OLD RAG MOUNTAIN VISITOR USE STUDY – FINAL REPORT

June 2020

Prepared for
Shenandoah National Park

RSG
the science of insight

Notice of Rights

Cover Image Credit: Katy Cain, NPS

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

GPS	Global Positioning System
NPS	National Park Service
PAOT	People-at-One-Time
SHEN	Shenandoah National Park

1.0 INTRODUCTION

Old Rag Mountain in Shenandoah National Park (SHEN) is among the most popular backcountry hiking destinations in the park. Much of the trail network that provides access to Old Rag summit, hereafter referred to as the "Old Rag Mountain Trail," is located within the SHEN Wilderness, where preservation of natural resource conditions and primitive visitor experiences are paramount. However, results of recent research suggest visitor use on sections of the Ridge and Saddle Trails along the Old Rag Mountain Trail may be reaching or has reached levels that conflict with prescribed conditions for Wilderness areas. For example, research conducted in the park to estimate natural resources conditions has characterized much of the Old Rag Mountain Trail as a Threshold Wilderness area, where visitor-caused impacts are noticeable and significant.

A 2012 study of visitor use on the Old Rag Mountain Trail found that during peak periods visitors experience crowding on the trail and at the summit.[1] Crowding impacts are particularly problematic in the rock scramble section of the trail, where long lines of visitors form and crowding-related delays to pass through the rock scramble occur. When this occurs, some visitors forgo hiking the sanctioned trail through the rock scramble area, and instead travel on visitor-created trails which skirt steep cliffs. This "off-trail" travel causes trampling impacts to vegetation and soils and may also increase hikers' risks of serious injury, which in turn, may increase the number of Search and Rescue incidents on Old Rag. Crowding in the rock scramble section of the trail, and on the summit of Old Rag, also impacts the quality of visitors' experiences and conflicts with Wilderness values.

The National Park Service (NPS) is now working to develop visitor use management strategies and actions to help address the impacts of visitor use on the Old Rag Mountain Trail. As part of this effort, NPS commissioned this study. The purpose of the study is to collect descriptive information about the types, volumes, and patterns of visitor use on the Old Rag Mountain Trail, and evaluative information regarding visitors' perceptions of, tolerances for, and attitudes about managing visitor use on the trail.

More specifically, the purpose of this study is to develop a precise, quantitative, and empirical understanding of the relationships among trail use volumes, use densities at key trail locations, and potential impacts to visitors' experiences. The research conducted to achieve these results and presented in this report involves several interrelated components including: 1) visitor use counts via infrared trail counters and direct observation; 2) GPS-based tracking of visitors' hiking routes; 3) direct observation counts of the number of people at one time (PAOT) at key locations; 4) a visitor experience survey regarding visitors' perceptions of visitor use and crowding; 5) statistical modeling of visitor use data; and 6) computer simulation modeling of

[1] Kelly, S. D. (2012). Opportunities for Solitude (Master's Thesis, Duke University).

visitor use on the Old Rag Mountain Trail. All data for the study were collected during the fall foliage season in 2019. An electronic copy of all data collected during the study (including associated codebooks) are archived with NPS.

The remainder of this report is organized as follows: Section 2.0 describes the study methods, including the study area; Section 3.0 reports results of the descriptive data; Section 4.0 reports results of the visitor experience survey; Section 5.0 reports results of a crowding-related thresholds and capacities analysis; and Section 6.0 provides an overview and reports the results of the computer simulation model.

2.0 METHODS

This section of the report describes the study methods for the Old Rag Mountain Visitor Use Study.

2.1 STUDY AREA

Old Rag Mountain Trail Loop System

Figure 1 provides a schematic diagram of the Old Rag Mountain Trail, including key study locations along the loop trail system. The Old Rag Mountain Trail has two parking areas. "Old Rag Parking" (denoted as "X1" in Figure 1) is Old Rag's main parking area near Nethers in the northeast corner of the study area . The second parking area is located at Berry Hollow in the southwest corner of the study area (denoted as "X5" in Figure 1).

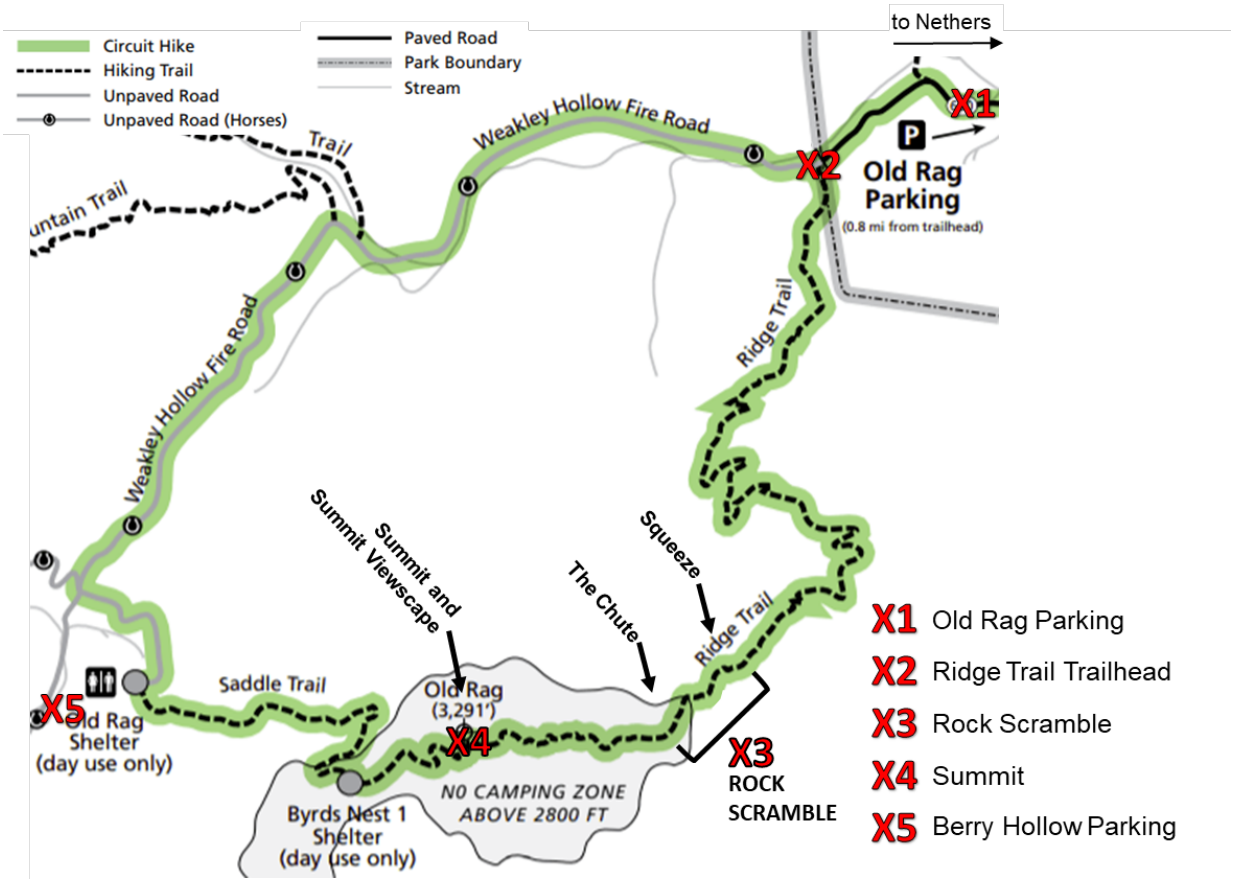

FIGURE 1. OLD RAG STUDY AREA: KEY LOCATIONS ALONG THE OLD RAG MOUNTAIN TRAIL

Most visitors enter the Old Rag Mountain Trail loop system from Old Rag Parking at Nethers and hike in a clockwise direction from the Ridge Trail Trailhead (denoted as “X2” in Figure 1) towards the rock scramble (“X3” in Figure 1 and described in detail below). From the rock scramble, visitors follow the trail to a spur trail that leads to the exposed rock summit (denoted as “X4” in Figure 1 and described in detail below). From the summit, the clockwise loop hike continues along the Saddle Trail and the Weakley Hollow Fire Road back to Nethers.

The 9.2-mile Old Rag Mountain Trail can also be hiked in a counterclockwise direction from Nethers, starting on the Weakley Hollow Fire Road and ending at the Ridge Trail Trailhead, but this is a less common route. An even less common hiking route to the Old Rag summit begins at the Berry Hollow parking area. This out-and-back hike follows the Saddle Trail to the Ridge Trail and the short spur trail to the summit. Hikers return on this route along the Saddle Trail to the Berry Hollow parking area. Relatively few visitors hike this route.

Rock Scramble

Visitors seeking a rugged hiking experience are drawn to the Old Rag Mountain Trail in part for the challenge offered by the rock scramble section along the Ridge Trail (Figure 1). The technical difficulty of the rock scramble generally slows hiking pace, which can result in lines of visitors waiting to proceed up the rock scramble, especially during busy periods. The rock scramble is an important area of focus for this study due to the potential for visitor crowding in this area.

There are two primary sections of the rock scramble; the lower section is referred to in this study as “the Squeeze” and the upper section is referred to as “the Chute” (Figure 1 and Figure 2). Data collection, analysis, and modeling for the rock scramble in this study focused on relationships between: 1) the number of people-at-one-time (PAOT) in the Chute, including people waiting in line in the queue that forms downhill of the Chute during busy periods; and 2) hiking times on the rock scramble section of the Ridge Trail, from just below the Squeeze to exiting out of the top of the Chute.

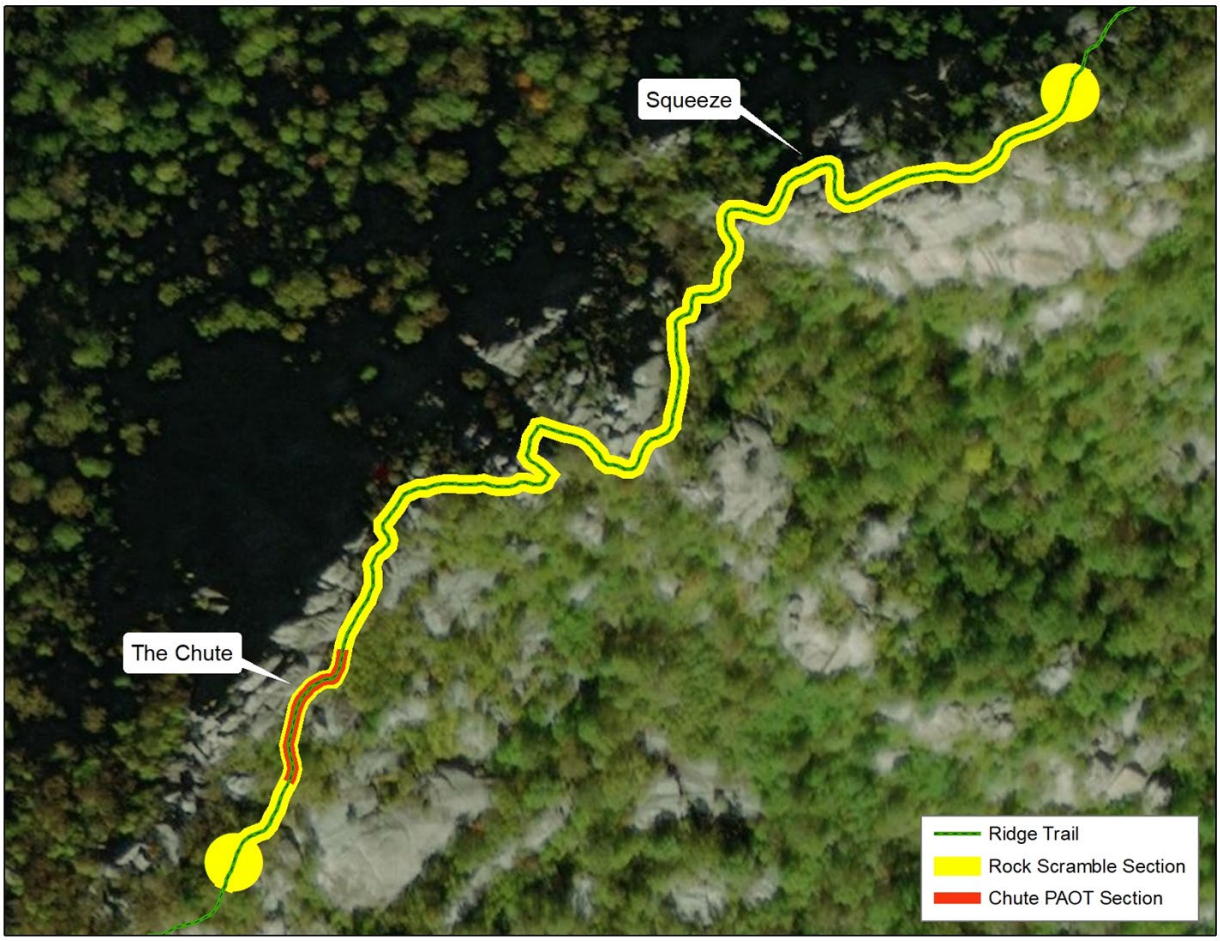

FIGURE 2. ROCK SCRAMBLE SECTION OF THE RIDGE TRAIL

Old Rag Summit

The expansive and rocky Old Rag mountain summit is a prominent feature of the Old Rag Mountain Trail system. At 3,291 feet, the exposed summit is a primary destination along the loop trail system, where visitors may pause to enjoy the views, drink water, and eat a snack or lunch. During busy periods, visitors may experience crowding on the mountain summit. In turn, the Old Rag summit is an important area of focus for this study. Data collection, analysis, and modeling in this study includes measures for the Old Rag summit in its entirety and for a subarea of the summit referred to hereafter as the “summit viewscape” (Figure 3).

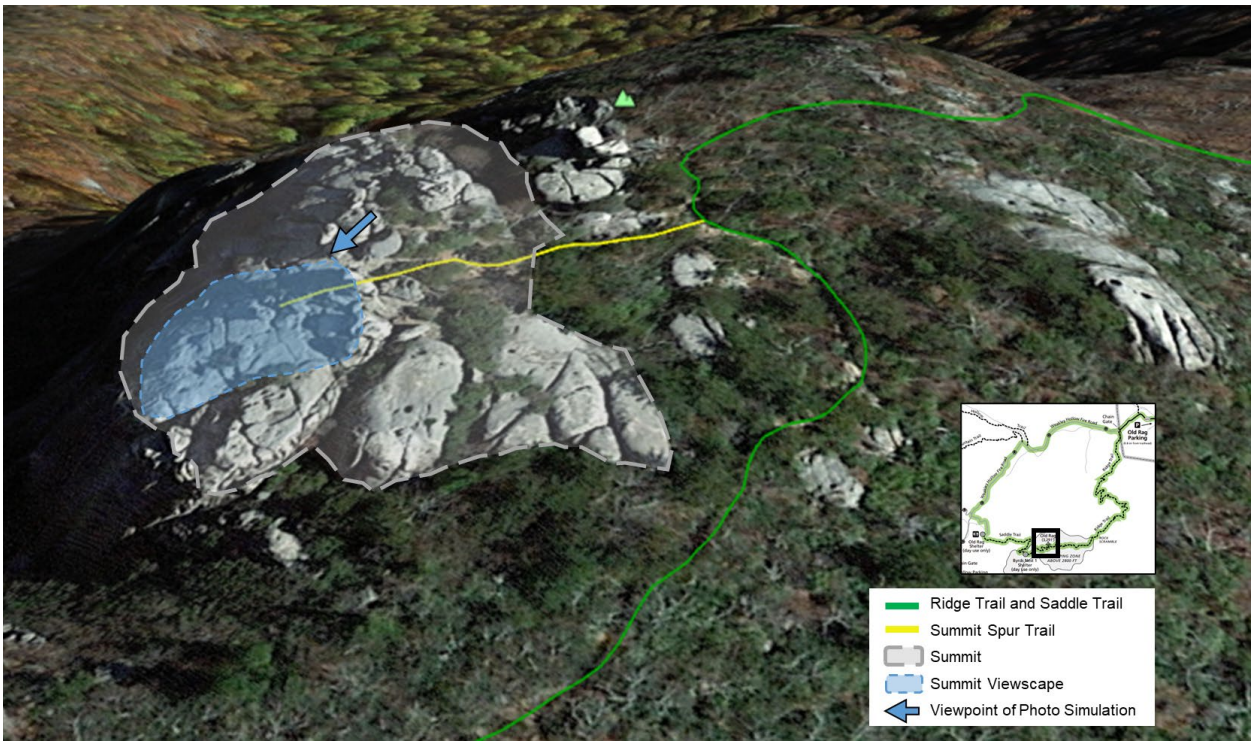

FIGURE 3. OLD RAG SUMMIT AND SUMMIT VIEWSCAPE

The Old Rag summit is depicted with grey shading in Figure 3 and the summit viewscape is denoted with blue shading. The summit viewscape was selected in consultation with NPS to be visually representative of the summit area from the perspective of visitors' experiences. A series of photographs of the summit viewscape were recorded by NPS for use in the study. The photographs recorded by NPS were used to produce a series of photo simulations depicting varying numbers of people-at-one-time (PAOT) in the summit viewscape (Figure 4 and Appendix A). These photo simulations were used in the study as a basis for a series of survey questions about visitor crowding on the summit of Old Rag. The photo simulations were also used to "register" the location of PAOT counts conducted in the summit viewscape as part of the study. The methods and results of these study components are described later in this report.

FIGURE 4. EXAMPLE PHOTO SIMULATION OF PEOPLE-AT-ONE-TIME (PAOT) IN THE OLD RAG SUMMIT VIEWSCAPE

2.2 DATA COLLECTION

As noted, this study was designed to collect descriptive information about the types, volumes, and patterns of visitor use on the Old Rag Mountain Trail, and evaluative information regarding visitors' perceptions of, tolerances for, and attitudes about managing visitor use on the trail. Data collection methods for the descriptive component of the study included visitor use counts via infrared trail counters, GPS-based tracking of visitors' hiking routes, and people-at-one-time (PAOT) counts. The evaluative component of the study included a visitor experience survey administered to sampled visitor groups at Nethers at the end of their hikes. The location where each study component was administered is illustrated in Figure 5.

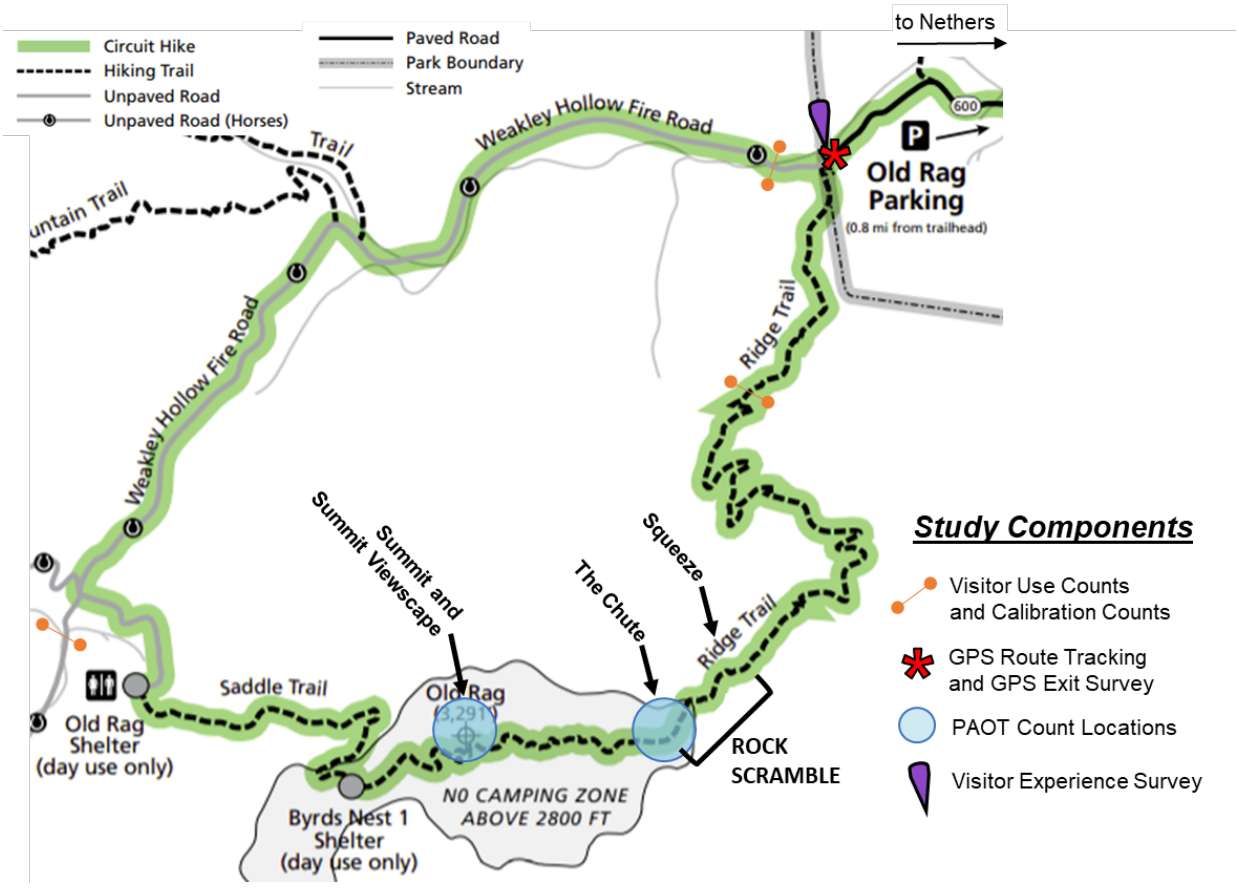

FIGURE 5. OLD RAG MOUNTAIN TRAIL STUDY AREA: DATA COLLECTION DEPLOYMENT LOCATIONS

Visitor use counts were conducted during a counting period from October 9 through November 11, 2019. Data collection for GPS route tracking and exit survey, PAOT counts, and the visitor experience survey was conducted during a subset of dates during the counting period (referred to hereafter as the "sampling period") from October 11 through October 24, 2019. The counting and sampling periods for the study were selected in consultation with NPS and coincided with the park's foliage season, which is a popular period of visitor use on the Old Rag Mountain Trail. The following sub-sections describe the methods for each study component.

Visitor Use Counts

Visitor use count data were collected with infrared trail counters at three locations along the Old Rag Mountain Trail (Figure 5). The counting locations were selected in consultation with NPS staff to estimate visitor use on the two trails diverging from Old Rag Parking (Ridge Trail and Weakley Hollow Fire Road), and visitor use from Berry Hollow. For consistency, the counter on

the Ridge Trail was deployed in approximately the same location as the counter deployed during the 2012 study (Kelly 2012).

The infrared trail counter deployed at Berry Hollow recorded visitor use counts as individual timestamps (i.e., date and time of each count, to the second), 24 hours per day, from October 9 through November 11, 2019. Because of the relatively high number of "events" (i.e., visitors passing the counter and triggering counts to be registered) on the Ridge Trail and Weakley Hollow Fire Road and associated data storage capacity considerations, the counters at those two locations were programmed to record counts in hourly "bins" instead of individual timestamps. The infrared trail counters deployed along the Ridge Trail and Weakley Hollow Fire Road recorded visitor use counts 24 hours per day, from October 11 through November 11, 2019.

Field staff conducted visitor use counts via direct observation for a minimum of 32 hours at each trail counter location (see Appendix B for a copy of the log sheet used to record visitor use counts via direct observation). The direct observation counts (or "calibration counts") were used to correct and adjust (i.e., calibrate) the raw infrared trail counter data, as described in Section 3.1 of this report.

GPS Route Tracking

GPS Tracking Units

GPS tracking units (Qstarz model BT-Q1000XT) were distributed to visitor groups hiking the Old Rag Mountain Trail from Nethers to collect information about the spatial and temporal patterns of visitor use. The GPS tracking units were configured to record visitors' GPS coordinates and corresponding timestamps every five seconds during the course of their entire hikes. The GPS tracking data were post-processed to derive visitors':

- Hiking direction (i.e., clockwise or counterclockwise)
- Hiking routes (e.g., all or part of the way to the Old Rag summit)
- Hiking times for the overall hike and on specific segments of the hike, including the rock scramble
- Dwell times on the Old Rag summit
- Hiking speeds, as a function of distance traveled between timestamps

Sampling Procedures

GPS route tracking was conducted on 11 days during the study's sampling period. Each GPS route tracking sampling day started at 8:00 a.m. and ended at 4:00 p.m. A total of 433 GPS tracking units were distributed and returned during the sampling period (Table 1).

TABLE 1. OLD RAG GPS ROUTE TRACKING SAMPLING EFFORT

DATE	SOLICITATIONS	ACCEPTANCES	REFUSALS	INELIGIBLE
10/11/19	59	54	3	2
10/12/19	52	47	4	1
10/13/19	57	50	6	1
10/14/19	60	55	5	–
10/17/19	53	48	2	3
10/18/19	20	19	1	–
10/19/19	62	51	9	2
10/20/19	13	13	–	–
10/21/19	52	49	2	1
10/22/19	3	3	–	–
10/23/19	44	44	–	–
Total	475	433	32	10

Note: Visitors were considered eligible if they were at least 18 years old, had not previously participated in the study, were on a recreational trip to the park, and were able to communicate with the English-speaking GPS administrator (i.e., did not have a language barrier), were not on an overnight backpacking trip, and were not planning to exit at Berry Hollow.

Sampling for the GPS route tracking occurred in the area adjacent to the intersection of the Ridge Trail Trailhead and the Weakley Hollow Fire Road (Figure 5). Sampling was conducted at this location because the vast majority of visitors who hike the Old Rag Mountain Trail start their hikes at Nethers; GPS sampling was not conducted at Berry Hollow due to the expectation of very low sampling efficiency.

On each GPS sampling day, the field technician contacted the first arriving visitor group and asked them to participate in the study. For the first half of the day (between 8:00 a.m. and noon), the field technician contacted arriving visitor groups using an every-other approach. As the name suggests, with an every-other approach, every other arriving group was contacted and asked to participate in the study. During the second half of the day when the flow of inbound visitors tended to be somewhat slower (from noon until 4:00 p.m.), GPS tracking units were administered using a 7-minute interval sampling approach. With a 7-minute interval approach, the field technician contacted the first arriving group after the start of each 7-minute interval.

Each contacted visitor group was greeted, briefly introduced to the purpose of the study, and asked to participate and screened for eligibility. Visitors groups were considered eligible for the study if they were at least 18 years old, had not previously participated in the study, were not overnight hikers, were not exiting the Old Rag Mountain Trail at Berry Hollow,[2] and were able to communicate with the English-speaking field technician (i.e., did not have a language barrier).

[2] Two contacts indicated they planned to exit at Berry Hollow and were considered ineligible.

Information from all contacts was recorded on a contact log. If visitors were eligible for the study and agreed to participate, they were asked which member (at least 18 years old) had the next birthday. The individual with the next birthday was selected to carry the GPS tracking unit for the group. The field technician clipped a GPS tracking unit to the clothing or backpack of the selected group member and instructed them to leave it in place during their hike. The study participant was further instructed to return the GPS tracking unit to the administrator at the end of their hike or to one of two drop boxes if the GPS administrator had left for the day. The drop boxes were located at the GPS administration location and at the entrance to the Old Rag Parking lot.

An interview, lasting approximately two minutes, was conducted with all eligible visitor groups, whether they agreed to participate in the study or not, to determine group size, whether they had visited Old Rag before, and their state or country of residence. The gender of the first-contacted group member and the time of contact was also recorded for each contacted group. For all "hard refusals" (groups who refused to participate in the study and in the brief interview), only the observational data (group size, gender of first-contacted group member, and time of contact) and refusal reason were recorded on the contact log.

The response rate for GPS route tracking was 93.1%.[3] A copy of the GPS administration contact log used to record information about survey response rates is contained in Appendix C.

Analysis Methods

Algorithms were developed to process the GPS tracks and eliminate cases with routes predominantly outside of the Old Rag Mountain Trail study area (e.g., routes predominantly on the Old Rag Fire Road, Corbin Hollow Trail, Indian Run Trail). GPS track processing involved identifying each GPS waypoint by a series of polygons, which represent key areas of interest in the study area. These areas of interest include: 1) the clockwise and counterclockwise starting locations on the Ridge Trail and Weakley Hollow Fire Road, respectively; 2) the start of the rock scramble, from the clockwise direction on the Ridge Trail, just downhill of the Squeeze, approximately 2.3 miles from the trailhead; 3) the end of the rock scramble, from the clockwise direction on the Ridge Trail, where hikers exit out of the top of the Chute, approximately 2.7 miles from the trailhead; and 4) the Old Rag Summit; and the junction of the Saddle Trail and Weakley Hollow Fire Road, near Post Office Junction.

Each GPS track retained for analysis was classified as a clockwise or counter-clockwise and full or partial route based on the time-series progression of waypoints through polygons noted. For example, a GPS track was classified as 'clockwise full' route if the GPS track waypoints progressed from the start location on the Ridge Trail, through the rock scramble, to the junction

[3] No non-response bias analysis was conducted on these data. Office of Management and Budget Standards and Guidelines for Statistical Surveys (2006) specify that non-response bias analysis is required when unit response rate is below 80%.

of the Saddle Trail and Weakley Hollow Fire Road (with or without a visit to the summit), and back to the start/trailhead of the Weakley Hollow Fire Road. Other GPS track classifications include: counterclockwise full, clockwise partial, and counterclockwise partial. All hiking times were calculated based on the difference in time between the last timestamped waypoint in the polygon preceding a hiked trail segment and the first timestamped waypoint in the polygon at the end of the hiked trail segment. Dwell times on the summit were calculated based on the first and last timestamped waypoint in the summit polygon.

Overall, 392 GPS tracks contained sufficient data density to be classified as routes. A subset of these GPS tracks contained sufficient data density within each pair of analysis polygons to calculate hiking times and sufficient data density in the summit polygon to calculate summit dwell times. In some cases with partially complete timestamped data (attributable to poor satellite reception in the rocky terrain, and possibly equipment malfunction), interpolation was used to estimate the first and last timestamped waypoints among polygons to calculate travel times and dwell times at the summit.

GPS Exit Survey

A three question GPS exit survey was administered to GPS route tracking study participants who completed their hikes before the end of the sampling day, when the field technician was onsite. The GPS exit survey included questions regarding:

- Whether or not the visitor's group hiked to the summit of Old Rag
- For those who did not hike to the summit, the reasons why they did not summit Old Rag
- Visitors' behavioral responses to crowding on the trail

For each visitor group that returned their GPS tracking unit to the field technician rather than to one of the two drop boxes, the field technician asked the group member who had been selected to carry the GPS tracking unit to complete the exit survey. The field technician recorded on the GPS contact log whether or not the visitor agreed to participate in the GPS exit survey. Of the 433 GPS route tracking participants, 259 were asked to complete the GPS exit survey. Of the 259 participants contacted, 251 completed a GPS exit survey for a response rate of 96.9% (Table 2).[4]

The GPS exit survey was designed by researchers at RSG, in consultation with NPS staff, and were reviewed and approved by the Office of Management and Budget (OMB). Appendix D contains a copy of the GPS exit survey.

[4] No non-response bias analysis was conducted on these data. Office of Management and Budget Standards and Guidelines for Statistical Surveys (2006) specify that non-response bias analysis is required when unit response rate is below 80%.

TABLE 2. OLD RAG GPS EXIT SURVEY SAMPLING EFFORT

DATE	SOLICITATIONS	ACCEPTANCES	REFUSALS	DROP BOX
10/11/19	33	31	2	21
10/12/19	26	23	3	21
10/13/19	27	25	2	23
10/14/19	37	36	1	18
10/17/19	20	20	–	12
10/18/19	21	21	–	15
10/19/19	25	25	–	26
10/20/19	10	10	–	3
10/21/19	29	29	–	17
10/22/19	3	3	–	–
10/23/19	28	28	–	16
Total	259	251	8	172

Note: The return of two GPS units to a drop box were not recorded on the contact log and are not represented in this table.

People-at-One-Time (PAOT) Counts

People-at-one-time (PAOT) counts were conducted in the Chute (Figure 2 and Figure 5), on the Old Rag summit (Figure 3 and Figure 5), and in the Old Rag summit viewscape (Figure 3, Figure 4, and Figure 5). The PAOT counting procedures for each area are described in the sub-sections below.

The Chute

Due to the nature of the Chute's relatively long expanse along a serpentine trail with tall and dispersed boulders, there was no suitable location for a field technician to accurately conduct instantaneous counts of the number of people in the Chute at one time. Thus, to conduct PAOT counts, a field technician was stationed at the bottom of the Chute (denoted "Bottom" in Figure 6) and a second field technician was stationed at the top of the Chute (denoted as "Top" in Figure 6). The field technician at the bottom of the Chute recorded the number of uphill arrivals to the bottom of the Chute and the number of downhill departures from the bottom of the Chute (Figure 6) each in 10-minute interval bins. At times when a queue developed at the bottom of the Chute, the field technician at the bottom of the Chute dynamically adjusted her count location downhill to include visitors in the queue in the recorded count of uphill arrivals at the bottom of the Chute. Only visitors who had newly arrived to the queue were recorded in each successive 10-minute count of arrivals. The field technician at the top of the Chute recorded the number of downhill arrivals to the top of the Chute and the number of uphill departures from the top of the Chute (Figure 6) each in 10-minute interval bins. The field technician at the top of the Chute did not adjust her count location at any time. The PAOT counts were conducted for

approximately 6 to 7 hours per day, with start times varying by day between 9:00 a.m. and 10:00 a.m., depending on the field technicians' hike time to the Chute.

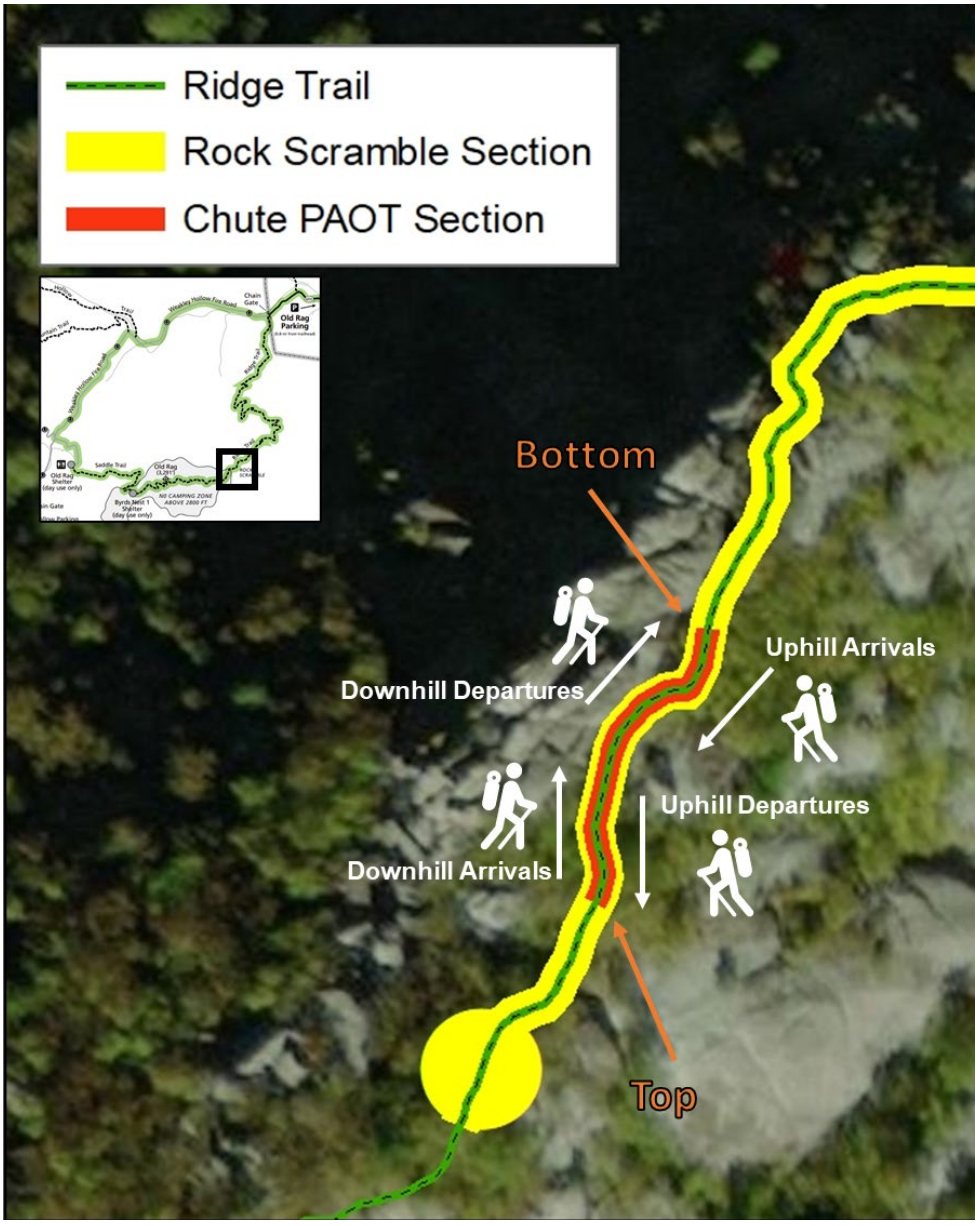

FIGURE 6. SCHEMATIC DIAGRAM OF PAOT COUNT PROCEDURE FOR THE CHUTE

On each sampling day, the two field technicians arrived at the bottom of the Chute at the same time. At the start of the first 10-minute interval after arriving (e.g., at 9:00, 9:10, 9:20, etc.), the field technician assigned to count at the bottom of the Chute began recording the number of arrivals and departures in 10-minute interval bins and continued throughout the sampling day.

At the same time, the field technician assigned to count at the top of the Chute began hiking up the Chute. As the field technician hiked up the Chute, she ensured that no visitors passed her while hiking, in order to "fix" the number of people who arrived into the system at the bottom and departed the system at the top at zero until she reached the top of the Chute. On all sampling days, the hike from the bottom to the top of the Chute took less than 10 minutes for the field technician to complete. While hiking up the Chute, the field technician recorded any visitors hiking down the Chute as downhill arrivals from the top in the first 10-minute count interval on her data collection sheet. Upon arrival at the top of the Chute, the field technician continued recording downhill arrivals from the top and started recording uphill departures from the top to complete the first 10-minute count interval bin. The field technicians at the top and at the bottom of the Chute then counted arrivals and departures from their counting locations throughout the rest of the sampling day.

The Chute PAOT count data were post-processed to derive PAOT counts for each 10-minute interval in the counting period. Each sampling day's first 10-minute interval count was calculated by subtracting the observed number of uphill and downhill departures in the first 10-minute interval bin from the observed number of uphill and downhill arrivals in the first 10-minute interval bin. Each successive 10-minute interval count was calculated by adding the net number of arrivals in the 10-minute interval to the count for the previous 10-minute interval.

The PAOT counts for the Chute were conducted on nine days during the sampling period. Paired PAOT counts (i.e., recorded concurrently at the top and bottom of the Chute) were recorded for a total of 353 10-minute intervals in the Chute (Table 3). A copy of the Chute PAOT count log form is included in Appendix E.

Old Rag Summit

Due to the nature of the Old Rag summit's relatively wide expanse with tall and dispersed boulders, there was no suitable location on the summit itself for a field technician to accurately conduct instantaneous counts of the number of people on the summit at one time. Thus, upon arrival to the summit, the assigned field technician conducted a roving count of all people on the summit and recorded this as the summit starting count (i.e. the number of people on the entirety of the summit of Old Rag at the start of the sampling day). The field technician then stationed herself at the junction of the summit spur trail with the Ridge Trail and the Saddle Trail (denoted by "X" in Figure 7) to count the number of visitors arriving to and departing from the Old Rag summit. Throughout the sampling day, the field technician recorded the number of arrivals to and departures from the summit in 10-minute interval bins for approximately 6 to 7 hours per day. Start times varied by sampling day between 9:00 a.m. and 10:00 a.m., depending on the field technician's hike time to the summit.

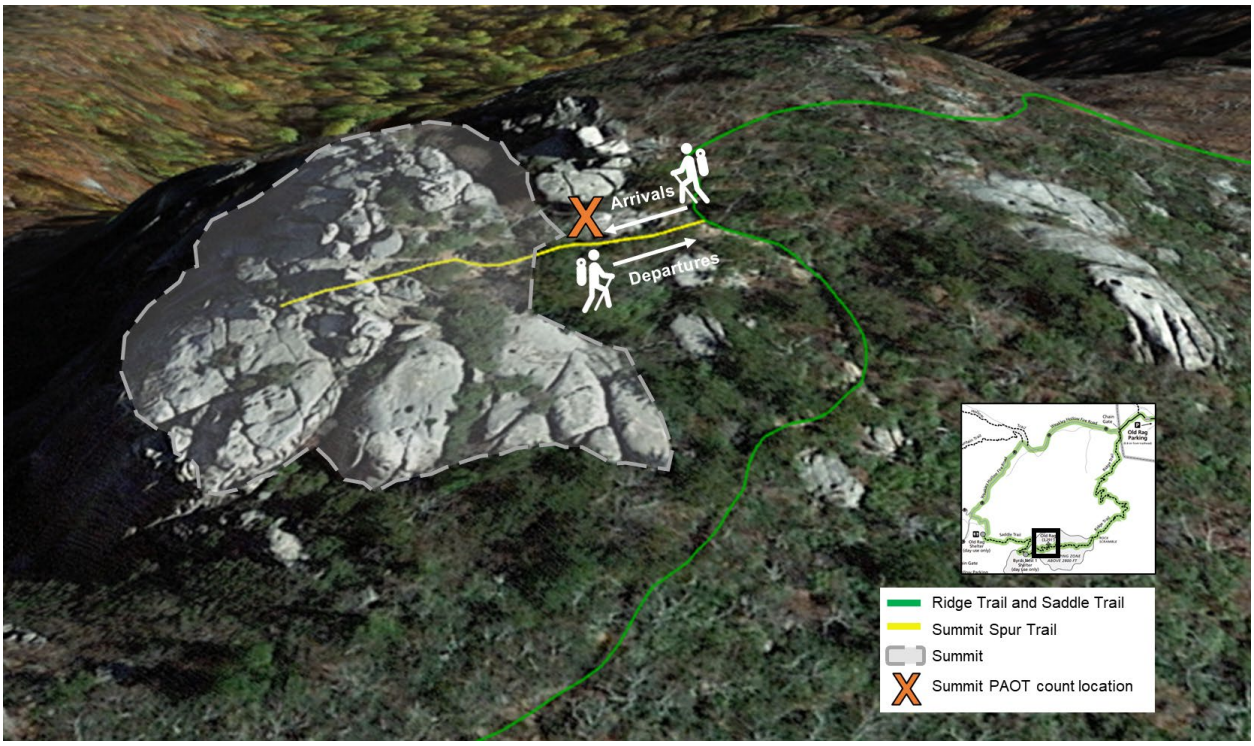

FIGURE 7. SUMMIT PAOT COUNT PROCEDURE

The summit PAOT count data were post-processed to derive PAOT counts for each 10-minute interval in the counting period. The first 10-minute interval summit PAOT count was calculated by adding the net number of summit arrivals (arrivals minus departures) in the first 10-minute interval bin to the starting count. Each successive 10-minute interval summit PAOT count was calculated by adding the net number of arrivals in the 10-minute interval to the PAOT count for the previous 10-minute interval.

Summit PAOT counts were conducted on four days during the sampling period and recorded for a total of 154 10-minute intervals (Table 3). A copy of the PAOT summit count log form is included in Appendix E.

TABLE 3. OLD RAG PEOPLE-AT-ONE-TIME (PAOT) COUNTS

DATE	CHUTE # OF OBSERVATIONS	SUMMIT # OF OBSERVATIONS	SUMMIT VIEWSCAPE # OF OBSERVATIONS
10/11/19	39	–	40
10/12/19	39	41	41
10/13/19	39	36	41
10/14/19	39	–	41
10/17/19	39	–	41
10/18/19	40	38	39
10/19/19	40	39	39
10/21/19	39	–	40
10/23/19	39	–	41
Total	353	154	363

Old Rag Summit Viewscape

PAOT counts for the Old Rag summit viewscape were conducted using direct observation. The summit viewscape PAOT counts were recorded as instantaneous counts once every 10-minutes for approximately 6 to 7 hours per day. Start times varied by sampling day between 9:00 a.m. and 10:00 a.m., depending on the field technician's hike time to the summit. The summit viewscape PAOT counts were conducted on nine days during the sampling period and a total of 363 observations were recorded (Table 3). A copy of the PAOT summit viewscape count log form is included in Appendix E.

Visitor Experience Survey

Survey Instrument

A visitor experience survey was administered to sampled visitors at Nethers upon completion of their hikes on the Old Rag Mountain Trail. The purpose of the visitor experience survey was to assess visitors' perceptions of preparedness, risk, safety, crowding, and acceptability of management actions, all with respect to visitor use on the Old Rag Mountain Trail.

The visitor experience survey was designed by researchers at RSG in coordination with NPS staff. The survey instrument and sampling protocol was reviewed and approved by the Office of Management and Budget. Appendix F contains a copy of the visitor experience survey. Appendix G contains a copy of the visitor experience survey contact log.

Questions were included in the survey instrument to measure visitor-based crowding thresholds. These questions were accompanied by digitally edited photographs, or photo simulations, noted in Section 2.1 and included in Appendix A. A randomly ordered set of six photo simulations with varying numbers of PAOT in the summit viewscape was presented to each respondent, one at a

time.[5] For each photo simulation, respondents were asked to indicate whether or not they would feel crowded on the summit of Old Rag with the number of people depicted in the photograph.

Sampling Procedures

The visitor experience survey was administered on 11 days during the study's sampling period. Sampling for the visitor experience survey occurred in the area adjacent to the intersection of the Ridge Trail Trailhead and the Weakley Hollow Fire Road (Figure 5). Sampling was conducted at this location because the vast majority of visitors who hike the Old Rag Mountain Trail start and end their hikes at Nethers; visitor experience survey sampling was not conducted at Berry Hollow due to the expectation of very low sampling efficiency.

At the start of each visitor experience survey sampling day, the field technician assigned to administer the survey contacted the first departing visitor group. Visitor groups participating in the GPS route tracking component of the study were excluded from the visitor experience survey sampling to minimize the study burden on any single visitor group. After each contact, the field technician contacted the next departing visitor group and asked them to participate (i.e., used a "first-after-last" sampling procedure).

Each contacted visitor group was greeted, briefly introduced to the purpose of the study, and asked to participate and screened for eligibility. Visitors groups were considered eligible for the study if they were at least 18 years old, had not previously participated in the study, and were able to communicate with the English-speaking survey administrator (i.e., did not have a language barrier). Information from all contacts was recorded on a contact log. If visitors were eligible for the study and agreed to participate, they were asked which member (at least 18 years old) had the next birthday. The individual with the next birthday was selected to complete the questionnaire for the group. An interview, lasting approximately two minutes, was conducted with all eligible visitor groups, whether they agreed to participate in the survey or not, to determine group size, whether they had visited Old Rag before, whether they felt prepared for their visit, whether they felt crowded on their hike that day, and whether they had to wait in a line during their hike. The gender of the first-contacted group member and the time of contact was also recorded for each contacted group. For groups that agreed to participate, the field technician then distributed the survey instrument to the member of the group with the next birthday and provided verbal instructions about how to complete the questionnaire. For all "hard refusals" (groups who refused to participate in the study and in the brief interview), only the observational data (group size, gender of first-contacted group member, and time of contact) and refusal reason were recorded on the contact log.

[5] Each respondent received one of nine possible pre-assembled photo sets. Each of these nine pre-assembled photo sets contained six simulated photographs in random order and according to an experimental design, drawn semi-randomly from a total of 26 photo simulations ranging from 0-100 PAOT.

Of the 506 eligible visitor groups asked to participate in the visitor experience survey, 405 completed the survey (Table 4), resulting in an overall response rate for the survey of 80.0%.[6]

TABLE 4. OLD RAG VISITOR EXPERIENCE SURVEY SAMPLING EFFORT

DATE	SOLICITATIONS	ACCEPTANCES	REFUSALS	INELIGIBLES
10/11/19	48	39	8	1
10/12/19	108	77	29	2
10/13/19	52	45	6	1
10/14/19	63	51	10	2
10/15/19	41	34	7	–
10/18/19	52	35	16	1
10/19/19	73	57	16	–
10/20/19	13	9	3	1
10/21/19	15	10	1	4
10/22/19	2	2	–	–
10/24/19	53	46	5	2
Total	520	405	101	14

Note: Visitors were considered eligible if they were at least 18 years old, had not previously participated in the study, and were able to communicate with the English-speaking survey administrator (i.e., did not have a language barrier).

[6] No non-response bias analysis was conducted on these data. Office of Management and Budget Standards and Guidelines for Statistical Surveys (2006) specify that non-response bias analysis is required when unit response rate is below 80%.

3.0 RESULTS: DESCRIPTIVE STUDY COMPONENTS

This section of the report presents summary statistics for the descriptive data collected in the Old Rag study area during the 2019 fall foliage season. Results are presented in the following sub-sections, by data type. It should be noted, the percentages in the tables and figures of results in this section of the report may not sum to 100% due to rounding or in cases where GPS exit survey respondents were instructed to select all response options that apply.

3.1 VISITOR USE COUNTS

Calibration

Regression analyses were conducted to model the relationship between raw mechanical trail counter data and the calibration counts collected via direct observation. This was done to derive an empirical basis to convert raw trail counter data to estimates of actual visitor use. Separate regression models were estimated for each counter, with direct observation counts of visitor use as the dependent variable and corresponding TRAFx infrared trail counter data as the independent variable in each model, to estimate correction factors for the infrared trail counter data. Regression results suggest that there are strong statistical relationships between the direct observation counts and visitor use counts recorded by the infrared trail counters.

- Adjusted R^2 values range from 0.90 to 0.99
- Coefficients ranged from 0.79 to 1.19
- The p-values for all three regression models were less than 0.0001
- Regression models without intercepts were the best fitting regression models for all three trail counters, and were the models used to calibrate trail counter data

These results provide a high degree of confidence that applying the correction factors to calibrate the visitor use counts recorded with the infrared trail counters (i.e., multiplying the infrared trail counter data by the corresponding parameter estimates from the regression models) results in very accurate estimates of visitor use in the Old Rag study area. The calibrated trail counter data were used for analysis and results reported in this report.

Arrival and Departure Volumes

This sub-section of the report summarizes total visitor use volumes and arrival volumes by trail counter location. Arrival volumes were calculated as the proportion of arriving visitors out of all visitors per hour for each counter, based on direct observation counts (i.e., calibration counts). This proportion was then applied to hourly calibrated visitor use counts to estimate hourly

arrivals at each trail counter location. The following summaries of visitor use volumes are presented in the sub-sections below:

- Daily visitor use volumes, by trail counter location and date during the counting period
- Hourly visitor use volumes, by trail counter location and date during the counting period
- Mean hourly arrivals and departures, by trail counter location and day of week category during the sampling period

Daily Visitor Use Volumes

Figure 8 presents total daily arrivals (i.e., daily visitor use), by trail counter location and date during the counting period. These data suggest:

- Visitor use on the Old Rag Mountain Trail is generally highest on weekend days and holidays (indicated by gray shading) but is weather dependent. Two of the lowest-use days during the counting period were on inclement weekend days (October 20 and October 27, 2019).
- The busiest day during the counting period occurred on October 19, 2019 with more than 1,800 total arrivals.
- The vast majority of visitor use on the Old Rag Mountain Trail originates on the Ridge Trail.

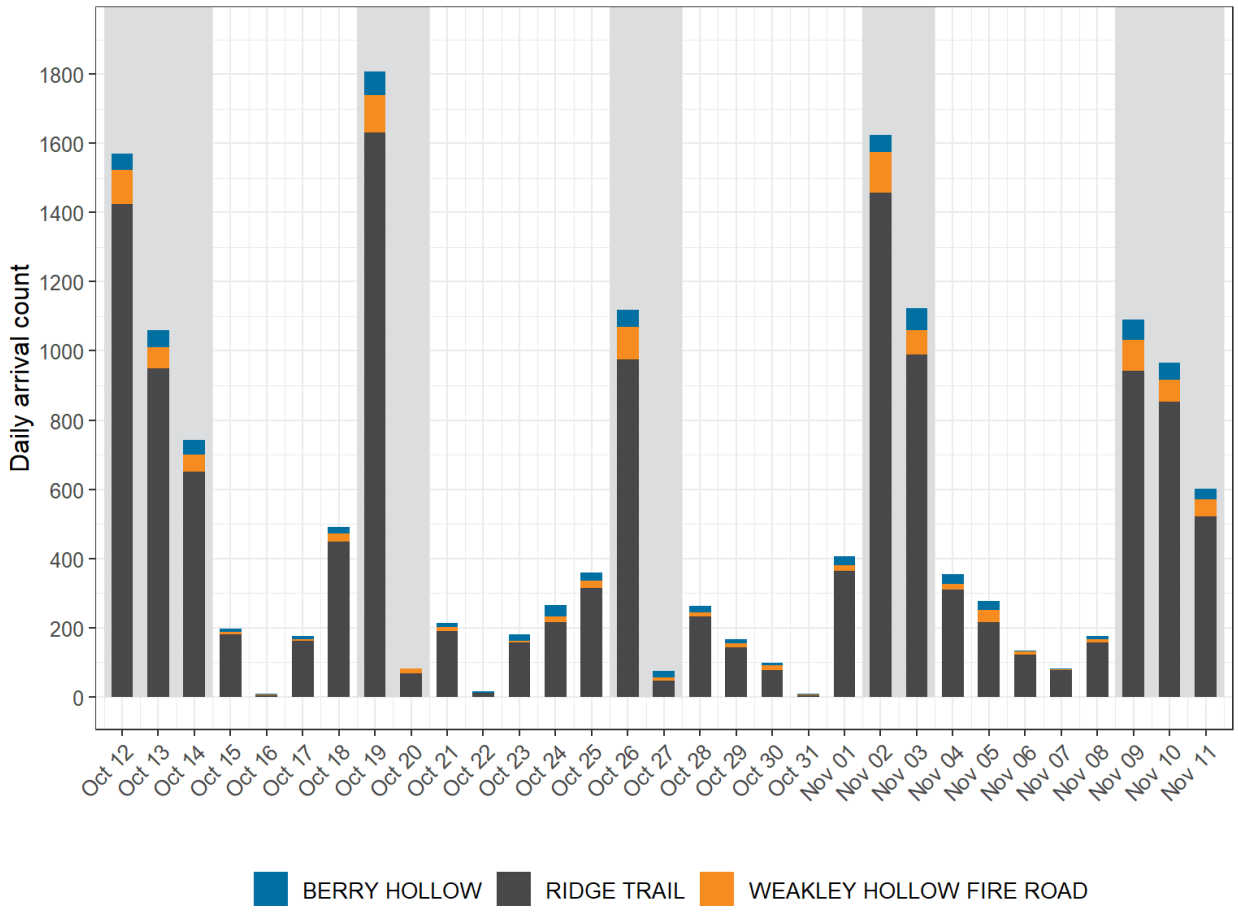

FIGURE 8. DAILY ARRIVALS (I.E., VISITOR USE), BY TRAIL COUNTER LOCATION AND DATE (GRAY SHADING INDICATES WEEKENDS/HOLIDAYS)

Hourly Visitor Use Volumes

Figure 9 displays hourly arrivals (i.e., hourly visitor use), by trail counter location and date during the counting period. The plots with continuous lines across dates in Figure 9 provide a "macro view" of hourly patterns of visitor use across the days of the counting period. The data suggest:

- Hourly visitor use during the counting period was highest, by far, on the Ridge Trail (note the varying scales on the y-axes of Figure 9). In comparison, hourly inbound visitor use was substantially lower on the Weakley Hollow Fire Road and at Berry Hollow.
- Peak hourly arrivals on the Ridge Trail ranged from approximately 50-100 visitors on weekdays and from approximately 150-350 visitors on most weekend days and holidays.
- There was only one day during the counting period when peak hourly arrivals exceeded 20 visitors at Berry Hollow and 40 visitors on the Weakley Hollow Fire Road.

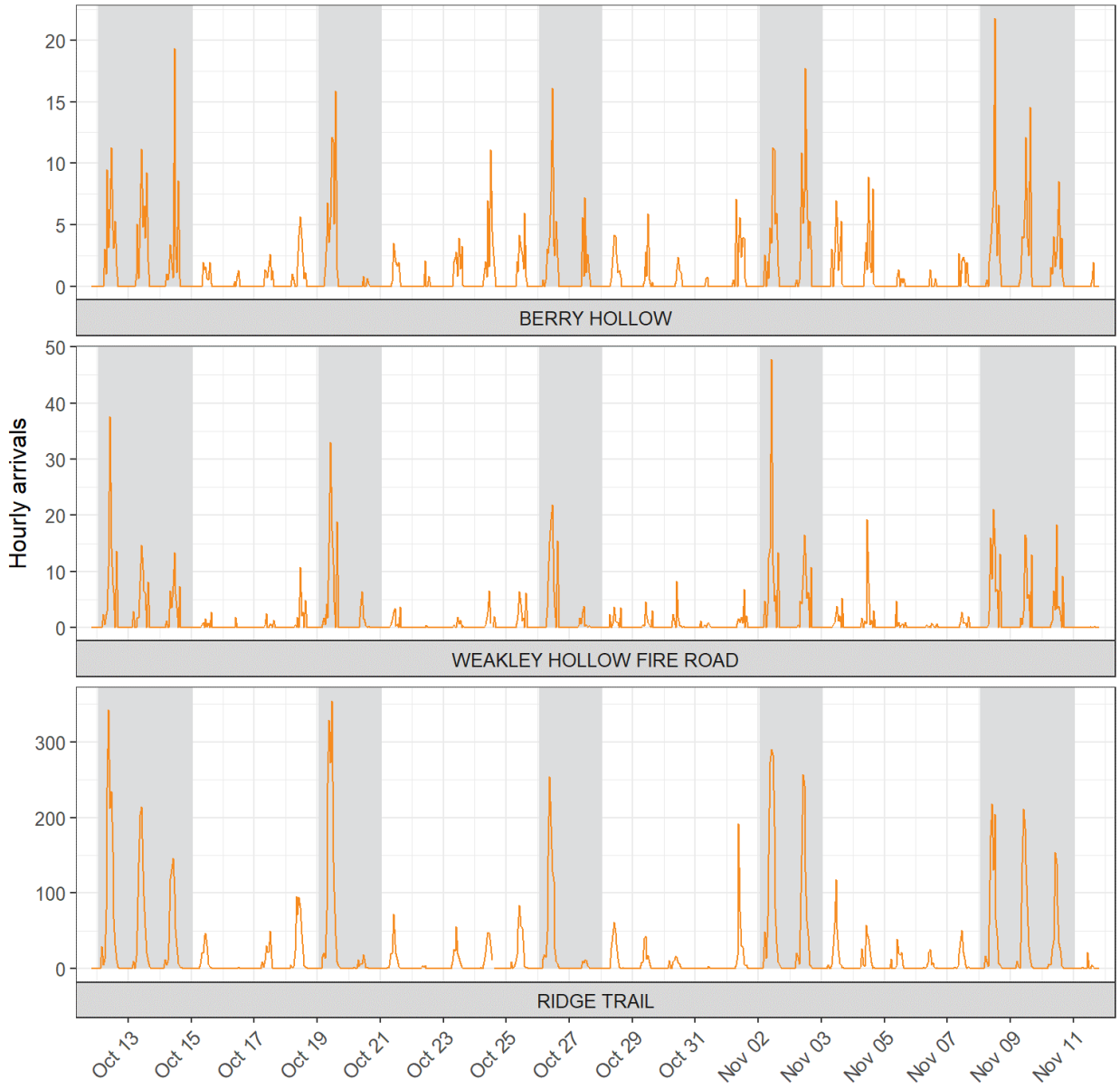

FIGURE 9. HOURLY ARRIVALS (I.E., VISITOR USE), BY TRAIL COUNTER LOCATION AND DATE (GRAY SHADING INDICATES WEEKENDS/HOLIDAYS)[7]

[7] It should be noted, the Y-axis scale varies by location to account for differences in the overall scale of visitor use at each location; if uniform Y-axis scales were used, details regarding visitor use volumes and patterns would be difficult to discern from the plots for the lower use locations.

Figure 10 displays hourly arrivals (i.e., hourly visitor use), by trail counter location and date during the sampling period in a complementary format to the plots in Figure 9 (separate lines, rather than a single continuous line, for each date displayed in the plot). The plots in Figure 10 provide a “micro view” of hourly patterns of visitor use across the hours of each day of the sampling period. The data suggest:

- As noted above, hourly visitor use is highest, by far, on the Ridge Trail (note the varying scales on the y-axes of Figure 10). There, visitor use generally started to occur around 6:00 a.m. and increased sharply on the two busiest days to a morning peak during the 9:00 a.m. hour. In the case of one of the two busiest days, October 19, there was a second peak of arrivals during the 11:00 a.m. hour. On the other days plotted, visitor use increased steadily, rather than sharply, during the morning hours and reached a peak sometime between 10:00 a.m. and 12:00 p.m. A maximum of approximately 350 arrivals occurred during the 11:00 a.m. hour on October 19.
- Hourly arrivals (i.e., visitor use) on the Weakley Hollow Fire Road were nominal, in comparison to those on the Ridge Trail. The temporal pattern of visitor use was similar to that on the Ridge Trail during the morning hours, with use generally starting to occur around 6:00 a.m. and peaking between 10:00 a.m. and 12:00 p.m. There was consistently a secondary peak of arrivals on the Weakley Hollow Fire Road in the afternoon. It is not possible to determine from the trail counter data if visitors arriving during the secondary peak in the afternoon hiked to the Old Rag summit. It is more likely these visitors were starting shorter out-and-back hikes on the fire road itself. In either case, the total number of hourly arrivals during the afternoon peak is nominal.
- Hourly visitor use at Berry Hollow is low and fluctuates throughout the day, starting around 6:00 a.m. and dropping off after 4:00 p.m.

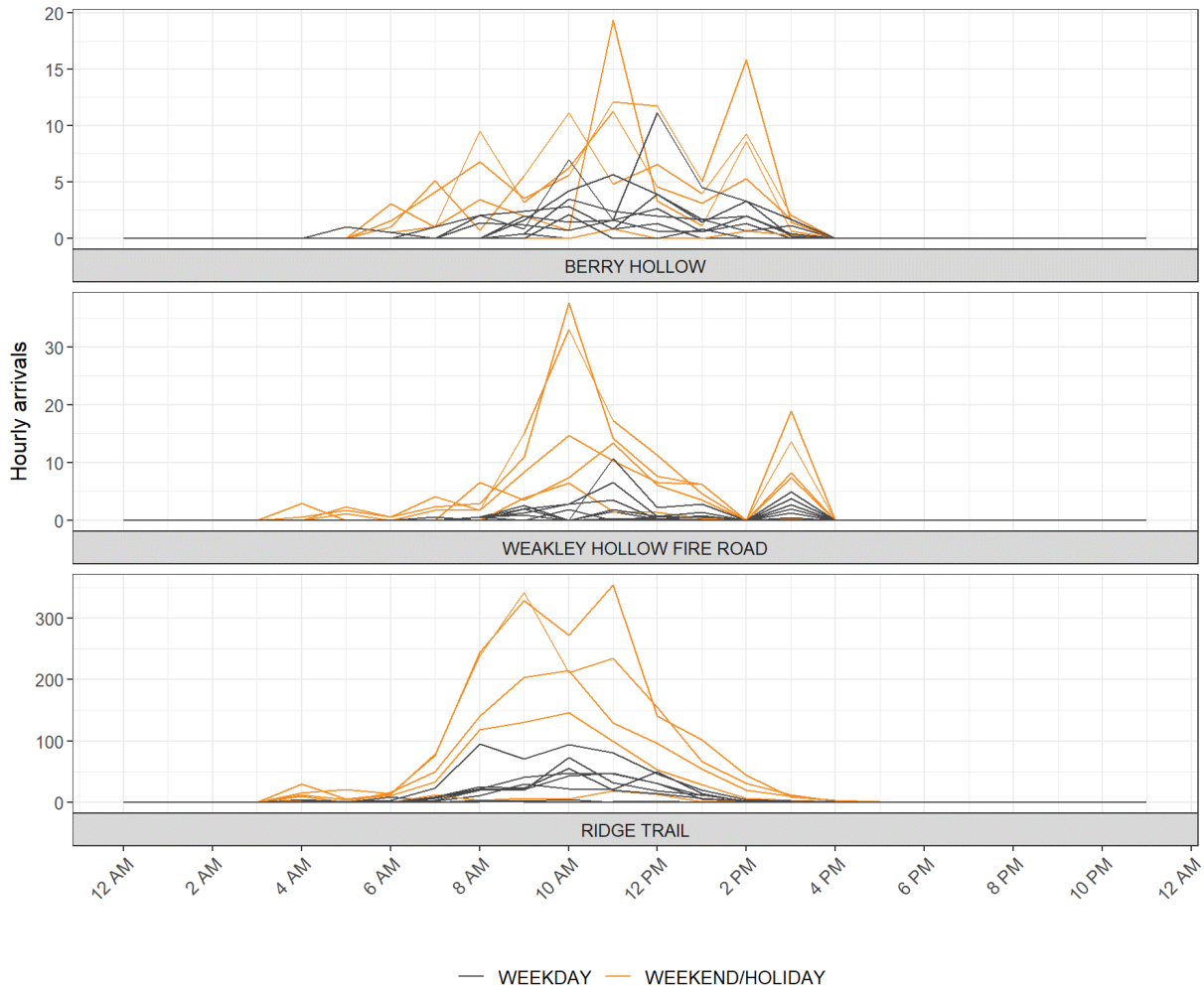

FIGURE 10. HOURLY ARRIVALS (I.E., VISITOR USE), BY TRAIL COUNTER LOCATION AND DATE[8]

[8] It should be noted, the Y-axis scale varies by location to account for differences in the overall scale of visitor use at each location; if uniform Y-axis scales were used, details regarding visitor use volumes and patterns would be difficult to discern from the plots for the lower use locations.

Mean Hourly Arrivals and Departures

Figure 11 presents mean hourly visitor arrivals and departures, by trail counter location and day of week category during the sampling period at all three study counters. These data suggest:

- Mean hourly arrival and departure patterns vary substantially across the three trail counter locations. The arrival and departure patterns on the Ridge Trail and Weakley Hollow Fire Road indicate a predominantly clockwise pattern of use on the Old Rag Mountain Trail, with most visitors arriving in the morning, hiking the Ridge Trail to the summit, and departing in the afternoon by way of the Weakley Hollow Fire Road.
- On average, hourly arrivals on the Ridge Trail increased sharply starting around 6:00 a.m. and peaked during the 9:00 a.m. hour on weekends and holidays. Mean hourly arrivals increased steadily, rather than sharply, on weekdays and peaked during the 10:00 a.m. hour.
- On weekends and holidays, mean hourly departures by way of the Weakley Hollow Fire Road peaked between 2:00 p.m. and 5:00 p.m., or about five to seven hours after mean hourly arrivals peaked on the Ridge Trail. On weekdays, mean hourly departures on the Weakly Hollow Fire Road peaked during the 2:00 p.m. hour, or about four to five hours after mean hourly arrivals peaked on the Ridge Trail. These findings suggest that hike times may be impeded, to some extent, during weekends and holidays when visitor use levels are high. Relationships between trail use levels and hiking times are explored more directly in subsequent sections of this report. In either case, departures by way of the Weakley Hollow Fire Road are somewhat less peaked (i.e., slightly more temporarily dispersed) than arrivals on the Ridge Trail. This is likely due to varying hiking speeds, hiking abilities, and summit dwell times among visitor groups that attenuate the more peaked arrival pattern.

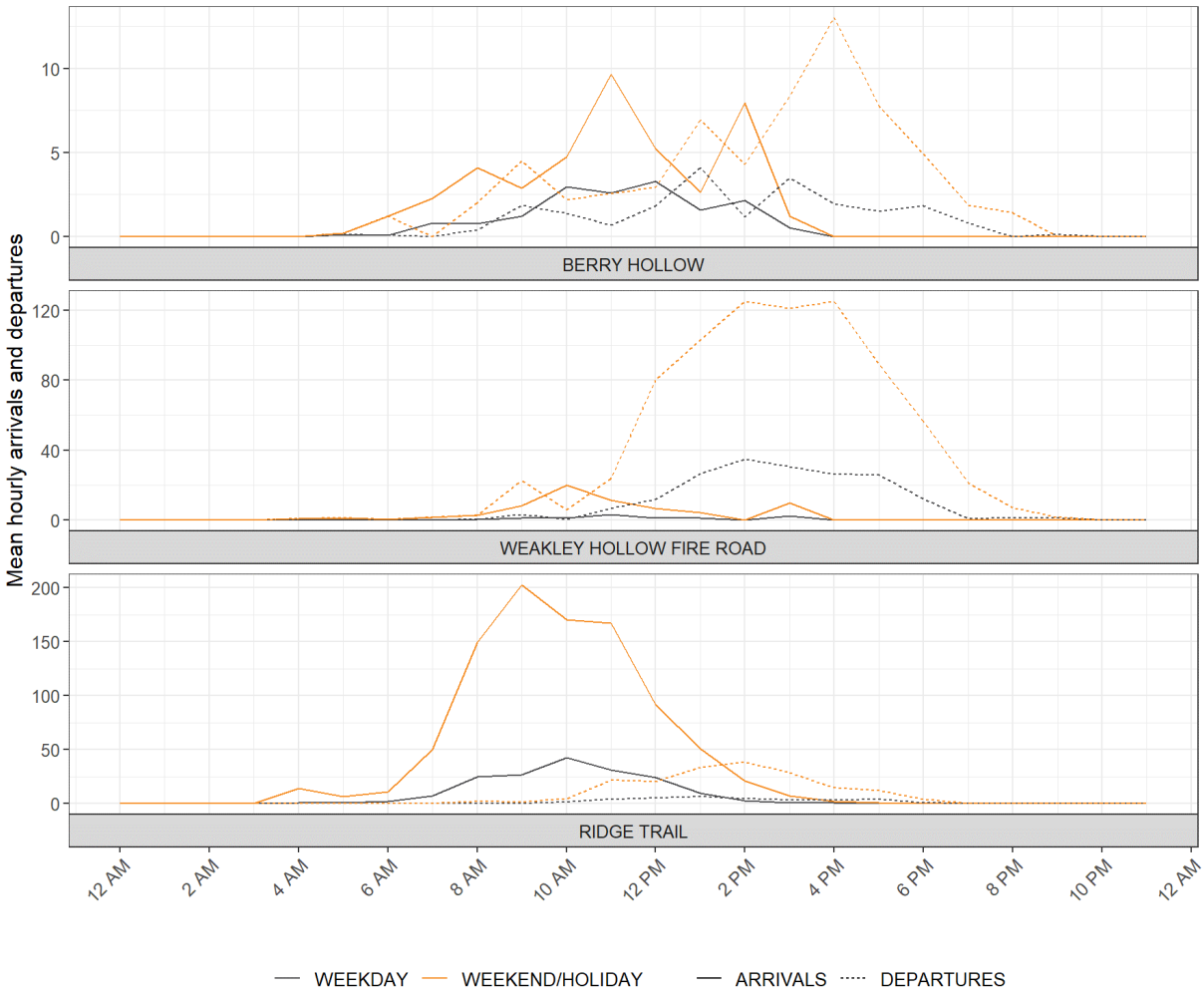

FIGURE 11. MEAN HOURLY ARRIVALS AND DEPARTURES, BY TRAIL COUNTER LOCATION AND DAY OF WEEK CATEGORY

3.2 GPS ROUTE TRACKING

This sub-section of the report presents descriptive summaries of visitor group hiking routes and times based on analyses of the GPS tracking data. Additional analyses with the GPS data are reported in the sections of the report regarding potential crowding-related thresholds and capacities (Section 5.0), and simulation modeling (Section 6.0).

Hiking Routes

As noted, visitor groups' hiking routes derived from the GPS tracking data were classified based on the direction of travel (clockwise or counterclockwise) and as a full loop or out-and-back (i.e., "partial") hike. Figure 12 presents the distribution of hiking routes of visitor groups who participated in the GPS tracking study. These data suggest:

- Overall, the vast majority (96%) of visitor groups traveled in a clockwise direction on the Old Rag Mountain Trail, and more than three-quarters (80%) of all visitor groups spent time on the summit.
- About three quarters (76%) of visitor groups that hiked the Old Rag Mountain Trail traveled the full clockwise loop, starting on the Ridge Trail, ascending through the Squeeze and Chute, reaching the summit, and ending on the Weakley Hollow Fire Road. A small proportion of visitor groups (7%) hiked the Old Rag Mountain Trail in a full clockwise loop but bypassed the summit.
- A small proportion (11%) of visitor groups hiked out-and-back on the Ridge Trail, turning back before reaching the summit. An even smaller proportion (2%) of visitor groups hiked out-and-back on the Ridge Trail to the summit.
- Very few (1%) visitor groups hiked the full counterclockwise loop starting on the Weakley Hollow Fire Road, reaching the summit, descending through the Chute and Squeeze, and ending on the Ridge Trail. No visitor groups traveled the full counterclockwise loop and bypassed the summit.
- A very small proportion (3%) of visitor groups hiked out-and-back on the Weakley Hollow Fire Road, turning back before reaching the Old Rag Summit. Even fewer (1%) visitor groups hiked out-and-back on the Weakley Hollow Fire Road to the summit.

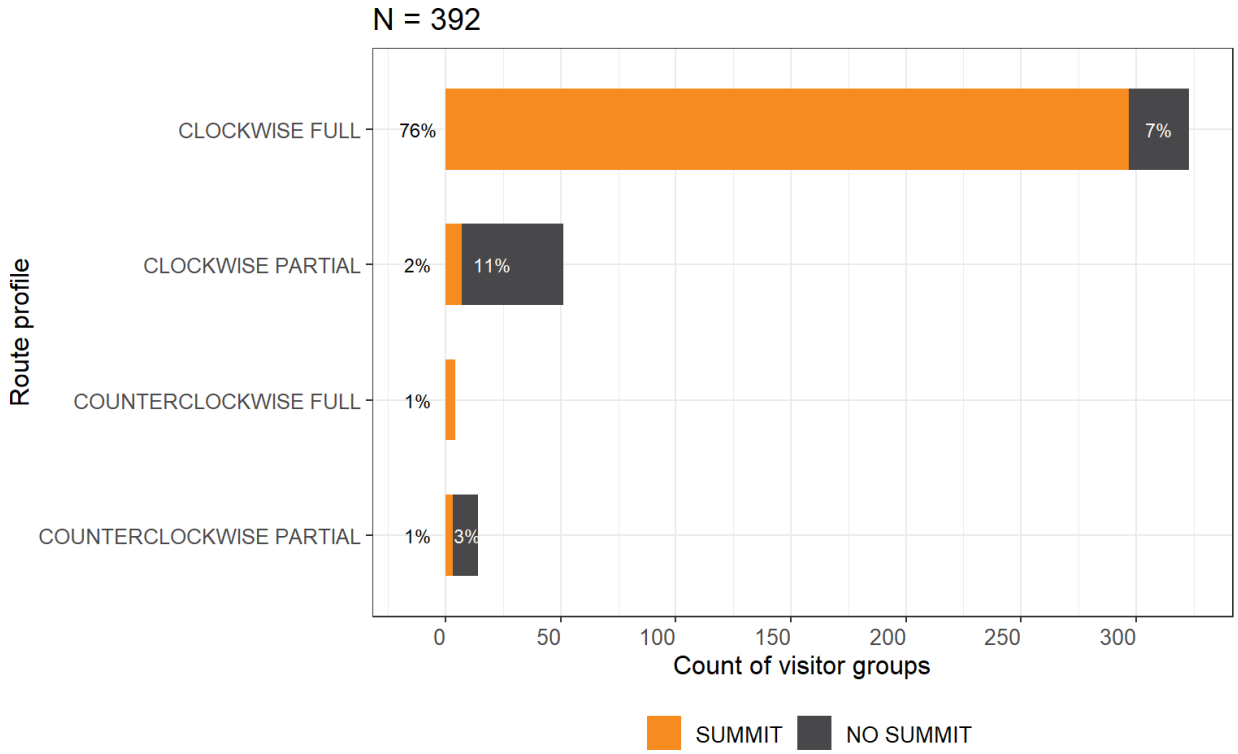

FIGURE 12. OLD RAG MOUNTAIN TRAIL HIKING ROUTE DISTRIBUTION

The hiking routes of visitor groups who participated in the GPS tracking study are summarized in greater detail in Figure 13, Table 5, and Table 6. The results in Figure 13 illustrate a typology of nine distinct route patterns that were observed within the GPS tracking data. Table 5 summarizes the distribution of hiking routes among those visitor groups who started their hikes on the Ridge Trail (i.e., in the clockwise direction). Table 6 summarizes the distribution of hiking routes among those visitor groups who started their hikes on the Weakley Hollow Fire Road (i.e., in the counterclockwise direction).

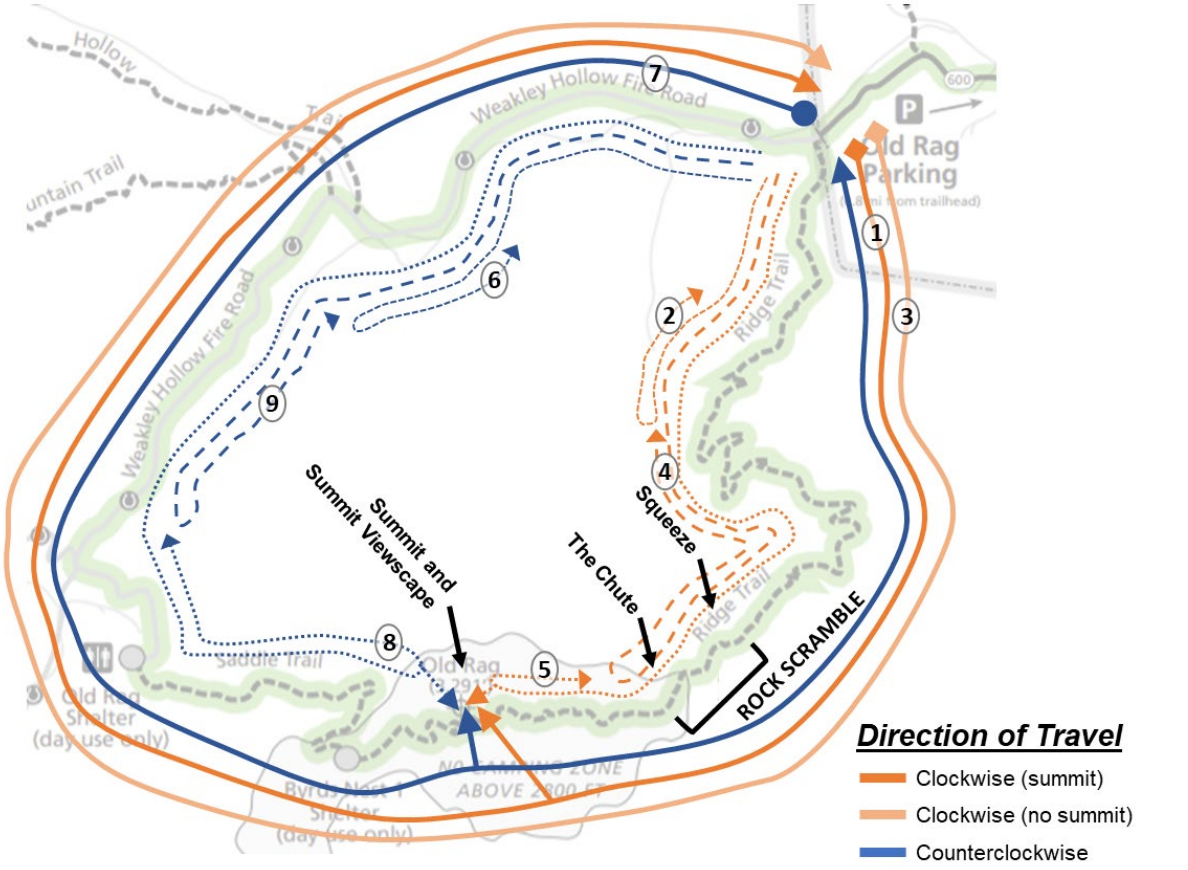

FIGURE 13. OLD RAG MOUNTAIN TRAIL HIKING ROUTE TYPOLOGY (NUMBERS CORRESPOND TO DESCRIPTIONS IN TABLE 5 AND TABLE 6)

TABLE 5. OLD RAG MOUNTAIN TRAIL HIKING ROUTE DISTRIBUTION FOR HIKES STARTING ON THE RIDGE TRAIL IN THE CLOCKWISE DIRECTION

HIKING ROUTE DESCRIPTION	COUNT	PERCENT
1. Ridge trail through the Chute, to the summit, returning along the Weakley Hollow Fire Road	297	79%
2. Ridge Trail only, returning before reaching the rock scramble area	36	10%
3. Ridge trail through the Chute but bypassing the summit, returning along the Weakley Hollow Fire Road	26	7%
4. Ridge Trail through the Chute, returning along the Ridge Trail	8	2%
5. Ridge Trail through the Chute, to the summit, returning along the Ridge Trail	7	2%
Total	374	100%

TABLE 6. OLD RAG MOUNTAIN TRAIL HIKING ROUTE DISTRIBUTION FOR HIKES STARTING ON THE WEAKLEY HOLLOW FIRE ROAD IN THE COUNTERCLOCKWISE DIRECTION[9]

HIKING ROUTE DESCRIPTION	COUNT	PERCENT
6. Weakley Hollow Fire Road only	8	44%
7. Weakley Hollow Fire Road past Post Office Junction to the summit, exiting through the Chute along the Ridge Trail	4	22%
8. Weakley Hollow Fire Road past Post Office Junction to the summit, returning along the Weakley Hollow Fire Road	3	17%
9. Weakley Hollow Fire Road to Post Office Junction before returning along the Weakley Hollow Fire Road	3	17%
Total	18	100%

[9] Results should be interpreted with caution due to low sample size of counterclockwise hiking routes.

Total Hiking Times

Figure 14 presents mean total hiking time, by hiking route profile, of visitor groups who participated in the GPS tracking study. Total hiking times include any stops or delays along the route (e.g., to rest, eat, drink water, enjoy the scenic view, and/or waiting in queue in the rock scramble section of the trail). These data suggest:

- The mean total time to hike the full clockwise loop was approximately five hours, while the average time to hike the full counterclockwise loop was one hour longer at approximately six hours.
- Those visitor groups who hiked out-and-back routes hiked for an average of just under four hours (3.7 hours and 3.9 hours on the Ridge Trail and Weakley Hollow Fire Road, respectively).
- Overall, the average total hiking time on the Old Rag Mountain Trail, regardless of direction of travel or full or partial completion of the loop trail, was just under five hours.

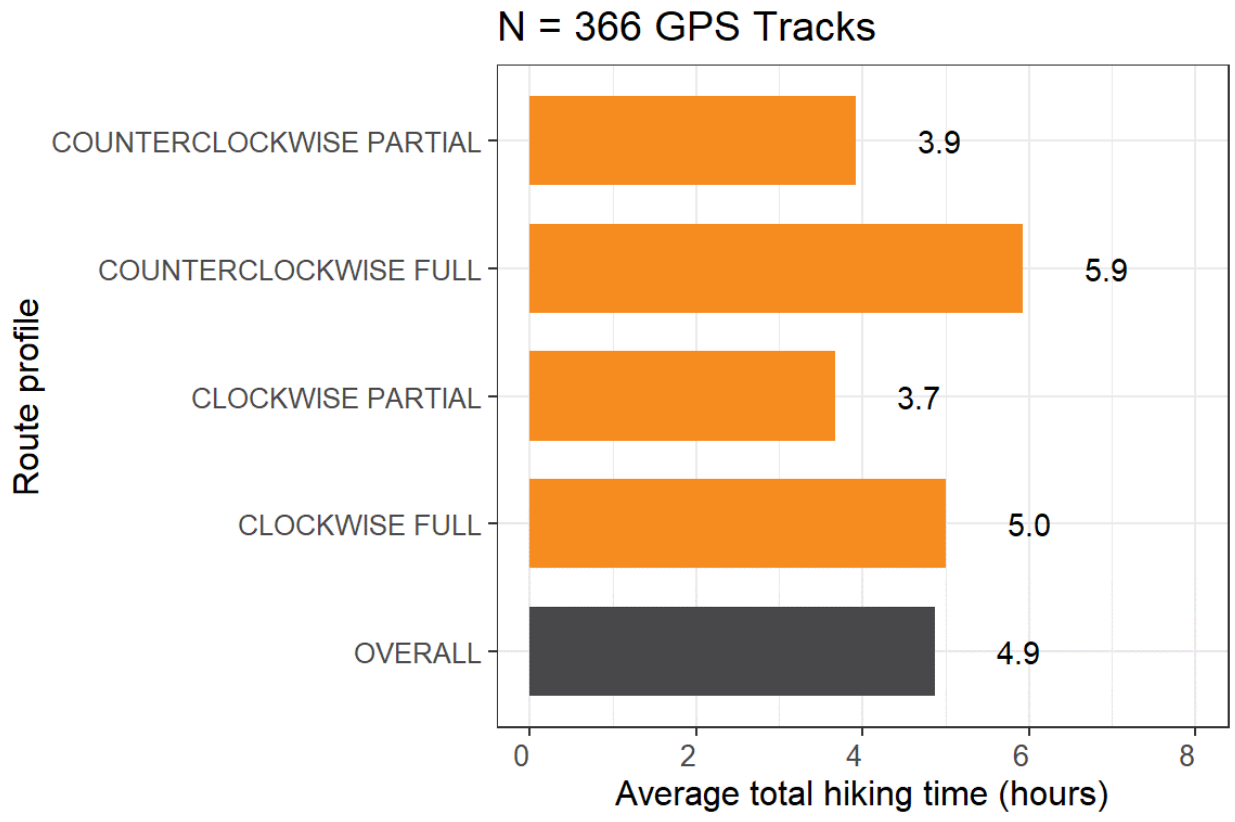

FIGURE 14. MEAN TOTAL HIKING TIME ON THE OLD RAG MOUNTAIN TRAIL, BY ROUTE PROFILE AND OVERALL

Table 7 presents the distribution of hiking times of visitor groups who participated in the GPS tracking study. These data suggest:

- The vast majority (82%) of visitor groups who hiked the Old Rag Mountain Trail spent four or more hours on the trail.
- Of the visitor groups who completed the full loop, 86% who traveled in the clockwise direction spent four or more hours on the trail, while 100% who traveled in the counterclockwise direction spent five or more hours on the trail.
- The vast majority (90%) of visitor groups who traveled in the counterclockwise direction and partially completed the Old Rag circuit loop spent less than six hours along the trail.
- The majority (76%) of visitor groups who traveled in the clockwise direction and partially completed the Old Rag circuit loop spent less than five hours along the trail.

TABLE 7. OLD RAG MOUNTAIN TRAIL TOTAL HIKING TIME DISTRIBUTION

TOTAL TIME	COUNTER-CLOCKWISE FULL (N = 4)	COUNTER-CLOCKWISE PARTIAL (N = 10)	CLOCKWISE FULL (N = 323)	CLOCKWISE PARTIAL (N = 29)	OVERALL (N = 366)
<1 hour	0%	10%	0%	7%	1%
1 to < 2 hours	0%	10%	0%	10%	1%
2 to < 3 hours	0%	20%	2%	17%	4%
3 to < 4 hours	0%	0%	13%	14%	12%
4 to < 5 hours	0%	40%	42%	28%	40%
5 to < 6 hours	50%	10%	27%	17%	26%
6 to < 7 hours	50%	0%	13%	7%	13%
7 to < 8 hours	0%	10%	3%	0%	3%
8+ hours	100%	100%	101%	100%	100%

Rock Scramble Hiking Times

Average, minimum, and maximum hiking times on the rock scramble section of the Ridge Trail (Figure 1 and Figure 2) are summarized in Table 8. These hiking times include passing through the Squeeze and the Chute and are presented separately for uphill travel (which is, by far, the predominant direction of travel on this section of the trail) and downhill travel (which is relatively rare). The reported hiking times include any time spent waiting in a queue during busy periods. It was not possible to discern from the GPS tracks visitor groups that circumvented the rock scramble by way of social trails/informal routes. As such, the hiking times reported include the times of any groups that may have skirted around the rock scramble at any point to avoid waiting in a queue at the Squeeze and/or Chute. Correspondingly, hiking times through the rock scramble section of the Ridge Trail varied substantially. The variation in hiking times through the rock scramble are a function, in part, of the number of people-at-one-time (PAOT) in the “pinch-points” (i.e., the Chute and the Squeeze) on this section of trail. The thresholds and capacities section (Section 5.0) of this report presents results of analyses to estimate statistical

relationships between PAOT in the Chute and hiking times through the rock scramble section of the trail. The descriptive data in Table 8 suggest:

- Uphill hiking times through the rock scramble ranged from a minimum of about 15 minutes to a maximum of over two hours (126 minutes). The average uphill hiking time was 50 minutes.
- Downhill hiking times through the rock scramble ranged from a minimum of about 20 minutes to a maximum of just under an hour (52 minutes). The average downhill hiking time was 32 minutes. These results should be interpreted with caution due to the low sample size of downhill hiking times.

TABLE 8. AVERAGE, MINIMUM, AND MAXIMUM HIKING TIME ON THE ROCK SCRAMBLE SECTION OF THE RIDGE TRAIL (MINUTES)

DIRECTION	COUNT	MIN	MEAN	MAX
Uphill	232	14.9	50.0	125.8
Downhill	12	19.1	32.5	51.6

Old Rag Summit Dwell Times

Figure 15 presents the mean and distribution of dwell times on the Old Rag summit for visitor groups who participated in the GPS tracking study and hiked to the summit.
These data suggest:

- Visitor groups who hiked to the Old Rag summit spent an average of 17.4 minutes on the summit.
- More than two-thirds (67%) of visitor groups who hiked to the Old Rag summit spent less than 20 minutes on the summit. Relatively few (approximately 17%) visitor groups who hiked to the summit spent 30 minutes or more there.

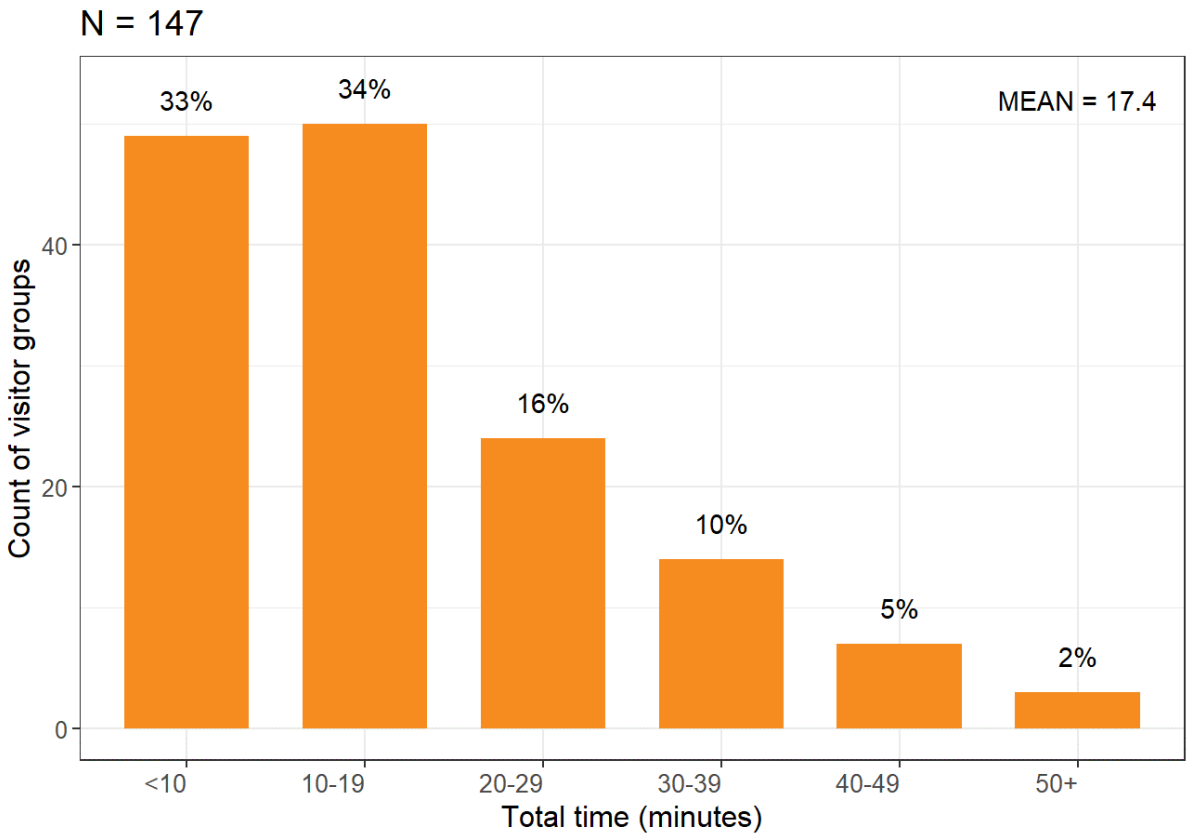

FIGURE 15. OLD RAG SUMMIT DWELL TIME DISTRIBUTION

3.3 GPS EXIT SURVEY

Visitors who carried a GPS unit on their hike were asked to respond to a short series of questions regarding visitor use, crowding, and safety on the Old Rag Mountain Trail. The questions focused on understanding:

- Why some visitors choose to turn around before reaching the Old Rag summit
- What actions visitors may have taken in response to crowding on the Old Rag Mountain Trail

This sub-section of the report summarizes responses to these questions. The results are presented in questionnaire order and include the question number, the question text in italics, select bulleted information, and data tables.

Summited Old Rag

Question 1

*Did you hike to the top of Old Rag today? Check **one**.*

Results (Table 9)

- The vast majority (88%) of respondents reported that they hiked to the top of Old Rag.

TABLE 9. DID YOU HIKE TO THE TOP OF OLD RAG TODAY? (N=249)

	COUNT	PERCENT
Yes	219	88%
No	30	12%
Total	249	100%

Reasons for Not Summiting Old Rag

Question 2

Note: This question was only asked of survey respondents who indicated on Question 1 that they did not hike to the top of Old Rag.

*Which of the following explains why you did not hike to the top of Old Rag today? Check **all that apply**.*

Results (Table 10)

- Just under half (43%) of the survey respondents indicated that they did not hike to the top of Old Rag because the trail was too crowded
- Over one-third (36%) of survey respondents indicated they did not hike to the top of Old Rag because the hike was taking too long because of crowding on the trail
- One quarter (25%) of survey respondents indicated they did not hike to the top of Old Rag because other member(s) of their group wanted to turn around
- Roughly one fifth (21%) cited other reasons for not hiking to the top of Old Rag (see Visitor Comments Appendix H for results)

TABLE 10. REASON FOR NOT HIKING TO THE TOP OF OLD RAG (N = 28)[10]

REASON	COUNT	PERCENT
The trail was too crowded	12	43%
It was taking too long due to crowding on the trail	10	36%
Other member(s) of my group wanted to turn around	7	25%
I was too tired	4	14%
Bad weather (e.g., thunder/lightening, high winds, rain, snow)	4	14%
The number of people on the trail made me feel unsafe	2	7%
I was too hot or too cold	2	7%
I did not have enough time	2	7%
I was uncomfortable with the sharp drop-offs	1	4%
I did not have enough water	1	4%
There were no restroom facilities on the trail	1	4%
I did not have proper footwear for the terrain	1	4%
Snowy, icy, or wet/slick conditions	1	4%
Others on the trail were behaving dangerously	0	0%
Other	6	21%

[10] Results should be interpreted with caution due to low sample size of respondents who did not hike to the top of Old Rag.

Responses to Crowding

Question 3

*Did you take any of the following actions in response to crowding on your Old Rag hike today? Check **all that apply**.*

Results (Table 11 and Table 12)

- Overall, a majority (53%) of survey respondents reported taking no actions in response to crowding during their hike on Old Rag
- A majority (56%) of respondents who hiked Old Rag on a weekend day or holiday reported taking one or more actions in response to crowding during their hike on Old Rag, while the majority (63%) of respondents who hiked Old Rag on a weekday reported taking no actions in response to crowding during their hike on Old Rag
- Nearly one-quarter (23%) of respondents said they rushed their hike to try to "beat the crowd"
- About one in seven (14%) respondents reported walking off trail to bypass people in response to crowding

TABLE 11. ACTIONS TAKEN IN RESPONSE TO CROWDING ON THE OLD RAG TRAIL (N = 239)

REASON	COUNT	PERCENT
None	129	53%
I rushed my hike to try to "beat the crowd"	56	23%
I walked off trail to bypass people	34	14%
I passed people on sections of trail with steep drop-offs	28	12%
I used unmarked side trails to bypass people	23	10%
I cut switchbacks to bypass people	6	3%
Other	25	10%

TABLE 12. PERCENTAGE OF RESPONDENTS WHO TOOK ACTION IN RESPONSE TO CROWDING ON OLD RAG ON WEEKDAYS AND ON WEEKEND DAYS AND HOLIDAYS

RESPONSE TO CROWDING	WEEKDAY (N = 127)	WEEKEND/HOLIDAY (N = 112)
No action	63%	44%
Took some action	37%	56%

X^2= 8.113, p= 0.004

3.4 PEOPLE-AT-ONE-TIME (PAOT) COUNTS

This sub-section of the report describes the results of PAOT counts conducted in the Chute, on the Old Rag summit, and in the Old Rag summit viewscape.

Mean and Maximum PAOT in the Chute

Daily mean and maximum PAOT in the Chute are presented in Table 13. These data suggest:

- The daily mean PAOT in the Chute ranged from 9 to 99 PAOT, and the daily maximum PAOT in the Chute ranged from 22 to 196 PAOT.
- Daily mean and maximum PAOT counts in the Chute were higher on weekend days and holidays than on weekdays. In fact, the maximum weekend day/holiday PAOT count (196 PAOT on October 19, 2019) was more than three times higher than the maximum weekday PAOT count (63 PAOT on October 18, 2019).

TABLE 13. AVERAGE AND MAXIMUM NUMBER OF PEOPLE-AT-ONE-TIME (PAOT) IN THE CHUTE

DATE	DAY TYPE	CHUTE PAOT	
		MEAN[11]	MAX
10/11/19	WEEKDAY	17	44
10/12/19	WEEKEND/HOLIDAY	47	100
10/13/19	WEEKEND/HOLIDAY	46	93
10/14/19	WEEKEND/HOLIDAY	64	125
10/17/19	WEEKDAY	10	50
10/18/19	WEEKDAY	42	63
10/19/19	WEEKEND/HOLIDAY	99	196
10/21/19	WEEKDAY	9	23
10/23/19	WEEKDAY	11	22

[11] Mean values were rounded to the nearest whole number.

Statistical summaries of the range of PAOT counts in the Chute, by hour of the day, are presented in Figure 16. The points represent mean hourly PAOT values and the vertical lines represent the full range of PAOT values observed, from the minimum value at the bottom of the vertical line to the maximum value at the top of the vertical line. These data suggest:

- On weekdays, PAOT generally remained relatively low throughout the day in the Chute, with hourly means ranging from 6 to 22 PAOT. Hourly maximum PAOT counts on weekdays were generally at or just above 50 PAOT from 10:00 a.m. to 4:00 p.m. (Figure 16).
- On weekend days and holidays, PAOT in the Chute was relatively low during the 9:00 a.m. and 10:00 a.m. hours, with hourly mean values at approximately 20 to 25 PAOT. Hourly mean and maximum PAOT in the Chute increased sharply from 11:00 a.m. through 2:00 p.m. Hourly mean PAOT in the Chute increased from 28 PAOT during the 10:00 a.m. hour to 106 PAOT during the 1:00 p.m. hour, and hourly maximum PAOT counts in the Chute reached nearly 200 PAOT during the 1:00 p.m. hour. Mean PAOT in the Chute declined during the afternoon, to 85 PAOT during the 2:00 p.m. hour and 54 PAOT during the 3:00 p.m. hour. Maximum PAOT counts in the Chute remained very high through the 2:00 p.m. hour and then declined substantially during the 3:00 p.m. hour.
- PAOT in the Chute ranged widely during the busiest hours of weekend days and holidays, with minimum values of 50 PAOT or fewer and maximum values of 150 PAOT or more in the same hour during the 12:00 p.m. through 2:00 p.m. hours.
- Hourly mean PAOT in the Chute from 12:00 p.m. through 3:00 p.m. on weekend days and holidays was higher than the maximum PAOT at any time on weekdays.

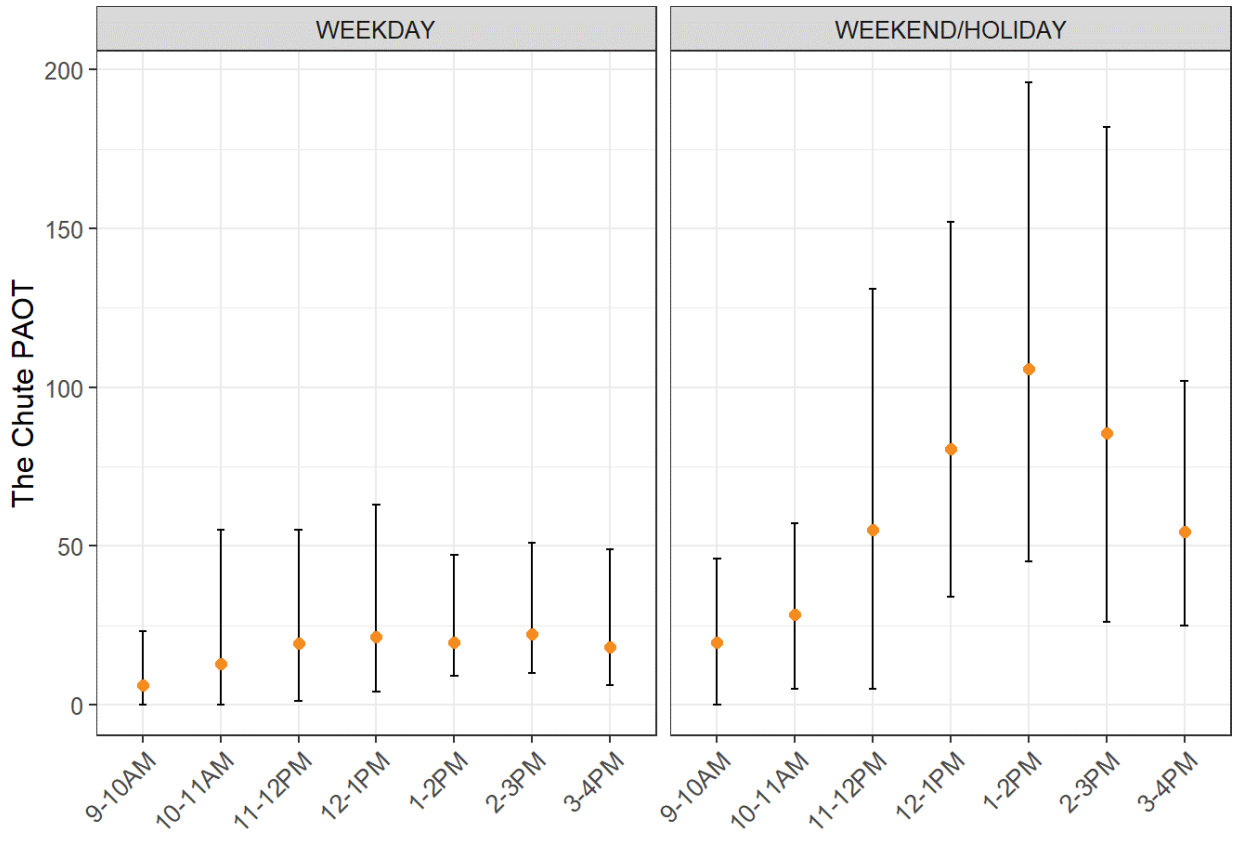

FIGURE 16. HOURLY AVERAGE, MINIMUM, AND MAXIMUM NUMBER OF PEOPLE-AT-ONE-TIME (PAOT): THE CHUTE

Mean and Maximum PAOT on the Old Rag Summit

Daily mean and maximum PAOT on the Old Rag summit are presented in Table 14. These data suggest:

- The daily mean PAOT on the summit ranged from 24 to 82 PAOT and the daily maximum PAOT ranged from 45 to 143 PAOT.
- Daily mean and maximum PAOT counts on the summit were higher on weekend days and holidays than on the one sampled weekday. In fact, the maximum weekend day/holiday PAOT count (143 PAOT on October 19, 2019) was more than three times higher than the weekday maximum PAOT count (45 PAOT on October 18, 2019).

TABLE 14. AVERAGE AND MAXIMUM NUMBER OF PEOPLE-AT-ONE-TIME (PAOT) ON THE SUMMIT

DATE	DAY TYPE	SUMMIT WHOLE AREA	
		MEAN[12]	MAX
10/12/19	WEEKEND/HOLIDAY	58	131
10/13/19	WEEKEND/HOLIDAY	49	78
10/18/19	WEEKDAY	24	45
10/19/19	WEEKEND/HOLIDAY	82	143

Statistical summaries of the range of the summit PAOT counts by hour of the day are presented in Figure 17. The points represent mean hourly PAOT values and the vertical lines represent the full range of PAOT values observed, from the minimum value at the bottom of the vertical line to the maximum value at the top of the vertical line. These data suggest:

- On weekdays, PAOT on the summit increased moderately during the morning hours, from an hourly mean of 2 PAOT during the 9:00 a.m. hour to a peak hourly mean of 36 PAOT during the 12:00 p.m. hour (Figure 17). During the afternoon hours, PAOT on the summit declined moderately to an hourly mean of 14 PAOT during the 4:00 p.m. hour. Hourly maximum PAOT on the summit never reached 50 PAOT.
- On weekend days and holidays, PAOT on the summit was at its lowest levels early in the morning, with an hourly mean of 21 PAOT during the 9:00 a.m. to 10:00 a.m. hour. Hourly mean PAOT increased throughout the morning and early afternoon, ranging from an hourly mean of 51 PAOT at 10:00 a.m. to 81 PAOT in the 12:00 p.m. to 1:00 p.m. hour. Hourly mean PAOT remained steady through 3:00 p.m. and then declined somewhat during the 3:00 pm hour to 57 PAOT.

[12] Mean values were rounded to the nearest whole number.

- PAOT on the summit ranged fairly widely during the afternoon hours on weekend days and holidays, with minimum values of just under 50 PAOT and maximum values of more than 100 PAOT in the same hour during the 12:00 p.m. through 2:00 p.m. hours.
- Hourly mean PAOT on the summit from 10:00 a.m. through the afternoon on weekend days and holidays was higher than the maximum PAOT at any time on weekdays in the summit whole area.

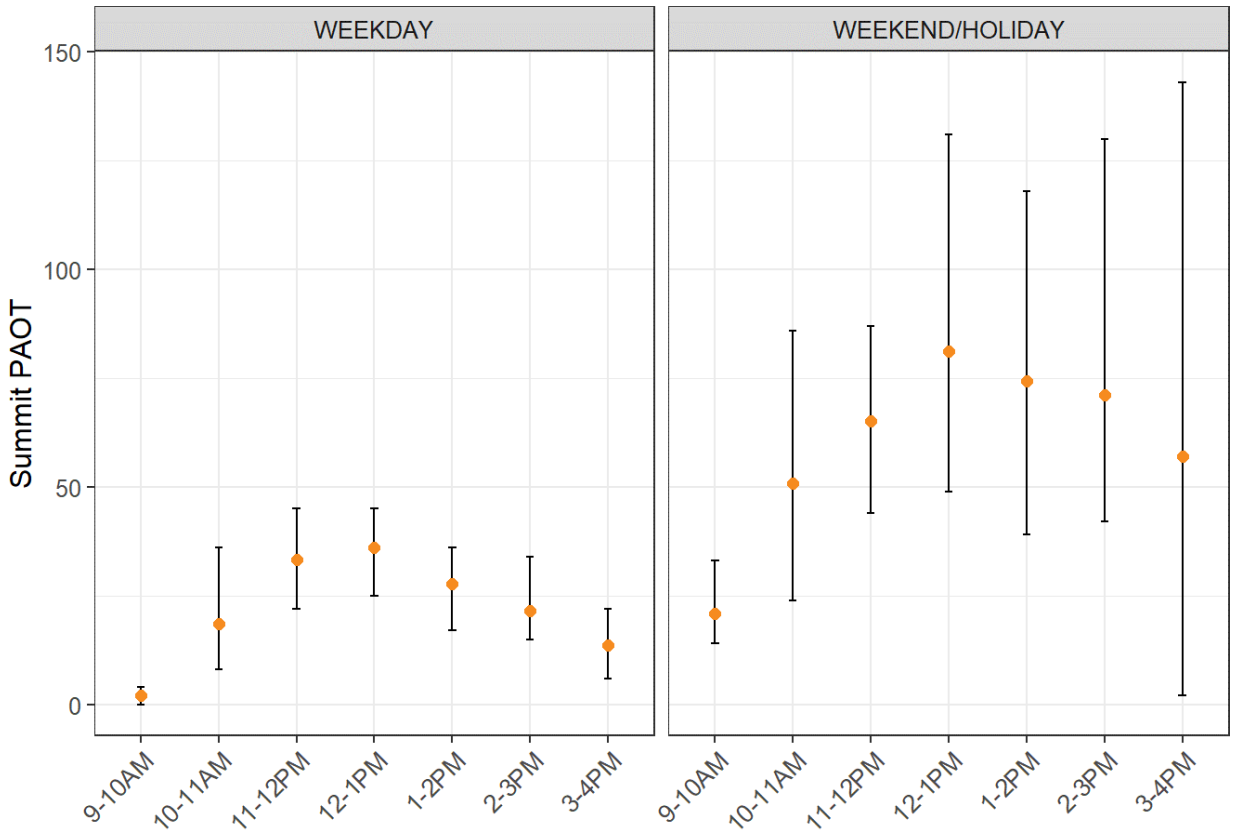

FIGURE 17. HOURLY AVERAGE, MINIMUM, AND MAXIMUM NUMBER OF PEOPLE-AT-ONE-TIME (PAOT): SUMMIT

Mean and Maximum PAOT in the Old Rag Summit Viewscape

Daily mean and maximum PAOT in the Old Rag summit viewscape are presented in Table 15. These data suggest:

- The daily mean PAOT in the summit viewscape ranged from 1 to 29 PAOT and the daily maximum PAOT ranged from 8 to 64 PAOT.
- Daily mean and maximum PAOT counts in the summit viewscape were higher on weekend days and holidays than on weekdays. The maximum weekend day/holiday PAOT count (59 PAOT on October 12, 2019) was approximately 1.5 times higher than the maximum weekday PAOT count (40 PAOT on October 11, 2019).

TABLE 15. AVERAGE AND MAXIMUM NUMBER OF PEOPLE-AT-ONE-TIME (PAOT) IN THE SUMMIT VIEWSCAPE

DATE	DAY TYPE	SUMMIT VIEWSCAPE	
		MEAN[13]	MAX
10/11/19	WEEKDAY	11	40
10/12/19	WEEKEND/HOLIDAY	21	59
10/13/19	WEEKEND/HOLIDAY	14	37
10/14/19	WEEKEND/HOLIDAY	15	33
10/17/19	WEEKDAY	1	18
10/18/19	WEEKDAY	4	16

Statistical summaries of the range of the summit viewscape PAOT counts by hour of the day are presented in Figure 18. The points represent mean hourly PAOT values and the vertical lines represent the full range of PAOT values observed, from the minimum value at the bottom of the vertical line to the maximum value at the top of the vertical line. These data suggest:

- On weekdays, PAOT was generally low throughout the day in the summit viewscape, with hourly means ranging from 0 PAOT at 9:00 a.m. to 1 PAOT by 12:00 p.m. (Figure 18). Hourly mean PAOT increased from 6 PAOT at 12:00 p.m. to 8 PAOT by 2:00 p.m. on weekdays, before decreasing to an hourly mean of 3 PAOT from 3:00 p.m. to 4:00 p.m.
- On weekend days and holidays, PAOT in the summit viewscape was at its lowest levels early in the morning, with an hourly mean of 5 PAOT during the 9:00 a.m. to 10:00 a.m. hour. Hourly mean PAOT increased throughout the morning and early afternoon, ranging from an hourly mean of 18 PAOT during the 10:00 a.m. hour to 30 PAOT in the 12:00 p.m. to 1:00 p.m. hour.

[13] Mean values were rounded to the nearest whole number.

- PAOT in the summit viewscape ranged widely during the busiest hours of weekend days and holidays, with minimum values of 10 PAOT or fewer and maximum values of nearly 60 PAOT or more in the same hour during the 12:00 p.m., 2:00 p.m., and 3:00 p.m. hours.
- Hourly mean PAOT in the summit viewscape from 10:00 a.m. through 3:00 p.m. on weekend days and holidays was higher than the maximum PAOT at any time on weekdays.

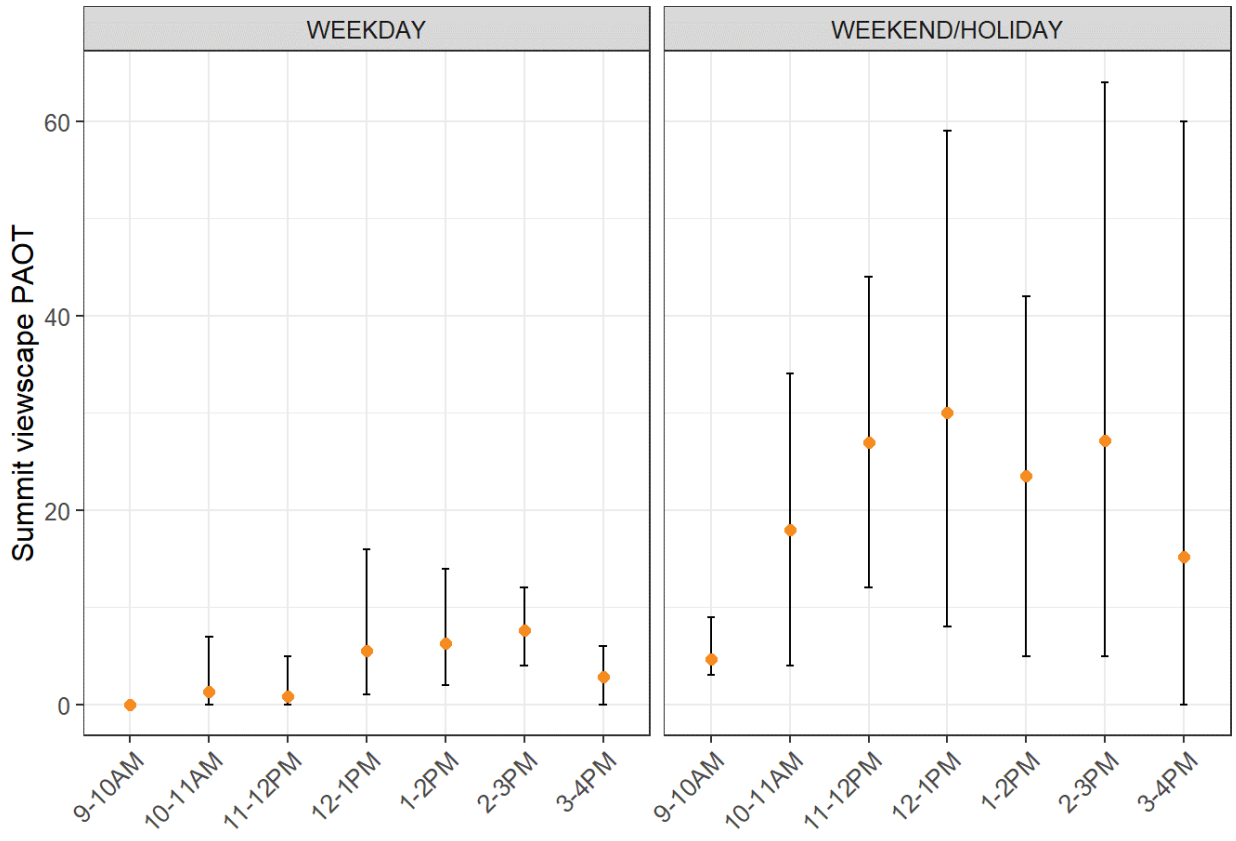

FIGURE 18. HOURLY AVERAGE, MINIMUM, AND MAXIMUM NUMBER OF PEOPLE-AT-ONE-TIME (PAOT): SUMMIT VIEWSCAPE

PAOT Regression Analysis: Old Rag Summit and Summit Viewscape

A regression analysis was conducted to estimate the statistical relationship between PAOT on the Old Rag summit and PAOT in the summit viewscape (Figure 19). The purpose of the regression analysis was to derive an empirical basis to convert estimates of summit PAOT counts to estimates of summit viewscape PAOT counts, primarily for the Old Rag Mountain Visitor Use Model (Section 6.0). The resulting coefficient of the regression equation (0.345) suggests that, on average, about one-third of the people on the summit at one time are in the summit viewscape.

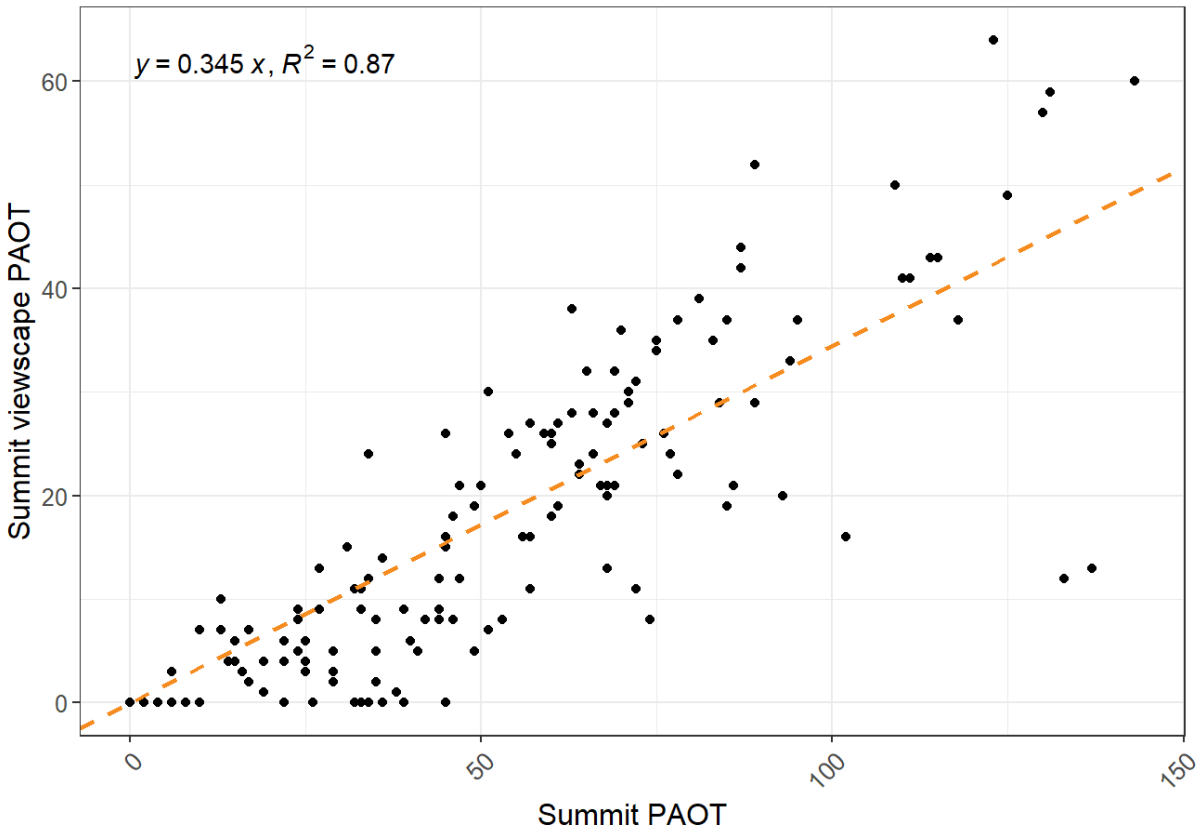

FIGURE 19. SCATTERPLOT AND REGRESSION EQUATION: PAOT ON THE OLD RAG SUMMIT AND PAOT IN THE SUMMIT VIEWSCAPE

4.0 RESULTS: VISITOR EXPERIENCE SURVEY

This section of the report presents the results for the visitor experience survey that was administered on the Nethers side of Old Rag Mountain to visitors upon completion of their hike on the Old Rag Mountain Trail. The results are generally presented in questionnaire order and include the question number, the question text in italics, select bulleted information, and data tables. Cross-tabulations are presented, where applicable.

It should be noted, due to rounding, the percentages summarized in the bulleted information may not exactly match manual summation of the percentages presented in the tables. The percentages in the tables may not sum to 100% due to rounding or in cases where survey respondents were instructed to select all response options that apply.

4.1 GROUP AND TRIP CHARACTERISTICS

This sub-section presents the results of survey questions that were focused on collecting information about survey respondents' groups (e.g., group size, group type) and their hikes (e.g., type of hike, start location, direction, time spent hiking, etc.). Additional questions for which results are reported in this sub-section address the timeframe and sources that survey respondents used to plan their hikes, and whether or not respondents felt prepared for common safety situations that they might encounter when hiking on the Old Rag Mountain Trail.

Group Size

Question 1

Including yourself, how many people were in your hiking group on Old Rag today? Fill in the blank.

Results (Table 16)

- Nearly half (47%) of survey respondents hiked in groups of two.
- Relatively small proportions of survey respondents hiked alone (15%) or in groups of three (12%) or larger groups.
- Nearly three-quarters (74%) of survey respondents hiked in groups of three or fewer.

TABLE 16. GROUP SIZE (N = 399)

	COUNT	PERCENT
1	60	15%
2	187	47%
3	47	12%
4	35	9%
5	26	7%
6	7	2%
7	9	2%
8	3	1%
9	6	2%
10 or more	19	5%

Number of Adults

Question 1

Including yourself, how many adults (aged 18 or older) were in your hiking group on Old Rag today? Fill in the blank.

Results (Table 17)

- Nearly half (48%) of survey respondents hiked in a group that included two adults.
- Nearly one-fifth (18%) of survey respondents hiked in a group that included only one adult.

TABLE 17. NUMBER OF ADULTS IN GROUP (N = 399)

	COUNT	PERCENT
1	73	18%
2	191	48%
3	42	11%
4	35	9%
5	20	5%
6	8	2%
7	7	2%
8	4	1%
9	3	1%
10 or more	16	4%

Number of Children

Question 1

Including yourself, how many children (under 18 years) were in your hiking group on Old Rag today? Fill in the blank.

Results (Table 18)

- The vast majority (90%) of survey respondents had no children in their hiking group.

TABLE 18. NUMBER OF CHILDREN IN GROUP (N = 399)

	COUNT	PERCENT
0	360	90%
1	16	4%
2	10	3%
3	4	1%
4	2	1%
5	2	1%
6	1	<1%
10 or more	4	1%

Group Type

Question 2

*Which of the following best describes your hiking group today? Please select **all that apply.** If "Organized group," please specify.*

Results (Table 19)

- Over half (52%) of survey respondents indicated that they were hiking in a group with friends.
- Nearly one-third (30%) of survey respondents indicated that they were hiking in a group with their family.
- Few (4%) survey respondents indicated that they were hiking with an organized group. See Appendix I for the specific types of organized groups that respondents were hiking in.

TABLE 19. GROUP TYPE (N = 404)

	COUNT	PERCENT
Alone	56	14%
Family	122	30%
Friends	212	52%
Organized group	17	4%

Hike Type

Question 3

*Which of the following best describes your hike on Old Rag today? Please mark **one**.*

If part of an overnight backpacking trip, SKIP TO QUESTION 6.

Results (Table 20)

- Nearly all (99%) survey respondents were on a day hike of Old Rag.

TABLE 20. TYPE OF HIKE (N = 396)

	COUNT	PERCENT
Day hike	392	99%
Part of an overnight backpacking trip	4	1%

Hike Start Location

Question 4

Note: This question was only asked of survey respondents who indicated on Question 3 that their hike on Old Rag was a day hike.

*Where did you start your day hike on Old Rag today? Refer to the map and mark **one**. If "Other," please specify.*

Results (Table 21)

- Of the survey respondents who were on a day hike, the vast majority (94%) began their hike on the Nethers side of Old Rag Mountain.
- Few (2%) survey respondents who were on a day hike indicated that they started at another location. See Appendix I for the specific other start locations listed by survey respondents.

TABLE 21. AMONG DAY HIKERS, STARTING LOCATION OF HIKE (N = 379)

	COUNT	PERCENT
Nethers	356	94%
Berry Hollow	14	4%
Other	9	2%

Note: Surveys were only distributed to visitors who completed their hike on the Nethers side of Old Rag Mountain; therefore, the distribution of starting locations is not representative of Old Rag hikers who started at Berry Hollow.

Hike Direction

Question 5

Note: This question was only asked of survey respondents who indicated on Question 3 that their hike on Old Rag was a day hike.

*In which direction did you complete your day hike on Old Rag today? Refer to the map and mark **one**.*

Results (Table 22)

- Of the survey respondents who were on a day hike, the vast majority (80%) completed their day hike of Old Rag as a clockwise loop.
- Very few (6%) day hikers completed their hike of Old Rag as a counterclockwise loop.
- A relatively small proportion (14%) of day hikers completed an out and back hike on Old Rag.

TABLE 22. AMONG DAY HIKERS, DIRECTION OF TRAVEL ON HIKE (N = 383)

	COUNT	PERCENT
Clockwise loop	308	80%
Counterclockwise loop	23	6%
Out and back, rather than a loop	52	14%

Time Spent Hiking Old Rag

Question 6

How much total time did you spend hiking on Old Rag today? Please list partial hours as ¼, ½, or ¾.[14]

Results (Table 23)

- Just over one-third (34%) of survey respondents spent five hours hiking Old Rag.
- The remaining survey respondents are split almost evenly into two groups. Just over one-third (34%) of survey respondents spent less than five hours hiking Old Rag, while nearly one-third (32%) of survey respondents spent six or more hours hiking Old Rag.
- Overall, most survey respondents (81%) spent 4-6 hours hiking Old Rag.

TABLE 23. TOTAL TIME (IN HOURS) SPENT HIKING OLD RAG TRAIL (N = 390)

	COUNT	PERCENT
1 hour	6	2%
2 hours	5	1%
3 hours	23	6%
4 hours	98	25%
5 hours	133	34%
6 hours	86	22%
7 hours	31	8%
8 hours	7	2%
9 hours	1	<1%

Note: Partial hours provided as fractions or decimals were rounded to the nearest whole number for presentation purposes.

[14] Two responses that were greater than 24 hours were excluded from this analysis.

Summited Old Rag

Question 7

*Did you hike to the top of Old Rag today? Please mark **one.***

Results (Table 24)

- The vast majority (90%) of survey respondents reported that they hiked to the top of Old Rag.

TABLE 24. PERCENTAGE OF RESPONDENTS WHO HIKED TO THE TOP OF OLD RAG (N = 394)

	COUNT	PERCENT
Yes	353	90%
No	41	10%

First Time Hiking Old Rag

Question 8

*Is your hike today the first time you have hiked on the Old Rag Trail? Please mark **one.***

Results (Table 25)

- Just over half (59%) of survey respondents indicated that their hike on the day they were contacted for the survey was the first time that they had hiked on Old Rag.
- Just under half (41%) of survey respondents indicated that they had hiked Old Rag previously.

TABLE 25. PERCENTAGE OF RESPONDENTS WHO INDICATED THAT IT WAS THEIR FIRST TIME HIKING ON OLD RAG (N = 394)

	COUNT	PERCENT
Yes	232	59%
No	162	41%

Number of Times Hiked Old Rag

Question 8a

Note: This question was only asked of survey respondents who indicated on Question 8 that they had hiked Old Rag before.

Including this hike today, how many times have you hiked on the Old Rag Trail?

Results (Table 26)

- A majority of returning hikers (55%) reported that they have hiked on Old Rag two or three times in total.
- Nearly one-quarter (22%) of returning hikers reported that they have hiked on Old Rag four to six times in total.
- Slightly under one-fifth (15%) of returning hikers reported that they have hiked on Old Rag over 10 times in total.

TABLE 26. AMONG RETURNING HIKERS, TOTAL NUMBER OF TIMES HIKED OLD RAG (N = 155)

	COUNT	PERCENT
2	58	37%
3	28	18%
4	13	8%
5	9	6%
6	12	8%
7	4	3%
8	5	3%
9	2	1%
Over 10	24	15%

Note: Numbers provided as fractions or decimals were rounded to the nearest whole number for presentation purposes.

Timeframe for Decision to Hike Old Rag

Question 9

*When did you decide to take this hike on Old Rag? Please mark **one.***

Results (Table 27)

- Very few (4%) survey respondents indicated that they decided in the spur of the moment (i.e., that day) to hike Old Rag.
- About one-third (38%) of survey respondents indicated that they decided to take this hike on Old Rag within the last week.
- About one-quarter each decided to take this hike on Old Rag within the last month (29%) or longer (27%).

TABLE 27. TIMEFRAME FOR DECISION TO HIKE OLD RAG (N = 395)

	COUNT	PERCENT
Today	14	4%
Before today, but in the last week	149	38%
More than a week ago, but in the last month	116	29%
More than a month ago, but in the last year	105	27%
More than a year ago	9	2%
Don't know/can't recall	2	1%

Sources of Information for Planning

Question 10

Did you use any of the following types of information to plan and/or prepare for your hike on Old Rag today? Please mark ***whether or not you used each information source.*** *If "Other website," please specify.*

Results (Table 28)

- Nearly two-thirds (62%) of survey respondents indicated that they had used the Shenandoah National Park website (nps.gov/SHEN) to plan and/or prepare for their hike on Old Rag; the same percentage (62%) of respondents indicated that they used information provided by their friends or family to plan for their hikes.
- Nearly half (47%) of survey respondents indicated that they had used a previous visit to plan and/or prepare for their hike on Old Rag.
- One-third (33%) of survey respondents indicated that they had used smartphone apps to plan and/or prepare for their hike on Old Rag.
- Nearly one-fifth (19%) of survey respondents indicated that they used another website to plan and/or prepare for their hike on Old Rag. See Appendix I for specific other websites used by survey respondents.
- Very few (10% or less) survey respondents reported using any of the other sources of information to plan and/or prepare for their hike on Old Rag.

TABLE 28. INFORMATION SOURCES THAT RESPONDENTS USED TO PLAN/PREPARE FOR HIKE

INFORMATION SOURCES	N	PERCENT USED
Shenandoah National Park website	382	62%
Friends and family	380	62%
Previous visit	378	47%
Maps/brochures	355	41%
Apps such as Strava, TrailLink, AllTrails, etc.	361	33%
Other website	315	19%
Inquiry to park via phone, mail, or email	357	10%
Social media (such as Facebook, Twitter, etc.)	346	9%
Travel guides/tour books (such as AAA, etc.)	343	5%
Other units of the National Park System	340	3%
State welcome center/visitors bureau/chamber of commerce	339	3%
Local businesses (hotels, motels, restaurants, etc.)	346	3%
Newspaper/magazine articles	341	1%
School class/program	341	1%
Television/radio programs/DVDs	340	1%

Felt Prepared for Common Safety Situations

Question 11

During your hike on Old Rag today, did you feel prepared for the following common safety situations that you may have encountered? Please mark ***whether or not you felt prepared for each situation.***

Results (Table 29)

- The vast majority (92% or more) of survey respondents felt prepared for almost all of the common safety situations listed in the survey.
- Nearly three-quarters (71%) of survey respondents felt prepared for bad weather/storms.

TABLE 29. PERCENTAGE OF RESPONDENTS WHO FELT PREPARED FOR COMMON SAFETY SITUATIONS

COMMON SAFETY SITUATIONS	N	PERCENT FELT PREPARED
Strength and fitness needed for the hike	390	97%
Exposure to sun	384	96%
Limited access to drinking water	386	96%
Steep sections of trail	383	95%
Cold temperatures at higher elevations	385	95%
Proper footwear required for the terrain	388	94%
Hot, humid weather	376	92%
Bad weather/storms	374	71%

4.2 VISITOR EXPERIENCE

This sub-section presents the results of survey questions regarding respondents' experiences during their hike and their support for various potential visitor use management actions. These include respondents' perceptions of crowding, time that they spent waiting in queues, whether they worried about or encountered various potential issues, attitudes about potentially limiting the number of hikers per day on the trail, and support for or opposition to other potential management actions. A combination of frequency distributions and cross-tabulations are presented to summarize results in this sub-section. Chi squares tests and p-values are presented alongside cross-tabulations and where appropriate, means are compared using t-tests to test for statistically significant differences. Some data are cross-tabulated to differentiate between "peak day" survey respondents, who hiked on days with over 700 daily visitor arrivals during the survey administration period,[15] and "non-peak day" survey respondents (Figure 8). Other data are cross-tabulated to differentiate between survey respondents who did or did not have to wait in a queue and survey respondents who did or did not feel crowded in the rock scramble. Descriptive statistics (mean, median, standard deviation) are presented in Appendix J for those variables for which measures of central tendency can be computed. For all open-ended questions and questions with open-ended response options, verbatim responses are reported in Appendix I.

[15] See Figure 8 for daily visitor arrivals across the survey administration period, 10/11/19 through 10/24/19. There were four peak visitation days within the survey administration period.

Reactions to Photo Simulations: Would You Feel Crowded?

Question 12

We would like to know how many other hikers you think it is acceptable to see on the top of Old Rag Mountain without it being too crowded. To help judge this, we have a series of photographs that show different numbers of hikers in this area. Please ask the survey administrator to show you these photos to answer the following question.

For each photograph, please tell us if you would feel crowded if you were on the top of Old Rag with the number of people depicted in the photograph. Please mark ***yes or no for each photograph****.*

Results (Table 30)

- The proportion of survey respondents indicating that they would feel crowded increased steadily as the number of people at one time (PAOT) depicted in the photographs increased.
- In photo simulations with fewer than 10 PAOT, 0% of survey respondents indicated that they would feel crowded.
- A “crowding response” is first detectable in the survey response data for photo simulations with 10 to 19 PAOT (12% would feel crowded).
- There is a much more pronounced crowding response in the survey response data for photo simulations with 20-29 PAOT, at which point more than half of survey respondents (53%) indicated that they would feel crowded.
- In photo simulations with 30 to 39 PAOT or more, greater than two-thirds (68% or more) of survey respondents indicated that they would feel crowded.

TABLE 30. PERCENT OF SURVEY RESPONDENTS WHO WOULD FEEL CROWDED, BY NUMBER OF PEOPLE AT ONE TIME (PAOT) IN PHOTO SIMULATIONS

PAOT	N	PERCENT WHO WOULD FEEL CROWDED
0–9	134	0%
10–19	89	12%
20–29	389	53%
30–39	304	68%
40–49	439	87%
50–59	257	95%
60–69	264	96%
70–79	174	98%
80–89	178	97%
90–100	127	99%

Note: A randomly assigned set of six photos selected from a total set of 26 photos ranging from 0 to 100 PAOT were shown to each respondent (see Appendix A).

Number of Hikers per Day Should Be Limited

Question 13

*Should the number of people allowed to hike Old Rag each day be limited if it is needed for any of the following reasons, even if it limits when you can hike Old Rag? Please mark **one for each row**.*

Results (Table 31)

- Nearly three-quarters (70%) of survey respondents agreed that the number of people allowed to hike Old Rag each day should be limited if it is needed to reduce environmental impacts, even if it limits when they can hike Old Rag.
- Two-thirds (66%) of survey respondents agreed that the number of people allowed to hike Old Rag each day should be limited if it is needed to protect visitor safety, even if it limits when they can hike Old Rag.
- Approximately half of survey respondents agreed that the number of people allowed to hike Old Rag each day should be limited if it is needed to protect Congressionally-designated Wilderness values (51%) or to protect the quality of visitor experiences (46%).

TABLE 31. PERCENTAGE OF RESPONDENTS WHO INDICATED THAT THE NUMBER OF HIKERS PER DAY SHOULD BE LIMITED FOR SPECIFIC REASONS

POTENTIAL REASONS	N	YES	NO	DON'T KNOW/ NOT SURE
To reduce environmental impacts	393	70%	19%	11%
To protect visitor safety	392	66%	25%	9%
To protect Congressionally-designated Wilderness values	394	51%	25%	24%
To protect the quality of visitor experiences (i.e., prevent crowding)	392	46%	38%	17%

Waited in a Queue on Days with Peak and Non-Peak Visitation

Question 15

*Did you have to wait in a bottleneck/line of people at any point during your hike on Old Rag today? Please mark **one.** If yes, please write the number of minutes that you waited in the bottleneck/line.*

Results (Table 32)

- Survey respondents who hiked on a "peak day" were significantly more likely to have to wait in a bottleneck/line of people (i.e., a queue) than survey respondents who hiked on a "non-peak day". Specifically, over two-thirds (69%) of survey respondents who hiked on a peak day waited in a queue, while only one-third (33%) of respondents who hiked on non-peak days had to wait.[16]

TABLE 32. PERCENTAGES OF RESPONDENTS WHO WAITED IN A QUEUE ON PEAK AND NON-PEAK DAYS

WAITED IN A QUEUE	PEAK DAY (N = 217)	NON-PEAK DAY (N = 170)
Had to wait in a queue	69%	33%
Did not have to wait in a queue	31%	67%

X^2=48.829, p<0.001

[16] Eleven survey respondents who indicated that they did wait in a queue but did not provide the amount of time that they waited were not included in any analyses using time waited in queue.

Number of Minutes in a Queue on Peak and Non-Peak Days

Question 15

*Did you have to wait in a bottleneck/line of people at any point during your hike on Old Rag today? Please mark **one.** If yes, please write the number of minutes that you waited in the bottleneck/line.*

Results (Table 33, Table 34)

- For those survey respondents who did have to wait in a queue, respondents on peak days were significantly more likely to have a longer wait time. On average, respondents who waited in a queue on peak days waited four times longer than respondents who waited in a queue on non-peak days.
- Of survey respondents who waited in a queue on peak days, nearly three-quarters (73%) waited more than five minutes, and over one-third (36%) waited more than 10 minutes.
- Of survey respondents who waited in a queue on non-peak days, the majority had to wait less than 5 minutes.

TABLE 33. AMONG RESPONDENTS WHO WAITED IN A QUEUE, MEAN TIME WAITED (IN MINUTES) ON PEAK AND NON-PEAK DAYS

	PEAK VISITATION DAY (N = 149)	NON-PEAK VISITATION DAY (N = 56)
Mean time waited in a queue	16 minutes	4 minutes

t=6.940, p<0.001

TABLE 34. AMONG THOSE WHO WAITED IN A QUEUE, NUMBER OF MINUTES WAITED ON PEAK AND NON-PEAK DAYS

TIME WAITED IN A QUEUE	PEAK VISITATION DAY (N = 149)	NON-PEAK VISITATION DAY (N = 56)
Waited less than 5 minutes	27%	64%
Waited 5-10 minutes	38%	32%
Waited more than 10 minutes	36%	4%

X^2=31.258, p<0.001

Note: Numbers provided as fractions or decimals were rounded to the nearest whole number for presentation purposes

Felt Crowded, by Location, on Peak and Non-Peak Days

Question 14

*Did you feel crowded at any of the following locations during your Old Rag hike today? Please mark **one for each row.***

Results (Table 35)

- Survey respondents visiting on peak days were significantly more likely to feel crowded than survey respondents on non-peak days in the parking lot (34% vs. 6%), in the rock scramble (58% vs. 15%), and on top of Old Rag (27% vs. 11%).

TABLE 35. PERCENT OF RESPONDENTS WHO FELT CROWDED, BY LOCATION, ON PEAK AND NON-PEAK DAYS

FELT CROWDED…	PEAK OR NON-PEAK VISITATION DAY	YES, I FELT CROWDED	CHI-SQUARE & P-VALUE
In the parking lot	Peak (n = 220) Non-peak (n = 170)	34% 6%	X^2=44.769 p<0.001
In the rock scramble	Peak (n = 219) Non-peak (n = 165)	58% 15%	X^2=73.595 p<0.001
On the top of Old Rag	Peak (n = 199) Non-peak (n = 166)	27% 11%	X^2=14.401 p<0.001

Note: Survey respondents who indicated that they did not visit a location by selecting "Did not visit today" were excluded from analysis for that location.

Impact of Waiting in Line on Feeling Crowded in the Rock Scramble

Question 15

*Did you have to wait in a bottleneck/line of people at any point during your hike on Old Rag today? Please mark **one.** If yes, please write the number of minutes that you waited in the bottleneck/line.*

Question 14

*Did you feel crowded at any of the following locations during your Old Rag hike today? Please mark **one for each row.***

Results (Table 36, Table 37)

- Of those survey respondents who felt crowded in the rock scramble, nearly three-quarters (73%) reported that they waited in a queue for five minutes or more during their hike. Of those survey respondents who did not feel crowded in the rock scramble, more than two-thirds (69%) reported that they did not wait in queue at all during their hike and nearly all (91%) reported that they waited no more than 5 minutes.
- Out of those survey respondents who did wait in a queue, those who felt crowded in the rock scramble waited an average of 18 minutes, while those who did not feel crowded in the rock scramble waited an average of 4 minutes.

TABLE 36. PERCENTAGE OF RESPONDENTS WHO FELT CROWDED IN THE ROCK SCRAMBLE, BY TIME WAITED IN A QUEUE

TIME WAITED IN A QUEUE	FELT CROWDED IN THE ROCK SCRAMBLE (N = 144)	DID NOT FEEL CROWDED IN THE ROCK SCRAMBLE (N = 227)
Did not wait in a queue	11%	69%
Waited less than 5 minutes	16%	22%
Waited 5 minutes or more	73%	9%

X^2=179.322, p<0.001

Note: Numbers provided as fractions or decimals were rounded to the nearest whole number for presentation purposes. Survey respondents who indicated that they did not visit the rock scramble by selecting "Did not visit today' were excluded from analysis.

TABLE 37. AMONG RESPONDENTS WHO WAITED IN A QUEUE, MEAN TIME WAITED BY FEELING CROWDED IN THE ROCK SCRAMBLE

	FELT CROWDED IN THE ROCK SCRAMBLE (N = 128)	DID NOT FEEL CROWDED IN THE ROCK SCRAMBLE (N = 70)
Mean time waited in a queue	18 minutes	4 minutes

t=-7.300, p<0.001

Worried About the Following Risks

Question 16

*Did you worry about any of the following risks during your hike on Old Rag today? Please mark **whether or not you were worried about each potential risk.***

Results (Table 38)

- Just under half (41%) of survey respondents indicated that they were worried about "slipping and having a bad fall while hiking on the trail."
- One-quarter (25%) of survey respondents indicated that they were worried about "being injured while hiking the trail."
- Less than 15% of survey respondents indicated that they were worried about any of the other risks mentioned in this survey question.

TABLE 38. PERCENTAGE OF RESPONDENTS WORRIED ABOUT POTENTIAL RISKS

POTENTIAL RISKS	N	PERCENT WORRIED
Slipping and having a bad fall while hiking on the trail	381	41%
Being injured while hiking the trail	384	25%
Being unable to make it through the rock scramble	385	14%
Not having access to restrooms on the trail	383	13%
Someone falling into me while hiking the trail	384	12%
Getting lost/losing the marked trail	384	10%
Unsafe/risky behavior of others threatening my safety	384	8%
Being unable to complete the whole hike	385	7%
Not finishing the hike before dark	385	5%

Encountered Issues on Old Rag Hike

Question 17

*Did you encounter any of the following on your Old Rag hike today? Please mark **one for each row.***

Results (Table 39)

- Just under half (43%) of survey respondents indicated that they encountered litter on their Old Rag hike.
- More than one-third (38%) of survey respondents indicated that they encountered individuals who they believed were unprepared for the hike. This is in contrast to the results in Table 29 which indicate the vast majority (over 92%) of survey respondents felt prepared, themselves, for almost all of the common safety situations listed in the survey.
- About one-quarter (26%) of survey respondents indicated that they encountered graffiti on their hike.
- Fewer than one-quarter (22% or fewer) of survey respondents indicated that they encountered any of the other issues asked about in this survey question.

TABLE 39. ISSUES ENCOUNTERED BY RESPONDENTS ON OLD RAG HIKE

	YES	NO	TOTAL	N
Litter	43%	57%	100%	387
Individuals you believe were unprepared for the hike	38%	62%	100%	386
Graffiti	26%	74%	100%	388
Loud noise or music created by other visitors	22%	78%	100%	384
Individuals walking off-trail/creating their own trail	21%	79%	100%	382
Dogs on the trail or summit	20%	80%	100%	380
Individuals cutting switchbacks	12%	88%	100%	384
Visible human or dog waste	9%	91%	100%	383
Dangerous behavior	9%	91%	100%	386
Human or dog waste odor	6%	94%	100%	385
Drone usage	4%	96%	100%	384
Falling rocks	1%	99%	100%	384

Support for Potential Management Actions

Question 18

*To what extent would you support or oppose each of the following potential management practices for hiking on Old Rag? Please mark **one for each row.***

Results (Table 40)

- Nearly half (46%) of survey respondents indicated that they support providing more rangers along the trail to reinforce safety, trail etiquette, and Leave No Trace principles.
- Just under half of survey respondents indicated that they support limiting the number of people allowed to hike Old Rag each day by means of a reserve in advance permit system (40%) and by means of a first come, first served permit system (40%).
- More than one-third (37%) of survey respondents indicated that they support setting hourly limits on the number of people allowed to hike Old Rag, to ensure the number of people on the trail at one time does not exceed a certain number.
- One-quarter (25%) of survey respondents indicated that they support requiring an orientation that reinforces safety, trail etiquette, and Leave No Trace principles.

TABLE 40. RESPONDENTS' LEVELS OF SUPPORT FOR POTENTIAL MANAGEMENT ACTIONS

ROW %	N	STRONGLY SUPPORT	SLIGHTLY SUPPORT	NEITHER SUPPORT NOR OPPOSE	SLIGHTLY OPPOSE	STRONGLY OPPOSE	TOTAL
Provide more rangers along the trail to reinforce safety, trail etiquette, and Leave No Trace principles	397	10%	35%	33%	14%	8%	100%
Limit the number of people allowed to hike Old Rag each day by means of a reserve in advance permit system	392	10%	30%	24%	19%	17%	100%
Limit the number of people allowed to hike Old Rag each day by means of a first come, first served permit system	387	9%	31%	21%	25%	14%	100%
Set hourly limits on the number of people allowed to hike Old Rag, to ensure the number of people on the trail at one time does not exceed a certain number	396	9%	28%	27%	19%	17%	100%
Require an orientation (e.g., a short video) that reinforces safety, trail etiquette, and Leave No Trace principles	395	5%	20%	23%	22%	31%	100%

Encountered a Uniformed Park Ranger

Question 19

*Did you encounter a uniformed Park Ranger on your Old Rag hike today? Please mark **one**.*

Results (Table 41)

- Just over one-third (37%) of survey respondents encountered a uniformed Park Ranger on their Old Rag hike.

TABLE 41. PERCENTAGE OF RESPONDENTS WHO ENCOUNTERED A UNIFORMED PARK RANGER ON OLD RAG HIKE (N = 393)

	COUNT	PERCENT
Yes	144	37%
No	249	63%

4.3 BACKGROUND INFORMATION

This sub-section presents the results of survey questions regarding survey respondents' demographic and background information, including age, gender, residence, ethnicity, race, and education level.

Age

Question 20

What is your age? Fill in the blank.

Results (Table 42)

- Just under half (42%) of survey respondents were under 30 years of age and nearly three-quarters (71%) were under 40 years of age.
- Less than one-quarter (22%) of survey respondents were 45 years of age or older.

TABLE 42. AGE OF SURVEY RESPONDENTS (N = 395)

	COUNT	PERCENT
18–24	76	19%
25–29	89	23%
30–34	65	16%
35–39	51	13%
40–44	29	7%
45–49	35	9%
50–54	24	6%
55–59	13	3%
60+	13	3%

Gender

Question 21

*What is your gender? Please mark **one.***

Results (Table 43)

- More than half (60%) of survey respondents identified their gender as male.

TABLE 43. GENDER OF SURVEY RESPONDENTS (N = 394)

	COUNT	PERCENT
Male	238	60%
Female	153	39%
Do not identify as male or female	1	<1%
I prefer not to answer	2	1%

U.S. State of Residence

Question 22

Where do you live? Fill in the blank.

Note: Survey respondents were asked to report their "U.S. ZIP code or country (if not U.S.)" by writing in the information in the appropriate blank.

Results (Table 44)

- The vast majority (98%) of survey respondents were U.S. residents.
- Over three-quarters (76%) of survey respondents lived in either Virginia, Maryland, or the District of Columbia, with 46% of survey respondents living in Virginia. Small percentages (5% or fewer) of survey respondents resided in one of 27 other states.

TABLE 44. STATE OF RESIDENCE OF U.S. SURVEY RESPONDENTS (N = 378)

	COUNT	PERCENT
Virginia	174	46%
Maryland	70	19%
District of Columbia	44	12%
Pennsylvania	20	5%
North Carolina	10	3%
Ohio	8	2%
Delaware	5	1%
Florida	4	1%
Illinois	4	1%
Michigan	4	1%
New Jersey	4	1%
New York	4	1%
West Virginia	4	1%
California	3	1%
Missouri	3	1%
Indiana	2	1%
Massachusetts	2	1%
13 other states	13	3%

Note: Thirteen states with only one survey respondent were collapsed into the "13 other states" category.

Country of Residence

Question 22

Where do you live? Fill in the blank.

Note: Survey respondents were asked to report their "U.S. ZIP code or country (if not U.S.)" by writing in the information in the appropriate blank.

Results (Table 45)

- Very few (2%) survey respondents resided in countries outside of the U.S., including Canada, Belgium, and Germany.

TABLE 45. COUNTRY OF RESIDENCE OF SURVEY RESPONDENTS, IF NOT U.S. (N = 7)

	COUNT	PERCENT
Canada	5	71%
Belgium	1	14%
Germany	1	14%

Ethnicity

Question 23

*Are you Hispanic or Latino? Please mark **one.***

Results (Table 46)

- Very few (6%) of survey respondents identified as Hispanic or Latino.

TABLE 46. ETHNICITY OF SURVEY RESPONDENTS (N = 398)

	COUNT	PERCENT
Yes, I am Hispanic/Latino	24	6%
No, I am not Hispanic/Latino	362	91%
I prefer not to answer	12	3%

Race

Question 24

*What is your race? Please mark **all that apply.***

Results (Table 47)

- The vast majority (81%) of survey respondents identified as White.
- Few (9% or fewer) survey respondents identified as any other race.

TABLE 47. RACE OF SURVEY RESPONDENTS (N = 398)

	COUNT	PERCENT
American Indian or Alaska Native	8	2%
Asian	35	9%
Black or African American	13	3%
Native Hawaiian or other Pacific Islander	2	1%
White	323	81%
I prefer not to answer	29	7%

Education Level

Question 25

*What is the highest level of formal education you have completed? Please mark **one.***

Results (Table 48)

- The vast majority (83%) of survey respondents reported graduating from college or completing higher levels of formal education.
- More than one-third (40%) of survey respondents reported completing a master's, doctoral, or professional degree.

TABLE 48. HIGHEST LEVEL OF FORMAL EDUCATION OF SURVEY RESPONDENTS (N = 389)

	COUNT	PERCENT
Less than high school	2	1%
Some high school	1	<1%
High school graduate or GED	9	2%
Some college, business, or trade school	51	13%
College, business, or trade school graduate	145	37%
Some graduate school	22	6%
Master's, doctoral, or professional degree	154	40%
I prefer not to answer	5	1%

5.0 ANALYSIS TO INFORM CROWDING-RELATED THRESHOLDS AND CAPACITIES

This section of the report describes a series of statistical analyses that were conducted to:

- Identify potential crowding-related thresholds for the number of people-at-one-time (PAOT) in the Chute and in the Old Rag summit viewscape
- Estimate the frequency with which current visitor use levels in the Chute and on the Old Rag Summit exceed those potential crowding-related thresholds

5.1 IDENTIFICATION OF POTENTIAL CROWDING-RELATED THRESHOLDS

People-at-One-Time (PAOT) in the Chute

GPS route tracking and PAOT counts in the Chute were conducted concurrently during the fall 2019 study period. Thus, it is possible to pair these data to conduct analyses of relationships between PAOT in the Chute and hiking times and crowding-related delays that occur on the rock scramble section of the Ridge Trail. Hiking times on the rock scramble section of the Ridge Trail were calculated for all GPS routes with sufficient data density. All uphill hiking times were paired with the nearest-in-time PAOT counts in the Chute; the sample of downhill hiking routes was too small to include in this analysis. Mean uphill hiking times were estimated for varying ranges of PAOT to identify a potential threshold beyond which PAOT in the Chute causes crowding-related delay on the rock scramble section of the Ridge Trail. Statistical comparisons of hiking times were conducted using a one-way analysis of variance ($F = 21.41$, $p<0.001$), with hiking time on the rock scramble section of the Ridge Trail as the dependent variable and with ranges of PAOT in the Chute as the independent variable (Table 49).

TABLE 49. MEAN ROCK SCRAMBLE HIKING TIME, BY PAOT IN THE CHUTE (IN MINUTES)[17]

PAOT	COUNT	MEAN TRAVEL TIME
< 10	34	42.58[a]
10–19	55	43.42[a]
20–39	34	40.80[a]
40–49	27	45.47[a]
50–69	24	58.34[b]
70–99	16	64.18[b]
100+	23	81.01[c]

[17] Superscripts denote statistically different mean travel times at α=0.05.

Mean uphill hiking times on the rock scramble section of the Ridge Trail ranged from 41-45 minutes when PAOT in the Chute was below 50 people. There was a substantive and statistically significant increase in hiking times when there were 50 or more PAOT in the Chute, at which point mean hiking times increase to approximately one hour or more. When there are 100 or more PAOT in the Chute, mean hiking times increase to 81 minutes on average.

These findings suggest 49 PAOT in the Chute might be an appropriate crowding-related threshold for monitoring and managing visitor use on the Old Rag Mountain Trail. When there are fewer than 50 PAOT in the Chute, visitors generally ascend the rock scramble section of the Ridge Trail in about 45 minutes or less. When there are 50 or more PAOT in the Chute, the amount of time it takes to ascend the rock scramble section of the Ridge Trail increases to a statistically significant degree.

PAOT on Old Rag Summit

As noted, respondents to the Old Rag visitor experience survey were presented with a series of photo simulations depicting varying numbers of PAOT in the Old Rag summit viewscape. For each photo simulation presented to them, respondents were asked to indicate whether or not they would feel crowded if they were on the summit of Old Rag with the number of PAOT in the summit viewscape depicted in the photo. Results of this portion of the visitor experience survey are presented in Figure 20 and suggest:

- In photo simulations with 12 or fewer PAOT in the viewscape on the summit of Old Rag, very few respondents reported that they would feel crowded.
- A notable crowding response is first detectable in the survey response data for the photo simulation with 16 PAOT, at which point there is an increase in the percentage of visitors who reported they would feel crowded (20%).
- There is a more pronounced crowding response in the survey response data for the photo simulation with 24 PAOT, at which point a majority (53%) of survey respondents reported that they would feel crowded
- In photo simulations with 40 or more PAOT in the summit viewscape, over 80 percent of survey respondents reported that they would feel crowded
- These findings suggest that 20 PAOT in the summit viewscape may be an appropriate crowding-related threshold for monitoring and managing visitor use on the Old Rag Mountain Trail. Specifically, when there are 20 or fewer PAOT in the summit viewscape, less than half of survey respondents reported that they would feel crowded, but when there are 24 or more PAOT in the summit viewscape, a majority of survey respondents reported that they would feel crowded.

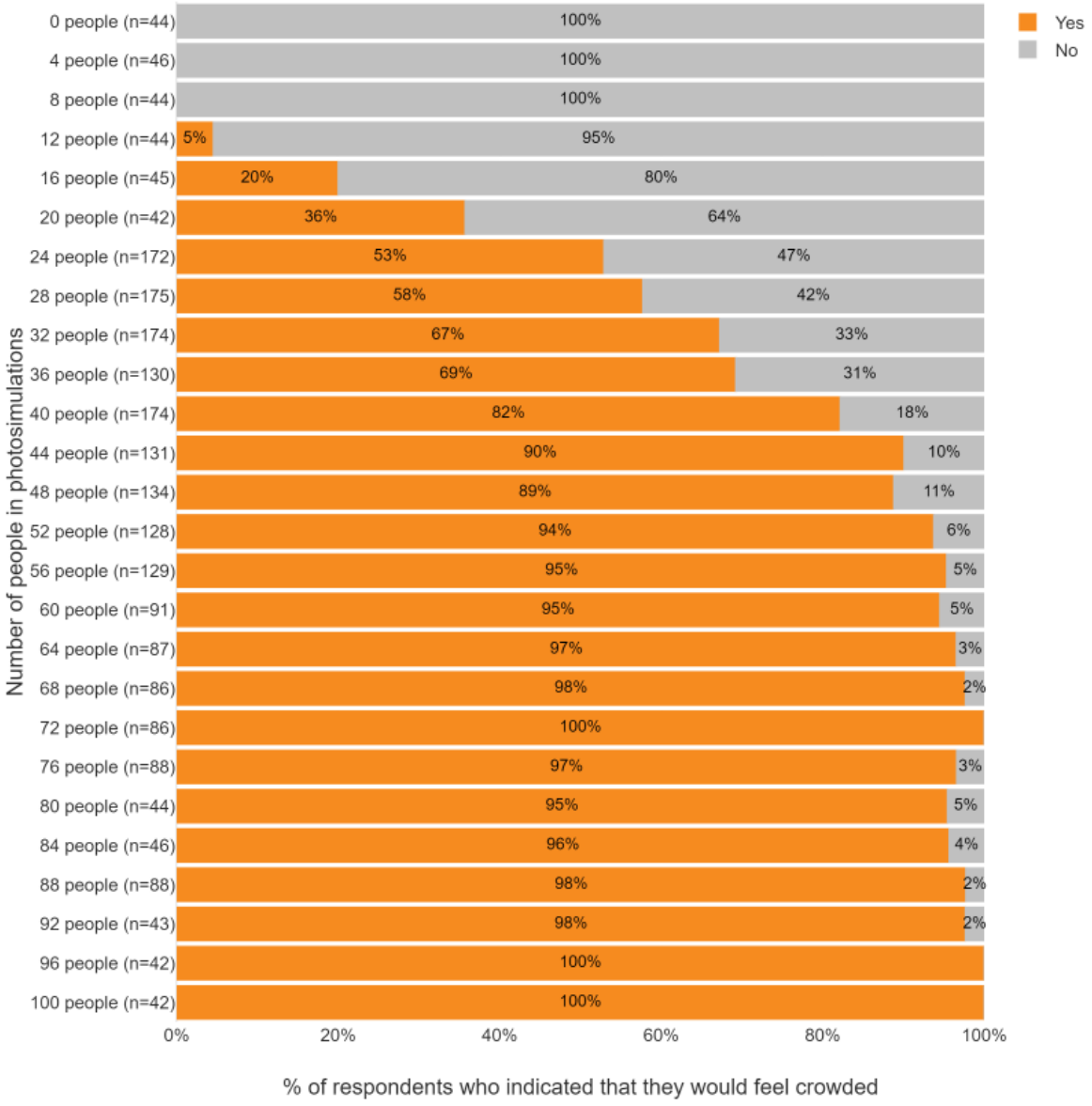

FIGURE 20. PERCENTAGE OF VISITORS WHO WOULD FEEL CROWDED ON THE SUMMIT OF OLD RAG, BY NUMBER OF PEOPLE-AT-ONE-TIME (PAOT) IN PHOTO SIMULATIONS

5.2 COMPARISON OF CURRENT PAOT LEVELS TO POTENTIAL CROWDING-RELATED THRESHOLDS

Summaries of PAOT count data for the Chute and the Old Rag summit viewscape suggest current visitor use conditions on weekend days and holidays on the Old Rag Mountain Trail frequently exceed the potential crowding-related thresholds presented in the previous section (Table 50). Current weekday use conditions exceed the potential crowding-related thresholds only a small percentage of the time. For example:

- On weekend days and holidays, about half (52%) of all PAOT counts recorded in the Chute exceeded the potential threshold of 49 PAOT. On weekdays, only 4% of the PAOT counts in the Chute exceeded the potential threshold.
- On weekend days and holidays, about half (48%) of all PAOT counts recorded in the Old Rag summit viewscape exceeded the potential crowding related threshold of 20 PAOT. On weekdays, only 4% of the PAOT counts in the summit viewscape exceeded the potential threshold.
- The maximum PAOT count at each location exceeded the potential crowding-related thresholds on every weekend day and holiday PAOT counts were conducted (Table 13 and Table 15).

TABLE 50. PERCENTAGE OF PEOPLE-AT-ONE-TIME (PAOT) COUNTS EXCEEDING POTENTIAL CROWDING-RELATED THRESHOLDS

		WEEKEND/HOLIDAY		WEEKDAY	
LOCATION	POTENTIAL CROWDING THRESHOLD (PAOT)	TOTAL COUNTS	PERCENTAGE OF COUNTS EXCEEDING THRESHOLD	TOTAL COUNTS	PERCENTAGE OF COUNTS EXCEEDING THRESHOLD
Chute	50	157	52%	196	4%
Old Rag Summit Viewscape	20	162	48%	201	4%

6.0 SIMULATION MODELING

A simulation model of visitor use on the Old Rag Mountain Trail was developed as a key component of the Old Rag Mountain Visitor Use Study. The specific purposes of the simulation model developed for this study are to provide:

- Precise, quantitative information about visitor use and crowding conditions in The Chute and in the Old Rag summit viewscape during "typically busy" weekend days and holidays during the 2019 fall foliage season.
- Scientifically rigorous estimates of the maximum number of visitors that can be accommodated per day on the Old Rag Mountain Trail without exceeding potential crowding-related capacities in The Chute and in the Old Rag summit viewscape.

This section of the report is organized into sub-sections that present: 1) an overview of the model; 2) model input data analysis methods and results; 3) model algorithm and programming; 4) simulation analysis methods and results; and 5) model validation methods and results.

6.1 METHODS

Model Overview

The study area for the Old Rag Mountain Visitor Use Model includes the entire Old Rag Mountain Trail, as depicted in green in Figure 1 and described in Section 2.1. Daily visitor use from Nethers, and to a lesser extent from Berry Hollow, provide the basis for programming the Old Rag Mountain Visitor Use Model and conducting simulations with the model. Both the Chute and the summit viewscape are points of focus for estimating visitor use and crowding-related capacities on the Old Rag Mountain Trail with the computer simulation model.

The following data served as the primary source of inputs for the Old Rag Mountain Visitor Use Model developed for this study:

- Visitor use counts
- People-at-one-time (PAOT) counts in the Chute
- PAOT counts in the Old Rag summit viewscape
- GPS route tracking

The methods used to collect these data are described in detail in Section 2.2 of this report and descriptive summaries of these data are presented in Section 3.1.

Model Input Analysis

The visitor use data collected in this study during the 2019 fall foliage season were analyzed to develop the model inputs needed to program the Old Rag Mountain Visitor Use Model and to conduct model simulations. The methods and results of these analyses are summarized in this sub-section of the report.

Hourly Visitor Use

Hourly visitor use levels specified in the simulation model were derived from calibrated visitor use counts and corresponding estimates of individual arrivals at each of the three trail counter locations in the study area. The calibrated hourly visitor arrivals from three weekend days in fall 2019 (October 12, October 13, October 19) were averaged to represent visitor use conditions on "typically busy" weekend days or holidays during fall foliage season. These average hourly visitor arrivals were transformed from estimates of individuals to estimates of the hourly number of visitor group arrivals by multiplying them by a "groups per people" factor. This factor was derived by dividing the number of groups in the frequency distribution presented in Table 52, by the number of people contained within the groups. The average hourly visitor group arrivals in Table 51 were used to program the model to estimate visitor use conditions on the Old Rag Mountain Trail on "typically-busy" weekend days and holidays during the fall foliage season.

TABLE 51. AVERAGE HOURLY VISITOR GROUP ARRIVALS, BY POINT OF ACCESS TO THE OLD RAG MOUNTAIN TRAIL (OCTOBER 12, 13, AND 19, 2019)

HOUR	RIDGE TRAIL	WEAKLY HOLLOW FIRE ROAD	BERRY HOLLOW
12:00 a.m.–1:00 a.m.	0	0	0
1:00 a.m.–2:00 a.m.	0	0	0
2:00 a.m.–3:00 a.m.	0	0	0
3:00 a.m.–4:00 a.m.	0	0	0
4:00 a.m.–5:00 a.m.	6	0	0
5:00 a.m.–6:00 a.m.	3	0	0
6:00 a.m.–7:00 a.m.	5	0	1
7:00 a.m.–8:00 a.m.	24	1	1
8:00 a.m.–9:00 a.m.	72	1	2
9:00 a.m.–10:00 a.m.	101	4	1
10:00 a.m.–11:00 a.m.	80	10	3
11:00 a.m.–12:00 p.m.	83	5	3
12:00 p.m.–1:00 p.m.	45	3	3
1:00 p.m.–2:00 p.m.	26	2	1
2:00 p.m.–3:00 p.m.	11	0	3
3:00 p.m.–4:00 p.m.	4	5	1
4:00 p.m.–5:00 p.m.	1	0	0

HOUR	RIDGE TRAIL	WEAKLY HOLLOW FIRE ROAD	BERRY HOLLOW
5:00 p.m.–6:00 p.m.	0	0	0
6:00 p.m.–7:00 p.m.	0	0	0
7:00 p.m.–8:00 p.m.	0	0	0
8:00 p.m.–9:00 p.m.	0	0	0
9:00 p.m.–10:00 p.m.	0	0	0
10:00 p.m.–11:00 p.m.	0	0	0
11:00 p.m.–12:00 a.m.	0	0	0
Total Daily Group Arrivals	460	31	19

Visitor Group Size

The frequency distribution of group sizes for simulated visitor groups in the model was derived from analysis of the GPS administration contact log data with extreme outliers removed (group size ≥ 60; Table 52). The group size frequency distribution in Table 52 was programmed into the model to assign group sizes to simulated visitor groups at each of the three points of access into the Old Rag Mountain Trail system.

TABLE 52. DISTRIBUTION OF VISITOR GROUP SIZES

GROUP SIZE	COUNT	PERCENT
1	60	13%
2	244	53%
3	62	14%
4	43	9%
5	20	4%
6	8	2%
7	4	1%
8	3	1%
9	2	<1%
10	3	1%
11	1	<1%
12	1	<1%
13	1	<1%
15	1	<1%
16	3	1%
20	1	<1%
29	1	<1%
30	1	<1%
Total	459	100%

Visitor Hiking Routes

As noted, the GPS route tracking data were analyzed to estimate the distribution of hiking routes on the Old Rag Mountain Trail for visitor groups who started their hikes at Nethers. The clockwise and counterclockwise hiking route distributions reported in Table 5 and Table 6 were programmed into the Old Rag Mountain Visitor Use Model to assign, for each simulated visitor group originating at Nethers, their hiking route along the Old Rag Mountain Trail, including whether or not the group traveled through the Chute and if they visited the summit. For simulated visitor groups originating at Berry Hollow, three-quarters were assigned to hike to the Old Rag summit via the Saddle Trail and return to Berry Hollow, while one-quarter were assigned to hike on the Saddle Trail toward the summit but not to it and return to Berry Hollow.

Hiking Times and Summit Dwell Times

As noted, the GPS route tracking data were analyzed to estimate mean and standard deviations of hiking times by trail segment and hiking direction along the Old Rag Mountain Trail. The means and standard deviations for hiking times by trail segment were used to specify lognormal distributions in the Old Rag Mountain Visitor Use Model to assign segment-specific hiking times to simulated visitor groups. As noted in Section 5.1, mean uphill hiking times through the rock scramble vary as a function of PAOT in the Chute during busy periods (Table 49). As such, hiking times for the rock scramble trail segment were assigned to simulated visitor groups dynamically in the model based on PAOT in the Chute at the time each simulated group arrived there. In other words, simulated visitor groups who hiked uphill through the rock scramble during times when PAOT in the Chute was relatively low were assigned shorter hiking times for the rock scramble than simulated visitor groups who hiked the rock scramble when PAOT in the Chute was higher.

As noted, the GPS route tracking data were analyzed to estimate the mean of dwell times on the Old Rag summit for those GPS study participants who hiked to the summit (Figure 15). The mean and corresponding standard deviation were used to specify a lognormal distribution in the Old Rag Mountain Visitor Use Model to assign summit dwell times for simulated visitor groups who visited the summit during their hike.

Model Algorithm and Programming

The results of the model input analyses described in the preceding sub-sections were used to develop the Old Rag Mountain Visitor Use Model. The model was developed using ExtendSim, a discrete-event systems simulation software, and was programmed to:

- Estimate visitor use conditions on the Old Rag Mountain Trail based on the level of visitor use selected to represent “typically-busy” weekend days and holidays during the 2019 fall foliage season

- Estimate crowding-related capacities for daily visitor use on the Old Rag Mountain Trail

The sequence of processes that occurs within the Old Rag Mountain Visitor Use Model is as follows:

- Simulated visitor groups are generated at the three primary access points to the Old Rag Mountain Trail System, according to hourly arrival distributions derived from visitor use counts (Table 51).
- Simulated visitor groups are attributed with group sizes, hiking routes, hiking times, and summit dwell times based on frequency distributions derived from GPS route tracking analyses (see Table 52, Table 5, Table 6, Table 49, and Figure 15, respectively).
- The rock scramble area is programmed in the model to "hold" simulated visitor groups for amounts of hiking time assigned based on the number of people in the Chute at the time of arrival to the rock scramble (Table 49). The number of people in the Chute is estimated in the model as a function of the total number of people in the rock scramble trail segment.
- The summit area is programmed in the model to "hold" simulated visitor groups for amounts of time based on a summit dwell time distribution derived from GPS route tracking analyses (Figure 15).
- The model monitors and records simulated crowding-related conditions (i.e., PAOT) in the Chute, the summit, and the summit viewscape, every five minutes of each simulated day.
- Simulated visitor groups are routed to exit the Old Rag Mountain Trail study area when their simulated hikes are completed.

These modeling processes are stochastic, meaning the outcomes vary with each replication of the model. Thus, mean values of outcome variables of interest are computed based on the results of multiple replications of the model. Outputs from the Old Rag Mountain Visitor Use Model were computed by averaging the results of 500 replications of the model.

6.2 SIMULATION ANALYSIS OF VISITOR USE AND CAPACITIES

The Old Rag Mountain Visitor Use Model was used to simulate visitor use conditions on "typically busy" weekend days and holidays during the 2019 fall foliage season. Results from these simulation runs were used to assess whether or not 2019 levels of fall foliage season visitation exceed preliminary draft thresholds for PAOT in the Chute and PAOT in the summit viewscape. The model was also used to estimate crowding-related capacities for the Old Rag Mountain Trail based on the preliminary draft thresholds.

This sub-section of the report first describes the potential draft thresholds that were used in the simulation analyses to estimate current visitor use conditions and crowding-related capacities for the Old Rag Mountain Trail. Then, results of the simulations of current visitor use conditions are presented, followed by results of simulation modeling to estimate crowding-related capacities for the Old Rag Mountain Trail.

Preliminary Draft Indicators and Thresholds for the Chute and the Summit Viewscape

Results from the analyses detailed in Section 5.0 suggest that when there are 50 or more PAOT in the Chute, visitor flow begins to breakdown and be impeded by the sheer number of people on the trail. As such, for the purposes of the simulation analyses conducted in this study, the following potential crowding-related threshold was specified for the Chute:

PAOT in the Chute does not exceed 49 at any time (0%) throughout the day, from 8:00 a.m. to 7:00 p.m.

Results from the visitor experience survey presented in Section 5.0 indicated that when there are 20 or fewer PAOT in the Old Rag summit viewscape, less than half of survey respondents reported that they would feel crowded. The results further indicated that when there are 24 or more PAOT in the summit viewscape, a majority of survey respondents reported that they would feel crowded. As such, for the purposes of the simulation analyses conducted in this study, the following potential crowding-related threshold was specified for the Old Rag summit viewscape:

PAOT in the summit viewscape does not exceed 20 for more than 10% of the time per day, from 8:00 a.m. to 7:00 p.m.

Simulation Results: Current Visitor Use Conditions

Simulation results of visitor use conditions on “typically busy” weekend days and holidays during the 2019 fall foliage season on the Old Rag Mountain Trail are presented in this sub-section. These results include estimates of PAOT in the Chute and estimates of PAOT in the summit viewscape, by time of day. The results also include information about the percentage of time the preliminary draft thresholds for PAOT were exceeded under current visitor use conditions simulations. As noted, the simulation analysis results are average values from 500 replications of the model for each set of results.

PAOT in the Chute

Mean PAOT in the Chute by time of day for the “typically busy” day simulations with the Old Rag Mountain Visitor Use Model is plotted in Figure 21. The horizontal line in Figure 21 represents the preliminary draft crowding-related threshold for PAOT in the Chute.

The results of the simulations suggest PAOT in the Chute exceeds the preliminary draft threshold approximately 36% of the time during the 8:00 a.m.–7:00 p.m. period on "typically busy" weekend days and holidays during the 2019 fall foliage season. These results suggest current levels of visitor use on the Old Rag Mountain Trail create potentially unacceptable levels of visitor crowding in the Chute, which negatively impacts visitors' experiences and may cause some visitors to travel off-trail to avoid crowding. This, in turn, may cause trampling impacts to vegetation and soils and may also increase the number of Search and Rescue incidents on Old Rag.

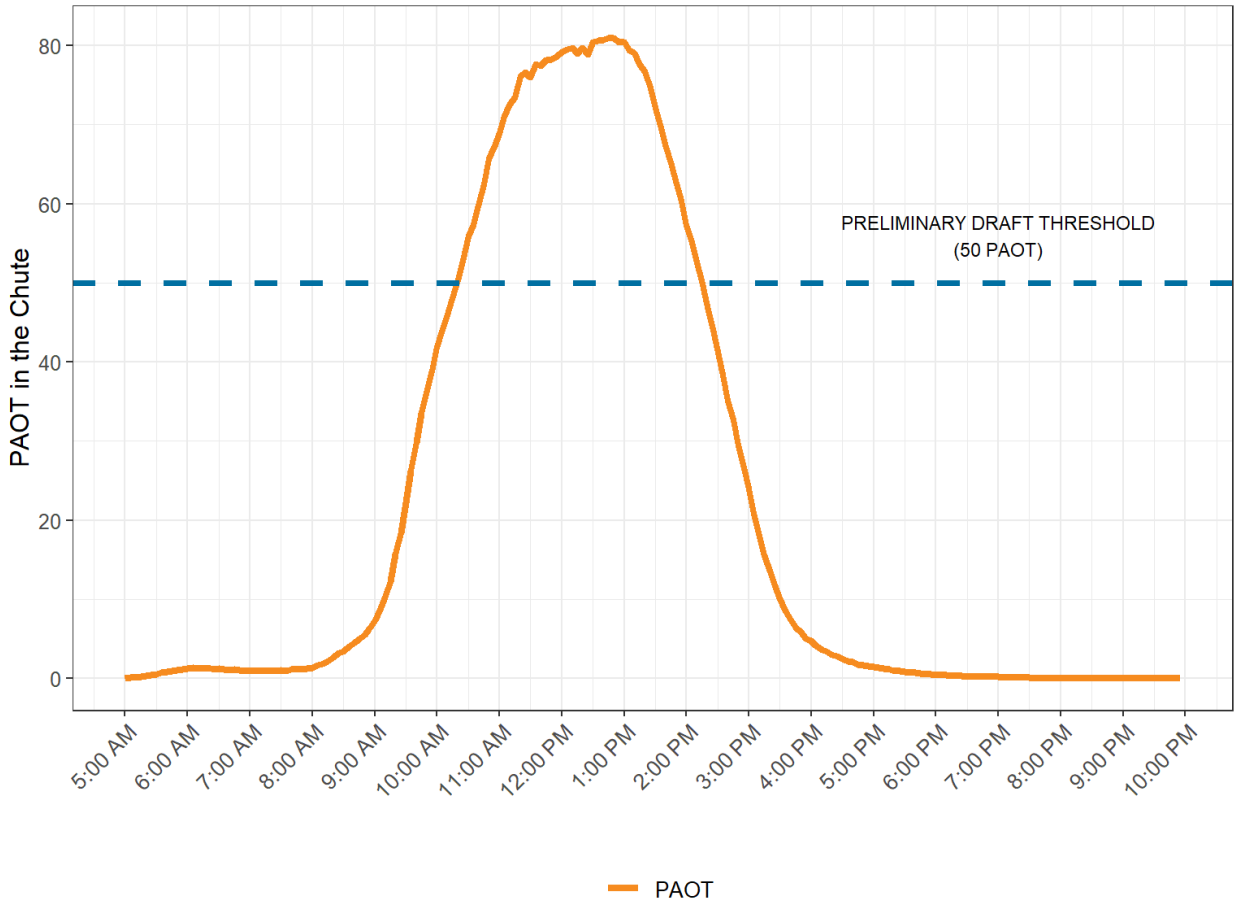

FIGURE 21. ESTIMATES OF "TYPICALLY BUSY" CONDITIONS—PAOT IN THE CHUTE

PAOT in the Summit Viewscape

Mean PAOT in the summit viewscape by time of day for the "typically busy" day simulations with the Old Rag Mountain Visitor Use Model are plotted in Figure 22. The horizontal line in Figure 22 represents the preliminary draft crowding-related threshold for PAOT in the summit viewscape.

The results of the simulations suggest PAOT in the summit viewscape exceeds the preliminary draft threshold approximately 32% of the time during the 8:00 a.m.–7:00 p.m. period on "typically busy" weekend days and holidays during the 2019 fall foliage season. These results suggest current levels of visitor use on the Old Rag Mountain Trail cause potentially unacceptable levels of visitor crowding on the Old Rag summit.

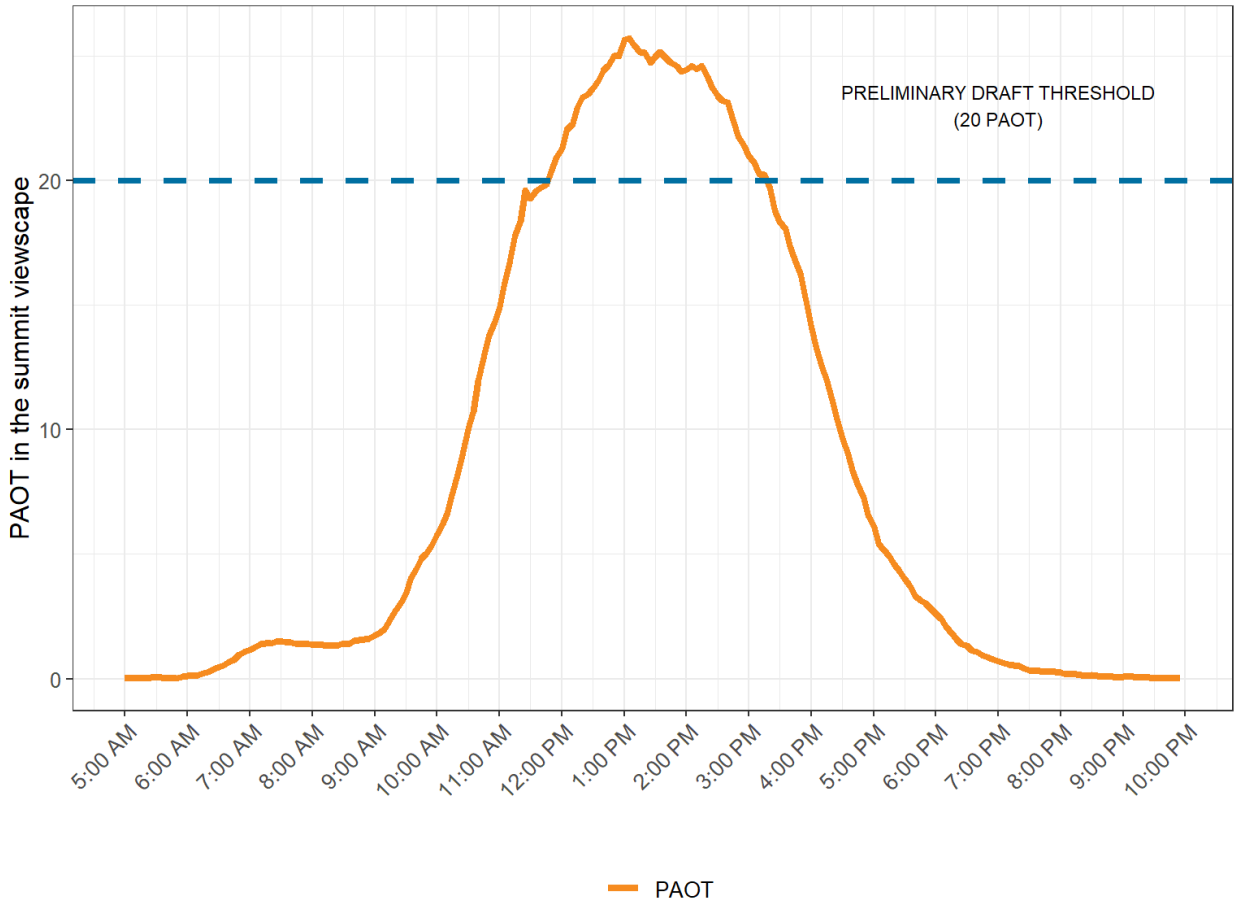

FIGURE 22. ESTIMATES OF "TYPICALLY BUSY" CONDITIONS—PAOT IN THE SUMMIT VIEWSCAPE

Simulation Results: Estimated Daily Crowding-related Capacities

This sub-section presents results of simulations to estimate crowding-related capacities for the Old Rag Mountain Trail. The capacity estimates are expressed as the maximum daily number of visitors that can be accommodated on the Old Rag Mountain Trail without exceeding the preliminary draft threshold for PAOT in the Chute, and separately, the maximum daily number of visitors that can be accommodated on the Old Rag Mountain Trail without exceeding the preliminary draft threshold for PAOT in the summit viewscape. An iterative process of

simulations with the Old Rag Mountain Visitor Use Model was used to derive the visitor capacity estimates with respect to each of the two preliminary draft thresholds; this was done by adjusting the simulated daily number of visitors in each subsequent simulation, based on the results of the preceding simulation. For example, if the simulated daily number of visitors in an iteration of the process produced results that exceeded the preliminary draft thresholds for PAOT, the subsequent simulations were programmed to simulate lower daily numbers of visitors. If the simulated daily number of visitors produced results that suggested more use could be accommodated without exceeding the preliminary draft thresholds for PAOT, the subsequent simulations were programmed to simulate higher numbers of daily visitors. This iterative process of simulation was continued to "solve for" the maximum daily number of visitors that can be accommodated on the Old Rag Mountain Trail, without exceeding the preliminary draft threshold for PAOT in the Chute, and separately, without exceeding the preliminary draft threshold for PAOT in the summit viewscape. As noted, the simulation analysis results at each step in the iterative process were average values from 500 replications of the Old Rag Mountain Visitor Use Model.

Results of the simulation analyses to estimate daily crowding-related capacities on the Old Rag Mountain Trail with respect to the preliminary draft thresholds for the Chute and the summit viewscape are presented in Figure 23 and Figure 24. The horizontal lines in Figure 23 and Figure 24 plot the estimated daily crowding-related capacities for visitors on the Old Rag Mountain Trail based on the preliminary draft thresholds for PAOT in the Chute and in the summit viewscape. The vertical bars in Figure 23 and Figure 24 plot the daily number of visitors on the Old Rag Mountain Trail measured during this study's 2019 fall counting period, organized by date and by descending order of daily number of visitors, respectively. The results of the simulations suggest:

- A maximum of approximately 1,100 visitors (or 26% fewer than the number of visitors simulated during "typically busy" weekend days and holidays) can be accommodated per day on the Old Rag Mountain Trail without exceeding the potential crowding-related threshold for PAOT in the Chute.
- A maximum of approximately 1,172 visitors (or 21% fewer than the number of visitors simulated during "typically busy" weekend days and holidays) can be accommodated per day on the Old Rag Mountain Trail without exceeding the crowding-related threshold for PAOT in the summit viewscape.
- The results in Figure 23 and Figure 24 further suggest that visitor use approached or exceeded the estimated crowding-related capacities for the Old Rag Mountain Trail on most weekend days during this study's fall 2019 counting period, with the exception of two weekend days with inclement weather (October 20 and October 27).

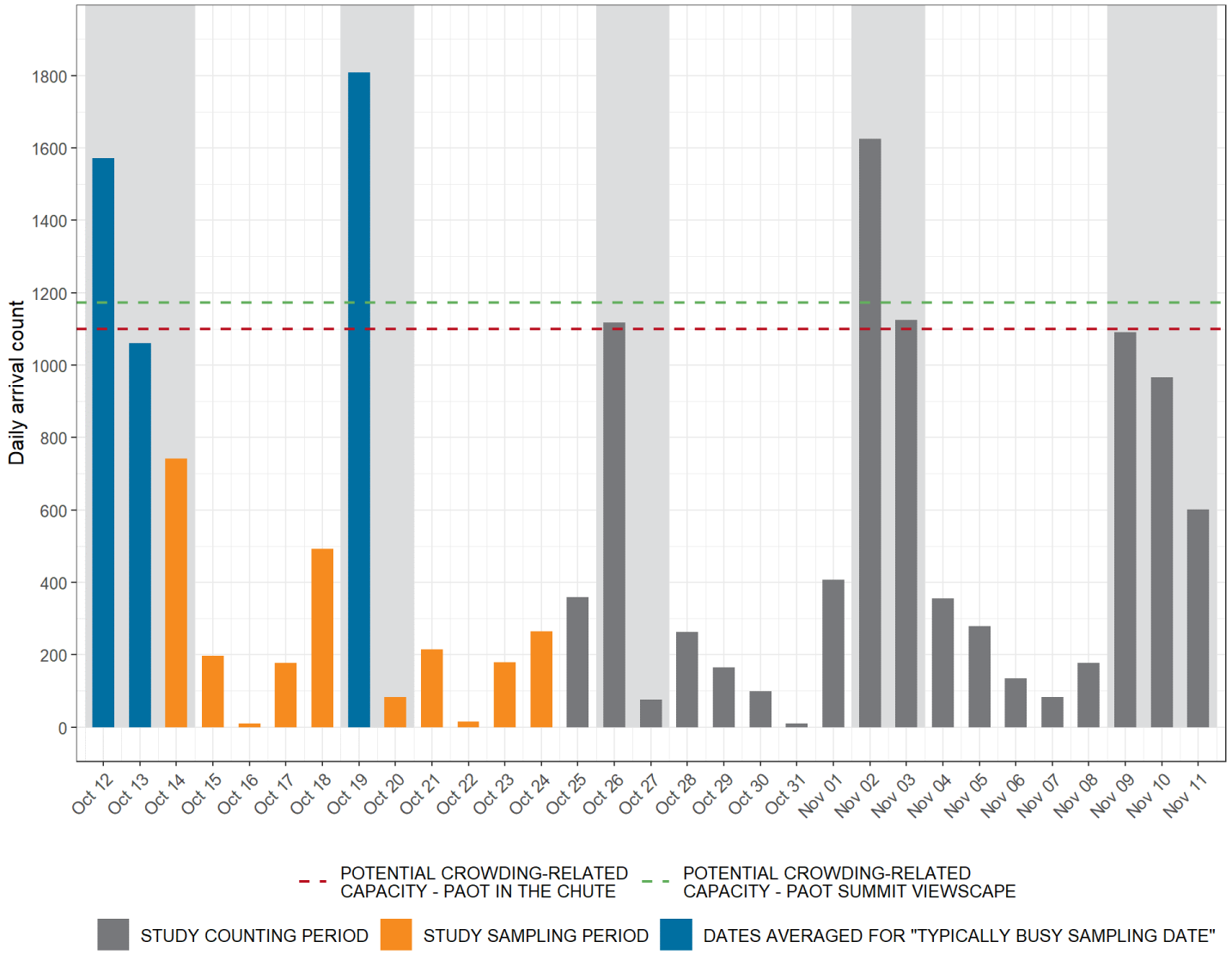

FIGURE 23. ESTIMATED CROWDING-RELATED CAPACITIES FOR DAILY NUMBER OF VISITORS ON THE OLD RAG MOUNTAIN TRAIL (GRAY SHADING INDICATES WEEKENDS/HOLIDAYS)

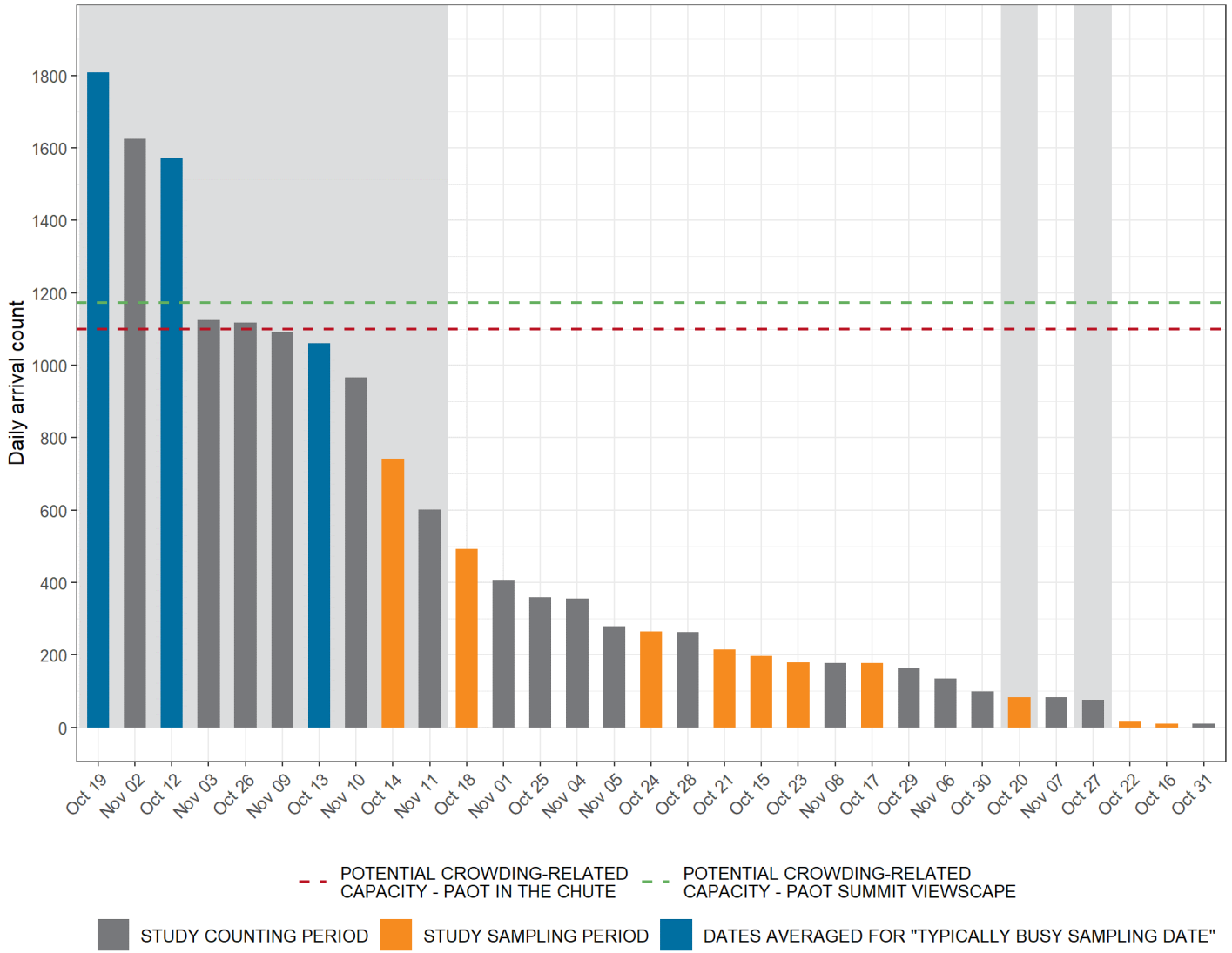

FIGURE 24. ESTIMATED CROWDING-RELATED CAPACITIES FOR DAILY NUMBER OF VISITORS ON THE OLD RAG MOUNTAIN TRAIL, SORTED IN DESCENDING ORDER OF DAILY NUMBER OF VISITORS (GRAY SHADING INDICATES WEEKENDS/HOLIDAYS)

Viewing the draft capacity estimates together in Figure 23 and Figure 24 suggests the Chute crowding-related capacity is slightly more limiting, but is similar to the summit viewscape crowding-related capacity. This, in turn, suggests that visitor use on the Old Rag Mountain Trail can be managed according to an overall range of approximately 1100-1200 visitors per day, based on the combined potential crowding-related capacities estimated in this study for the Old Rag Mountain Trail. That said, the thresholds used in the simulation analyses are hypothetical; capacity estimates would differ, if alternative crowding-related thresholds are specified by NPS.

These capacities are based on thresholds for crowding-related indicators for the Chute and the summit. There are many other potential indicators, thresholds, and capacities, for example, with respect to resource protection. Resource protection-related capacities for Old Rag may be exceeded, even if crowding-related capacities are not. Therefore, it is paramount for NPS to have science-based estimates of social and resource-related capacities for Old Rag and a systematic process to reconcile these capacities. Ultimately, capacities require management judgement by NPS officials to ensure that types and levels of visitor use on Old Rag do not cause unacceptable impact to visitors' experiences, wilderness values, and natural resources.

6.3 MODEL VALIDATION

Model validation is defined as “the process of determining whether a simulation model is an accurate representation of a system, for particular objectives of the study” (Law and Kelton 2000). In this project, a series of simulations was conducted with the Old Rag Mountain Visitor Use Model to assess the validity of the simulation model estimates and results. Specifically, estimates from the Old Rag Mountain Visitor Use Model for the two indicators of interest in this project (PAOT in the Chute and PAOT in the Old Rag summit viewscape) were validated against observation data collected on the Old Rag Mountain Trail during this study’s 2019 fall sampling period. Results of the model validation are presented in this sub-section.

PAOT in the Chute

As noted in Section 2.2, PAOT counts were conducted in the Chute during the 2019 fall sampling period. These data, coupled with visitor use counts for the days on which PAOT counts were conducted, provide a basis to assess the validity of the Old Rag Mountain Visitor Use Model. Specifically, a series of simulations was conducted with the model programmed to separately simulate the visitor volume for October 12, October 13, and October 19, 2019. The average PAOT estimates from 500 replications of the model for each simulated date were compared to the corresponding PAOT data collected through direct observation in the Chute (Figure 25, Figure 26, Figure 27). The scatterplots of direct observation counts and corresponding model estimates of PAOT in the Chute area closely overlap, suggesting the model estimates of PAOT are in the same range as on-the-ground observations of PAOT. These results provide a high degree of confidence in the validity of the Chute PAOT estimates from the Old Rag Mountain Visitor Use Model presented in this report.

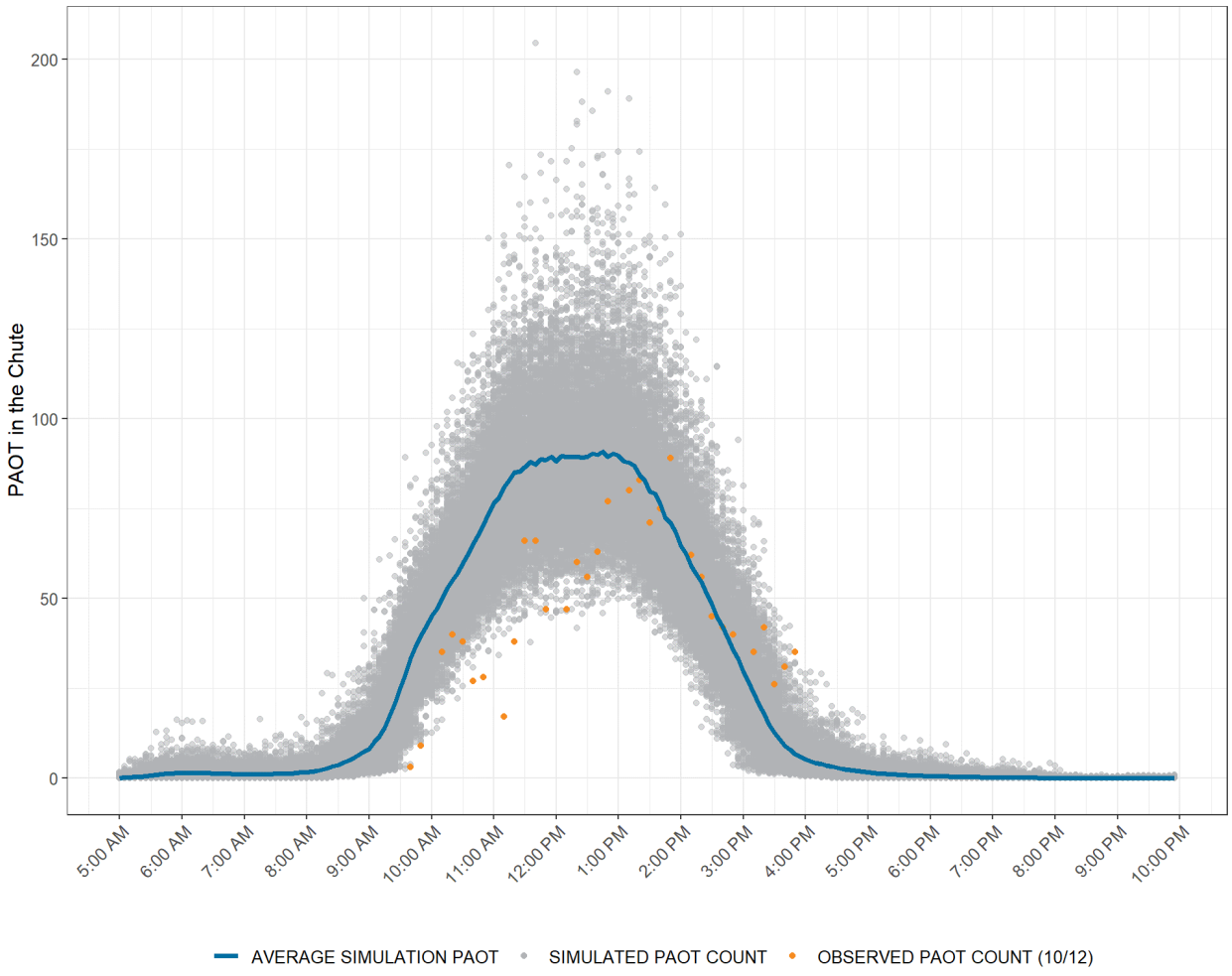

FIGURE 25. VALIDATION RESULTS FOR ESTIMATES OF PAOT IN THE CHUTE (OCTOBER 12, 2019)

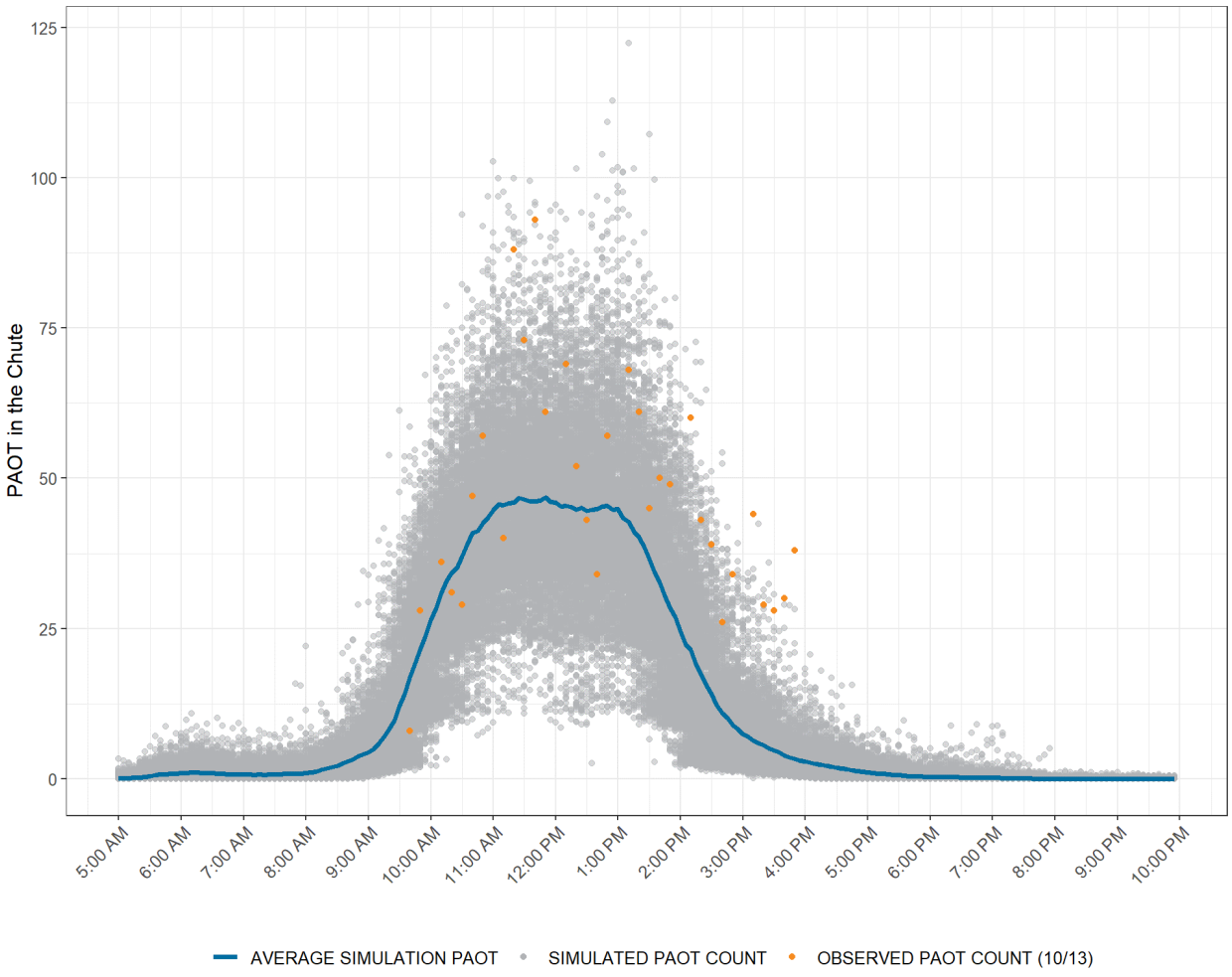

FIGURE 26. VALIDATION RESULTS FOR ESTIMATES OF PAOT IN THE CHUTE (OCTOBER 13, 2019)

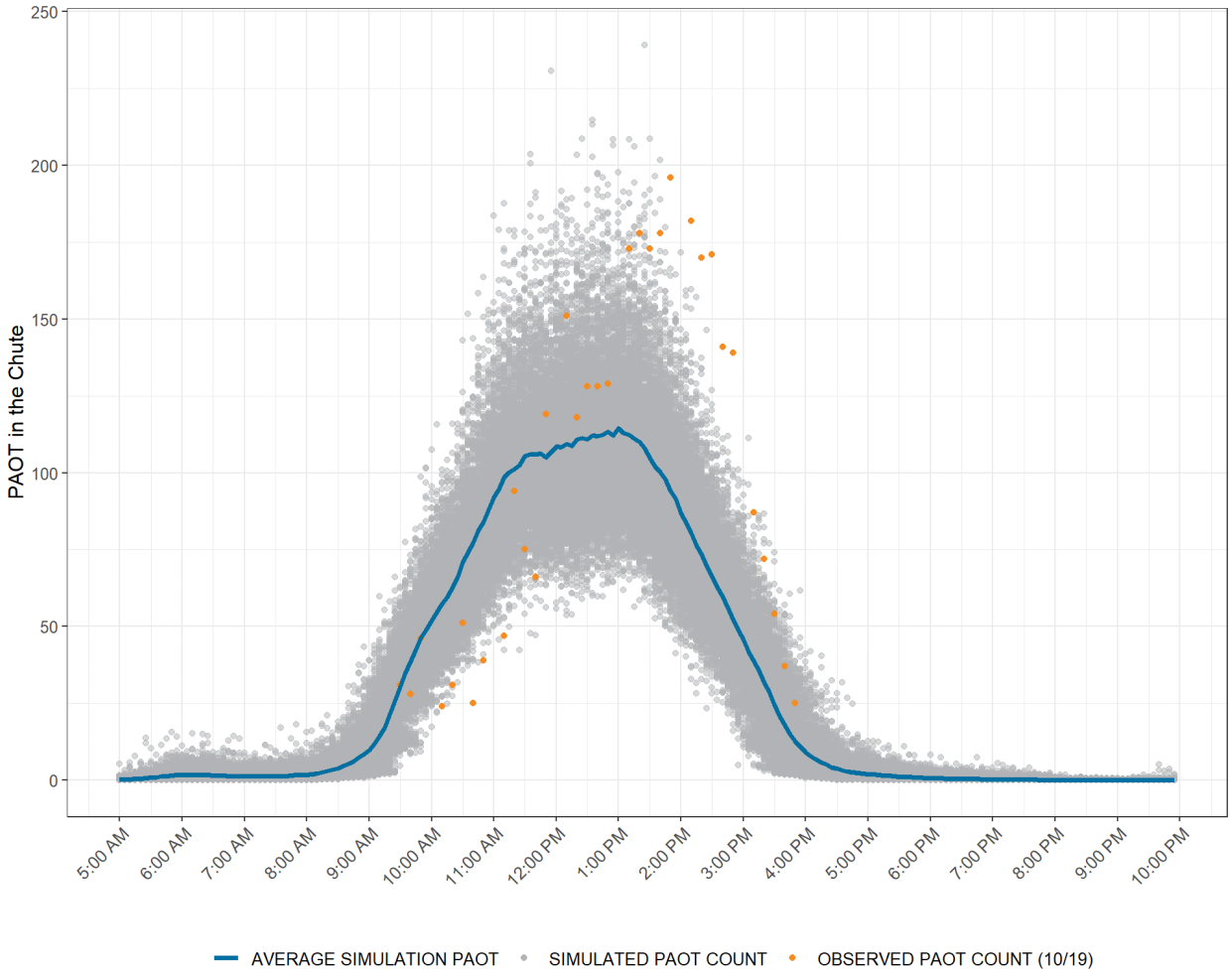

FIGURE 27. VALIDATION RESULTS FOR ESTIMATES OF PAOT IN THE CHUTE (OCTOBER 19, 2019)

PAOT in the Summit Viewscape

As noted in Section 2.2, PAOT counts were conducted in the Old Rag summit viewscape during the 2019 fall data collection period. These data, coupled with visitor use counts for the days on which PAOT counts were conducted, provide a basis to assess the validity of the Old Rag Mountain Visitor Use Model. Specifically, a series of simulations was conducted with the model programmed to separately simulate the visitor volume for October 12, October 13, and October 19, 2019. The average PAOT estimates from 500 replications of the model for each date were compared to the corresponding PAOT data collected through direct observation in the summit viewscape (Figure 28, Figure 29, Figure 30). The scatterplots of direct observation counts and corresponding model estimates of PAOT in the summit viewscape closely overlap, suggesting the model estimates of PAOT are in the same range as on-the-ground observations of PAOT. These results provide a high degree of confidence in the validity of the summit viewscape PAOT estimates from the Old Rag Mountain Visitor Use Model presented in this report.

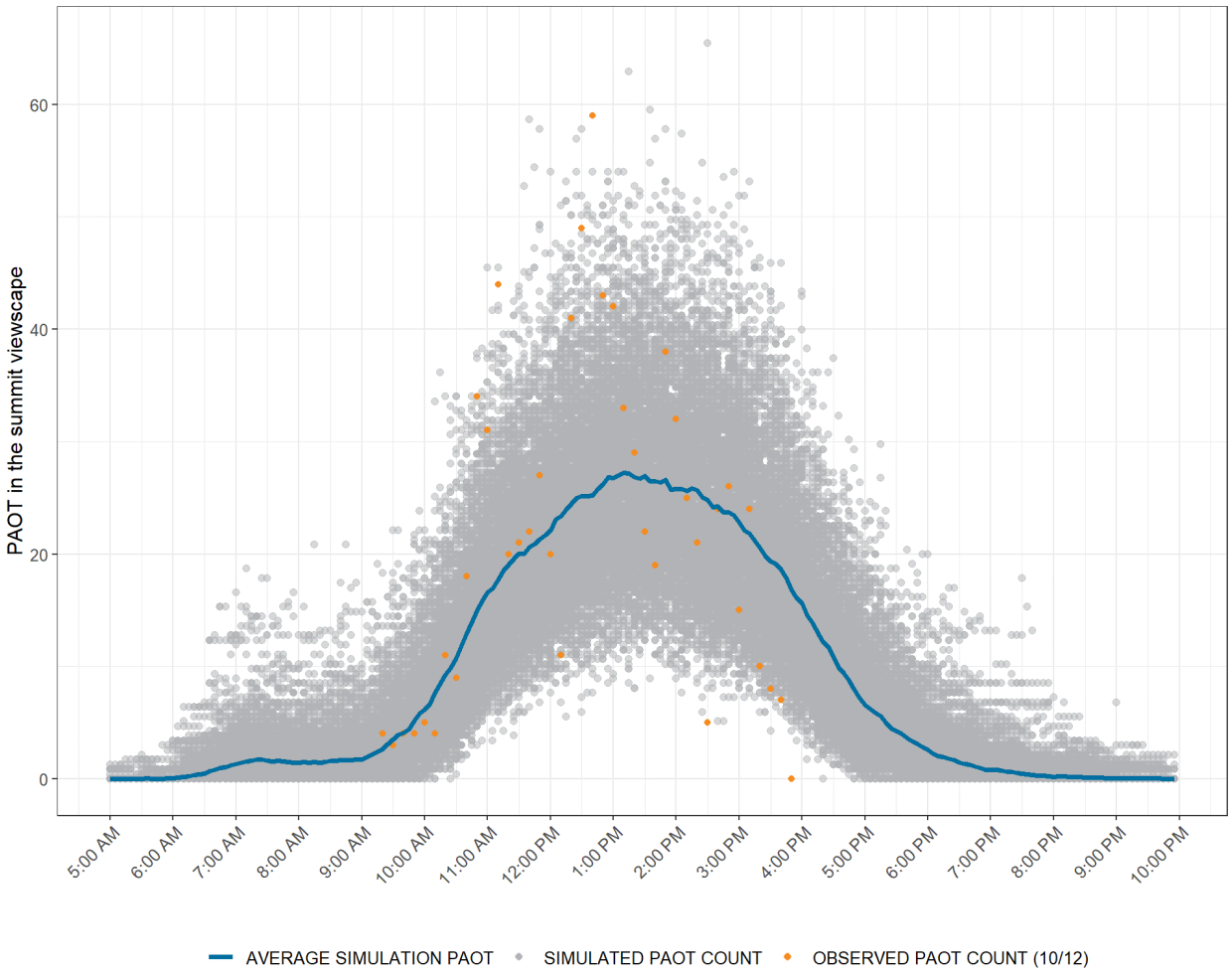

FIGURE 28. VALIDATION RESULTS FOR ESTIMATES OF PAOT IN THE SUMMIT VIEWSCAPE (OCTOBER 12, 2019)

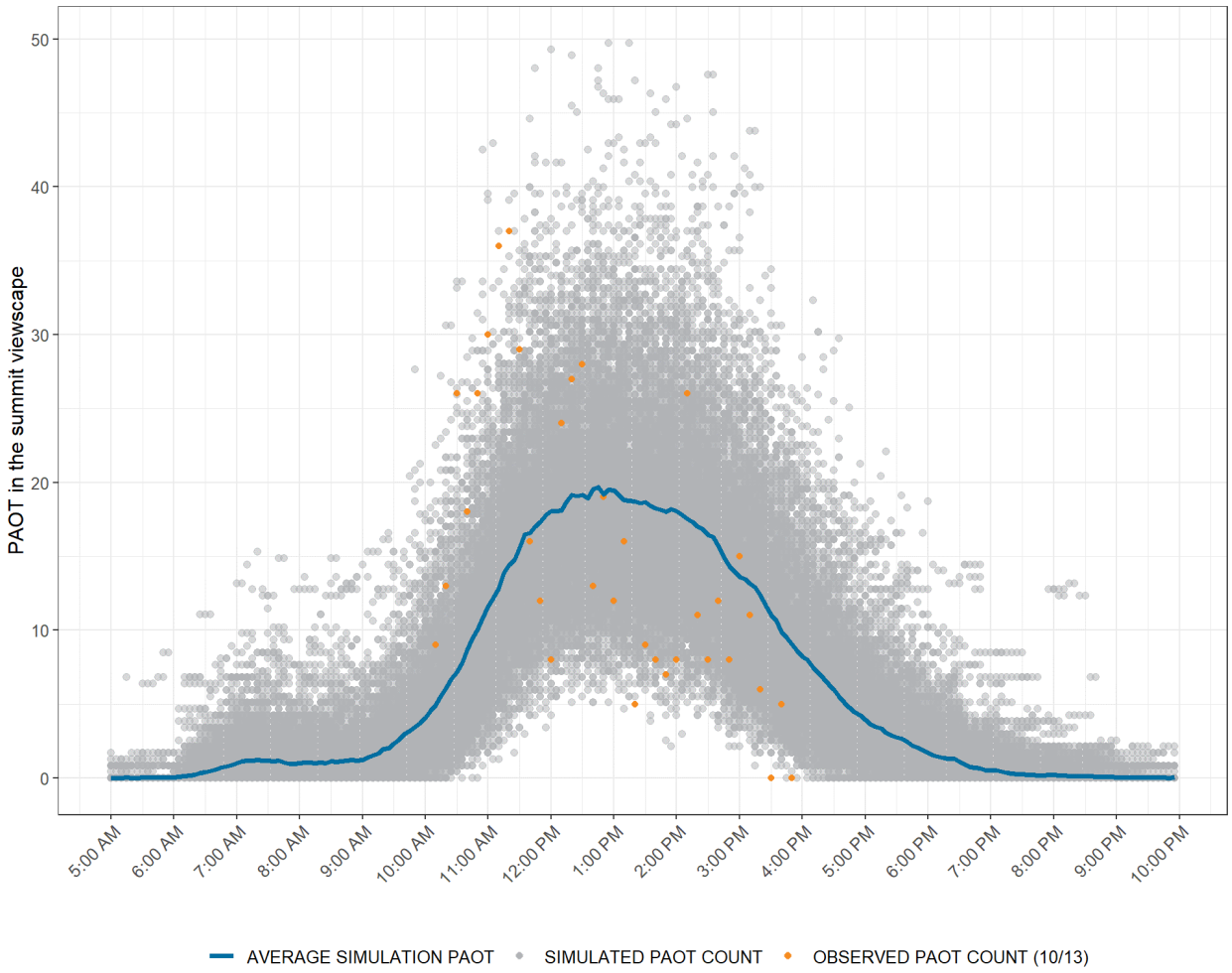

FIGURE 29. VALIDATION RESULTS FOR ESTIMATES OF PAOT IN THE SUMMIT VIEWSCAPE (OCTOBER 13, 2019)

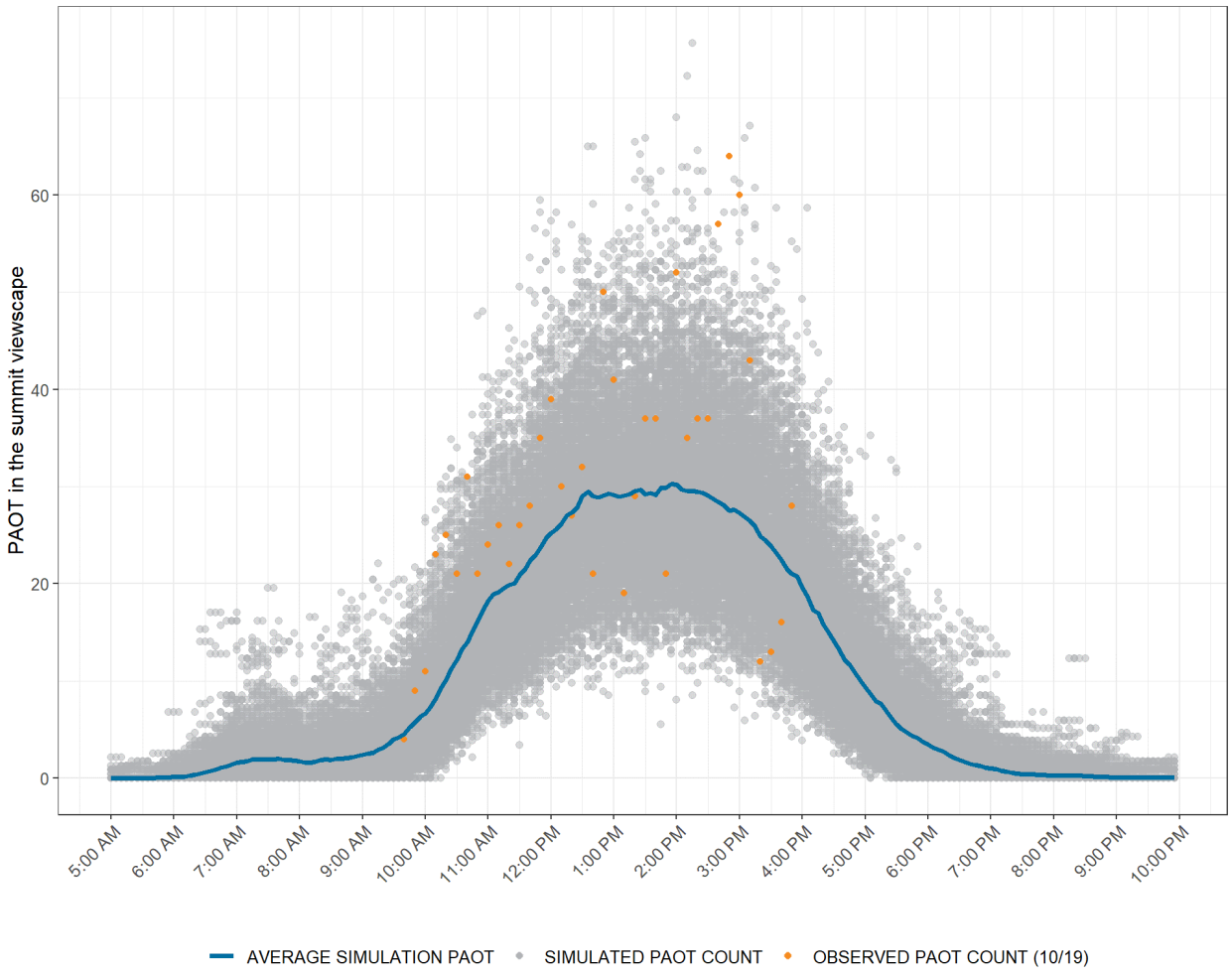

FIGURE 30. VALIDATION RESULTS FOR ESTIMATES OF PAOT IN THE SUMMIT VIEWSCAPE (OCTOBER 19, 2019)

55 Railroad Row
White River Junction, VT 05001
802.295.4999
www.rsginc.com