2018 14ER HIKER USE REPORT BACKGROUND

EXPLANATION OF INTENT

Colorado Fourteeners Initiative has been working to preserve and protect the natural integrity of the state's 14,000-foot peaks (a.k.a. the "14ers") since 1994 through active stewardship and public education. CFI began trying to estimate the number of people hiking the 14ers starting in 2014 with a pilot test of the TRAFx infrared trail counters. Understanding the amount of hiking use on the 14er trails, the timing of use across the season and the rate of change in use are all factors that help better understand how on-the-ground condition of trails change over time. CFI's first comprehensive estimate of hiking use across the 14ers occurred in 2015. Updates have been released annually. CFI has gathered information from a growing number of counters (10 in 2015, 20 in 2016-2017, and 22 in 2018) that provide daily totals of passing hikers. Information from the sensors is combined with external research, statistical analysis, and mathematical modelling to produce a finalized approximation for each peak. These annual reports help our organization select how to allocate resources to the trails that need it most, and to educate the public regarding usage and stewardship.

DATA SOURCING AND CLEANING

We consider several sources of information when constructing this model, the most significant being the **Colorado Fourteeners Initiative's 2018 Sustainable Trails Program counters**. Additionally, we obtain data from trail counters placed by federal land managers, counters placed by other agency partner organizations, summit registers, and trailhead registers. CFI uses a modeling system to calculate estimates for locations where hiker counts do not exist in any form through reference to multiple factors, which are explained in further detail later.

Sustainable Trails Program Counters

In 2018, 22 TRAFx infrared counters were strategically placed over several peaks to gather season-long data. CFI carefully considers several factors when deploying this technology, keeping in mind the location, direction, and stability of various sites. This is done to ensure that the counters stay concealed and record accurate information throughout the peak months of hiking season, while not infringing on the naturalness of the 14ers. They are placed far enough from the trailhead—usually above the last trail junction to another destination—to record only those people who are legitimately attempting to summit each peak. Weather, fitness and other factors may mean that all of the people counted do not actually summit. However, they are far enough in from the trailhead—an average of more than two miles—that they are truly affecting

the condition of the summit trail. The counters are hidden in cairns above treeline or mounted on trees along the route at narrow passages to avoid impacting users' experiences and lessen the frequency of tampering. From the very beginning of the peak hiking season (late May, when trails clear of snow) to the middle of fall, these sensors record and report heat signatures to summarize hiker counts. They are then checked routinely throughout the summer, to make sure that they are recording an accurate representation of the people passing by.

For this report, CFI placed sensors on trails accessing 23 distinct peaks (Blanca/Ellingwood, Castle/Conundrum, Challenger/Kit Carson, Democrat, Elbert, Grays/Torreys, Handies, Huron, La Plata, Lindsey, Pikes, Quandary, Redcloud/Sunshine, Shavano/Tabeguache, Sherman, Sneffels, and Wilson Peak). Most sensors remained on the mountains from May/June through September/October. A few were left over the winter to obtain off-season usage data. The data from each source was gathered, examined, and scrubbed, to make sure that any anomalies or false reports were removed. Then, after each data set was manually cleaned, the resulting gaps were filled using predictive analysis. A program, developed in R-Studio, accepted all incoming data and projected out what the values for missing days should be, producing a linear regression analysis. For a more detailed discussion of this calculation process, see the below section on *Model Building*. If data from these sensors was drastically different from what it had been in previous years, the case was examined and adjustments were made according to any pertinent and researched information, such as a windstorm that blew snow in front of a counter or a trail race that passed by where the counter was placed.

Other Agency Trail Counter Information

The South Platte Ranger District of the Forest Service placed a TRAFx trail counter in 2018 on Mount Bierstadt that provided a full season of hiker data. The counter was placed far enough from the trailhead for CFI to have confidence that the data collected was similar to that had the counter been placed by CFI. Other Forest Service Ranger Districts placed TRAFx trail counters near trailheads accessing Belford/Oxford/Missouri, Harvard/Columbia and Massive (North Halfmoon Trail). Since these counters were placed close to trailheads that provide access to destinations other than 14ers, CFI viewed these counters as providing upper bounds with which to judge the modeled estimates.

Data from the National Park Service's work on Longs Peak in 2002 was used to create a baseline estimation for numbers in more recent years. The NPS spent several years periodically documenting and observing the number of people who began the Longs Peak Trail, and also those who reached the summit, to get a general sense of park attendance and summit success rate. Counters were placed at several locations, including the "homestretch" just short of the actual summit. Taking into account population growth, the changing dynamics of Denver's metropolitan area, and the recent surge in hikers attempting to climb fourteeners, this number

was included in our model as a baseline estimation. Requests to the NPS for more recent Longs Peak data did not receive responses.

14er Checklist Statistics

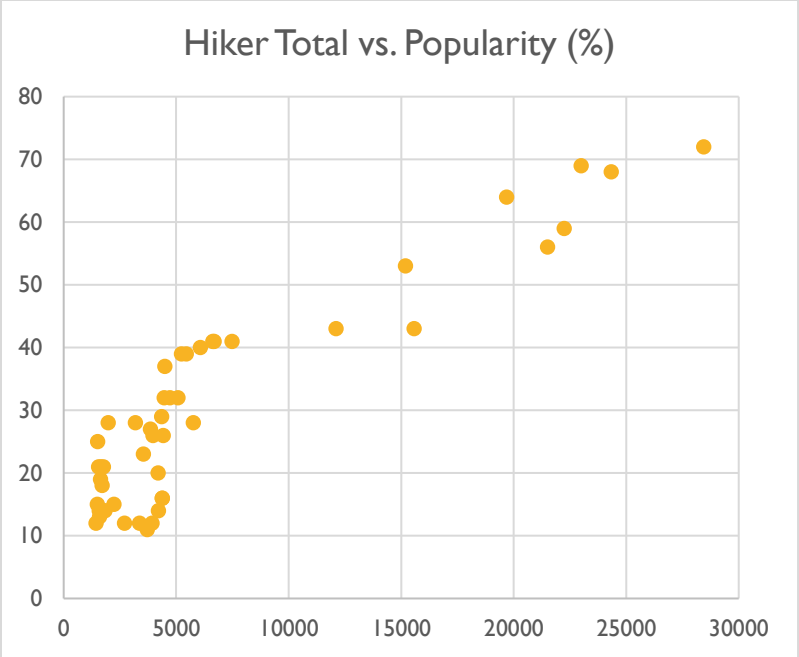
Information was pulled from the 14ers.com climber checklists regarding the frequency with which reports were written about summits to each peak. 14ers.com receives over 25,000 visitors a day during peak climbing season and serves as a living document for the conditions and experiences of hikers on these mountains. Users on the website are encouraged to keep track of the peaks that they summit with a digital checklist. To date more than 16,500 people have done so. These checklists are then compiled under the "Peak Popularity Statistics" folder of the website. We drew on these popularity statistics to give a general sense of the distribution of climbers across all 14ers, and although the website appeals to a non-representative subsection of the general climbing population, there is still a strong correlation between the reports and our findings with the thermal sensors. Taking into account the type of person who uses the website and how they might not be the average weekend climber, these values were inserted into the model and adjusted accordingly.

MODEL BUILDING

To create a full estimate of each peak, even those for which no data are available, all of the above sources of information were run through an R-Studio program, first developed by Emily Barnes and later edited by Nick Dahl. This R-code program develops a linear regression for each peak, taking into account the range of the mountain, the relative difficulty rating, the 14er.com popularity ranking, the length of the hike itself, the day and week of the year, and the increase that occurs due to holiday weekends, to generate predictions for total hiker number day-to-day across all 58 peaks for the entire season.

This model creates a range that not only represents the variability from other factors, such as weather, inconsistent trail conditions, roads closures, and promotional activities, but also the statistical noise that is to be expected from datasets this large. Through using the external information as well as the sensors, each source was evaluated for relevance with an analysis of variance test. For variables like the popularity of the mountains versus the total count of climbers, logarithmic transformations were performed to linearize the data points:

Here on the right you can see that there is a relationship between hiker totals and reported popularity that is not necessarily linear. So that the data would fit into the linear model, the popularity values were all squared. This flattened the curve and raised the r-squared value of the model significantly. Similar translations were performed on the count data to bolster the linear model's accuracy.



The r-squared value for the model in 2017 was 0.7143, which means that 71.43% of the variability in the number of people who climbed each peak can be explained by the variables selected in the model as listed above. The p-value of 2.2E-16 means that there is a next to negligible chance that the variation in climber numbers was due to chance alone and not by the factors we included. These two statistics combined tell us that the model does a good job at predicting climber numbers on peaks, even when we didn't have full or any data on them.

TOTAL USE ESTIMATE METHODS

To approximate the number of people who climbed across every peak this year, we took the best guess sums from each individual peak that the R-Studio program produced and combined them with trail reports/manual observations to estimate totals, first by mountain range and then cumulatively. Then, the values were adjusted with the consideration that many hikers will complete several peaks in a single day, specifically between Shavano/Tabegauche, Oxford/Belford, Redcloud/Sunshine, Democrat/Lincoln/Bross, and Grays/Torreys. Other similar adjustments were made in cases where manual observations outweighed statistical modelling. For instance, from experience we know that Wilson Peak receives more traffic than either El Diente or Mt. Wilson, and so we capped their estimated total to account for the fact that they should not exceed that of Wilson Peak. The entire CFI staff reviewed predictions, drawing on years of 14er climbing, trail maintenance and service to determine accuracy, and collectively combed and approved the report.

SOURCES OF ERROR

The very nature of data retrieved by remote sensors makes it difficult to know the true quality of the datasets, which is why an increase in the number of reference points gives us a much higher confidence in our final numbers. It would clearly be preferable, if economically prohibitive and impractical, to monitor every trail year-round with its own sensor. However, this is not realistic. Further, the Forest Service rejected a CFI application to place trail counters on peaks in designated wilderness, which constitute a majority of all 14ers. Thus, we coded the program to fill in the gaps when we cannot get exact data. The sensors themselves also can be sources of error, because they are unable to distinguish heat signatures created by people to those created by animals. Similarly, several people walking in tandem can show up as a single, large heat signature, which will be recorded as a single person instance. We do our best to mitigate these errors by placing sensors at about hip height so that shorter animals do not register, and by selecting points on the trails where people will most likely have to walk in single file and at a constant pace. CFI has field checked some of the counters by doing manual observations. These have shown the counters to be highly accurate. Even then we can't guarantee that hikers will behave as expected and stay on the trail. Hikers will always take inconsistent routes, no matter how well the trail is marked, and they won't be included in total counts.

Our estimates tend to be on the conservative side. We don't unnaturally inflate our counts under the assumption that individuals are not being counted consistently. Quite often, data points were removed without significant or definite statistical proof that they were invalid. Drawing on the collective decades of experience on these trails, decisions were made by the core Fourteeners staff on occasion to omit data that seemed invalid. In some cases, this was an easy call, like 650 people in the middle of winter climbing a peak on a single day. (Likely the result of illuminated vegetation and snow blowing in front of the sensor). In other cases was more based on intuition about who climbs what peaks. Prediction science is not a perfect science, and there is always room for error, which is why in our final report sheet every peak is binned in a data range. While we are more confident than ever in the values that we publish, it is irresponsible to pretend that the Colorado mountains are a controlled environment where absolute truths can be determined. Uncontrollable factors rule in one of the more remote and inaccessible terrains on the continent, and though we can continue to learn, adapt, and improve our strategies, we will never be able to eliminate those factors that influence our data and confidence intervals.

FUTURE DIRECTIONS FOR RESEARCH

Each season here at CFI gives us more experience and more opportunity to improve the accuracy of fourteeners use estimates. With 22 CFI counters now deployed, we now have a better picture of these peaks than ever before, and we now rely less on estimation and more

on datasets. There are, of course, going to be limits on the breadth of peaks we can monitor, due to economic infeasibility and restrictions on private/wilderness-protected lands, but the consistent year-to-year gathering of data gives us a better sense of the evolving nature of population dynamics on the peaks. Trends emerge when we get consecutive years of good data that not only let us predict where one peak is headed in the next decade, but where the experience of climbing fourteeners as a whole is headed. Use levels on peaks with the more reliable history of data collection suggest overall 14er hiking use is growing at 5 percent annually. Through further cooperation with the other groups involved in this same space, CFI seeks to build bridges and collectively pool our knowledge to produce accurate and dynamic reports, for the public's education and aid of trail stewards everywhere.

SOURCES USED

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