Air Pollution and Outdoor Recreation on Urban Trails: A Case Study of the Elizabeth River Trail, Norfolk, VA

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AIR POLLUTION AND OUTDOOR RECREATION ON URBAN TRAILS:
A CASE STUDY OF THE ELIZABETH RIVER TRAIL, NORFOLK, VA

by

James E. McCann
B.S. Park, Recreation, & Tourism Studies, August 2019, Old Dominion University

A Thesis Submitted to the Faculty of
Old Dominion University in Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE
PARK, RECREATION, & TOURISM STUDIES

OLD DOMINION UNIVERSITY
December 2020

Approved by:

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Dr. Eddie Hill (Member)

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Dr. Xihe Zhu (Member)
ABSTRACT

AIR POLLUTION AND OUTDOOR RECREATION ON URBAN TRAILS:
A CASE STUDY OF THE ELIZABETH RIVER TRAIL, NORFOLK, VA

James E. McCann
Old Dominion University, 2020
Director: Chris A. B. Zajchowski, PhD

Poor air quality represents a significant health risk, especially when recreating outdoors in urban parks and trails. It is important for managers of urban parks and trail to understand how potential visitors’ perceptions of air quality and health risks and benefits may affect visitation. The goal of this study was to investigate temporal variance in air quality along the Elizabeth River Trail, an urban trail located in Norfolk, Virginia, as well as trail users’ perceptions of air quality and of health benefits in relation to trail use. The researcher rode a bicycle with a Dylos DC1700-PM mobile air quality monitor mounted to it along the 16.9-km (10mi) trail for 10 weeks to collect PM$_{2.5}$ and PM$_{10}$ data. The following spring, a visitor use survey was conducted with ERT users, measuring perceived health outcomes and perceived air quality, as well as other experiential factors. Two repeated-measures analyses of variance (ANOVAs) were used to determine whether there were significant differences in average PM density at different times of day or days of the week. PM was higher ($p < .001$) between 11am-1pm and on weekends. Perceived air quality and health outcomes were regressed onto self-reported trail use. Perceived health outcomes, but not perceived or preferred air quality, significantly predicted trail use, $p = .006$. Results suggest that whereas motivation directly predicts recreational choices, experiential factors may do so only under specific circumstances, such as when air quality is very poor. Further research is merited to determine how experiential factors can best be integrated with other theories of motivation to understand recreational decision-making.
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<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
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<td>AQ</td>
<td>Air Quality</td>
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<td>AQI</td>
<td>Air Quality Index</td>
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<td>CO</td>
<td>Carbon Monoxide</td>
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<td>EPA</td>
<td>U.S. Environmental Protection Agency</td>
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<td>ERT</td>
<td>Elizabeth River Trail</td>
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<td>EVT</td>
<td>Expectancy Valence Theory</td>
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<td>IPA</td>
<td>Importance Performance Analysis</td>
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<td>NO2</td>
<td>Nitrogen dioxide</td>
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<td>O3</td>
<td>Ozone</td>
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<td>ODU</td>
<td>Old Dominion University</td>
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<td>PHORS</td>
<td>Perceived Health of Recreation Scale</td>
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<td>PM</td>
<td>Particulate Matter</td>
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<td>PPB</td>
<td>Parts Per Billion</td>
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<tr>
<td>PPM</td>
<td>Parts Per Million</td>
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<tr>
<td>SO2</td>
<td>Sulphur Dioxide</td>
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<td>VOC</td>
<td>Volatile Organic Compound</td>
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CHAPTER 1
INTRODUCTION

Air quality has gained visibility over the past decade, with some referring to air quality as one of the greatest environmental health risks of the 21st century (Ebenstein et al., 2017; Zajchowski & Rose, 2018). Exposure to ambient air pollutants, such as particulate matter (PM) and ozone (O3), is associated with stroke, respiratory and cardiovascular diseases (Wells et al., 2012), as well as increased risk of premature death (Sun & Zhu, 2019). Air pollution reporting in popular media has increased (Mayer, 2012), and air quality information has become ubiquitous on weather, running, and other smartphone apps, such as the Weather Channel app (Bousquet et al., 2019). The increased availability of air quality data impacts outdoor recreation choices, such as choosing to recreate indoors instead of outdoors (Zajchowski et al., 2019). More specifically, previous research has suggested that when people are aware of poor air quality, they are discouraged from exercising outdoors (Bunds et al., 2019). This potential reduction in outdoor recreation could have broad impacts on conservation, health, and local economies.

Recreation in natural or green spaces has been linked to increased pro-environmental attitudes and behaviors and increased support for conservation policies (e.g., Scannell & Gifford, 2017). Recreation in nature also confers health benefits not found from activities in other locations, including reduced stress, improved brain function, and faster recovery from illnesses (Wolf et al., 2020). Furthermore, reduced visitation to natural areas (i.e., parks, urban trails) due to air quality concerns could reduce the amount of funds appropriated, and could also affect attempts to secure funding from other sources (e.g., Perry et al., 2018). It is also important for managers of recreational opportunities to have a good sense of local air pollution and pollution sources in order to provide visitors with information, mitigate the effects of air pollution, and
protect airsheds (Zajchowski et al., 2018; Hewitt et al., 2019). Finally, outdoor recreation impacts local economies, especially in urban settings, as visitors spend money at local businesses (Southwick et al., 2009). Thus, it is important for recreationists, urban recreation managers, and local stakeholders to have access to research on local outdoor recreation, the perceptions of recreationists, and air quality levels and trends.

Norfolk, Virginia is a highly industrialized city in the southeastern United States, home to over 240,000 people (U.S. Census Bureau, 2019) and the seventh largest port in the U.S. (Burnson, 2019), as well as the world’s largest naval station and over 50,000 active duty military personnel (Hampton Roads Chamber, 2020). The Port of Virginia and associated rail terminal, known as Lambert’s Point, raise concerns about local air pollution, in particular due to the uncovered coal trains that unload at the port. The port is the largest coal shipping facility in the U.S., and receives over 200,000 coal cars annually (Grymes, 2019), all uncovered and blowing an estimated 500 lbs of coal dust off each car (Lyon, 2016). Although a 2017 Virginia Department of Health study found that PM$_{10}$ near Lambert’s Point remained in the U.S. Environmental Protection Agency (EPA)’s “good” range, local residents have repeatedly expressed concerns (AP, 2015; Dixon, 2018). Residents in nearby neighborhoods report excessive coal dust deposits in their homes and a range of respiratory symptoms (Dixon, 2018; Mayfield, 2017). Additionally, the 2017 Virginia Department of Health study did not measure PM$_{2.5}$. This suggests a lack of clarity on the experienced air quality near the Norfolk International Terminals and the Port of Virginia, particularly along urban trail resources.

Norfolk is densely urban, with a high concentration of minority (57%) and residents below the poverty line (20%; U.S. Census Bureau, 2019). The Elizabeth River Trail (ERT) is one of the few areas for outdoor recreation or green spaces available to city residents and is
conveniently located for visiting tourists. In fact, the ERT constitutes 60% of available bicycling paths in Norfolk (Jovanovic & Case, 2019). The trail runs for 16.9 kilometers along the Elizabeth River, including the Norfolk International Port and Lambert’s Point railway terminal (Elizabeth River Trail Foundation, n.d.). Visitors may run, walk, or bicycle, taking advantage of bicycle stations along the route, or visit one of four small urban parks along the route. The trail is maintained by a nonprofit organization, the Elizabeth River Trail Foundation, and relies heavily on public and private donations for funding. Therefore, a critical function of the ERT Foundation is gathering evidence of the benefits of the trail, to help with securing funds. This means that the trail is vulnerable to concerns about air pollution in a way that city, state, and national parks may not be.

This study investigated the problem of local air quality and its effects on urban trail visitation. First, to determine local air quality trends, a mobile Dylos air quality monitor was mounted to a bicycle and used to collect air quality along the ERT, similar to Hong and Bae’s (2012) study of urban bicyclists’ exposure to air pollution in Seattle. However, Hong and Bae used an Aethalometer to measure black carbon, whereas the current study used the Dylos to collect particulate matter readings. Although black carbon is a serious concern for active commuters due to its high rate of emission from vehicle traffic (Hong & Bae, 2012), particulate matter is emitted from several different sources and is more commonly used as a measure of air quality (e.g., An et al., 2019). Additionally, particulate matter raises greater health concerns, due to the ability of PM$_{2.5}$ to penetrate deep into lung tissue (Hayes et al., 2020). Second, several trail counters are situated along the trail, creating convenient trail segments to compare segment-specific air quality readings to visitor counts over time. Jiang et al. (2019) used a similar approach to examine the relationship between air quality and urban park visitation, but used
district-level air quality monitoring. They found a significant effect for heavy and severe air pollution, but no significant correlation between visitation and air quality at more moderate levels. A third goal of this study was to examine visitors’ perceptions of air quality and the perceived health effects of urban trail use, using subjective measures. Research suggests that perceived air quality may influence behavior, although with a smaller effect compared to media alerts (Wen et al., 2009), and that health benefits may be a primary motivation for trail use (Gomez & Hill, 2016). This study used expectancy-valence theory (EVT; Vroom, 1964) and experiential benefits theory (Driver, 1977) to model the effects of air quality and health benefits perceptions on trail use. Following the expectancy-valence model, the Perceived Health Outcomes of Recreation Scale (PHORS; Gomez et al., 2016) was used to investigate perceived health effects of trail use. Based on the experiential benefits approach, an Importance Performance Analysis (IPA; e.g., Draper, 2016) was also conducted with trail users rating managed trail resources, including air quality, to determine the effects of perceived air quality on trail use.

Outdoor recreation has become increasingly important in recent years, as disease and mortality due to preventable conditions such as obesity continue to rise (Ghimire et al., 2017). Even on urban trails, outdoor recreation has been linked to a host of physical, psychological, and spiritual benefits (Fong et al., 2018; Gladwell et al., 2012; Li et al., 2011). However, there is a paucity of research that combines visitors’ perceptions of the health benefits of urban trails, perceived risks due to air pollution, and motivations for trail use, all of which play a role in whether residents and tourists choose to visit urban trails. Therefore, it is important to understand motivations and potential barriers to recreation, as well as associated risks such as exposure to ambient air pollution.
CHAPTER 2
LITERATURE REVIEW

This review of literature will provide technical definitions for air quality and particulate matter measurements and information regarding sources of pollution. Past research supporting the importance of focusing on local air quality will be reviewed. The link between air quality and health outcomes, both in terms of the importance of this study and in terms of recreationists’ perceptions and the impact of these perceptions on behaviors, will be detailed. Perceived health outcomes of outdoor recreation will be contextualized using expectancy-valence theory (EVT) and previous research on outdoor recreationists’ motivations. Next, urban trails will be defined, and research related to urban trail use and air quality along urban trails will be reviewed. Finally, the purpose of this study will be framed in terms of air quality, perceived health outcomes, and urban trails.

Air Quality

Air quality is affected by pollution (substances that can cause adverse effects to humans and the environment; definition from Tiwary et al., 2018), from point (industrial and manufacturing facilities), area (neighborhoods, cities), and mobile (vehicles, airplanes) source emissions (Reynolds et al., 2003). Air quality is also affected by weather, such as temperature and wind (e.g., Li & Kamargianni, 2017), and natural factors, such as pollen (Morita et al., 2009). Early efforts to address air quality in the U.S. began with the Air Pollution Control Act of 1955 and the Clean Air Act of 1963, which largely focused on research and publication of findings (Ahlers, 2015). The Clean Air Acts were amended in 1965, 1967, and 1970, but focused almost entirely on vehicle emissions and are generally viewed as failing to implement strong,
even enforcement (Ahlers, 2015). Later amendments created permit programs, broadened regulations to apply to other industries, and gave the EPA greater regulatory power (1977); expanded the number of air pollutants to be regulated, and made EPA regulation mandatory (1990) (Ahlers, 2015; Zajchowski et al., 2019). The 1977 and 1990 amendments, in particular, have been linked in research with strong reductions in air pollution (Greenstone, 2002; Likens et al., 2000).

Ambient pollutants include particulate matter (PM$_{2.5}$ and PM$_{10}$), ozone (O$_3$), sulphur dioxide (SO$_2$), nitrogen dioxide (NO$_2$), carbon monoxide (CO), lead (Pb), cadmium (Cd), platinum (Pt), volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAH), and peroxyacetyl nitrates (PANs). These are the primary recognized and regulated pollutants around the world (Tiwary et al., 2018). Tiwary et al (2018) document that these pollutants can mix with fog to form noxious smog over cities, or react with sunlight and other chemicals to form irritating haze. For example, Khaniabadi et al. (2017) explain that excess atmospheric ozone results when NO$_2$ or VOCs degrade or react with other chemicals in the presence of sunlight. For all ambient pollutants, concentrations in the air are measured in $\mu$g/m$^3$ (PM$_{2.5}$ and PM$_{10}$), parts per million (ppm; CO), or parts per billion (ppb; SO$_2$, O$_3$, and NO$_2$) (Office of Air Quality Planning and Standards, 2014).

In the United States (U.S.), the U.S. EPA ranks air quality on an index (AQI) from 0 to 500, divided into six levels: good, moderate, unhealthy for sensitive groups, unhealthy, very unhealthy, and hazardous (Office of Air Quality Planning and Standards, 2014). Five criterion pollutants contribute to calculation of AQI: particulate matter (both 2.5 and 10), CO, SO$_2$, O$_3$,

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1 PM$_{2.5}$ is defined as particulate matter up to 2.5 $\mu$m in diameter; PM$_{10}$ is particulate matter between 2.5 $\mu$m and 10 $\mu$m.
and NO\textsubscript{2} (AirNow, 2020). The AQI level is based on the highest level of any of the five criterion pollutants. Most other countries also use an air quality index to rate air quality; however, the pollutants included, index scales, and acceptable levels of pollutants vary (e.g., Kobus et al., 2020). For example, Kuklinska et al. (2015) noted that Canada uses a scale from one to ten, and the Common Air Quality Index that attempts to correlate AQIs from different countries across the European Union uses a five-step scale. Similarly, the European Union cutoff for PM\textsubscript{10} is 50 \(\mu\text{g/m}^3\), while that of the US is 150 \(\mu\text{g/m}^3\). These differences make it difficult to equate air quality levels in different regions (Kuklinska et al., 2015). This proposal will use the U.S. EPA’s AQI when referring to AQI or AQI categories.

Tiwary et al. (2018) report a variety of sources of ambient air pollution, including motor vehicle traffic, power generation and industrial plants, factories, waste treatment, agriculture, fossil fuel extraction and distribution, and nature. The distribution of these pollutant sources varies widely; for example, almost all SO\textsubscript{2} is emitted from fossil fuel combustion, whereas trees and plants may be responsible for two-thirds of VOC emissions. Tiwary et al. (2018) note that most NO\textsubscript{2} is likely from fossil fuel combustion. Carbon is emitted both by natural processes (wildfires, volcanoes, etc.) and fossil fuel combustion. Ozone is a secondary pollutant, arising from photochemical reactions in the atmosphere, and fueled by NO\textsubscript{2} and VOCs.

Across pollutants, anthropogenic (human-induced) emissions now far outstrip natural sources, and have resulted in unhealthy levels for millions of humans (Tiwary et al., 2018). Because of this, anthropogenic ambient pollution has come under increasing global scrutiny in recent years (Kuklinkska et al., 2015). More serious policy efforts began to see implementation

\footnote{Although lead (Pb) is a criteria pollutant and included in the National Ambient Air Quality Standards, it is not included in calculation of AQI in the U.S.}
in the 1990s, including the Kyoto treaty and phased implementation of the more stringent regulations of the 1990 Clean Air Act (Lau et al., 2012; Likens et al., 200). However, public perception lagged until air quality data was more widely available to the public, and mounting evidence linking health conditions to air pollution began making headlines in the media (Kuklinska et al., 2015). Recent studies suggest that air pollution is now a primary concern among urban dwellers (Bunds et al., 2019).

**Particulate Matter.**

Particulate matter (PM) are airborne particles smaller than 10 μm, which due to their small size can remain suspended in the air for days and bypass filtration in the lungs to deposit in the bronchioles and alveoli of the respiratory tract, where they can cause severe irritation and exacerbate pre-existing health conditions (Tiwary et al., 2018; Ware, 2000). In fact, PM is more strongly linked to increased risk of death from any cause than any other ambient pollutant (Ware, 2000). PM is particularly associated with increased risk of death due to heart attacks, strokes, and respiratory conditions (Bazyar et al., 2019). PM can be fine dust or sand particles, salt from ocean spray, ash, soot, sulphates, nitrates, or hydrocarbons. These can be picked up by the wind or emitted into the air in industrial plumes or by internal combustion engines and, in some cases, transported transnationally by weather systems (Tiwary et al., 2018). For particulate matter smaller than 1 μm, such as sulphates and nitrates, sedimentation is extremely slow; this is why haze often lingers until a rainfall. Whereas dust, sand, salt, and ash are considered primary particles, these sulphates and nitrates are examples of secondary particles. Secondary particles form from collisions or photochemical reactions between gases, such as SO₂, ammonia (NH₃), and elemental carbon (Tiwary et al., 2018).
Particulate matter is of increasing concern in many countries, due to recent studies raising awareness of health risks and the lack of improvement in PM levels over the last two decades (e.g., Ferrante et al., 2012). Primary PM is largely natural, stemming from volcanoes, wildfires, erosion, and ocean spray, and thus is highly dependent on weather, whereas secondary PM is largely anthropogenic, or human-caused (Tiwary et al., 2018). During the decade from 2000-2010, primary PM fell due to weather conditions, yet secondary PM rose (Ferrante et al., 2012). This suggests that anthropogenic emissions, leading to secondary PM, are continuing to increase on a global level, despite efforts to improve air quality, and that ambient pollution is likely to remain at levels hazardous to human health for the foreseeable future (Climate Action Tracker, 2019). The current study focused on particulate matter, due to its importance to air quality and to human health.

**Air Quality and Health**

Poor air quality is one of the top five contributing factors to premature deaths across the globe (Tiwary et al., 2018). Air quality has been linked to stroke, respiratory diseases, and cardiovascular diseases (Cohen et al., 2017). Sensitive populations, including the young, the elderly, and those with pre-existing conditions, are most vulnerable to poor air quality (WHO, 2009). Additionally, it is well-documented that racial and ethnic minorities and low-socioeconomic status populations bear disproportionate burdens of air pollution (Boyce, 2020; O’Lenick et al., 2019). This is largely due to collocated industries, such as petroleum refineries. For example, African Americans are exposed to 50% more air pollution from industrial sources compared to white Americans (Nguyen & Marshall, 2018). Minorities are also more likely to live close to major transport arteries, resulting in higher exposure to vehicular emissions (Rickenbacker et al., 2019). Lack of awareness of air pollution and of mitigation strategies also
constitute a major concern. For example, when asked what air pollutant(s) have adverse health effects over long-term exposure, directly related to cancer, a group of 72 residents recruited from vulnerable neighborhoods averaged 50% accuracy (Rickenbacker et al., 2019). Additionally, Stuart et al. (2012) found that minorities and low-income groups are more likely to live farther from air quality monitoring sites, calling into question the accuracy of AQI data they may receive. Ward and Beatty (2015), on the other hand, found that neither race nor income predicted significant differences in exposure averting behavior, whereas older participants were significantly more likely to avoid air pollution. These findings support the need for more local measurement of air quality, and additional research to determine whether vulnerable populations respond differently to poor air quality.

There are often large disparities in air quality on the local or regional level. For example, Michoacan province, Mexico, recently recorded 498 ppb SO₂ and 57 µg PM_{2.5}, while Zacatecas province, 5 hours (433 km) north, recorded 1 ppb SO₂ and 4 µg PM_{2.5} (World Air Quality Index Project, 2020). However, most research has either drawn on datasets gathered from large geographical areas such as the U.S. and China, or focused on high-smog locations such as Los Angeles and Beijing (e.g., Yu, An, & Andrade, 2017). In these locations, air quality leads to a diversity of behavioral responses. For example, Hu et al. (2017) collected data from exercise app users across China, finding that users were less likely to run, bike, or walk outdoors when air quality was low. Noonan (2014) found that older visitors and exercisers were less likely to use a major park in Atlanta, GA, on days when smog alerts were issued. These results, while valuable, may mask variance in behavior due to smaller-scale, local air quality trends. Additionally, while apps and weather forecasts generally report data from local or regional air quality monitors (Castell et al., 2017), media reporting on air quality may tend toward covering national trends.
and heavily polluted areas (e.g., San Diego Air Pollution Control District, 2020), potentially influencing viewers’ perceptions of local air quality. For example, Cisneros and Schweizer (2018) found that media reporting on poor air quality due to wildfires in California misrepresented the actual air quality in those areas. Similarly, the Weather Channel app reports satellite data, rather than local, stationary air monitoring data (Copernicus, 2020). This suggests that peoples’ perceptions may not accurately reflect local air quality (Paas et al., 2016), and could discourage them from visiting outdoor areas such as urban trails and parks (e.g., Keiser, Lade, & Rudik, 2018; Zajchowski et al., 2019). Perceived air quality has been found to influence behavior, sometimes more than media alerts, with the primary behavior change being avoiding the outdoors (Borbet, 2018). Perception of air quality relies on smell and visibility, and while visibility can be a good proxy for air quality (Ozer et al., 2006), neither of these correlates consistently with measured air quality (Prophet et al., 2018).

Thus, accurate measurement and reporting of air pollution on the local and micro-spatial level is critical, as some groups (elderly, racial and ethnic minorities, those below the poverty line) are at a high risk of suffering health complications due to air pollution (Boyce, 2020). These high-risk groups are also likely to benefit most from outdoor physical activity (Westbrook, 2017), yet more likely to face transportation challenges, such as being unable to visit a less-polluted area of a city (Winter et al., 2020). Additionally, outdoor activity increases health risks due to air pollution, as increased respiration equates to greater intake and retention of particulate matter in the bronchi and alveoli (Daigle et al., 2003). Everyone, but especially high-risk groups, should have access to accurate information concerning local air pollution and the consequent hazards during outdoor physical activity, in order to weight the risks and benefits of these activities.
Perceived Health Outcomes and Outdoor Recreation.

Perceived health outcomes, as well as perceived air quality, can affect pollutant exposure mitigation behaviors including reduction in outdoor recreation. For example, Rickenbacker et al.’s (2019) survey found that few respondents were able to link potential health outcomes with responsible pollutants. Additionally, Oltra and Sala (2018) found relatively low levels of self-efficacy, reporting that participants rarely (30%) felt that efforts to mitigate exposure would be effective, but that self-efficacy was significantly linked to avoiding air pollution, changing recreational activities, or wearing a mask. These findings suggest that perceived health risks and self-efficacy contribute to the likelihood of avoidance behaviors. However, avoidance of outdoor recreation carries its own set of health risks.

Outdoor recreation can be protective against conditions such as heart disease and diabetes, by reducing obesity (Ghimire et al., 2017), heart rate, blood pressure, and stress hormones such as adrenaline and cortisol; increasing heart rate variability; and improving immune response (Gladwell et al., 2012; Laumann et al., 2003; Li et al., 2011; Park et al., 2010). Outdoor recreation is especially well-known for conferring psychological and spiritual benefits, such as reduced depression, improved subjective well-being, spiritual well-being, and resilience, and increased self-esteem (Fong et al., 2018; Heintzmann, 2020; Rathmann, 2020). Urban trails attempt to bring these benefits to crowded urban areas with little available space for greenery. Research suggests that urban green spaces confer similar benefits to activities in wilderness areas, including lowered stress, anger, and anxiety, improved mental health, more positive affect, and greater tendency to engage in physical activities (Hines, 2017).
**Motivations, Preferences, and Perceptions and Outdoor Recreation.**

People might be particularly likely to avoid urban parks and trails, due to negative perceptions of the health risk imposed by air pollution, unless their positive perceptions of health outcomes due to outdoor recreation outweigh these perceived risks. Theories of motivation provide a path to understanding how people make recreational choices. Expectancy-valence theory (EVT) (Vroom, 1964) explains motivation in terms of valence, expectancy, and instrumentality. Valence is the amount of value that an individual places on a reward, such as health or fitness. Expectancy refers to how the person perceives their effort – such as traveling to a park or walking on a trail – resulting in success. Instrumentality is how likely the reward is perceived to be based on the action, such as outdoor recreation. EVT has been applied broadly to the outdoor recreation field in disparate attempts to study the recreational experience (Fix et al., 2018). For example, Paudyal et al. (2018) applied EVT to study visitor perceptions of high- and low-quality endangered species habitats, by linking scenic beauty with recreation satisfaction.

Different approaches to measuring and studying experience, such as the Recreational Experience Preference (REP) Scale and the Recreation Opportunity Spectrum, were developed using EVT. Indeed, Fix et al. (2018) and Veal (2017) both call for a more unified model of recreational experience. Although this theoretical gap is beyond the scope of the current paper, Gomez et al. (2016) noted that the REP scale was also inconsistently applied, due to its length (328 items across 19 scales), and lacked measures of mental and physical health expectancies. The PHORS closed this gap by providing a short, reliable scale that focused on perceived physical and psychological health outcomes of recreational experiences (Gomez et al., 2016).

Therefore, to assess whether health outcomes are a key motivation for urban trail use and what these perceived health outcomes may be, the current study used the Perceived Health
Outcomes of Recreation Scale (PHORS). The PHORS was conceived to measure previously neglected benefits of recreation, including preventative health, improving health and fitness, and psychological benefits (Gomez et al., 2016). This scale has been used to study the perceived benefits of mountain biking (Hill & Gomez, 2020), triathlons (McIntosh, Hill, & Morgan, 2019), rock climbing (Hill et al., 2018), and urban-proximate park use (Gomez & Hill, 2016), and to investigate exercise addiction (Kula et al., 2020). Kula et al. (2020) compared PHORS scores to Exercise Addiction Scale scores and found that high health perceptions correlated with high levels of over-focus and emotional change, leading to exercise dependence. Of more relevance to the current study, Gomez and Hill (2016) surveyed 304 visitors to an urban-proximate state park, and found that perceived psychological outcomes, but not health/fitness outcomes, significantly predicted park usage. However, the PHORS has not previously been applied to examining user expectations for urban trails. Urban trails like the ERT have fewer facilities, activities, or natural setting to offer. Thus, it is important to investigate other types of benefits that can be offered. Psychological and physiological benefits can be realized with fewer resources, and depending on how visitors view and experience these benefits, managers can focus limited resources on improving the visitor experience.

Models of motivation such as the push–pull model (Dann, 1977) and the experiential approach (Driver, 1977) attempt to predict choice through preferences. Dann (1977) defined push factors as personal preferences, whereas pull factors are attributes of the recreation site. These factors are suggested to determine travel and recreation site choices. A different approach, proposed by Driver (1977), focuses on experiential factors linked to desired outcomes. This framework suggests that choice is driven by preferences for these experiential factors, which in turn are driven by motivations for different outcomes (Whiting et al., 2017). Thus, in the
outcome-focused management framework (Driver, 2008), preferences are situated between motivations and outcomes, and are therefore central to understanding both (Rice et al., 2020). Previous research on urban trail use has focused on motivations, preferences, and constraints, but not experiences (e.g., Keith et al., 2018); indeed, Larson et al. (2016) expressed surprise that experiential benefits emerged as the most important ecosystem service category among urban trail users.

Research also suggests that urban trail users’ perceptions, preferences, and patterns of use may vary depending on specific geographies. For example, Keith et al. (2018) and Larson et al. (2016) found that diverse trail users in Atlanta, Georgia, and San Antonio, Texas, perceived the most important benefit to be the natural setting. In contrast, Reynolds et al. (2007) found negative associations between trail use and level of vegetation in Chicago, Illinois; Dallas, Texas; and Los Angeles, California. Campagnaro et al. (2020) reported similar findings in Italy, attributing this to concerns regarding safety in less open areas. Similarly, Kraft et al. (2018) found that Latinos were more likely to express safety concerns and to avoid urban trail sections in predominately white neighborhoods. These results suggest that it is important to consider the intersection of regional perceptions and preferences with local air quality trends.

Accordingly, in addition to motivational drivers for use on the ERT, to further investigate the perceptions and preferences of visitors, the current study used an importance-performance analysis (IPA), inclusive of questions related to air pollution and scenic views. IPAs analyze the importance of key experiential variables to visitors together with visitors’ perception of the quality (performance) of these variables (Draper, 2016). Experiential variables with high importance and low performance are interpreted as in urgent need of improvement. Variables high in both importance and performance should be maintained; variables low in importance but
high in performance may require less investment; and variables low in both importance and performance are generally interpreted as being low priority items. IPAs help managers decide where to invest limited resources (Draper, 2016). As a result, the inclusion of these additional subjective perceptions in this study facilitated the extraction actionable management implications related to air quality and other experiential variables of importance along the ERT.

**Purpose**

Previous research on the effects of air quality is mostly focused on active commuting (e.g., Bigazzi & Gehrke, 2018), or on physical activity irrespective of type or location (e.g., An & Xiang, 2015). However, existing research gaps include temporal micro-spatial air quality variance, analyses of air quality in urban park settings, and perceptions of air quality and of its impact on health outcomes. Micro-spatial monitoring takes place at the sub-city level, such as by neighborhood, park, or trail (Pattinson et al., 2017). Most research and reporting on an area are based on one air quality monitor, such as the EPA’s monitor at Tidewater Community Campus in Suffolk, which is relied on for all of Norfolk, Virginia Beach, Chesapeake, and outlying areas (Office of Air Quality Monitoring, 2015). However, there could be important differences in air quality in different neighborhoods or regions of a city. For example, Stuart et al. (2012) and Rickenbacker et al. (2019) both call for increased monitoring in low-income/minority neighborhoods, which are often collocated with industrial sources of pollution. Similarly, Bari and Kindzierski (2018) compared measurements at two monitoring stations in Calgary, Alberta, Canada, and found that although average PM$_{2.5}$ concentrations were similar, one monitor demonstrated variance due to traffic while the other did not.
Air quality in urban parks and trails, specifically, is even less researched. Jiang et al. (2019) noted that the effects of air pollution on urban park visitation behaviors are poorly understood. Air quality in an urban park might differ from that at the monitoring station due to increased greenery, proximity of high-traffic roads, or nearby industrial sources. Thus, the air quality experienced at the park might be better or worse than visitors perceived it to be. Air quality could also vary reliably across times or days, for example, due to traffic or industrial emissions patterns. Awareness of these temporal patterns would allow recreationists to avoid peak air pollution periods while reaping the benefits of outdoor recreation. Additionally, there is little research on how people weigh the health risks and benefits of air pollution and outdoor recreational activity. Wolter et al. (2019) identified a need for research on the health benefits of trail use, using context-specific variables identified in collaboration with park and recreation practitioners. Understanding visitors’ health perceptions related to urban park and trail use is a first step towards understanding how they may weight potential benefits against risks from air pollution.

Accordingly, the purpose of this research was to investigate the temporal variance in air quality exposure along a scenic trail (the Elizabeth River Trail) within a densely populated urban area (Norfolk, Virginia, USA), trail visitors’ perceptions of air quality, and the importance of these perceptions in dictating visitation behaviors. We were also interested in whether visitors’ perceived health outcomes varied with their perceptions of air quality. These multiple goals support the research questions listed in Table 1. All research components of this proposal were approved by Old Dominion University’s Institutional Review Board (Appendix A), and information regarding informed consent was obtained from each human participant prior to data collection.
### Table 1

*Research Questions*

<table>
<thead>
<tr>
<th>Research Question</th>
<th>Predictor Variable</th>
<th>Outcome Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>What is the exposure to PM2.5 and PM10 for outdoor recreationists using an urban waterfront trail?</em></td>
<td>Day of week</td>
<td>PM$<em>{2.5}$, PM$</em>{10}$ Concentration</td>
</tr>
<tr>
<td></td>
<td>Time of day</td>
<td>PM$<em>{2.5}$, PM$</em>{10}$ Concentration</td>
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<tr>
<td><em>Do subjective perceptions of air quality and health benefits influence trail use?</em></td>
<td>Perceived health (PHORS)</td>
<td>Trail use frequency</td>
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<td></td>
<td>Perceived air quality (IPA)</td>
<td>Trail use frequency</td>
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CHAPTER 3
METHODS

Phase 1

Design.

The first phase of this study used a 7 (days of week) x 5 (time of day) repeated measures design to investigate average air quality along the ERT and determine whether concentrations of PM$_{2.5}$ and PM$_{10}$ differed significantly by time of day or by day of the week.

*Stratified sampling approach*

PM data was collected for a total of 10 weeks between September 11 and November 22, 2019. Five two-hour blocks from 7am to 5pm were chosen to collect PM readings. These times were chosen to include the hours of normal industrial operation and traffic (i.e., pollution sources). Collection times and days were stratified in an attempt to ensure an equal number of times and days of collection (e.g., five, 9:00am Monday measurements; five, 9:00am Tuesday measurements, etc.). First, Microsoft Excel’s random number generator was used to generate random collection times and days resulting in an equal number of collection periods across conditions. Next, these times and days were staggered so that collection did not occur at the same time two days in a row (Table 2). This was intended to maximize collection under different conditions across the study period, since air pollution can be affected by weather, holidays, or unexpected events. Weather conditions, such as ambient temperature and cloud cover, were also recorded at the time of collection.
Table 2

*Sample two weeks of stratified air quality collection schedule.*

<table>
<thead>
<tr>
<th>Time</th>
<th>8-Sep-19</th>
<th>9-Sep-19</th>
<th>10-Sep-19</th>
<th>11-Sep-19</th>
<th>12-Sep-19</th>
<th>13-Sep-19</th>
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<td>15-Sep-19</td>
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</table>

*Note: Shaded cells indicate air quality collection periods.*

*Route*

PM data was ultimately collected along the entire 16.9 km length of the ERT; however, the entire trail did not receive equal use by the research team. Each ride started and ended at Old Dominion University (ODU) to accommodate the students who accompanied the researcher during collection. Most rides proceeded south (toward Waterside; Figure 1), but several rides included the section of the trail north of ODU (towards the Hermitage Museum).
Although PM values along the entire trail were collected, the area of critical interest was the section of the trail from ODU to Waterside (highlighted in yellow on Figure 1), due to the relatively higher visitor use observed in this area by trail counters (Santos, 2020) and the
presence of critical pollutant sources, such as the Norfolk Southern coal terminal at Lambert’s Point, the nearby Norfolk International Port, and the Portsmouth Marine Terminal located across the Elizabeth River from the Lambert’s Point area. The second most frequently collected trail area was the section from ODU to the North end of the trail, near the Hermitage Museum (Figure 1). These data were excluded from further analyses, since a one-way analysis of variance (ANOVA) revealed a significant difference between this data and the rest, which may have been due to the relatively small sample size or other factors.

**Materials.**

A Dylos DC1700-PM mobile air quality monitor was used to collect air quality data. The Dylos DC1700-PM collects PM$_{2.5}$ and PM$_{10}$ simultaneously, sampling once per minute and providing the mass concentration per m$^3$ of detected particles. The Dylos also records the time at which each sample was collected. The Dylos was mounted to a Gravity mountain bicycle using a bicycle clamping kit bolted to the front handlebars (Figure 2), and a correction factor from the U.S. EPA’s monitor at Tidewater Community Campus in Suffolk was entered. The Dylos stores up to 10,000 samples on its internal memory, which were then downloaded to a Windows 10 PC using the Dylos Logger software, version 3.1. The Dylos DC1700-PM readings closely (> .87 correlation) approximate those of the GRIMM and TSI 3330 OPS stationary monitors when used indoors (Jovasevic-Stojanovic et al., 2015). Worthington (2015) compared the Dylos to the SHARP 5030 PM stationary monitor in an outdoor environment, and only achieved a correlation of $R^2 = .63$. During previous accuracy testing, however, the Dylos was stationary. It is not known how movement may affect the accuracy of the Dylos.
Procedure.

The researcher collected air quality data along the ERT while introducing groups of undergraduate students to the ERT and to the ERT Ambassador program. The researcher’s bicycle, with the Dylos DC1700-PM mounted to it, was ridden from ODU either north or south (generally south), as shown in Figure 1, then back to the ODU. After each ride, the air quality data was downloaded as an Excel file. The temperature, cloud cover, and segments ridden were also recorded by the researcher after each ride. The Dylos monitor used was updated to version 2.09m, which automatically converted from particle count per cubic foot to micrograms per cubic meter. Additionally, this version is able to detect PM$_{2.5}$ and PM$_{10}$, whereas earlier versions only detected PM$_{2.5}$ and PM$_{0.5}$. 

Figure 2

*Dylos DC1700-PM mounted to bicycle for data collection.*
Phase 2

**Design.**

The second phase of the study used a cross-sectional design to assess ERT users’ subjective perceptions of the health benefits of the trail and of the air quality along the trail, to predict trail use frequency from these perceptions (Figure 3). In the Spring 2020, graduate students in the Park, Recreation, and Tourism Studies (PRTS) program distributed business cards with links to an online survey (ERT Survey) to participants recreating along the ERT. After the declaration of a national emergency due to the COVID-19 pandemic (Wainwright et al., 2020), on-site survey distribution was halted due to the adoption of social distancing measures and the survey links were distributed using social media chain referrals. The ERT Survey was a visitor use study developed in cooperation between ODU’s PRTS program and the ERT Foundation. The researcher was involved in the development and administration of this survey, and the perceived health and air quality data represent a subset of the data from this survey.

**Figure 3.**

*Conceptual Model of Phase 2*
Materials.

The Perceived Health Outcomes of Recreation Scale (PHORS; Gomez et al., 2016) was used to measure trail visitors’ perception of health benefits related to trail use. The PHORS measures perceived physiological and psychological health benefits using three sub-scales, Improvement (IMPV), Prevention (PREV), and Psychological (PSYC). The IMPV scale taps into the construct of improving physical health and fitness; the PREV scale taps into preventing poor health outcomes, such as diabetes; and the PSYC scales taps into psychological benefits, such as self-esteem. For example, an item from the IMPV scale is, “I visit the ERT because I feel it improves my overall health.” Items are scored on a 7-point Likert scale, with 1 indicating “Not like me at all” and 7 indicating “Very like me.” Based on Gomez et al.’s (2016) confirmatory factor analysis of the PHORS scale, 13 validated items of the original 16-item scale were used in this survey (see Appendix B). These 13 items were tested by Gomez et al. (2016) and found to have high factor loadings, ranging from .54 for Question 11 to .93 for Questions 1, 3, and 13. This indicates that the retained questions do a good job of explaining variance in the three factors (IMPV, PREV, PSYC) of perceived health benefits. Sub-constructs had high composite reliability, with Cronbach’s α ranging from .89 for IMPV to .91 for PREV. The three sub constructs also demonstrated good discriminant validity.

An Importance-Performance Analysis (IPA) was used to assess visitors’ perception of the importance and quality of experiential variables, such as trail cleanliness, fitness equipment, and directional signage. This section of the survey (Appendix C) listed several trail experience variables (n = 21) selected in consultation with the ERT Foundation and asked the user to rate them in importance and performance, on a Likert-type scale from 1-5, with 1 indicating “Extremely dissatisfied [with the variable]” or “[the variable is] extremely unimportant”, and 5...
indicating “Extremely satisfied” or “Extremely important.” The questions related to air quality asked for the importance of and for users’ satisfaction with “clean air”. Air quality items were framed consistently with previously validated items from a National Park Service clean air study (Kulesza et al., 2013). The importance question was used as a benchmark of the value of clean air to participants. The satisfaction question was used to assess participants’ perceptions of how ‘good’ or ‘bad’ air quality is along the ERT.

**Participants.**

Recreationists along the ERT were contacted in person from 28 February - 24 March 2020, after which participant recruiting continued online due to the COVID-19 pandemic, until 7 April 2020 (see Appendix D for demographic question). Participants (n = 215) were mostly white (94%), Norfolk residents (82%), with a four-year degree or higher (82.8%), female (62%), and aged 25-34 years (36.3%). Additionally, most participants reported an annual household income of over $50,000 (87.6%). Ethnicity/race and income diverged strongly from local demographics, as only 43.6% of Norfolk residents are white, and the median income is $49,146 (U.S. Census, 2018). The completion rate from on-site distribution was quite low, potentially due to the disruption caused by the COVID-19 pandemic that occurred just a week into data collection, while the response rate for online recruiting could not be estimated. Although participants were offered the opportunity to enter a drawing for a chance to win an ERT merchandise package at the end of the survey, this potential compensation was not mentioned prior to participants agreeing to complete the survey.
Procedure.

During the first part of data collection, pairs of ODU graduate students were stationed at trail heads and approached visitors to the ERT. The script for making contact was, “Hello, my name is ________, and I am a master student at Old Dominion University working with the Elizabeth River Trail Foundation, and we are conducting research to determine perceptions of the ERT. Are you willing to help by providing your email address and/or taking this business card to complete a survey?” Participants who chose to share their email address were emailed a link to the online survey. The entire survey consisted of 83 questions hosted on the Qualtrics survey tool. A total of 95 surveys were collected using this approach. After COVID-19 restrictions were emplaced on March 24, survey links were distributed using the ERT Foundation email listserve and a viral social media campaign through the ERT Facebook page, Instagram, Ghent Norfolk Facebook, Bike Norfolk, Hampton Road Cyclists, Social Cycling Norfolk, and West Gent Civic League. The use of local social media outlets may have affected the proportion of participants who were Norfolk residents. An additional 121 surveys were collected via online recruiting.
CHAPTER 4
JOURNAL ARTICLE: LANDSCAPE AND URBAN PLANNING
AIR POLLUTION AND OUTDOOR RECREATION ON URBAN TRAILS:
A CASE STUDY OF THE ELIZABETH RIVER TRAIL, NORFOLK, VA

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Research Highlights

- Air quality exhibits unexpected temporal variations
- Urban trail users value clean air, but visitation does not vary due to perceived air quality
- Perceived health outcomes of recreation significantly predict urban trail use
- Experiential factors likely have a complex relationship with recreational choices
Abstract

Poor air quality represents a significant health risk for individuals recreating outdoors in urban parks and trails. Both temporal trends in and exposure to air quality in urban parks and protected areas are neglected areas of research. The goal of this study was to investigate temporal variability in exposure to air quality (i.e., particulate matter) along an urban waterfront trail. We also aimed to investigate the impacts of trail users’ perceptions of air quality and health benefits on trail use. Particulate matter data (PM$_{2.5}$ and PM$_{10}$) were collected for 10 weeks during the fall of 2019. Average air quality during the collection period was “good” (PM10) to “moderate” (PM$_{2.5}$). A visitor use survey was conducted three months later ($N = 185$), measuring perceived health outcomes, perceived air quality, and other experiential factors. Two repeated-measures ANOVAs were conducted to compare average PM density at different times of day and days of the week. PM density was significantly higher ($p < .001$), though still in the “moderate” range, between 7-9am, 11am-1pm, and 3-5pm, and on weekends. Perceived air quality and health outcomes were regressed onto self-reported trail use. Perceived health outcomes, but not perceived or preferred air quality, significantly predicted trail use. Results suggest that experiential factors may affect recreational choices depending on other factors, such as salience. Further research is merited to determine how experiential factors can best be integrated with other theories of motivation to understand recreational decision-making.

Keywords:
Air quality  Ecosystem services  Urban trails  Motivations  Perceived health  Outdoor Recreation
1. Introduction

Recreating outdoors confers psychological and physical health benefits (‘ecosystem services’; Millennium Ecosystem Assessment, 2005) beyond those associated with indoor exercise (Wolf et al., 2020). Outdoor recreation can be protective against conditions such as heart disease and diabetes, by reducing obesity, heart rate, blood pressure, and stress hormones such as adrenaline and cortisol; increasing heart rate variability; and improving immune response (Ghimire et al., 2017; Gladwell et al., 2012; Laumann et al., 2003; Li et al., 2011; Park et al., 2010). Outdoor recreation is especially well-known for conferring psychological and spiritual benefits, such as reduced depression, improved subjective well-being, spiritual well-being, and resilience, and increased self-esteem (Fong et al., 2018; Heintzmann, 2020; Rathmann, 2020).

When weighing cost-benefit decisions surrounding outdoor recreation, preferences and motivations for these benefits are key factors in recreationists’ choices (Goodall, 1991). For example, Asan and Emeksiz (2018) found that participating in nature recreation was significantly determined by motivations, such as those for relaxation, learning, and sociality, and by activity preferences (e.g., cultural or entertainment). Similarly, Whiting et al. (2017) examined recreation site choices and identified four motivational categories (social interaction, physical health and fitness, relaxation and restoration, and nature interaction) and three site-related preferences (natural, maintained, or developed sites), which significantly affected site choice.

Despite the multiple benefits conferred from outdoor recreation, natural environments where recreation takes place may also feature what has been referred to as “ecosystem disservices,” (Blanco et al. 2019; p. 3) or “functions, processes and attributes that [result] in perceived or actual negative impacts on human well-being” (Shackleton et al., 2016; p. 591). Poor air quality is one such ecosystem disservice, one of the greatest environmental health risks
of the 21st century (Ebenstein et al., 2017). Air quality has been linked to stroke, respiratory diseases, and cardiovascular diseases (Cohen et al., 2017). For example, ozone exacerbates respiratory conditions such as asthma and COPD (Khaniabadi et al., 2017). Particulate matter is especially strongly linked to increased risk of heart attack, arrhythmia, heart failure, and stroke (Hayes et al., 2020). Di et al. (2017) found an increased risk of all-cause mortality associated with PM$_{2.5}$ and O$_3$ among sensitive populations (minority and low-income), even at concentrations below the U.S. Environmental Protection Agency’s (EPA) health standards.

Accordingly, recent research has suggested that awareness of poor air quality can discourage people from exercising outdoors (Bunds et al., 2019). As a result, it is important to understand how air quality (perceived or actual) affects outdoor recreationists’ decision-making. Existing literature suggests research gaps, such as regional and temporal air quality variance (Rickenbacker et al., 2019), recreationists’ perceptions of air quality (Zajchowski et al., 2018), and perceived health benefits of outdoor recreation (Wolter et al., 2019). Understanding outdoor recreationists’ air quality perceptions and perceived health benefits can provide an indication of relevant preferences and motivations in conditions of varying air quality, which, in turn, may explain the effects of air quality on urban trail visitation (Jiang et al., 2019). This information can help managers of parks and protected areas and urban green spaces to inform visitors and plan for and mitigate the effects of air pollution (Hewitt et al., 2019). Therefore, the purpose of this investigation is to understand the role of air quality and health perceptions in determining frequency of use of an urban waterfront trail in Norfolk, Virginia, U.S.. The following sections review definitions of air quality, how recreational choices have been modeled, and recreational choice and perceived health conceptualizations for the current study.
2. Air Quality

Air quality is affected by natural and anthropogenic sources, but anthropogenic pollution (i.e., factory emissions) currently exceed natural sources (i.e. dust) and have come under increasing global scrutiny (Kuklinkska et al., 2015; Tiwary et al., 2018). Although over 187 ambient pollutants have been identified, the U.S. EPA’s Air Quality Index (AQI) focuses on five: particulate matter (PM$_{2.5}$ and PM$_{10}$), CO, SO$_2$, O$_3$, and NO$_2$ (AirNow, 2020; Office of Air Quality Planning and Standards, 2014). These criteria pollutants have been strongly linked to negative health outcomes and are largely anthropogenic in origin (Sun & Zhu, 2019; Tiwary et al., 2018). For example, PM$_{2.5}$ and PM$_{10}$ are airborne particles smaller than 2.5 µm and 10 µm, respectively. Due to their size, these particles bypass lung filtration and irritate the respiratory tract (Tiwary et al., 2018; Ware, 2000). PM is more strongly linked to increased risk of death from any cause than any other ambient pollutant (Ware, 2000). PM measurement has attracted global attention due to increased awareness of health risks and the lack of improvement in PM levels relative to other pollutants (Ferrante et al., 2012). Although there has been some improvement in larger PM, partly due to cyclic reduction in natural sources, smaller and largely anthropogenic PM rose between 2000-2010 (Ferrante et al., 2012).

Poor air quality is the fifth leading factor in premature death across the globe, linked to stroke and respiratory and cardiovascular diseases (Institute for Health Metrics and Evaluation, 2017). Outdoor exercise exacerbates the effects of air pollution due to increased respiration (Daigle et al., 2003). However, inequities exist, with vulnerable populations often disproportionately exposed, and large disparities in air quality across geographic areas (Boyce, 2020; World Air Quality Index Project, 2020). Most research on air quality, health, and averting behaviors focuses on high-visibility locations such as Beijing or large geographical regions (i.e.,
nations; e.g., Yu et al., 2017). For example, Chen and Lin (2016) found that Chinese participants were significantly more concerned with air quality than South Korean participants.

While this research is valuable, it may obscure other regional or local trends in air quality or similar geographies of aversion behaviors. Additionally, there is emerging evidence that peoples’ perceptions do not accurately reflect local air quality, potentially resulting in unnecessary avoidance of outdoor recreation (Borbet, 2018; Paas et al., 2016). As mobile apps and recent headlines make AQI more accessible and salient to the public (e.g., Mishanec, 2020), studies suggest that air quality is of increasing concern to urban residents (Bunds et al., 2019; Kukinska et al., 2015). For example, an adaptive choice study found that air pollution and other environmental factors were significantly more important to participants when choosing a walking route than time or distance (Bunds et al., 2019). Since urban areas experience significantly worse air quality than rural areas (Strosnider et al., 2017), and given the importance of urban parks and trails to achieving health benefits (Larson et al., 2016), it is important to understand how perceptions of air quality influence urban residents’ recreational choices.

3. Theoretical Frameworks for Recreational Choice and Desired Attributes

Recreational choices are often driven by motivations. Theories to explain motivations include Expectancy-valence theory (EVT), the push-pull model, and the experiential approach (Dann, 1977; Driver, 1977; Vroom, 1964). EVT (Vroom, 1964) explains motivation in terms of valence (value of a reward), expectancy (perception of effort), and instrumentality (self-efficacy). The push-pull and experiential models, on the other hand, attempt to predict motivation through the preferences that motivations are generally believed to affect (Rice et al., 2020). Dann (1977) defined push factors as personal preferences, whereas pull factors are
attributes of the recreation site. These factors, such as weather and particulate matter (e.g., Zhang & Smith, 2018) are suggested to determine travel and recreation site choices. A different approach, proposed by Driver (1977), focuses on experiential factors linked to desired outcomes. This framework suggests that choice is driven by preferences for these experiential factors, which in turn are driven by motivations for different outcomes (Whiting et al., 2017). Previous research on urban trail use focused on motivations, preferences, and constraints, but not experiences (e.g., Keith et al., 2018); indeed, Larson et al. (2016) expressed surprise that experiential benefits emerged as the most important ecosystem service category among urban trail users.

In this study we employed both EVT and the experiential approach to explore the role of air quality and individuals’ perceptions in their outdoor recreation visitation. First, the Perceived Health Outcomes of Recreation Scale (PHORS) measures the valence, expectancy, and instrumentality of health outcomes in recreational settings to predict motivation (Gomez et al., 2016). Health-related motivations are particularly relevant for urban trail users, since users must weigh the risks of potential negative health (i.e., air pollution) against the health benefits of outdoor activity. The PHORS has not previously been applied to examining user experiences on urban trails. Urban trails often feature fewer facilities or natural settings (Reynolds et al., 2007), thus, it is important to investigate other types of benefits that can be offered. Psychological and physiological benefits can be realized with fewer resources, and, depending on how visitors view and experience these benefits, managers can focus limited resources on improving the visitor experience. Second, Importance-Performance Analyses (IPAs) are a common tool for studying values and perceptions of experiential factors (Martilla & James, 1977). In the outdoor recreation and park and protected area studies, IPAs also help managers decide where to invest limited
resources (Draper, 2016; Frauman & Banks, 2011) by assessing both the importance of specific experiential attributes and agency performance in managing these attributes. Thus, the inclusion of these additional subjective perceptions in this study allows for actionable management implications related to air quality and other experiential variables of importance.

4. Research Questions.

Accordingly, this study aims to answer the following research questions:

1. What is the exposure to PM$_{2.5}$ and PM$_{10}$ for outdoor recreationists using an urban waterfront trail?
   a. Is there significant temporal variability in PM$_{2.5}$ and PM$_{10}$ exposure?
2. Do subjective perceptions of air quality and health benefits influence trail use?
   a. Do perceptions appear to generally align with EPA Air Quality Index values?

5. Methods

To answer these questions, this study focused on the Elizabeth River Trail (ERT), in Norfolk, Virginia, and was conducted in two phases. The first phase focused on assessing temporal variability in exposure to PM$_{2.5}$ and PM$_{10}$ along this urban, waterfront trail. The second phase investigated to what degree visitors’ subjective air quality and health perceptions predicted the frequency of visitation and aligned with objective measurements.

5.1. Study site, respondents, and procedure

The Elizabeth River Trail (ERT) is the longest urban trail (16.9 km) in Norfolk, Virginia. Norfolk is a highly-industrialized, major port city in the southeastern U.S., with a high concentration of low-income (20% below poverty line) and minority (57%) populations, who are
statistically more-vulnerable to air pollution (Boyce, 2020; U.S. Census Bureau, 2019). The ERT runs along the Elizabeth River near the Norfolk International Port and the largest coal shipping terminal in the U.S. (Grymes, 2019). The nearby Norfolk Southern coal terminal receives over 200,000 coal cars annually (Grymes, 2019), all uncovered and blowing an estimated 500 lbs. of coal dust off each car (Lyon, 2016). Although a 2017 Virginia Department of Health study found that PM$_{10}$ near Lambert’s Point remained in the EPA’s “good” range, local residents have repeatedly expressed concerns (AP, 2015; Dixon, 2018). This makes independent monitoring of air quality conditions vital to understanding local air quality trends and impacts on recreationists’ choices.

5.2. Instrumentation

5.2.1. Mobile monitoring

For the first phase of this study, air quality data was collected in two-hour time blocks (i.e., 7am-9am, 9am-11am, 11am-1pm, 1pm-3pm, and 3pm-5pm) for 10 weeks from September through November, 2019. Stratified sampling (by day of the week and time of day) was used to ensure that an equal number of time blocks were collected for each weekday and time block across the sampling period. A Dylos DC1700-PM mobile air quality monitor mounted to a bicycle was used to collect time-stamped PM$_{2.5}$ and PM$_{10}$ simultaneously, in $\mu$g/m$^3$, sampling once per minute. The Dylos is a laser particle counter that assesses particles crossing a sharp, defined optical volume, based on the number and intensity of scattering light signals caused by each particle. Equating impulse intensity to particle size, the Dylos determines how many particles in each size range are present (e.g., Shen et al., 2019). Time and day of collection were staggered to ensure a representative sampling of air quality across the collection period and under different conditions. Since collection of the entire trail length was sometimes impossible,
collection was focused on the central section (highlighted in yellow on Figure 1), due to the relatively higher visitor use observed in this area by trail counters (Santos, 2020) and the presence of potential pollutant sources, such as the Norfolk Southern coal terminal at Lambert’s Point, the nearby Norfolk International Port, and the Portsmouth Marine Terminal located across the Elizabeth River from the Lambert’s Point area. Transient winds could also bring additional particulate matter into the area from surrounding industrial facilities or local transportation corridors (i.e., Hampton Boulevard), potentially worsening PM values along the ERT.

5.2.2. Visitor survey

For the second phase, a visitor use survey was distributed to visitors along the ERT in March 2020. The survey was developed in cooperation between a local academic institution and the ERT Foundation and contained items related to visitors’ perceptions of health outcomes of recreation (PHORs), importance and performance of experiential variables, including air quality data.

The PHORS, a 13-item questionnaire used to measure perceived health outcomes, includes three sub-scales, Improvement (IMPV), Prevention (PREV), and Psychological (PSYC). The IMPV scale measures subjective perceptions of the role of recreational resources in improving physical health and fitness; the PREV scale taps into preventing poor health outcomes, such as diabetes; and the PSYC relates to psychological benefits, such as self-esteem. For example, an item from the IMPV scale is, “I visit the ERT because I feel it improves my overall health.” Items are scored on a 7-point Likert scale, with 1 indicating “Not like me at all” and 7 indicating “Very like me.” Based on Gomez et al.’s (2016) confirmatory factor analysis of the PHORS scale, 13 validated items of the original 16-item scale were used in this survey (see
Appendix B). These 13 items were tested by Gomez et al. (2016) and found to have high factor loadings, ranging from $\lambda = .54$ to $ .93$, and reliability, ranging from Cronbach’s $\alpha = .89$ to $.91$.

**Figure 1**

*Map of the Elizabeth River Trail with data collection section.*

Source: Original graphic created in Google Maps.

The Importance-Performance Analysis (IPA) was used to assess visitors’ perception of the importance and quality of experiential variables, such as air quality, trail cleanliness, trail safety, and the condition of the trail surface. This section of the survey listed several trail
experience variables (n = 21) and asked the user to rate them in importance and performance on a Likert-type scale from 1-5, with 1 indicating “Extremely dissatisfied [with the variable]” or “[the variable is] extremely unimportant”, and 5 indicating “Extremely satisfied” or “Extremely important”. Trail visitors’ perceptions of air quality, therefore, were operationalized as satisfaction with air quality along the trail during their most recent visit.

Initially, in-person contacts were used to recruit participants along the trail, by distributing business cards with links to the online ERT Survey. After the declaration of a national emergency on March 13, 2020 due to the COVID-19 pandemic (Wainwright et al., 2020), on-site survey distribution was halted to comply with the adoption of social distancing measures, and convenience sampling was used to distribute the ERT survey links through social media (i.e., Instagram, Facebook) and the email listserve of the ERT Foundation. On-site sampling had a low completion rate (20.2%) compared to the overall completion rate for those who accessed the online survey (61.8%).

5.2.2. Data Analysis

5.2.2.1. Phase 1

All analyses were conducting using IBM SPSS Statistics 27.0, and the criterion for statistical significance was 𝑝 ≤ .05. Outliers were not excluded, since PM measurement and classification can be imprecise, and apparent outliers may reflect real variations in air quality (Jovasevic-Stojanovic et al., 2015). Statistical assumptions for analysis of variance (ANOVA) were tested. Although the air quality data were significantly non-normal, the Shapiro-Wilk test is overly sensitive for large sample sizes; therefore, skew and kurtosis were used to evaluate
normality (Yap & Sim, 2011). Kurtosis values were high for both PM$_{2.5}$ (6.53) and PM$_{10}$ (10.96), so a square root transformation was used to reduce the kurtosis of PM$_{2.5}$ to .92 and PM$_{10}$ to 2.26.

5.2.2.2. Phase 2

A total of 346 trail users accessed the online survey, and 214 questionnaires were completed over 37 days of sampling for an overall completion rate of 61.8%. The response rate from on-site distribution was quite low (20.2%), potentially due to the disruption caused by the emerging COVID-19 pandemic that occurred during the onsite data collection period, while the response rate for online recruiting could not be estimated. Items with missing answers were deleted listwise, leaving $N = 185$ responses for further analyses. Descriptive statistics were used to assess demographic characteristics of the sample and for the PHORS and IPA survey sections. Next, multiple regression was used to test the degree to which air quality and health perceptions predict frequency of trail use.

6. Results

6.1. Phase 1

The average for PM$_{2.5}$ across the entire collection period was 14.59 $\mu$/m$^3$ ($SD = 8.65$), or ‘moderate’ according to the US EPA’s AQI scales (see Figures 2-5). PM$_{10}$ was 37.89 $\mu$/m$^3$ ($SD = 29.07$) on average, or ‘good’. However, extreme outliers (i.e., Sunday PM$_{10} = 195.3$ $\mu$/m$^3$) surpassed the ‘unhealthy’ air quality threshold during peak pollution periods. PM$_{2.5}$ readings peaked between 11:00 am-1:00 pm ($M = 18.26$ $\mu$/m$^3$) and 3:00-5:00 pm ($M = 14.94$ $\mu$/m$^3$). PM$_{10}$ readings peaked between 7:00-9:00 am ($M = 40.22$ $\mu$/m$^3$) and 11:00 am-1:00 pm ($M = 52.49$ $\mu$/m$^3$). PM readings were also higher on Saturdays ($M = 20.75$ $\mu$/m$^3$ [PM$_{2.5}$], 60.56 $\mu$/m$^3$ [PM$_{10}$]) and Sundays ($M = 23.84$ $\mu$/m$^3$ [PM$_{2.5}$], 68.84 $\mu$/m$^3$ [PM$_{10}$]) than weekdays.
Figure 2.

*Mean Concentrations of PM$_{2.5}$ by Time Block*

![Bar chart showing PM$_{2.5}$ concentrations by time block with error bars indicating 95% C.I.](chart.png)

*Note:* Error bars represent 95% C.I. *Concentration in µg/m$^3$.*

Figure 3.

*Mean Concentrations of PM$_{10}$ by Time Block*

![Bar chart showing PM$_{10}$ concentrations by time block with error bars indicating 95% C.I.](chart.png)

*Note:* Error bars represent 95% C.I. *Concentration in µg/m$^3$.*
Figure 4.

*Mean Concentrations of PM$_{2.5}$ by Day of Week*

![Bar chart showing PM2.5 concentrations by day of week.]

**Note:** Error bars represent 95% C.I. *Concentration in µg/m$^3$.

Figure 5.

*Mean Concentrations of PM$_{10}$ by Day of Week*

![Bar chart showing PM10 concentrations by day of week.]

**Note:** Error bars represent 95% C.I. *Concentration in µg/m$^3$.
One-way repeated-measures ANOVAs were conducted to compare pollution levels across days of the week and time block (see Table 1). Since the assumption of sphericity was violated for all tests, the Greenhouse-Geisser correction was used to interpret results. Fine particulate matter (PM$_{2.5}$) was significantly higher between 3:00-5:00pm ($M = 14.94$ μ/m$^3$, $SD = 6.39$) and between 11:00am-1:00pm ($M = 18.26$ μ/m$^3$, $SD = 13.85$) than all other times, $F(2.58, 1289.16) = 31.40$, partial $\eta^2 = .06$, $p < .001$. Coarse particulate matter (PM$_{10}$) was significantly higher at 7:00-9:00am ($M = 40.22$ μ/m$^3$, $SD = 33.43$) and 11:00am-1:00pm ($M = 52.49$ μ/m$^3$, $SD = 58.90$), and significantly lower at time 9:00-11:00am ($M = 29.85$ μ/m$^3$, $SD = 18.50$), $F(1.95, 970.75) = 38.61$, partial $\eta^2 = .07$, $p < .001$.

Table 1.  

**ANOVA Summary for Air Quality by Time Block and Day of Week**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Sum of Squares</th>
<th>$df$†</th>
<th>Mean Square</th>
<th>$F$</th>
<th>$p$</th>
<th>$\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time Block</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM$_{2.5}$</td>
<td>9888.289</td>
<td>2.58</td>
<td>3827.49</td>
<td>31.40</td>
<td>.000**</td>
<td>.059</td>
</tr>
<tr>
<td>PM$_{10}$</td>
<td>161335.58</td>
<td>1.95</td>
<td>82931.94</td>
<td>38.61</td>
<td>.000**</td>
<td>.072</td>
</tr>
<tr>
<td>Error PM$_{2.5}$</td>
<td>157138.56</td>
<td>1289.16</td>
<td>121.89</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error PM$_{10}$</td>
<td>2085319.83</td>
<td>970.75</td>
<td>2148.15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Day of Week</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM$_{2.5}$</td>
<td>46163.22</td>
<td>3.38</td>
<td>13667.51</td>
<td>114.10</td>
<td>.000**</td>
<td>.329</td>
</tr>
<tr>
<td>PM$_{10}$</td>
<td>450698.73</td>
<td>2.50</td>
<td>180008.71</td>
<td>77.76</td>
<td>.000**</td>
<td>.250</td>
</tr>
<tr>
<td>Error PM$_{2.5}$</td>
<td>94270.34</td>
<td>786.98</td>
<td>117.85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Error PM$_{10}$</td>
<td>1350542.85</td>
<td>583.38</td>
<td>2315.05</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note:* †All reported degrees of freedom are Greenhouse-Geisser corrected. **$p < .001$  

In terms of day of the week, fine particulate matter (PM$_{2.5}$) dropped significantly from Monday ($M = 12.97$ μ/m$^3$, $SD = 7.61$) to Tuesday ($M = 9.10$ μ/m$^3$, $SD = 5.59$), then rose significantly from Wednesday ($M = 12.25$ μ/m$^3$, $SD = 8.22$) through Sunday ($M = 23.84$ μ/m$^3$, $SD = 13.68$), $F(3.38, 786.98) = 114.10$, partial $\eta^2 = .33$, $p < .001$. Coarse particulate matter (PM$_{10}$) dropped significantly from Monday ($M = 31.50$ μ/m$^3$, $SD = 19.57$) to Wednesday ($M =
23.51 μ/m³, SD = 14.93), then rose significantly from Thursday (M = 29.19 μ/m³, SD = 29.35) through Sunday (M = 68.84 μ/m³, SD = 59.70), F(2.50, 583.38) = 77.76, partial η² = .25, p < .001.

6.2. Phase 2

6.2.1. Demographics

Participants (n = 185) were mostly white (94%), Norfolk residents (82%), with a four-year degree or higher (82.8%), female (62%), and aged 25-34 years (36.3%). Additionally, most participants reported an annual household income of over $50,000 (87.6%). Ethnicity/race and income diverged strongly from local demographics, as only 43.6% of Norfolk residents were white, and the median household income was $49,146, as of 2017 (U.S. Census, 2018). The average participant reported visiting the trail 78.09 (SD = 88.09) times over the past year, 4.22 (SD = 1.23) times per month on average, and 2.47 (SD = 1.87) times per week on average, suggesting that most visitors sampled frequently incorporate the ERT into their recreation or fitness routines.

6.2.2. Descriptive Statistics

Air quality perceptions (IPA) and health perceptions (PHORS) were both normally distributed, according to the Shapiro-Wilk test. The IPA data did not contain any significant outliers, and skew (-1.68) and kurtosis (4.08) values were acceptable. The PHORS data were also assessed for non-normality by testing the skewness and kurtosis of individual items (Osborne, 2012), resulting in the removal of two outliers. Annual trail use was also normally distributed, with low skew and kurtosis values.
The average PHORS composite score was 5.3 (SD = 1.35) on a seven-point scale, indicating that most trail users perceived important health benefits from trail use. Descriptive statistics for the PHORS are listed in Table 2. Participants rated Questions 1 (I visit the ERT because I feel it improves my overall fitness) and 3 (I visit the ERT because I feel it improves my overall health) highest, $M = 6.32$ and 6.39, respectively (Table 2). Question 11 (I visit the ERT because I feel it reduces my chance of developing diabetes) had the lowest average rating ($M = 4.39$). Physiological improvement (i.e., fitness) was the highest perceived benefit ($M = 6.01$), while prevention of negative health outcomes was the lowest perceived benefit ($M = 4.61$).

Table 2.

*Descriptive Statistics for PHORS Constructs*

<table>
<thead>
<tr>
<th>Construct</th>
<th>$M$</th>
<th>$SD$</th>
<th>Cronbach’s $\alpha$</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMPV</td>
<td>6.01</td>
<td>0.99</td>
<td>.94</td>
</tr>
<tr>
<td>PSYC</td>
<td>5.33</td>
<td>1.38</td>
<td>.73</td>
</tr>
<tr>
<td>PREV</td>
<td>4.61</td>
<td>1.67</td>
<td>.92</td>
</tr>
<tr>
<td>Overall</td>
<td>5.32</td>
<td>1.35</td>
<td></td>
</tr>
</tbody>
</table>

Trail users indicated a high level of satisfaction with air quality along the trail, with an average rating of 4.38 (SD = .91) on a five-point scale, with only 1.9% of respondents rating air quality extremely bad (1 on a 5-point scale) compared with 58% rating air quality extremely good (5 on a 5-point scale). The importance of air quality was rated even higher, at 4.6 on average (SD = .66), indicating that most trail users valued clean air (see Figure 6). Although this study focused on air quality, a variety of items related to trail experience were also measured. For example, similar experiential factors were also rated highly, including cleanliness of trail ($M = 4.37, SD = .85$), trail safety ($M = 4.24, SD = .88$), and condition of trail surface ($M = 4.18, SD = .96$). Drinking water and restroom availability, by contrast, received low satisfaction ratings (drinking water $M = 2.33, SD = .96$; restrooms $M = 2.24, SD = .95$), and were of high importance.
to users (drinking water $M = 4.30$, $SD = .79$; restrooms $M = 4.30$, $SD = .84$). The average participant reported visiting the trail 78.09 (SD = 88.09) times over the past year, suggesting that most visitors frequently incorporate the ERT into their recreation or fitness routines.

Figure 6

*Importance-Performance Analysis Coordinate Plane of the Values of Elizabeth River Trail Users*

![Importance-Performance Analysis Coordinate Plane of the Values of Elizabeth River Trail Users](image)

*Note:* Original values were on a 1-5 scale, 1 = *Extremely dissatisfied/unimportant* and 5 = *Extremely satisfied/important*, but were transformed to a –2 to 2 scale to better illustrate the spread of the data.

6.2.3. Inferential Statistics

To assess the effects of perceived air quality and health benefits on trail use, the IPA ‘clean air’ satisfaction item and PHORS scores were regressed onto reported usage (Table 3). The clean air variable was entered first, to best be able to detect an effect. The model predicting usage from clean air scores was not significant, $F(1, 183) = .313$, $p = .577$. However, the model predicting usage from both clear air and PHORS was significant, $F(2, 182) = 4.05$, $p = .019$. For each one-point increase in PHORS score, annual trail use increased by 18.63 visits, $t = 2.79$, $p =$
.006. These results suggest that although trail users value clean air, they do not consider air quality when choosing to use the trail. It is also possible that decision-making is influenced more by motivations (modeled by the PHORS) than by preferences for clean air.

Table 3.

Regression Analysis Summary for IPA and PHORS Predicting Trail Use

<table>
<thead>
<tr>
<th>Variable</th>
<th>B</th>
<th>95% CI</th>
<th>β</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>53.31</td>
<td>[-36.86, 143.48]</td>
<td>1.18</td>
<td>.245</td>
<td></td>
</tr>
<tr>
<td>Clean Air</td>
<td>5.54</td>
<td>[-14.00, 25.08]</td>
<td>.041</td>
<td>.56</td>
<td>.577</td>
</tr>
<tr>
<td>Step 2</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constant</td>
<td>-30.39</td>
<td>[-136.91, 76.13]</td>
<td>-.56</td>
<td>.574</td>
<td></td>
</tr>
<tr>
<td>Clean Air</td>
<td>2.25</td>
<td>[-17.08, 21.58]</td>
<td>.017</td>
<td>.23</td>
<td>.819</td>
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<tr>
<td>PHORS</td>
<td>18.63</td>
<td>[5.45, 31.80]</td>
<td>.20</td>
<td>2.79</td>
<td>.006</td>
</tr>
</tbody>
</table>

Note. ‘Clean Air’ indicates the ‘Satisfaction with Clean Air’ item from the survey IPA section. R^2 adjusted = -.004 (Step 1) and .032 (Step 2), respectively. CI = confidence interval for B.

7. Discussion

This study illustrated the importance of understanding regional air quality exposure and urban park and protected area visitors’ motivations and preferences. The average concentration of both fine and coarse particulate matter across the collection period was within the EPA’s ‘good’ or ‘moderate’ ranges, suggesting that trail users are generally able to experience clean air while recreating. This is an important finding, given local concerns over the coal terminal and shipping port (Dixon, 2018), and the large number of locals residing in close proximity (33,409 within 1 mile of the terminal, according to geospatial data from the 2017 U.S. Census; Maptive, 2020). However, there was significant temporal variability in air quality, with the lunch hour (11am-1pm) and weekends exhibiting significantly higher particulate matter values than other
days and times. This was contrary to expectations; for example, PM$_{2.5}$ was significantly lower (better air quality) during morning rush hour (7-9 am), and PM$_{10}$ was significantly lower (better air quality) leading into evening rush hour (3-5pm), despite increased traffic volumes during those times (Belfield et al., 2020). This could be partly explained by local emission source patterns. For example, PM$_{2.5}$ is more often due to anthropogenic activities (Ferrante et al., 2012), and could rise throughout the day due to industrial emissions, while PM$_{10}$ might be more closely linked to vehicle traffic or other emission sources. However, both PM$_{2.5}$ and PM$_{10}$ rose significantly on weekends, suggesting that other activities may contribute more to air pollution than daily work activities. Regardless of source attribution, however, this information can help trail users avoid peak pollution times/days, and could also help future investigators elucidate key emissions sources.

Although neither models with subjective perceptions (satisfaction) nor preferences for (importance) air quality were significant, the effects of health motivations on trail use were significant and coincided with previous research (e.g., Gomez & Hill, 2016). These results suggest that while trail users value clean air, they may not consciously consider this factor when deciding when and how frequently to recreate on the ERT. A potential inference, in light of similar previous research (e.g., Zhang & Smith, 2018), is that expectancy-valence theory (operationalized as PHORS in this study) is a superior predictor of recreation choices compared to experiential factors (e.g., air quality). However, in light of experiential and outcomes/benefits-based research such as that of Whiting et al. (2017) and Larson et al. (2016), another possibility is that experiential benefits are subsumed within valence, with varying degrees of salience to the recreationist. Thus, air quality could be important to the recreationist, but not salient when the air quality is perceived as good, as in the current study; whereas other factors, such as proximity to a
park or trail, may be equally important yet more salient and therefore better predictors of park/trail use. Health benefits may be more salient to recreationists, especially within a group of avid trail users, explaining why the PHORS was such a good (medium effect size) predictor of ERT use frequency.

Participants were generally satisfied with the air quality along the trail, uniformly rating their satisfaction with clean air highly. Since average air quality during the collection period was in the ‘Good’ to ‘Moderate’ range, this suggests that participants’ perceptions of air quality were well aligned with measured air quality. Participants also rated the value of clean air highly, suggesting that managers would do well to pay attention to this experiential variable.

8. Implications

Although certain studies noted that perceptions of air quality poorly correlate with actual air quality (e.g., Prophet et al., 2018), the current findings failed to support this. Participants uniformly perceived air quality as ‘Good,’ and average air quality readings throughout the collection period were indeed within the ‘Good’ to ‘Moderate’ range. This does not, however, eliminate the possibility that air quality preferences and perceptions could affect trail use if users perceived air quality as poor. Nonetheless, for trail users particularly sensitive to air quality, managers could provide more awareness of air quality, such as through social media, signage, or marketing, to trail users. Since the ERT’s air quality is quite ‘Good’ on average, this would generally reflect well on the ERT while allowing trail users to avoid peak air pollution times. For example, Badlands National Park, Theodore Roosevelt National Park, and Wind Cave National Park are among those that participate in the National Park Service’s air quality monitoring program (NPS, 2018). Parks that monitor air quality often alert visitors of degraded AQ using
advisories at entrance stations and visitor centers, local media, and park websites and social media pages. Recreation professionals at those locations with regular advisories report that recreationists may reschedule park visits or substitute indoor recreation activities in response to AQ advisories (Zajchowski et al., 2019)

Despite the ‘Good’ particulate matter values measured in this setting, it would be worthwhile for park and protected area managers to consider installing their own air quality monitors, such as stationary monitors for 24-hour monitoring (i.e., PurpleAir\(^3\)). This would allow managers to keep visitors informed, raise awareness of air quality, and if needed, conduct their own air quality research or identify key local emissions sources. Local air quality can differ significantly within a few miles depending on weather conditions and pollution emitters; for example, on 5 November 2020, PM\(_{2.5}\) measured by PurpleAir monitors in Rock Hill, SC (PM\(_{2.5}\) = 136 μm/m\(^3\)) was 8.5 times higher than in Hancock, SC (PM\(_{2.5}\) = 16 μm/m\(^3\)), 11 miles away.

The motivational influence of health benefits illustrated by this and previous research (e.g., Hill et al., 2018) suggests that managers should target fitness facilities and health information in their media, marketing, and resource allocations. For example, the National Recreation and Park Association’s three pillars are conservation, health and wellness, and social equity (Gomez & Hill, 2016). Private-public partnerships such as the ERT might do well to leverage this approach, both to demonstrate the health benefits existent in the resource, attract users and to secure funding opportunities.

Since air quality and health are closely aligned, items related to respiratory illness would add to the health perceptions aspect of the PHORS as well as providing a useful measure for

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\(^3\) https://www.purpleair.com/map?opt=1/mAQI/a10/cC0#10.09/36.9744/-76.276
future research on air quality perceptions. By tapping into the motivational construct, such an expanded scale might better be able to tap into impacts of health-related air quality perceptions on outdoor recreation choices.

9. Limitations

Since the EPA’s AQI categories are designed for a 24-hour collection period, whereas the PM concentration in this study was only collected for two hours per day, the conclusions regarding average air quality should be interpreted cautiously. For example, the maximum PM$_{2.5}$ and PM$_{10}$ values recorded during the collection period exceeded the “Unhealthy for Sensitive Groups” category, which could indicate poorer AQI if sustained over 24 hours. Another limitation is that Dylos air quality readings were not compared to a nearby reliable, stationary monitor, such as the GRIMM to ensure accuracy. Additionally, the natural variability in weather conditions, such as wind, temperature, and inversions, were not controlled for in the statistical analyses, and might have helped to explain the temporal patterns in air quality. Future research could improve on the accuracy of the data collection methods in this study by conducting comparisons with stationary air quality monitors such as the GRIMM, and by statistically controlling for local weather conditions by adding these variables to air quality models. Additionally, AQ and survey data were collected three months apart; therefore, average air quality during the survey period could have been significantly different from the AQ results presented in this paper. This could have affected participants’ perceptions of air quality and future efforts could pair real-time air quality measurements with participants perceptions.

One limitation of the second phase of this study is that white, highly educated, female, and higher income participants were highly represented among survey respondents. This could
have been partly due to the on-trail recruiting at trailheads rather than at trail facilities, which tend to be preferred more by non-whites (Gobster, 2002). Conversely, this predominant demographic may be resultant of the shift in sampling strategies instituted due to COVID-19 pandemic; social distancing policies potentially skewed the sample towards a select group of especially dedicated trail users who regularly access social media sites associated with the ERT as opposed to the “average” ERT user. Future research should aim to replicate these findings to assess if recreationists are more demographically representative of the City of Norfolk or align with the results presented here. As communities of color are often the sites of environmental injustices (Parris et al., 2020) and the African American community of Lambert’s Point has historically addressed perceived issues of coal dust in the communities the ERT bisects (Mayfield, 2017), it is crucial that future efforts assure representation their perspectives on these important issues.

10. Conclusion

The purpose of the current study was to investigate particulate matter exposure and temporal air quality trends along an urban waterfront trail, as well as the impacts of perceived air quality and perceived health benefits on trail usage. In doing so, this study aimed to fill research gaps related to local air quality, as opposed to larger regional or country-level air quality research, and outdoor recreationists’ air quality perceptions, motivations, and preferences. Two conceptual frameworks were applied to explore motivations and preferences: EVT and experiential benefits theory. Experiential benefits have previously been identified for further research (Larson et al., 2016), but in this study, did not add significantly to the model predicting trail use. It is suggested that this framework be re-examined, to potentially identify experiential benefits as a complex component of EVT. Perceived health outcomes were significant
motivational predictor of trail use, corroborating previous research (Gomez & Hill, 2016).

However, the PHORS only explained 3.2% of the variance in trail use, so exploration of other potential factors is merited. Additional research is called for to help bring disparate frameworks such as push-pull theory, experiential benefits, and EVT into a unified motivational framework for recreation researchers.

11. References


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4 This list contains only references occurring within the journal article (Chapter 4).


12. Tables

1. ANOVA Summary for Air Quality by Time Block and Day of Week
2. Descriptive Statistics for PHORS Constructs and Questions with Factor Loadings
3. Regression Analysis Summary for IPA and PHORS Predicting Trail Use

13. Figures

1. Map of the Elizabeth River Trail with data collection section.
2. Boxplots of PM$_{2.5}$ by Time Block
3. Boxplots of PM$_{10}$ by Time Block
4. Boxplots of PM$_{2.5}$ by Day of Week
5. Boxplots of PM$_{10}$ by Day of Week
6. Importance-Performance Analysis Coordinate Plane of the Values of Elizabeth River Trail Users
REFERENCES


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5 This reference list includes all works cited throughout this document.


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APPENDIX A

IRB APPROVAL

OFFICE OF THE VICE PRESIDENT FOR RESEARCH

Old Dominion University

DATE: February 29, 2020

TO: Chris Zajchowski, Ph.D.

FROM: Old Dominion University Education Human Subjects Review Committee

PROJECT TITLE: Elizabeth River Trail Visitor Use Survey

REFERENCE #: [1665046-1]

SUBMISSION TYPE: New Project

ACTION: DETERMINATION OF EXEMPT STATUS

DECISION DATE: February 29, 2020

REVIEW CATEGORY: Exemption category # 2

Thank you for your submission of New Project materials for this project. The Old Dominion University Education Human Subjects Review Committee has determined this project is EXEMPT FROM IRB REVIEW according to federal regulations.

We will retain a copy of this correspondence within our records.

If you have any questions, please contact Laura Chezan at (757) 683-7055 or lchezan@odu.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within Old Dominion University Education Human Subjects Review Committee's records.
APPENDIX B
PERCEIVED HEALTH OUTCOMES OF RECREATION SCALE

The next block of questions are focused on the health and economic benefits of the ERT.

Using the scale from 1 to 7, where 1=Not like me at all and 7=Very like me, please indicate the extent to which you feel the statement reflects your opinion on the following topics

<table>
<thead>
<tr>
<th>I visit the ERT because I feel it improves my overall fitness</th>
<th>1 Not like me at all</th>
<th>2 Not like me</th>
<th>More or less not like me</th>
<th>4 Neutral</th>
<th>5 More or less like me</th>
<th>6 Like me</th>
<th>7 Very Like me</th>
</tr>
</thead>
<tbody>
<tr>
<td>I visit the ERT because I feel that improves my muscle strength</td>
<td></td>
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</tr>
<tr>
<td>I visit the ERT because I feel it improves my overall health</td>
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<tr>
<td>I visit the ERT because it gives me a sense of self-reliance</td>
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<tr>
<td>I visit the ERT because I recognize that it gives me a sense of higher self-esteem</td>
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<tr>
<td>I visit the ERT because I recognize that it causes me to appreciate life more</td>
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<tr>
<td>I visit the ERT because I recognize that it causes me to be more satisfied with my life</td>
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<tr>
<td>I visit the ERT because I recognize that it makes me more aware of who I am</td>
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<tr>
<td>I visit the ERT because I recognize that it is connected to other positive aspects of my life</td>
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<tr>
<td>I visit the ERT because I feel it reduces my number of illnesses</td>
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<tr>
<td>I visit the ERT because I feel it reduces my chances of developing diabetes</td>
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<tr>
<td>I visit the ERT because I feel it reduces my chances of having a heart attack</td>
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<tr>
<td>I visit the ERT because I feel it reduces my chances of premature death</td>
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<td></td>
</tr>
</tbody>
</table>
APPENDIX C

IMPORTANCE-PERFORMANCE ANALYSIS QUESTIONS

Using a scale from 1 to 5, where 1 = Extremely dissatisfied and 5 = Extremely Satisfied, how satisfied are you overall with the following trail conditions, amenities, business, and services on the ERT?

<table>
<thead>
<tr>
<th>Service/Condition</th>
<th>Extremely dissatisfied</th>
<th>Somewhat dissatisfied</th>
<th>Neither satisfied nor dissatisfied</th>
<th>Somewhat satisfied</th>
<th>Extremely satisfied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directional signage</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Information provided at trailheads</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Elizabeth River Trail website</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Condition of trail surface</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Trail safety</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Cleanliness of trail</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Clean air</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Scenic views</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Exhibits / interpretive panels</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Maintenance / Upkeep of trail facilities</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Restaurants / Dining opportunities along the trail</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Grocery Stores along the trail</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Overnight lodging (hotels / motels, bed &amp; breakfast facilities) along the trail</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Rimsite repair / Maintenance services along the trail</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
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</tr>
<tr>
<td>Drinking water availability along the trail</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Restroom availability along the trail</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Parking availability along the trail</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Fitness equipment along the trail</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Playground equipment along the trail</td>
<td>○</td>
<td>○</td>
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<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Kayak launches along the trail</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Public art along the trail</td>
<td>○</td>
<td>○</td>
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<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
Using the list below, please select the top five most important trail conditions, amenities, business, and services for your experience on the ERT? (Drag and drop selected items into the "Top 5" bin)

<table>
<thead>
<tr>
<th>Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directional signage</td>
</tr>
<tr>
<td>Information provided at trailheads</td>
</tr>
<tr>
<td>Elizabeth River Trail website</td>
</tr>
<tr>
<td>Condition of trail surface</td>
</tr>
<tr>
<td>Trail safety</td>
</tr>
<tr>
<td>Cleanliness of trail</td>
</tr>
<tr>
<td>Clean air</td>
</tr>
<tr>
<td>Overnight lodging (hotels / motels, bed &amp; breakfast facilities)</td>
</tr>
<tr>
<td>along the trail</td>
</tr>
<tr>
<td>Fitness equipment along the trail</td>
</tr>
<tr>
<td>Playground equipment along the trail</td>
</tr>
<tr>
<td>Kayak launches along the trail</td>
</tr>
<tr>
<td>Public art along the trail</td>
</tr>
<tr>
<td>Overnight lodging (hotels / motels, bed &amp; breakfast facilities)</td>
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<tr>
<td>along the trail</td>
</tr>
<tr>
<td>Bicycle repair / Maintenance services along the trail</td>
</tr>
<tr>
<td>Drinking water availability along the trail</td>
</tr>
<tr>
<td>Restroom availability along trail</td>
</tr>
<tr>
<td>Parking availability along the trail</td>
</tr>
<tr>
<td>Fitness equipment along the trail</td>
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<tr>
<td>Playground equipment along the trail</td>
</tr>
<tr>
<td>Kayak launches along the trail</td>
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<tr>
<td>Public art along the trail</td>
</tr>
</tbody>
</table>

Top 5
### DEMOGRAPHICS

In this final section, please provide some brief demographic information about you and your household.

**What is the 5-digit ZIP code of your permanent residence?**

**What year were you born?**

**What is your gender?**
- [ ] Male
- [ ] Female
- [ ] Other

**Have you ever served on active duty in the U.S. Armed Forces, Reserves, or National Guard?**
- [ ] Never served in the military
- [ ] Only on active duty for training in the Reserves or National Guard
- [ ] Now on active duty
- [ ] On active duty in the past, but not now
Which of the following best describes your race and/or ethnicity (select all that apply)

- White / Caucasian
- Black / African American
- Chinese
- Filipino
- Asian Indian
- Vietnamese
- Korean
- Japanese
- Other Asian
- Pacific Islander
- Samoan
- Native Hawaiian
- American Indian or Alaskan Native
- Mexican American or Chicano
- Puerto Rican
- Cuban
- Latinx
- Other

What is your highest completed level of education?

- Less than high school
- High school graduate
- Some college
- 2 year degree
- 4 year degree
- Graduate or professional degree
- Do not wish to answer

What was your household income during the past year?

- Less than $24,999
- $25,000 - $34,999
- $35,000 - $49,999
- $50,000 - $74,999
- $75,000 - $99,999
- $100,000 - $149,999
- $150,000 - $199,999
- $200,000 or more
- Do not wish to answer
### APPENDIX E

**SELF-REPORTED ERT USAGE**

#### How many visits have you made to the ERT since March 2019 (including this trip)?

<table>
<thead>
<tr>
<th>Number of visits</th>
</tr>
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<tr>
<td>0</td>
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</table>

#### Approximately how many years have you visited ERT (including this 2020)?

<table>
<thead>
<tr>
<th>Number of years</th>
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<tbody>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

#### In an average week, how often do you visit ERT? (please use the slider to select average number of days / week)

<table>
<thead>
<tr>
<th>Days</th>
</tr>
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<tbody>
<tr>
<td>0</td>
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</table>

#### In an average month, how often do you visit ERT? (please select average number of days / month)

- [ ] 0 days / month
- [ ] 1 day / month
- [ ] 2 days / month
- [ ] 3 days / month
- [ ] 4 or more days / month
<table>
<thead>
<tr>
<th>Feature</th>
<th>Extremely unimportant</th>
<th>Somewhat unimportant</th>
<th>Neither important or unimportant</th>
<th>Somewhat important</th>
<th>Extremely important</th>
</tr>
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<tbody>
<tr>
<td>Directional signage</td>
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<tr>
<td>Information provided at trailheads</td>
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<td>Elizabeth River Trail website</td>
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<tr>
<td>Condition of trail surface</td>
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<td>Trail safety</td>
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<td>Cleanliness of trail</td>
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<td>Clean air</td>
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<tr>
<td>Overnight lodging (hotels / motels, bed &amp; breakfast facilities) along the trail</td>
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<tr>
<td>Fitness equipment along the trail</td>
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<tr>
<td>Playground equipment along the trail</td>
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<tr>
<td>Kayak launches along the trail</td>
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<td>Public art along the trail</td>
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<td>Overnight lodging (hotels / motels, bed &amp; breakfast facilities) along the trail</td>
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<td>Bicycle repair / Maintenance services along the trail</td>
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<td>Drinking water availability along the trail</td>
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<td>Restroom availability along the trail</td>
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<td>Parking availability along the trail</td>
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<td>Fitness equipment along the trail</td>
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<td>Playground equipment along the trail</td>
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<td>Kayak launches along the trail</td>
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