Wilderness Character on Shenandoah’s Old Rag Mountain: Opportunities for Solitude

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Abstract
The Shenandoah Wilderness was designated by Congress in 1976, and includes areas that receive extensive use from day hikers and backpackers alike. One such area within the Shenandoah Wilderness is Old Rag mountain, a popular destination for hikers seeking a challenging hike that offers scenic vistas and a rock scramble, and which can be hiked in a day. The Wilderness Act of 1964 states that wilderness areas must be managed to provide “outstanding opportunities for solitude or a primitive and unconfined type of recreation,” which presents a challenge to wilderness managers in Shenandoah National Park who seek to avoid placing undue restrictions on the number of people having access to the mountain.

The objective of this study was to answer three fundamental questions posed by the Backcountry and Wilderness division at Shenandoah National Park, providing managers with much-needed information about the existing conditions and trends in use along the Old Rag loop trail. The questions addressed in the study are how many people are currently using the Old Rag trail, what is the temporal distribution of that use, and what experiences and opportunities for solitude are visitors having on the Old Rag trail?

Through manual and automated collection of field data and the development of a Hiking Simulation Model, this study estimates that between 71,600 and 86,500 visitors are using the trail annually, that there is significant temporal variation in use patterns at the hourly, daily, and monthly time scale, and that opportunities for solitude vary greatly along with use patterns. While it is clear that opportunities for solitude and associated visitor experiences are sometimes impaired, this has been the case throughout the history of the park’s wilderness. It is recommended that managers provide additional public education and information, continue to build upon the baseline data collected in this study, and monitor trends in visitor use to ensure that opportunities for solitude are not degrading over time.
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Introduction

The Wilderness Act of 1964 developed a framework for the establishment of federally designated wilderness areas to be “administered for the use and enjoyment of the American people in such manner as will leave them unimpaired for future use and enjoyment as wilderness, and so as to provide for the protection of these areas, the preservation of their wilderness character, and for the gathering and dissemination of information regarding their use and enjoyment as wilderness.” Among other legislative requirements outlined by The Wilderness Act, wilderness areas are required to provide “outstanding opportunities for solitude or a primitive and unconfined type of recreation.”

While numerous large wilderness areas exist in the mountain west, wilderness areas in the east are much smaller and less plentiful, often resulting in crowding as visitors from across the region seek out wilderness experiences in the same few areas.

One such wilderness area overlaps with the popular Old Rag loop trail in Shenandoah National Park. Old Rag, a popular 7.2-mile loop trail on the eastern boundary of Shenandoah National Park, features a vertical elevation gain of over 2200 feet, a challenging rock scramble, and scenic vistas in all directions. The Old Rag loop consists of the Old Rag Ridge Trail, the Old Rag Saddle Trail, and the Weakley Hollow Fire Road. Since 1974, the park has leased a private field for overflow parking that can accommodate up to 250 vehicles at one time (NPS 2008). Visitors currently walk 0.8 miles along the side of State Route 600 in order to reach the trailhead, resulting in a total hiking distance of 8.8 miles round trip.

The National Park Service estimates that the trail receives approximately 50,000 visitors each year (NPS 2008), which results in crowding during peak visitation times during the summer and fall leaf change. This crowding presents a threat to solitude and results in the need for additional management in the wilderness area, thereby threatening the overall character of the wilderness (Landres et al 2008). In addition to a reduction in opportunities for solitude and primitive recreation, crowding has resulted in vegetation damage and unsafe conditions as visitors develop social trails to avoid lines in the rock scramble (Figure 1).

![Figure 1. Social trail adjacent to the rock scramble](image-url)
Shenandoah National Park is currently investigating the feasibility of several proposed management scenarios which would alter traffic and usage patterns for the Old Rag trail. It is hoped that some of the proposed changes might result in less crowding on the Old Rag trail. This would allow the area to recover from natural resource damage caused by social trails, reduce the degree of intensive management required to protect existing resources, restore the wilderness character of the area, and improve the overall visitor experience.

**Objective**

The objective of this study was to answer three fundamental questions posed by the Backcountry and Wilderness division at Shenandoah National Park, providing managers with much-needed information about the existing conditions and trends in use along the Old Rag loop trail.

**Question 1: How many people are using the trail?**

Prior to this study, no systematic visitor counts had been conducted for the Old Rag trail. Fee staff regularly conduct and record car counts at the leased parking area, but data have been limited to busy days of the year when park staff are present (weekends between March and November), and provide only a rough approximation of the total number of visitors using the trail. Data were not collected early in the morning or late in the afternoon, during periods of adverse weather, or on days when staff were assigned to other duty stations due to extenuating circumstances. The present study aimed to develop a robust data set with fewer gaps, finer resolution, and greater precision than data previously collected by the park, thereby providing managers with an accurate and detailed set of baseline data.

**Question 2: What is the temporal distribution of trail use?**

Park staff are aware that the Old Rag trail is among the most popular trails in the park, and that it receives a great deal of visitor use which results in crowding (Figure 2), but data collected in past studies are inadequate to parse out the temporal distribution of trail use.

Figure 2. Visitors wait in line to pass through upper “squeeze point” in rock scramble.
The present study aimed to allow trail use trends to be analyzed at hourly, daily, weekly, and monthly scales, thereby allowing managers to identify when opportunities for solitude were at their greatest, and when solitude may not be achievable along the trail corridor.

**Question 3: What experiences are visitors having?**

Since the Wilderness Act explicitly defines wilderness areas as being those areas where “outstanding opportunities for solitude” exist, it is important that trails passing through these designated areas do not prevent these opportunities from occurring. “Solitude” in wilderness is typically measured by the number of encounters that one group has with other groups while in the wilderness areas (Hall 2001, Dawson & Hendee 2009). Due to the unique nature of the Old Rag trail, three measures of solitude were established for the purpose of this study: wait times at “squeeze points” along the rock scramble, total number of encounters experienced by each group, and people at one time at the Old Rag summit.

**Methods**

**Data Collection**

In order to answer the primary questions outlined above, several types of data were collected in the park between July 2011 and March 2012. The majority of manual data collection took place between August and October due to greater anticipated visitor use during these months. The following data sets were collected as part of the study: hourly counts of visitors on the trail, hiking group size, travel direction, time delay at the rock scramble, line length at the rock scramble, and time spent at summit. Hourly car counts were also collected most weekends during the study period, but should be examined in a separate study to determine whether car counts accurately estimate total visitation to the mountain. Data on hiking speed were collected in a non-random manner, primarily by hiking the trail at different speeds with different people and by overhearing conversations about hiking times while collecting other data. A more accurate means of collecting hiking speed data would have been to conduct a survey of hikers exiting the trail or to issue GPS units with “tracklogs” to park visitors, but resource limitations and NPS regulations regarding visitor surveys presented challenges that were prohibitive. Details on each data set collected are outlined in Table 1, below.
Table 1. Data Collected

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cars in Parking Lot</td>
<td>Hourly car counts were taken by park fee staff. Data collection was limited to weekend days and a few week days during high-use periods. Gaps exist in the data sets due to the need for park staff to prioritize their fee collection and visitor use management duties above data collection.</td>
</tr>
<tr>
<td>Visitors per hour</td>
<td>Data were collected at two points along the trail using TrafX infrared trail counters. Counter data were calibrated using observational data (Figure 3). Data from the Ridge Trail counter were used as the primary data source for this study, while data from the Saddle Trail counter were used to support estimates of trail use patterns derived from manually collected data.</td>
</tr>
<tr>
<td>Party Size</td>
<td>Party size data (number of visitors per group) were collected on six days during the peak season. Manual data collection took place at the Ridge Trail trailhead and the Saddle Trail trailhead.</td>
</tr>
<tr>
<td>Proportion of travel in each direction</td>
<td>Direction of travel was manually recorded at the summit, the Ridge Trail trailhead, and the Saddle Trail trailhead.</td>
</tr>
<tr>
<td>Time spent at summit</td>
<td>From the primary access point to the summit, the entrance and exit time of every 5th party was recorded on three days during the peak season.</td>
</tr>
<tr>
<td>Speed of travel</td>
<td>I hiked the trail approximately twelve times at different speeds and recorded start and finish times. Additionally, I recorded all hiking times that I overheard in order to get a general sense of the range and mode of hiking speed.</td>
</tr>
<tr>
<td>Crowding at top of the rock scramble</td>
<td>Data on line length (number of people in queue) and time to get through the line were collected on peak visitation days.</td>
</tr>
<tr>
<td>Crowding at bottom of the rock scramble</td>
<td>Data on line length (number of people in queue) and time to get through the line were collected on peak visitation days.</td>
</tr>
</tbody>
</table>

Figure 3. Regression model for actual vs. automated hourly hiker counts (data collected on Sept 4, 2011 and Oct 22, 2011)
Trail Use Model

To overcome the inability to directly measure crowding along the trail, a model was developed to simulate visitor experiences along the trail (Figure 4). The model generates estimates of people at one time (PAOT) at the summit for each fifteen-minute time interval, and information on the number of groups surpassed, surpassed by, and encountered (going the other direction) for each group on the trail. These data permit two quantitative measures of crowding and subsequent opportunities for solitude.

![Figure 4. Steps of Hiking Simulation Model](image)

The Hiking Simulation Model was developed using Python scripting language (see Appendix A), so that simulations can be run on any standard desktop computer. While more complex models have been developed by others (Itami et al 2003, Gimblett et al 2000, Gajda et al 2000), they require considerably more input data and special software in order to operate. Additionally, very little has been done to verify the accuracy of these models, so it is unclear whether or not they would generate more meaningful results than the model used in this study. The ability of this model to run with few inputs and without special software also enables park managers and planners to develop their own scenarios of visitor use, run the model, and generate data on visitor experiences. This can be done without outside assistance or the need for expensive software.

The Python script operates on two data sets that are input as csv (comma-separated value) files. The first of these is a list of cumulative impedance values that were exported from the attribute table of an ArcMap-generated raster file. To create the raster file, a cost-distance calculation was conducted along the clockwise path of the Old Rag loop trail, then converted to a raster of integer values (Figure 5). An attribute table was then attached (see Appendix B) and the data were manually exported into a dbf file, which was subsequently converted to a csv file using Microsoft Excel. Now that the cumulative impedance values have been calculated and converted to csv format, there is no
need for managers or planners to replicate the process when conducting additional analyses with the model, but the script is written to allow for new impedance values with only slight modifications.

The second of the two data sets used by the Python script is a user-generated file containing data about groups using the trail. The csv file contains the start time, direction, base speed, and time at the summit for each group of hikers. These data can either be generated by stationing someone at the Ridge Trail trailhead, recording information for each group, or can be simulated using data from the TrafX trail counters and other information gathered during the study.

Start time is recorded in fifteen-minute increments, and is coded in integer values, with 0 representing the start of the day. For example, 0 represents 12:00am, 48 represents 12:00 noon, and 95 represents 11:45pm. Direction of travel is coded as 1 for clockwise travel and 2 for counterclockwise travel. Based on field data, approximately 90% of travel takes place in a clockwise direction, so for the purposes of this study, 90% of groups should be assigned a direction of 1, and 10% of groups should be assigned a direction of 2, with directions assigned randomly or based on observational data. The present version of the model does not allow for “up and back” travel, which represents a small fraction of overall trail use (estimated at between 0 and 6%), but may be integrated into future versions of the model. Speed is entered as miles per hour, and represents the approximate speed that a group would travel on a flat surface free of obstacles. For the purposes of the simulation runs for this report, speeds were randomly assigned to groups from a random distribution with a mean of 3.25 mph and a standard deviation of 0.625 mph. These base speeds are used to determine how much impedance a group can traverse in a fifteen-minute time step. Time at the summit is measured in minutes, and was used to “lag” groups when they reached the summit in the model. These values ranged from 2 to 72 minutes, and were randomly assigned to groups.
following the same distribution as the time at summit data that were manually recorded in the field (n=59 groups).

The Python script (Appendix A) works by importing these two data sets, simulating the hikers’ movement along the trail through time, and calculating the types and numbers of encounters that groups have with one another. After inputting data, the model operates in fifteen-minute time increments. With every iteration, each group is moved forward in space based on its base hiking speed. Interactions with other groups is determined by comparing the relative location of each group to each other group in the current time step to the relative location of each group to each other group in the previous time step. The model calculates encounters with groups going the other direction, instances of passing other groups, instances of being passed by other groups, and instances of traveling in the same space as another group (as determined by occupying the same 31 foot square raster cell). For each fifteen-minute time step, the model also calculates the number of groups (and individuals) at the summit to estimate people at one time. After running a simulation of a given day, the model exports the data (along with labels) to a csv file, which can then be easily manipulated in Excel in order to further examine the data.

Assumptions of the Model

The model makes several assumptions about visitor use and hiking patterns to increase ease of use and to compensate for the minimal amount of input data needed to generate output. While these assumptions are unlikely to cause major changes to the output variables, they are worthy of discussion in order to fully explain the processes that generate data for land managers.

The first potential source of error, discussed above, is that hiking speeds were randomly assigned to simulated groups on the trail based on a rough estimate of the mean and average range of hiking speeds for all groups. Based on this assumption, it is possible for a group in the model to complete the Old Rag loop in as little as 1.75 hours or as much as 8.75 hours, but the average group in the model will complete the 7.2 mile loop in 3.5 hours.

The model is based upon the assumption that hiking speed has a linear relationship with the slope of the terrain, and that the relationship does not change over time as hikers become fatigued. While RBSim and other models include a visitor fatigue factor and human decision simulations (Itami et al 2003), the model developed for this project does not include these factors since they require data about visitor fitness and information about cognitive processes related to decision-making. While it would be ideal to include these sorts of processes in the model, gathering the
necessary data would require access to resources that neither the Park Service nor the researcher are able to acquire. The linear relationship used in the model varies the timing of visitor encounters, but differences in most variables should be negligible. The only variable which might exhibit skew based on this assumption is “SamePlace,” which estimates the number of time steps that a group spends in the same grid cell as another group. If two groups were to start at the same time, spend the same amount of time at the summit, and travel at the same speed, they will share the same grid cells for the duration of the hike, resulting in higher “SamePlace” values. It is highly unlikely that two groups will share the exact same speed so long as the speeds are randomly generated using the current method, which includes ten digits in the speed. The model would only be expected to over-predict “SamePlace” outputs if hiking speeds are rounded off to fewer significant figures. This variable was excluded from analysis due to the potential for error, but may be refined in future versions of the model.

Another significant assumption of the model is that groups stay together throughout the duration of the hike. In practice, this is seldom the case with larger groups, which tend to split into subgroups for the ascent and then regroup at the summit. As a result of this assumption, the number of encounters recorded for each group will likely be smaller than the actual number of encounters that a group experiences on a hike, since the one large group in the model will be encountered as multiple small groups in an actual hike. The encounter data that are generated by the model therefore represent a “best case scenario” from a crowding perspective, since lower numbers of encounters are desirable in a wilderness area.

Finally, the current version of the model uses fifteen-minute time steps to simulate movement along the trail. The fifteen-minute increment was chosen since it represents the greatest resolution of data collected for the project, and represents a reasonable balance of accuracy and efficiency for the purpose of the model and for future data collection. A finer temporal resolution would result in greater precision of PAOT outputs at the summit and rock scramble, but would not significantly improve the accuracy of group encounter outputs.

**Results**

The field data collected and the output of the Hiking Simulation Model yielded preliminary answers to all three of the questions posed by Shenandoah National Park. Below is a summary of results, followed by a discussion of each of the variables investigated.
Question 1: How many people are using the trail?

Between September 3, 2011, and March 2, 2012, the Ridge Trail TrafX counter recorded 26,766 hikers, yielding a corrected estimate of 35,600 hikers passing the trail counter (most of whom completed the full loop trail), or approximately 29,500 hikers starting up the Ridge Trail in a clockwise direction. Assuming that the proportion of groups hiking up to the summit and back by the same route is less than 6% (best estimate based on data collected in the field), this indicates a total count of approximately 34,900 hikers during this six month period. Park estimates of monthly visitation between 1969 and 2006 (NPS 2008) suggest that only about 40% of annual visitation takes place between the start of September and the end of February. Assuming the park’s estimates to be accurate, that visitation patterns on Old Rag resemble visitation patterns for the park as a whole, and that the observed trends remain in effect, we can project that the overall visitation of Old Rag between September 2011 and August 2012 will fall somewhere between 71,600 and 86,500 visitors - significantly more than the Park Service’s 2008 estimate of 50,000 Old Rag visitors annually. This estimate can be further refined as additional trail counter data are collected.

The size of groups was recorded at both the Ridge Trail and the Saddle Trail, resulting in a sample of six days and 767 groups. The mean daily party size varied between 2.7 and 3.6 on the six days sampled, with a cumulative mean of 3.2 hikers per party and a standard deviation of 2.9 hikers. The number of hikers per group ranged from 1 to 33. Not surprisingly, the distribution of party size exhibits a strong right skew since most hikers prefer to travel in small groups (Figure 6).

![Figure 6. Frequency Distribution of Party Size](image)
Question 2: What is the temporal distribution of trail use?

A TrafX infrared trail counter was installed out of sight along the Ridge Trail, just outside the wilderness boundary (Figure 7). The counter collected hourly data from September 3, 2011 to March 4, 2012 (184 days). One-hour gaps in the data occur approximately once a month during which time data were downloaded and the trail counters were maintained. An effort was made to conduct maintenance during off-peak hiking times to preserve data quality during peak periods. Strong trends were identified for all three temporal variables examined: time of day, day of week, and month of year.

Hourly distribution of hikers approximated a normal distribution, and was concentrated during the middle of the day (Figure 8). It would seem reasonable to expect that during the summer when daylight hours are longer, trail use would likely be distributed over a greater time-span, but data have not yet been collected for summer months. While there was some trail use between the hours of 7:00pm and 7:00am, the daily average number of hikers per hour was less than one for these time periods, and the majority of instances of trail use during these hours were during peak use days, with the highest hourly count during the entire study period being 16.5 hikers per hour (recorded during the 6:00AM hour on October 22). The lack of night time trail use indicates that the Hiking Simulation Model’s use of daily time increments should not present a significant source of error since very few groups cross the midnight boundary when the model resets for the next day.
The day of the week also had a significant impact on the number of hikers using the trail, with a majority (66%) of visitor use taking place on weekends, and with lowest usage during mid-week (Figure 9). Since manual data collection took place on weekends and shoulder days (Friday and Monday) during the peak season, it is reasonable to expect that crowding trends captured reflect those trends experienced during high-use days.

As previous estimates suggested, month of the year also has a significant impact on visitor use (Figure 10). While data have not yet been collected for the summer months, trends exhibited in September through February closely correspond to those trends estimated by the park. A notable difference however, is that the disparity between October and November visitation appears to be
much less than estimated by park-wide visitation data, and winter-time use appears to be significantly greater for Old Rag than for the park at large (NPS 2008).

To determine the proportion of hikers traveling in each direction, the direction of travel for groups was recorded at both trailheads and the direction of travel of each individual was recorded at the summit on two separate days. Ninety-one percent of hikers reached the summit via the Ridge Trail (n=1234), and 91% of hikers descended via the Saddle Trail (n=1059), suggesting that approximately 9 out of 10 groups hiking Old Rag follow a clockwise path of travel. While a few groups travel up and back via the same route, without conducting a survey or photographing every hiker using an infrared-triggered camera, it is not possible to estimate the proportion of groups with any precision. On extremely busy days, some hikers reported that they had ascended via the Ridge Trail until reaching an extraordinarily long line at the rock scramble, where they then decided to turn around and return to the trailhead rather than continue to the summit.

**Question 3: What experiences are visitors having?**

The final attributes investigated were the degree of solitude that visitors experience while hiking Old Rag and the length of lines that developed at the two squeeze points in the rock scramble.

Solitude was measured by the number of encounters each group has with each other group and the number of people at one time (PAOT) at the summit. To estimate these two variables, the Hiking Simulation Model was run on two manually collected data sets – one from a moderately high usage day (September 4, 2011 – 524 visitors) and one from the day of highest usage during the study period (October 22 – 1701 visitors). As described in the Methods section of this report, hiking speed
and time spent at the summit were randomly assigned to groups based on data collected manually throughout the study period, while all other variables were input from direct observation on these two dates. Random variables were re-assigned ten times to generate ten input data sets for each date, and the model was then run using each input data set. Averages were then manually calculated to identify mean measures of crowding on each date. While there was some variation in the results from one model run to the next, the overall trends remained consistent throughout all runs of the model, suggesting that speed and time spent at summit have only limited impact on the outputs so long as they retain their original frequency distribution.

On September 4, the moderate visitation day, it is estimated that at least 65 percent of groups encountered 51 or more groups during their circuit hike on Old Rag (Figure 11). Significantly less than five percent of groups encountered ten or fewer other groups while hiking the trail. It should also be noted that approximately ten percent of groups encountered over 100 other groups while hiking the trail. These ten percent consisted of those groups hiking the trail in a counterclockwise direction, so they encountered almost every other group on the trail, albeit for only a short period of time as they were traveling in opposite directions.

Figure 11. Estimated frequency of encounters with other hikers (Sept 4, 2011 – 524 hikers in 171 groups)
On October 22, the busiest day of the study period (and likely the busiest day of the year based on past visitor use trends), the vast majority (about 80%) of groups encountered over 100 other groups while hiking the Old Rag loop trail (Figure 12). Once again, those groups hiking the trail in a counter-clockwise direction had the most encounters due to their direction of travel.

The next component of the visitor experience to be investigated was the length of lines that form at “squeeze points” near the top and bottom of the rock scramble and the approximate wait times caused by these lines. Data collected at the top and the bottom of the rock scramble on the busiest weekend of the year (October 22-23) established that the longest line formed at the lower squeeze point was 26 people, resulting in a seven-minute wait time. The longest line formed at the upper squeeze point was 73 people, resulting in a wait of 33 minutes. It is important to note however, that at the upper squeeze point, many visitors began using a social trail to bypass the challenging portion of the rock scramble when the line exceeded about 25 people in length. Once the line reached this length, those at the end of the line found themselves standing directly adjacent to the start point of a social trail. This resulted in a shorter wait time for those who chose to remain in the line. Almost all visitors traveling in a counter-clockwise direction chose to use the social trail or to jump down from a rock above the trail rather than attempt to descend through the squeeze point against the flow of traffic.
The final measure of visitor experience was people at one time (PAOT) at the summit. On three days, the duration of time that groups spent at the summit was manually recorded. Information for every fifth group to arrive at the summit was collected, resulting in a total sample of 59 groups. The mean period of time spent at the summit was 24 minutes, with a standard deviation of 18 minutes (Figure 13). While most groups spent less than half an hour at the summit, a few groups spent significantly more time at the summit.

![Figure 13. Frequency Distribution of Time Spent at the Summit (July 24, Sept 16, Oct 22, 2011; n=59)](image)

The number of people at one time at the summit was estimated using the Hiking Simulation Model, which counted the number of people estimated to be at the summit at each fifteen-minute time step throughout the day. As with the output on group encounters, the PAOT output varied somewhat from one model run to the next, but the trends remained consistent. It should be noted that the results do not take into account the fact that lines at the rock scramble are likely to “smooth” the peak PAOT levels somewhat, since the lines create a more even temporal distribution of hikers less than an hour away from the summit. Likewise, it should be noted that the left tails of both graphs are somewhat misleading, and are an artifact of the fact that data were not collected early in the morning, resulting in at least a few missed hikers during the early hours. It is reasonable to assume that the “true” left tails more closely resemble the right tails than is shown in the model output.
On September 4, when 524 visitors hiked Old Rag, the estimated number of people at one time at the summit seldom exceeded 50, and peaked between 11:00am and 4:00pm (Figure 14). It should be noted that during the entire study period, the total number of visitors exceeded 500 only ten percent of the time, suggesting that the maximum PAOT at the summit was at or below 50 on 90% of the days during the study period. The total number of visitors exceeded 250 only 23% of days during the study period, suggesting that crowding at the summit is usually much lower than what was seen on September 4.

On October 22, when 1701 visitors hiked Old Rag, the estimated number of people at one time at the summit exceeded 50 from 11:00am to 4:00pm, and exceeded 100 from 12:00-3:00pm (Figure 15). Most model runs predicted that the maximum PAOT would exceed 150 for at least some portion of the day.
Discussion & Recommendations

The data generated by this study provide quantitative information about the degree of crowding present in the wilderness area encompassing the Old Rag loop trail. Park managers have long known that Old Rag receives heavy use and accordingly, have designated it “Threshold Wilderness” (the least primitive wilderness designation in the park). Existing data sets have provided only rough estimates of trail use, whereas information generated in the current study provides a set of baseline data on opportunities for solitude. What was formerly understood anecdotally can now be understood quantitatively, allowing park staff to cite specific facts and figures about visitor use as they attempt to manage the resource and to communicate with the public.

What is most clear in all of the data generated by the study is that opportunities for solitude exhibit significant temporal variation, and exist almost every day of the year for those who are willing to plan their trips accordingly. Opportunities for solitude are absent though, during most daylight hours on weekends, and on many “shoulder days” as well. Opportunities for “a primitive and an unconfined type of recreation” are limited in the Old Rag wilderness area due to management actions that have been undertaken for the sake of resource protection and visitor safety. Signs and physical barriers have been installed at the summit to protect natural resources, and trails
have been hardened to accommodate high levels of use. While park managers have done their best to protect the visitor experience on Old Rag using minimum management techniques, the desire to avoid placing restrictions on visitor use results in less than optimal wilderness conditions on Old Rag.

The area’s current classification as “Threshold Wilderness” in the 1998 Backcountry and Wilderness Management Plan allows for any number of parties to be encountered within the wilderness area in a given day (NPS 1998). It is worth noting however, that the next most restrictive management classification of “Semi-Primitive Wilderness” recommends that the number of daily trail encounters not exceed twelve, a far cry from the dozens or hundreds of encounters that a group can be expected to have on the Old Rag trail. The issue of heavy public use was at the forefront of Congressional debate about the Shenandoah Wilderness in 1975 and 1976, so Superintendent Robert Jacobsen immediately instituted a policy of “non-degradation” to ensure that wilderness character did not diminish over time (NPS 1998). It would seem prudent to revisit the issue of permissible encounters in the Old Rag area in the next Backcountry and Wilderness Management Plan, as the current lack of standards may lead to degradation of wilderness character should the Old Rag trail receive increased use.

In 2009, a Finding of No Significant Impact was issued for a new Old Rag Parking lot to be located about 0.4 miles closer to the trailhead than the existing leased lot, and for the existing lot to be reduced in size in order to maintain a maximum parking capacity of 262 spaces. While this action will improve the safety of park visitors due to decreased travel along State Route 600, it will also likely result in greater visitation due to the elimination of 0.8 miles of walking along the road, the least attractive portion of the existing hike. Since neighbors will likely continue to “rent out” parking space on peak use days when the NPS parking lots fill, the new lot will not result in a decrease in crowding levels as some had hoped in the early stages of planning.

The implementation of a quota system (similar to the new quota system at Half Dome in Yosemite National Park) is another option available to the Park Service to help manage adverse impacts to wilderness character. While some visitors on the trail volunteered that they would support such a quota system, other visitors expressed the opinion that they did not mind the crowding along the trail, and that it added to the social experience of hiking Old Rag. This is consistent with other visitor use studies in popular wilderness areas that have suggested that solitude is not a priority for many visitors to popular wilderness areas (Dawson & Hendee 2009, Hall 2001). Additionally, instituting a quota system would be politically challenging due to the popularity of the
Old Rag trail with hikers from the DC metro area, many of whom drive out from the suburbs solely to experience a day hike on Old Rag. Driving two hours only to be told that the trail was available by reservation only would undoubtedly result in a negative experience for thousands of visitors during the first few years after implementing such a system.

The more feasible and effective way to increase opportunities for solitude while allowing visitors to choose their desired level of crowding is to increase current efforts to educate visitors about the Old Rag experience. Providing visitors with access to data on the most and least crowded times of the day, week, and year to visit Old Rag would likely result in a more positive visitor experience, as many visitors would likely adjust their plans accordingly. Likewise, visitors arriving on busy days might be encouraged to try other scenic and challenging hikes in the vicinity such as the Nicholson Hollow, White Oak Canyon, Cedar Run, and Corbin Hollow trails, all of which provide much of the physical challenge of Old Rag without requiring hikers to wait in long lines. Managers would need to monitor conditions on these alternative trails however, to ensure that wilderness character not be adversely impacted by this redistribution of use.

Many visitors who approached me about my research were unaware that the Old Rag trail passes through federally designated wilderness, and many did not understand what wilderness was. Boundaries to federally designated wilderness could also be marked, and accompanied by discrete interpretive panels explaining the significance of wilderness and ways for visitors to help protect the resource.

All of these visitor education and information provision recommendations require an increase in resources and personnel to help disseminate information and answer questions. Over the course of this study, I encountered many visitors seeking information, interpretation, and advice about their use of the park’s resources. While the National Park Service lacks the funding necessary to fully staff all of its information stations, it would be beneficial to increase staff availability during peak visitation seasons, and to enlist the help of park volunteers to provide information and consultation to visitors of the Old Rag area. Without adequate personnel, it is impossible to properly inform the public about the diverse hiking options available and the experiences they should anticipate if they choose to hike Old Rag during peak times.

This project has made substantial progress toward developing a solid set of baseline wilderness character data along the Old Rag trail, but the data set is incomplete. Since TrafX trail monitors have already been installed along the trail and field research has established an accurate method to correct the data, it is highly recommended that the Ridge Trail counter, if not both
counters, be left in the field and maintained throughout the 2012 season. This would require downloading data and replacing the desiccant packs once every one to two months, and then correcting the data for analysis. Likewise, it would be beneficial to spend several more days in the field collecting data on trail use patterns to confirm that the data collected thus far are not dependent on season of the year. Finally, it is strongly recommended that a survey be implemented to confirm the assumptions that this study makes about trail use patterns and to determine how acceptable current levels of crowding are to visitors. An intercept survey protocol is attached as Appendix C.

While this study has highlighted a number of issues related to the management of the Old Rag loop trail, it also presents an opportunity to move forward with the development of comprehensive baseline data. Additionally, it identifies periods of peak use and identifies significant management issues along with proposing steps to remedy these issues. Even on the busiest days, the Old Rag trail provides almost all visitors with a positive experience, and the unique nature of the trail presents the NPS with an excellent opportunity to expose new visitors to the National Park Service and the National Wilderness Preservation System. Capitalizing on this opportunity is the next step in promoting stewardship of the nation’s natural resources and the wilderness ideal.

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Works Cited


Appendix A – Python Script for Hiker Simulation

## STEPS OF THE ANALYSIS
#1. Convert the trail shapefile to a raster dataset
#2. Develop a cost surface based on slope using the trail as a mask
#3. Export cost surface of the trail into a csv file to define impedance
#4. Run a loop for each 15 minute time step, adding hikers based on user-defined times
# These values are imported from GroupData.csv
# Column 1: StartTime, 2: Speed (mph), 3: Direction (1=cw, 2=ccw), 4: TimeAtSummit, 5: GroupSize
#5. Agents move along the trail based on the impedance values and their average hiking time
#6. Calculate encounters and People At One Time @ Summit at each time step

## Each "Agent" (group) in the script has the following variables:
# Time - Start time, with 0 being 12:00am and 95 being 11:45pm
# Speed - The agent's speed of travel on a flat, well-maintained surface, in MPH
# Direction - The agent's direction of travel. 1 is CW, 2 is CCW
# Encounters - Adds one every time you encounter folks going in opposite direction
# Surpass - Adds one every time you pass someone going the same direction
# SurpassedBy - Adds one every time someone passes you going the same direction
# SamePlace - Adds one every time an agent is sharing a location with another agent
# Location - Based on integer value of location raster cell
# Location based on how much impedance distance is traveled in one time step, with the agent's
# speed determining the number of impedance units that can be traversed in one time step
# PrevLocation - Location value of previous time step
# CurrentCell - The cell number in which the agent is located. Used to determine whether two agents are in
# the same raster cell as each other (even if impedance values vary slightly)
# SummitTime - Amount of time spent at the summit

## SCRIPT SETUP CREATES VARIABLES AND IMPORTS GROUP AND IMPEDANCE DATA
# Creates empty variables
Time = []
Speed = []
Direction = []
Surpass = []
SurpassedBy = []
SamePlace = []
Encounters = []
Location = []
PrevLocation = []
CurrentCell = []
SummitTime = []
GroupSize = []
Impedance = []
GridCell = []
AtSummit = []
SummitCount = []
PeopleAtSummit = []

### IMPORTS AGENT DATA FROM CSV
# Opens file and assigns data to a list of strings "lineStrings"
fileObj = open("GroupInput9-4i.csv", 'r') #Modify to reflect input file name
lineStrings = fileObj.readlines()
fileObj.close()

# Loops through each line of data
for lineString in lineStrings:
    lineData = lineString.split(",") #Splits lineString into a list of values, lineData
    Time.append(int(lineData[0]))
    Speed.append(float(lineData[1]))
    Direction.append(int(lineData[2]))
    SummitTime.append(int(lineData[3]))
    GroupSize.append(int(lineData[4]))
    Surpass.append(int(0))
    SurpassedBy.append(int(0))
    SamePlace.append(int(0))
    Encounters.append(int(0))
    Location.append(int(1))
    PrevLocation.append(int(0))
    CurrentCell.append(int(0))
    AtSummit.append(int(0))
print "There are " + str(len(Location)) + " agents."

### IMPORTS IMPEDANCE VALUES FROM CSV
# Opens file and assigns data to a list of strings "lineStrings"
fileObj = open("ImpedanceCW.csv", 'r')
lineStrings = fileObj.readlines()
fileObj.close()

# Loops through each line of data
for lineString in lineStrings:
    Impedance.append(lineString)
    GridCell.append(0)
TrailLength = len(Impedance)
print "There are " + str(TrailLength) + " cells in the trail."

### DEFINES STANDARD VARIABLES
TotalAgents = len(Location) # This is the total number of agents.
MaxLocation = len(Impedance) # This is the total number of cells in the trail.
MaxImpedance = int(Impedance[MaxLocation - 1]) # Determines the impedance value of the last cell on the trail
CurrAgent = 0
OtherAgent = 0
TimeOfDay = 0 # This is used to step through each 15 minute increment
CountSame = 0 # Prevents an agent from getting multiple "SamePlace" counts in the same time step.
OutOfTheLoop = 0 # Variable to exit out of some loops
CountUp = 0 # Allows "counting up" in loops
SummitVal = 3228 # Cell value of Old Rag summit. Used to determine number of agents at summit
print "Maximum impedance is " + str(MaxImpedance)

## FOR EACH TIME STEP AND EACH AGENT, MOVES AGENT FORWARD AND DETERMINES RELATIVE
## POSITION OF ALL OTHER AGENTS.
# Runs loop for each time 15 minute step.
while TimeOfDay < 96:
   SummitCount.append(0)
   PeopleAtSummit.append(0)
   print "CURRENT TIME: " + str(TimeOfDay)
   # For each agent, agent forward in space if their start time (Time) is less than or equal to
   # the current time (TimeOfDay) and their Location is less than or equal to the MaxLocation.
   while CurrAgent < TotalAgents:
      if Direction[CurrAgent] == 1:
         if Time[CurrAgent] <= TimeOfDay and Location[CurrAgent] <= MaxImpedance:
            if PrevLocation[CurrAgent] < SummitVal and Location[CurrAgent] >= SummitVal:
               AtSummit[CurrAgent] = 1
               PrevLocation[CurrAgent] = Location[CurrAgent]
            elif (Location[CurrAgent] > int(Impedance[CountUp]) and Location[CurrAgent] < MaxImpedance):
               CountUp = CountUp + 1
            else:
               CurrentCell[CurrAgent] = CountUp
               OutOfTheLoop = 1
               CountUp = 0
               #print "Agent " + str(CurrAgent) + " is in cell " + str(CurrentCell[CurrAgent])
         AtSummit[CurrAgent] = 0
         SummitCount[TimeOfDay] = SummitCount[TimeOfDay] + 1
         PeopleAtSummit[TimeOfDay] = PeopleAtSummit[TimeOfDay] + GroupSize[CurrAgent]
         Location[CurrAgent] = Location[CurrAgent] + int(((Speed[CurrAgent]*102) * ((15 - SummitTime[CurrAgent]) / 15)))
      else:
         SummitCount[TimeOfDay] = SummitCount[TimeOfDay] + 1
         PeopleAtSummit[TimeOfDay] = PeopleAtSummit[TimeOfDay] + GroupSize[CurrAgent]
         while OutOfTheLoop == 0:
            if Location[CurrAgent] > int(Impedance[CountUp]) and Location[CurrAgent] < MaxImpedance:
               CountUp = CountUp + 1
            else:
               CurrentCell[CurrAgent] = CountUp
               OutOfTheLoop = 1
               CountUp = 0
               #print "Agent " + str(CurrAgent) + " is in cell " + str(CurrentCell[CurrAgent])
      CurrAgent = CurrAgent + 1
      OutOfTheLoop = 0
   elif Direction[CurrAgent] == 2:
      if Time[CurrAgent] == TimeOfDay:
Location[CurrAgent] = MaxImpedance
PrevLocation[CurrAgent] = MaxImpedance + 1
CurrentCell[CurrAgent] = MaxLocation - 1
if Time[CurrAgent] <= TimeOfDay and Location[CurrAgent] > 0:
    if PrevLocation[CurrAgent] > SummitVal and Location[CurrAgent] <= SummitVal:
        AtSummit[CurrAgent] = 1
    PrevLocation[CurrAgent] = Location[CurrAgent]
    if AtSummit[CurrAgent] == 0:
        Location[CurrAgent] = Location[CurrAgent] - int((Speed[CurrAgent]*102))
    elif SummitTime[CurrAgent] < 15:
        SummitCount[TimeOfDay] = SummitCount[TimeOfDay] + 1
        PeopleAtSummit[TimeOfDay] = PeopleAtSummit[TimeOfDay] + GroupSize[CurrAgent]
        Location[CurrAgent] = Location[CurrAgent] - int(((Speed[CurrAgent]*102) * ((15 - SummitTime[CurrAgent]) / 15)))
    AtSummit[CurrAgent] = 0
else:
    SummitCount[TimeOfDay] = SummitCount[TimeOfDay] + 1
    PeopleAtSummit[TimeOfDay] = PeopleAtSummit[TimeOfDay] + GroupSize[CurrAgent]
while OutOfTheLoop == 0:
    if Location[CurrAgent] > int(Impedance[CountUp]) and Location[CurrAgent] < MaxImpedance:
        CountUp = CountUp + 1
    else:
        CurrentCell[CurrAgent] = CountUp
        OutOfTheLoop = 1
        CountUp = 0
        #print "Agent " + str(CurrAgent) + " is in cell " + str(CurrentCell[CurrAgent])

CurrAgent = CurrAgent + 1
OutOfTheLoop = 0

# print "Agent Locations have been changed successfully."

### In the following loop, RelPosition is 0 if the other agent is behind the current agent, 
### 1 if they’re in the same place, or 2 if the other agent is in front of the current agent 
while CurrAgent < TotalAgents:
    while OtherAgent < TotalAgents:
        if OtherAgent != CurrAgent and PrevLocation[OtherAgent] != (0 or MaxImpedance + 1) and 0 < Location[CurrAgent] < MaxImpedance:
            # Determines relative position of the other agent to the Agent in previous time step
            if PrevLocation[OtherAgent] < PrevLocation[CurrAgent]:
                PrevRelPosition = 0
            elif PrevLocation[OtherAgent] == PrevLocation[CurrAgent]:
                PrevRelPosition = 1
            else:
                PrevRelPosition = 2
            # Determines relative position of other agent to the current Agent in current time step
if Location[OtherAgent] < Location[CurrAgent]:
    CurrRelPosition = 0
elif Location[OtherAgent] == Location[CurrAgent]:
    CurrRelPosition = 1
else:
    CurrRelPosition = 2

# Determines whether the two agents are in the same location. Agent only gains 1 SamePlace
# per time step.
if CurrRelPosition == 1 and CountSame != 1:
    if CurrentCell[CurrAgent] == CurrentCell[OtherAgent] and CurrentCell[CurrAgent] != 0:
        # SamePlace scores will over-calculate if 2 groups start at same time and same speed
        # Assumes no fluctuation in hiking speed other than slope.
        SamePlace[CurrAgent] = SamePlace[CurrAgent] + 1
        CountSame = 1

# Calculates for CurrAgent and OtherAgent both CW
if Direction[CurrAgent] == 1 and Direction[OtherAgent] == 1:
    if PrevRelPosition == 0 and CurrRelPosition == 2 and Location[OtherAgent] < MaxImpedance:
        SurpassedBy[CurrAgent] = SurpassedBy[CurrAgent] + 1
    elif PrevRelPosition == 1 and CurrRelPosition == 0:
        Surpass[CurrAgent] = Surpass[CurrAgent] + 1
    elif PrevRelPosition == 1 and CurrRelPosition == 2 and Location[OtherAgent] < MaxImpedance:
        SurpassedBy[CurrAgent] = SurpassedBy[CurrAgent] + 1
    elif PrevRelPosition == 2 and CurrRelPosition == 0:
        Surpass[CurrAgent] = Surpass[CurrAgent] + 1

# Calculates for CurrAgent CCW, OtherAgent CW
elif Direction[CurrAgent] == 2 and Direction[OtherAgent] == 1 and CountEncounters != 1:
    if PrevRelPosition == 0 and CurrRelPosition == 2 and Time[OtherAgent] <= TimeOfDay and
        Location[OtherAgent] < MaxImpedance:
        Encounters[CurrAgent] = Encounters[CurrAgent] + 1
        CountEncounters = 1
    elif PrevRelPosition == 1 and CurrRelPosition == 2 and Time[OtherAgent] <= TimeOfDay and
        Location[OtherAgent] < MaxImpedance:
        Encounters[CurrAgent] = Encounters[CurrAgent] + 1
        CountEncounters = 1

# Calculates for CurrAgent CW, OtherAgent CCW
elif Direction[CurrAgent] == 1 and Direction[OtherAgent] == 2 and CountEncounters != 1:
    if PrevRelPosition == 1 and CurrRelPosition == 0 and Location[OtherAgent] > 0:
        Encounters[CurrAgent] = Encounters[CurrAgent] + 1
        CountEncounters = 1
    elif PrevRelPosition == 2 and CurrRelPosition == 0 and Location[OtherAgent] > 0:
        Encounters[CurrAgent] = Encounters[CurrAgent] + 1
        CountEncounters = 1
# Calculates for CurrAgent and OtherAgent CCW
elif Direction[CurrAgent] == 2 and Direction[OtherAgent] == 2:
    if PrevRelPosition == 0 and CurrRelPosition == 2 and Location[CurrAgent] > 0:
        Surpass[CurrAgent] = Surpass[CurrAgent] + 1
        #print "Agent " + str(CurrAgent) + " surpassed Agent " + str(OtherAgent)
    elif PrevRelPosition == 1 and CurrRelPosition == 0 and Location[OtherAgent] > 0:
        SurpassedBy[CurrAgent] = SurpassedBy[CurrAgent] + 1
    elif PrevRelPosition == 1 and CurrRelPosition == 2 and Location[CurrAgent] > 0:
        Surpass[CurrAgent] = Surpass[CurrAgent] + 1
        #print "Agent " + str(CurrAgent) + " surpassed Agent " + str(OtherAgent)
    elif PrevRelPosition == 2 and CurrRelPosition == 0 and Location[OtherAgent] > 0:
        SurpassedBy[CurrAgent] = SurpassedBy[CurrAgent] + 1

OtherAgent = OtherAgent + 1
CountEncounters = 0
CurrAgent = CurrAgent + 1

## LINES BELOW ARE FOR DEBUGGING ONLY
print "Encounters " + str(Encounters)
print "Location " + str(Location)
print "PrevLocation " + str(PrevLocation)
print "CurrentCell" + str(CurrentCell)
print "Speed " + str(Speed)

TimeOfDay = TimeOfDay + 1

#TotalEncounters = Surpass + SurpassedBy + Encounters
#print "TOTAL ENCOUNTERS " + str(TotalEncounters)
print "Surpass " + str(Surpass)
print "Surpassed by " + str(SurpassedBy)
print "SamePlace " + str(SamePlace)
print "Encounters " + str(Encounters)
print "Group Size " + str(GroupSize)
print "Summit Count" + str(SummitCount)
print "The script has completed."

fileObj = open("Group9-4_10.csv", 'w')  #Modify to reflect output file name
fileObj.write("Time, " + str(Time))
fileObj.writelines("\n" + "Speed, " + str(Speed))
fileObj.writelines("\n" + "Direction, " + str(Direction))
fileObj.writelines("\n" + "SummitTime, " + str(SummitTime))
fileObj.writelines("\n" + "Surpass, " + str(Surpass))
fileObj.writelines("\n" + "SurpassedBy, " + str(SurpassedBy))
fileObj.writelines("\n" + "SamePlace, " + str(SamePlace))
fileObj.writelines("\n" + "Encounters, " + str(Encounters))
fileObj.close()

fileObj = open("Summit9-4_10.csv", 'w') #Modify to reflect output file name
fileObj.write("Time of Day, ")
CountUp = 0
while CountUp < 96:
    fileObj.write(str(CountUp) + ", ")
    CountUp = CountUp + 1
fileObj.writelines("\n" + "Groups at Summit, " + str(SummitCount))
fileObj.writelines("\n" + "People at Summit, " + str(PeopleAtSummit))
fileObj.close()}
Appendix B – ArcMap Model to Generate Impedance Values for Python Model
Appendix C – Intercept Survey Protocol

Overview
The following survey is to be administered at the upper Old Rag parking lot to groups entering the area from the Weakley Hollow Fire Road and Old Rag Ridge Trail.

Sampling Method
The survey will be administered to every fifth group entering the area from the fire road or Ridge Trail. If a group declines to be surveyed, a “declined” response will be recorded, and the next fifth group will be approached. Surveys will be conducted on days where crowding can be expected, including weekends, holidays, and days during the fall leaf change, and will be administered from 9:00am to 5:00pm, with a 15 minute break at the end of every two hours.

Survey Instrument
Hello. I am a Duke University graduate student, and was wondering if you would be willing to take part in a one-minute survey about your hiking experience today. The research will be used by the park to help manage the Old Rag trail. Would you like to participate?

Answer: No
Response: Thank you anyway, and have a nice day.

Answer: Yes
Response: Great. Let’s get started.

Record the time.

Question 1: How many people are in your group?

Question 2: Did your group hike Old Rag today?
   If not, thank them for their time, and let them know that’s all the information you need.

Question 3: Did you make it to the summit?
   If not, thank them for their time, and let them know that’s all the information you need.

Question 4: Did you go up and back on the same trail, or did you do a loop hike?
   Have a map ready in case they have questions.

Question 5: What time did you start your hike?
   If unknown, tell them not to worry about it and move on to the next question.

Question 6: We’re trying to determine how hikers felt about their experience today. Was the number of other hikers you encountered on the trail and at the summit today too few, about right, or too many?

Thank you for your help.
If the subjects have questions about the research, explain that you have to get ready for the next survey, and provide a business card so they can contact you via e-mail to get more information.