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

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Abstract: Poor air quality represents a significant health risk for individuals engaging in recreation activities outdoors in urban parks and trails. This study investigated temporal variability in particulate matter (PM) exposure along an urban waterfront trail. We also used recreation choice frameworks to examine the effects of visitors' perceptions of air quality (AQ) and health benefits on trail use. Average air quality during the collection period was "good" (PM₁₀) to "moderate" (PM_{2.5}). We found that PM density was significantly higher ($p < 0.001$), though still in the "moderate" range, at 7–9 a.m., 11 a.m.–1 p.m., and 3–5 p.m., and on weekends. Visitors' self-reported perceptions of health outcomes, but not air quality, significantly predicted trail use. Results suggest that these experiential factors may affect recreational choices depending on other factors, such as salience. Further research is merited to determine how experiential factors can be integrated with other theories of motivation to understand recreational decision-making.

Keywords: air quality; particulate matter; urban trails; motivation; perceived health; outdoor recreation



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1. Introduction

Recreation activities outdoors confer psychological and physical health benefits beyond those associated with indoor exercise [1]. Outdoor recreation can be protective against 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 [2–6]. Outdoor recreation also confers psychological and spiritual benefits, such as reduced depression and improved subjective and spiritual wellbeing, resilience, and self-esteem [7–9].

However, natural environments can also expose recreationists to poor air quality (AQ). AQ has been linked to stroke, respiratory diseases, and cardiovascular diseases [10]. Particulate matter (PM) is especially strongly linked to increased risk of heart attack, arrhythmia, heart failure, and stroke; Di et al. found an increased risk of all-cause mortality associated with PM_{2.5} and O₃ among minority and low-income populations, even at concentrations below the US Environmental Protection Agency's (EPA) health standards [11].

Research suggests that perceived poor AQ can discourage people from exercising outdoors [12]. Preferences and motivations are key factors in recreationists' choices regarding outdoor recreation. For example, participation in outdoor recreation is significantly determined by motivations for relaxation, learning, and sociality, and by activity preferences (e.g., cultural or entertainment) [13]. Similarly, Whiting et al. examined recreationists' 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 [14].

Thus, it is important to understand how AQ (perceived or actual) affects recreationists' decision making. Existing literature suggests research gaps, such as temporal AQ variance [15], perceptions of AQ [16], and perceived health benefits of outdoor recreation [17].

Understanding recreationists' AQ and health benefit perceptions may explain the effects of AQ on urban trail visitation [18]. This information can help managers of parks and protected areas to inform visitors and mitigate the effects of air pollution [19].

1.1. Air Quality and Exercise

AQ is affected by natural and anthropogenic sources, but anthropogenic pollution (e.g., factory emissions) exceeds natural sources (e.g., dust) and has come under increasing global scrutiny [20]. Although over 187 ambient pollutants have been identified, the US EPA's AQ Index (AQI) focuses on five: PM (PM_{2.5} and PM₁₀), CO, SO₂, O₃, and NO₂ [21]. These criteria pollutants have been linked to negative health outcomes and are largely anthropogenic in origin [20,22]. For example, PM_{2.5} and PM₁₀ 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 [20,23]. PM is more strongly linked to an increased risk of death from any cause than any other ambient pollutant [23]. 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 [24]. For example, global PM_{2.5} levels rose between 2000 and 2010 [24].

Outdoor exercise exacerbates the effects of air pollution due to increased respiration [25]. However, inequities exist, with vulnerable populations often disproportionately exposed, and large disparities in AQ across geographic areas [26]. Most research on AQ, health, and averting behaviors focuses on high-visibility locations such as Beijing or national averages [27]. Additionally, there is emerging evidence that people's perceptions do not accurately reflect local AQ, potentially resulting in unnecessary avoidance of outdoor recreation [28,29]. As mobile apps and recent headlines make AQI more accessible and salient to the public [30], studies suggest that AQ is of increasing concern to urban residents [12]. For example, an adaptive choice study found that air pollution was significantly more important to participants when choosing a walking route than time or distance [12]. Since urban areas experience worse AQ than rural areas [31], and given the importance of urban parks and trails to achieving health benefits [32], it is important to understand how perceptions of AQ influence urban residents' recreational choices.

1.2. Theoretical Framework

Recreational choices are largely driven by motivations. Theories to explain motivations include expectancy–valence theory (EVT), the push–pull model, and the experiential approach [33–35]. EVT explains motivation in terms of valence (value of a reward), expectancy (perception of effort), and instrumentality (self-efficacy). The push–pull and experiential models attempt to predict motivation through the preferences that motivations are believed to affect [36]. Dann defined push factors as personal preferences, whereas pull factors are attributes of the recreation site [33]. These factors, such as weather and PM [37], are suggested to determine travel and recreation site choices. A different approach, proposed by Driver, focuses on experiential factors linked to desired outcomes [34]. This framework suggests that choice is driven by preferences for these experiential factors, which in turn are driven by motivations for different outcomes [14]. Previous research on urban trail use focused on motivations, preferences, and constraints, but not experiences [38]; indeed, Larson et al. expressed surprise that experiential benefits emerged as the most important factor for urban trail users [32].

In this study, we employed both EVT and the experiential approach to explore the role of AQ 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 [39]. Health-related motivations are particularly relevant for urban trail users, since users must weigh the risks of negative health potential (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; thus, it is important to investigate other benefits offered. Psychological and physiological benefits can be realized with fewer resources, and managers can use visitors' perceptions to focus limited resources. Second, importance–performance analyses (IPAs) are a common tool for studying valuation and perceptions of experiential factors [40]. IPAs also help managers to decide where to invest limited resources by assessing both the importance of specific experiential attributes and agency performance in managing these attributes [41,42]. Thus, the inclusion of these perceptions helps to determine actionable management implications related to AQ and other experiential variables.

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

1. What is the exposure to PM_{2.5} and PM₁₀ for outdoor recreationists using an urban waterfront trail?
2. Is there significant temporal variability in PM_{2.5} and PM₁₀ exposure?
3. Do subjective perceptions of AQ and health benefits influence trail use?
4. Do perceptions appear to generally align with EPA AQ Index values?

2. Materials and Methods

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 PM₁₀ along this urban, waterfront trail. The second phase investigated to what degree visitors' subjective AQ and health perceptions predicted trail usage. All research components of this proposal were approved by Old Dominion University's Institutional Review Board (Approval #1565046-1), and information regarding informed consent was obtained from each human participant prior to participation.

2.1. Study Site

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 US, with a high concentration of low-income (20% below poverty line) and minority (57%) populations, who are statistically more vulnerable to air pollution [26,43]. The ERT was selected for this study as it runs along the Elizabeth River near the Norfolk International Port and the largest coal shipping terminal in the US. The nearby Norfolk Southern coal terminal receives over 200,000 coal cars annually, all uncovered and potentially-blowing an estimated 500 lbs. of coal dust off each car [44]. Although a 2017 Virginia Department of Health study found that PM₁₀ near Lambert's Point remained in the EPA's "good" range, local residents have repeatedly expressed concerns [45,46]. This makes independent monitoring of AQ conditions vital to understanding local AQ trends and impacts on recreationists' choices.

2.2. Ambulatory AQ Monitoring

For the first phase of this study, AQ data were collected in two-hour time blocks (i.e., 7–9 a.m., 9–11 a.m., 11 a.m.–1 p.m., 1–3 p.m., and 3–5 p.m.) 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 AQ monitor (Dylos Corporation, Riverside, CA, USA) mounted to a bicycle was used to collect PM_{2.5} and PM₁₀ concentration simultaneously, in µg/m³, 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 [47]. Time and day of collection were staggered to ensure a representative sampling of AQ 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 and the presence of potential pollutant sources, such as the Norfolk Southern coal terminal at Lambert's Point.



Figure 1. Map of the Elizabeth River Trail with data collection section. *Note:* Original graphic created using Google Maps.

2.3. Visitor Survey

For the second phase, a visitor use survey was distributed to visitors along the ERT in March 2020. The survey contained items related to visitors' perceptions of health outcomes of recreation (PHORs) and of the importance and performance of experiential variables, including AQ data.

The PHORS, a 13-item questionnaire used to measure perceived health outcomes, includes three subscales, 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 assesses motivations related to the 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." The 13 items were tested by Gomez et al. and found to have high factor loadings, ranging from $\lambda = 0.54$ to 0.93, and reliability, ranging from Cronbach's $\alpha = 0.89$ to 0.91 [39].

The importance–performance analysis (IPA) was used to assess visitors' perception of the importance and quality of experiential variables ($n = 21$), such as AQ, trail cleanliness, and the condition of the trail surface. Items were selected in consultation with managers of the Elizabeth River Trail Foundation. Users were asked to rate these in importance and performance on a Likert-type scale from 1–5, with 1 indicating "Extremely dissatisfied" or "Extremely unimportant", and 5 indicating "Extremely satisfied" or "Extremely important." Trail users' perceptions of AQ were operationalized as satisfaction with AQ along the trail during their most recent visit.

Initially, starting on 1 March 2020, in-person contacts were used to recruit participants along the trail, through distributing business cards with links to the online ERT Survey. After the declaration of a national emergency on 13 March 2020 due to the COVID-19 pandemic, 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 listserv of the ERT Foundation. Online dissemination of the survey continued through the end of March 2020.

2.4. Analyses

All analyses were conducted using IBM SPSS Statistics 27.0 (Armonk, NY, USA), and the criterion for statistical significance was $p \leq 0.05$. Outliers were not excluded, since PM measurement and classification can be imprecise, and apparent outliers may reflect real variations in AQ. Statistical assumptions for analysis of variance (ANOVA) were tested. Although the AQ 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 [48]. Kurtosis values were high for both PM_{2.5} (6.53) and PM₁₀ (10.96), so a square root transformation was used to reduce the kurtosis of PM_{2.5} to 0.92 and PM₁₀ to 2.26.

A total of 346 trail users accessed the online survey, and 214 questionnaires were completed (61.8%). 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 AQ and health perceptions predicted frequency of trail use.

3. Results

In the following sections, we illustrate (1) the temporal distribution of PM on the Elizabeth River Trail, (2) the sociodemographics, recreational use patterns, perceived trail amenity importance, and quality and perceived health outcomes from trail use reported by our sample, as well as (3) the significant influence of perceived health outcomes, but not perceived air quality, on recreational behavior for trail users.

3.1. Ambulatory AQ Monitoring

The average for PM_{2.5} across the entire collection period was $14.59 \mu\text{m}^3$ ($SD = 8.65$), or “moderate” according to the US EPA’s AQI scales (Figure 2). PM₁₀ was $37.89 \mu\text{m}^3$ ($SD = 29.07$) on average, or “good”. However, extreme outliers (i.e., Sunday PM₁₀ = $195.3 \mu\text{m}^3$) surpassed the “unhealthy” AQ threshold during peak pollution periods. PM_{2.5} readings peaked between 11:00 a.m.–1:00 p.m. ($M = 18.26 \mu\text{m}^3$) and 3:00–5:00 p.m. ($M = 14.94 \mu\text{m}^3$). PM₁₀ readings peaked between 7:00–9:00 a.m. ($M = 40.22 \mu\text{m}^3$) and 11:00 a.m.–1:00 p.m. ($M = 52.49 \mu\text{m}^3$). PM readings were also higher on Saturdays ($M = 20.75 \mu\text{m}^3$ (PM_{2.5}), $60.56 \mu\text{m}^3$ (PM₁₀)) and Sundays ($M = 23.84 \mu\text{m}^3$ (PM_{2.5}), $68.84 \mu\text{m}^3$ (PM₁₀)) than on weekdays.

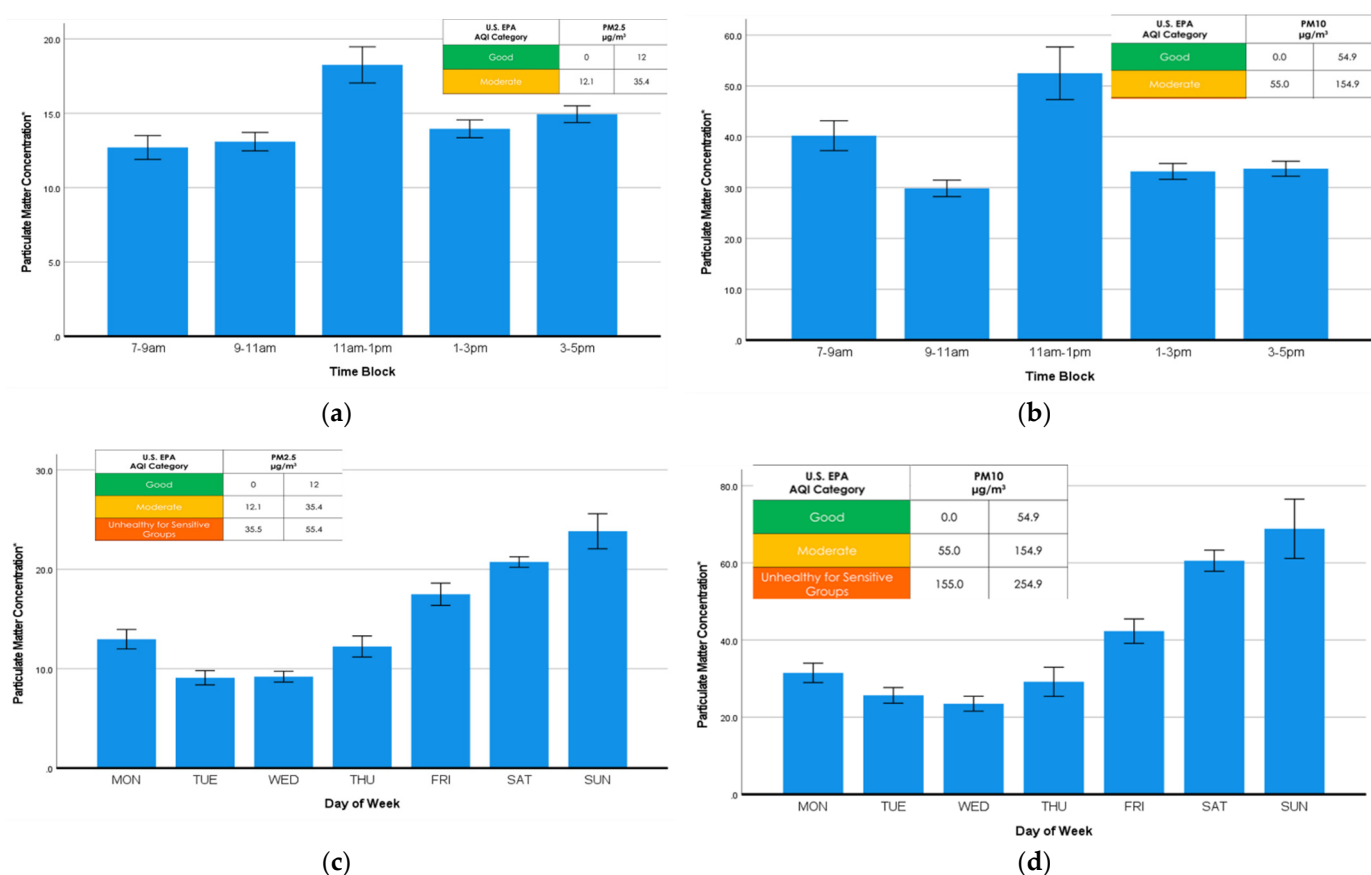


Figure 2. Temporal distribution of PM by time of day, week, and particle size: (a) boxplots of PM_{2.5} by time block; (b) boxplots of PM₁₀ by time block; (c) boxplots of PM_{2.5} by day of week; (d) boxplots of PM₁₀ by day of week. *Note:* Error bars represent 95% C.I. * Concentration in $\mu\text{g}/\text{m}^3$.

One-way repeated-measures ANOVAs were conducted to compare PM levels across weekday and time block (Table 1). Since the assumption of sphericity was violated for all tests, the Greenhouse–Geisser correction was used to interpret results. PM_{2.5} was significantly higher between 3:00 and 5:00 p.m. ($M = 14.94 \mu\text{g}/\text{m}^3$, $SD = 6.39$) and between 11:00 a.m. and 1:00 p.m. ($M = 18.26 \mu\text{g}/\text{m}^3$, $SD = 13.85$) than all other times, $F(2.58, 1289.16) = 31.40$, partial $\eta^2 = 0.06$, $p < 0.001$. PM₁₀ was significantly higher at 7:00–9:00 a.m. ($M = 40.22 \mu\text{g}/\text{m}^3$, $SD = 33.43$) and 11:00 a.m.–1:00 p.m. ($M = 52.49 \mu\text{g}/\text{m}^3$, $SD = 58.90$), and significantly lower at 9:00–11:00 a.m. ($M = 29.85 \mu\text{g}/\text{m}^3$, $SD = 18.50$), $F(1.95, 970.75) = 38.61$, partial $\eta^2 = 0.07$, $p < 0.001$.

Table 1. PM density by time block and day of week.

Measure	Sum of Squares	df †	Mean Square	F	p	η^2
<i>Time Block</i>						
PM _{2.5}	9888.289	2.58	3827.49	31.40	0.000 **	0.059
PM ₁₀	161,335.58	1.95	82,931.94	38.61	0.000 **	0.072
Error PM _{2.5}	157,138.56	1289.16	121.89			
Error PM ₁₀	2,085,319.83	970.75	2148.15			
<i>Day of Week</i>						
PM _{2.5}	46,163.22	3.38	13,667.51	114.10	0.000 **	0.329
PM ₁₀	450,698.73	2.50	180,008.71	77.76	0.000 **	0.250
Error PM _{2.5}	94,270.34	786.98	117.85			
Error PM ₁₀	1,350,542.85	583.38	2315.05			

Note: † All reported degrees of freedom are Greenhouse–Geisser corrected. ** $p < 0.001$.

In terms of day of the week, PM_{2.5} was significantly higher on Monday ($M = 12.97 \mu/m^3$, $SD = 7.61$) than on Tuesday ($M = 9.10 \mu/m^3$, $SD = 5.59$) and was higher on each following day from Wednesday ($M = 12.25 \mu/m^3$, $SD = 8.22$) through Sunday ($M = 23.84 \mu/m^3$, $SD = 13.68$), $F(3.38, 786.98) = 114.10$, partial $\eta^2 = 0.33$, $p < 0.001$. PM₁₀ was significantly higher on Monday ($M = 31.50 \mu/m^3$, $SD = 19.57$) than on Wednesday ($M = 23.51 \mu/m^3$, $SD = 14.93$) and was significantly higher on each following day from Thursday ($M = 29.19 \mu/m^3$, $SD = 29.35$) through Sunday ($M = 68.84 \mu/m^3$, $SD = 59.70$), $F(2.50, 583.38) = 77.76$, partial $\eta^2 = 0.25$, $p < 0.001$.

3.2. Visitor Survey

3.2.1. Demographics

Participants ($n = 185$) were predominantly 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 USD 50,000 (87.6%). Ethnicity/race and income diverged strongly from local demographics, as US Census documents only 43.6% of Norfolk residents are white, and the median household income is USD 49,146, as of 2017 [43]. 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 frequently incorporate the ERT into their outdoor recreation or fitness routines.

3.2.2. Descriptive Statistics

The IPA and PHORS data were normally distributed, according to the Shapiro–Wilk test. The IPA data did not contain any significant outliers, and skewness (−1.68) and kurtosis (4.08) values were acceptable. The PHORS data were assessed for non-normality by testing the skewness and kurtosis of individual items, resulting in the removal of two outliers. Annual trail use was also normally distributed, with low skewness 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. Question 11 (I visit the ERT because I feel it reduces my chance of developing diabetes) had the lowest average rating ($M = 4.39$). Improved 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 and items with factor loadings.

Item	I Visit the ERT Because I Feel That It ...	M	SD	λ^2	λ		
					PSYC	PREV	IMPV
<i>Impv1</i>	... improves my overall fitness	6.32	0.85	0.87	−0.013	−0.035	0.946
<i>Impv2</i>	... improves my muscle strength	5.32	1.35	0.47	−0.030	0.100	0.660
<i>Impv3</i>	... improves my overall health	6.39	0.77	0.82	0.060	−0.014	0.887
<i>Mean</i>		6.01	0.99				
<i>Psyc1</i>	... gives me sense of self-reliance	5.09	1.45	0.64	0.765	0.003	0.082
<i>Psyc2</i>	... gives me a sense of higher self-esteem	4.86	1.49	0.71	0.761	0.142	0.023
<i>Psyc3</i>	... causes me to appreciate life more	5.80	1.27	0.79	0.922	−0.095	0.008
<i>Psyc4</i>	... causes me to be more satisfied with my life	5.69	1.29	0.80	0.913	−0.040	−0.014
<i>Psyc5</i>	... makes me more aware of who I am	4.81	1.49	0.68	0.783	0.161	−0.114
<i>Psyc6</i>	... is connected to other positive aspects of my life	5.72	1.30	0.69	0.853	−0.093	0.031
<i>Mean</i>		5.33	1.38				

Table 2. Cont.

Item	I Visit the ERT Because I Feel That It ...	M	SD	λ^2	λ		
					PSYC	PREV	IMPV
Prev1	... reduces my number of illnesses	4.78	1.49	0.69	0.176	0.751	−0.039
Prev2	... reduces my chance of developing diabetes	4.39	1.75	0.88	−0.005	0.939	−0.006
Prev3	... reduces my chances of having a heart attack	4.62	1.72	0.93	−0.063	0.974	0.048
Prev4	... reduces my chances of premature death	4.59	1.79	0.90	−0.063	0.964	0.025
Mean		4.61	1.67				
Total		5.32	1.35				
Eigenvalue					6.10	2.13	1.62
% of Variance					46.97	16.37	12.44
Cronbach's α					0.73	0.92	0.94

Note: λ^2 represents the item variance explained by the common factor (e.g., improvement). λ = factor loadings; factor loadings > 0.40 are in boldface.

Trail users indicated a high level of satisfaction with AQ along the trail ($M = 4.38$, $SD = 0.91$ on a five-point scale), with only 1.9% of respondents rating AQ as extremely bad (1 on a 5-point scale) compared with 58% rating AQ as extremely good (5 on a 5-point scale). The importance of AQ was rated even higher ($M = 4.6$, $SD = 0.66$), indicating that most trail users valued clean air (see Figure 3).

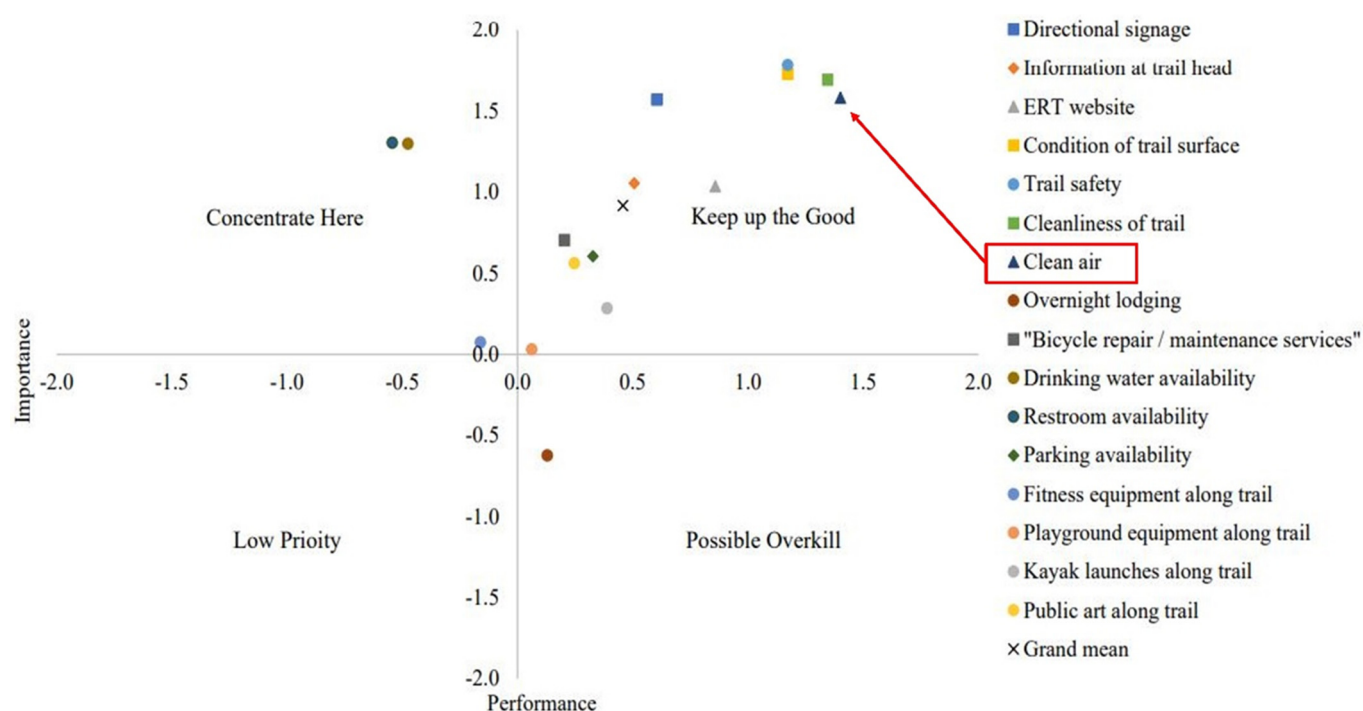


Figure 3. Importance Performance Matrix of Elizabeth River Trail amenities and services.

3.2.3. Inferential Statistics

To assess the effects of perceived AQ and health benefits on trail use, the IPA "clean air" satisfaction and PHORS scores were regressed onto reported usage (Table 3). The clean air variable was entered first to detect an effect. The model predicting usage from clean air scores was not significant, $F(1, 182) = 0.027$, $p = 0.869$. However, the model predicting usage from both clean air and PHORS was marginally significant, $F(2, 182) = 3.00$, $p = 0.052$, $r^2 = 0.03$. For each one-point increase in IMPV score, annual trail use increased by 0.77 visits, $t = 2.44$, $p = 0.016$. These results suggest that although trail users value clean air, they do

not consider AQ when choosing to use the trail. It is also possible that decision making is influenced more by motivations, such as IMPV from PHORS, than by perceived AQ.

Table 3. Regression analysis summary for IPA and PHORS predicting trail use.

Variable	B	95% CI	β	<i>t</i>	<i>p</i>
<i>Step 1</i>					
Constant	3.79	[2.52, 5.07]		5.88	0.000
Clean Air	−0.02	[−0.299, 0.253]	−0.012	−0.17	0.869
<i>Step 2</i>					
Constant	3.10	[1.72, 4.47]		4.43	0.000
Clean Air	−0.06	[−0.33, 0.22]	−0.032	−0.43	0.669
IMPV		[0.15, 1.39]	0.18	2.44	0.016

Note. “Clean air” indicates the “satisfaction with clean air” item from the survey IPA section. R^2 adjusted = −0.005 (Step 1) and 0.021 (Step 2), respectively. CI = confidence interval for B.

4. Discussion

Results of this effort underscored the importance of understanding local AQ and urban park visitors’ motivations and preferences. The average concentrations of both $PM_{2.5}$ and PM_{10} across the collection period were within the EPA’s “good” or “moderate” ranges, suggesting that trail users generally experience “clean air” while recreating. However, there was significant temporal variance in AQ, with the lunch hour (11 a.m.–1 p.m.) and weekends exhibiting significantly higher PM than other days and times. This was contrary to expectations; for example, $PM_{2.5}$ was significantly lower during morning rush hour (7–9 a.m.), and PM_{10} was significantly lower leading into evening rush hour (3–5 p.m.), despite increased traffic volumes during those times [49]. This could be partly explained by local emission source patterns. For example, $PM_{2.5}$ is more often due to anthropogenic activities [14] 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 work-related activities. Regardless of source attribution, which is certainly an area of future research within the region, this information can help trail users to avoid peak pollution times/days.

Although neither satisfaction with nor preference for AQ significantly predicted trail use, health motivations did, agreeing with previous research [50]. These results suggest that while trail users value clean air, they may not consciously consider this factor when deciding whether to recreate on the ERT. In light of similar previous research [37], it is possible that expectancy–valence theory (operationalized as PHORS in this study) is a superior predictor of recreation choices compared to experiential models. Another possibility is that experiential benefits are subsumed within valence, with varying degrees of salience to the recreationist [14,32]. In other words, AQ could be important to recreationists, but not salient when the AQ is perceived as good, as in the current study; whereas other factors, such as health benefits, may be equally important yet more salient and therefore better predictors of trail use.

Participants were generally satisfied with the AQ along the trail, uniformly rating their satisfaction with clean air highly. Since average AQ during the collection period was in the “good” to “moderate” range, this suggests that participants’ subjective perceptions of AQ were well aligned with objective AQ conditions. That said, managers could provide information about AQ variance, through social media, signage, or marketing to trail users. Since the ERT’s AQ is “good”, on average, this would reflect well on the ERT, while allowing trail users to avoid peak air pollution times. In other management settings, for example, Badlands National Park and Wind Cave National Park, managing entities participate in AQ monitoring programs. Parks that monitor AQ alert visitors of degraded AQ using advisories at entrance stations and visitor centers, park websites, and social media pages. Recreation professionals at locations with regular advisories report that recreationists

may reschedule park visits or substitute indoor recreation activities in response to AQ advisories [16].

Additionally, despite the “good” PM values measured in this setting, it would be worthwhile for outdoor recreation managers to consider installing their own low-cost AQ monitors. This would allow managers to keep visitors informed, conduct their own AQ research, or identify key local emissions sources. Local AQ can differ significantly within a few kilometers depending on weather conditions and pollution sources; for example, on 5 November 2020, PM_{2.5} measured by PurpleAir monitors in Rock Hill, SC (PM_{2.5} = 136 µm/m³) was 8.5 times higher than in Hancock, SC (PM_{2.5} = 16 µm/m³), 17.7 km away.

Since AQ and health are closely aligned, items related to respiratory illness would add to the health perceptions aspect of the PHORS, as well as provide a useful measure for future research on AQ perceptions. By tapping into the motivational construct, an expanded scale might better assess impacts of health-related AQ perceptions on outdoor recreation choices.

Limitations

Since the EPA’s PM categories are designed for a 24 h collection period, whereas PM in this study was only collected for 2 h per day, the AQ results should be interpreted cautiously. For example, the maximum PM_{2.5} and PM₁₀ values recorded during the collection period exceeded the “Unhealthy for Sensitive Groups” category, which could indicate poorer AQI if sustained over 24 h. Another limitation is that Dylos PM readings were not compared to a nearby stationary monitor, such as the GRIMM, to ensure accuracy. Additionally, variance in weather conditions, such as wind and ambient temperature, were not controlled for in the statistical analyses and might have helped to explain the temporal patterns in AQ. Additionally, AQ and survey data were collected three months apart; therefore, while subjective perceptions and objective measurements of AQ were aligned, average AQ during the survey period could have been different from the AQ results presented in this paper. Future efforts could pair real-time AQ measurements with participants’ perceptions.

An additional survey limitation was that white, highly educated, female, and higher income participants were disproportionately represented among survey respondents. In the pre-pandemic phase of data collection, this could have been partly due to the initial on-trail recruiting at trailheads rather than at trail facilities, which tend to be preferred more by people of color [51]. In the subsequent, online sampling during the start of the pandemic, online survey distribution could have skewed responses toward especially dedicated trail users who regularly access social media sites associated with the ERT. Thus, future research should aim to replicate these findings to assess whether visitor demographics of the ERT align with the results presented here. As communities of color are often the sites of environmental injustices [52] and the African American community of Lambert’s Point has historically addressed perceived issues of coal dust near the ERT, it is crucial to ensure representation of their perspectives.

5. Conclusions

The purpose of the current study was to investigate PM exposure and temporal AQ trends along an urban waterfront trail, as well as the impacts of perceived AQ and perceived health benefits on trail usage. This study aimed to fill research gaps related to local AQ, as opposed to regional or national AQ research, and outdoor recreationists’ AQ 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 [32], but in this study, they 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 a significant motivational predictor of trail use, corroborating previous research [50]. However, the PHORS only explained 2.1% of the

variance in trail use, so exploration of other potential factors is merited. Additional research is called for to help to bring disparate frameworks such as push–pull theory, experiential benefits, and EVT into a unified motivational framework for recreation researchers. Finally, the importance of managing the ERT and similar resources for trail users to achieve their desired health outcomes cannot be overstated. As the COVID-19 pandemic has illustrated, managing recreational and active transit corridors in urban settings is key to fostering sustainable transitions and community wellbeing, particularly in the light of increasing urbanization and a changing climate.

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