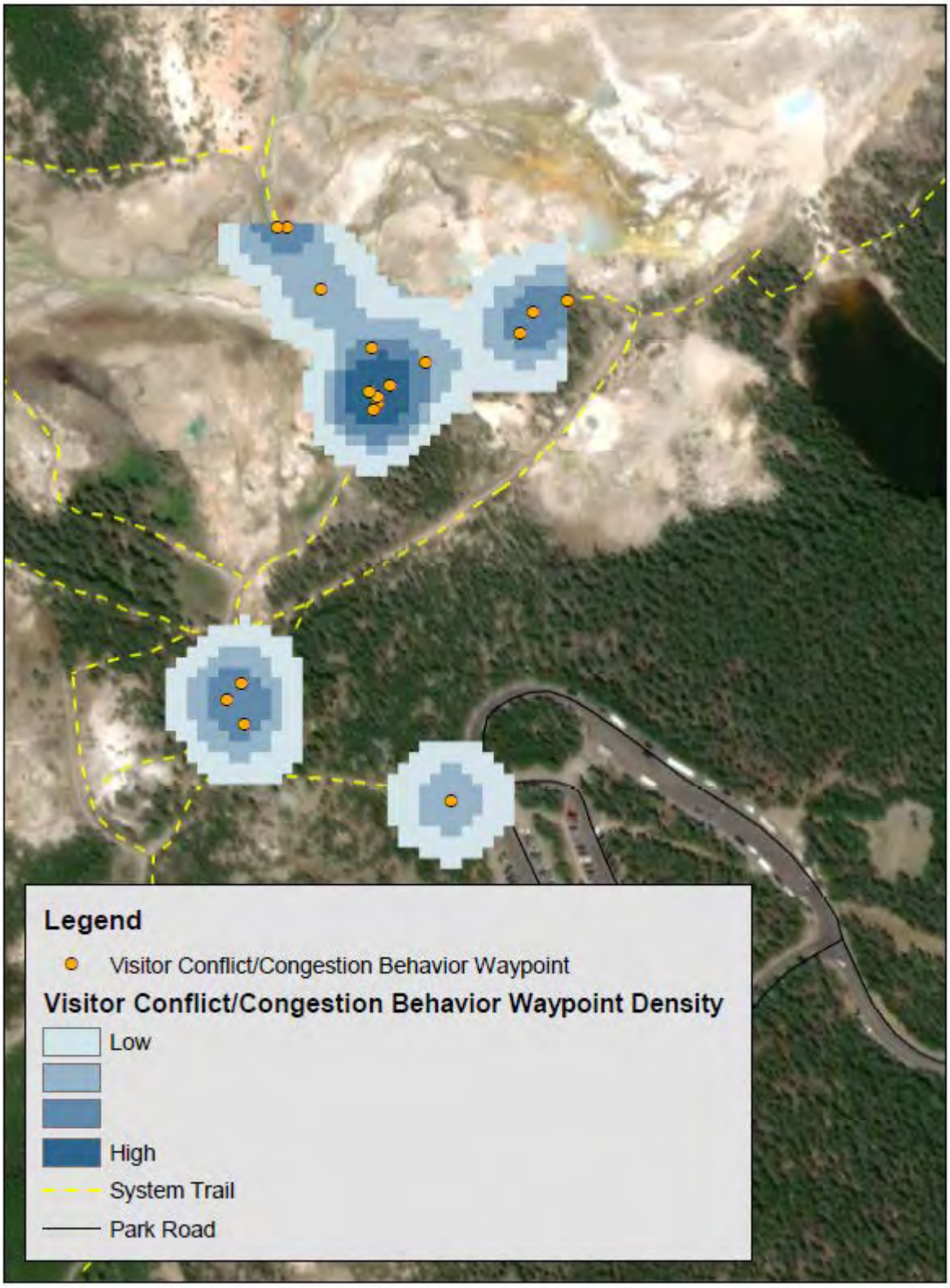

Figure 54. Visitor conflict and congestion impact behavior waypoint density analysis at Norris Geyser Basin.

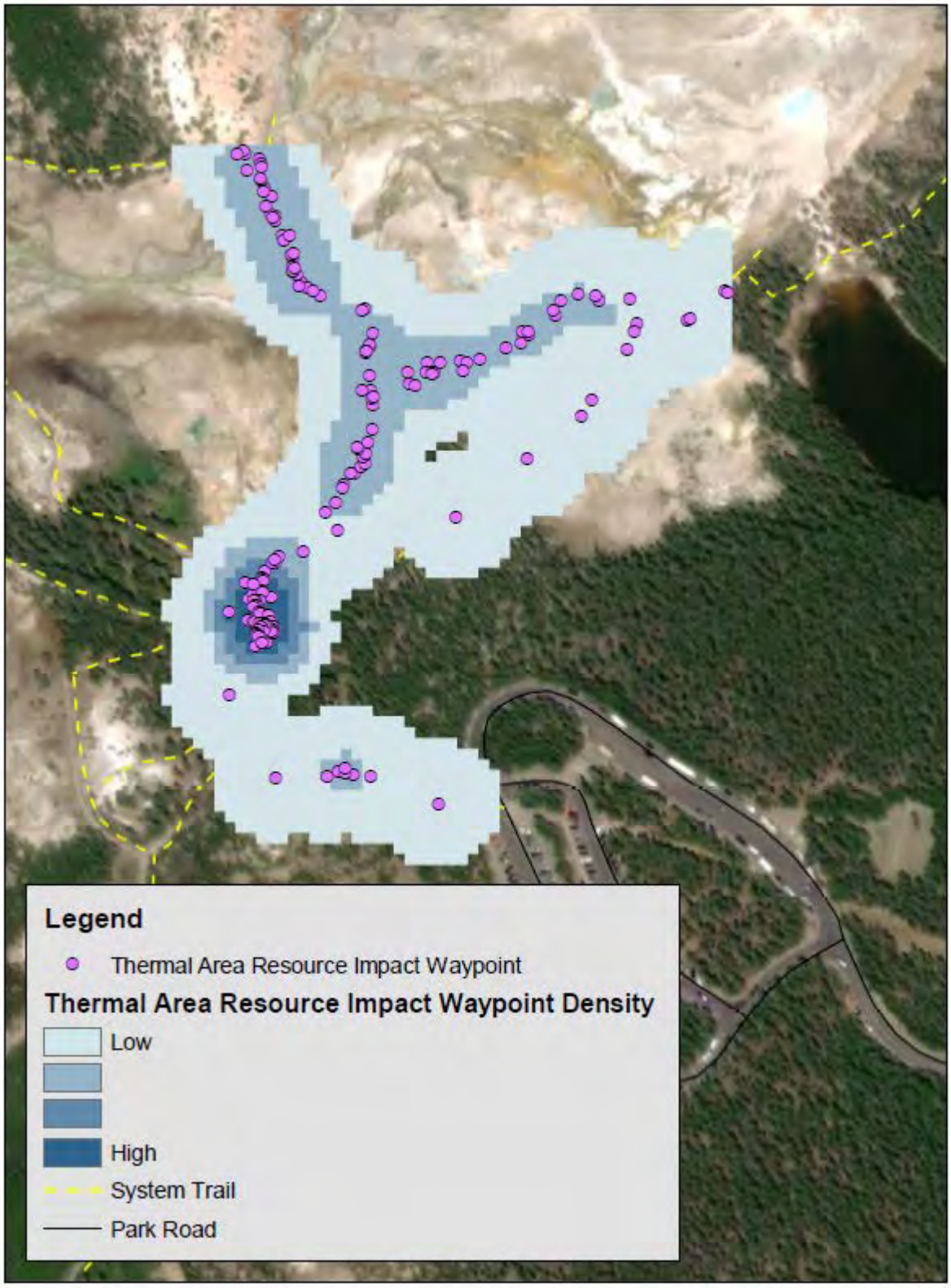

Figure 55. Thermal resource impact waypoint density analysis at Norris Geyser Basin.

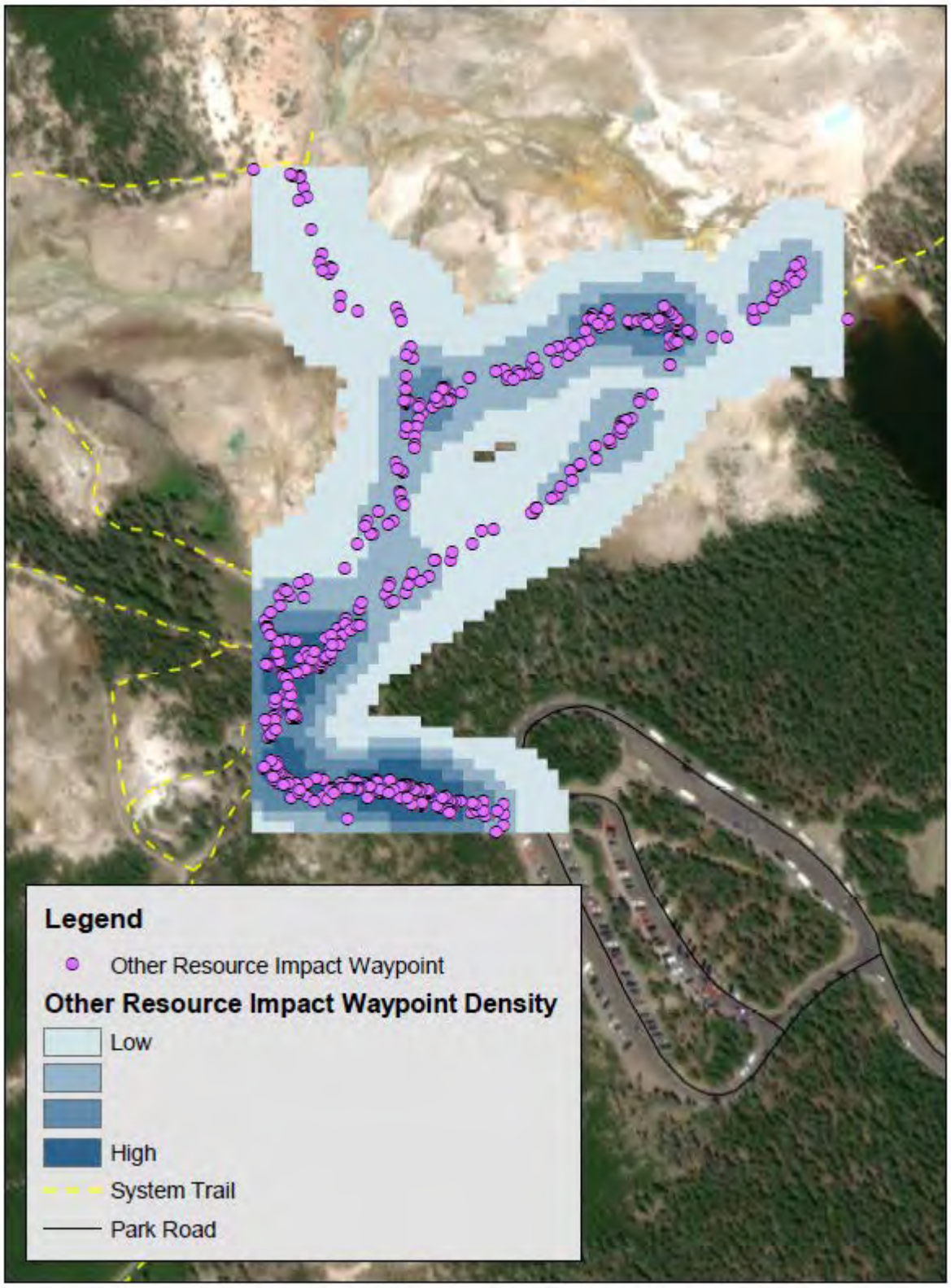

Figure 56. Other resource impact waypoint density analysis at Norris Geyser Basin.

Old Faithful Geyser Basin

Visitor Use Estimation

Due to the size and complexity of the parking lots at Old Faithful Geyer Basin, data were not collected in parking areas by YCC Crews during the 2018 season; therefore, parked vehicle counts, tour bus counts, and restroom line and occupancy counts were not collected at Old Faithful Geyser Basin Subsequently, these sections are omitted from the visitor use estimation section of this report for Old Faithful Geyser Basin.

Automatic Trail Counters

The trail counter at Old Faithful Geyser Basin was deployed from June 13, 2018, through October 24, 2018. The counter collected data continuously, except during the time period from July 21 through August 21, 2018. During this time the counter did not record data because it was not properly relaunched, or reset, after download. This erroneous data was not included in any analyses or data summarizes. The counter recorded data in hourly time bins. Summaries of the data are reported according to season of use, with data collected from June 13, 2018, through September 3, 2018 (Labor Day), being categorized as peak use season data and data collected from September 4, 2018, through October 24, 2018, being categorized as shoulder season data. Peak season data are reported here in the body of the report. The same graphical and tabular summaries are presented for the shoulder season data in Appendix F.

The count data included in this report are calibrated data; uncalibrated count data are not presented. Five hours of calibration data collected across four days throughout the peak use season were used to calibrate the Old Faithful Geyser Basin counter. Ten hours of calibration data were collected; however, due to the missing count data for July 21 through August 21, 2018, five hours of the calibration data could not be used in the analysis as it did not have paired count data to associate with the calibration data.

The calibration coefficient for the 2018 deployment of the Old Faithful Geyser Basin counter is 2.05. A calibration coefficient over a value of one indicates that the counter was undercounting the number of passes in front of the counter. The calibration coefficient of 2.05 suggests the counter at Old Faithful Geyser Basin was under counting by a factor of two. The R^2 value for the regression equation used to generate the calibration coefficient is 0.93, suggesting the counter tended to consistently undercount the number of passes. The high calibration coefficient, and accompanying R^2 value, suggest the placement of the counter could be improved to reduce the amount of error in the originally collected count data. Specifically for the installation at Old Faithful Geyser Basin, the counter was placed low such that the counter's infrared beam was not aimed at breast height for the average pedestrian. Therefore, the counter likely missed passing individuals, resulting in an under count. For reference calibration coefficients between 0.75 and 1.25 are usually considered within the normal range of counter error for well-placed counters. Despite the high calibration coefficient, this does not compromise the quality of the counter data that was collected once it has been corrected for counter error. However, better counter placement does result in higher quality data prior to calibration.

Across the peak use season, for the days on which count data were recorded, daily total counts at the Old Faithful Geyser Basin counter location ranged from just over 4,000 counts on August 30, 2018, to a peak of just over 10,000 counts on July 2, 2018 (figure 57). A count is considered one pass by the counter; it cannot be interpreted as an individual. The counters record a tally each time an individual passes the count location regardless of direction of travel. Counts reported here correspond to either an entrance or an exit from the Old Faithful Geyser Basin trail system at the counter location.

The Old Faithful Geyser Basin trail system is complex with multiple entry and exit points from the system. Therefore, the count data reported here should be considered a representative measure of use from one of several busy entry

and exit points in the Old Faithful Geyser Basin trail system. The counts reported should not be interpreted as overall visitation to Old Faithful Geyser Basin. The counter placement in 2018 was moved from a walkway near one of the central parking areas to on a bridge further into the trail system. The decision to move the counter was made to simplify monitoring efforts for the YCC Crews, making the collection of data more reliable and improving the feasibility of data collection at Old Faithful Geyser Basin in 2018.

Looking across hours of the day (table 36), counts tended to begin occurring at the Old Faithful Geyser Basin count location in the 6:00 hour, increasing steadily to triple digits at 8:00 and through the morning (see percent changes in table 37) to a peak at 14:00 with an average of 773 counts (table 36; figure 58). Average hourly counts exceeded 700 counts until 17:00 when counts decreased (see table 37) to an average of 486. Counts continued to decrease through the evening, with 20:00 being the last hour of triple digit visitation. Compared to the averages themselves, the standard deviations for the hourly estimates are relatively low, being less than 20% of the estimate for the most part. This suggests the averages presented fluctuated only slightly across hours of the day during the use season, indicating the averages are likely representative of conditions throughout the peak use season, on the days for which data are available.

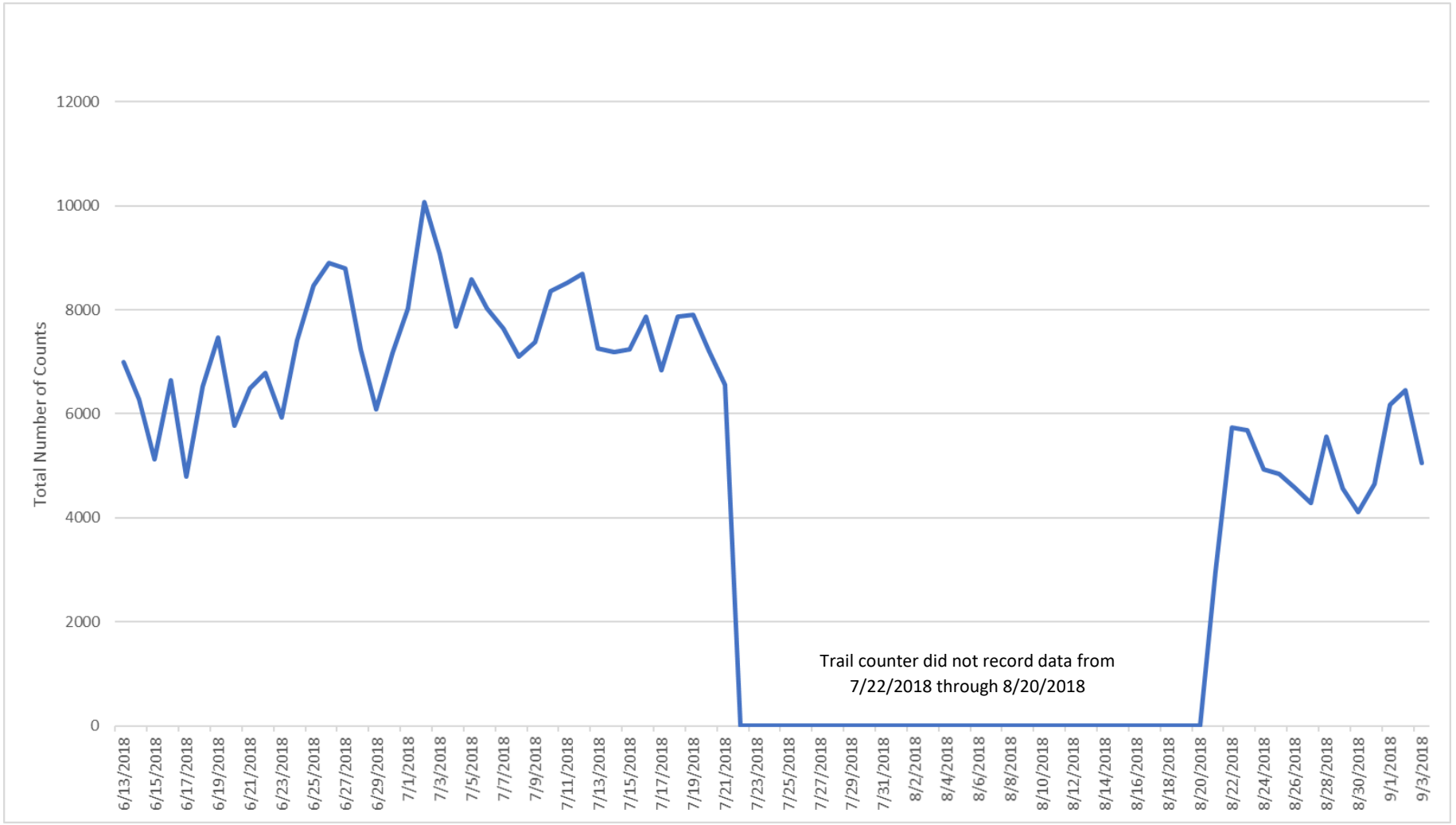

Figure 57. Daily total number of counts passing the Old Faithful Geyser Basin counter during the peak use season from June 13 through July 21, 2018, and August 21 through September 3, 2018.

Table 36. Average number of hourly counts during the peak use season (June 13 through July 21, 2018, and August 21 through September 3, 2018) at the Old Faithful Geyser Basin counter location. SD = standard deviation; N = sample size.

Hour	Average	±SD	N*
0:00	2	3	51
1:00	0	1	51
2:00	0	1	51
3:00	0	1	51
4:00	0	1	51
5:00	4	4	51
6:00	23	16	51
7:00	66	32	51
8:00	175	71	51
9:00	362	115	51
10:00	584	159	52
11:00	696	211	52
12:00	686	164	52
13:00	734	181	51
14:00	773	186	53
15:00	750	215	53
16:00	708	199	53
17:00	486	157	53
18:00	312	100	53
19:00	234	79	52
20:00	173	90	52
21:00	66	52	52
22:00	7	6	52
23:00	3	5	52

*N varies across hours of the day based on the hour of counter installation, the hours of data download, and the hour of counter removal.

Table 37. Percent change in hourly counts at the Old Faithful Geyser Basin trail counter.

Time	Percent Change in Total Counts by Hour
6:00 to 7:00	187 %
7:00 to 8:00	165 %
8:00 to 9:00	107 %
9:00 to 10:00	61 %
10:00 to 11:00	19 %
11:00 to 12:00	-1 %
12:00 to 13:00	7 %
13:00 to 14:00	5%
14:00 to 15:00	-3 %
15:00 to 16:00	-6 %
16:00 to 17:00	-31 %
17:00 to 18:00	-36 %
18:00 to 19:00	-25 %
19:00 to 20:00	-26 %
20:00 to 21:00	-62 %
21:00 to 22:00	-89 %
22:00 to 23:00	-57 %
23:00 to 24:00	-100 %

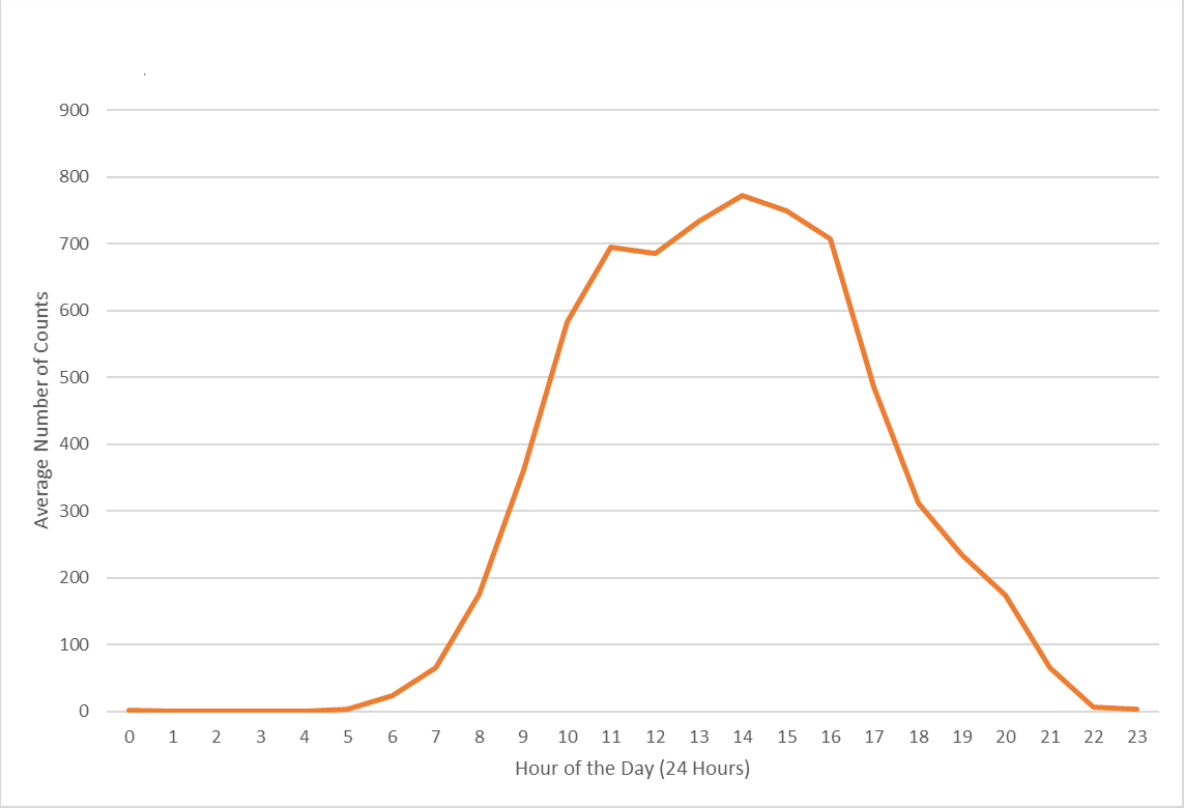

Figure 58. Average number of hourly counts at the Old Faithful Geyser Basin count location during the peak use season from June 13 through July 21, 2018, and August 21 through September 3, 2018.

Across all days of the week, the average number of counts ranges between approximately 6,000 and 7,000 counts (table 38; figure 59). Weekdays had the highest average number of counts, with Monday and Tuesday having the highest number of counts at 7,094 and 7,026, respectively. Wednesday and Thursday experienced the next highest average visitation. Weekend days, on average, experienced lower visitation than weekdays at the Old Faithful Geyser Basin counter location. The standard deviations for all average estimates were relatively consistent and the magnitudes are small relative to the average estimate. This suggests that averages are likely representative of actual conditions experience at the Old Faithful Geyser Basin count location across days of the week in the peak use season for which data are available.

Table 38. Average number of daily counts by day of week during the peak use season (June 13 through July 21, 2018, and August 21 through September 3, 2018) at the Old Faithful Geyser Basin count location.

Day	Average	±SD	N*
Sunday	6,517	1,334	7
Monday	7,094	1,992	7
Tuesday	7,026	2,169	7
Wednesday	6,991	1,501	7
Thursday	6,873	1,557	7
Friday	6,261	1,249	7
Saturday	6,519	880	7

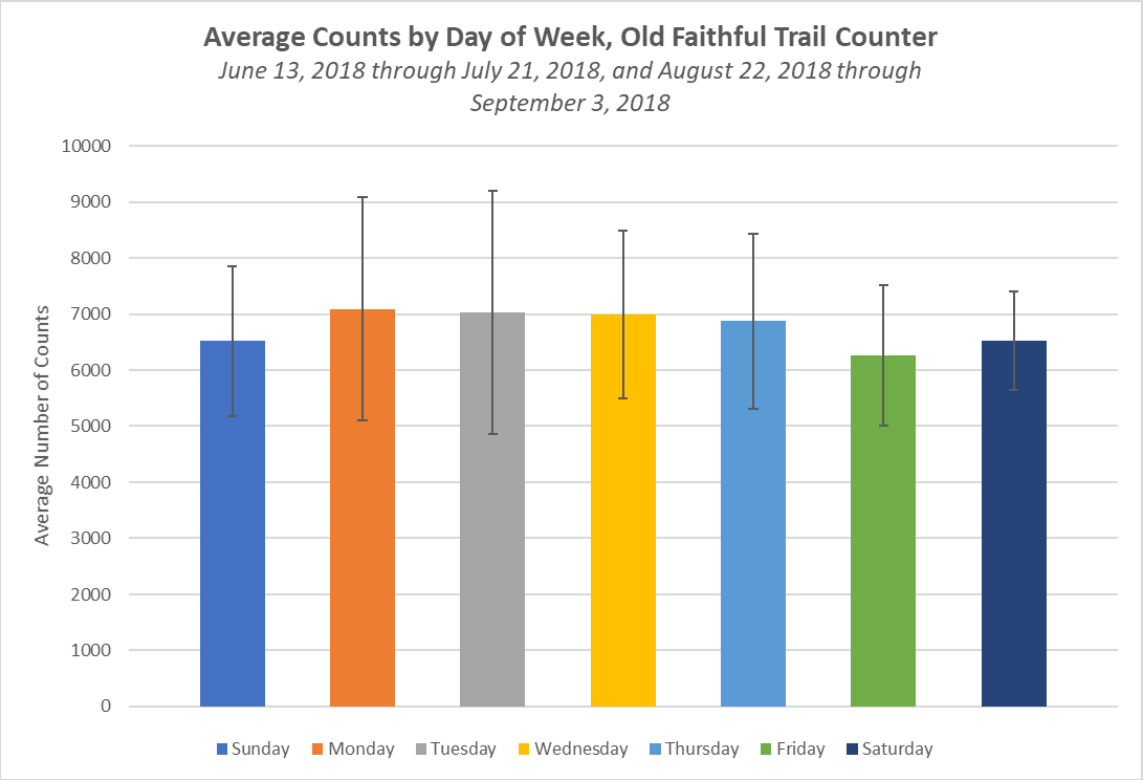

Figure 59. Average number of counts, by day of week, at the Old Faithful Geyser Basin count location during the peak use season from June 13 through July 21, 2018, and August 21 through September 3, 2018. The vertical black

bars extending above and below the top of the colored bars represent the standard deviation for the estimate of the mean for each day.

Visitor Use/Capacity Measures

As occurred at Norris Geyser Basin, there appeared to be some confusion at Old Faithful Geyser Basin on how to conduct encounter counts and PAOT counts. Encounter counts for sections of the trail at Old Faithful Geyser Basin were often incomplete, as it appears YCC Crews were sometimes unable to complete a full loop in 20 minutes time. While this is not a problem, instead of continuing with where the crew members left off to complete the entire loop, it seems as if YCC Crews would re-walk the same section (either from the Old Faithful Inn to Geyser Hill or just the Geyser Hill loop). Therefore, these encounter counts were not able to be combined into an estimate of total encounters for the entire loop from the Old Faithful Inn around the Geyser Hill loop (they were spaced too far in time). In addition to encounters for the whole trail, also summarized are encounters for sections of the Geyser Hill trails (table 39).

The Old Faithful Geyser Basin focal attraction site, and specifically the Geyser Hill loop trail, has two PAOT locations: the "Z" section of the trail on the lower area of the Old Faithful Geyser Basin area and the boardwalk near Beehive Geyser (see figure 6). As occurred at Midway Geyser Basin, PAOT counts were occasionally combined at Old Faithful Geyser Basin for a total PAOT for both the Beehive section of the boardwalk and the "Z" portion of the boardwalk (table 40). Due to some counts being combined, the total sample size for each individual PAOT locations are lower in 2018 than they were in 2017. Only three days of data collection occurred for each PAOT location. Despite this, multiple counts of each location were taken each day but the PAOT counts for 2018 may not be as accurate as those collected in 2017.

YCC Crews counted visitor encounters along the approximately 0.6-mile trail for Geyser Hill and on average encountered 433 other visitors along the trail (table 39). The minimum number of encounters recorded was 109 visitors (recorded on 7/6/2018) and the maximum was 1,170 visitors (recorded on 7/2/2018) in a single hike of the boardwalk. Due to the YCC Crews also recording repeated encounter measures on sections of the Geyser Hill boardwalk, the average encounters from these two portions can be compared. On average, visitor encounters are similar for both loop portion of the boardwalk system and the bottom portion of the boardwalk system (towards the "Z" bridge area; table 38).

The "Z" bridge had an average of 45 PAOT, while the Beehive Geyser section of the boardwalk had an average of 55 visitors (table 40). These averages may have been pulled up by counts occurring on or around Old Faithful Geyser eruptions as is evident by the high SD for these averages (table 40 and see counts on 7/2/2018). Both PAOT locations had a significant amount of variability (figures 60 and 61), possibly because Old Faithful Geyser eruptions can be seen from both locations and thus PAOT may be influenced by Old Faithful eruption schedule. Peaks for PAOT for both locations occur in early afternoon (around 14:00) but again, these peaks may coincide with Old Faithful Geyser eruptions.

PAOT counts were also taken during Old Faithful Geyser eruptions (table 40 and figure 62). A total of 22 Old Faithful Geyser eruption counts were taken during the YCC Crews data collection effort at Old Faithful Geyser Basin. On average, 2,179 visitors are on the platform in front of Old Faithful during eruption times (table 40). Eruptions that occur after noon, appear to have slightly more PAOT on the platform (figure 62). It is important to remember that PAOT counts are variable and occur at one instant in time, so low values can be observed during periods of overall high visitor use and higher counts can be observed during overall lower use times (e.g., high counts occurring in the afternoon even though overall use tends to be highest in the morning hours). PAOT and trail counters provide a more site-specific metric of how visitor experiences may vary at a location.

Table 39. Summary of trail encounters (number of visitors passed) for sections of the loop of Geyser Hill and down to the "Z" bridge area. N = number of counts that equaled that section of trail length.

	Old Faithful Inn to Geyser Hill					Geyser Hill Loop					Both Sections Combined				
Date	**Average**	**±SD**	**Min**	**Max**	**N**	**Average**	**±SD**	**Min**	**Max**	**N**	**Average**	**±SD**	**Min**	**Max**	**N**
6/19/2018	285	117	181	501	6	332	135	207	492	4	252	79	179	318	3
6/27/2018	192	128	15	320	4	254	112	142	389	4	287	85	222	383	3
7/2/2018	83	NA	83	83	1	NA	NA	NA	NA	NA	824	318	375	1,170	7
7/6/2018	178	NA	178	178	1	116	NA	116	116	1	262	122	109	437	7
7/24/2018	NA	NA	NA	NA	NA	264	121	83	491	12	NA	NA	NA	NA	NA
7/30/2018	277	83	214	435	6	404	NA	404	404	1	NA	NA	NA	NA	NA
8/3/2018	197	93	131	263	2	214	98	138	324	3	157	54	119	195	2
8/9/2018	228	42	159	269	5	267	45	185	300	7	NA	NA	NA	NA	NA
Overall	**237**	**98**	**15**	**501**	**25**	**267**	**107**	**83**	**492**	**32**	**433**	**332**	**109**	**1170**	**22**

Table 40. PAOT summary for PAOT locations at Old Faithful Geyser Basin and Geyser Hill. SD = standard deviation; N = sample size.

	"Z" Bridge					Beehive Geyser					Both Boardwalk Locations					Old Faithful Geyser Basin Eruptions				
Date	**Average**	**±SD**	**Min**	**Max**	**N**	**Average**	**±SD**	**Min**	**Max**	**N**	**Average**	**±SD**	**Min**	**Max**	**N**	**Average**	**±SD**	**Min**	**Max**	**N**
6/19/2018	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	55	24	12	103	15	1,706	653	1,098	2,536	4
6/27/2018	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	67	33	29	150	18	3,603	1,240	2,398	4,922	4
7/2/2018	132	28	105	167	4	195	70	128	268	3	NA	NA	NA	NA	NA	2,629	341	2,388	2,870	2
7/6/2018	7	6	0	13	4	35	39	3	93	5	NA	NA	NA	NA	NA	1,476	430	1,172	1,780	2
7/24/2018	NA	NA	NA	NA	NA	56	26	20	126	14	NA	NA	NA	NA	NA	1,447	481	971	1,935	4
7/30/2018	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	38	14	18	63	8	1,871	5	1867	1,874	2
8/3/2018	17	10	6	37	7	9	4	2	15	7	NA	NA	NA	NA	NA	1,475	602	1049	1,900	2
8/9/2018	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	51	19	29	102	16	3,004	49	2969	3,039	2
Overall	**45**	**56**	**0**	**167**	**15**	**55**	**60**	**2**	**268**	**29**	**55**	**26**	**12**	**150**	**57**	**2,179**	**1,031**	**971**	**4,922**	**22**

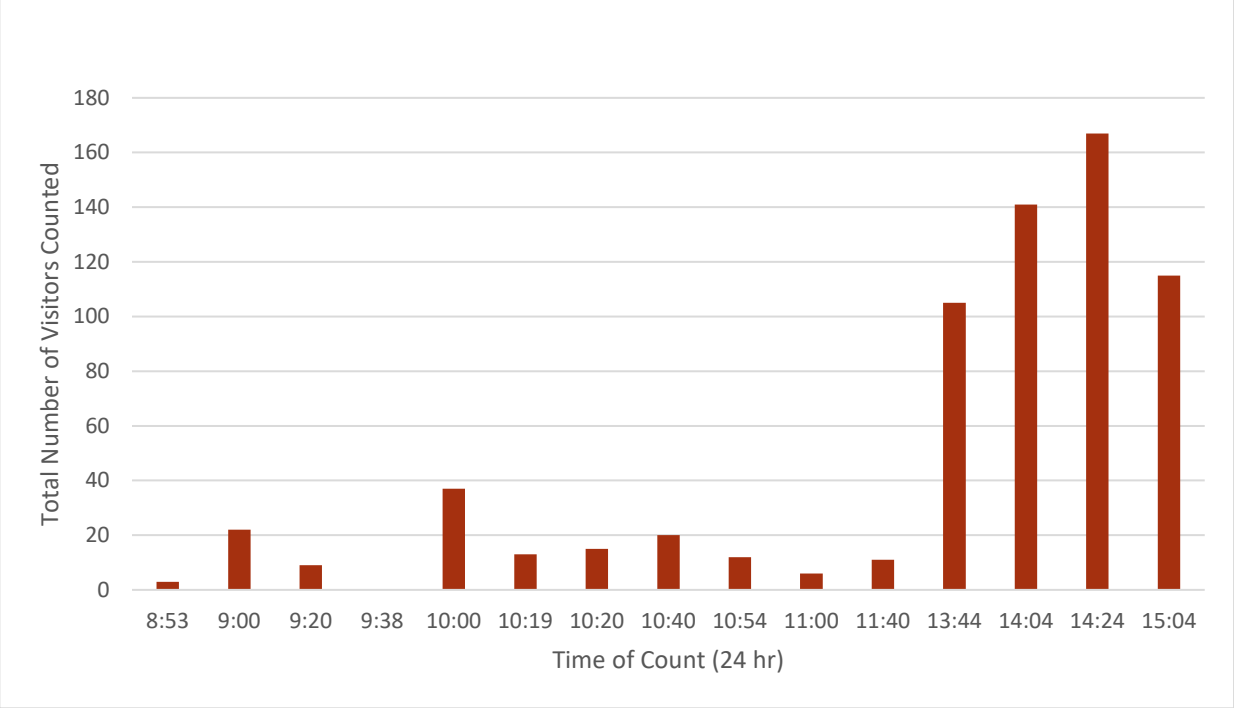

Figure 60. All individual PAOT counts organized by time at the boardwalk where there is a "Z" turn leading to Geyser Hill at Old Faithful Geyser Basin. Spikes in PAOT may be related to the timing of Old Faithful Geyser eruptions.

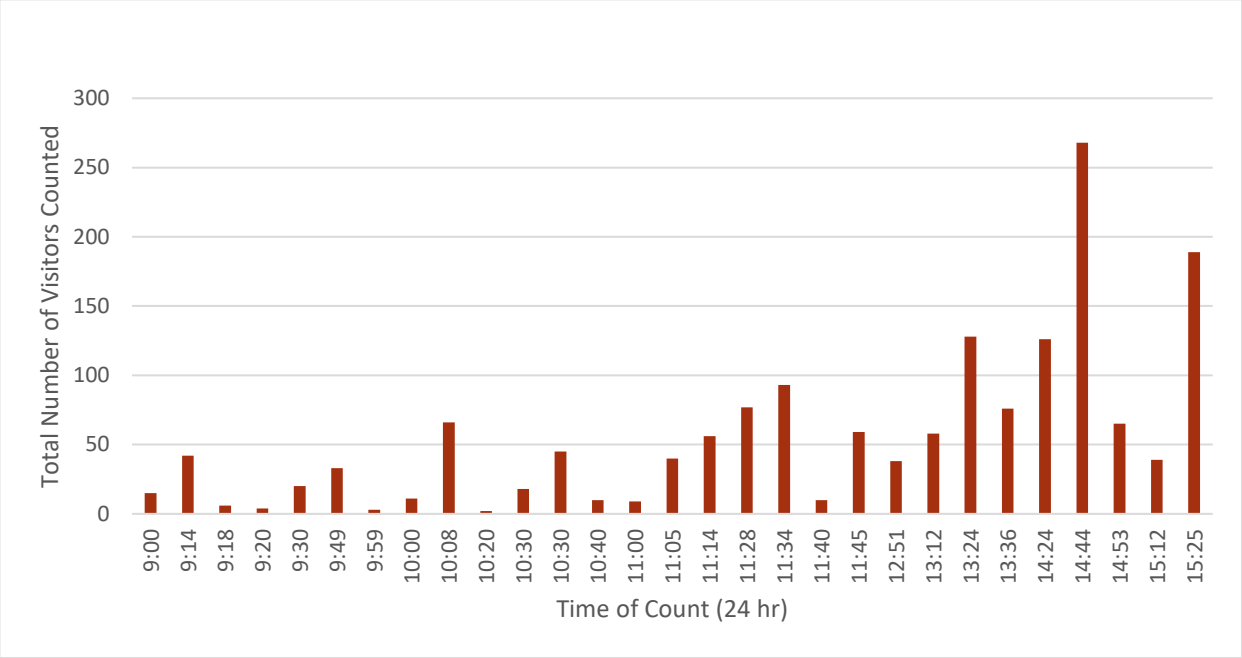

Figure 61. All individual PAOT counts organized by time at the boardwalk near Beehive Geyser at Geyser Hill at Old Faithful Geyser Basin. Spikes in PAOT may be related to Old Faithful geyser eruptions.

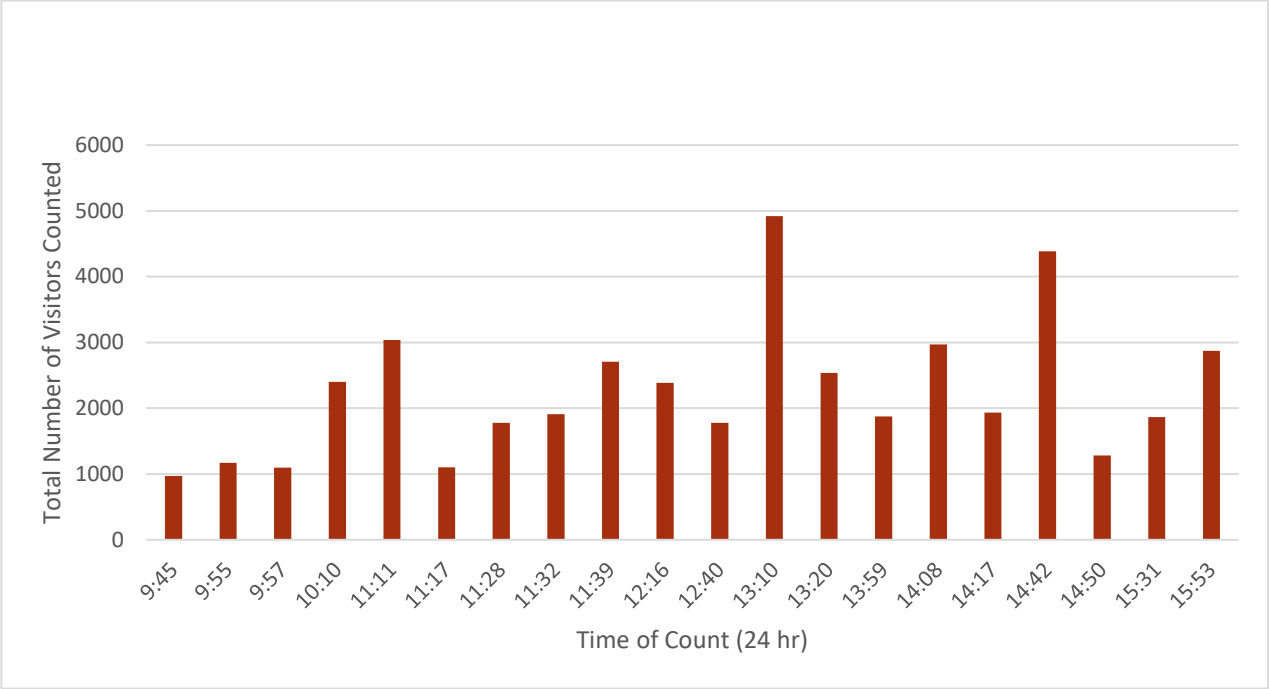

Figure 62. All PAOT counts organized by time at the viewing platform at Old Faithful Geyser. These counts only occurred during geyser eruptions.

Visitor Spatial Behavior

Note on density maps: For this section, on all kernel density maps, although the blue density layer may extend beyond the trail or boardwalk, that does not necessarily mean use or impacts extends that far. The width of the blue density layer on the maps provided in this section is an artifact of the analysis type. See "Methods" section for more detail.

GPS-based Tracking

Figure 63 and figure 64 show the extent and density for GPS study participants at Old Faithful Geyser Basin. The GPS tracks collected from participants at Old Faithful Geyser Basin are displayed in figure 63, with the blue dots representing collected GPS tracking data. A portion of visitors participating in the GPS study traveled throughout the basin, accessing areas as far as Biscuit Basin and Summit Lake from the GPS distribution point. On average, visitors hiking on the trail/boardwalk system at Old Faithful Geyser Basin spend approximately 1 hour and 20 minutes recreating. The minimum visit duration in the sample was 2 minutes and the maximum visit duration in the sample was 5 hours and 59 minutes (table 41).

Table 41. Average, minimum, and maximum amount of time spent in the trail system at Old Faithful Geyser Basin by GPS participants.

Measure	Time (h:mm: ss)
Average	1:20:00
±SD	1:10:00
Minimum	0:02:00
Maximum	5:59:00

Many visitors who visit the Old Faithful Geyser Basin are staying around Old Faithful Geyser or going to Geyser Hill. This is evidenced by the darker and medium blue colors are found on the north side of Old Faithful Geyser and up around the Geyser Hill Loop in the figure 64 kernel density analysis. Additionally, a portion of visitors tend to continue further into the trail system towards the Castle-Grand area. This area is also highlighted with a darker blue patch, indicating a higher density of points, in figure 64. A minority of visitors continue even further into the trail system, traveling across the road to Biscuit Basin; coloring on these sections of trail indicates that the density of points in these areas is smaller than experienced at the other, more popular locations.

In addition to GPS tracking of visitor travel patterns at Old Faithful Geyser Basin, two types of GPS waypoints were collected to mark where behaviors expected to cause resource impacts occur along the trail (hereafter impact behavior waypoints) and to mark where resource impacts have already occurred along the trail (hereafter resource impact waypoints). For waypoints labeled as “Other” please see detailed table in Appendix H listing the comment recorded by the YCC Crews for each “Other” waypoint. A total of 782 waypoints were collected at Old Faithful Geyser Basin across eight days of sampling (figure 65). The darker blue portions of the kernel density map in figure 65 indicate a higher number of waypoints occurred at these locations. At Old Faithful Geyser Basin, the highest density of waypoints occurred on the east side of the monitoring area on the section of trail/boardwalk that crosses the Firehole River leading to the Upper Basin.

To generate a more detailed understanding of how specific resource impacts or impact behaviors are spatially distributed at Old Faithful Geyser Basin, the resource impact and impact behavior waypoints were separated for further analysis. Waypoints were matched to behavior codes using a spatial join. During the match process, 42 waypoints were unable to be matched due to missing behavior codes, resulting in a 95% match rate between recorded behavior codes and marked GPS waypoints. The results to follow are generated from the 740 matched waypoint and behavior code pairs.

Figure 66 shows the frequency distribution and number of observations for impact behavior waypoints at Old Faithful Geyser Basin. A total of 63 impact behavior waypoints were marked, with the majority of those waypoints being classified as visitors being observed less than 1m off a boardwalk in a thermal area (OB1), another type of impact behavior without a code (OTHER1), or groups obstructing the flow of other groups (FLOW). Figure 67 shows the frequency distribution and number of observations for the resource impact waypoints at Old Faithful Geyser Basin. A total of 667 resource impact waypoints were marked, with the overwhelming majority of those waypoints marking locations where litter was observed in a thermal area (THLIT2) or a non-thermal area (LIT2). Refer to table 2 for detailed descriptions for each impact behavior and resource impact code.

Figure 63. Raw, cleaned GPS-based tracking point data collected from visitors at Old Faithful Geyser Basin. GPS units were handed out between the Visitor Center and Old Faithful Geyser Basin Geyser.

Figure 64. Density of GPS-based tracking points collected from visitors at Old Faithful Geyser Basin. GPS units were handed out between the Visitor Center and Old Faithful Geyser. Low densities are an estimated count 7-96 points per 1 m^2 and high densities are an estimated count of 837-1,888 points per 1 m^2**.**

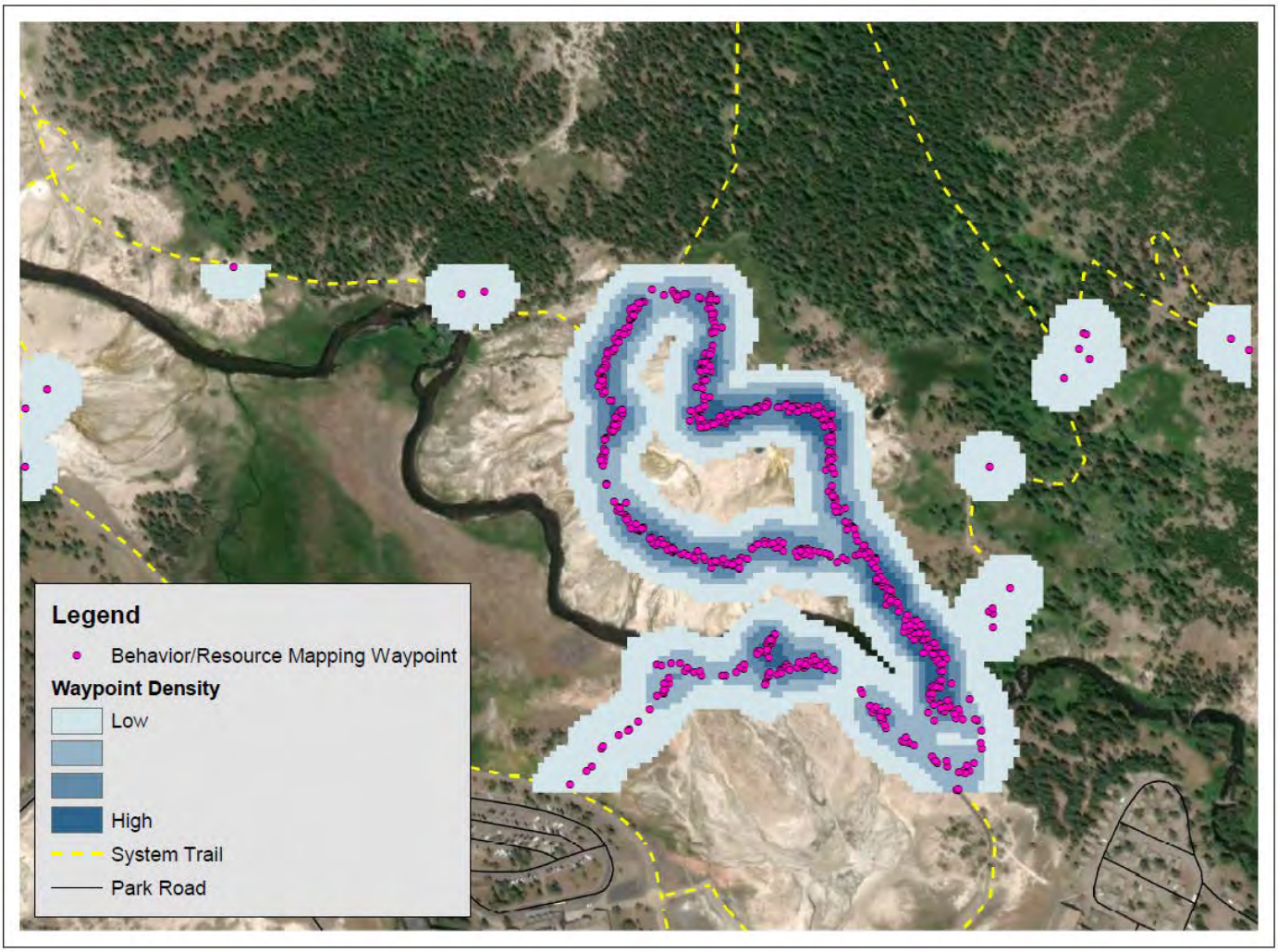

Figure 65. Density of impact behavior and resource impact waypoints at Old Faithful Geyser Basin. Low densities are an estimated count of < 1- 3 points per 1 m^2 and high densities are an estimated count of 14- 25 points per 1 m^2**.**

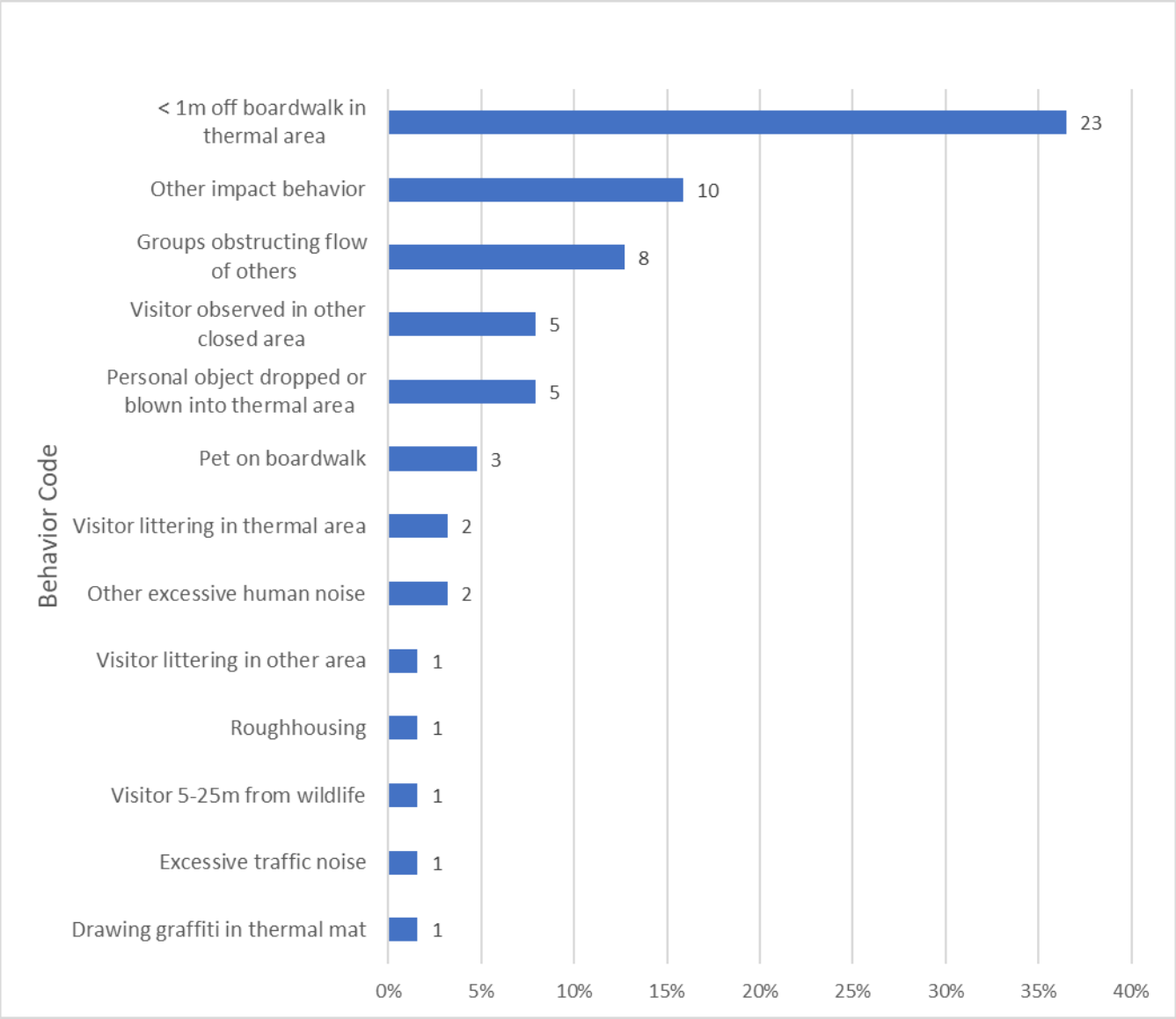

Figure 66. Frequency and counts of impact behavior code waypoints collected at Old Faithful Geyser Basin. Number next to bar represents the "n" value, or number of observations per category.

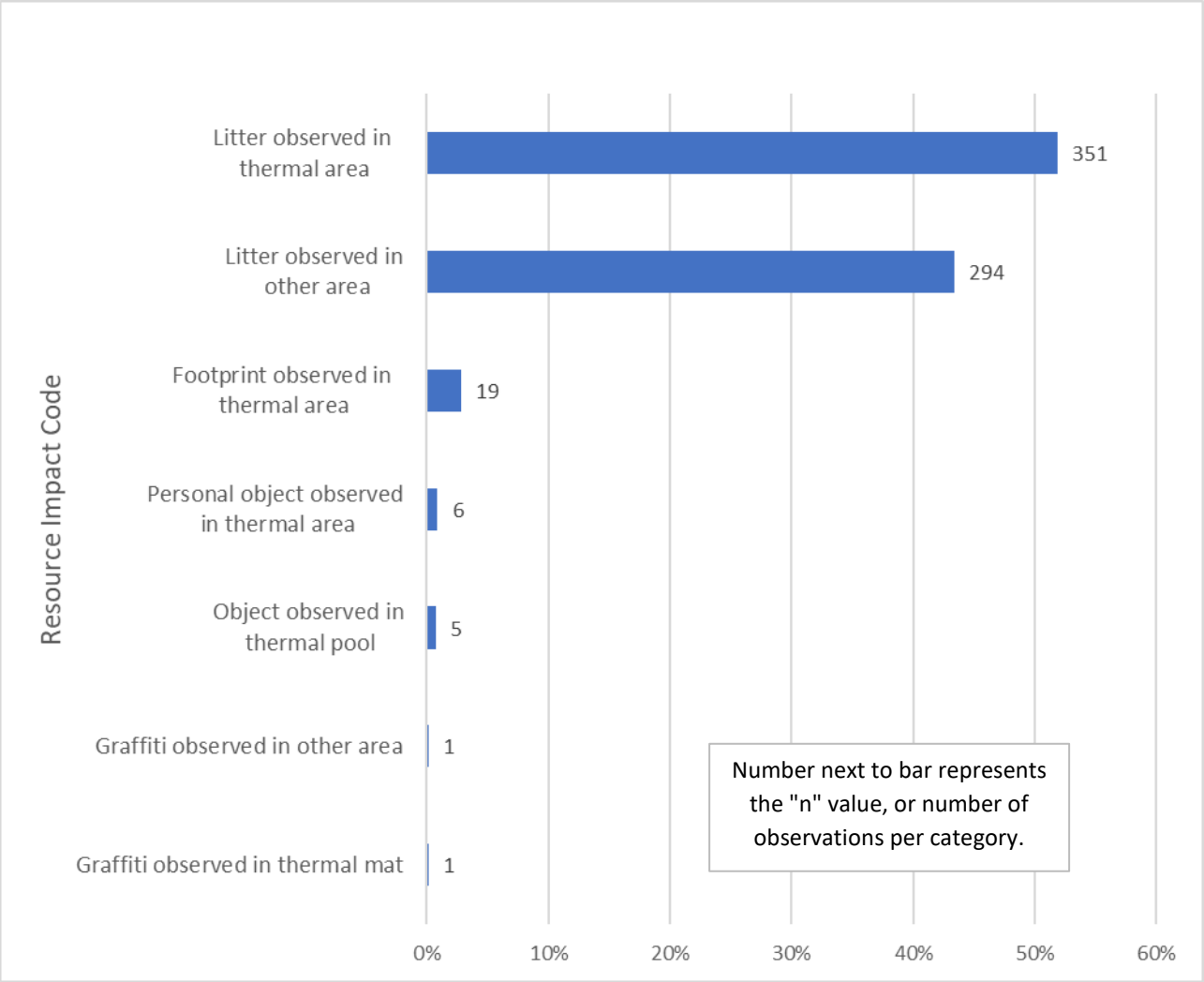

Figure 67. Frequency and counts of resource impact code waypoints collected at Old Faithful Geyser Basin. Number next to bar represents the "n" value, or number of observations per category.

Impact behavior and resource impact waypoints were further categorized into six groups for kernel density analysis. Impact behavior waypoints were categorized into thermal area/mat impact behaviors, other impact behavior, visitor conflict and congestion, and wildlife impact behavior. Resource impact waypoints were categorized into thermal area resource impact or other area resource impact. Kernel density analyses were performed on each of the six categories to identify where specific impact behaviors or resource impacts are likely to occur at Old Faithful Geyser Basin. Figure 68 through figure 73 display the results of these targeted impact behavior and resource impact analyses. For the most part, thermal and other (non-thermal) resource impact behaviors were intermixed at Old Faithful Geyser Basin, with higher density clusters of these behaviors occurring intermittently throughout the geyser basin. High density areas for both types of behaviors did tend to occur in locations from with Old Faithful Geyser could be viewed. Visitor conflict and congestion behaviors tended to occur in higher densities on the southwest side of the Upper Basin boardwalk/trail system near Depression Geyser. Wildlife impact behaviors were few, occurring on the north side of the Firehole River. Resource impacts, both to thermal and non-thermal areas, occurred in highest densities in the Upper Basin, with the section of boardwalk/trail leading from the south bank to the north bank of the Firehole River and north toward the Upper Basin being the area with the highest density of impacts among the areas monitored at Old Faithful Geyser Basin.

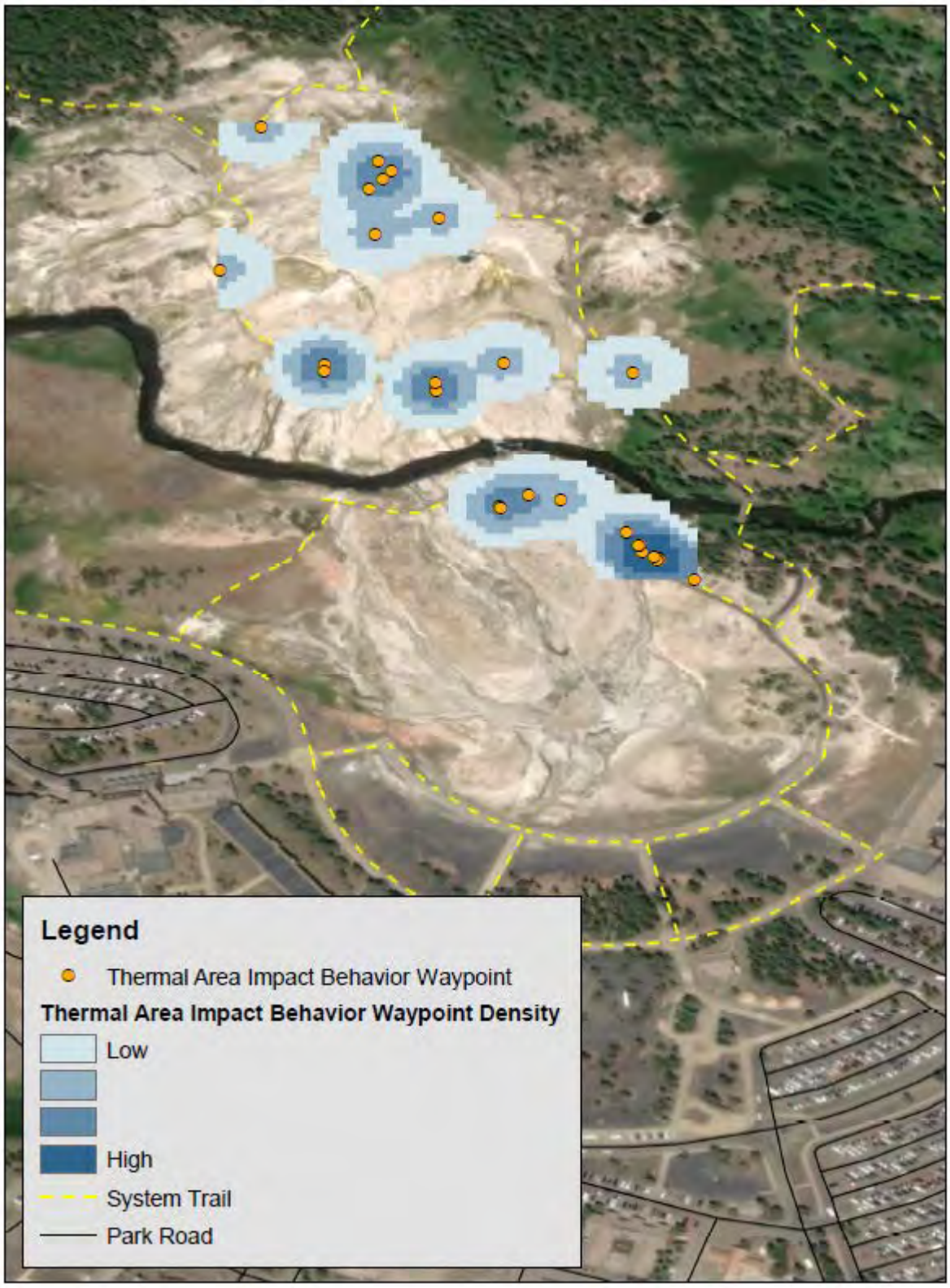

Figure 68. Thermal area impact behavior waypoint density analysis at Old Faithful Geyser Basin.

Figure 69. Other area impact behavior waypoint density analysis at Old Faithful Geyser Basin.

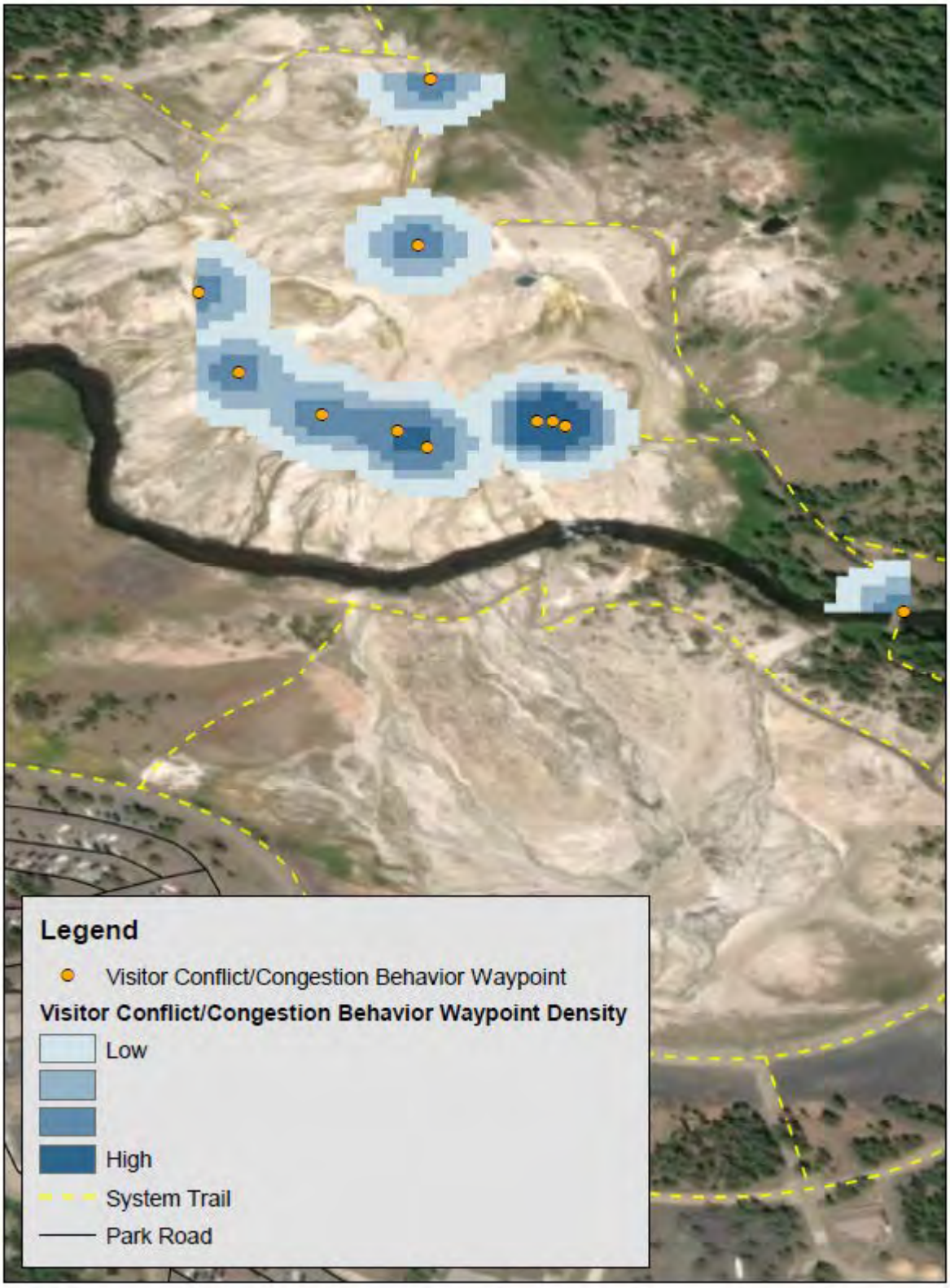

Figure 70. Visitor conflict and congestion impact behavior waypoint density analysis at Old Faithful Geyser Basin.

Figure 71. Wildlife impact behavior waypoint density analysis at Old Faithful Geyser Basin.

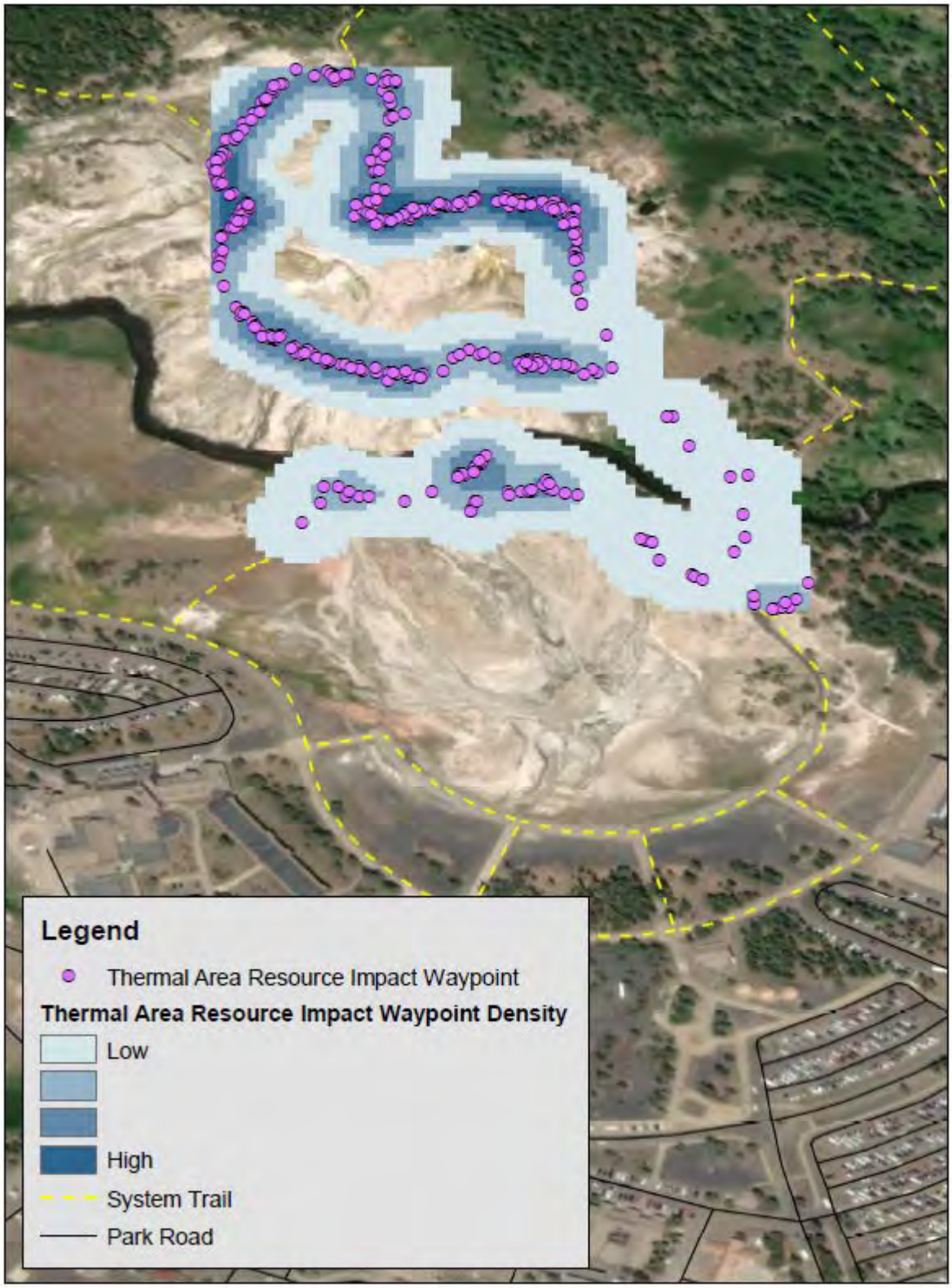

Figure 72. Thermal area resource impact waypoint density analysis at Old Faithful Geyser Basin.

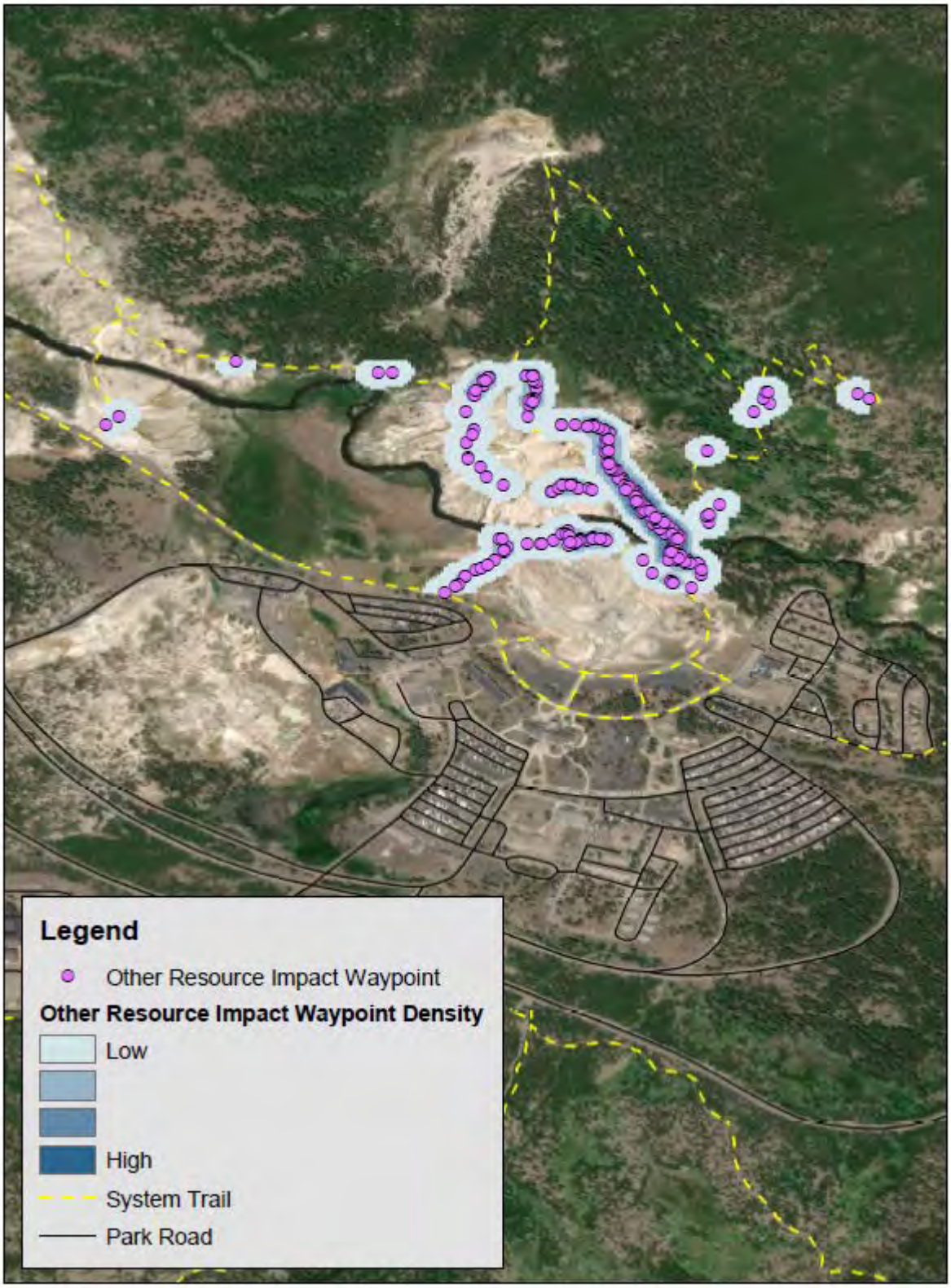

Figure 73. Other resource impact waypoint density analysis at Old Faithful Geyser Basin.

All Sites Visitor Use Estimation Comparison

This section of the report presents examples of ways the data collected by the YCC Crews can be analyzed across focal attraction sites to understand relative conditions between sites. Figure 74 and figure 75 present the parking count and trail count data to compare visitor use across the focal attraction sites.

Visitor use of parking lots varied across the three focal attraction sites at which these data were collected: Fairy Falls, Norris Geyser Basin, and Midway Geyser Basin. Looking at the peak average number of parked vehicles for each focal attraction, the peaks vary throughout the day (figure 74). Fairy Falls experiences its peak average number of parked vehicles around 11:00 at just over 140 vehicles. Norris Geyser Basin experiences peak use with an average of 190 vehicles late in the day at approximately 15:00. This trend could be a function of active parking lot management and closure by YELL staff that occurs at Norris Geyser Basin when the parking lot reaches capacity and vehicles begin to back up along the road. At Midway Geyser Basin, the average number of parked vehicles peaks at an average of approximately 150 vehicles at 13:00, with vehicles numbers only decreasing slightly over the following two hours. This could indicate Midway Geyser Basin is a popular post-lunch destination for visitors. Use at all parking lots remains high through the end of data collection by the YCC Crews (15:00). The trends across the hours of the day of YCC Crew sampling displayed in figure 65 suggest parking dynamics vary across hours of the day at each focal location and uniform trends in parking lot usage do not exist among the focal attractions.

In contrast, the number of counts at each focal attraction trail counter location displayed in figure 75 demonstrates a similar pattern of use across hours of the day while varying magnitudes of use occur. Looking at the trend lines for each focal attraction, the average number of counts per hour increases steadily throughout the morning, reaching a peak use level between roughly 11:00 and 12:00 and that peak is followed by consistent visitor use at that peak level. Peak use begins to decline (on average) between 17:00 and 19:00, with Fairy Falls declining earlier (on average) around 14:00. What differs among the focal attractions is the magnitude of use. Midway Geyser Basin experiences the highest average number of counts across all hours of the day, followed by Norris Geyser Basin, then Old Faithful Geyser Basin, and finally Fairy Falls. On average during the peak use season, Midway Geyser Basin receives a peak average number of counts of over 14,000 counts an hour at 12:00. This is roughly double the amount of counts received at Fairy Falls at its peak average counts of approximately 600 counts an hour at 12:00. Peak visitation at Midway Geyser Basin also exceeds peak visitation at Old Faithful Geyser Basin and Norris Geyser Basin count locations by a factor of slightly less than two.

Table 42 takes the average number of visitor encounters documented by the YCC Crews and standardizes them across 10 meters of trail. Given the relatively short length of trail available to visitors at Midway Geyser Basin, and the high level of visitor use seen at this site, visitors to Midway Geyser Basin could expect to experience eight encounters per every 10 meters of trail. Old Faithful Geyser Basin has the second highest average number of encounters for its trail section, but due to the more expansive trail system available to visitors, visitors to Old Faithful Geyser Basin would expect to experience four encounters per 10 meters of trail. Overall, this analysis demonstrates the importance of the intersection of visitor use and the facilities and infrastructure in terms of both resource impacts and potential impacts to the visitor experience.

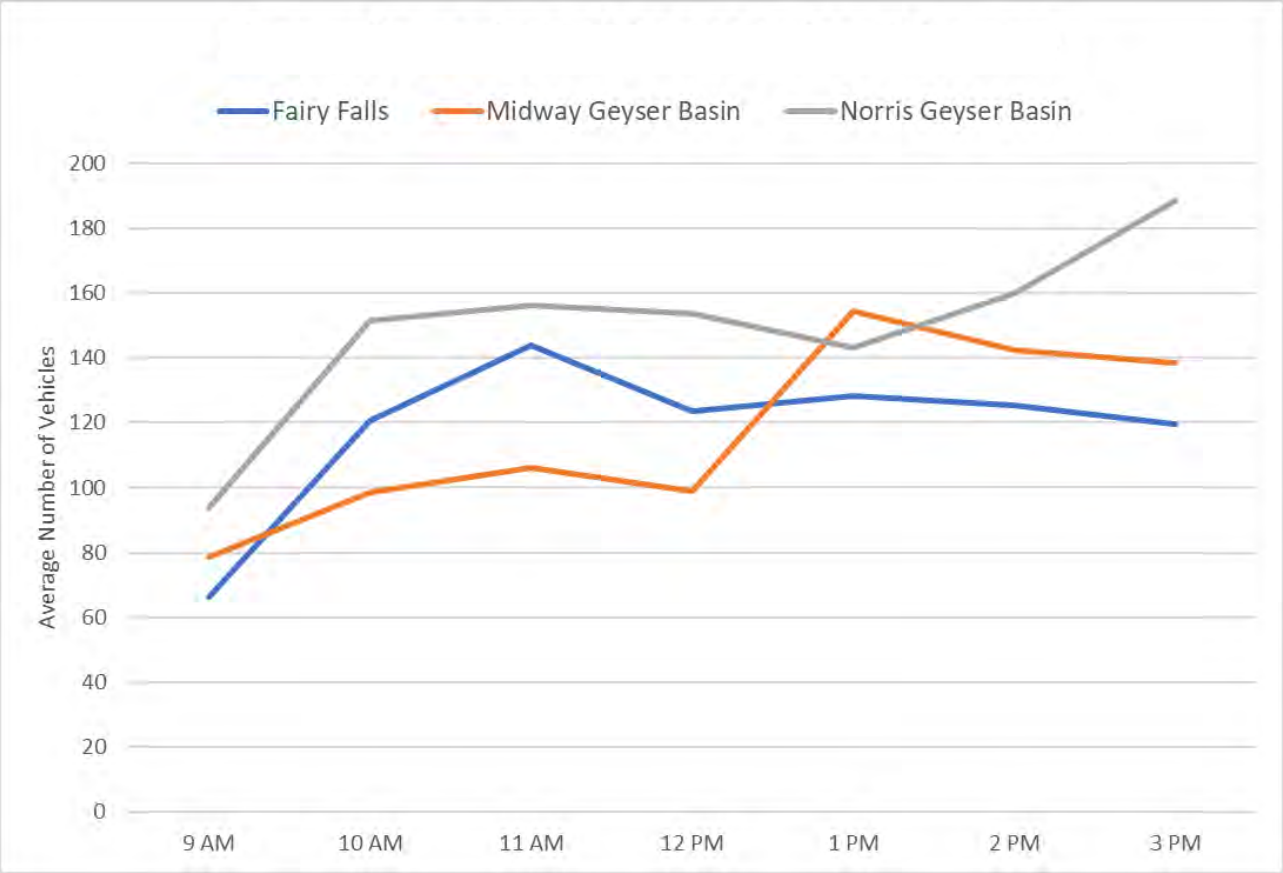

Figure 74: Average number of parked vehicles at each focal location, by hour. Total vehicles is the sum of vehicles parked in designated spots, undesignated spots, and along the roadside.

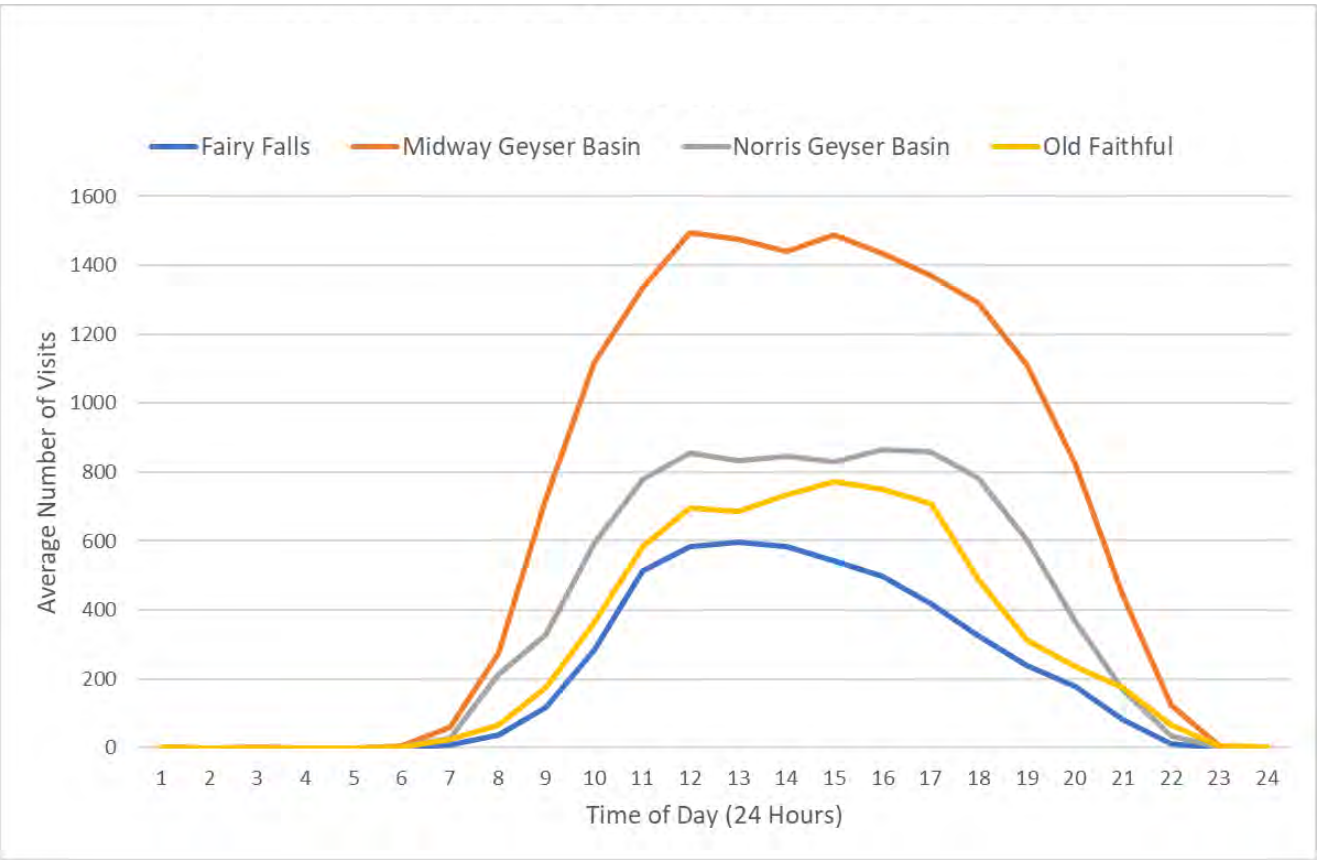

Figure 75: Average number of total counts (i.e., counts) per hour as estimated by automatic trail counters located at all focal attraction sites.

Table 42. Standardization of visitor encounters by trail length for each focal attraction site.

Focal Attraction Site	Focal Area Trail Length (m)	Average Number of Encounters (± SD)	Encounters/10 meters of trail
Fairy Falls	589	248 (± 100)	4
Midway Geyser Basin	739	585 (± 257)	8
Norris Geyser Basin	704	245 (± 90)	3
Old Faithful Geyser Basin	1,052	433 (± 332)	4

Recommendations

In the same manner as the 2017 data collection, the 2018 data collection by the YCC Crews was impressive, generating a convenience sample of six types of data collected across four different focal locations from mid-June through mid-August. The YCC Crews and YELL staff did an excellent job collecting high quality, consistent monitoring data during summer 2018. Specifically, the improvements made to the data collection in 2018, namely the implementation of the season-long installation of trail counters and addition of a YELL intern focused on YCC Crew data collection, increased the quality of data generated in 2018.

Review and analysis of the 2018 data also identified some areas for continued adaptation of the protocols. The following bullet points are general recommendations on how to improve the citizen science monitoring effort based on analysis of the data and comments from YELL staff. Many of these recommendations were already incorporated into the 2019 YCC Crew Data Collection Effort.

- The trail counter installation in 2018 likely contributed to the high calibration coefficients experienced at each of the focal location counters. Slight changes to the placement of the installed trail counters for 2019 will likely result in reduced calibration coefficients, increasing the accuracy and reducing the variability within counter estimates. Counters should be installed in areas where the trail narrows, at breast height for an average adult (depending the height of the person installing that could be lower), and away from areas that may trigger erroneous counts (e.g., away from brush, tree limbs that move in the breeze). In 2018, many of the trail counters were placed below breast height for most individuals and in wide sections of the trail.

- When trail counters are downloaded, care should be taken to ensure the counters are properly relaunched for continued data collection. Two focal locations experienced gaps in the count data recorded due to not being relaunched after downloads. This is an accidental error that can easily happen in the field, particularly due to bright lighting during the daytime and not being able to see the counter's flashing lights which indicate proper relaunch. Replacing desiccation packets and wiping the counter electronics with an alcohol wipe after use can also reduce download errors.

- During the 2018 data collection, the labeling of PAOT locations for sites with two PAOT locations was done inconsistently across YCC Crews. At times, the data were recorded separately. At times, the data were summed without individual counts being recorded. Additionally, the YCC Crews used inconsistent names for the same locations across weeks. In 2019, the PAOT count locations were assigned specific names and the protocols was edited to reiterate the importance of using the correct names and keeping the counts separate. Crew leaders should also highlight the importance of following established naming conventions during crew training.

- Similarly, the naming and saving of GPS files collected from participating visitors was done inconsistently in 2018. Specifically, some GPS tracks were assigned the same name, so one name represented multiple tracks. While this did not result in lost data, it did result in additional time and effort to identify the issues and resolve naming errors during data cleaning. In the future, crew leaders should further highlight the importance of following the protocols and the YELL intern working with the project should check for this error early and often to help YCC Crews improve on this aspect of data collection.

- In 2017 and 2018 the waypoint behavior mapping has been implemented following the same protocols. YCC Crew members are instructed to mark a waypoint only once during a sample day for a resource impact and to mark a waypoint every time an impact behavior is scene during a rove. Across 2017 and 2018 the

implementation of these protocols has varied across YCC Crews regarding the interpretation of when to mark a waypoint and when not to mark a waypoint. For behavior hotspots identified through the kernel density maps produced from the 2018 data, it is recommended a calibration procedure be added to the waypoint mapping protocol or a new data collection technique be implemented that stores and displays past waypoints.

Next Steps

This report is the final report for the Summer Visitor Use and Resource Monitoring at Focal Attractions and Trails in Yellowstone National Park: Summer 2018 Data Collection Effort. Accompanying this YCC Crew data collection focused report is a final report for the repeat photography project that was conducted in conjunction with the YCC Crew data collection.

A separate addendum to this report will include a comparative analysis of data collected in the 2017 and 2018 data collection effort. This comparative analysis report will compare data collection methods at the same locations across the two years of collection. While trend analysis with two data points is not possible, this report will provide the template for the addition of the YCC Crew's 2019 data. Three years of quality, monitoring data will allow YELL to begin to identify trends (if they exist) at these four focal attraction sites. The analysis will identify the magnitude and direction of any differences that may exist between 2017 and 2018. This comparative report was not a deliverable that was explicitly listed in the CESU Agreement between YELL and OSU, but is desired by YELL and is seen by OSU as an important part of this project. Delivery of this addendum will occur in fall 2019.

Finally, a second, separate addendum to this report will include a small analysis examining how eruptions of Steamboat Geyser may be influencing visitor behavior at Norris Geyser Basin. GPS tracking data from 2017 (when Steamboat Geyser was not as active) will be compared to 2018 and 2019 GPS-based tracking data collected at Norris Geyser Basin. Specifically, differences in where visitors go at Norris Geyser Basin and how long visitors spend near Steamboat Geyser will be calculated and compared between years.

Finally, OSU was funded for a third year of work with YELL on both the YCC Data Collection Effort and the Repeat Photography work (see separate report). The new CESU agreement to summarize the data collection by the YCC Crews will run from September 1, 2019, to August 31, 2020.

Appendices Lists

All listed appendices are provided as separate PDFs to allow for easier navigation of this report.

Appendix A: Summer 2017 YCC Crew Data Collection Calendar

Appendix B: Summary of Data Collection Hours and Effort by YCC Crews in Summer 2018

Appendix C: Locations of PAOT Counts at Each Focal Attraction Site

Appendix D: Summary Tables for Parking Lot Counts

Appendix E: Average Hourly Counts of Vehicles Parked in Designated Spots at Focal Attraction Sites by Date

Appendix F: Summary Figures for Shoulder Season Trail Counts at Focal Attractions

Appendix G: Summary Figures for Trail Counters Located Outside YCC Focal Attraction Sites

Appendix H: Maps for all Individual Waypoint Codes for Each YCC Location

References

D'Antonio, A., C. Monz, S. Lawson, P. Newman, D. Pettebone, and A. Courtemanch. 2010. GPS-based measurements of backcountry visitors in parks and protected areas: examples of methods and applications from three case studies. Journal of Parks and Recreation Administration 28:42-60.

Hammitt, W.E.,D.N. Cole, and C.A. Monz. 2015. Wildland recreation: ecology and management. John Wiley & Sons, Hoboken, New Jersey, USA.

Manning, R.E. 2007. Parks and carrying capacity: commons without tragedy. Island Press, Washington, D.C., USA.

Manning, R.E. 2011. Studies in outdoor recreation: search and research for satisfaction. Oregon State University Press, Corvallis, Oregon, USA.

Monz, C., A. D'Antonio, and K. Heaslip. 2014. Moose-Wilson corridor use levels, types, patterns, and impacts in Grand Teton National Park: technical report – summer/fall 2013. Utah State University, Logan, Utah, USA.

National Park Service (NPS). 2019. NPS STATS. https://irma.nps.gov/Stats/

Otak. 2017. Yellowstone National Park: transportation and mobility study. Final technical report.

Pettebone, D., P. Newman, and S. Lawson. 2010. Estimating visitor use at attraction sites and trailheads in Yosemite National Park using automated visitor counters. Landscape and Urban Planning 97:229-238.

Sidder, S. A, and A. D'Antonio. 2019. Summer visitor use and resource monitoring at focal attractions and trails in Yellowstone National Park: data summary from summer 2018 data collection effort & repeat photography study. Technical report. Oregon State University, Corvallis, Oregon, USA.

TRAFx (2018a). TRAFx Infrared Trail Counter. https://www.trafx.net/brochures/TRAFx_Infrared_Trail_Counter.pdf?v=170803

TRAFx (2018b). TRAFx Datanet. https://www.trafx.net/datanet/demo