Improving Access to U.S. National Park Visitor Data: An Examination of Usability and Geovisualization

Colby Parkinson

College of Health and Human Development, The Pennsylvania State University

Noah Gehman

College of Information Sciences and Technology, The Pennsylvania State University

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Dr. Frank E. Ritter

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Abstract

The collection of visitor use data in public recreation areas is oftentimes government-funded, with mandatory reporting requirements. However, the stakeholders for this data and its intended uses are undefined and underexamined. This is exemplified by the data collected and provided by the U.S. National Park Service (NPS), which is made available online through the Integrated Research Management Application (IRMA) portal. The data in IRMA's database is presented in an Excel-like format. We hypothesize that the design of this system may hinder users' ability to effectively access visitor use data. To achieve this, we aimed to identify stakeholders and tasks that are likely performed using the portal via collaboration with managers of IRMA. Additional examination of usability limitations in the current IRMA portal for some user groups when completing the identified tasks and using automated usability testing software. During our user studies, we studied users via interface tracking software (n = 4), hierarchical task analysis (n = 4), and semi-structured interviews (n = 7). Our findings highlighted consistent usability errors related to the design of the portal (e.g., contrast, labeling, aesthetic) that caused inefficient or inaccurate use of the system. We anticipate this research will result in the development of an alternative dashboard that utilizes data geovisualization approaches for the IRMA database, which can in turn inform the design and implementation of similar visitor use portals across other government agencies.

Keywords: geovisualization, usability, accessibility, parks and protected areas, tourism

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Introduction and Literature Review

The U.S. National Park Service (NPS) provides access to publicly available data online through the Integrated Research Management Application (IRMA) portal. This system is a complex database, catering access to a broad swath of data (e.g., visitor use statistics, public planning, environmental reports) for a variety of potential users (e.g., professionals conducting research or designing management strategies, tourists planning trips). Complex environments can have substantive impacts on usability and user-centered design, requiring a deep understanding of all users and their use cases for a system (Ritter et al., 2014). Therefore, we aimed to examine the usability of a subsection of the IRMA portal, the publicly available visitor use statistics, and identify various users and stakeholders of the portal. We discuss our findings as they relate to further rigorous research on sharing visitor use statistics and the design of an alternate prototype for sharing data provided by IRMA that incorporates our findings.

Human System's Potential Contribution to the National Park Service

The contributions of this research are two-fold. First, from a bottom-up perspective, the risk-driven spiral model provides a conceptual and theoretical justification for examining human interfaces with systems and collaborating with stakeholders through a continuously iterating design process (Boehm, 1988). The model argues in favor of viewing all decision-making as a function of how likely and impactful potential risks are (Boehm & Hansen, 2001). Evidence suggests that addressing risks through the consideration of usability has, for example, saved U.S. military agencies millions of dollars and peoples' lives (Booher & Minninger, 2003). To equate NPS visitor use statistics, which are metrics that regard visitor behavior within tourism and recreation destinations (Manning, 2011), with the design of an Apache helicopter may seem misguided, however, the benefits of reducing risks through the implementation of usability

research and design are similarly valuable. Within the current IRMA portal, risks to users may include a lack of awareness of data availability, difficulty retrieving data, and uncertainty of data constraints, each of which could be heightened by certain physical or mental disabilities and impairments (Ritter et al., 2014). From an institutional perspective, those user risks may generate negative perceptions of the NPS and reduce the impact (and therefore the potential future allocation) of government-funded research and data collection. Those risks warrant address in the face of heightened resource demand and gradually inflation-adjusted spending cuts on public lands that provide socially, economically, environmentally, and culturally valuable experiences and resources (Fancy & Bennetts, 2012; Haefele et al., 2016; Miller-Rushing et al., 2021; Walls, 2022).

Second, from a top-down perspective, all government agencies are required to adhere to accessibility requirements under Section 508 of the Rehabilitation Act and Section 255 of the Communication Act. These requirements largely relate to creating government systems more equitable and supporting individuals with disabilities. Research on usability for other government agencies, for example, examinations of access to public health records for the public and practitioners (Bloland & Macneil, 2019; Howe et al., 2021), have shown, however, that there is much more progress within government agencies to meet and go above and beyond these legal requirements to make their systems more usable. That prior research supports that improving these systems can improve stakeholders' decision-making and increase the impact of government-funded work.

Principles of Usability and Geovisualization

The current IRMA portal for sharing visitor use statistics relies primarily on a national map with points indicating the location of various U.S. national park units

(https://irma.nps.gov/Stats/; see Supplement 1 for an overview of primary webpages in IRMA). The user is expected to click on one of those points or use a search bar to view visitor use statistics for specific units or click on a web link to view national statistics. The user is then sent a webpage that provides a list of titles of separate reports (e.g., annual park recreation visitors, monthly public use, YTD report) that serve as weblinks. Within those links, the data itself is downloadable, typically visualized as tables, and often filterable by specific year or month and location parameters. By integrating principles from geovisualization, which is a branch of visual analytics that centers computation, design, and visualization on spatial and cartographic features with an emphasis on interactivity and user-centered design (Çöltekin et al., 2017; Robinson, 2017), and broader usability research on website design, we hypothesize that data retrieval from the portal could be faster, require fewer clicks, and result in a more positive experience and perception of the system.

Design principles from geovisualization suggest that platforms should aim to convey who, what, when, and where (Steptoe et al., 2018; Xiao-Ting & Bi-Hu, 2012). Prominent methods for communicating volume of human movement and visitation, which is most visitor use data for the NPS, involve depicting relative visitation to specific destinations as heat where less visited destinations are closer to a neutral color and more visited destinations are a deeper, warmer color (e.g., Steptoe et al., 2018; Xiao-Ting & Bi-Hu, 2012) or as concentric circles with sizes relative to visitation at specific destinations (Andrienko & Andrienko, 2013; Gonçalves et al., 2015). Gonçalves et al. (2015) observed that users preferred and felt more comfortable using these 2D visualization methods compared to more complex approaches and Ostermann (2010) observed that these approaches were well understood by recreation managers. Lastly, to promote interactivity, geovisualizations should offer filters based on time, characteristics, and place

(Brehmer et al., 2016; Nelson & Maceachren, 2020) and share data in a way that transcends scales from aggregate, high-level to sub-group and individual analysis (Puri et al., 2015; Zeng et al., 2017). For the IRMA portal, these principles generally support maintaining a national web map for accessing data, however, the web map should also visualize data directly rather than as separate webpages. Specifically, that map should integrate heatmaps to share relative visitation to states, concentric circles to show relative visitation to individual parks, and offer users the ability to filter the data they want within the first landing page based on time (e.g., last year) and space (e.g., specific state). These design principles informed our decision-making on how to examine subjects and will inform our future development of an alternate method for sharing data from IRMA that is more accessible.

Usability and geovisualization research also provide helpful information on the design and development of research protocols. Most importantly, it is best practice to formally collaborate with stakeholders and end users of the geovisualization platform and to create designs through an iterative process to create usable visualizations (Boehm & Hansen, 2001; Dow, 2011; Fuhrmann et al., 2005; Lewis, 2014). Research designs should also seek to fill gaps in understanding salient to the research topic. Over the preceding decades, there has been an expanding role of GIS applications and visualizations in outdoor recreation research (Riungu et al., 2021). However, limited research has examined the usability of geovisualization platforms with stakeholders of recreation areas, with both exceptions occurring only in urban park and transportation settings (Nelson & Maceachren, 2020; Ostermann, 2010) or for tools for recreationists to track their recreational performance (Wood, 2015). Even less research has identified the information of interest to these users, which includes rates of visitation (Peterson et al., 2020). Each article confirmed that there are special considerations for this subset of users,

such as their demand for simple, accessible descriptive information. This leaves a lack of information on broader contexts, such as recreation and tourism-specific destinations like national parks, broader users, such as researchers and marketers, and broader use cases, such as recreation trip planning or grant writing. We aim to fill that gap by developing a list of potential stakeholders and identifying some of their use cases for the IRMA portal to inform future research design.

Aims

For this research, we had four specific aims: (i) establish collaboration with IRMA portal managers, (ii) identify current domestic stakeholders of publicly available visitor use data on the IRMA portal, (iii) pre-test methods for examining the cognitive processes of users seeking visitor use information and using the IRMA portal, and (iv) gain insights into how to develop an alternative portal for visualizing prominent visitor use statistics that emphasizes usability.

Methods

Collaborating with Stakeholders

The research team fostered direct collaboration with both employees who work on the visitor use statistics portion of the IRMA portal. The collaboration involved meeting two times. During the first meeting, the collaborators identified information regarding their bandwidth for collaboration, the practical steps they anticipate they could take from our anticipated research, provided approval for the overall research design, and identified groups they believed may serve as stakeholders or users for the IRMA database. During the second meeting, one collaborator shared raw data from the IRMA portal to facilitate our design of an alternative prototype and reviewed their preferred method and system for visualizing visitor use statistics. During these

meetings, the research team identified key check-in points and deliverables for the current and future projects.

User Research

Within the IRMA portal, there are many ways that users may retrieve information. However, in its current format, we hypothesize that users will rarely choose the most efficient. Therefore, through two mutually exclusive convenience samples, we examined the amount of time and effort it takes to retrieve information through interface tracking (n = 5) and examined methods taken to complete tasks through hierarchical task analysis complemented by verbal protocol (n = 4). All interface tracking participants studied recreation, park, and tourism management at Penn State University, though only one studied U.S. National Parks and one studied national parks in other countries. Three participants in the hierarchical task analysis sample identified as tourists or recreationists while one identified as a recreation researcher. All participants from the hierarchical task analysis sample as well as three additional national park researchers with prior experience using IRMA were interviewed using a semi-structured interview approach to obtain more qualitative information on the user experience. The collective sample for all user research studies, therefore, reflected two users: national park researchers and tourists or recreationists. All samples consisted of adults ages 18-40.

Interface Tracking

For interface tracking, all participants were told to retrieve the total number of visitors to Grand Canyon National Park in July 2023. Participants started from a Google search engine home page on a mouse-enabled laptop and were given flexibility to choose the online platform for their search. Users had to navigate to IRMA to complete the task as it is the sole repository of the exact data. All data was collected in person on the same laptop.

Interface tracking was measured using the platform recording user input (RUI), which was specifically developed for usability testing when platforms use computer interfaces (Kukreja et al., 2006). RUI actively recorded all keystrokes and clicks by all participants with a timestamp. The collected data was analyzed to determine the minimum, maximum, and mean values for time elapsed, keystrokes, and clicks. Those values included a field for the task completed by one of the authors to permit comparisons between users with and without expertise. For more information on this study, see Gehman & Parkinson (2024).

Hierarchical Task Analysis

Hierarchical Task Analysis (HTA) is a structured method for dissecting complex tasks into manageable sub-tasks (Ritter et al., 2014). The purpose of HTA is to classify a hierarchical structure, akin to a branching tree, that reveals every step involved in completing a specific task. HTA transcends mere task analysis, especially when it is complemented by other data collection and analysis methods like talk-aloud and interviews (Ericsson & Simon, 1980).

Upon providing consent, participants answered some background information in a closed-ended format. Participants were then informed of their task, which was to identify the second busiest U.S. national park in either 2022 or 2023, and informed how to perform talk-aloud procedures via similar instructions outlined by Ericsson and Simon (1980). Participants began the task at the home page of the IRMA portal. Participants completed the task remotely while sharing their screen over the video conferencing software Zoom, consistent with prior research (Ritter et al., 2012).

Screen and audio recordings were captured by the video conferencing software. The researcher took notes on verbal protocols to identify instances of confusion shared by the participant. Screen recordings and researcher notes were used to detail the webpages that

participants sequentially visited and the parts of the webpages that users interacted with as tasks. These were compared to the “most efficient” method to complete those tasks (i.e., the method that would require the fewest number of clicks). The hierarchical procedure followed by each participant and the most efficient method were depicted based on their clicks or navigation (e.g., when they scrolled, when they stated out loud that they were searching). When participants went to a new page on the portal, a new number in the hierarchy was recorded, whereas steps within each page were assigned separate values. All data were analyzed descriptively. In vivo codes from exemplary moments participants talked out loud were used to reinforce findings. For more information on this study, see Parkinson & Gehman (2024).

Semi-Structured Interviews

Semi-structured interviews involved asking three to five questions among the sample regarding their challenges using the IRMA portal and their advice for prototype design. Interviews were conducted both in person and remotely over Zoom with quotes directly transcribed by the researcher during the interview. In-vivo coding was used to share information from the interviews that exemplified unique findings or consistent perspectives (Saldana, 2009).

Automated Usability Evaluation

The web accessibility evaluation for this research was conducted using the Web Accessibility Evaluation Tool (WAVE), a free online tool developed by WebAIM (WebAIM, n.d.). WAVE is easy to use and allows for testing multiple websites in quick succession. This was a pertinent factor since retrieving data from the NPS requires going through multiple websites, testing each step of the process allowed us to pinpoint where accessibility issues arise. WAVE's evaluation criteria align with the Web Content Accessibility Guidelines (WCAG), the international standards for web accessibility established by the World Wide Web Consortium

(W3C). There is particular emphasis on color contrast, ARIA attributes, navigation, and accessibility, all of which are outlined by the W3C (WCAG 2.1, 2023). This ensures the evaluation is grounded in best practices and recognized accessibility standards within the field.

For each webpage selected the following actions were taken (a) The website URL was entered into the text field labeled "Web page address:" on the WAVE homepage (https://wave.webaim.org/, see Figure 4), (b) The ‘ENTER’ button was pressed to initiate the evaluation, and (c) WAVE analyzed the webpage and displayed the results overlaid on the webpage itself. We documented the number and types of accessibility issues identified (errors, contrast errors, and alerts), specific key issues leading to accessibility problems (e.g., small text, poor contrast), and descriptions of the key accessibility issues identified by WAVE.

Results

Collaboration with Stakeholders

The collaboration with stakeholders yielded insights into stakeholder and user groups that the research team had not previously identified. The collaboration resulted in consensus that the user groups of primary interest were U.S. federal government employees, U.S. national park or adjacent field researchers, nonprofit or conservation organization employees, state, local, and regional tourism boards and employees, tourists and recreationists, and journalists. Furthermore, the collaborators acknowledged that they don’t have insight into all the tasks that users may be seeking to accomplish on the website. However, they trusted that retrieving annual or monthly visitation to specific national parks or for all national parks simultaneously were likely the most salient tasks across users. They noted that our visualizations and analyses should focus on these tasks: (i) visitation to parks in total the prior year, (ii) visitation up to this date in prior years, and (iii) trending parks (parks that have experienced increase demand relative to preceding years).

The collaboration also yielded insights into potential risks that could influence the impact and output of the project. The collaborators noted that they are a small team in charge of several datasets from more than 100 separate units throughout the country. As a result, they need data solutions that are easy to manage, can accommodate variations in reporting quality and consistency, and scalable. Aligned with these insights, the collaborators noted that the project should likely not seek to develop a system to replace IRMA, but rather to create a visualization that may reduce users need to use IRMA to access their data. Specifically, they suggested using visualization platforms that we can provide thorough documentation to or that they are familiar with, such as Power BI.

Interface Tracking

Table 1 presents performance metrics for each participant in the interface tracking study. Among the sample, the minimum completion time for the task (88.2 seconds) was more than double the research team's (38.2 seconds), while the maximum was more than 20-fold longer (937.6 seconds). These results signify a substantial range of 15.1 minutes. Proportionally, the differences in keystrokes were near-identical. However, there was much less variation in clicks, with one participant requiring one fewer clicks, 16, than the research team. The participant who took the maximum time also gave up rather than successfully completing the task, whereas all other participants completed the task successfully.

Table 1

Participant Exercise Results

Participant	Task Completed	Time Elapsed	Keystrokes	Clicks
Research Team	Yes	38.2	15	17
P1	Yes	149.6	68	32
P2	Yes	88.2	39	20
P3	No	937.6	299	49
P4	Yes	88.3	73	16
P5	Yes	497.7	126	55

Verbal protocol analysis and hierarchical task analysis

Table 2 presents the results from the hierarchical task analysis. The table details the method for retrieving visitor use data that would be most efficient, requiring the fewest number of clicks, as well the hierarchical procedure followed by each participant based on their clicks or navigation. Every participant visited at least two additional pages than the most efficient method for their respective task. Participant 3 stated, “seems like the most efficient use of my time is to just scroll through the last list.” They stated this when they were using a different dataset than intended that shared the same visitor use information without any filtering capabilities. Therefore, rather than seeing a list ordered by visitation, they scrolled through more than 100 national park units and tried to keep a mental record of the second-highest value of visitation.

Participants 3 and 4 never identified the proper dataset, despite it being the first dataset on the landing page they had searched. Participant 4 experienced a similar challenge when completing the task, wherein they tried to use a different dataset to answer the question that technically contained the right information but required going to multiple pages and mentally recording the most visited park because it was not sorted.

Participant 4 was the only participant who did not retrieve the correct answer for the task. They attributed their error to not realizing that there were multiple more pages in the dataset than they used to answer the question. They acknowledged having reservations about the small number of park units they encountered when completing the task, but they did not see any function to find data for more parks in the dataset they had accessed. When they were shown the efficient methods, they could have used to access the information, they attributed their error to unclear labeling of datasets.

Table 2. Hierarchical Task Analysis Results

Most Efficient Method	Participant 1 Method
1. Click “National Reports”	1. Click on search function for “Select a Park”
2. Click "Annual Park Ranking"	1.1. Click on data for a specific park
	2. Search for data
	2.1. Go back a page
	3. Click "Reports"
	3.1. Click "National Reports"
	4. Click "Annual Park Ranking"
Most Efficient Method	**Participant 2 Method**
1. Click “National Reports”	1. Click on search function for “Select a Park”
2. Click "Annual Park Ranking"	2. Click “National Reports”
2.1 Click “2022” from Report Year	2.1. Search for dataset
3. Click “View Report”	3. Click “Annual Visitation Summary Report”
	3.1. Click “Back”
	3.2 Search for different dataset
	4. Click “Annual Park Ranking”
	5. Click “2022” from Report Year
	6. Click “View Report”
Most Efficient Method	**Participant 3 Method**
1. Click “National Reports”	1. Click "Park Reports"
2. Click "Annual Park Ranking"	1.1 Click "Back"
2.1 Click “2022” from Report Year	2. Click “National Reports”
3. Click “View Report”	2.1. Search for dataset
	3. Click "Annual Visitation by Year"
	3.1. Click "2022" from Reports
	3.2. Search for information and way to filter
	3.3 Click "Back"
	4. Click "Compare Annual Visitation"
	4.1. Click "Back"
	5. Click "Annual Visitation by Year"
	5.1. Scroll list for second highest number
	5.2. Use “Ctrl+F” to find second highest number from recall
Most Efficient Method	**Participant 4 Method**
1. Click “National Reports”	1. Click "Reports"
2. Click "Annual Park Ranking"	1.1. Click "Back"
2.1 Click “2022” from Report Year	2. Click on search function for “Select a Park”
3. Click “View Report”	3. Click "National Reports"
	4. Click "Annual Visitation by Record Year"
	4.1. Clicked first region in "Region" field
	4.2. Clicked first park in "Park" field
	5. Clicked "View Report"
	5.1. Hovered over and read different buttons
	5.2. Scrolled through options on first page of 10

Semi-Structured Interviews

During interviews following the completion of the tasks, participants provided some insights regarding their perceptions of the platform's limitations. In reference to a question about the limitations of the current database, a participant who identified as a tourist stated, "I might just give up looking for the information because it looks like it hasn't been updated in the last 10 years." They assumed the data must be up-to-date or we wouldn't have requested they complete the task, but they would not have thought so if they arrived to the portal independently. Two participants suggested that the color scheme of links could be clearer. Because the link to national reports is light brown, they did not believe that it was a link to information. Only one participant used this link during hierarchical task analysis, despite it being the most efficient method, perhaps because the others did not notice it.

One participant from the hierarchical task analysis and all participants separately interviewed about the platform recommended that the datasets themselves offer enhanced sorting functions to improve the retrieval of information after the datasets have been accessed. Despite there being a search bar in the current portal, one participant stated, "you'd really think they'd just provide a search bar rather than making you click through states." In general, the interviewees expressed some contempt for how difficult it can be to find the data they are looking for. One participant stated, "I was humbled by the challenge of finding my data," and another said, "the system is not user friendly."

Automated Usability Evaluation

The WAVE test highlighted accessibility issues in all 3 of the webpages tested (for full results see Supplement 2). Some of the pages were better than others with the National Reports Webpage on Visitor Use Statistics webpage recording the most errors (see Table 1). The most

prevalent issue across all 3 webpages was a WAVE Alert regarding small text size. Text that is too small can be difficult to read for everyone, but especially for people with low vision.

Table 1

WAVE Summary for NPS Webpages

URL	WAVE Errors	WAVE Contrast Errors	WAVE Alerts
https://irma.nps.gov/Portal/	1	0	4
https://irma.nps.gov/Stats/	1	2	11
https://irma.nps.gov/Stats/Reports/National	3	29	21

On the National Reports Webpage on Visitor Use Statistics webpage WAVE found 29 instances of unacceptable color choices leading to contrast issues. Poor color contrast between text and background creates readability problems, especially for people with visual impairments. When there's not enough contrast, the text blends in with the background, making it hard to read or even see the text altogether. This is especially true for people with low vision or certain color vision deficiencies. Another concern with low contrast is for people who rely on assistive technologies, like screen readers, who might not be able to perceive the information if the color contrast is poor.

Another issue that came up was that of device dependency. Many field events do not have handlers for both mouse and keyboard. The primary concern here is users who rely on assistive technologies like screen readers or voice control software, since they rely on keyboards and often can't interact with elements that depend solely on mouse clicks. Another concern is that not everyone uses a traditional mouse and keyboard. People with dexterity impairments or those using touchscreens may not be able to interact with elements that require hovering, dragging, or right-clicking. This issue will require more work to fix then the basic frontend issues of text size and color choice as it will require backend changes for many fields.

There were additional issues, including: heading structure, missing elements, empty elements, and redundant links. These issues have a lower impact on accessibility and mostly stem from good practices in web development, although they still warrant noting and addressing in future implementation of the IRMA portal.

Discussion

As a result of our multi-phase project that included establishing collaboration with key stakeholders, conducting user studies, and using automated software to examine the IRMA portal, we laid the foundation for future research and the development of an alternative method for visualizing publicly available visitor use data. Among the most valuable information we learned were the additional stakeholders we had not considered for the IRMA portal, specifically journalists and destination marketing boards and agencies.

The platform in its current state also introduces many risks that warrant attention through iterative, human-centered design (Boehm, 1988). Most notably, two participants in the user studies could not successfully or accurately retrieve data from the portal. Furthermore, participants stated having negative feelings toward the acceptability of the overall design and layout of the portal. Failing to address these risks could result in the platform failing to serve its stated aim as the "one-stop for data and information related to National Park Service." That failure could cause destination marketing organizations to miss out on economic value, tourists and recreationists to fail to plan their restorative and educational trips, and prevent ground-breaking research on recreation ecology. Using the apparent negative perceptions of the website as a justification for further investment could stave off a worst-case scenario of disinvestment due to lack of trust in and access to this valuable information.

In terms of design, our insights from our automated usability and user studies were consistent. The current platform has navigability issues due to its current contrast, search functionality, and labeling system. Additionally, ambiguity in design leads users to have poor confidence and take inefficient approaches in retrieving data and information. Using principles from geovisualization and related lines of research on sharing publicly available government data

to complement our findings could yield an alternative method that is more accessible and usable (e.g., Bloland & Macneil, 2019; Howe et al., 2021). In light of our collaboration with stakeholders, we know that there is the possibility of making that alternative design publicly accessible to supplant users need to use the IRMA portal.

Implications for Future Research

For further research on the IRMA portal, these preliminary studies shed light on best practices. From the interface tracking study, we noted that there may be search engine optimization problems that make it challenging to identify the IRMA portal as the best source of information on national park visitation. That limitation may warrant its own future research or management, however, for our purposes it revealed that usability research should be conducted once users are already within a web page hosting the portal.

While users did not always successfully retrieve data or information, participants all confirmed that they understood the tasks that they were assigned. Considering those tasks are consistent with the anticipated likely user tasks identified by our collaborators, this suggests they are appropriate for a future line of research. This is a valuable contribution because no prior research has sought to identify the tasks that users may try to conduct when accessing visitor use data.

There were several procedural insights that our research taught us. First, we noted that participants who spoke English as a second language tended to take longer to complete tasks and used less efficient methods. Therefore, future research should make sure to measure this information. Second, we found Zoom to work satisfactorily for conducting usability studies, in line with prior research (Ritter et al., 2012). However, to retain the privacy of users when recording their screens, the researcher should devise protocol for helping them change their

names and remove their cover photos if they are identifiable. Additionally, part of the protocol for setting up examination should include ensuring that screen share is turned on for participants. Third, for the talk aloud procedure, several participants would begin their task describing their actions and steps clearly. However, as participants got confused or further along in the task, they tended to become less communicative. It is the duty of the researcher to ensure they maintain protocol.

We identified two areas for future research beyond the scope of this project for other researchers to consider. First, one participant noted that they did not believe the information was current because the design of the website appeared old. Future researchers could examine the relationship between perceptions of website quality and "how new" the website looks as it informs user perceptions of trust and access. Second, there are many government agencies within the U.S. and many more in other countries. While relatively few agencies may have or share information on visitor use statistics in recreation areas, comparative studies across these platforms could be valuable. Specifically, future researchers may seek to identify the relative accessibility of various data-sharing platforms within the U.S. such as public health data from the CDC, visitation statistics from NPS, and data aggregators like data.gov to inform design.

Implications for Prototype Design

Based on the data collected throughout our usability studies we intend to develop a new protype software that could serve as a replacement for the current IRMA portal. This system will attempt to address the useability and accessibility pain-points users currently experience when using the IRMA portal. This should ultimately lead to increased productivity and success rates for task completion.

In both our user studies and automated study, the results highlighted some fundamental low-level design issues that hindered the usability and accessibility of the IRMA portal. In this case, we are classifying low-level issues as ones that can be easily avoided by following universally accepted rules and have low costs to fix. In the case of the IRMA portal, the low-level issues identified were font choice, text size, and text color. The W3C (2023) has established rules and guidelines for how to pick fonts, text size, and color related to web design. Our prototype will follow these guidelines to ensure we have readable text with appropriate color contrast.

Our study results also uncovered some high-level design issues. These issues do require more planning, and while there are some general guidelines there is not one exact rule that can be followed. Through our prototype we intend to provide a template to further these guidelines, specifically those related to geovisualization. The high-level issues apparent in the current IRMA portal include space allocation, device dependency, and the geo visualization technique itself.

A basic guideline for white space from W3C (2023) is to "[p]ut white space around objects and text, including boxes, paragraph headings, and content, so that each section is clearly separated". Following these guidelines will help us make more efficient and balanced use of white space when compared to the current IRMA portal.

Incorporating transcending scales as the primary mode of geovisual communication will make our prototype more in line with current best-practice (Puri et al., 2015; Zeng et al., 2017). We will enable users to transcend scales from aggregate, high-level to sub-groups for individual analysis. Transcending scales displays data in a hierarchical way allowing users to see different levels of information visually with seamless and simple navigation. In the case of our prototype level 1 will be a map of the entirety of the United States, the map will serve as a heatmap based

on the statistical parameter selected by the user. The user can navigate to level 2 by clicking on any of the states, this level will show all the national parks in the state as well as additional user-parameter statistics. By clicking on a specific park within level 2 the user will navigate to level 3 where a map of the selected park and additional park statistics will be displayed. This implementation will greatly reduce the number of actions a user is required to take to access all available data. In addition, at each level data is made available and displayed visually to the user for increased communication and usability.

Ensuring there is not device dependency in our system will help insure accessibility across platform and for various potential user disabilities. Generally, there should not be any interaction tied to just one form of input. For example, there should be event handlers for keyboard, mouse, and touch-screen interactions (W3C, 2023). This will ensure wider accessibility across different platforms and make site accessible to a wider userbase.

In the future, we plan to run further studies on our prototype to verify our protypes improvements in both usability and accessibility of information. We believe that, by properly addressing the underlying design issues, the new system will significantly address user pain-points. In proving this our research and prototype may serve as a template that similar geo visualization systems can follow to ensure both useability and accessibility of data.

Conclusion

There are many systems that are built with similar goals and user groups as the IRMA portal. Specifically, government systems and systems with a requirement to make data publicly available may be susceptible to the same usability and accessibility pitfalls that the IRMA portal faced. Broad stakeholder groups in large public systems makes designing accessibility and usability more challenging compared to systems with smaller well-defined user groups. The

issue we have highlighted in the IRMA portal may serve as a guideline that is generalizable to systems that are similar. An important takeaway is that ensuring data availability does not ensure data accessibility. However, even in large systems like the IRMA portal minor changes low-level design choices can make a significant impact to the overall usability and accessibility of that system.

Across a variety of industries geovisual data is becoming more common and important. While geovisualization techniques and best practices have been established, they are still not commonplace or implemented uniformly across these industries. Guided by our research we have selected geovisual design patterns with the deliberate aim of increasing usability and accessibility of systems that share data. The choices we have made and design patterns we have followed may serve as a template for other similar geovisualization platforms.

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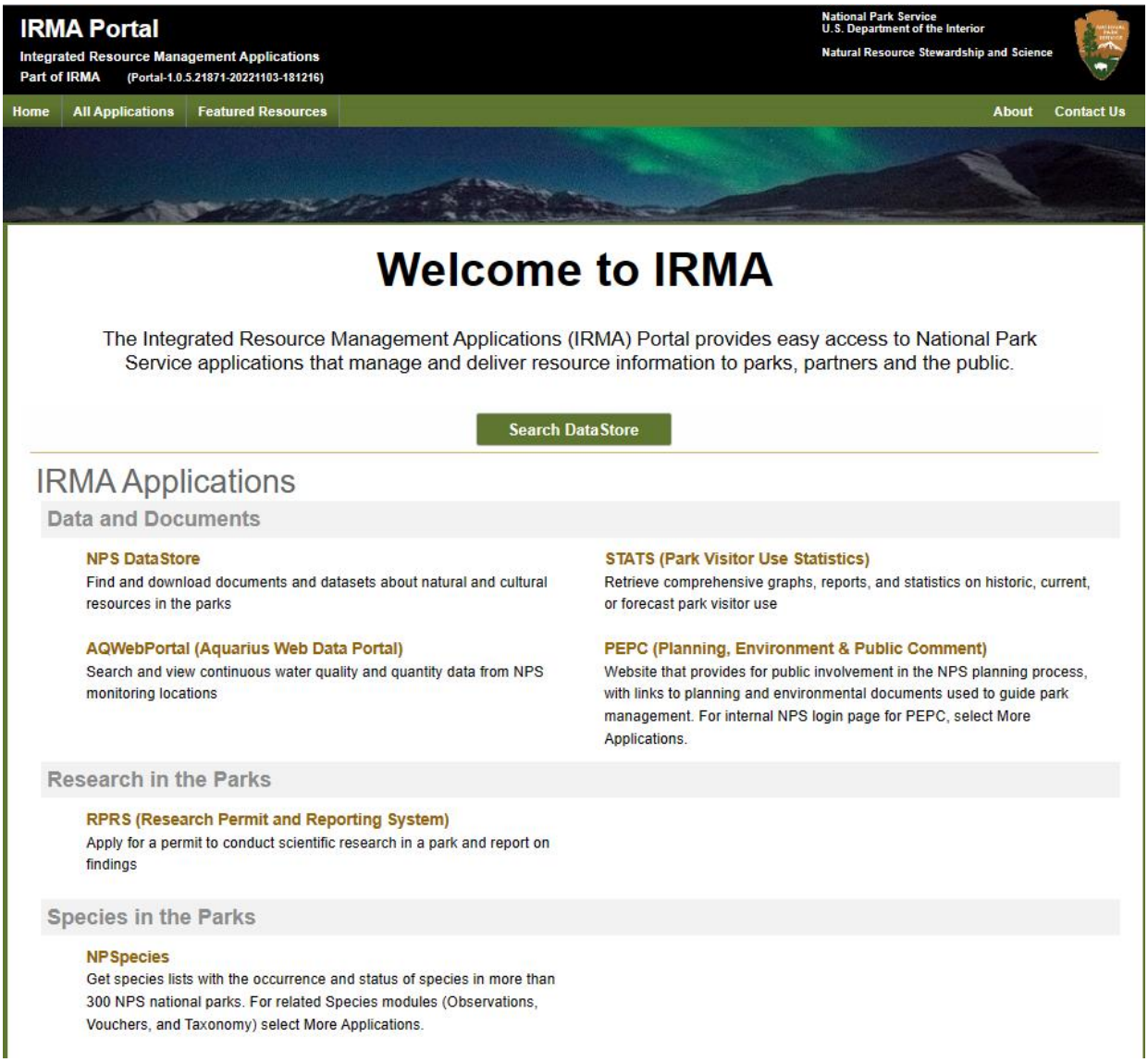
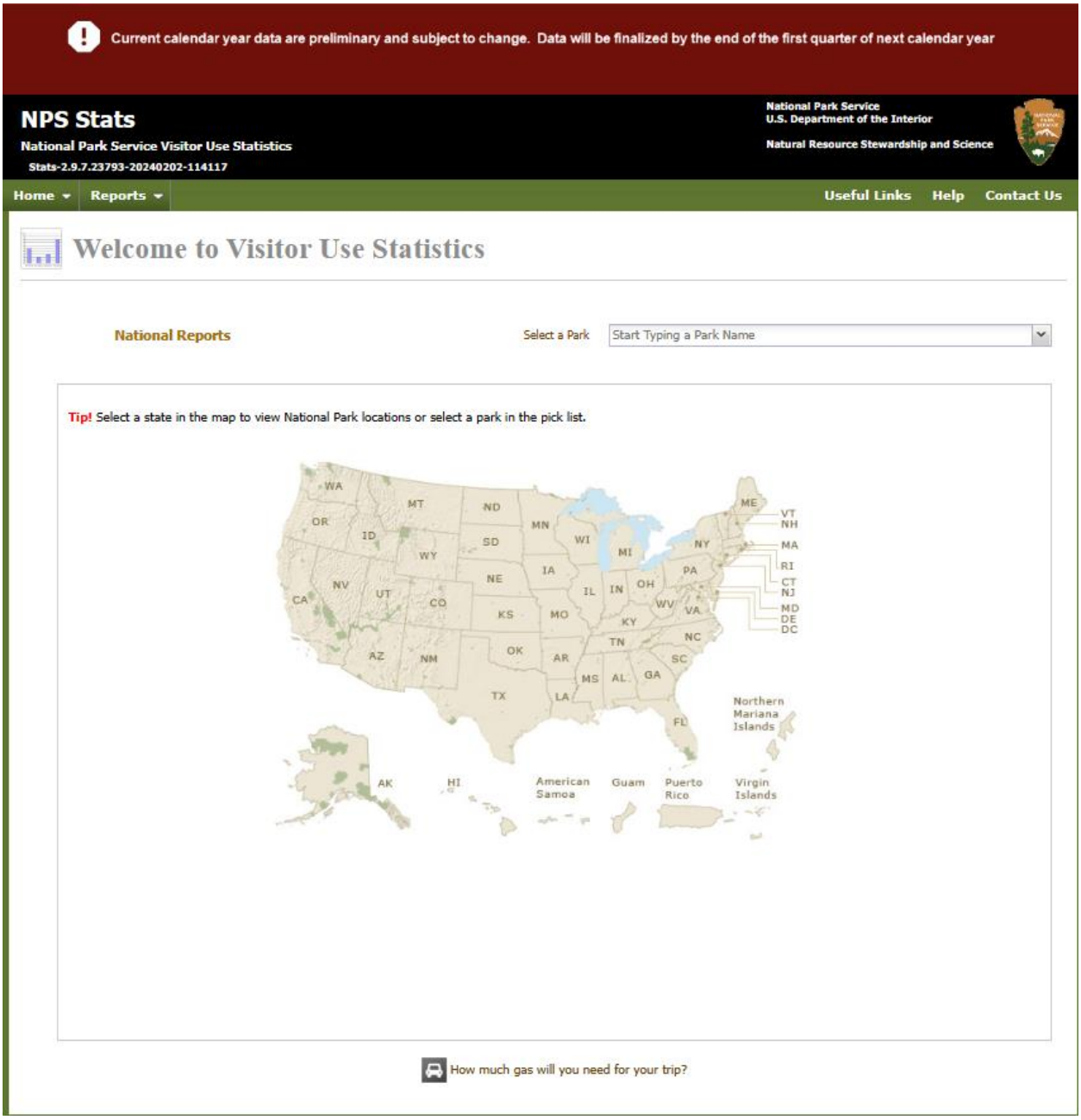
Supplement 1.1

Screenshot of IRMA Portal Front Page



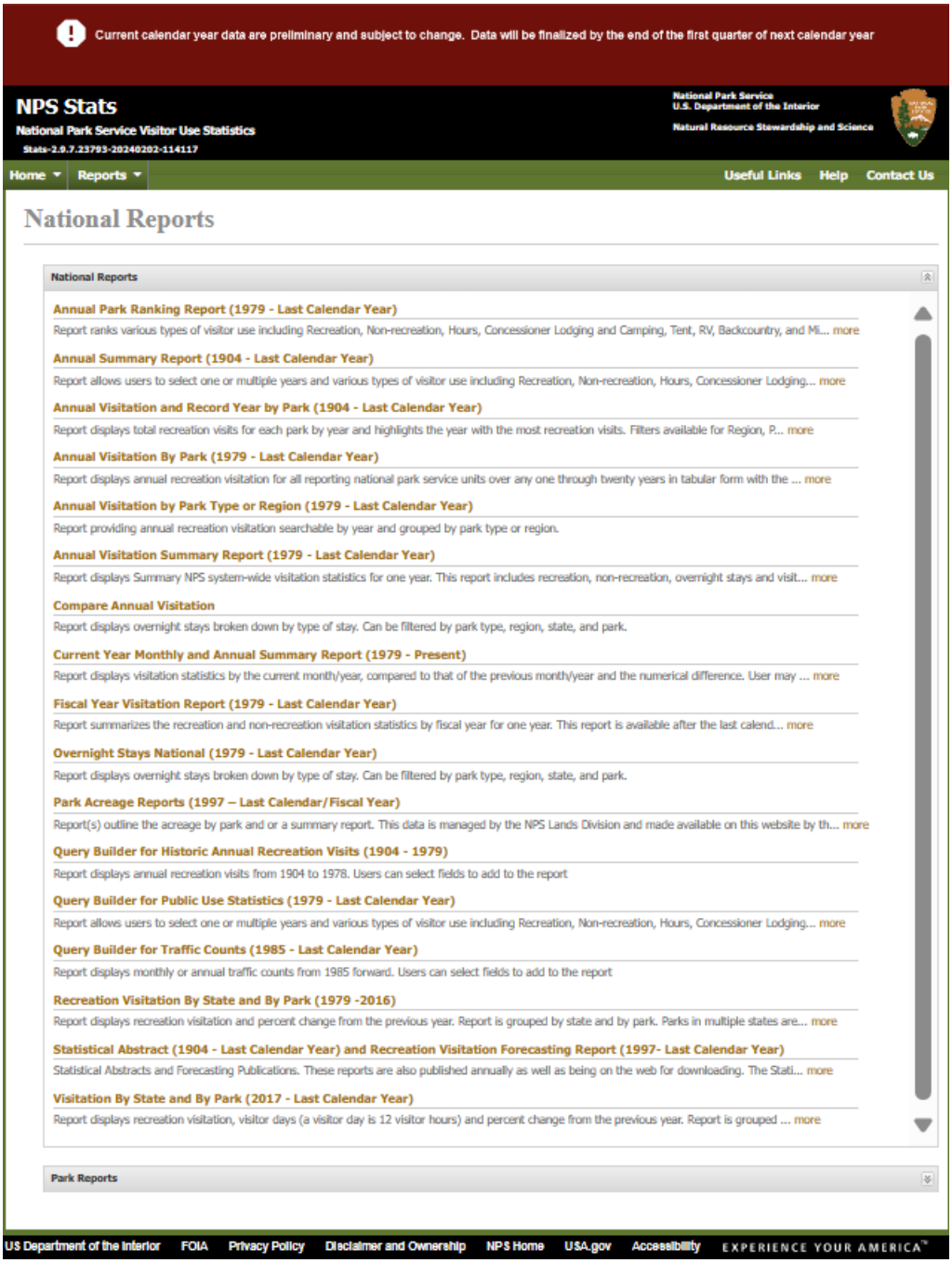
Supplement 1.2

Screenshot of IRMA Visitor Use Statistics Page



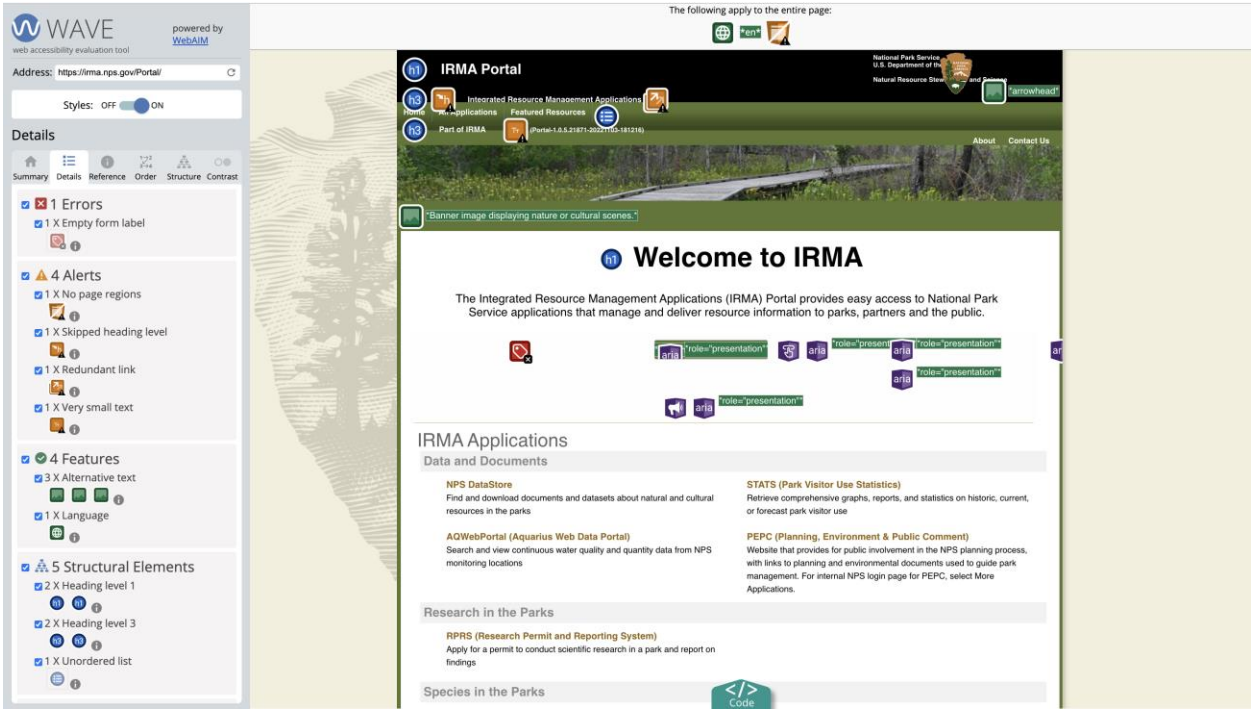
Supplement 1.3

Screenshot of IRMA NPS Statistics Page



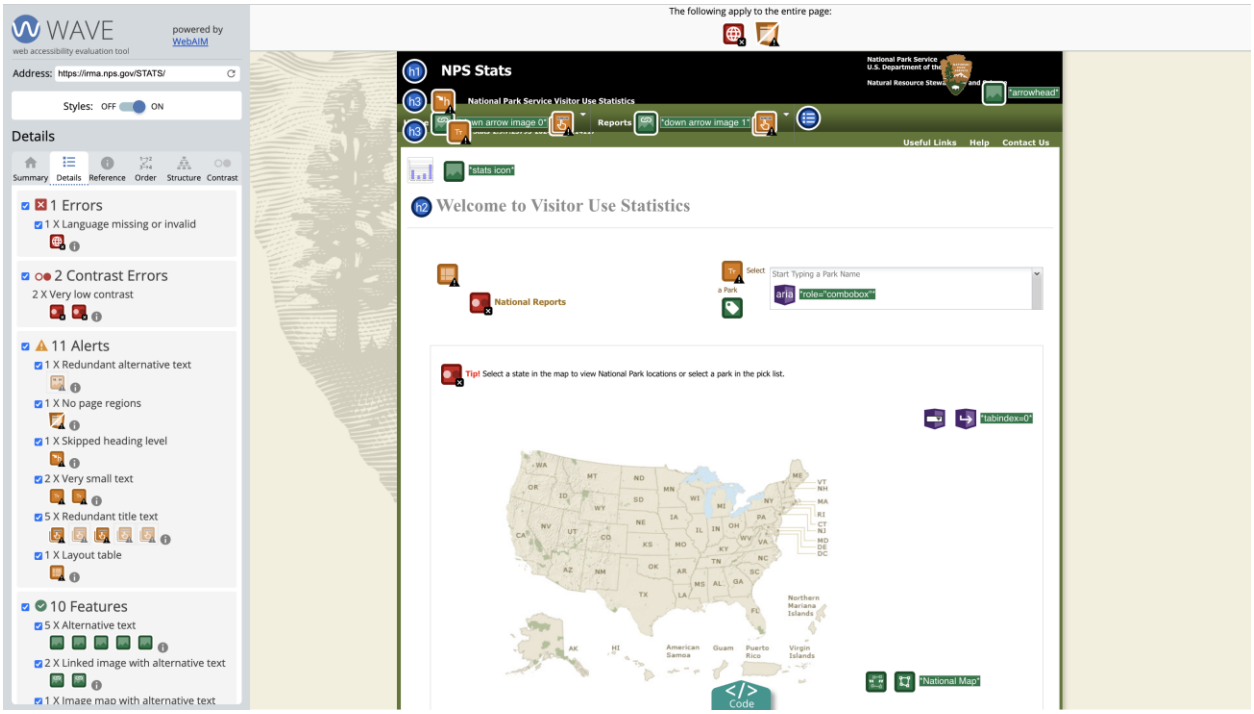
Supplement 2.1

Screenshot of WAVE Results for IRMA Portal Front Page



Supplement 2.2

Screenshot of WAVE Results for Visitor Use Statistics Page



Supplement 2.3

Screenshot of WAVE Results for NPS Statistics Page