

LOST ON THE TRAIL:  
INVESTIGATING HIKING WAYFINDING AND TRAIL NAVIGATION  
WITHIN THE NATIONAL PARKS

by

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## **LIST OF ABBREVIATIONS**

<b>Abbreviations</b>	<b>Descriptions</b>
NPS	National Park Service
SAR	Search and Rescue
YOSAR	Yosemite Search and Rescue
YDS	Yosemite Decimal System
SAC	Swiss Alpine Club
ADA	Americans with Disabilities Act
AT	Appalachian Trail



## **ABSTRACT**

Every year, thousands of search and rescue (SAR) operations are performed to locate and save lost or missing persons in the national parks. Yosemite National Park is one of three National Park Service units with the highest occurrences for search and rescue operations (Heggie and Amundson 247). Yosemite's Search and Rescue (YOSAR) team performs approximately 250 rescues per year. Nearly 70% of those rescues are to locate lost, missing, or injured hikers (Dill). The primary factors contributing to hikers becoming lost or reported as missing include losing the trail (and then being overtaken by darkness), taking the wrong trail, and miscalculating the time or distance of the planned route (Doke 44). Inadequate signage placement, poor typographic design, and lack of signage at decision points are among the issues found when analyzing wayfinding throughout the park. The results of the project will include preliminary designs of a hiking signage and marker system inspired by the Czech Hiking Markers Standard, Appalachian Trail marker system, and the trail difficulty ratings from the National Ski Areas Association. The purpose of this project is to investigate Yosemite National Park's hiking trail wayfinding system in order to design an improved solution and to reduce the amount of SAR operations for lost or missing hikers.

## **I. INTRODUCTION**

On average, Yosemite National Park has over 4 million visitors a year with peak tourism occurring during the summer months. The busiest area in the park attracts 75% of the visitors in Yosemite Valley, and is home to the infamous El Capitan and Yosemite Falls. With over 800 hiking trails, it is no wonder Yosemite Valley has been identified as a “hot spot” for lost hikers, with numerous search and rescue operations along the Yosemite Valley rim, Glacier Point, Sentinel Dome, and Badger Pass Ski Area each year (Doke 73). Yosemite National Park’s Search and Rescue reported 225 rescues in 2019. 61% of those rescues were for injured or lost hikers (Park Statistics - Yosemite National Park (U.S. National Park Service)). In 2005, Yosemite accounted for 10% of all NPS SAR operations and 25% of the total NPS SAR costs, making the park a viable geographic area to study when investigating the reasons behind the number of SAR operations (Heggie and Amundson). In 2009, Yosemite National Park’s Visitor Services conducted a visitor survey to gather tourism data from 1,219 visitor groups over the period of one week during peak tourism season. The study revealed that 57% of park visitors were visiting the park for the very first time (Park Statistics - Yosemite National Park (U.S. National Park Service)). This means over half of the park visitors are experiencing unfamiliar terrain on hiking trails, therefore a good wayfinding system is important. The main factors contributing to hikers becoming lost were losing the trail accidentally, failure to communicate the hiking plan, and miscalculating the time or distance it would take to complete the hike (Doke 44). The trail signs in Yosemite are an

important part of trail navigation: they lead hikers to their intended destinations, provide information about the distance to destinations, and give indication of the marked trail.

Current design guidelines were created in 2004 by the National Park Service Management to create overall consistency in trail markers and directional signage design throughout the park. The guidelines clearly state that all signs must be integrated into the park landscape and work harmoniously with the park environment. The design theme must be cohesive and reflect the character and uniqueness of the park. Signage must serve a functional purpose without competing with park features (National Park Service (U.S.) 72). Every national park has its own unique, natural features that are unlike those in other national parks within the United States. If based on these guidelines, the NPS were to adopt a universal trail wayfinding system, each park would have consistent signage that also highlights the natural features of that particular park.

In 2002, the National Park Service published the “UniGuide: Identification, Wayfinding and Visitor Information for National Parks.” The UniGuide serves as a standards manual for the design and creation of all wayfinding signage in the national parks. The guide, however, provides minimal direction for the design of hiking signs or markers used for hiking trail navigation. The UniGuide states that park signs are the most frequently used communication between the park and its visitors. The entrance signs greet and welcome visitors, road signs direct traffic through the park so visitors know where to go to see park destinations, and all park signs are part of a system that represents the entire National Park Service. Park signs are also meant to inform visitors of dangerous areas and educate them about wildlife encounters.

From the UniGuide:

The UniGuide Sign Standards illustrated on the following pages provide, for the first time, standards that address the full range of signs that parks typically need. These standards offer a variety of benefits to those who manage and to those who visit parks. The UniGuide standards will help coordinate signs with other parts of a park's communication program. With consistent applications signs will reinforce the agency's identity. As a result, communications will be more certain, more rapid, and more effective, and visitor safety, convenience, and enjoyment will be more assured (*UniGuide: Identification, Wayfinding and Visitor Information for National Parks*).

Entrance signs, road signs, and facility signs are all necessary components of the communication between a park and its visitors. The UniGuide, however, does not fully outline design guidelines for hiking trail signage or markers, nor does it state who is responsible for ensuring the safety of visitors through a cohesive trail marker system. The "Sign Program" outlined in the UniGuide should be inclusive of the trail markers that are already in existence within the NPS, and it should be evaluated for effectiveness. Hiking trail sign and marker designs should be emphasized in the UniGuide so that it establishes consistent guidelines for all trails in the parks. The guide already notes the importance of signs and of communication with park visitors, therefore hiking trail signs should be included as part of that communication effort.

Varying sign design throughout the park's hiking trails can be confusing for park visitors, not to mention that it is in conflict with the design guidelines set by the NPS. In a geographical graduate thesis study by Jared Doke, it was determined that there is poor trail signage near Sentinel Dome/Taft Point which could be a contributing factor to visitors becoming lost in that area (Doke 73). It is important to note that the signage design used on the Sentinel Trail varies. One of the signs found along the Sentinel Trail appears to be a metal sign fixed to a metal post. The type is punched into the metal, and

the design consists of an arrow indicating the direction of the trail. These signs are supposed to be representative of the landscape and are not to interfere with the natural features of the park; at the same time they are to maintain their functional purpose. The functional purpose of the sign is to give clear direction. Therefore, the design should be rendered in an easy-to-read typeface, and with clear design elements. The sign placed on the Sentinel Trail is difficult to read because of the punched out type used to indicate the name of the trail and the distance to the next destination. The type takes on the color and pattern of the background which creates legibility issues and frustration for the reader.

According to the park design guidelines, it is important for the signage found throughout the park to be consistent (National Park Service (U.S.) 177). However, along the aforementioned area of Sentinel Trail that features a metal wayfinding sign, hikers will also find a sign made of natural wood, fixed to a wooden post, and printed in white embossed type. Varying signs can create confusion for visitors making them question if they are in fact on the trail they intended to hike. This is just one example of an area in Yosemite National Park where the wayfinding design changes from sign to sign along the same hiking trail. This could contribute to the fact that Yosemite Valley has become a “hot spot” for lost hikers. In the book, “A Sense of Place: Design Guidelines for Yosemite National Park,” the differences in trail signage design are identified:

Signs are found throughout Yosemite National Park, in both densely developed settings like Yosemite Village and on trails deep in the remote Yosemite Wilderness. In these varied locations, signs have considerable differences in frame and support character, including fabrication, size, construction, materials, and function. Some signs use a simple style bending natural brown colors and embossed features appropriate to the area, such as the triangle in the frames of signs at the Indian Village and acorns at Lower Yosemite Fall and other areas. More rustic signs feature stone pedestals or log frames, making them appear to

be constructed from surrounding materials (National Park Service (U.S.) 74).

While both sign examples found along the Sentinel Trail align with some design guidelines, they do not align with all of them, which indicates that the hiking trail signage needs to be improved. The wayfinding system should represent the unique landscape of the park, but it should also have a consistent voice that can be used on every trail sign throughout the park. Every trail sign should use the same typography, materials, colors, and construction regardless of the placement. The materials and construction should be representative of the entire park rather than of one specific area within the park. Signage design consistency will give the park trail signs a similar voice and therefore reduce confusion. Improved wayfinding and appropriate sign placement along hiking trails could reduce the number of lost or injured hikers in Yosemite Valley, thus saving the lives of park visitors and reducing the number of search and rescue operations.

### **Overview of Study Area**

There are three primary reasons why Yosemite National Park was chosen for this study. One, Yosemite National Park has the second highest reported search and rescue incidents in US National Parks, accounting for 25% of all NPS SAR costs (Heggie and Amundson). Two, significant ‘hot spots’ for lost hikers have been identified in the park from a previous study (Doke 38). Three, Yosemite National Park is the fifth most visited national park in the United States with millions of unique visitors each year. It is important to examine the design guidelines outlined by the National Park Service (NPS) Management Policies and the appropriateness of the varying wayfinding systems used throughout Yosemite Valley which have the potential to improve the hiking experience for those visitors (“Stats Report Viewer”).

Yosemite National Park was first established as protected land in 1864 by President Abraham Lincoln and was the first land protected by the United States government to be designated for public use (People - Yosemite National Park (U.S. National Park Service)). Yosemite is in the western Sierra Nevada mountain range in central California and spans an area of 759,620 acres (1,187 square miles) with elevations ranging from 2,000 to 13,000 feet. The park is managed by the National Park Service and primarily consists of designated wilderness areas which make up 95.45% of Yosemite (“Park Statistics - Yosemite National Park (U.S. National Park Service)”).

Weather impacts the conditions of hiking trails depending on the time of year, and YOSAR responds to more weather-related rescues during the winter season. February and March have the highest reported incidents per 100,000 visitors because of inclement weather (Doke). Snow and ice accumulate on the ground during winter, potentially making trails indistinct or dangerous for hikers to travel. Park rangers close sections of trails to hikers in the winter to avoid exposing hikers to dangerous areas in the park. Snowfall begins as early as November, but it is typically light and melts within a few hours. Winter starts in December and continues until March and is typically snowy with multiple road and trail closures. Snowpack increases throughout the winter and can reach dozens of feet at higher elevations. Snowfall may continue into the spring which starts in April and continues through May. Snow may still be visible on hiking trails until early to mid-summer and some trails will not become accessible until mid-June or later. Based on elevation, Yosemite can have dramatic weather changes which influence trail conditions. Daytime temperatures in the valley are mild in the summer with a range in the 70s F and as low as in the 30s F at night. Occasionally, temperatures can reach up to 100 °F in the

summer (“Park Statistics - Yosemite National Park (U.S. National Park Service)”). Park visitation increases in the summer with peak visitation in July and August and starts to decrease in the fall. The increase in park visitors correlates to the increase in more rescues during the summer months (Doke 57). During this time, trails are heavily traveled and trail conditions can change because of the amount of foot traffic. Congested trails are more difficult to navigate and congestion increases travel time on popular trails, which exposes visitors to the heat for extended periods of time. Yosemite is located 195 miles from San Francisco and 315 miles from Los Angeles. The park is known for its unique landscape that boasts large granite cliffs, deep valleys, giant sequoias and diverse wildlife (“Geology - Yosemite National Park (U.S. National Park Service)”).

### **Overview of Observation Area**

For this study, six trails were considered for observation based on popularity, the number of search and rescue operations performed, trail difficulty ratings, and varying sign usage for comparison.



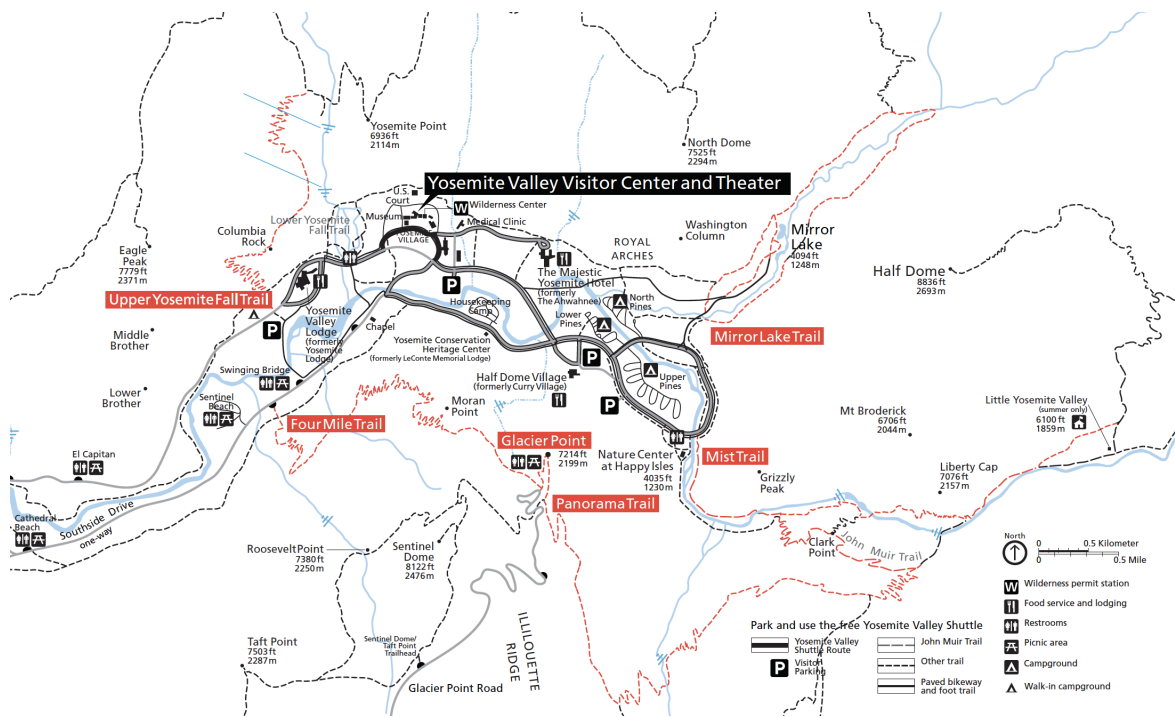


Figure 1.1. Map showing hiking trails in Yosemite National Park where observations took place.

The Mist Trail was chosen because it is one of the most popular trails in the park, featuring three popular park destinations: Vernal Fall, Nevada Fall, and Half Dome. Four Mile Trail was chosen because it is another popular trail in the park and because it leads hikers to Glacier Point, another popular hiking destination. Yosemite Falls Trail is a popular trail for hikers because it features North America's tallest waterfall, Upper Yosemite Fall. It was chosen because it has a higher percentage of search and rescue operations than other trails based on the data gathered for this study. Glacier Point was chosen for observation based on the recommendation of a park ranger to the author as an area where hikers frequently get lost. Glacier Point is a destination in the park where multiple trails connect, making the area more complex for navigation. Mirror Lake was chosen because it varies in sign usage and trail difficulty rating. It was important to

include a trail with varying difficulty to observe the difference in sign placement and trail conditions. Panorama Trail was chosen because of its connection to backcountry trails and varying sign usage. The observation areas were chosen to give a broad overview of the different types of trails and signs in a single national park.

### *Mist Trail*

Mist Trail is one of Yosemite's signature hiking trails. It is located in eastern Yosemite Valley where approximately 25% of all rescues take place (Dill). It is also the most dangerous trail in the park due to overcrowding and year-round wet trail conditions just above the raging Merced River. The trail is 2.7 miles one way to the top of Nevada Fall. The elevation at the trailhead is 4,000 feet. There is a 1,000 foot elevation gain to Vernal Fall and a 1,900 foot elevation gain to Nevada Fall ("Vernal Fall and Nevada Fall Trails - Yosemite National Park (U.S. National Park Service)"). The trail is known for favorable scenery across the valley combined with the majesty of two waterfalls and the Merced River, making it an extremely popular trail in the summer. The trail's name derives from the mist that sprays from the waterfalls. According to the National Park Service, the difficulty of the trail is classified as moderate/strenuous depending on how far a hiker decides to travel. The difficulty increases with the elevation. There are 600 steep granite steps that lead to Vernal Fall ("Vernal Fall and Nevada Fall Trails - Yosemite National Park (U.S. National Park Service)"). The steps are wet because of the mist; therefore, the steps are slick and especially dangerous when overly crowded. The trail overlaps with the John Muir Trail and connects to Half Dome Trail which leads to the top of Half Dome. The Mist Trail is partially paved and clearly defined, making it easy to locate and navigate. The trailhead contains a single sign with the trails listed, an

arrow, and a hiking trail symbol. In the summer, a hiker can expect to find a staffed information booth with Yosemite Conservancy employees providing information about the hike. The signs at the booth contain information about the dangers of hiking Mist Trail. In addition, are signs posted a few hundred feet from the information booth with trail rules and maps of the trail. The sign contains information about black bear safety and winter trail closures. Another trail sign contains information about the High Sierra Loop Trail with a list of trails and distances. Near the footbridge, visitors can expect to see signs from Yosemite Conservancy warning hikers about the dangers of swimming in the water. Hikers will not find clear trail markers along the trail, however, there are rusty trail signs where certain trails connect.

#### *Four Mile Trail*

The Four Mile Trail is located south of Yosemite Valley and boasts strenuous switchbacks and panoramic views of the valley. The original trail was constructed in 1872 to connect the Valley floor to Glacier Point in only four miles. Over the years, park crews rerouted sections of the trail resulting in a longer route of about 4.8 miles one way (“Four Mile Trail - Yosemite National Park (U.S. National Park Service)”). The trail starts at an elevation of 4,000 feet and consists of a 3,000 foot elevation gain to the top of Glacier Point (Yosemite Hikes: The Four-Mile Trail). According to the National Park Service, the trail is classified as strenuous because of the steep switchbacks, the length, and the elevation gain. This trail is popular in the summer because it connects two of Yosemite’s most popular locations and the scenery is some of the best in the park (“Four Mile Trail - Yosemite National Park (U.S. National Park Service)”). Four Mile Trail has two trailheads, one at Glacier Point and the other near Yosemite Valley. Hikers who

choose to start in the valley will hike to Glacier Point and have the option to hike back down or they may take Panorama Trail for a long loop back to the valley. The trail can be accessed at shuttle stop number 7 or at the base of Sentinel Dome.

### *Yosemite Falls Trail*

Yosemite Falls Trail, often referred to as Upper Yosemite Falls Trail, is located north of Yosemite Valley and is one of the oldest historic hiking trails in the park. The trail leads to the top of North America's tallest waterfall, Yosemite Falls. The trail is open year-round; however, conditions on the trail vary depending on the season. For instance, the upper part of the trail may become icy in the winter due to spray from Yosemite Falls ("Yosemite Falls Trail - Yosemite National Park (U.S. National Park Service)"). The trail is accessible from Camp 4 and crosses the Valley Loop Trail. The trail has a 2,700-foot elevation gain (Yosemite Hikes: The Upper Yosemite Falls Trail). According to the National Park Service, Yosemite Falls Trail is graded as strenuous with an estimated completion time between 6 and 8 hours. The first 1,000 feet of elevation gain will take hikers to Columbia Rock with an overview of Yosemite Valley. Hikers may continue past Columbia Rock for 0.5 miles for a view of Yosemite Falls. Hikers may continue past Yosemite Falls and hike east for approximately 1.6 miles round trip to reach Yosemite Point (6,339 feet) or hike west for approximately 5.8 miles round trip to reach Eagle Peak (7,779 feet) and El Capitan (7,569 feet) ("Yosemite Falls Trail - Yosemite National Park (U.S. National Park Service)").

### *Mirror Lake Loop Trail*

Mirror Lake Loop Trail is located on the east end of Yosemite Valley. The trail got its name from the reflections in the lake of surrounding cliffs. According to the National Park Service the trail is rated as easy and is approximately 2 miles round trip to the lake and 5 miles for the full loop. The entire trail is mostly flat and can be hiked in 1-2 hours. Hikers may continue past Tenaya Creek on Snow Creek Trail and continue the loop before returning to Mirror Lake on the south side of Tenaya Canyon. The trail is open year-round and may become icy in the winter. The loop is partially paved for bikers and vehicles with a handicap placard. (“Mirror Lake Trail - Yosemite National Park (U.S. National Park Service)”)

### *Glacier Point*

Glacier Point is located southeast of Yosemite Valley and is an overlook with views of the Valley, Half Dome, and Yosemite Falls. The area is accessible by car during the summer months and into October or November. The road to Glacier Point closes in the winter and is only accessible to cross-country skiers and people on snowshoes. The overlook was named for the glacier that formed the Valley and created the spectacular views admired by visitors today. Glacier Point can be accessed from three hiking trails; Four Mile Trail, Pohono Trail, and Panorama Trail. All are classified as strenuous by the National Park Service. The elevation at Glacier Point is 7,214 feet, which is 3,200 feet above Curry Village. Hiking trails around Glacier Point include McGurk Meadow, Dewey Point, Taft Point, Sentinel Dome, Four Mile Trail, Panorama Trail, Mt. Starr King View, Ostrander Lake, and Pohono Trail. Glacier Point has a small amphitheater for educational programming about bird watching, stargazing, photography, and history by

the National Park Service (“Day Hikes along the Glacier Point Road - Yosemite National Park (U.S. National Park Service)”).

### *Panorama Trail*

Panorama Trail is located southeast of Yosemite Valley and it starts at Glacier Point. The route takes hikers to Yosemite Valley past Illilouette, Nevada, and Vernal Falls. The hiking trail is 8.5 miles one way with a 4,000-foot elevation gain. According to the National Park Service this trail is rated as strenuous (“Day Hikes along the Glacier Point Road - Yosemite National Park (U.S. National Park Service)”). The entire trail can be hiked in 6-8 hours. Panorama Trail has three intersections and leads to two unmarked backcountry trails as well as the John Muir Trail. The Panorama Trail and Four Mile Trail may be combined for a large loop that directs hikers back to Glacier Point (“Yosemite Hikes: The Panorama Trail”).

## **II. RESEARCH AND LITERATURE**

The research for this study includes an analysis of current trail sign design in Yosemite, of trail wayfinding systems in and outside of the United States, and an evaluation of hiking rating systems in Yosemite and other national parks. The purpose of this research is to learn about the design challenges of hiking trail systems in the national parks, and to provide insight into how parks are communicating with visitors. It will also aid in providing design and wayfinding guidelines for new designs that will be important for creating a consistent, easy to implement system.

### **Design Analysis of Yosemite Hiking Signs**

There are multiple signs in Yosemite for navigating roads, trails, and shuttle routes. In the village, there are signs that direct visitors to the shops and cafes. The signs designed for navigating roads and shuttle routes have been carefully planned and designed using UniGuide standards. The trail sign design, however, varies throughout the park and from trail to trail. According to the Historical Marker Database, there are 32



Figure 2.1. Historical marker on Mirror Lake Trail in Yosemite National Park.

historical markers in Yosemite Valley. The markers are placed on hiking trails throughout the park to educate visitors on the history of the area they are exploring (“Historical Marker Pages Containing ‘Yosemite Valley’ - The Historical Marker Database”). These markers have little information about navigating the trail, and should only be used for the purpose of education. The markers may include a map, but most maps do not provide accurate, helpful information for wayfinding. For example, the historical marker on the Mirror Lake Loop Trail does not show the entire loop, and can create confusion for hikers about their hiking route. The historical markers are similar in size, material, and design. The design is consistent on most historical markers, and features a background image of the surrounding area, or one that is relevant to the historical information. All signs have a brown box that bleeds off the right side of the sign. The box contains the title of the geographic area for which the information is relevant. Directly underneath the box is a larger title introducing the paragraph that sits to



the right. On the left side of the sign there is a larger brown box that bleeds off the left side of the sign. Contained under the larger brown box is additional information about the trail or surrounding area. The hierarchy of the sign would lead the user to read the information at the top right first before they continue to the information on the left side of the sign. Any subsequent information is placed under the higher paragraph to fill the remaining space. This informs visitors how to stay safe on the trail by warning them about the dangers of wildlife or even waterfalls. The typography used on the signs is Helvetica, designed by Max Miedinger and Eduard Hoffmann, and Times New Roman, designed by Stanley Morison and Vincent Lardent.

The trail signs that are made of wood with embossed white typography are placed sporadically on trails and often use the names of destinations, the distances to those destinations, and occasionally directional arrows. Some signs also use iconography for communicating trail restrictions and rules. The design of the signs can vary from sign to sign and from trail to trail. An example of the differences can be seen in figure 2.2.



Figure 2.2. (L-R) Trail signs on Mirror Lake Trail and near El Capitan.

The sign in figure 2.2 lists the name of the first destination followed by the distance to the destination and then a directional arrow. If the user needs to turn right, then the arrow may be right aligned on the sign but if the user needs to turn left, the arrow should be left aligned on the sign, like it is shown in figure 2.2. If the user needs to continue straight, the arrow should be left aligned. The important thing is to align the arrows in a consistent manner on all signs. The alignment is a matter of preference, however one might argue it is best to align all arrows on one side of the sign so the user only has to look in one area to determine direction of travel. The two other destinations on the sign are listed below, followed by the distance to the destination. The directional arrow does not follow the distance, rather, it is displayed before the destination name and it is right aligned.

Another sign of similar design uses icons, destinations, the distances to the destinations, and directional arrows. The arrows are aligned on the right side of the sign, even though one arrow directs hikers to continue straight and the other arrow directs hikers to turn left. The arrows should be left aligned, however, there are icons in the place where the arrows should be. It is also important to note that the distance is listed after the directional arrow. The two signs lack consistency in regard to design layout.



Figure 2.3. (L-R) Trail sign near El Capitan and Upper Yosemite Fall.

Figure 2.3 is a comparison of two signs that both use iconography, destination names, distances to destination, and directional arrows. The sign on the left uses an icon to represent a climbing area and falling rocks. The sign then lists destinations followed by

directional arrows and then the distance to the destinations. Below the destinations there is a warning accompanied by an icon to warn hikers about the possibility of falling rock. The sign on the right lists the destination first followed by the distance to the destination and then the directional arrow. The icons are listed near the bottom of the sign to communicate that pets and bicycles are not allowed on the trail—indicated by the red slash through the icon—and that hikers can use the trail. This is an example of the differences in layout design when using icons, and of how layout design varies from sign to sign in the same park.

Trail signs are not read in the same way users read print materials, such as newspapers or books. Traditionally, readers read sequentially from left to right and from top to bottom. However, signs are read in an unstructured way using a scanning and glancing process, which is the same way a user would evaluate an unfamiliar environment. If users are glancing at signs instead of reading them, this means information on trail signs needs to be designed so users can quickly understand the information and continue hiking (Arthur and Passini 162-163). Therefore, the law of proximity is important to establish on all trail signs so that the information can be understood by glancing. Gestalt's law of proximity means items that are set close together seem to be part of a group, and items that are set far apart are perceived as separate (Graham 10). If users are glancing at signs instead of reading them, then the information needs to be structured so it can be processed more easily, which means that the destinations need to be put into smaller groups. If a trail sign contains three or more destinations, then the information needs to be grouped with no more than three or four

destinations per group (Arthur and Passini 180). Otherwise, the information will not be processed, and in a national park this can be the difference between life and death.

The typeface used on signs in the national parks is not a true typeface but instead is a set of paths cut out by a router and then painted white (The University of Kansas). The typeface is set in all caps. There are often slight differences that can be seen from letter to letter on the same sign. The national parks do not universally use the same typeface on trail signs and there are slight differences when comparing typefaces. The difference in typefaces shows that Yosemite does not apply the same rules for design as other national parks. This is apparent on most signs throughout the park, which appear to be outdated and do not align with current design guidelines.

Yosemite uses another type of sign on hiking trails to guide hikers and to provide them with information they may need for completing their hike. This sign communicates the same information as the wooden sign, however the sign is made out of metal and is fixed to a metal post. The signs appear at trail junctions on some of the most popular hiking trails in the park. They often include the name of destinations and the distances to destinations but do not feature a directional arrow. The signs list the destination followed by the distance to the destination. The typography used on the metal signs is not the same as that used on the wooden signs. Although the signs seem as if they have not been updated, the sign that was posted on the Mist Trail in August 2014 was not the same sign that was posted in August 2019. It is important to note that even though the signs were changed, the design was not updated, and the sign was not replaced with a wooden trail sign.



## **Comparative Analysis of Other Signage Systems**

This section analyzes several trail signage systems in order to discover why they are in place and how they are used for wayfinding. A comparison of Czech trail signage systems, US ski resort wayfinding signage, and existing hiking trail signage systems in the United States was completed to learn about current systems in use today. The signage systems evaluated include skiing trail difficulty ratings, hiking trail difficulty ratings, and directional signs. The analysis will be used for the goals and objectives outlined in this study, and parts of each system will be applied to the preliminary designs of the hiking trail signage and marker system created for this project.

### *Czech Republic Hiking System*

The Czech Republic has one of the densest trail networks in the world, so it is no wonder they have a well-designed hiking marker system to help hikers navigate the trails. The Czech Hiking Markers Standard is a trail marking system used throughout the Czech Republic and other European countries for hikers, cyclists, skiers, and equestrians. The Czech Hiking Club was founded in 1888, and the Hiking Markers Standard was designed in 1889. The trail marking system has been maintained by the Club ever since. The Club is responsible for all tourist trails found in the Czech Republic, and it works to ensure the safety of tourists who use the trails as means for travel or recreational activities. Their system is so successful that it has expanded to neighboring countries, such as Slovakia, Romania, Croatia, Bosnia, Poland, Ukraine, and even as far as Peru and Brazil (“Czech Tourist Club”). The system is low cost and easy to implement, requiring only basic materials for the markers. The system is also easy to understand, which means hikers are

at a reduced risk of becoming lost on the trail. This system could provide inspiration for a new wayfinding design in our nation's parks.

The Czech Hiking Club is separated into different sections which are each responsible for their own part of the system. These sections include: hiking, cycling, skiing, cross-country hiking, horseback riding, and modern hiking to name a few ("Czech Tourist Club"). On their website, each section of the club has a point of contact so that users may communicate with a specific person about that section. In the United States, the National Parks System is responsible for maintaining the conditions of the trails within our nation's parks. According to the National Park System website, in the 1970s many of the trails in our national parks saw an increase in visitors, which resulted in trail erosion. The managers of the parks struggled to maintain the trails, and many of them turned to local communities for assistance. They partnered with volunteers, state-run conservation groups, and non-profit organizations to keep the trails in good hiking condition. Today they continue to rely on these groups to help maintain the trails, which means that those community groups would be responsible for maintaining any new wayfinding system designed for our nation's parks ("Trail Management & Maintenance - Trails & Hiking (U.S. National Park Service)").

The design of the Czech Hiking Markers Standard is simple and easy to understand, and serves as an international system that communicates across language barriers. Trails are marked with a simple square composed of three stripes. The first and last stripes are white, and surround a middle stripe of color, each communicating specific information about the trail. The middle stripe is either red, blue, green, or yellow. The red stripe indicates long-distance routes, the blue stripe notes routes that connect to

prominent places, the green stripe marks additional routes, and the yellow stripe point to short connecting routes. The system uses directional arrows in place of the middle stripe at decision points along the trail to indicate the direction for the hiker. These stripes come in many forms and are often painted onto natural elements (rocks, trees, etc.). Some of the marks are posted on signs, especially in urban areas. Oftentimes where multiple trails meet there will be a multicolor tag with arrows and stripes indicating which direction to take for that color trail. At a trailhead, a hiker would find multiple yellow informational signs fixed to a post. Each sign includes the name of the trail and duration it would take to complete the hike. The sign also includes the belt mark and a directional arrow. The posts have a red tent-like roof for ease of recognition at a distance. At the end of the trails there is an end mark, a simple square with a smaller square in the middle, the same color as the middle stripe of that trail. This sign will be accompanied with other signs that might indicate a lookout point, castle ruins or other interesting objects (“Czech Tourist Club”).





Figure 2.5. Trail marker fixed to a wooden post in the Czech Republic.

The skiing trail signs in the Czech Republic are the same as the hiking trail signs with only one slight difference: the color of the outside stripes is orange. The orange stripes make the sign visible against the snow. The hiking signs with white outer stripes would not be as visible. The directional signs are slightly different in layout, however the information remains the same, with the name of the trail and the length of the trail listed similarly to the hiking trail signs. The design choices of the skiing trail signs should be taken into consideration for areas where snow is prevalent on hiking trails for hiking trail wayfinding signage (“The System of Wayfinding Trail in the Czech Republic” 1).



Figure 2.5. Trailhead sign in the Czech Republic.

The Czech Hiking Markers Standard is used in multiple countries across Europe and even South America because it communicates across multiple languages and is easy to implement and maintain (“Czech Tourist Club”). The system could easily be implemented by our National Park Service with some slight modifications. The system would not be designed to be maintained by one organization but should be designed so that multiple organizations can maintain it without confusion. The primary critique of the Czech Hiking Markers Standard is that it does not utilize natural elements, rather it covers up natural elements by bringing manmade components into a natural environment through the use of a placed marker. Instead, blazes could be used to mark the trail. The shape and simplicity of the mark would eliminate the need for a placed marker. This would cut down on the materials needed to maintain the system. The Czech system also lacks information about trail difficulty. Though it lists the distance of a trail, it does not

provide information about the terrain. This system is good inspiration for working towards a new design for our nation's parks. Elements of it should be considered for creating a successful wayfinding and trail difficulty system.

### *Ski Resort Wayfinding*

In 1964, the National Ski Areas Association (NSAA) adopted the first system of wayfinding signage and difficulty of terrain ratings for use at ski resorts across the United States. The NSAA was pressured by insurers to make skiing safer, and therefore, a color-coded terrain difficulty system was created. The signs used today are different from the original designs due to a series of changes that were made after the NSAA realized that the color-coded US and European systems were causing confusion among international skiers. Fewer than three years after the NSAA developed their original wayfinding signage, The Walt Disney Company announced that they wanted to build their own ski resort, and as part of that began exploring options for a unique wayfinding and signage system. They user-tested various shapes and colors with skiers to develop a completely new system. The testing determined the system's effectiveness at allowing skiers to read and understand trail difficulty with ease. The NSAA switched to this new system in 1968, and it is still in use today (Fry and Cram 19).

The ski terrain difficulty rating system in the United States consists of four colors and shapes, each indicating a different level of difficulty based on the slope gradient shown in figure 2.6. A green circle indicates the easiest of trails with a slope gradient of less than 25%. A blue square indicates an intermediate trail with a slope gradient between 25% and 40%. A black diamond indicates an advanced trail with a slope gradient of more than 40%. A double black diamond has the same slope gradient as a black diamond, but

the trail might include hazards such as drop-offs, boulders, narrow trails, and exposure to strong winds. A double black diamond has a level of difficulty for advanced skiers only. There are very few triple black diamond trails, but it is worth mentioning that these few, extremely dangerous trails do exist. The triple black diamond rating is at the very top of the terrain difficulty rating scale. A rounded, oblong orange rectangle indicates a terrain park with ski jumps and rails for performing tricks, and should only be used by advanced skiers and snowboarders. Each rating is clearly identifiable on trail signs because of the difference in shape and color associated with the level of difficulty (Lippus 76).



Figure. 2.6. Skiing trail difficulty ratings by the NSAA.

Even though signage design varies depending on the ski resort, the system consistently uses the same colors and shapes to define terrain difficulty. Trail wayfinding at the Heavenly Ski Resort in Lake Tahoe, Nevada uses a black, rectangular sign with white typography indicating the name of the trail, a white square with the color and shape indicating the terrain difficulty, followed by another white square with a black arrow indicating the direction of the trail. The sign is fixed to a cedar post with yellow padding at the base to protect skiers from injuring themselves should they collide with the sign. The location of the signage varies from trail to trail, but the trail signs are typically placed



at the beginning of every trail, when two trails connect or intersect, and where there is a curve in the trail when the skier might question the direction of the ski lift or lodge.



Figure 2.7. Skiing trail sign in Lake Tahoe, California.

The wayfinding typeface at Heavenly Ski Resort is a sans-serif font that is left-aligned on the sign followed by a difficulty marker and a directional arrow, both of which are aligned on the right. The font choice is readable and can be read by skiers traveling at a high speed. The typeface used in wayfinding is equally important as the shapes and colors used to determine the terrain difficulty for the user. A skier must be able to identify the letterforms from a distance while also traveling at a high rate of speed.

Trail signs are not the only signage found on the mountain that might assist skiers in navigating the trails. There are wayfinding signs that include directional information for ski lifts, restrooms, restaurants, and first aid. These signs are designed similarly to the trail signs, but the terrain difficulty rating icons are replaced with appropriate icons paired with typography and an arrow.

Additional signage can be found directly under ski lift signs in high-traffic areas. These signs include instructional information and warnings to the skiers on the trail or on the lift. The lift sign is paired with a wayfinding sign to point to the trails each lift specifically serves. These high-traffic areas are also an opportunity for the resort to advertise activities offered throughout the resort. Those signs are typically not as large as the wayfinding or informational signs and are often placed in a position with less



Figure 2.8. Wayfinding sign for skiing in Durango, Colorado.

hierarchical importance, therefore, the wayfinding signage takes precedence over other signs on the mountain.

The same terrain difficulty system can be found at other mountain ski resorts across the United States, and while the wayfinding signage communicates the same message, is often designed in distinct ways. Varying design from one resort to another gives each the ability to demonstrate its own unique style. The wayfinding used at Purgatory Ski Resort in Durango, Colorado includes rectangular signs filled with the corresponding color of the terrain difficulty for that specific trail. If the trail is rated as intermediate terrain, the sign is blue with a white arrow, white typography, and a white square indicating the level of difficulty. It is important to note that the difference in design does not change the system, but it communicates the terrain difficulty in a different way.

Ski resort wayfinding and terrain difficulty ratings systems have been successfully used across the United States for the past 50 years (Fry and Cram 19). The color-coded and shape dependent system communicates the difficulty and direction of each trail on the mountain to skiers. Simple shapes such as the circle, square, diamond, and oblong rectangle are paired with four primary colors, green, blue, black, and orange respectively, making the entire system easy to use. The difficulty rating system remains the same from one resort to another despite slight differences in the overall design of the signage. Visual consistencies and placement of signs make this system good inspiration for other outdoor wayfinding systems.

### *Existing Hiking Rating Systems in the United States and Europe*

The hiking trails found throughout the United States lack a universal trail rating based on the same difficulty scale. A universal hiking trail rating system should coincide with design guidelines and be applied to a signage and marker system. Parks in the United States have their own scales to determine difficulty, and none are exactly the same. Shenandoah National Park in Virginia uses a numerical rating and an algorithm to measure the difficulty of hiking trails within the park (“How to Determine Hiking Difficulty - Shenandoah National Park (U.S. National Park Service)”). The Willamette National Forest in Oregon uses trail conditions, steepness, elevation gain/loss and the number of natural obstacles to grade and rate each hiking trail (“Willamette National Forest - Hiking”). The Yosemite Decimal System is a three-part system designed by the Sierra Club, and is primarily used to classify hikes and climbs in California. The first two classes can be used to grade hiking trails while the more difficult classes are used to grade climbing routes (“Trail Management & Maintenance - Trails & Hiking (U.S. National Park Service)”). In Europe, the Swiss Alpine Club (SAC) created the Swiss Hiking Scale to inform hikers of the difficulty of hiking trails based on terrain difficulty. The scale covers a range of mountains and alpine hiking, and can be applied to any hiking trail within the Alps region of Europe (“SAC- Berg- Und Alpinwanderskala”). In addition to the ranking systems used in states, regions, and parks, websites such as The Hiking Project, list trails within a geographic area, and have designed their own systems for grading trails. The Hiking Project uses a combination of shapes and colors similar to a skiing trail rating system. The United States needs to have a hiking trail rating system designed to inform hikers of the difficulty of the terrain on any given trail, and the same



system should be used at every state or national park to eliminate confusion for hikers. The differences between the current systems do not give an accurate grade to hiking trails and leave room for error in understanding terrain difficulty.

Shenandoah National Park in Virginia uses a mathematical formula to determine the difficulty of trail terrain. The formula takes into account elevation gain plus the distance of the trail. Using this formula would allow any hiker to determine the difficulty of the trail without needing a previously determined grade for a specific trail. The following information is from the National Park Service website for Shenandoah National Park. If a hiker wants to embark on a 10-mile hike, and the hiker knows the trail will incur a 2,000-foot elevation gain, the hiker would apply the following equation:

$$2,000 \times 2 = 4,000$$

$$4,000 \times 10 = 40,000$$

Next, the hiker would take the square root of 40,000 for a final number of 200. The number would then be applied to grade descriptors to give the hiker a general term used to describe the difficulty of the trail. The descriptors range from ‘easiest’ to ‘very strenuous’ with variation accounting for steepness in terrain, or the requirement of scrambling over a short section of trail. The easiest grading range is less than 50. The moderate grading range is from 50-100. The moderately strenuous grading range is from 100-150. The strenuous grading range is from 150-200. The very strenuous grading range is greater than 200. The example of the 10 mile hike above would classify the hike as very strenuous because of its numerical value of 200 (“How to Determine Hiking Difficulty - Shenandoah National Park (U.S. National Park Service)”). This system is a good basis for determining the difficulty of trail terrain, however, it does not consider

trail barriers nor short distances that require advanced hiking skills. Both of these factors can change the difficulty of a trail, but cannot be determined by a mathematical equation. Therefore, this formula cannot be used to establish a universal system for all hiking trails within the United States.

The Willamette National Forest in Oregon uses a trail rating system based on steepness, elevation gain/loss, trail conditions, and natural barriers. It is important to note that the system has different ratings based on the kind of activity used on the trail. For example, the hiking trail rating system differs from the mountain bike trail rating system. The scale uses descriptors to grade the difficulty of the trail. The descriptors include a range of easy, moderate, and difficult ratings. The easy rating is used when the trail has a 20% grade, a trail size of 18-24 inches, and a trail condition composed of natural materials that do not increase walking difficulty. The moderate rating is used when the trail has a 30% grade, a trail size of 12-18 inches, and the trail condition is composed of materials that might create natural barriers, testing various hiking abilities. The difficult rating is used when the trail has a 30% or greater grade, a trail size of 12 inches, and a trail neither a discernible path nor easily recognized trail barriers (“Willamette National Forest - Hiking”). The Willamette National Forest hiking rating system is easy to follow, but can become confusing because there is not enough information provided for each rating. The multiple activity ratings could be combined into one rating because of the fact that steepness of the terrain and natural barriers do not change. This system also does not include the length of the trail, which is an important factor in designing rating systems for hikers.

The Yosemite Decimal System (YDS) was designed by the Sierra Club in the 1950s and has ratings that cover terrain difficulty for hikers and route grades for rock climbers, which is what the system is primarily used for today. The YDS comprises 5 classes: Class 1 is on the low end of the spectrum, and describes a clearly identified hiking trail that covers relatively flat terrain. Class 2 refers to longer trails which are classified as “cross country” and which require basic navigation. Class 3 trails might require some scrambling, which means that the hiker would be expected to use their hands on the trail. The terrain on a class 3 trail would be difficult and likely include natural barriers. Class 4-5 rankings can no longer be used for hiking because these classes are primarily used to rate the level of difficulty for climbing routes. One important aspect to note about the YDS is it considers almost every difficulty that is encountered on the trail. For example, a 2-mile, flat trail that would otherwise be classified as a 2 is instead classified as a 4 because the trail includes a half mile section of scrambling where using a rope is necessary (“The Yosemite Decimal System”). Because it includes classes that are not used by hikers, the YDS is not ideal as a hiking rating system. However, it is a successful system for climbers, and could influence the design of a new hiking rating system. The YDS cannot be used for all hiking trails in the U.S. because the system lacks a detailed analysis of trail steepness and length.

The Swiss Hiking Scale was designed by the Swiss Alpine Club and is used in Alpine countries. The scale is a 6-part system that uses a combination of mountain and alpine hiking. T1 is the easiest grade and is used to grade a typical hiking trail with well-marked trails and flat terrain with a slight incline. T2 is the next grade for a hiking trail with trails that may or may not be marked and includes steeper terrain than seen on a T1

trail. T3 is used to grade mountain hiking with trails that are not always visible, exposed areas secured with ropes or chains, and could include sections where hikers need to use their hands. T4 is used to grade alpine hiking with steep rocky terrain, snow passages and difficult sections. T5 is used to grade alpine hiking and includes pathless trails, exposed/difficult terrain with sections of scrambling that would require hikers to use their hands. T6 is the most difficult and is used to grade alpine hiking. The trails are not marked, the terrain is extremely difficult and should only be used by very experienced hikers and climbers (“SAC- Berg- Und Alpinwanderskala”). The Swiss Hiking Scale provides hikers with a broad continuum for rating hiking trail difficulty. The system includes detailed descriptions of each rating, however trail distance does not seem to be a factor. This system provides useful terminology and a good scope for terrain difficulty for alpine hikers and is a good resource for a newly designed hiking rating system.

Hiking Project, the website, is currently owned by Recreational Equipment Incorporated (REI), and they use a three-part difficulty rating. There are many hiking rating scales available online, but I will be focusing on the system used by Hiking Project because it mimics the same system used for skiing trail ratings. The trail ratings are classified as either easy, intermediate, or difficult. The easiest trail is marked with a green circle and is considered flat with no obstacles. The intermediate trail is marked with a blue square and indicates uneven terrain with a slight incline, and with no more than a 10% grade. The difficult trail is marked with a black diamond and includes tricky terrain, and a steep grade of no more than 15%. The system also uses combination marks if the difficulty falls between two ratings. The easy/intermediate trail is marked with a green circle in a blue square and is mostly flat, but includes some sections of uneven terrain.

The intermediate/difficult trail is marked with a black diamond in a blue square, and includes some terrain barriers and moderate steepness but does not have a grade percentage. The extremely difficult trail is marked with a double black diamond and involves very steep, potentially hazardous terrain (“FAQ”). REI uses this system on The Hiking Project website because the symbols are easy to process visually, and create a better experience for the online user. If a user has an account with Hiking Project, they can create user generated content by submitting a trail and rating it with the predetermined system on the website. Hiking Project currently uses this rating system for any hiking trail logged in their system regardless of geographic location. This system could be the most successful if the determination of trail difficulty rating were easy to follow and implement in every park across the United States.

Each system that has been outlined can be used as inspiration for a hiking rating system design. The Shenandoah National Park numerical equation can be used as a baseline for determining trail difficulty but should not be used alone, as it does not account for natural barriers. The system used by the Willamette National Forest is easy to understand, but the size of the trail does not seem to affect the difficulty and instead increases the risk of trail erosion or injury or death depending on the location of the trail. There are more factors that need to be included for that system to be effective. The YDS takes natural barriers into account and adjusts the rating according to the most difficult part of the trail. This approach could be combined with the Shenandoah National Park’s numerical equation to fully determine the level of difficulty. The system used by Hiking Project could then be applied to a combination system, composed of the Shenandoah National Park formula and YDS system. The ratings would have the determined

difficulty ranking and would be communicated using simple shapes and colors to reduce confusion for hikers. Finally, the system should be as thorough as the Swiss Hiking Scale to ensure all bases are covered. A newly designed system is necessary, and with effective implementation, could be a system that communicates efficiently with hikers on any trail found in the United States.

### **Goals and Objectives**

The research from this project will contribute to existing research on lost, missing, or injured hikers within the national parks. The results may be used to improve existing wayfinding systems currently used in national parks, as well as state or local parks. This project will conclude with a proposed nature-inspired, sustainable wayfinding solution. The solution will be designed using best practices around environmental graphic design to create effective communication for trail navigation. All new designs will take into consideration the design guidelines already established within Yosemite National Park. With this consideration, the new design will create a cohesive voice and a consistent system which will be easy for hikers to navigate, and which makes minimal impact on the existing trails and natural environment.

Yosemite National Park is an ideal research environment for this project because literary and observational research has identified multiple areas for hiking wayfinding improvements. This project will indicate improvements in hiking trail navigation and hiking wayfinding in the national parks. A new wayfinding system designed from the research of this project will serve as a guide for future hiking wayfinding and will be adaptable for national, state, and local parks across the United States.

The objectives of this study are as follows:

1. Identify design flaws in current national park wayfinding and signage for hiking trails.
2. Provide evidence of design flaws through documentation of current hiking trail signs in Yosemite National Park.
3. Produce information about hiking trail experiences by conducting human surveys about Yosemite's most popular hiking trails.
4. Explain how users currently view trails and how the information provided proves there are wayfinding inconsistencies.
5. Explain wayfinding and design principles that should be applied to national park hiking trail systems.
6. Provide a solution to the wayfinding issues through wayfinding system examples.
7. Explain the importance of hiking trail navigation at night and explain how biomimicry can play a role in improving nighttime navigation.
8. Provide data collection results from YOSAR rescue reports in order to identify hot spots in Yosemite as potential hiking trail wayfinding issues.

## **Hypothesis**

Improved hiking trail sign designs paired with newly designed trail markers for the current national parks trail wayfinding system will create credibility using consistent design guidelines. The preliminary designs will increase daytime and nighttime readability through improved layout design using better typography and a biomimetic proposed solution, as well as reduce confusion using better sign placement and fewer trail signs, and reassure hikers on official trails. The results from this project will aid in fewer search and rescue operations for lost or injured hikers in the US national parks.

### **III.METHODOLOGY**

The primary goal of observations and user surveys was to understand the design challenges of current trail signage, and to learn how and if hikers used the trail signs. The research followed the IDEO design thinking, human-centered, approach to understand what the user needs. This understanding was gained by learning and looking through trail observations, asking users questions through surveys, analyzing data from search and rescue operations, and testing preliminary designs (virtual prototype) with users to evaluate the system (“Design Thinking Defined”). The observations were completed on hiking trails of varying difficulty in different locations throughout the park. The surveys were conducted after users had completed a hike so that they could answer questions about the trail and the trail signs on a specific trail. Again, the trails chosen for the surveys varied in difficulty and were located in different areas of the park so a variety of experiences could be collected for analysis. The data from YOSAR was collected in order to understand where rescues frequently occur, the types of rescues they perform, the time of day most rescues occur, statistics about subjects rescued, and the season when most rescues occur. The information gained through observations, surveys, and data collection inspired the preliminary design outcome for this study.

#### **Observations**

Observations in Yosemite National Park were made on Four Mile Trail, Upper Yosemite Falls Trail, Mist Trail, Panorama Trail, Mirror Lake Trail, and at Glacier Point. Observations included documenting trail conditions, collecting photos of sign evidence, and noting sign placement. Observations were made on foot at the start of trailhead signs.



Observations were carried out in the summer and winter seasons to understand how the trail changes under a multitude of weather conditions and foot traffic patterns from park guests. John Dill's Yosemite Search and Rescue presentation at the Yosemite Theatre provided insight into current challenges for Yosemite Search and Rescue, the types of rescues they perform, the most dangerous hiking trails, how to stay safe while enjoying the park, navigating trails, the SAR phases, how they locate, and how to get found by SAR.

According to Dill, Mist Trail is the busiest trail in the park with approximately 25% of all rescues taking place along that trail. In the summer season, this trail can become congested with foot traffic at popular spots such as the Vernal Fall footbridge, the base of Vernal Fall and Nevada Fall, the top of Nevada Fall, and the base of the cables that lead to Half Dome (Dill). The trail is very clearly marked at the trailhead with multiple signs. The main trailhead sign contains a map of the trail and is accompanied by a list of trail rules. The same sign warns hikers about black bears that potentially could be in the area.



Figure 3.1. Trail sign at the beginning of Mist Trail in Yosemite National Park.

Approximately 10 feet past the main trailhead sign is a sign warning hikers that dogs and bikes are not allowed on the trail. On the same post, signs are posted to communicate whether the cables to Half Dome are up or down.



Figure 3.2. Sign on Mist Trail in Yosemite National Park.

Approximately 20 feet past the trailhead sign, hikers pass another sign warning that there is no treated drinking water beyond that point. Approximately 300 feet past the trailhead is a sign that lists trails that are along the High Sierra Loop Trail. It is important to note that the High Sierra Loop Trail is not mentioned nor listed on the map at the trailhead, nor on printed materials handed out at the park entrance and visitor center. The sign contains the following trails with distance noted in miles and kilometers: Vernal Fall footbridge, top of Nevada Fall, Little Yosemite campground, Glacier Point, Clouds Rest, Merced Lake, Tenaya Lake, Tuolumne Meadows, Mount Whitney, and the John Muir Trail. As hikers approach 0.8 miles they will arrive at the Vernal Fall footbridge.



Figure 3.3. Trail sign on Mist Trail in Yosemite National Park.

There is a pop-up metal sign warning hikers about the dangers of leaving the trail and swimming in the water. The sign also reminds hikers to drink enough water while on the trail. Approximately 800 feet past the Vernal Fall footbridge, there is a junction where the John Muir Trail continues to the right and the Mist Trail continues to the left. There are



three signs placed at the junction. All signs are made out of metal, they are rusty and they have punched out type. The sign for the John Muir Trail is placed approximately 15 feet from the trail junction.



Figure 3.4. Trail sign on John Muir Trail in Yosemite National Park.

The sign indicates the trail with the name “John Muir Trail” at the top, above all secondary information. The secondary information includes the following destinations and the distance to those destinations: Nevada Fall, Glacier Point, Half Dome, Clouds Rest, Merced Lake, Tenaya Lake, and Tuolumne Meadows. The sign for the Mist Trail is placed at the entrance of the trail gate that is typically closed in the winter season.



Figure 3.5. Trail sign at trail junction on Mist Trail in Yosemite National Park.

The sign indicates the trail with the name “Mist Trail” at the top. The following destinations and the distance to those destinations are listed: Vernal Fall, Nevada Fall, and Half Dome. The third sign at the junction is a sign for hikers traveling in the opposite direction. The sign indicates the trail name “John Muir Trail” and the distance to Yosemite Valley. The trail junction at the John Muir Trail is an orientation cue for hikers, therefore, it should include signage to guide the hiker to their intended destination. However, rather than three signs, the trail junction needs a single sign which indicates trail names, direction of travel, and distances to destinations.

Glacier Point is a popular hiking destination within the park, with 11 hiking trails originating at that location. Glacier Point Road closes in the winter season making Glacier Point inaccessible to hikers. Trails that lead to Glacier Point, such as Four Mile Trail, are partially closed to reduce access to the area. Glacier Point is accessible to cross country skiers and snowshoers from the Badger Pass Ski Area. All hiking trails vary in difficulty from easy to strenuous, with a majority of the trails rated as strenuous.

Panorama Trail is a well-hiked trail leading hikers from Glacier Point to the Valley floor.

A ranger at the visitor center pointed out problem areas for hikers in the park, and two points were circled along Panorama Trail.

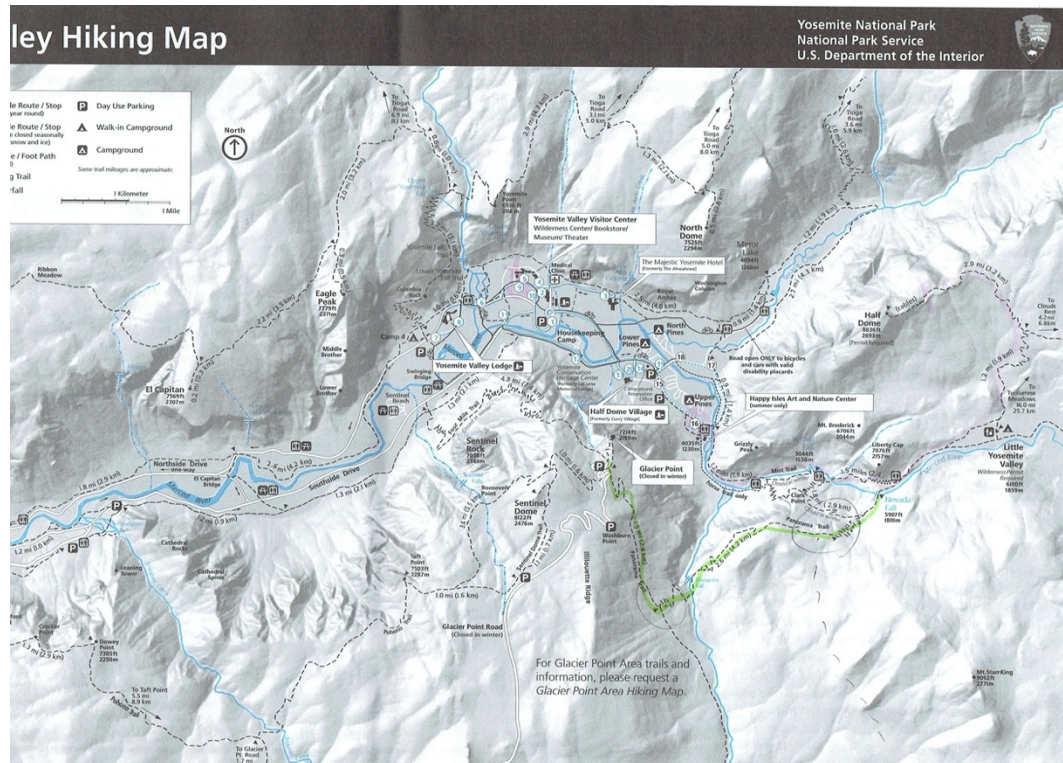


Figure 3.6. Yosemite Valley Hiking Map.

The two wayfinding problem areas are both trail junctions that lead to unnamed backcountry trails, one of which is not marked on the trail map. The beginning of Panorama Trail has a wooden trailhead sign, indicating the start of Panorama and Pohono Trails, and containing the following trails with distance in miles: Illilouette Fall, Nevada Fall, Vernal Fall, Yosemite Valley, Sentinel Dome, Taft Point, and Wawona Tunnel.





Figure 3.7. Trailhead sign for Panorama Trail in Yosemite National Park.

The trailhead sign does not indicate the direction of travel for Panorama or Pohono Trail, meaning there is no clear indication for the beginning of either trail. Panorama Trail and Pohono Trail have metal signs with destinations and distances listed approximately 20 feet past the wooden trailhead sign.



Figure 3.8. Trail sign at beginning of Panorama Trail in Yosemite National Park.

Neither metal sign indicates whether it is for Panorama Trail or Pohono Trail, and hikers must distinguish between the two trails by referring to a trail map. The Panorama Trail is an established dirt path trail with a junction 1.4 miles past the trailhead. There, the trail splits with an option to continue hiking on the trail toward Illilouette Fall, or, to turn right, leave Panorama Trail, and take an unnamed trail. There are three metal trail signs at the junction, all placed in different locations around the junction.





Figure 3.9. Trail sign on Panorama Trail in Yosemite National Park.

The trail sign that continues on Panorama Trail has the following destinations and the distances to those destinations: Illilouette Fall, Nevada Fall, Yosemite Valley, and Merced Lake.



Figure 3.10. Trail sign on Panorama Trail in Yosemite National Park.

The trail sign for the unnamed trail has the following destinations and the distance to those destinations: Mono Meadows, Buena Vista Lake, Buck Campground, Ottoway Lake, Moraine Meadows, and Fernandez Pass.



Figure 3.11. Trail sign on Panorama Trail in Yosemite National Park.

The trail sign that is placed for hikers traveling on Panorama Trail in the opposite direction has the following destinations and the distances to those destinations: Glacier Point and Yosemite Valley. This junction should only have one trail sign to minimize confusion for hikers. Hikers who continue on Panorama Trail will approach Illilouette Fall approximately 1 mile from the trail junction. Hikers will experience more rocky terrain as they approach the bridge that crosses the water. The terrain can cause confusion because the trail is not clearly defined by the natural features of the landscape. Panorama



Trail is a long, strenuous trail that could benefit from a marker system because of the trail junctions and numerous areas of unclear trail terrain. Each trail junction serves as an orientation cue, therefore, each trail junction along Panorama Trail needs to have a single sign which indicates trail names, direction of travel, and distances until destinations. A marker system would eliminate confusion in areas where the trail is not clearly defined, therefore, the use of reassurance markers is recommended.

The Upper Yosemite Falls Trail starts with a wooden trailhead sign indicating to hikers that they are starting the ascent of Yosemite Falls Trail. The name is listed at the top of the sign with the following information about destinations and the distances to those destinations: Top of Yosemite Fall, Yosemite Point, Eagle Peak, and North Dome.



Figure 3.12. Trail sign on Yosemite Falls Trail in Yosemite National Park.

The sign warns hikers to stay on the trail and that horses are not permitted without a guide. Inconsistency between the name of the trail as posted on the sign and the name of the trail as written on the map can cause confusion for hikers. The Yosemite Valley Hiking Map handed out at the visitor center lists the trail as Upper Yosemite Falls Trail, however, Yosemite Falls Trail is the official name. Another point of confusion is that while Yosemite Falls Trail overlaps with Snow Creek Trail, Snow Creek Trail is not labeled nor listed on the map and it is not mentioned on the sign located at the trailhead. Approximately 0.5 miles from the trailhead, hikers may wish to stop at a location called Columbia Rock. This point is marked on the hiking map, however, there are no signs that indicate hikers have arrived at that destination. A safety handrail is the only orientation cue that indicates a point of interest. Columbia Rock is not mentioned on the trailhead sign, even though it seems like a popular point of interest for hikers not interested in hiking on to Yosemite Falls. As hikers arrive at the junction of Yosemite Falls Trail and Snow Creek Trail, there are two metal signs that give directional information without giving the distance to the destination. One sign informs hikers with a directional arrow and the word “overlook” toward the right of the sign. Hikers can then take the Upper Yosemite Falls Overlook Trail for scenic views of Yosemite Valley over the top of Yosemite Falls. Another sign informs hikers with a directional arrow and two destinations: Yosemite Point and North Dome. The sign does not indicate the hiking trail name, however, this trail junction is at the split of Yosemite Falls Trail and Snow Creek Trail. The location of these signs serves as an orientation cue for hikers and a decision point for hikers who might wish to continue to Yosemite Point, North Dome, Eagle Peak, or El Capitan. The junction should contain a single sign with trail names, points of

interest, direction of travel, and the distance to those destinations. Yosemite Falls Trail is a clearly defined trail until hikers have reached the trail junction. The lack of clear signage at the trail junction is based on an assumption that most hikers on Yosemite Falls Trail are only hiking to observe the waterfall, and therefore, do not need a sign to explore the areas at the end of the trail. A marker system would be helpful to direct hikers to the waterfall or towards Snow Creek Trail without the introduction of additional signage. Minimal marker placement along Yosemite Falls Trail would ensure hikers that they are hiking in their intended direction of travel, and it would help guide them when they reach the top of the falls. Reassurance markers would be ideal for this trail because of the lack of signage and the need to reassure hikers that they did not miss a trail junction. The markers would also add clarity where multiple trails overlap, and where there are unnamed trails on the hiking trails map.



Figure 3.13. Illustration of varying signs in Yosemite National Park.

The Four Mile Trail trailhead is located along Southside Drive, the road that leads into Yosemite Valley and at Glacier Point. The trailhead in the Valley has three different signs, a historical marker describing the history of the trail, a directional sign with the

trail name and a directional arrow, and a shuttle sign. Approximately 300 feet past the trailhead in the Valley is a trail junction for Valley Loop Trail, with a wooden sign on the left side of Four Mile Trail that directs hikers to continue traveling straight if they want to hike to Glacier Point.



Figure 3.14. Trail sign on Four Mile Trail in Yosemite National Park.

There is a wooden sign to the right of Four Mile Trail on the Valley Loop Trail that contains the following names of destinations and distances: El Capitan, Bridalveil Fall, and Pohono Trail. There is a wooden sign to the left of Four Mile Trail on the Valley Loop Trail that contains the following destinations and distances: Curry Village and Stables. Approximately 730 feet from the trailhead there is a wooden sign that includes the following destinations and distances in miles and kilometers: Union Point, Glacier Point, and Sentinel Dome. Approximately 2.8 miles from the trailhead, hikers come to a trail junction where they can choose to continue hiking the Four Mile Trail or



they may take a short 220 foot trail to Union Point for a view of the Valley floor. The trail junction has three metal signs which direct hikers. One sign directs hikers to Union Point, another sign informs hikers how far away they are from Glacier Point and Sentinel Dome, and a third sign is placed for hikers traveling in the opposite direction, which guides them back to Yosemite Valley. Approximately 300 feet from the trailhead at Glacier Point there is a metal sign placed for hikers traveling to the Valley. The sign contains the following destinations and the distances to those destinations: Union Point and Valley Floor. Approximately 200 feet from the trailhead at Glacier Point there is a wooden sign which lists the trail name and indicates hikers are traveling toward the Valley. The trailhead at Glacier Point has a single wooden sign with Glacier Point and Four Mile Trail listed as destinations. Distances are not listed, however, directional arrows are used to direct hikers in the general direction of those destinations. Four Mile Trail would benefit from reducing the number of signs currently used to direct hikers. The trailhead in Yosemite Valley should include a single sign with hiking trail information, destinations, and the distances to the destinations. The trail junction at the Valley Loop Trail would benefit from a marker system to reduce sign pollution. Orientation markers should be placed to indicate the Valley Loop Trail, and to give direction for hikers wanting to continue on the Four Mile Trail. Reassurance markers should be used along the trail for hikers traveling in both directions, especially since the trail contains a considerable number of switchbacks. A single sign should be posted at Union Point to mark the point of interest. The marker system should start again after Union Point and continue to the trailhead at Glacier Point. The trailhead at Glacier Point should include a single sign which indicates hikers are starting their hike on Four Mile

Trail. The trailhead sign should include the hiking trail information, destinations, and the distances to the destinations. Glacier Point includes multiple trailheads and is the destination for multiple hiking trails, therefore, placement of trailhead signs must be carefully considered for optimal visibility.

Mirror Lake Loop Trail has a historical marker at the trailhead containing information about the trail, a map of the main trail, and wildlife warnings. The map on this sign is cut off and does not include the entire loop, which can lead to confusion for hikers wanting to hike beyond Mirror Lake.



Figure 3.15. Historical marker on Mirror Lake Trail in Yosemite National Park.

The historical marker is the only sign at the start of the trail, so it naturally appears to be the trailhead sign. Across from the historical marker is a sign placed for hikers traveling in the opposite direction, which directs hikers toward Happy Isles and



Curry Village using directional arrows and the distances to those destinations.

Approximately 1000 feet from the trailhead on the right side of the loop there is a single wooden sign (figure 3.16) at a trail junction where the Valley Loop Trail overlaps with the Mirror Lake Loop Trail.



Figure 3.16. Trail sign on Mirror Lake Trail in Yosemite National Park.

Approximately 1 mile past the trailhead there is a single wooden sign with the words “Mirror Lake” to mark a point of interest along the trail. Approximately 1600 feet past the trailhead on the left side of the loop is a trail junction. There is a single wooden sign approximately 15 feet past the junction directing hikers toward Group Camp, Yosemite Village, and Mirror Lake. Approximately 0.8 miles from the trailhead there is a historical marker, similar in design to the marker located at the trailhead. On the same sign there is a map of the trail, however, the trail is cut off and part of the trail loop is

missing. It is important to note that there are inconsistencies between the maps on the two historical markers. The maps differ in design and orientation and neither map shows the trail in its entirety. There is another sign in close proximity to the historical marker made out of metal with two icons, indicating that dogs and bikes are no longer allowed past that point on the trail. Approximately 300 feet past the historical marker there is an unmarked trail junction and therefore no indication of the correct direction of travel for Mirror Lake Loop Trail. If hikers hike to the right, they will take a loop that brings them closer to Mirror Lake, and if hikers hike to the left, they will bypass the lake and continue on the Mirror Lake Loop Trail. Approximately 700 feet past the historical marker at Mirror Lake there is another historical marker with information about the name of the area. Approximately 300 feet past the previous historical marker is another historical marker explaining the history of the land. There is also a single wooden sign with the words “Mirror Lake” to indicate that hikers have arrived at the point of interest. Mirror Lake has an abundance of signs already in place to mark the historical significance of the trail. These signs add to the unique identity of the park and one could argue that they enhance the hiking experience by educating hikers about the significance of the area they are exploring. Adding more signage on the well defined, paved areas of trail would cause sign pollution: more signs are not needed in those areas., However, as hikers continue past Mirror Lake to complete the full loop, trail junctions are not marked clearly, and a marker system is needed. There are multiple areas where the trail splits with no indication of which trail to take to complete the loop. As hikers make their way around the loop, markers would be helpful to create reassurance that they are traveling in their intended direction, especially since there are multiple social trails that lead away from the main

trail. According to the National Park Service, social trails are created when hikers step off the established trail. Hikers forge their own trails in order to avoid mud or standing water on the established trail, to access viewpoints that are not accessible from the main trail, or to avoid parts of the trail that are difficult, such as sections of switchbacks or rocky terrain. These social paths create confusion for hikers by leading them to areas that are not developed for hiking. Social trails are dangerous and are discouraged by the NPS. Currently, the NPS uses signs to inform hikers about the importance of staying on the trail, however, there is evidence that these social trails continue to be heavily used on the Mirror Lake Loop Trail.

### **User Surveys**

The data obtained for this study was collected through human surveys in Yosemite National Park and was approved for collection by the Texas State IRB on Thursday, June 20th, 2019. Access to human subjects for the collection of information was granted by the United States Department of the Interior National Park Service Scientific Research and Collecting Permit (YOSE-2019-SCI-0087). The data was collected during the winter season from 86 human surveys conducted over the course of four days on hiking trails in Yosemite Valley. The surveys were conducted after hikers completed a hike on a designated hiking trail, which ensured that they had experience of and knowledge about the trail. Surveys were conducted on the following trails: Mirror Lake, Mist Trail/Muir Trail (a large section of this popular trail was closed by park rangers because trail conditions were not safe enough to hike due to snow and ice,) and Upper Yosemite Falls. The survey questions focused on general hiking preparedness, hiking difficulty/current conditions on the trail, and trail signage. A majority (46%) of

those surveyed were between the ages of 25-34. The next highest (23%) age range was 18-24 followed by the age ranges of 35-49 and 50-69 (15%). Fewer than 1% of hikers surveyed were over the age of 70. Of those surveyed, 53% were male and 47% were female. Hiking experience varied, however, the majority (57%) had enough hiking experience to consider themselves moderate hikers, meaning they have had experience with hiking various types of terrain and elevation. They have also had experience hiking for a few hours with frequent breaks as the distance or the elevation increases. The next highest experience level was novice/beginner (22%) meaning that they were new to hiking or had little experience. Novice hikers hike at a slow/easy pace and generally hike on flat, easy terrain. A low percentage of hikers surveyed considered themselves advanced (17%) meaning that they have experience hiking at least half a day. They can handle several thousand feet in elevation gain. They can keep a moderate pace and have enough experience to know when to conserve energy on the trail. They have experience hiking in multiple weather conditions and know how to prepare for both cold and hot conditions. Fewer than 1% considered themselves expert hikers.

**Table 3.1.** Experience level of all surveyed hikers.

Experience Level	n	%
Novice/Beginner	18	21%
Moderate	49	57%
Advanced	15	17.4%
Expert	4	4.6%
Total	86	100.0%

Most hikers regularly hiked with at least one other person (48%), while only 13% reported regularly hiking alone. When surveyed about hiking at night, 43% reported that they have hiked in the dark at Yosemite or another national park. When surveyed about getting lost while hiking, 37% reported that they have been lost at some point in their lives while on a hiking trail. The following information is about making signage inclusive for hikers who do not speak English: 21% of hikers completely agree while 12% completely disagree that hiking signage should include multiple languages, 13% of hikers somewhat agree while 5% somewhat disagree that hiking signage should include multiple languages, 9% of hikers slightly agree and 10% slightly disagree that hiking signage should include multiple languages, and 30% of hikers neither agree nor disagree that hiking signage should include multiple languages.

### *Mirror Lake*

The data collected at Mirror Lake was obtained from 20 of the 86 surveys conducted for this study. Hikers were asked to list difficulties (if any) they had while hiking the Mirror Lake Trail. 40% reported they had difficulty ensuring they were on the correct trail, 20% reported the trail signs were difficult to locate, and 10% reported difficulty locating the trailhead.

**Table 3.2.** Hiking difficulties experienced by hikers on Mirror Lake

Hiking difficulties	n	%
Ensuring they were on the correct trail	8	40%
Locating the trail signs/markers	5	25%
Locating the trailhead	2	10%
Planning enough time for the hike	1	5%
Planning enough food/water for the hike	1	5%
Terrain changes	1	5%
Planning for the hike	0	0%
Completing the hike	0	0%
None	10	50%

Hikers were asked to list the items they carried while on the hike. 100% carried a cell phone, 75% carried a paper map, 30% carried a flashlight or headlamp, 20% carried a compass, and 10% carried a GPS device (Garmin, Magellan, etc.). Hikers were asked if they checked the weather, and 95% reported that they checked the weather before starting their hike. The experience levels of hikers varied on the trail despite the difficulty rating determined by the NPS. These numbers can be seen in table 3.3. A majority of hikers on Mirror Lake classified themselves as either novice/beginner (15%) or moderate (65%) hikers.

**Table 3.3.** Experience level of hikers on Mirror Lake.

Experience Level	n	%
Novice/Beginner	3	15%
Moderate	13	65%
Advanced	2	10%
Expert	2	10%
Total	20	100.0%

According to the NPS, Mirror Lake has a rated difficulty as Easy (flat and short). Hikers were asked to rate the difficulty of the trail on a scale of 1-10 (1=EASY, 10=VERY STRENUOUS). Table 3.4 shows the results of trail difficulty ratings according to the hikers surveyed.

**Table 3.4.** Trail difficulty of Mirror Lake according to park visitors.  
(1=EASY, 10=VERY STRENUOUS)

1	2	3	4	5	6	7	8	9	10
25%	25%	10%	25%	10%	5%	0%	0%	0%	0%

Hikers were asked if they used the signs at the trailhead before starting their hike, and if they used the trail signs during their hike. 78% reported they did use the signs before starting their hike and 85% reported they did use the signs during their hike. Hikers were asked if they left the marked trail during their hike. 45% reported they did leave the marked trail, even though it is against the rules to leave any marked trail within a national park. Hikers were asked if they were ever confused about the direction of travel while on the trail. 45% reported they were confused at least once while on the marked trail. Hikers were asked if they ever used a paper map to assist with navigating the trail. 60% reported they did use their paper map while navigating the trail. Hikers were asked if they used an electronic device to assist with navigating the trail. The electronic device could include a cell phone, GPS device, etc. Only 30% reported they used an electronic device to assist with navigation. 40% of hikers used a paper map instead of an electronic device to assist with navigation. Only 10% of hikers who used an electronic device did not use a paper

map. Hikers were asked to rate the signage used on the hiking trail based on ease of readability, convenience of location, helpfulness of information, whether or not the signage disrupted their hiking experience, whether there seemed to be an appropriate amount of signage, and whether signs should include languages other than English. Hikers were allowed to agree or disagree with statements regarding the signage. The following information is about readability of signage found on the hiking trail: 35% of hikers completely agreed while 10% completely disagreed that signage was easy to read and understand, 20% of hikers somewhat agreed while 5% somewhat disagreed that signage was easy to read and understand, 15% of hikers slightly agreed while 10% of hikers slightly disagreed that signage was easy to read and understand, and 5% of hikers neither agreed nor disagreed that signage was easy to read and understand. The following information is about the convenience of signage placement along the trail, and the ease of locating signage when needed: 20% of hikers completely agreed while 10% completely disagreed that signs were conveniently placed and easy to locate, 25% of hikers somewhat agreed while 10% somewhat disagreed that signs were conveniently placed and easy to locate, 20% of hikers slightly agreed while 5% slightly disagreed that signs were conveniently placed and easy to locate, and 10% of hikers neither agreed nor disagreed that signs were conveniently placed and easy to locate. The following information is about signage providing helpful information about the hiking trail: 25% of hikers completely agreed while 5% completely disagreed that signage provided helpful information, 25% of hikers somewhat agreed while 5% somewhat disagreed that signage provided helpful information, 25% of hikers slightly agreed while 0% slightly disagreed that signage provided helpful information, and 15% of hikers neither agreed nor



disagreed that signage provided helpful information. The following information is about whether signage disrupted the hiking experience: 0% of hikers completely agreed while 45% completely disagreed that the signage disrupted the hiking experience, 0% of hikers somewhat agreed while 15% somewhat disagreed that the signage disrupted the hiking experience, 5% of hikers slightly agreed while 10% slightly disagreed that the signage disrupted the hiking experience, and 25% of hikers neither agreed nor disagreed that the signage disrupted the hiking experience. The following information is about whether there is an appropriate amount of signage provided on the trail: 10% of hikers completely agreed while 25% completely disagreed that there were not enough signs on the trail, 15% of hikers somewhat agreed while 0% somewhat disagreed that there were not enough signs on the trail, 20% slightly agreed while 0% slightly disagreed that there were not enough signs on the trail, and 30% of hikers neither agreed nor disagreed that there were not enough signs on the trail. The following information is about making signage inclusive for hikers who do not speak English: 10% of hikers completely agreed while 15% completely disagreed that hiking signage should include multiple languages, 10% of hikers somewhat agreed while 15% somewhat disagreed that hiking signage should include multiple languages, 15% of hikers slightly agreed and 15% slightly disagreed that hiking signage should include multiple languages, and 20% of hikers neither agreed nor disagreed that hiking signage should include multiple languages.

### *Upper Yosemite Falls*

The data collected at Upper Yosemite Falls Trail was obtained from 28 out of 86 surveys conducted for this study. Hikers were asked to list difficulties they had (if any) while hiking the Upper Yosemite Falls Trail. 14% reported that the trail signs were

difficult to locate, 11% reported difficulty locating the trailhead, 22% reported difficulty with planning enough time for the hike, 14% reported difficulty with planning the correct amount of food and/or water needed for the hike, 18% reported difficulty with completing the hike, and 44% reported having no difficulties with the hike.

**Table 3.5.** Hiking difficulties experienced by hikers on Upper Yosemite Falls.

Hiking difficulties	n	%
Planning enough time for the hike	9	32.1%
Planning for the hike	5	17.8%
Ensuring they were on the correct trail	4	14.2%
Locating the trail signs/markers	4	14.2%
Locating the trailhead	3	10.7%
Terrain changes	2	7.1%
Completing the hike	2	7.1%
Planning enough food/water for the hike	1	3.5%
None	12	42.8%

Hikers were asked to list the items they carried while on the hike. 85% carried a cell phone, 33% carried a paper map, 33% carried a flashlight or headlamp, and 7% carried a GPS device (Garmin, Magellan, etc.). Hikers were asked if they checked the weather, and 74% reported they checked the weather before starting their hike.

The experience levels of hikers varied on the trail despite the difficulty rating determined by the NPS. These numbers can be seen in table 3.6. The highest percentage was for moderate hikers (42.9%) even though the trail is rated at a strenuous trail.

**Table 3.6.** Experience level of hikers on Upper Yosemite Falls.

Experience Level	n	%
Novice/Beginner	8	28.6%
Moderate	12	42.9%
Advanced	6	21.4%
Expert	2	7.1%
Total	28	100.0%

According to the NPS, Upper Yosemite Falls Trail has a rated difficulty of Strenuous (steep and long). Hikers were asked to rate the difficulty of the trail on a scale of 1-10 (1=EASY, 10=VERY STRENUOUS). Table 3.7 shows the results of trail difficulty ratings according to the hikers surveyed.

**Table 3.7.** Trail difficulty of Upper Yosemite Falls Trail according to park visitors.  
(1=EASY, 10=VERY STRENUOUS)

1	2	3	4	5	6	7	8	9	10
0%	0%	0%	11%	7%	33%	22%	25%	3%	0%

Hikers were asked if they used the signs at the trailhead before starting their hike and if they used the trail signs during their hike. 81% reported that they did use the signs before starting their hike and 59% reported that they did use the signs during their hike. Hikers were asked if they left the marked trail during their hike. 25% reported that they did leave the marked trail even though it is against the rules to leave any marked trail within a national park. Hikers were asked if they were ever confused about the direction of travel while on the trail. 18% reported that they were confused at least once while on the marked trail. Hikers were asked if they ever used a paper map to assist with navigating

the trail. 22% reported that they did use their paper map while navigating the trail. Hikers were asked if they used an electronic device to assist with navigating the trail. The electronic device could include a cell phone, GPS device, etc. 59% reported that they did use an electronic device to assist with navigation. 37% of hikers who used an electronic device did not use a paper map to assist with navigation while 100% of hikers who used a paper map also used an electronic device. Hikers were asked to rate the signage used on the hiking trail based on ease of readability, convenience of location, helpfulness of information, whether the signage disrupted their hiking experience, whether there seemed to be an appropriate amount of signage, and whether signs should include languages other than English. Hikers were allowed to agree or disagree with statements regarding the signage. The following information is about readability of signage found on the hiking trail: 48% of hikers completely agreed while 0% completely disagreed that signage was easy to read and understand, 22% of hikers somewhat agreed while 7% somewhat disagreed that signage was easy to read and understand, 7% of hikers slightly agreed and 7% of hikers slightly disagreed that signage was easy to read and understand, and 18% of hikers neither agreed nor disagree that signage was easy to read and understand. The following information is about the convenience of signage placement along the trail and the ease of locating signage when needed: 40% of hikers completely agreed while 0% completely disagreed that signs were conveniently placed and easy to locate, 14% of hikers somewhat agreed while 11% somewhat disagreed that signs were conveniently placed and easy to locate, 18% of hikers slightly agreed while 11% slightly disagreed that signs were conveniently placed and easy to locate, and 7% of hikers neither agreed nor disagreed that signs were conveniently placed and easy to locate. The following

information is about whether signage provided helpful information about the hiking trail: 33% of hikers completely agreed while 3% completely disagreed that signage provided helpful information, 33% of hikers somewhat agreed while 3% somewhat disagreed that signage provided helpful information, 3% of hikers slightly agreed while 11% slightly disagreed that signage provided helpful information, and 14% of hikers neither agreed nor disagreed that signage provided helpful information. The following information is about whether signage disrupted the hiking experience: 0% of hikers completely agreed while 59% completely disagreed that the signage disrupted the hiking experience, 7% of hikers somewhat agreed while 22% somewhat disagreed that the signage disrupted the hiking experience, 0% of hikers slightly agreed while 7% slightly disagreed that the signage disrupted the hiking experience, and 11% of hikers neither agreed nor disagreed that the signage disrupted the hiking experience. The following information is about whether the appropriate amount of signage was provided on the trail: 18% of hikers completely agreed while 22% completely disagreed that there were not enough signs on the trail, 7% of hikers somewhat agreed and 7% somewhat disagreed that there were not enough signs on the trail, 22% slightly agreed while 25% slightly disagreed that there were not enough signs on the trail, and 0% of hikers neither agreed nor disagreed that there were not enough signs on the trail. The following information is about making signage inclusive for hikers who do not speak English: 25% of hikers completely agreed while 11% completely disagreed that hiking signage should include multiple languages, 18% of hikers somewhat agreed while 0% somewhat disagreed that hiking signage should include multiple languages, 11% of hikers slightly agreed and 7% slightly

disagreed that hiking signage should include multiple languages, and 29% of hikers neither agreed nor disagreed that hiking signage should include multiple languages.

### *Mist Trail*

The data collected at Mist Trail was obtained from 38 out of 86 surveys conducted for this study. Hikers were asked to list difficulties they had (if any) while hiking the Mist Trail to Vernal Fall footbridge. The remaining part of Mist Trail was closed due to unsafe conditions from ice on the trail. The Mist Trail and the John Muir Trail diverged, and hikers had the option of continuing their hike via the John Muir Trail, which remains open during the winter season. 10% reported the trail signs were difficult to locate, 7% reported difficulty locating the trailhead, 23% reported difficulty with planning enough time for the hike, 2% reported difficulty with planning the correct amount of food and/or water needed for the hike, 7% reported difficulty with completing the hike, 10% reported difficulty with ensuring they were on the correct trail, and 28% reported having no difficulties with the hike. If the difficulty they incurred was not listed as a multiple choice answer, they were given an option to add other difficulties. A few of those difficulties included: lack of knowledge about the grade of the trail and lack of knowledge about the trail closure.

**Table 3.8.** Hiking difficulties experienced by hikers on Mist Trail

Hiking difficulties	n	%
Planning enough time for the hike	6	15.7%
Completing the hike	5	13.1%
Locating the trail signs/markers	4	10.5%
Planning enough food/water for the hike	4	10.5%
Locating the trailhead	3	7.8%
Planning for the hike	2	5.2%
Ensuring they were on the correct trail	0	0%
Terrain changes	0	0%
None	12	31.5%

Hikers were asked to list the items they carried while on the hike. 100% carried a cell phone, 44% carried a paper map, 36% carried a flashlight or headlamp, and 7% carried a GPS device (Garmin, Magellan, etc.), and 10% carried a compass. Hikers were asked if they checked the weather and 71% reported they checked the weather before starting their hike.

The experience levels of hikers varied on the trail despite the difficulty rating determined by the NPS. These numbers can be seen in table 3.9. The highest percentage was for moderate hikers (63.2%) even though the trail is rated at a strenuous trail.

**Table 3.9.** Experience level of hikers on Mist Trail

Experience Level	n	%
Novice/Beginner	7	18.4%
Moderate	24	63.2%
Advanced	7	18.4%
Expert	0	0%
Total	38	100.0%

According to the NPS, Mist Trail has a rated difficulty of Strenuous (steep and long). Hikers were asked to rate the difficulty of the trail on a scale of 1-10 (1=EASY, 10=VERY STRENUOUS). Table 3.10 shows the results of trail difficulty ratings according to the hikers surveyed.

**Table 3.10.** Trail difficulty of Mist Trail according to hikers  
(1=EASY, 10=VERY STRENUOUS)

1	2	3	4	5	6	7	8	9	10
0%	2%	7%	10%	23%	26%	15%	10%	2%	0%

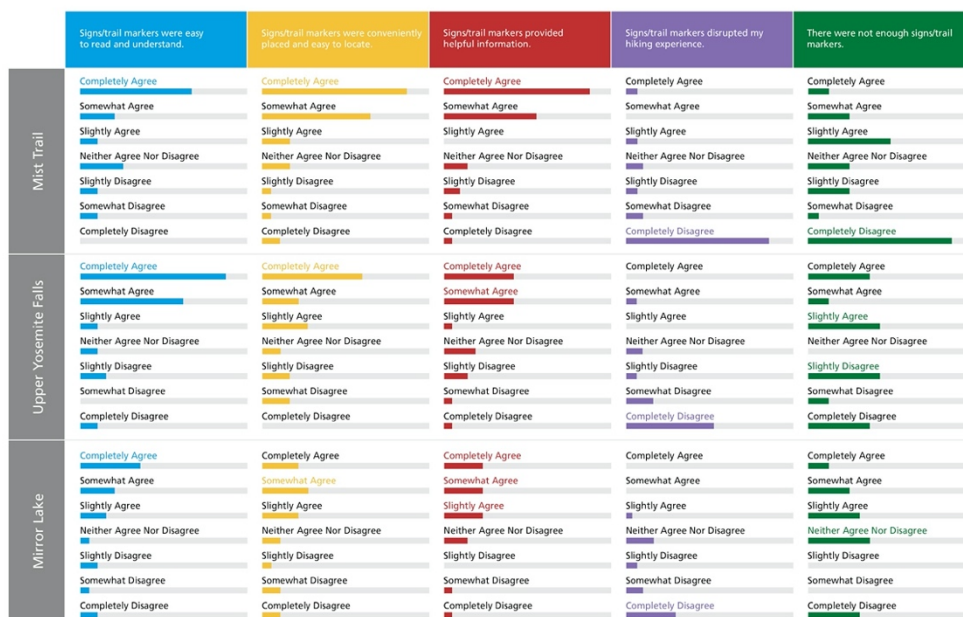
Hikers were asked if they used the signs at the trailhead before starting their hike and if they used the trail signs during their hike. 84% reported they did use the signs before their hike and 81% reported they did use the signs during their hike. Hikers were asked if they left the marked trail during their hike. 26% reported they did leave the marked trail, even though it is against the rules to leave any marked trail within a national park. Hikers were asked if they were ever confused about the direction of travel while on the trail. 13% reported they were confused at least once while on the marked trail. Hikers were asked if they ever used a paper map to assist with navigating the trail. 34% reported they did use their paper map while navigating the trail. Hikers were asked if they used an electronic device to assist with navigating the trail. The electronic device could include a cell phone, GPS device, etc. 26% reported they did use an electronic device to assist with navigation. 20% of hikers who used an electronic device did not use a paper map to assist with navigation while 53% of hikers who used a paper map also used an electronic device. Hikers were asked to rate the signage used on the hiking trail based on ease of



readability, convenience of location, helpfulness of information, whether or not the signage disrupted their hiking experience, whether there seemed to be an appropriate amount of signage, and whether signs should include languages other than English. Hikers were allowed to agree or disagree with statements regarding the signage. The following information is about readability of signage found on the hiking trail: 44% of hikers completely agreed while 5% completely disagreed that signage was easy to read and understand, 31% of hikers somewhat agreed while 0% somewhat disagreed that signage was easy to read and understand, 5% of hikers slightly agreed and 7% of hikers slightly disagreed that signage was easy to read and understand, and 5% of hikers neither agreed nor disagreed that signage was easy to read and understand. The following information is about the convenience of signage placement along the trail and the ease of locating signage when needed: 42% of hikers completely agreed while 5% completely disagreed that signs were conveniently placed and easy to locate, 31% of hikers somewhat agreed while 2% somewhat disagreed that signs were conveniently placed and easy to locate, 5% of hikers slightly agreed while 2% slightly disagreed that signs were conveniently placed and easy to locate, and 7% of hikers neither agreed nor disagreed that signs were conveniently placed and easy to locate. The following information is about signage providing helpful information about the hiking trail: 50% of hikers completely agreed while 2% completely disagreed that signage provided helpful information, 31% of hikers somewhat agreed while 2% somewhat disagreed that signage provided helpful information, 5% of hikers slightly agreed while 0% slightly disagreed that signage provided helpful information, and 7% of hikers neither agreed nor disagreed that signage provided helpful information. The following information is about signage

disrupting the hiking experience: 5% of hikers completely agreed while 68% completely disagreed that the signage disrupted the hiking experience. 0% of hikers somewhat agreed while 7% somewhat disagreed that the signage disrupted the hiking experience, 5% of hikers slightly agreed and 5% slightly disagreed that the signage disrupted the hiking experience, and 7% of hikers neither agreed nor disagreed that the signage disrupted the hiking experience. The following information is about whether there was an appropriate amount of signage provided on the trail: 7% of hikers completely agreed while 36% completely disagreed that there were not enough signs on the trail, 10% of hikers somewhat agreed and 5% somewhat disagreed that there were not enough signs on the trail, 21% slightly agreed while 10% slightly disagreed that there were not enough signs on the trail, and 10% of hikers neither agreed nor disagreed that there were not enough signs on the trail.

**Table 3.11.** Survey questions and results about trail signs/markers on Mist Trail, Upper Yosemite Falls, and Mirror Lake



## **Explanation of Findings**

The Mirror Lake Loop Trail is a partially paved trail with a clearly defined path, however, there were multiple trail junctions that did not have trail signs nor an indication of the correct direction of travel. The hikers surveyed for this study who consider themselves advanced hikers were confused about the direction of travel at some point on the trail while hiking the Mirror Lake Loop Trail. The remaining hikers who were confused about the direction of travel considered themselves to be moderate hikers while one hiker considered themselves to be a novice/beginner. This is important because even though the path is clearly defined, experienced hikers still became confused while navigating an easy (flat and short) trail. Mirror Lake Loop Trail is a popular trail, and based on the low difficulty rating set by the NPS, is likely to be hiked by inexperienced hikers. Therefore, theoretically, this trail should be without wayfinding issues. The majority of the hikers who were confused about the direction of travel agreed that there were not enough trail signs nor trail markers on the Mirror Lake Loop Trail. 45% of the hikers who were surveyed on the Mirror Lake Loop Trail admitted to stepping off the trail during their hike. This observation was commonly made in the winter season because the lake had little water and multiple hikers explored the lakebed off of the trail. Only one of those hikers reported that they were confused about the direction of their travel. This means that stepping off the Mirror Lake Loop Trail did not increase the number of people who were confused about direction, even though there was no trail or trail signage to point them in their intended direction of travel.

Hikers were asked to rate the hiking trail based on difficulty with the assumption that novice/beginner hikers with little to no experience would rate the trails as more

difficult than currently graded by the NPS. While this assumption holds true for the Mirror Lake Loop Trail, the hikers who considered themselves experts rated the trail similarly to those who considered themselves novice/beginner hikers. The NPS might want to reconsider how trails are graded or the grading scale they use to determine the difficulty. One could argue that the NPS should adjust trail difficulty based on the most difficult terrain of the trail. There are hiking trails in Yosemite where hikers tend to stop hiking after they view the area or point of interest, and then hike back in the opposite direction without completing the trail in its entirety. Considering this, difficulty grade variation by section along the same trail would better prepare hikers by providing information for the specific sections they plan to travel. For example, the section of the trail that leads to Mirror Lake would be graded as easy (flat and short) because it is paved, clearly defined, and it does not include an elevation change that would be difficult for a novice/beginner hiker. However, the same trail becomes slightly more difficult past the lake where the terrain becomes rocky. There, it is no longer paved, and there are trail junctions without proper signage. This section should be graded differently than the other section to prepare hikers for unfamiliar terrain. More research is needed to create an improved universal hiking rating scale that can be applied to different levels of terrain and expand on what is already being used to grade trails. The rating scale should be consistent across all national parks throughout the United States so visitors can expect similar terrain based on difficulty, regardless of geographic location.

The Mist Trail is a strenuous trail with steep and long terrain, and with multiple destinations along the trail, including Vernal Fall footbridge, Vernal Fall, and Nevada Fall. It was observed that hikers hiked to these destinations and then hiked in the opposite

direction without hiking the trail in its entirety. The elevation increases between each destination, which means the level of difficulty also increases as hikers continue up the trail. Just as the Mirror Lake Loop Trail should note difficulty grade variation by section of the trail, Mist Trail should as well. The trail difficulty grade should change based on sections most commonly hiked and with differentiation in difficulty. While the trail is graded as strenuous, over 80% of those surveyed were not advanced or expert hikers. This means hikers are likely to hike beyond their known ability and experience. Therefore, it is important to educate hikers about trail difficulty and expectations in order to reduce injuries and even deaths that occur on the Mist Trail. The park map given to hikers at the visitor center says, “Strenuous trails may be considered moderate if only a portion of the trail is hiked.” This statement supports the argument for difficulty grading variation on the same trail, especially for sections of the park’s popular trails that may be too challenging for novice/beginner and even some moderate hikers.

The trail is very well defined, leaving minimal room for confusion among those surveyed. However, of the hikers who became confused while hiking the Mist Trail, a majority had gone off trail during the hike. This means that while the trail may be defined and easy to follow, if hikers leave the trail, the surrounding terrain makes it difficult to find the established trail again. It is important to note that in the winter season, the Mist Trail can become covered in snow, making it difficult to see the trail and to see trail markers or signs. This also means the trail is less defined, making it difficult to determine if hikers are hiking on the established trail. When the trail cannot be seen due to snow, the difficulty of the trail increases. There should be extra warning given to hikers in the winter season, either on current signage or on printed materials used for navigation. The

use of a marker system that is placed at different heights to accommodate varying weather conditions would be beneficial when the trail signs are no longer visible. The marker system would alleviate the need for additional signage. As well, it would be less costly to add markers at different heights than it would be to add more signs.

The hikers who did not agree that the signs/trail markers were easy to read and understand classified themselves as moderate or novice/beginner hikers. Based on the data, we know that a majority of the hikers who hike Mist Trail were moderate or beginner/novice, therefore, it is important that trail signs on strenuous trails provide the information necessary to minimize confusion for less experienced hikers. All of the novice/beginner hikers surveyed, with the exception of one hiker, agreed that there were not enough signs on the trail. The remaining hikers who agreed that there were not enough signs on the trail classified themselves as moderate hikers. One hiker classified themselves as advanced. A majority of the hikers who agreed there were not enough signs on the Mist Trail used the signs at the trailhead and the signs along the trail for navigation. Given that the majority of hikers who hike Mist Trail are moderate and novice/beginner hikers, the need for a marker system is imperative. On a trail where hikers prefer more signage, a marker system could alleviate confusion and give reassurance to hikers with less experience without creating sign pollution. A marker system that coincides with the trail map would also help hikers navigate when using a paper map on the trail, and would eliminate the need for additional signage.

## **Data Gathering and Analysis**

The data represented in this study relied on spreadsheets constructed by Jack Hoeflich, the Emergency Program Manager of Yosemite Search and Rescue (YOSAR). According to this data, between January and October in the 2019 season, YOSAR reported 208 search and rescue incidents (Hoeflich). The data was analyzed in order to determine the locations of the incidents in the park, the types of incidents, the times of day at which the incidents took place, and the conditions of those incidents. Subjects involved in the incidents were primarily male, and the average age was 37.

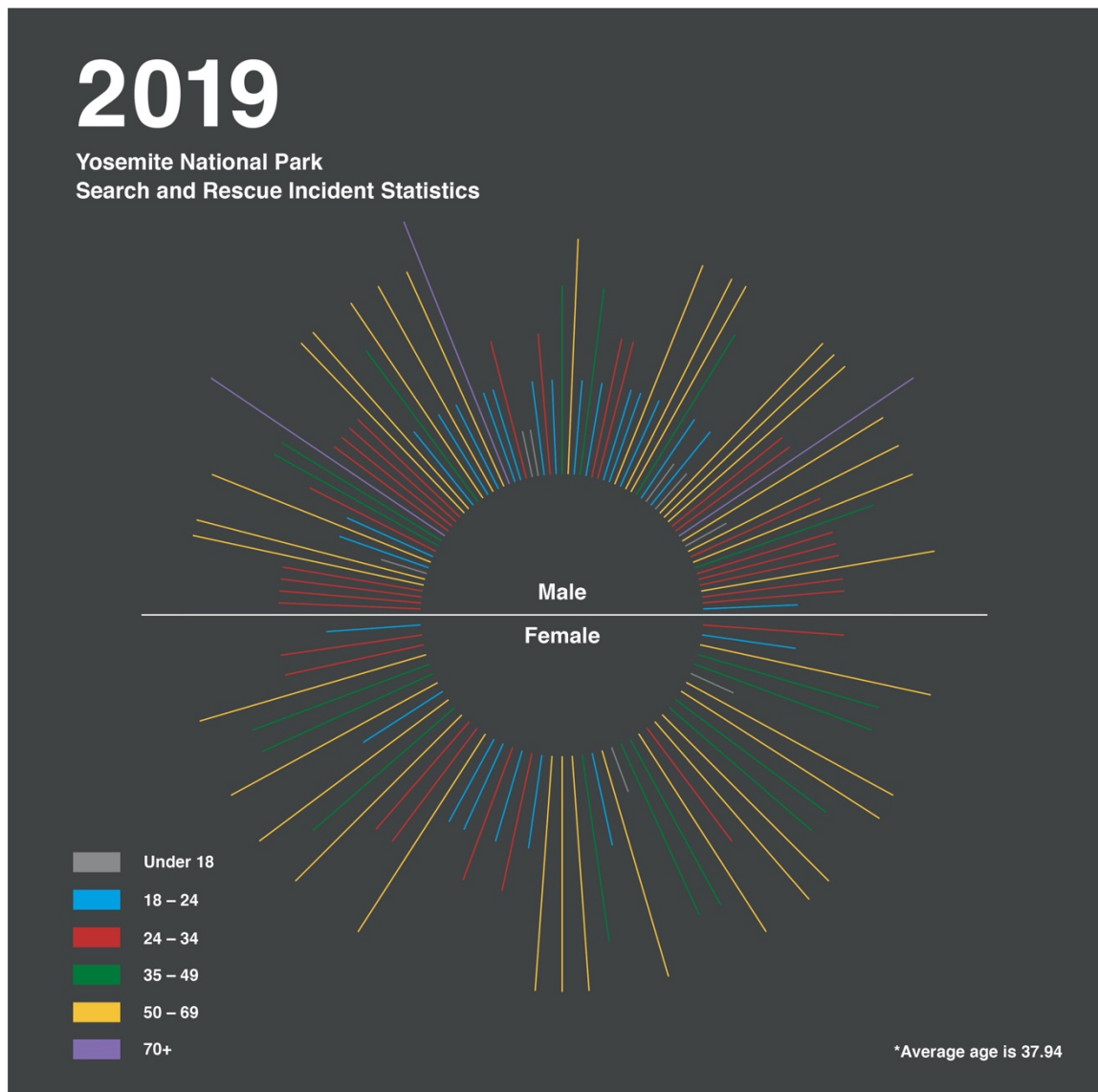


Figure 3.17. Data visualization of search and rescue subject statistics for gender and age range in Yosemite National Park (Hoeflich).

Most incidents occurred in summer and fall, which could be due to the increase of visitors during those seasons. The data indicated the two areas in the park with the greatest concentration of search and rescues were on Mist Trail and Upper Yosemite Fall. In 2019, 47% of rescues were for day hikers and 14% were for overnight hikers. These findings were lower than expected because YOSAR claims that nearly 70% of rescues



are for hikers. There was an unusually high number of incidents involving campers, which was due to a single flooding occurrence that left the campers stranded.



Figure 3.18. Data visualization of where search and rescue operations took place in Yosemite Valley (Hoeflich).

A majority of all rescues in 2019 occurred between the hours of 10 a.m. and 9 p.m. This does not mean subjects did not contact search and rescue outside of those hours, but it was discovered that YOSAR does not typically respond to incidents in the

dark due to increased risk for the team members. YOSAR waits until morning to rescue if the subjects are alive and well, and are not in dire need of rescuing.

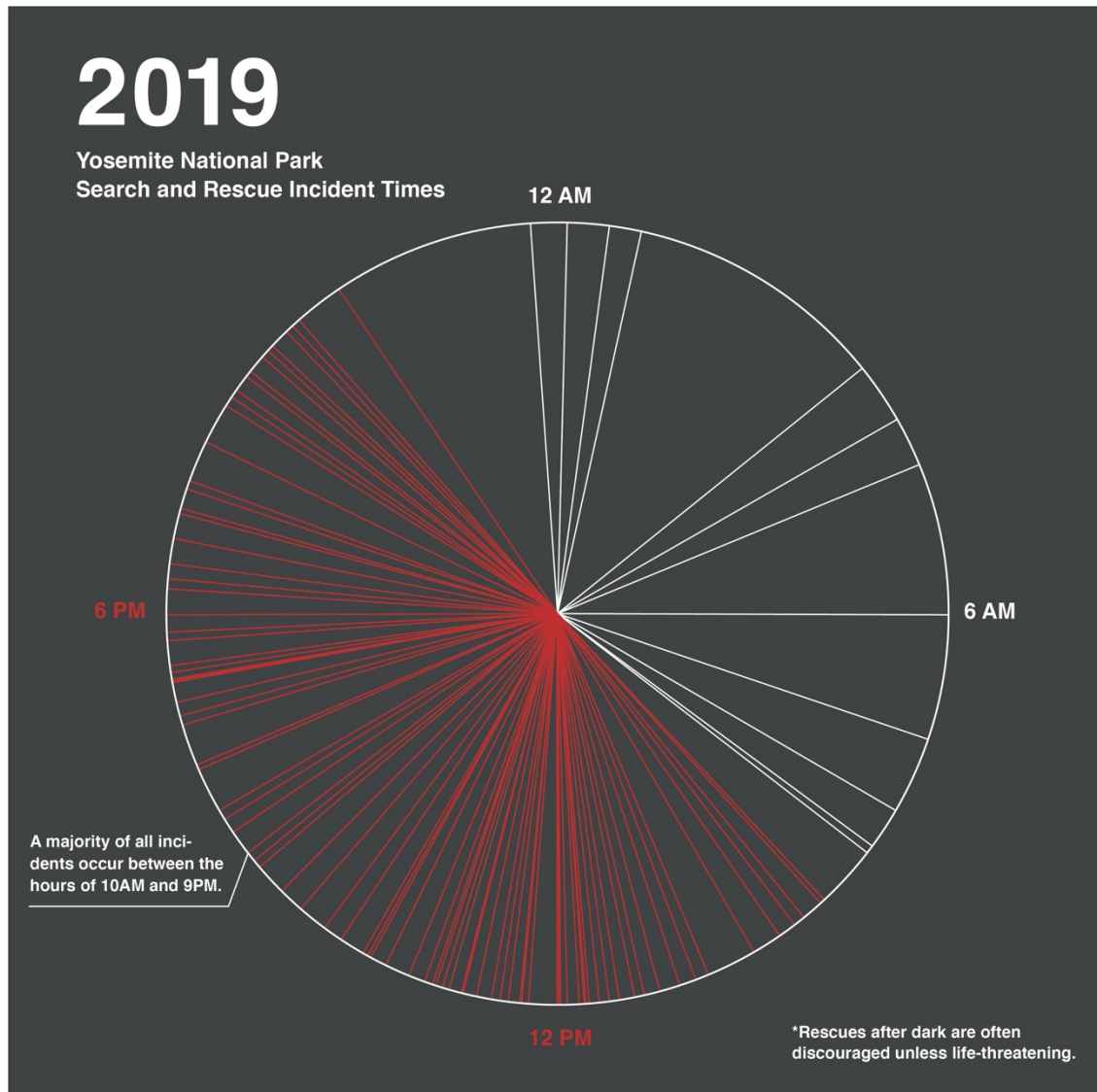


Figure 3.19. Data visualization shows the time of day most rescues occur in Yosemite National Park (Hoeflich).

The data indicated that 70% of rescues were for subjects who were ill or injured. 56% of subjects needed to be saved, which means search and rescue needed to intervene in order to keep the subjects alive and well. 11% of rescues were fatal and 1% were never found.

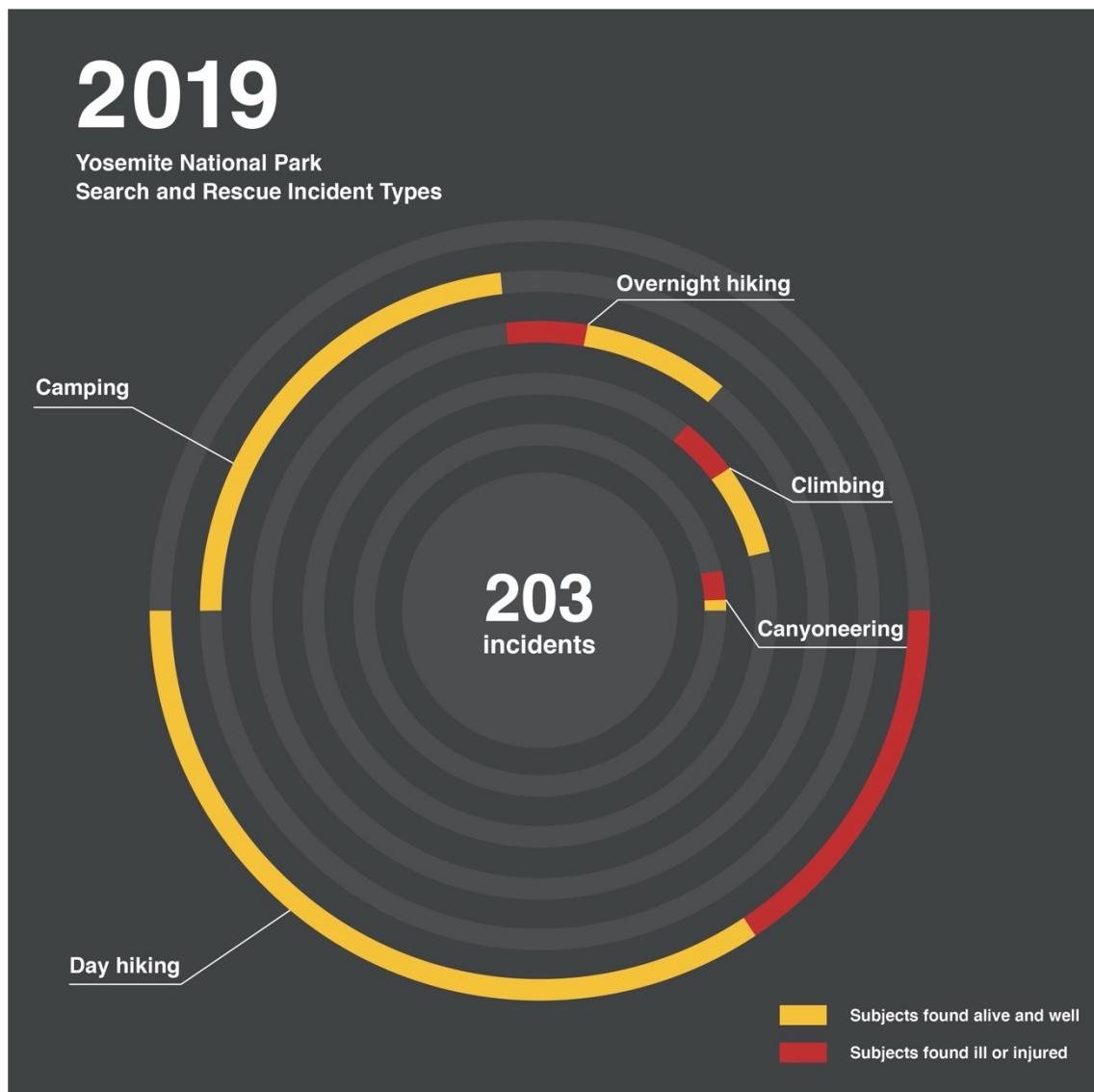


Figure 3.20. Data visualization shows the types of rescues performed by Yosemite Search and Rescue (Hoeflich)

# 2019

Yosemite National Park  
Search and Rescue Incident Conditions

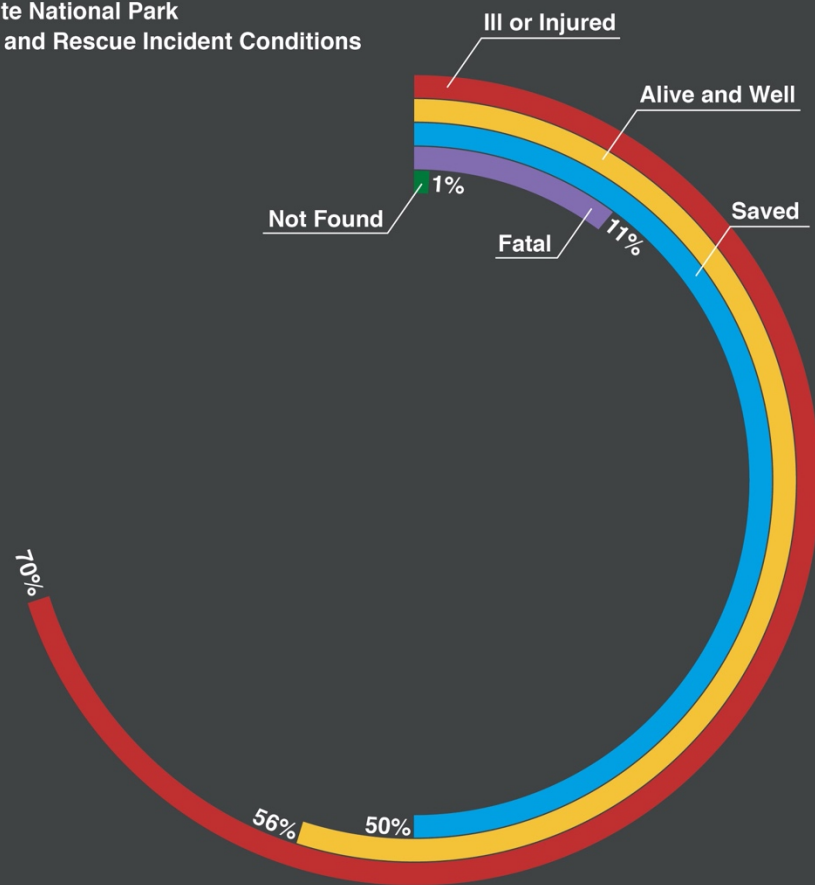


Figure 3.21. Data visualization of search and rescue operations per season in Yosemite National Park (Hoeflich).

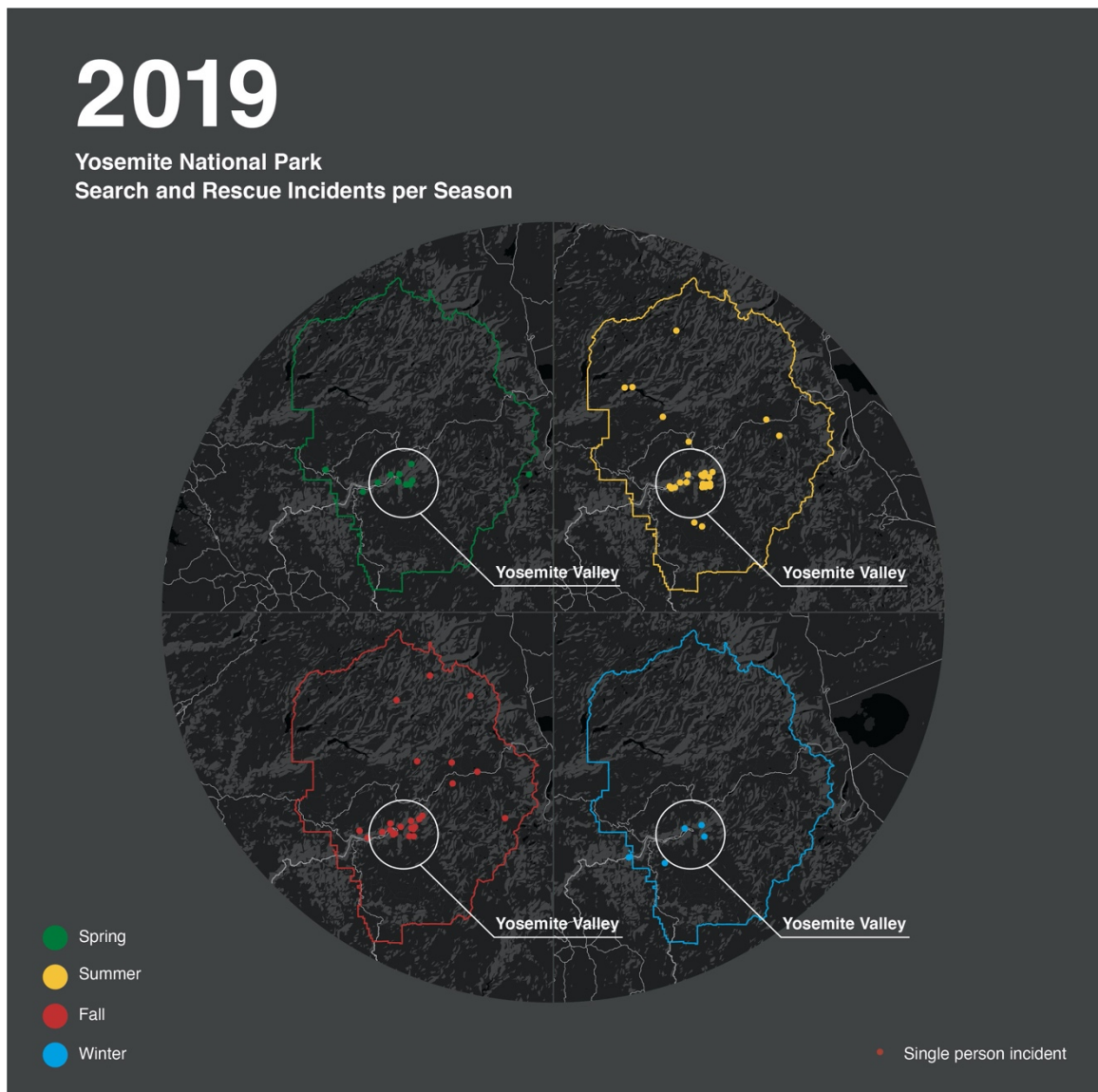


Figure 3.22. Data visualization showing the incident conditions for rescues in Yosemite National Park (Hoefflich).

The trails observations, collection of surveys, and analysis of data revealed areas of improvement related to hiking wayfinding in Yosemite. Trail observations confirmed inconsistencies in trail sign design related to layout, typography, placement of signs, and signage materials. Observations on Mirror Lake revealed there is an overabundance of signs in some areas and not enough in others. The data from the surveys confirmed that users had difficulty locating trails signs/markers and ensuring they were on the correct

trail. Observations on Upper Yosemite Falls revealed the trailhead sign needs to be replaced because of natural damage caused from being outdoors. The trailhead sign revealed a difference in trail name in the map given to park visitors at the visitor center and entrance station. The observations also revealed that more signs need to be placed on the trail, especially at points of interest. The surveys showed that most people had difficulties planning for the hike, as well as locating trail signs/markers and the trailhead. This means there needs to be changes made to the signs so they match the information given to visitors on park printed materials and online. Observations on Mist Trail revealed inconsistencies in trail sign design related to signage materials and layout design. Mist Trail uses a variety of signs at the trailhead, however, a majority of the hikers surveyed did not have difficulties with locating the trailhead and signs/markers on the trail. The author learned during observations that hikers will occasionally start their hikes just after midnight to watch the sunrise at various points of interest throughout the park. The hiking surveys also revealed that almost half of the subjects admitted to hiking at night in Yosemite or another national park. Therefore, it is important to consider adding a component to the wayfinding system that would assist hikers who hike when there is low visibility on the trails. The data collected and analyzed from YOSAR confirmed that Mist Trail is a common area for search and rescue incidents. Upper Yosemite Falls is another area in the park that has a high number of search and rescue incidents. The data also confirmed that a majority of search and rescue operations are for hikers, both day and overnight. The information learned in this section helped identify design flaws in current national park wayfinding and signage for hiking trails, provide evidence of design flaws through documentation of current hiking trail signs, explain

how users currently view trails, give insight into how the park communicates with park visitors, show areas in the park where incidents commonly occur, and support the need for low light visibility on the trails.



## **IV.DESIGN PROPOSAL**

This section of the study includes wayfinding and design principles, a biomimetic approach to low light navigation, a new wayfinding system with trail sign designs and trail markers, and user testing results. The proposal introduces an approach to wayfinding and designing for different types of trails that are all part of the same system in the National Park Service. The most important aspect of the designs is consistency in the way information is communicated to hikers. The designs created for this study are preliminary, and are expected to change as more research becomes available for a system that can accommodate all of the challenges associated with hiking trails in the national parks.

### **Wayfinding Principles**

Wayfinding is a system of navigational cues used to help a person find their way in a physical environment. There are wayfinding design principles that must be addressed in order to communicate how a designer might approach a wayfinding design challenge. The wayfinding for an outside environment differs from wayfinding design for indoor use. For this project, wayfinding design principles for an outside environment will be discussed, and used for the final outcome. The design principles are relatively the same regardless of location, with slight variation. These guidelines should be applied to hiking trail wayfinding in order to create consistency in overall design, as well as in hiking signage and marker placement.

The wayfinding guidelines provide a good foundation for consistency in future trail sign design. Wayfinding principles are different from design principles because they

directly address the consistency of the entire signage system, usage of landmarks, and the placement of signs and markers. It is important to consider the existing design used in the park so as to not stray too far from the park's established identity.

- 1. Create an identity for each park using a cohesive voice and similar styling  
(National Park Service (U.S.) 72)**

Any navigational space should use a unique identity to assist the navigator in identifying immediate surroundings. The identity makes a space distinguishable, minimizing confusion for the user. However, there also need to be common attributes that group the space in order to make it identifiable. (Arthur and Passini 1992) The most important rule when designing a wayfinding system is to create an identity for the system that is cohesive: using markers of similar styling at every trail junction and at every location on the trail where reassurance is necessary. Every park already has a unique identity, therefore, each park should have its own unique marker system which is used on every hiking trail throughout the park. Each element in the system should have similar design characteristics, with enough variation to be distinguishable. The marker system should be carried over on all trailhead signage and on park maps. No other markers or design alterations should be introduced to the system unless those changes are made and carried throughout the entire system. Cohesiveness of identity on trail signage is needed to minimize confusion and to create a unifying voice for all National Park Service hiking trails regardless of their geographic location.

- 2. Use landmarks to provide orientation cues (Sorrows and Hirtle 4)**

Landmarks serve as a navigational tool to aid the user in making navigational decisions and identifying points of interest. They provide assurance that the user is on the

correct route. Landmark navigation provides the user with enough differentiation between trail features that they can create a cognitive map of the surrounding area (Sorrows and Hirtle 39). A cognitive map is a mental map of one's surroundings. A well-designed hiking trail will feature a scenic overlook, waterfall, lake, or another positive control point which makes a hiking trail desirable for the intended user. Along the trail, landmarks should be visible as a way for the user to quickly orient the correct direction of travel. These landmarks should be identified on a park map or on the trailhead signage to assist the hiker with orientation. If landmarks are not visible, the designer should provide another type of orientation cue in the form of a reassurance marker (see wayfinding principle #5). It is important to note that wayfinding signage can serve as a landmark, such as the trailhead sign or trail junction sign. Because of this, designers do not need to solely rely on naturally occurring landmarks for the system.

### **3. Provide signs or trail markers at decision points (Kettunen 247)**

Landmarks are used at decision points to assist the user in identifying their location for wayfinding. Landmarks do not need to be natural features of the landscape. Signs used along a trail serve as important landmarks for a user, therefore, they should be provided at decision points where a user may decide to change their direction of travel in order to stay on the intended route. Signs or trail markers should be provided at decision points on all hiking trails throughout the park. Decision points are points along the trail where two trails connect or intersect, and a decision about the direction of travel is made by the user. Trailhead signs are major decision points, because they indicate the beginning of a prominent, well-established trail. The trailhead sign is an opportunity to educate the user about the conditions of the trail. Trailhead signs should include the

following information: name of trail, trail difficulty, distance of trail, terrain grade, trail junctions, trail icons for intended trail use, trail marker key, and a map of the trail in reference to prominent landmarks used for orientation. Trail signs, which include the trail name, distance until the end of the trail, and a trail marker indicating trail difficulty should be used when multiple trails intersect or connect, and a user has multiple directions of travel from which to choose. Trail markers should be used as a means of communication to indicate that the user is on the correct trail and is traveling in the correct direction.

#### **4. Install trail markers for high visibility (“Willamette National Forest - Hiking”)**

When installing trail markers, the markers should be placed so that they are visible to hikers traveling in either direction. The marker should be placed on the same point of interest because this indicates intentional placement, and gives the marker credibility. It is important to be conservative with placing markers so as to not create “sign pollution” on a trail. Trail markers must be placed in such a way that they have the highest chance of being seen by a hiker. The designer must take into account the direction of travel, weather conditions that may obscure markers, nighttime visibility, and potential distractions, such as overlooks or viewpoints along the trail that may detract the hiker’s attention away from navigating. Too many signs or markers can create confusion for a user.

## **5. Use reassurance markers to identify hiking trail (“Willamette National Forest - Hiking”)**

Reassurance markers are markers used to mark the trail when the tread is difficult to follow and may cause confusion for the user. A reassurance marker is a trail marker that indicates to the user that they are on the correct trail, and that they are traveling in the correct direction. Reassurance markers should only be used when A) the direction of travel is unclear; B) the trail is no longer distinctly visible; C) a significant travel distance has been completed and the hiker needs indication that they did not miss a trail junction. These markers are similar to a trail marker, however, they are not used at a trail junction where the user will need to make a decision about the direction of travel. A reassurance marker reassures the user that they are traveling the intended route in cases where the trail is not clearly identifiable, snow is present, or the trail is obscured by weather, such as fog or heavy rain. The markers should be placed periodically with the indicated marker set by the design guidelines for the system. The USDA recommends that easy terrain trails should be marked with more markers than a trail with moderate or difficult terrain. This is debatable based on observational research conducted at Yosemite National Park. Easy terrain trails, such as Lower Yosemite Falls, are paved and well-indicated paths, marked with a generous amount of signage. This trail does not need reassurance markers because it is easily identifiable based on visible landmarks and the distance of the trail. Difficult terrain trails, such as Panorama Trail, require more reassurance markers. In the case of the Panorama Trail, this is because the trail is 7.4 miles longer than Lower Yosemite Falls trail, and there are sections of the Panorama Trail that are not easy to follow because the tread is indistinct. Trails rated for easy terrain with an obvious trail

will not need as many reassurance markers as a trail rated for moderate or difficult terrain. It is also important to mention that the markers should be placed so that they are visible from any point on the trail, and therefore do not cause confusion for the user.

### **Design Principles**

Trailhead signs serve multiple functions, but perhaps the most important is that these signs are the first impression a hiker has before they start their hike. The trailhead sign provides an opportunity for parks to educate by communicating relevant information about what hikers may encounter on the trail. The trailhead should represent the overall aesthetic of the geographic area, and it should be consistent with the design of other types of signage, such as trail signs or markers. It is important for the trailhead sign to serve as the primary visual representation of that trail, and any subsequent signs should reflect the same look and feel. According to the Appalachian Trail “Planning a Trailhead Kiosk” guidelines, the following information should be included on a trailhead sign: name of the trail, map of the trail, trail difficulty rating, emergency services contact, trail management, specific prohibitions for the A.T., basic safety/education, basic trail description, Leave No Trace poster, interpretive information, and technology enhancements (“Planning a Trailhead Kiosk – 2012 | Partnership for the National Trails System”). Currently, the trailhead signs in Yosemite include the following information: trail name, trail rules, map of the trail, safety guidelines, and trail closures. Not every trailhead sign includes the same information. For example, the trailhead sign for Panorama Trail and Pohono Trail at Glacier Point only include the trail name, and trail names and distances to their respective destinations. At the very least, trailhead signs used in the national parks should include the following information: name of the trail,

map of the trail, trail difficulty rating, basic safety information, and trail description. The materials used for the trailhead signs will vary from park to park, and will be based on availability of materials.

Graphic information on a wayfinding sign comes in two forms: verbal (typographic) and non-verbal (pictographic). For users to find their way on a hiking trail, there should be verbal graphic information which identifies both the trail they are on and the trail or destination they are trying to reach. In Yosemite, the verbal information can cause confusion for a user when the information on signs and paper maps is in conflict.



Figure 4.1. Yosemite Falls trailhead sign

For example, the verbal information identifying the trail at Upper Yosemite Fall uses a variety of disparate language, even on the same paper map. On the paper map given to

guests at the visitor center, the trail is indicated as "Yosemite Falls Trail" with Upper Yosemite Fall described as a point of interest. On the back of that map, the same trail is labeled "Upper Yosemite Fall." On the paper map given to guests at the entrance gate, the trail is not given a name, but rather points of interest along the trail, such as Columbia Rock, are named. When a user starts to hike toward Upper Yosemite Fall, they will see a sign with an arrow and the distance to the point of interest. The trailhead sign indicates "Yosemite Falls Trail" as the name of the trail, with points of interest listed below.

However, Upper Yosemite Fall is not listed, and instead the verbiage "Top Yosemite Fall" is used in its place.

It is important for verbal graphic information to be consistent across all communication, such as: paper maps, signs, maps on signs, online information, and phone applications, in order to reduce confusion for the user.

The goal of typography in any environment is that it is legible to the user. The information needs to be clear and concise. The Appalachian Trail "Planning a Trailhead Kiosk" guidelines strongly encourage the use of Arial for their kiosk signs ("Planning a Trailhead Kiosk – 2012 | Partnership for the National Trails System"). The size of the font is decided by the designer but they encourage using a size that will "catch people's attention" or that can be read if the user is standing four feet from the sign. They discourage mixing fonts, and therefore, Arial is the only font approved for the kiosks designed for the Appalachian Trail. In contrast, the fonts used on hiking trail signage in the national parks vary depending on the sign. The use of a single typeface for all signs is not the objective, however, there should be typographic design guidelines for displaying verbal graphic information. There should also be clear guidelines for the size of



typography on all signs in order to create consistent letter sizing which complies with ADA regulations for the visually impaired.

### **1. The x-height and cap-height ratio**

The best fonts to use for hiking wayfinding design should have an appropriate x-height and cap-height ratio of at least 3:5. ADA regulations require letters and numbers to have a width-to-height ratio between 3:5 and 1:1 and a stroke width-to-height ratio between 1:10 and 1:5 (Arthur and Passini 154-155). An x-height is the measure of the letter “x” in the lowercase form of that particular font. Fonts that have small x-heights should be disregarded as a viable option for hiking wayfinding signage because they are not as legible as fonts with tall x-heights (Arthur and Passini 166-167).

### **2. Uppercase and lowercase letters should be used**

When users are reading signs in a hiking environment they do not read the signs the way we typically read a book. Instead, the user reads in a series of glances and recognizes words based on shapes. If the shape is the same on every sign because the designer used only uppercase letters, then the signs will be difficult to read when read at a glance. Therefore, it is important for the fonts to use a mixture of upper and lowercase letters in order to make the words easier to distinguish.

### **3. Sans serif fonts should be used on hiking signs**

“It is vital that all signs be read easily and understood quickly. This demands the consistent use of a distinctive typeface throughout the entire system. Research has shown that the most ‘appropriate’ typeface for this purpose is a regular sans serif” (Unimark International et al. 4). The National Park Service currently uses two typefaces as part of their brand identity, NPS Rawlinson and Adobe Frutiger. The Frutiger typeface is a sans

serif type family designed to be highly legible for indoor and outdoor use. The large x-height and open letterforms make it ideal for reading at a distance. This typeface should be considered for hiking trail signs because it is already part of the NPS identity and because “of its clarity at small sizes (as on printed materials, such as maps), and at a distance (as on signs)” (*UniGuide: Identification, Wayfinding and Visitor Information for National Parks*). If Frutiger is not used for trail signs, another sans serif typeface with similar characteristics to Frutiger may be considered.

#### **4. Letter size should be determined by viewing distance**

Choosing the appropriate type size and spacing between the letters is important for creating signs that are legible under different conditions. Minimum letter size recommendations (Arthur and Passini 166) should be considered based on the following factors that can reduce legibility:

- Angular distortion occurs when a user approaches a sign at an angle
- Weather and lighting conditions change depending on time of year or day
- Visual impairments vary from user to user

The letter size of one inch of cap-height yields a distance of 50 feet for the font Helvetica. Helvetica has an x-height of 0.725 inches when the cap-height is one inch. If Frutiger is used as the font of choice and the cap-height equals one inch then the x-height would need to be no smaller than 0.6 inches in order to have the correct cap-height to x-height ratio. The x-height for Frutiger is 0.73 inches when the cap-height is one inch, therefore, Frutiger meets the regulations and may be used by the National Park Service for hiking signage. The letter size may need to be increased if the viewing distance exceeds 50 feet (Arthur and Passini 166).

**5. Non-verbal pictographic information (symbols or icons) should be used sparingly and often times with verbal information**

The NPS uses non-verbal language to communicate with park visitors using an icon system created as part of the UniGuide Standards Manual. The system includes 112 symbols with varying system formats to communicate about park activities, warnings, and prohibitions (*UniGuide: Identification, Wayfinding and Visitor Information for National Parks* 2.5-4-5). The national recreation symbols used by the NPS belong to the following categories: general, accommodations, services, water recreation, land recreation, and winter recreation. The land recreation category contains 18 symbols that could potentially be used on signs located on hiking trails. There are also symbols in other categories that could be used, such as: restroom, picnic site, falling rocks, and campground, to name a few. These symbols may be used alone or in conjunction with words because park visitors may not be familiar with specific symbols. Symbols are typically used to communicate without words so that illiterate people can easily understand imminent hazards or identify areas in the park. However, pictographs perform all these functions effectively because most people don't recognize more than a handful of glyphs. This means that people may not understand what they are being prohibited from doing or warned against (Arthur and Passini 170). One might argue that the 112 symbols used by the NPS are impractical because people cannot fully recognize all of the symbols without words to affirm the messages. Words should be combined with the symbols until the symbols have been learned by the user.

The color and shape of the symbols are seen first, and establish the context of the message, such as a warning or prohibition. The UniGuide uses the color red for

prohibition, yellow for warning, and black and white, or the reverse in brown, for positive messages (*UniGuide: Identification, Wayfinding and Visitor Information for National Parks* 2.4-2). The glyph used in the symbol should easily communicate the intended message to the user. The verbal message should reiterate the message of the glyph so that the user has a clear understanding of the meaning for the symbol. The combination should be used on trailhead signs or when it is likely that the user is seeing the symbol for the very first time (Arthur and Passini 172). Symbols used on hiking trails should enhance the communicative message. If the symbol is not needed then it should not be used.

#### **6. Arrow placement should be consistent**

The UniGuide uses three different variations (pedestrian, roadway, highway) of directional arrows for directing users in parks depending on their mode of travel. Pedestrian arrows are used for trail guides, double column guides, and narrow profile trail guide signs. The pedestrian arrows should be used on hiking trail signs. The format for the directional arrows follows standard wayfinding guidelines by aligning left and straight arrows to the left side of the sign and aligning right arrows to the right side of the sign. The other option for arrow alignment would be to align all arrows to the left side of the sign. Doing so would create a consistent layout for all signs, and could result in less confusion for the user. However, this format would need to be user tested to determine which format is preferred.

#### **7. Trail sign layout should be consistent with minimal information**

The layout for park signs varies based on the type of sign. Signs should be consistent in layout when displaying navigational information for park destinations along

hiking trails. The destinations should be grouped in 3-4 destinations (Arthur and Passini 51). Destinations should be paired with the distance to the destination in miles.

Destinations do not always need to be highlighted with a directional arrow if it is not necessary, such as when all listed destinations are straight ahead on the trail. Information used to educate the hiker about trail guidelines, current trail conditions, park rules, etc. should be provided at a trailhead sign and should not be provided on additional signage. Too many signs can lead to sign pollution which can cause confusion for the hiker (Arthur and Passini 52). In addition, extra signage can incur unnecessary costs for sign production and maintenance.

### **Biomimicry**

One of the main objectives of this study was to determine how many hikers were hiking in the dark in Yosemite or other national parks. Nearly half of those surveyed for this study admitted to hiking in the dark at Yosemite National Park or another national park. Therefore, there is a clear need for a marker system with night visibility to keep hikers safe and on the trail when there is little to no light. It was also important to consider a solution that would be sustainable and have little impact on the natural environment, where the system would be applied. The practice of biomimicry can be useful to designers who are solving design challenges in which sustainability is important. In 1997, Janine Benyus popularized the emerging discipline of biomimicry, and it has since grown in popularity with designers. Biomimicry is an innovative approach to design challenges which imitates nature's processes, forms, or systems to create sustainable solutions. "In a biomimetic world, we would manufacture the way animals and plants do, using sun and simple compounds to produce totally biodegradable

fibers, ceramics, plastics, and chemicals” (Benyus 2). In contemporary design, designers might find inspiration by evaluating existing man-made technologies or through analyzing user pain points to solve complex design challenges. Biomimicry takes the designer out of the material world and introduces them to solutions that are already developed and thriving in the natural world. The emulation of “nature’s genius” (Benyus 2) is what will drive designers toward creating innovative, sustainable solutions. Contemporary designers are called by their audiences to create with sustainability in mind in order to minimize the impact design solutions have on the environment. Professor Mehmet Sarikaya of the University of Washington believes that as researchers in the field of biomimetics continue to investigate new, sustainable design solutions, there will be a shift in the creation of materials (Benyus 95). He claims, “we are on the brink of a materials revolution that will be on par with the Iron Age and the Industrial Revolution. We are leaping forward into a new era of materials. With the next century, I think biomimetics will significantly alter the way in which we live” (Benyus 95). Biomimicry is a compelling approach to solving design challenges because it allows for interdisciplinary collaboration, innovative solutions through exploration of nature’s processes, and it answers the call for sustainability.

A biomimetic approach to design encourages the inclusion of disciplines outside the field of design to help with learning and understanding how the natural world has remained sustainable, and how nature has solved challenges on its own. “After 3.8 billion years of research and development, failures are fossils, and what surrounds us is the secret to survival” (Benyus 6). Biomimicry does not recreate the organism or farm the organism so that the work of that organism is used to solve the challenge. It is important

to note that biomimicry is not about copying but it is about learning. Collaborating with other disciplines encourages the designer to think outside the realms of design. Biologists or biochemists can assist designers in learning the process and emulating the function of the organism. Both designers and scientists work together using best design principles. In Janine Benyus' book entitled *Biomimicry Innovation Inspired by Nature*, she explains the biomimetic principles and how a designer should approach a design challenge using biomimicry (fig. 4.2). Benyas describes three principles: nature as model, nature as measure, and nature as mentor.

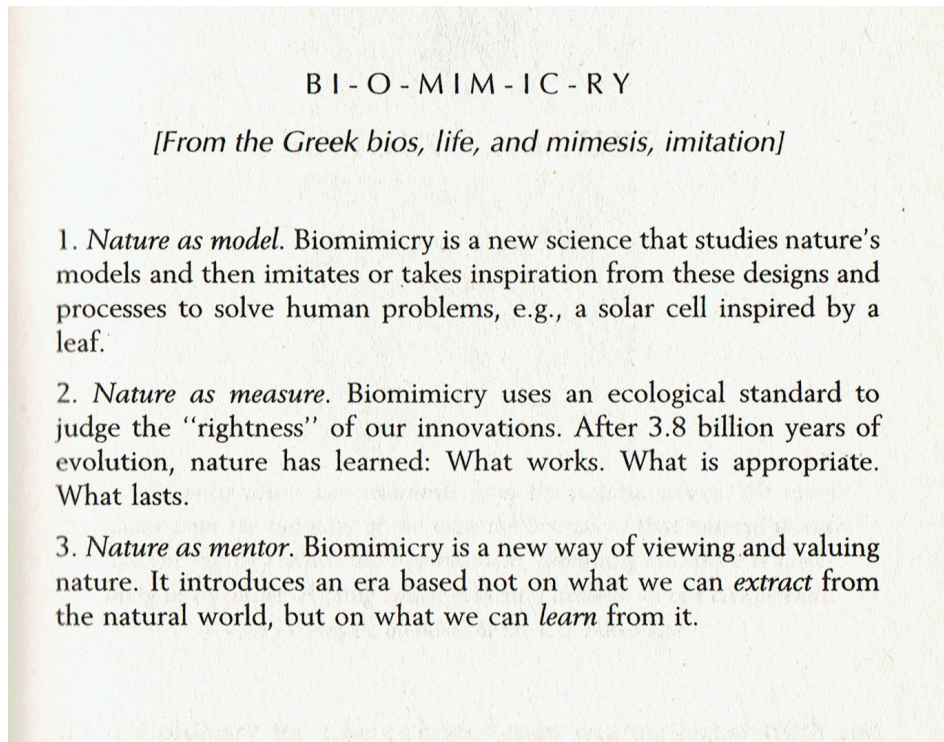


Figure 4.2. List of the three biomimicry principles.

The biomimetic principles are basic, yet they outline how a designer should look to nature for solutions to complex challenges. Nature as model: designers use biomimetic principles to find inspiration in nature's patterns. Nature as measure: even though natural patterns are vital to our world, it is more important for designers to understand why patterns are needed and how they affect human behavior. Nature as mentor: The designer must adopt a curious approach to design challenges, and create a solution during the process of exploration and discovery of nature's genius by questioning why certain patterns are necessary in a specific environment.

Natural patterns, and the knowledge gained from those patterns can be used in the creation of graphics to fulfill the need of a small part in a large project. "It is necessary to take a closer look at how organisms live, function and communicate. In doing this, designers will come to realize that creatures have the same intuitive intelligence as humans do that allows them to recognize certain symbols. For instance, bees find honey down a diverging maze by navigating colonized directional patterns after a few attempts" (McKosky 100).

Biomimicry is changing the way designers approach a design challenge and the strategy for design research. The practice has impacted a variety of fields including architecture, medicine, transportation, agriculture, energy, and even communication. The Shinkansen Bullet Train in Japan is a fascinating example of biomimicry in design. By studying birds, specifically the kingfisher, an engineer reduced air pressure noise for the fastest train in the world (fig. 4.3).

Eiji Nakatsu, an engineer with JR West (or the West Japan Railroad Company) and a birdwatcher, used his understanding of kingfishers' splashless water entry to address



drag when the train moved from open air to a tunnel, and his understanding of owls' silent flight to decrease the sound generated by the trains. Kingfishers move quickly from air, a low-resistance, low-drag medium, to water, a high-resistance, high-drag medium. The kingfisher's beak provides an almost ideal shape for such an impact. The beak is streamlined, steadily increasing in diameter from its tip to its head. This reduces impact as the kingfisher essentially wedges its way into the water, allowing the water to flow past the beak rather than being pushed in front of it. Because the train faced the same challenge when it moved from low-drag open air to high-drag air in the tunnel, Nakatsu designed the forefront of the Shinkansen train based on the beak of the kingfisher ("Beak provides streamlining").



Figure 4.3. Kingfisher diving into water.

To mitigate the very loud noise of the bullet train, engineers created small vortices, similar in design to serrations in an owl feather. The vortices were added to the structure

of the train, reducing noise and improving aerodynamics. The beauty of the solution was that it had been time-tested by nature and was therefore already proven effective. The Shinkansen Bullet Train now travels 10% faster using 15% less energy than before biomimicry and is a direct result of those improvements.

Using biomimicry to solve a complex design challenge requires the designer to follow the three stages: scoping, creating, and evaluation (Benyus 4). Scoping is used to formulate a design question and translate the question using biological terms. In the scoping phase, the designer must first identify the challenge in the form of a question. This is the section where asking “How might we...” is helpful to understanding how nature can help solve the challenge. This is the same question posed during the human-centered design process, however instead of only thinking of the user, the designer must also think about how nature solves the challenge. Designers should investigate the functions of organisms, systems, patterns, principles, or strategies used by nature. Next, the designer should define the context of the challenge. The context will allow the designer to fully understand the environment and the conditions of that environment. Finally, the designer will need to use biological terms to formulate the final design question they will be using to solve the design challenge. Creating is the second stage to solving a biomimetic design challenge. In the creating stage, designers must use what they discovered in the scoping stage. This stage is about brainstorming and innovation and exploring the knowledge gained from nature to solve the design challenge. Sustainable solutions are achieved by learning how to emulate the process carried out by the organism. The system where the form and process exist is another important factor for creating a sustainable solution. The solution does not exist on its own. It is part of an

ecosystem, that is part of a biome, that is within a biosphere. It is necessary to understand how the form and process live within the larger system so that a biomimetic designer can create a solution without causing harm to the natural world. Evaluation is the third and final step of the biomimicry based design process for designing a sustainable, nature-inspired solution. This stage is when the designer must evaluate the results or circumstances of the solution. The solution must match the way nature would solve for the design challenge by emulating the process or function of nature's genius.

Designers have an ethical responsibility to create sustainable technologies for the future of our planet without causing harm to the natural world. It is important to be innovative without being destructive. The future of design could look completely different if designers use nature's genius to solve complex design challenges. What would life on Earth look like if design solutions adapted to changing conditions? What if all design was multifunctional? Designers in all fields, including visual communication, need to look past man-made technologies and repetitive design solutions that limit the potential for innovation. Designers need to answer the call for sustainability with nature-inspired solutions by learning and imitating nature's processes, forms, or systems. Nature has already solved many of these challenges, and it is up to future designers to discover the technologies that have withstood the test of time and turn them into usable strategies for a more sustainable future.

Bioluminescence is how nature solves for low light visibility. "The natural phenomenon of bioluminescence is the emission of visible light by living organisms mediated by an enzyme-catalyzed ('luciferase') reaction of molecular oxygen with a substrate ('luciferin'). Bioluminescent organisms are diverse and widely distributed in

nature, for example bacteria, dinoflagellates, fungi and insects” (Weitz 4-5). For this study, fungi were collected and studied in order to observe the light-emitting phenomenon, and to determine if a potential solution for a luminescent wayfinding marker system could be created without the use of an external energy source. First, it is important to understand how the bioluminescent process works, and why this specific process is best for solving low light visibility on hiking trails within the national parks.

The bioluminescent reaction occurs in two stages:

1. The reaction involves a substrate (D – luciferin), combining with ATP and oxygen, which is controlled by the enzyme (luciferase).
2. The chemical energy in stage 1 excites a specific molecule (the luminescent molecules; the combining of luciferase and luciferin). The excitement is caused by the increased energy level of the luminescent molecule. The result of this excitement is decay which is manifested in the form of photon emissions that produce the light. The light given off does not depend on external light or other energy taken in by the organism and is just the by-product of the chemical reaction and is therefore cold light” (Ilondu and Okiti 133).

The challenge of imitating the luminescent process is in creating the luminescence without the presence of the organism, or any part of the organism. Through the practice of biomimicry, the chemical process must be learned and imitated in order to create a similar result. The protein enzyme luciferase has been successfully extracted by Dr. Bruce R. Branchini, Danielle M. Ablamsky and Justin C. Rosenberg of Connecticut College. Dr. Branchini and his team of researchers extracted luciferase, and it was reported that when the protein was stored, it retained 90% activity for at least 6 weeks

(Branchini et al. S4). Dr. Branchini's research could lead to a solution for imitating the process that they are currently using to retain luminescence. If the chemical process can be imitated using environmentally safe and sustainable products, then this would lead to a biomimetic solution for nighttime navigation. The luminescent material would be used in a paint applied to the marker system and also applied to natural features on hiking trails, such as trees, boulders, rocks, wooden posts, etc. The markers would appear as painted symbols in the daylight. Those same markers would glow for nighttime hikers, thus reducing the chance of hikers stepping off the trail and becoming lost. A glowing marker can be seen in figure 4.4, demonstrating how this might look on a natural element in the dark. This paint would also be applied to the hiking trail signs so hikers could read the signs when hiking at night.



Figure 4.4. Glowing marker on a rock.

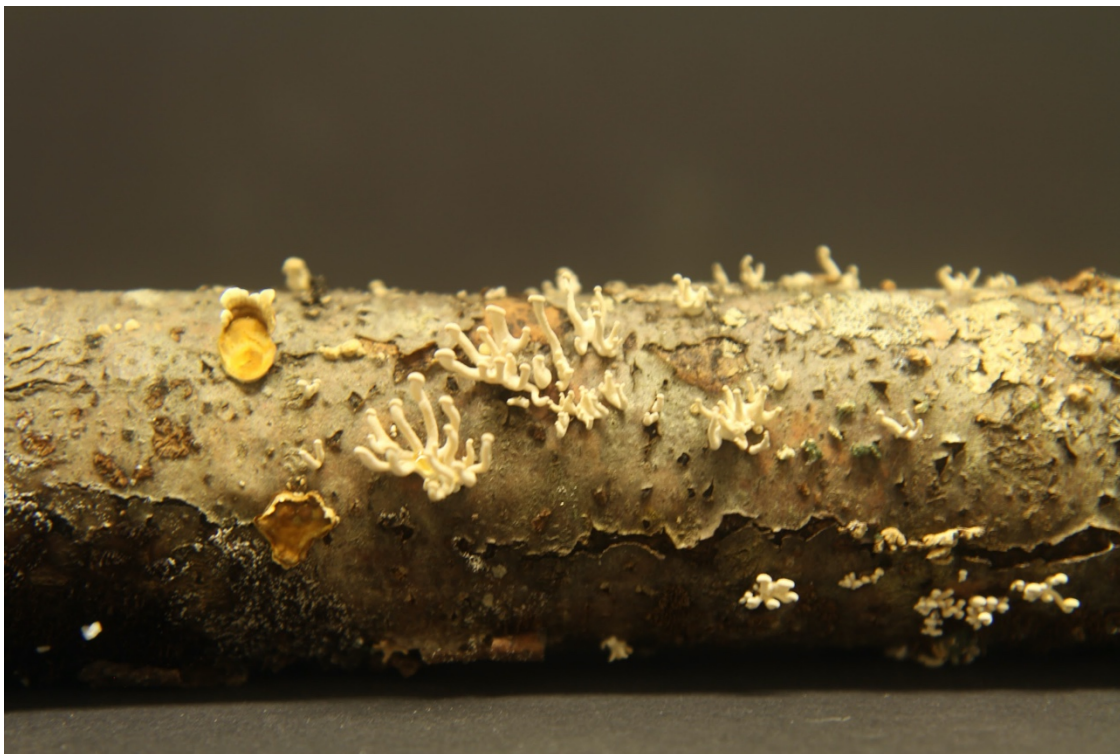


Figure 4.5. *Panellus Stipticus* on a branch.

A few examples of luminescent fungi found in North America include: *Panellus Stipticus*, *Panellus Pusillus*, *Omphalotus Illudens*, and *Mycena Haematopus*. The fruiting bodies of *P. stipticus* were collected from fallen hardwoods at a single site in Connecticut.

The bodies were photographed and observed in order to formulate a hypothesis for this study. Under little to no light, the fungi continuously emitted a greenish light which seemed to appear after the human eye had time to adjust to the low light conditions.



Figure 4.6. *Panellus Stipticus* glowing in the dark.

If a hiker has been exposed to darkness for an extended period of time, the glow of the fungi would appear without an adjustment period. If an external light source such as a flashlight is used, however, the hiker would have to wait for their eyes to adjust. Ideally, once the chemical process of luminescence is imitated, the glow will take the color of the marker instead of emitting a single color. The luminescent glow is bright enough to be seen for trail indication, however, it is also faint so as to not be disruptive to the natural environment. This is all hypothetical, however, and the main objective is to develop a biomimetic solution by creating a paint that can glow without an external energy source. This solution would work best in the national parks where, in remote areas, electricity is scarce and expensive to supply to hiking trails.

## **New Proposed System**

This study of search and rescue hot spots in Yosemite National Park, current wayfinding navigation in national parks and other sites, survey results from Yosemite hikers, and biomimicry principles has resulted in a proposed new system for sign design in Yosemite National Park. The signage design in this new system is similar in style to the current wooden signs found at Yosemite National Park with improvements to overall design and hierarchy of information. The size of the sign post is 52 inches in height, which is the same height as the fingerboard, single post signs described in the UniGuide and used for wayfinding in highly populated areas, such as Yosemite Village (*UniGuide: Identification, Wayfinding and Visitor Information for National Parks 4.2 -111*).



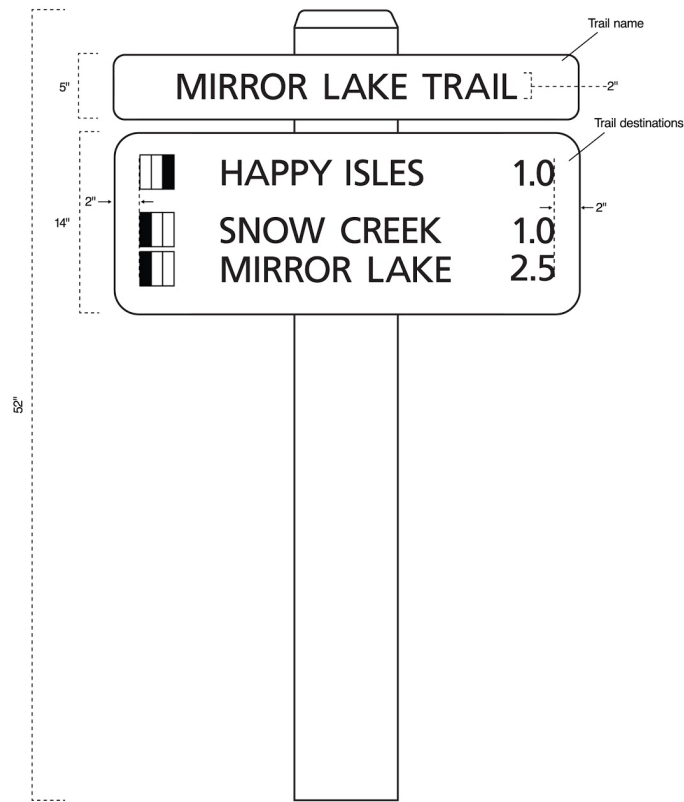


Figure 4.7. New proposed design for hiking trail sign with specifications.

The design example shows multiple panels to separate the information and create hierarchy. The panel at the top, i.e. trail name panel, will only list the name of the trail to aid hikers in identifying the trail. The trail name panel is located two inches from the top of the post. The name of the trail should be centered horizontally and vertically in the panel. The size of the type should be no smaller than one inch in height to yield 50 feet of visibility for the hiker (Arthur and Passini 166).

Figure 4.7 shows the name of the trail at 2 inches in height. The second panel, i.e. destination panel, will list the trail destinations in order of closest proximity to the current

location of the sign. The destination panel is located one inch below the trail name panel. The destination panel has trail markers to indicate the direction of travel for specific destinations. The markers should be left-aligned regardless of direction indication. The destination should be listed to the right of the marker followed by the distance to that destination measured in miles. The example shows the name of the destinations and distances at 2 inches in height. The distance should be right aligned to the panel. Subsequent destinations in the same direction do not need an additional marker because grouping the destinations indicates the same direction for those destinations. Groups of destinations should not exceed more than 4 destinations listed. This will aid the user in retaining information. The margin recommendation on signs should be a minimum of two inches all the way around so no graphic elements are set too close to the edge when signs are created.

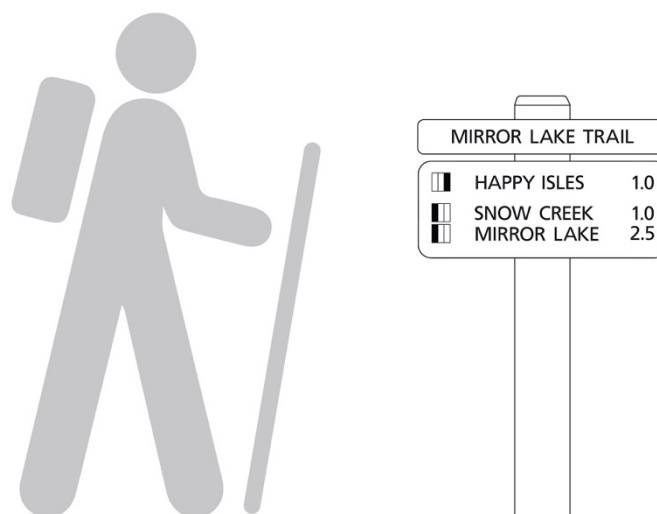


Figure 4.8. Hiking sign and pictogram for size comparison.

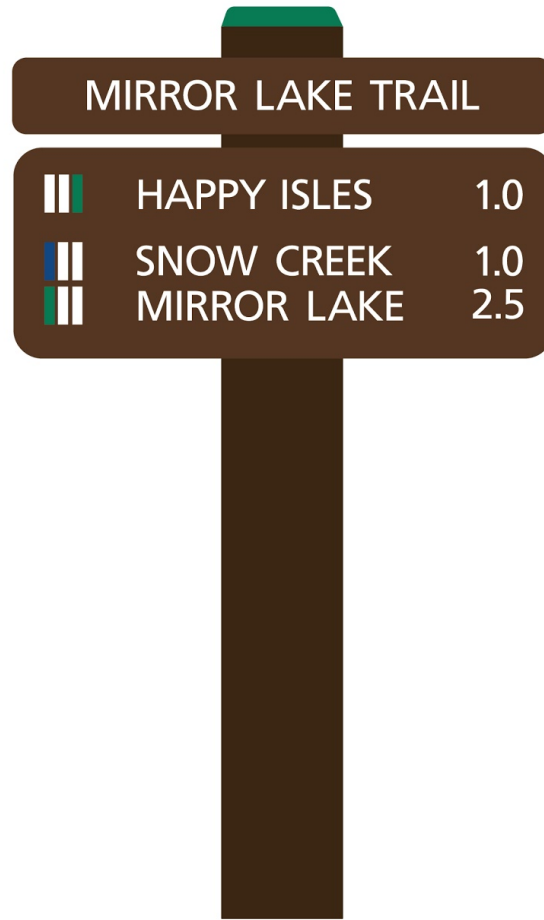


Figure 4.9. New proposed design for hiking trail sign in color.

The sign post will include a color at the top of the post, above both sign panels, to indicate the trail difficulty for the current trail. This same color will also be used on the trail markers used for navigating the trail and should also be used on paper maps.

The trail marker design is heavily influenced by the Czech Hiking Marker Standards and the Appalachian Trail marker system. The colors of the markers communicate the difficulty of the trail as determined by the NPS. The colors are similar

to the colors used to communicate skiing trail difficulty by the NSAA at ski resorts across the United States. The shapes designed for each marker are used to help orient the hikers. The markers are 6-inch squares, each one communicating the direction of travel intended for a specific trail or changes to the trail that are important for the hiker to know for trail navigation. The entire marker system contains 24 markers, 8 markers for each level of difficulty.

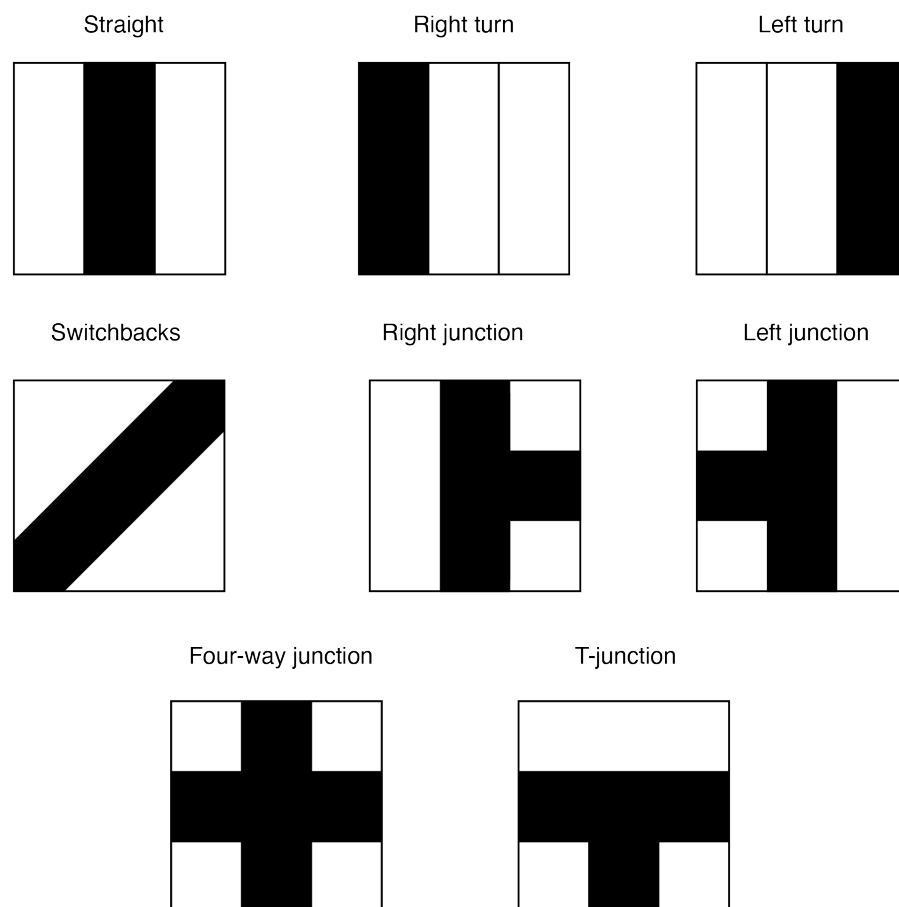


Figure 4.10. New proposed design for hiking trail markers in black and white.

The marker indicating that one should continue straight has three vertical rectangular shapes. The outer rectangles are white and the inner rectangle is rendered in

the color that indicates the difficulty of the trail. The middle rectangle communicates to the hiker that they should continue straight ahead on the trail. The marker indicating that one should turn left has three vertical rectangular shapes. The rectangles on the right and in the middle are white while the rectangle on the left is the color indicating the difficulty of the trail. The rectangle on the left communicates to the hiker that they are approaching an area of the trail that turns to the left. The marker indicating that one should turn right has three vertical rectangular shapes. The rectangles on the left and in the middle are white, while the rectangle on the right is the color indicating the difficulty of the trail. The rectangle on the right communicates to the hiker that they are approaching an area of the trail that turns to the right. The marker indicating that the hiker is approaching switchbacks is a square with a centered, diagonal stripe in between two triangles. The color of the diagonal stripe indicates the difficulty of the trail, while the two triangles on either side are white. A switchback is a portion of the trail where the hiker travels in a series of sharp alternating turns to gain a large amount of elevation. Switchbacks are different from a single left or right turn on the trail because they occur immediately one after the other, therefore, a marker to indicate switchbacks is necessary so that the trail does not become polluted with left and right turn markers. Only one switchback marker is needed, reducing the number of markers on the trail to indicate changes in the direction of travel. The marker indicating a left connecting trail is designed similarly to the marker indicating that one should continue straight, designed with three vertical rectangular shapes. The main difference is the white rectangle that is aligned to the left has a color of difficulty square centered in the white rectangle, and connected to the middle rectangle rendered in the same color of difficulty. This square indicates a trail junction is straight

ahead, warning hikers that they are approaching an area of the trail where they may want to move onto an adjoining trail. It is important to note that the color of the square does not change regardless of the difficulty of the connecting trail. The marker indicating a right connecting trail is designed similarly to the left connecting trail marker. The right connecting trail marker has a square aligned to the right and connected to the middle rectangle, rendered in the same color of difficulty. The marker indicating a four-way trail junction is designed to show that the hiker is approaching two intersecting trails. The

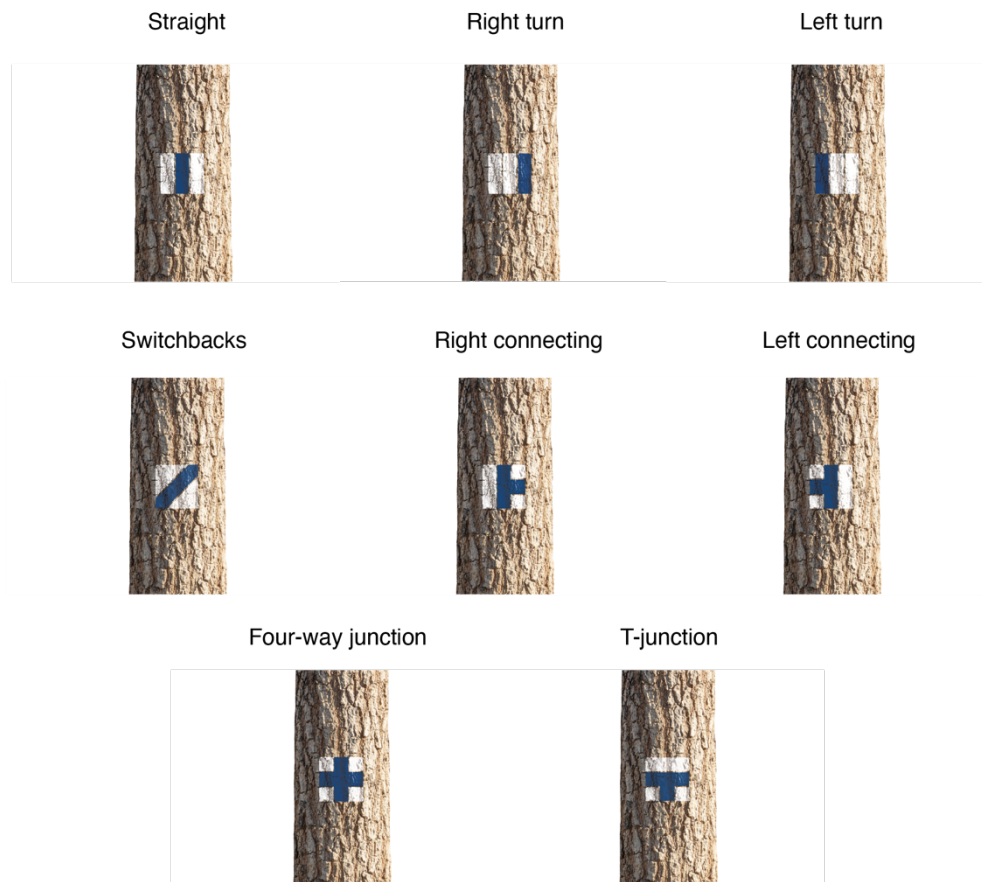


Figure 4.11. Moderate trail markers shown on tree trunks.

marker is a cross symbol with four white squares in each corner of the cross, completing the square marker. The cross symbol is rendered in the color noting difficulty. The marker indicating a three-way junction is designed similarly to the markers indicating a left and right trail junction, however, the rectangular shape is horizontally oriented and the square is aligned to the bottom, connected to the middle rectangle, and rendered in the same color of difficulty. The location of the markers is dependent on the environment of the trail. Markers should be painted on natural elements, such as trees, rocks, boulders,

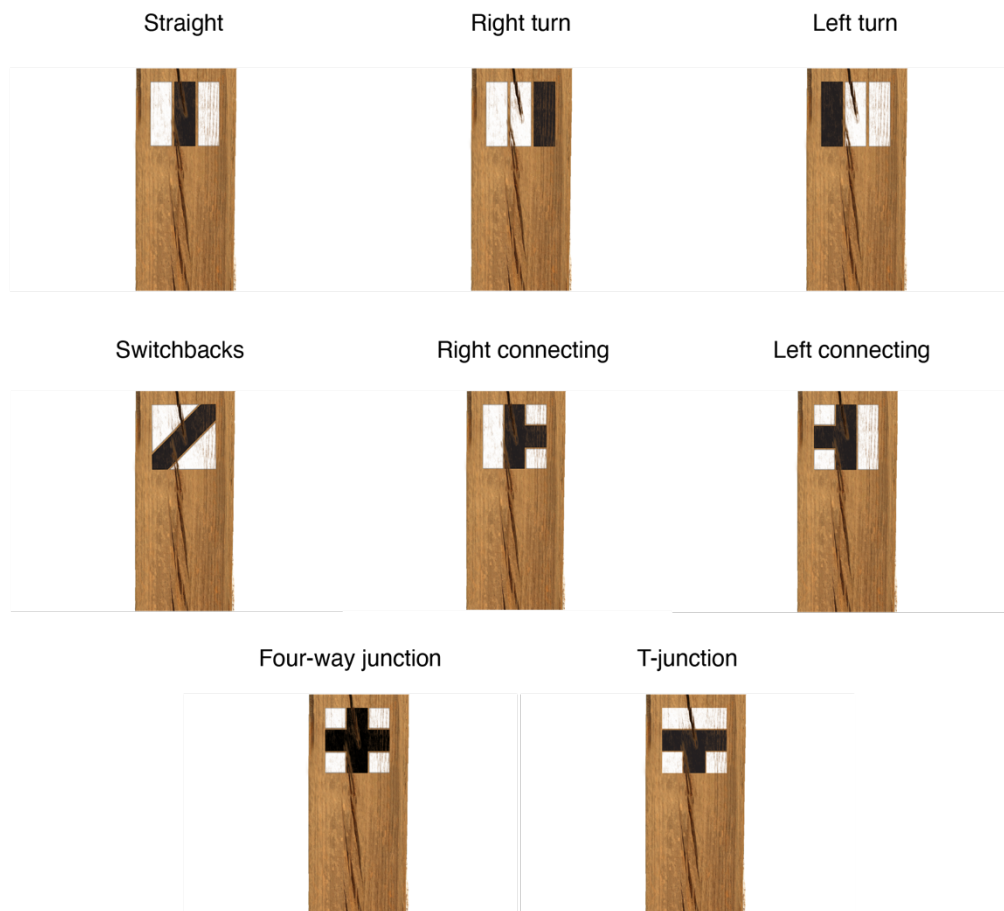


Figure 4.12. Strenuous trail markers shown on wooden posts.

etc. If a marker needs to be located in a place where a natural element does not exist, then a wooden post should be installed to support the marker. The markers should be placed 47 to 63 inches above the ground.

The marker placement should fit within the “cone of vision” which is at a level that is appropriate for able-bodied pedestrians, both adults and children, and for individuals in wheelchairs. The cone of vision is a height range that indicates where the marker should be placed for optimal readability. This level is designed to accommodate as many people as possible, including individuals with low vision (Arthur and Passini 200). The level typically refers to an area inside a building on a wall or door, and does not take weather interference into account. The geographic location of the hiking trail can greatly impact where the marker should be placed on a natural element. Locations that see yearly snowfall should take into account the average amount of snowpack on trails to determine if the placement of the marker should be higher than 63 inches above the ground.

The paint used by the Appalachian Trail Conservancy for trail markers on the AT is called Nelson BarkMark Tree Marking paint. This paint comes in a variety of bright colors and it can be applied to almost all tree types. It is also easy to clean up because it is a water based paint. It can last for up to three years, making it an ideal paint for trails because the maintenance costs are fairly low. BarkMark should be used as the paint for creating and maintaining all trail markers.



## **System Implementation**

The location of hiking trail signs and trail markers is important for communicating to the hiker and minimizing confusion for trail navigation. Wayfinding principles should be followed when choosing the locations for signs and trail markers. Trail signs should always be placed at decision points. Decision points are locations along the trail where two or more trails connect or intersect and a decision about the direction of travel is made by the user. Most decision points only need one trail sign to list the names of the destinations, direction of travel, and distance to the destinations. If a trail connects with another trail, a trailhead sign is not necessary at that location, however, a trail sign should be placed to aid the user in deciding which direction of travel they intend to hike. If the decision point is a trail that turns to the left or right, the sign should be placed at the turn with the new trail name on the sign, indicating that the hiker is now on a different trail. If the decision point is at a three-way junction, the sign should be placed so that it is facing the trail that connects perpendicularly to the other trail. This will help the hiker understand how to interpret where destinations are when the hiker is facing the sign. If the decision point is at a four-way junction, there should be two signs so that each direction of travel is clear to the user. Each sign should contain information on both sides of the same post. The signs should be placed in opposite corners at the four-way junction to ensure that any side of the sign can be read from any direction. “Once any destination is featured on a directional sign at a given intersection, there is an obligation to include it on every subsequent directional sign until the destination is reached” (Arthur and Passini 200). It is important to strategically place destinations on

signs in the order the user will encounter them. It is also important not to list too many destinations, so as not to overload the user with information that may not be relevant.

Trail marker locations vary depending on the complexity of the trail. Trail markers should be placed immediately following the trailhead sign and any subsequent trail sign. Trail markers should also be placed before and after a trail junction, and before and after a change in trail direction, such as a left or right turn or switchbacks. According to the *North Country National Scenic Trail: A Handbook for Trail Design, Construction, and Maintenance* created by the NPS in 1996, “Blazes should be placed immediately beyond any trail junction or road crossing—even if there is a directional sign. A second blaze (for safety) should be placed within another 50 to 100 feet. Otherwise, it is not desirable to have more than one blaze visible in either direction at any one time. However, exceeding 100 yards between blazes is not desirable. Striking a balance so as not to ‘over-blaze’ or ‘under-blaze’ is the key” (“Handbook for Trail Design, Construction and Maintenance - North Country National Scenic Trail (U.S. National Park Service)” 129-130). It is important to place reassurance markers on the trail where there have not been any changes in the trail direction for 100 yards, in order to reassure the hiker that they are still on their desired trail. It is also important to place the markers in both directions to create credibility and to communicate to hikers traveling in both directions. The distances for marker placement have not been tested, therefore, the distance is merely a suggestion until further research and user testing can clarify the ideal distance between markers that is necessary for providing reassurance.

## User Testing

The data obtained for user testing was collected through virtual surveys from six users who had not previously seen nor been introduced to the system. The users were shown each marker on a wooden sign post, and asked to identify the direction of travel as indicated by the marker.

The following marker has appeared on the trail you are currently hiking.



Please identify the upcoming trail direction as indicated by the marker shown above:

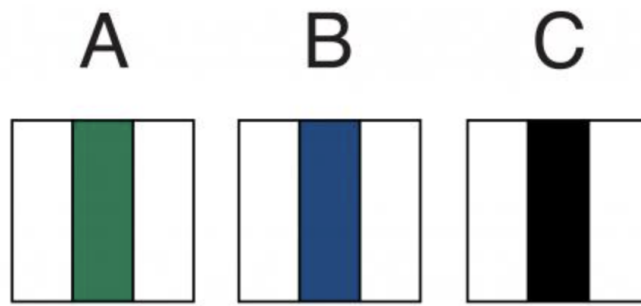
- ✓ Continue Straight
- Turn Left
- Turn Right
- Connecting Left
- Connecting Right
- T-Junction
- Four-way Junction
- Switchbacks



Figure 4.13. User testing survey question about marker.

Five out of the six users surveyed considered themselves moderate hikers. One hiker considered themselves to be an advanced hiker. All users were able to identify the following markers: continue straight, right turn, left turn, t-junction, and four-way junction. Five out of six users were able to identify the marker indicating a right connecting trail. Four out of six of users were able to identify the marker indicating a left connecting trail. Two out of six users were able to identify the marker indicating switchbacks. The switchbacks marker should be adjusted to a different variation so that it clearly shows the shape of the trail and it should then be tested again in another user test.

The users were shown three different colors and asked to label the colors for a difficulty rating. The three colors are the same colors used by the NSAA for skiing trail difficulty ratings. It is important to note that at least one of the users is color blind. All users were able to correctly identify all three colors with green for easy trails, blue for moderate trails, and black for strenuous trails.



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Which difficulty color would you expect to see on a "Strenuous" trail?

Option A

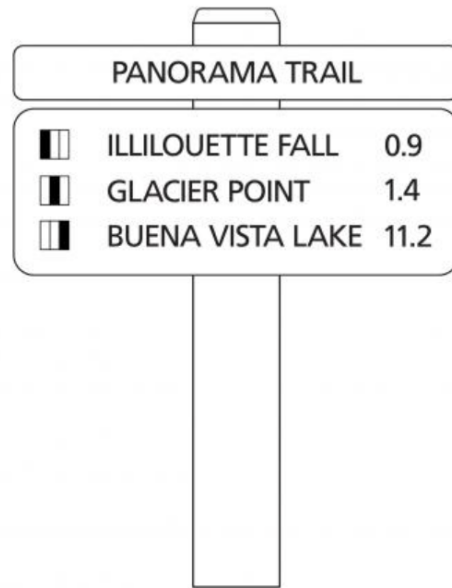
Option B

Option C

Figure 4.14. User testing survey question about color.

The users were asked about which direction they would go to get to specific points of interest if the sign appeared in front of them on the trail. All users correctly identified the direction of travel using the marker associated with the point of interest.

The following sign appears at a trail junction on Panorama Trail.



Which direction would you hike to get to Illilouette Fall?

Continue Straight

Turn Left

Turn Right

Figure 4.15. User testing survey question about direction.

At the end of the survey the users were asked to choose the sign they would prefer to see on the trail. Both signs showed the same information, however, one sign contained

directional arrows and the other sign contained markers from the system in place of the arrows. Four out of the six users preferred the sign with the directional arrows. Two out of the six users preferred the sign with the markers.

## V. CONCLUSION

This study evaluated hiking trail signs in Yosemite National Park in order to document differences in sign design, primarily relating to layout design, sign location, and sign materials. Design flaws were identified through trail observations and hiker surveys conducted on trails in Yosemite Valley. The results from those surveys indicated wayfinding challenges with the current trail signage system. Wayfinding and design principles were created to establish consistency with the system. The current trail signs do not use consistent layout design or sign materials. It is important for trail signs and markers to be consistent on all the trails throughout a single park. Consistency in layout design helps a user know where to look for the information they need while they are navigating trails. If the design is inconsistent, the user might not bother to read the sign, or might misread the sign and then travel in the wrong direction. The signs should be updated on a regular basis in order to keep information relevant and park visitors safe when hiking. If signs are regularly updated this could reduce the number of signs that use differing materials. Any new signs should use the same materials, and old signs should be removed when new signs are placed. The park should reduce the number of signs used at trail junctions to reduce sign pollution. A marker system would aid in reducing sign pollution by replacing signs with markers in order to communicate trail direction to hikers. The marker system would cut down on the costs associated with maintaining and creating trail signs, because the markers would take the place of unneeded signs. The marker system uses fewer materials and is easier for volunteers to maintain than a system that only uses trail signs.

The marker and trail sign designs for this study are meant to be preliminary and should be adjusted over time as new research is done on wayfinding in the outdoors. The designs were created to increase daytime and nighttime readability of current trail signage using better



typography and a proposed biomimetic solution, reduce sign pollution at trail junctions, and assist in reducing the number of search and rescue operations for injured or lost hikers. The designs clearly communicate direction of intended travel without the need for directional arrows. The use of directional arrows increases the number of signs at a trail junction because at least two signs are needed to communicate to two-way traffic. Pairing a marker that indicates changes in the trail with a single sign which communicates the direction of travel for multiple destinations reduces the number of signs at a trail junction. Reducing the number of signs at a trail junction decreases the likelihood of an overload of information for the hiker, which can lead to confusion and frustration. This new system also allows the parks to keep parts of their current identity by not drastically changing the design of current trail signage. This is important because the parks already have a well-established identity, which gives credibility to all signs in the park.

### **Study Limitations**

There were multiple limitations to the study that hindered collection of data and user testing results. Yosemite Search and Rescue was not able to share the full amount of data requested by the author because of technological restrictions. The data retrieved from the database was a small sample of what could have been available if the data were retained in a single location. YOSAR does not have the time nor resources to organize and provide search incident data, and there needs to be an initiative to make sure this data is available for future studies. Data analysis of past incidents over the span of a decade could reveal areas in the park that need improved wayfinding.

Precautions related to COVID-19, or coronavirus disease 2019, restricted access to in-person user testing for this study. User testing was meant to take place in a local park with a group of users ranging in hiking experience. The users were not able to participate due to social distancing

recommendations in place at the time of the study. User testing was limited to a virtually administered survey where users had to imagine they were on a hiking trail. Users were shown a series of trail markers and signs via photographs, and therefore, user-testing methods used could not test readability based on distance or materials used.

### **Future Research**

This study identifies shortcomings in current wayfinding systems on hiking trails in Yosemite National Park. These wayfinding issues are not limited to Yosemite, and there should be more research to learn about hiking trail wayfinding in other national parks across the United States. The marker system with the new signage designs could be applied to all national parks to create a cohesive system that is recognized by visitors anytime they visit a national park. More research should be done to determine how to apply the system on a larger scale, and whether all national parks would benefit from having the system.

Hiking trail difficulty ratings are subjective and vary from park to park. The evaluation and creation of a new hiking rating scale that is used by all national parks needs to be created so hiking trail difficulty ratings are consistent across the United States. A new hiking trail difficulty rating scale is necessary in order to establish consistent guidelines for grading trails regardless of terrain and geographical location. This can be done with research that is dedicated to understanding how to grade trails and by creating a formula for determining the difficulty of hiking trails. Hiking trails do not necessarily need one difficulty rating for the entire trail, but trails should have multiple difficulty ratings for varied sections of a single trail. If the marker system is used properly, the difficulty color indication would change in relation to the trail difficulty, and communicate to hikers that they are approaching a more difficult or more easy

section of the trail. This flexible marker system would also aid hiker navigation by creating sections of a trail that could help orient hikers if they are unsure of their location.

The biomimicry aspect of this study will need additional research outside the field of design. A biomimetic solution could potentially improve low light visibility on hiking trails through the imitation of the bioluminescent process. Research from this study and other studies have demonstrated the need for nighttime readability on hiking trails in national parks (Doke 43). Experts in chemistry and biology will need to be heavily involved in the creation of a luminescent paint or ink to be used on hiking trail signs and markers. The collection and study of bioluminescent organisms could help with understanding how the bioluminescent process works, and how the process can be imitated. More research should be dedicated to nighttime readability and whether a luminescent marker or sign could aid hikers in trail indication while they are hiking at night. The biomimetic outcome would need to be tested in order to determine whether the luminescent signs and markers disrupt the natural environment and the organisms that occupy that environment.

The user testing for this study needs to be expanded, and should be done once COVID-19 restrictions are no longer limiting research. In person user testing should be conducted on hiking trails to test the system the way it was designed. Further testing should be done to examine the height ratios of typography used on trail signs, the height of the physical signs, the height of the trail markers, the distance between trail markers, the colors used to indicate trail difficulty, the location of trail signs and markers, and the number of trail signs and markers used on a single trail. The designs of the trail markers, especially unfamiliar markers such as switchbacks, left connecting, and right connecting should be adjusted as more research is done to improve the system. These tests can be conducted and studied at a later date in order to improve the system.

## APPENDIX A

### *Signs, and Hiking Preparedness Asked of Hikers in Yosemite National Park*



Select an option

Welcome to the Hiking Wayfinding and Trail Navigation survey!

Sara Mitschke, a graduate student at Texas State University, is conducting a research study to improve hiking trail wayfinding, trail navigation and communication of trail difficulty for hikers. You are being asked to complete this survey because you are familiar with hiking in Yosemite.

Participation is voluntary. The survey will take approximately 5-7 minutes to complete. You must be at least 18 years old to take this survey.

This study involves no foreseeable serious risks. We ask that you try to answer all questions; however, if there are any items that make you uncomfortable or that you would prefer to skip, please leave the answer blank. Your responses are anonymous.

The benefit of this study could lead to improved trail wayfinding, an improved trail difficulty rating system and a better user experience for hikers while on hiking trails.

Reasonable efforts will be made to keep the personal information in your research record private and confidential. Any identifiable information obtained in connection with this study will remain confidential and will be disclosed only with your permission or as required by law. The members of the research team and the Texas State University Office of Research Compliance (ORC) may access the data. The ORC monitors research studies to protect the rights and welfare of research participants.

Data will be kept for three years (per federal regulations) after the study is completed and then destroyed.

You will receive a granola bar and/or water for completing the survey.

If you have any questions or concerns feel free to contact Sara Mitschke or her faculty advisor:

Sara Mitschke, graduate student  
School of Art and Design  
210-324-0142  
s\_m421@txstate.edu

Omari Souza, Professor  
School of Art and Design  
512-245-2611  
oas21@txstate.edu

This project #6550 was approved by the Texas State IRB on Thursday, June 20th 2019. Pertinent questions or concerns about the research, research participants' rights, and/or research-related injuries to participants should be directed to the IRB chair, Dr. Denise Gobert 512-716-2652 – (dgobert@txstate.edu) or to Monica Gonzales, IRB Regulatory Manager 512-245-2334 - (meg201@txstate.edu).

If you would prefer not to participate, please do not fill out a survey.

If you consent to participate, please complete the survey.

By clicking the button below, you acknowledge that your participation in the study is voluntary, you are 18 years of age, and that you are aware that you may choose to terminate your participation in the study at any time and for any reason.

---

- ☐ I consent
- ☐ I do not consent



---

What is your age? \*

- ☐ 18-24
- ☐ 25-34
- ☐ 35-49
- ☐ 50-69
- ☐ 70+



---

What is your gender? \*

- ☐ Male
- ☐ Female
- ☐ I prefer not to say



Select an option

Novice/Beginner (I am new to hiking or I have little experience with hiking. I hike at a slow/easy pace and I generally hike on flat, easy terrain)

Moderate (I have experience with hiking different types of terrain and elevation. I have experience hiking for a few hours with frequent breaks as the distance or elevation increases)

Advanced (I have experience with hiking at least half a day. I can handle several thousand feet in elevation gain. I can keep a moderate pace and I have enough experience to know when to conserve energy on the trail. I have experience hiking in multiple weather conditions and I know how to prepare for cold and hot conditions.)

Expert (I have experience with full day hikes in different weather conditions. I know how to prepare for hikes with severe elevation gain and difficult terrain. I know how to conserve energy at a slow pace and when to rest. I have the ability to plan for multi-day hikes.)

- 
- ☐ Novice/Beginner
  - ☐ Moderate
  - ☐ Advanced
  - ☐ Expert



---

How would you rate your fitness level?

- ☐ Very active (Exercise at least 3-4 times per week)
- ☐ Active (Exercise at least 1-2 per week)
- ☐ Somewhat active (Exercise a few times per month)
- ☐ Never active (Rarely exercise)



---

How many people do you generally hike with? \*

- ☒ Alone
- ☐ One other person
- ☐ Two other people
- ☐ Three or more



▼ Select an option

🔍 Search by choice...

- ☐ Mist Trail/Muir Trail
- ☐ 4-Mile Trail
- ☐ Mirror Lake
- ☐ Lower Yosemite Falls
- ☐ Upper Yosemite Falls



What (if any) difficulties did you have with this hike? (Please select all that apply) \*

- ☐ Planning for the hike
- ☐ Finding the trailhead
- ☐ Ensuring I am on the correct trail
- ☐ Locating the trail markers
- ☐ Planning the correct amount of time for the hike
- ☐ Planning the correct amount of food/water needed for hike
- ☐ Completing the hike
- ☐ None
- ☐ Other



How did you gather information about this hiking trail? (Please select all that apply) \*

- ☐ Google
- ☐ Pinterest
- ☐ Blog
- ☐ Smartphone app
- ☐ National Parks Service website
- ☐ Park staff
- ☐ Hiking trails website
- ☐ Park map
- ☐ Book
- ☐ Park signage
- ☐ I did not have previous knowledge about this trail
- ☐ Other



Which of the following items did you carry with you on this trail? (Please select all that apply) \*

- ☐ Smart phone
- ☐ GPS device (Garmin, Magellan, etc.)
- ☐ Food
- ☐ Water
- ☐ Flashlight/Headlamp
- ☐ Extra batteries
- ☐ Knife
- ☐ Compass
- ☐ Map
- ☐ Bear spray
- ☐ Rain gear
- ☐ Other



Did you check the weather before starting your hike? \*

- ☐ Yes
- ☐ No
- ☐ I do not remember



How would you rate the difficulty of this trail? (0=EASY, 10=VERY STRENUOUS) \*

1	2	3	4	5	6	7	8	9	10
---	---	---	---	---	---	---	---	---	----



Did you use trail signs at the trailhead BEFORE starting your hike? \*

- ☐ Yes
- ☐ No



Did you use trail markers or other trail signs DURING your hike? \*

- ☐ Yes
- ☐ No



Did you leave the marked trail at any time during your hike? \*

- ☐ Yes
- ☐ No
- ☐ I do not know



Were you ever confused about the direction of travel while on the trail? \*

☐ Yes

☐ No



Did you use a paper map or guidebook to assist you in navigating the trail? \*

☐ Yes

☐ No



Did you use an electronic device to assist you in navigating the trail? (e.g. cell phone, gps device, etc.) \*

☐ Yes

☐ No



Signs/trail markers were easy to read and understand. \*

- ☐ Completely disagree
- ☐ Somewhat disagree
- ☐ Slightly disagree
- ☐ Neither agree nor disagree
- ☐ Slightly agree
- ☐ Somewhat agree
- ☐ Completely agree





Signs/trail markers were conveniently placed and easy to locate. \*

- ☐ Completely disagree
- ☐ Somewhat disagree
- ☐ Slightly disagree
- ☐ Neither agree nor disagree
- ☐ Slightly agree
- ☐ Somewhat agree
- ☐ Completely agree







Signs/trail markers provided helpful information. \*

- ☐ Completely disagree
- ☐ Somewhat disagree
- ☐ Slightly disagree
- ☐ Neither agree nor disagree
- ☐ Slightly agree
- ☐ Somewhat agree
- ☐ Completely agree





Signs/trail markers disrupted my hiking experience. \*

- ☐ Completely disagree
- ☐ Somewhat disagree
- ☐ Slightly disagree
- ☐ Neither agree nor disagree
- ☐ Slightly agree
- ☐ Somewhat agree
- ☐ Completely agree





There were not enough signs/trail markers. \*

- ☐ Completely disagree
- ☐ Somewhat disagree
- ☐ Slightly disagree
- ☐ Neither agree nor disagree
- ☐ Slightly agree
- ☐ Somewhat agree
- ☐ Completely agree





Trail signs/markers should include multiple languages. \*

- ☐ Completely disagree
- ☐ Somewhat disagree
- ☐ Slightly disagree
- ☐ Neither agree nor disagree
- ☐ Slightly agree
- ☐ Somewhat agree
- ☐ Completely agree





---

Have you ever hiked in the dark at Yosemite or another national park? \*

☐ Yes

☐ No



---

Have you ever become lost while hiking? \*

☐ Yes

☐ No

☐ Prefer not to say

## APPENDIX B

### *Qualtrics Questions for User Testing Survey*



*The rising STAR of Texas*

Welcome to the Hiking Sign and Marker User Testing survey!

Sara Mitschke, a graduate student at Texas State University, is conducting a research study to improve hiking trail wayfinding, trail navigation and communication of trail difficulty for hikers. You are being asked to complete this survey because you have hiking experience.

This survey is a virtual user test to learn how a hiker might respond to a new hiking trail marker and signage system while hiking on a trail. There are no right or wrong answers.

Participation is voluntary. The survey will take approximately 5-7 minutes to complete. You must be at least 18 years old to take this survey.

This study involves no foreseeable serious risks. We ask that you try to answer all questions; however, if there are any items that make you uncomfortable or that you would prefer to skip, please leave the answer blank. Your responses are anonymous.

The benefit of this study could lead to improved trail wayfinding, an improved trail difficulty rating system and a better user experience for hikers while on hiking trails.

Reasonable efforts will be made to keep the personal information in your research record private and confidential. Any identifiable information obtained in connection with this study will remain confidential and will be disclosed only with your permission or as required by law. The members of the research team and the Texas State University Office of Research Compliance (ORC) may access the data. The ORC monitors research studies to protect the rights and welfare of research participants.

Data will be kept for three years (per federal regulations) after the study is completed and then destroyed.

You will receive an REI gift card for participating in the survey.

If you have any questions or concerns feel free to contact Sara Mitschke or her faculty advisor:

Sara Mitschke, graduate student  
School of Art and Design  
210-324-0142  
s\_m421@txstate.edu

Omari Souza, Professor  
School of Art and Design  
512-245-2611  
oas21@txstate.edu

This project #6550 was approved by the Texas State IRB on Thursday, June 20th 2019. Pertinent questions or concerns about the research, research participants' rights, and/or research-related injuries to participants should be directed to the IRB chair, Dr. Denise Gobert 512-716-2652 – (dgobert@txstate.edu) or to Monica Gonzales, IRB Regulatory Manager 512-245-2334 - (meg201@txstate.edu).

If you would prefer not to participate, please do not fill out a survey.

If you consent to participate, please complete the survey.

By clicking the button below, you acknowledge that your participation in the study is voluntary, you are 18 years of age, and that you are aware that you may choose to terminate your participation in the study at any time and for any reason.

I consent

What is your hiking experience?

Novice/Beginner (I am new to hiking or I have little experience with hiking. I hike at a slow/easy pace and I generally hike on flat, easy terrain)

Moderate (I have experience with hiking different types of terrain and elevation. I have experience hiking for a few hours with frequent breaks as the distance or elevation increases)

Advanced (I have experience with hiking at least half a day. I can handle several thousand feet in elevation gain. I can keep a moderate pace and I have enough experience to know when to conserve energy on the trail. I have experience hiking in multiple weather conditions and I know how to prepare for cold and hot conditions.)

Expert (I have experience with full day hikes in different weather conditions. I know how to prepare for hikes with severe elevation gain and difficult terrain. I know how to conserve energy at a slow pace and when to rest. I have the ability to plan for multi-day hikes.)

The following marker has appeared on the trail you are currently hiking.



Please identify the upcoming trail direction as indicated by the marker shown above:







The following marker has appeared on the trail you are currently hiking.



Please identify the upcoming trail direction as indicated by the marker shown above:





The following marker has appeared on the trail you are currently hiking.



Please identify the upcoming trail direction as indicated by the marker shown above:





The following marker has appeared on the trail you are currently hiking.



Please identify the upcoming trail direction as indicated by the marker shown above:



The following marker has appeared on the trail you are currently hiking.



Please identify the upcoming trail direction as indicated by the marker shown above:



The following marker has appeared on the trail you are currently hiking.



Please identify the upcoming trail direction as indicated by the marker shown above:





The following marker has appeared on the trail you are currently hiking.



Please identify the upcoming trail direction as indicated by the marker shown above:

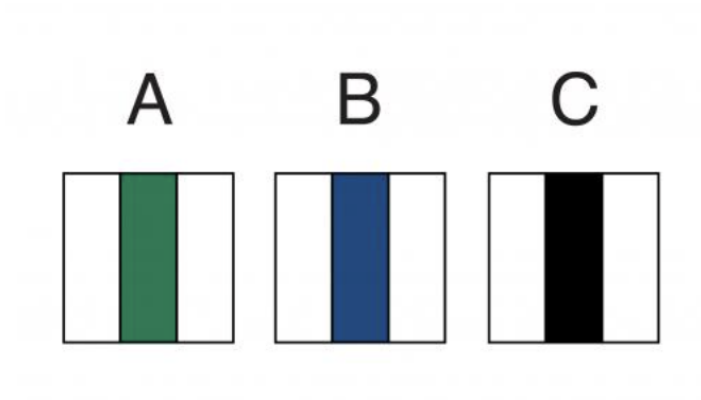


The following marker has appeared on the trail you are currently hiking.



Please identify the upcoming trail direction as indicated by the marker shown above:





---

Which difficulty color would you expect to see on a "Strenuous" trail?

Option A

Option B

Option C

---

Which difficulty color would you expect to see on an "Easy" trail?

Option A

Option B

Option C



---

Which difficulty color would you expect to see on a "Moderate" trail?

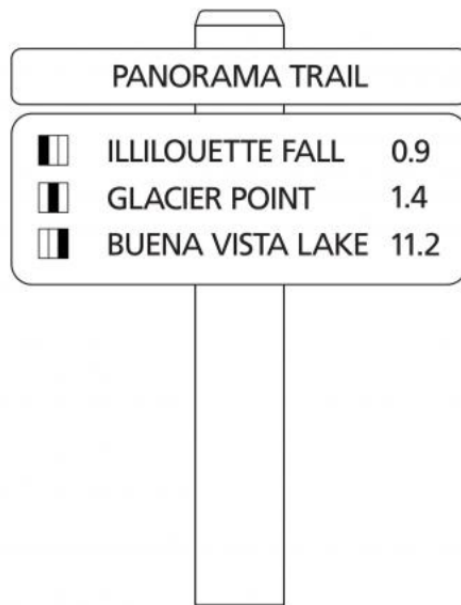
Option A

Option B

Option C



The following sign appears at a trail junction on Panorama Trail.



---

Which direction would you hike to get to Illilouette Fall?

Continue Straight

Turn Left

Turn Right

---

Which direction would you hike to get to Glacier Point?

Continue Straight

Turn Left

Turn Right

---

Which direction would you hike to get to Buena Vista Lake?

Continue Straight

Turn Left

Turn Right

---

---

A



B



---

Which sign would you prefer to see while hiking Mirror Lake Trail?

Option A

Option B



## REFERENCES

Hoeflich, Jack. *2019 SAR Report*, 2019, Microsoft Excel File.

“Alpine, Mountaineering, & Hiking Grades.” *Bergfreunde*, Bergfreunde,  
[www.bergfreunde.eu/alpine-grades-calculator](http://www.bergfreunde.eu/alpine-grades-calculator). Accessed 4 July 2020.

Arthur, Paul, and Romedi Passini. *Wayfinding: People, Signs, and Architecture*.  
New York, McGraw Hill, 1992.

Banda, Roderick Lim. “Building Architecture as a Reference for Architecture  
Intensive Disciplines.” *KASE*, Knowledge Architecture Systems  
Engineering, 15 May 2003,  
[www.kase.co.za/patterns/framework/content.htm](http://www.kase.co.za/patterns/framework/content.htm).

“Beak provides streamlining.” *Biomimicry Institute*.  
<https://asknature.org/strategy/beak-provides-streamlining/>. Accessed on  
16 April 2019.

Benyus, Janine M. *Biomimicry: Innovation Inspired by Nature*. New York,  
HarperCollins Publishers, Inc., 1997.

Benyus, Janine M. *Biomimicry Handbook: A Biomimicry Primer*.  
Biomimicry 3.8., n.d.

Branchini, Bruce R., et al. "Chemically Modified Firefly Luciferase Is an Efficient Source of Near-Infrared Light." *Bioconjugate Chemistry*, vol. 21, no. 11, 2010, pp. 2023–30. *Crossref*, doi:10.1021/bc100256d.

CNN Wire. "Yosemite among Top 5 Most Visited U.S. National Parks of 2019." *KTLA5*, Nexstar Broadcasting, Inc., 19 Apr. 2020, [ktla.com/news/nationworld/yosemite-among-top-5-most-visited-u-s-national-parks-of-2019](http://ktla.com/news/nationworld/yosemite-among-top-5-most-visited-u-s-national-parks-of-2019).

"Czech Tourist Club." *Klub Českých Turistů*, Klub českých turistů, [kct.cz/english](http://kct.cz/english). Accessed 2 April 2019.

"Day Hikes along the Glacier Point Road - Yosemite National Park (U.S. National Park Service)." *National Park Service*, U.S. Department of the Interior, [www.nps.gov/yose/planyourvisit/glacierhikes.htm](http://www.nps.gov/yose/planyourvisit/glacierhikes.htm). Accessed 25 July 2019.

Dill, John. Personal Interview. May, 2020.

Doke, Jared. "Analysis of Search Incidents and Lost Person Behavior in Yosemite National Park." *KU ScholarWorks*, University of Kansas, 17 Feb. 2013, [kusolarworks.ku.edu/handle/1808/10846](http://kusolarworks.ku.edu/handle/1808/10846).

“FAQ.” *Hiking Project*, Adventure Projects, Inc.,

[www.hikingproject.com/help/21/overview-of-site-name-features](http://www.hikingproject.com/help/21/overview-of-site-name-features).

Accessed 6 September 2019.

“Four Mile Trail - Yosemite National Park (U.S. National Park Service).”

*National Park Service*, U.S. Department of the Interior,

[www.nps.gov/yose/planyourvisit/fourmiletrail.htm](http://www.nps.gov/yose/planyourvisit/fourmiletrail.htm). 6 September 2019.

Fry, John, and Bob Cram. “When Trails Turned Colors.” *Skiing History*, Sept.

2012, p. 19.

“Geology - Yosemite National Park (U.S. National Park Service).” *National Park*

*Service*, U.S. Department of the Interior,

[www.nps.gov/yose/learn/nature/geology.htm](http://www.nps.gov/yose/learn/nature/geology.htm). Accessed 19 August 2019.

Graham, Lisa. “Gestalt Theory in Interactive Media.” *Journal of Humanities and*

*Social Sciences, Volume 2, Issue 1*, 2008.

“Handbook for Trail Design, Construction and Maintenance - North Country

National Scenic Trail (U.S. National Park Service).” *National Park*

*Service*, U.S. Department of the Interior,

[www.nps.gov/noco/learn/management/ncttrailconstructionmanual1.htm](http://www.nps.gov/noco/learn/management/ncttrailconstructionmanual1.htm).

Accessed 25 July 2019.

Heggie, Travis W., and Michael E. Amundson. "Dead Men Walking: Search and Rescue in US National Parks." *Wilderness & Environmental Medicine*, vol. 20, no. 3, 2009, pp. 244–49. *Crossref*, doi:10.1580/08-weme-or-299r.1.

Hesselbarth, Woody, et al. *Trail Construction and Maintenance Notebook* . 6E62A33, Missoula, MT, USDA Forest Service Technology and Development Program, 2007.

"Historical Marker Pages Containing 'Yosemite Valley' - The Historical Marker Database." *The Historical Marker Database*, The Historical Marker Database, [www.hmdb.org/results.asp?SearchFor=yosemite+valley](http://www.hmdb.org/results.asp?SearchFor=yosemite+valley). Accessed 25 July 2019.

"How to Determine Hiking Difficulty - Shenandoah National Park (U.S. National Park Service)." *National Park Service*, U.S. Department of the Interior, [www.nps.gov/shen/planyourvisit/how-to-determine-hiking-difficulty.htm](http://www.nps.gov/shen/planyourvisit/how-to-determine-hiking-difficulty.htm). Accessed 16 April 2020.

"Design Thinking Defined." IDEO Design Thinking <https://designthinking.ideo.com/>. Accessed on 2 June 2020.

Ilondu, E. M., and A. A. Okiti. "Bioluminescence in Mushroom and Its Application Potentials." *Nigerian Journal of Science and Environment*, vol. 14, 2016, pp. 1–8,



www.semanticscholar.org/paper/BIOLUMINESCENCE-IN-  
MUSHROOM-AND-ITS-APPLICATION-Ilundu-  
Okiti/29bf06b3fc368e3659a55a776222267032369da6.

Kettunen, Pyry, Irvankoski, Katja, Krause, Christina M., Sarjakoski, L. Tiina.

“Landmarks in nature to support wayfinding: the effects of seasons  
and experimental methods.” *Marta Olivetti Belardinelli and  
Springer-Verlag Berlin Heidelberg*, 2013.

Lauren. “Signs of the Slopes Blog.” *Colorado Ski Country USA*, Colorado Ski  
Country USA, 3 Nov. 2016, [www.coloradoski.com/blog/signs-of-the-  
slopes](http://www.coloradoski.com/blog/signs-of-the-slopes).

Lippus, Amy Elizabeth. “The History and Evolution of North American Ski  
Resort Map Style and Design.” *ScholarWorks at University of Montana*,  
University of Montana, 2015, [scholarworks.umt.edu/etd/4518](http://scholarworks.umt.edu/etd/4518).

McKosky, Margaret. “Graphic Design + Biomimicry.” *RIT Scholar Works*,  
Rochester Institute of Technology., 2012,  
[scholarworks.rit.edu/theses/7019](http://scholarworks.rit.edu/theses/7019).

“Mirror Lake Trail - Yosemite National Park (U.S. National Park Service).”

*National Park Service*, U.S. Department of Natural Resources,  
[www.nps.gov/yose/planyourvisit/mirrorlaketrail.htm](http://www.nps.gov/yose/planyourvisit/mirrorlaketrail.htm). Accessed 6  
September 2019.

National Park Service (U.S.). *A Sense of Place: Design Guidelines for Yosemite  
National Park*. First, Interior Department National Park Service, 2012.

“Park Statistics - Yosemite National Park (U.S. National Park Service).” *National  
Park Service*, U.S. Department of Natural Resources,  
[www.nps.gov/yose/learn/management/statistics.htm](http://www.nps.gov/yose/learn/management/statistics.htm). Accessed 19 August  
2019.

“People - Yosemite National Park (U.S. National Park Service).” *National Park  
Service*, U.S. Department of Natural Resources,  
[www.nps.gov/yose/learn/historyculture/people.htm](http://www.nps.gov/yose/learn/historyculture/people.htm). Accessed 19 August  
2019.

“Planning a Trailhead Kiosk – 2012 | Partnership for the National Trails System.”  
*Partnership for the National Trails System*, [pnts.org/new/planning-a-  
trailhead-kiosk-2012](http://pnts.org/new/planning-a-trailhead-kiosk-2012). Accessed 6 September 2019.

“SAC- Berg- Und Alpinwanderskala.” *Wanderskala SAC*, Schweizer Alpen-Club  
SAC, Sept. 2012, [www.sac-](http://www.sac-)

cas.ch/fileadmin/Ausbildung\_und\_Wissen/Tourenplanung/Schwierigkeitsskala/Wanderskala-SAC.pdf.

“Stats Report Viewer.” *National Park Service*, U.S. Department of the Interior, [irma.nps.gov/STATS/SSRSReports/Park%20Specific%20Reports/Monthly%20Public%20Use?Park=GRSM](http://irma.nps.gov/STATS/SSRSReports/Park%20Specific%20Reports/Monthly%20Public%20Use?Park=GRSM). Accessed 19 August 2019.

“The System of Wayfinding Trail in the Czech Republic.” *Czech Republic Ministry of Regional Development*, 2017, pp. 1–2.

The University of Kansas. “Professor Jeremy Shellhorn and Design Outside Studio Students Enhancing Visitor Experiences at Rocky Mountain National Park.” *School of Architecture & Design*, 22 Jan. 2019, [arcd.ku.edu/cherry-picked-iconic-signs-inspire-new-typeface](http://arcd.ku.edu/cherry-picked-iconic-signs-inspire-new-typeface).

“The Yosemite Decimal System.” *Climber.Org*, [climber.org/data/decimal.html](http://climber.org/data/decimal.html). Accessed 16 April 2019.

“Trail Management & Maintenance - Trails & Hiking (U.S. National Park Service).” *National Park Service*, U.S. Department of Natural Resources, [www.nps.gov/subjects/trails/trail-management-and-maintenance.htm](http://www.nps.gov/subjects/trails/trail-management-and-maintenance.htm). Accessed 3 January 2020.

*UniGuide: Identification, Wayfinding and Visitor Information for National Parks*. Washington, D.C., Department of the Interior, 2002.

Unimark International, et al. *New York City Transit Authority: Graphics Standard Manual*. 1st ed., New York, NY, Standards Manual, 2015.

“Univers Font Combinations & Free Alternatives :.” *Typewolf*, Jeremiah Schoaf, [www.typewolf.com/site-of-the-day/fonts/univers](http://www.typewolf.com/site-of-the-day/fonts/univers). Accessed 8 January 2020.

“Vernal Fall and Nevada Fall Trails - Yosemite National Park (U.S. National Park Service).” *National Park Service*, Department of Natural Resources, [www.nps.gov/yose/planyourvisit/vernalnevadatrail.htm](http://www.nps.gov/yose/planyourvisit/vernalnevadatrail.htm). Accessed 6 September 2019.

Weitz, Weitz Hedda J. "Naturally Bioluminescent Fungi." *Mycologist* 18.1 (2004): 4-5. Print.

“Willamette National Forest - Hiking.” *United States Department of Agriculture Forest Service*, U.S. Department of Agriculture, [www.fs.usda.gov/detail/willamette/recreation/hiking/?cid=stelprdb510300](http://www.fs.usda.gov/detail/willamette/recreation/hiking/?cid=stelprdb510300) 6. Accessed 3 January 2020.

“Yosemite Falls Trail - Yosemite National Park (U.S. National Park Service).” *National Park Service*, U.S. Department of Natural Resources, [www.nps.gov/yose/planyourvisit/yosemitfallstrail.htm](http://www.nps.gov/yose/planyourvisit/yosemitfallstrail.htm). Accessed 6 September 2019.

“Yosemite Hikes: Mirror Lake.” *Yosemite Hikes*, Russ Cary,

[www.yosemitedhikes.com/yosemite-valley/mirror-lake/mirror-lake.htm](http://www.yosemitedhikes.com/yosemite-valley/mirror-lake/mirror-lake.htm).

Accessed 6 September 2019.

“Yosemite Hikes: The Four-Mile Trail.” *Yosemite Hikes*, Russ Cary,

[www.yosemitedhikes.com/yosemite-valley/four-mile-trail/four-mile-trail.htm](http://www.yosemitedhikes.com/yosemite-valley/four-mile-trail/four-mile-trail.htm). Accessed 6 September 2019.

“Yosemite Hikes: The Mist Trail.” *Yosemite Hikes*, Russ Cary,

[www.yosemitedhikes.com/yosemite-valley/mist-trail/mist-trail.htm](http://www.yosemitedhikes.com/yosemite-valley/mist-trail/mist-trail.htm).

Accessed 6 September 2019.

“Yosemite Hikes: The Panorama Trail.” *Yosemite Hikes*, Russ Cary,

[www.yosemitedhikes.com/glacier-point-road/panorama-trail/panorama-trail.htm](http://www.yosemitedhikes.com/glacier-point-road/panorama-trail/panorama-trail.htm). Accessed 6 September 2019.

“Yosemite Hikes: The Upper Yosemite Falls Trail.” *Yosemite Hikes*, Russ Cary,

[www.yosemitedhikes.com/yosemite-valley/upper-yosemite-falls/upper-yosemite-falls.htm](http://www.yosemitedhikes.com/yosemite-valley/upper-yosemite-falls/upper-yosemite-falls.htm). Accessed 6 September 2019.