ABSTRACT

JACKSON, STEVEN BRENT. The Impacts of Outdoor and Nature-related Experiences on Science, Conservation, and Well-being Outcomes for Adolescents (Under the direction of Dr. Kathryn T. Stevenson).

Youth experiences in nature play an important role in shaping outcomes associated with science, conservation, and health and well-being. Childhood has been identified as a key life stage for introducing science and environmental education experiences that have the potential to foster life-long engagement with science and the environment. Childhood also represents an important developmental stage where recreation patterns develop that shape an individuals health, well-being, and connection to nature. The outdoors can serve as an instructional space that may be particulalry effective at engaging youth with science and conservation topics. Outdoor spaces are also important recreation venues that facilitate exposure to nature, physical activity, and social interaction, all of which play a key role in maintaining adolescent health and well-being. This dissertation employs three studies to investigate the use of outdoor spaces for education and recreation with a focus on adolescent science, conservation, and well-being outcomes. Study one investigates how childhood participation in science education, environmental education, and outdoor science education interact to encourage long-term participation in science and support for local environments. Study two investigates the effects of COVID-19 on the outdoor recreation participation and subjective well-being of adolescents, as well as how participation in outdoor activities may mitigate declines in subjective well-being. Study three explores the role that connection to nature plays in mediating the relationship between outdoor and nature-related recreation participation and subjective well-being during the COVID-19 pandemic. Together, these studies provide insights into effective approaches for generating scientifically and environmentally literate citizens, as well as identifying the role that

outdoor, nature-based experiences may play in building resilience and helping youth cope with global stressor events like the COVID-19 pandemic.

The Impacts of Outdoor and Nature-related Experiences on Science, Conservation, and Well-being Outcomes for Adolescents

by
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DEDICATION

This dissertation is dedicated to my family. For my parents, Drs. Bette and Jerome Jackson, who instilled in me a passion for the natural world. For my wife, Colleen, whose unwavering love, support, and encouragement made this dream a reality. And for my daughter, Quinn, whose burgeoning appreciation for the wonders of nature motivate and inspire me.

BIOGRAPHY

Childhood experiences in nature have had a profound impact on Brent's interests and trajectory in life. Playing in the woods, attending summer camps, and visiting national parks with his family sparked a love and appreciation for the natural world. As Brent went through primary school his experiences led to an interest in ecology and conservation, which eventually led to Brent's matriculation in the Environmental Studies program at Florida Gulf Coast University (FGCU). After completing his undergraduate degree, Brent continued his education, pursuing a Master of Science in Environmental Science from FGCU. During this time Brent got the opportunity to serve as a teaching assistant. He immediately fell in love with teaching, as it allowed him to share his passion for the natural world with others. Following graduation Brent taught as an adjunct professor and later an instructor before coming to North Carolina State University (NCSU) to pursue a doctoral degree. During his time as a Ph.D. student Brent had the opportunity to reflect on the experiences that shaped his trajectory in life. It was during these musings that he became interested in the role of outdoor experiences and their potential for shaping individual's affinity for nature, eventually leading to the research contained in this dissertation. Brent plans to continue teaching and conducting research with the overarching goal of conserving the natural world by sharing its wonder and beauty.

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This research would not have been possible without my graduate advisor, Dr. Kathryn Stevenson, whose guidance, support, and patience have been instrumental to my success. I would also like to thank the rest of my graduate committee, Dr. Nils Peterson, Dr. Lincoln Larson, and Dr. Erin Seekamp. Their advice, insights, and support made this research possible. Another huge thank you goes to my lab mates, Danielle Lawson, Jenna Hartley, Caitlin Reilly, and Lauren Gibson. Working and learning alongside such an incredible group of people has been paramount to my development and success as a student, researcher, and educator. Most importantly, I would like to thank my wife, Colleen, for always supporting and believing in me. I couldn't have done it without you.

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CHAPTER 1: Introduction

The Benefits of Time in Nature

Spending time outdoors yields numerous benefits that have the potential to address many of the environmental issues currently facing our species. Human induced environmental challenges such as climate change (IPCC, 2018) and biodiversity loss (Cardinale et al., 2012) threaten the ecosystem services that make human civilization possible (Díaz et al., 2006; Steffen et al., 2007). Attending to environmental challenges of this magnitude requires a society that is willing and capable of addressing complex environmental problems. Within this context, spending time outdoors represents a valuable mechanism for change, as it facilitates contact with nature, which has been shown to contribute to increased scientific knowledge and skills (Cronin-Jones, 2000; Rios & Brewer, 2014), and increases the adoption of pro-environmental behaviors (PEB) (Rosa et al., 2018; Wells & Lekies, 2006; Whitburn et al., 2019). Contact with nature also improves human health and well-being (Frumkin et al., 2017; Hartig et al., 2014). Taken together, benefits associated with exposure to nature may play an important role in addressing environmental challenges, while simultaneously providing relief from the negative health impacts symptomatic of such challenges.

While everyone can reap the benefits associated with nature contact (Kuo, 2015), the benefits may be more pronounced for youth. For instance, significant life experience (SLE) research provides support for experiences outdoors that shape an individuals' relationship with nature throughout their life (Chawla, 1999; Tanner, 1980). SLE scholars argue that childhood experiences can shape what individuals' value later in life – in this case, nature and the environment. Changing' attitudes of adults, who already have well-established values and beliefs is extremely difficult (Heberlein, 2013), and numerous studies indicate that participation in

nature-based activities during childhood cultivates positive environmental attitudes and to some degree PEB in adulthood (Chawla & Derr, 2012; Evans et al., 2018; Wells & Lekies, 2006). In addition to laying the groundwork for a lasting relationship with nature, childhood experiences in nature may also encourage continued contact with nature in adulthood (Asah et al., 2012; Bixler et al., 2002), which could maximize the benefits of contact with nature across the lifespan (Pensini et al., 2016). Studies exploring leisure activity participation across the lifespan demonstrate that engaging in leisure participation during adolescence predicts participation later in life (Scott & Willits, 1998), and participation in nature-based recreation during childhood increases participation in nature-based recreation in adulthood (Larson et al., 2011; Rosa et al., 2019). Additionally, participation in leisure activities during adolescence contributes to an individuals' leisure repertoire, providing an assortment of familiar activities individuals can draw from as they age (Bocarro et al., 2008; Mobily et al., 1991). Establishing patterns of positive interactions with nature may help ameliorate human induced environmental challenges by supporting lifelong interest in science and engagement in pro-environmental behavior across the lifespan.

Studies investigating the factors that contribute to pro-environmental behavior emphasize the complexity of changing behavior, while also highlighting a number of behavioral antecedents such as attitudes, knowledge, and skills, which play an important role in shaping behavioral intentions (Kollmuss & Agyeman, 2002; Marcinkowski & Reid, 2019). While knowledge alone does not drive behavior, it plays an important role alongside attitudes in contributing to what Kolmuss and Agyeman (2002) refer to as 'pro-environmental consciousness', which interacts with external factors to drive behavior. Many environmental education programs that rely on nature as a setting for learning focus on environmental knowledge as an outcome (Ardoin et al.,

2018) and are quite successful at building it. Some studies also show that outdoor education can be useful in building a general knowledge of and interest in science (Rios & Brewer, 2014; Stevenson et al., 2021), which is arguably needed to address increasingly complex environmental challenges. Similarly, contact with nature, particularly during youth, has been shown to contribute to the development of environmental attitudes and knowledge (Ardoin et al., 2020; Ewert et al., 2005), with retrospective studies demonstrating that nature experiences can have lasting impacts that result in PEB (Rosa et al., 2018; Wells & Lekies, 2006). With the exception of retrospective research, there are few studies that examine the long-term benefits of childhood nature contact and its potential for driving continued science engagement and PEB.

Beyond providing the benefit of supporting life-long engagement in science and nature, establishing patterns of regular contact with nature may also support life-long health and well-being, which will be increasingly important as environmental challenges escalate (Cinner & Barnes, 2019). The role of contact with nature in driving improved health and well-being has largely been attributed to humans having an evolutionary-based affinity for living things and natural settings (Kellert & Wilson E. O., 1993; Wilson, 1984). Ulrich (1993) provides support for this "biophilia" hypothesis, indicating that benefits associated with exposure to nature are a product of selection for positive responses to natural landscapes that played an important role in humans evolutionary past. Studies investigating the mechanisms by which contact with nature drives improved health and well-being point to a multitude of potential pathways including environmental factors, physiological and psychological states such as connection to nature (Dean et al., 2018; Mayer & Frantz, 2004; Nisbet et al., 2011), and pro-environmental behaviors (Kuo, 2015). Specific health and well-being benefits associated with nature contact are numerous and varied, ranging from reduced mortality to increased happiness and well-being (Frumkin et al.,

2017; Kuo, 2015). Accordingly, childhood experiences in nature that encourage continued contact with nature may support health and well-being across the lifespan. Many of the studies investigating the relationship between contact with nature and human health are specifically focused on understanding impacts to mental well-being (Berto, 2014; Bratman et al., 2019). Research in this vein demonstrates nature's potential in improving mental health by providing restoration from stress (Berto, 2014; Hartig et al., 2003), as well as building psychological resilience that can buffer individuals against negative health impacts associated with stress (van den Berg et al., 2010). These outcomes are particularly relevant in light of concerns regarding the mental health impacts associated with environmental challenges (Berry et al., 2010), including the COVID-19 pandemic (Cullen et al., 2020; Holmes et al., 2020; Lee, 2020). Additional studies investigating the effect of contact with nature on mental well-being during times of increased stress may provide insights into effective strategies for building resilience to negative psychological impacts associated with environmental challenges.

Although there is a growing body of evidence around the myriad of benefits linked to contact with the outdoors (Bratman et al., 2015; Chawla, 2015; Frumkin et al., 2017; Hartig et al., 2014), the current global environmental and related health crises necessitate additional research to support the establishment and maintenance of these benefits across diverse populations. First, as environmental challenges are increasingly complex, we will continue to need a scientifically and environmentally literate populace (Bickford et al., 2012). Youth experiences in nature support these goals, but more research is needed to understand the degree to which these experiences fuel sustained engagement with science and nature. Secondly, the COVID-19 pandemic presented severe health challenges across the globe, including unprecedented mental health challenges (Cullen et al., 2020). This context offers an opportunity

to improve our understanding of the role that outdoor recreation and connection to nature play in supporting mental health during times of increased stress.

This dissertation addresses these challenges in the three ensuing chapters. Chapter two focuses on the persistence of affective attitudes related to science engagement and PEB, as well as the degree to which those attitudes drive behavioral intentions in emerging adults. Chapter three explores the impacts of COVID-19 on adolescent outdoor activity participation and mental well-being, as well as the degree to which participation in outdoor activities buffers individuals from declines in their mental well-being. Chapter four investigates COVID-19 impacts on connection to nature, as well as connection to nature's role in mediating the relationship between outdoor activity participation and mental well-being both before and during the pandemic. These studies ultimately provide novel insights into the benefits of contact with nature for adolescents, contributing to the development of effective strategies and policies to improve conservation efforts and enhance mental well-being.

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CHAPTER 2: Lasting Conservation and Science-related Outcomes Associated with Science Education, Environmental Education, and Outdoor Science Education

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Abstract

Science and environmental education may promote life-long engagement in science and environmental conservation. We used hierarchical multiple linear regression to investigate how childhood participation in science education, environmental education, and outdoor science education interact to encourage long-term participation in science and support for local environments. Our survey of 231 high school students in North Carolina suggests outdoor science education is positively associated with enjoying time outdoors ($p = 0.065$) and the perception of the value of local natural resources ($p = 0.021$) four to seven years later. We also found support for science confidence following a science education program ($p = 0.004$).

Introduction

To address current environmental challenges, we need citizens who understand the science of complex environmental problems, have the skills to address them, and are motivated to do so. Environmental challenges including biodiversity loss (Cardinale et al., 2012) and climate change (IPCC, 2018) represent pressing global issues with potentially devastating repercussions. These are complex problems requiring a scientifically and environmentally literate citizenry. Scientific literacy includes scientific knowledge, dispositions, skills, and behaviors (Laugksch, 2000; OECD, 2014). Environmental literacy includes parallel constructs, but emphasizes affective (e.g., pro-environmental attitudes) and behavioral dimensions (Hollweg et al., 2011), and is often developed through nature-based learning (Ballantyne & Packer, 2002; Kuo, Barnes, & Jordan, 2019). In short, scientific literacy includes what people know and can do about science, and environmental literacy includes a focus on what people know and how people feel and act with regard to the environment.

Perhaps because the fields have developed in parallel, science education (SE) and environmental education (EE) can result in synergistic benefits for learners. These fields have distinct instructional approaches, with SE efforts most often situated in formal settings like classrooms and focusing on outcomes related to knowledge and skills, and EE efforts focusing more on outcomes related to affect and behavior in non-formal and informal settings like the outdoors (Dillon & Scott, 2002; Gough, 2002; Littledyke, 2008; Wals, Brody, Dillon, & Stevenson, 2014). Despite these differences, SE and EE have been intertwined for decades, creating significant overlap (Wals et al., 2014). For instance, SE was presented as the primary tool for solving environmental problems (Gough, 2002), early conceptualizations of EE emphasized science learning (e.g., the Tbilisi Declaration; UNESCO, 1977), and, when included

in formal settings, EE is typically conducted in conjunction with science instruction rather than other subjects such as social studies, English, or art (Gough, 2002; Rickinson, 2001). Outdoor science education (OSE) explicitly bridges SE and EE by focusing on science content knowledge while simultaneously encouraging pro-environmental attitudes (Carrier et al., 2014; Cronin-Jones, 2000), creating an opportunity to foster both SE- and EE- related outcomes.

When SE and EE approaches are employed in tandem through OSE, they may result in long-term gains for both science and environmental literacy outcomes. Specifically, OSE may boost science learning (Cronin-Jones, 2000; Rios & Brewer, 2014), provide context that reinforces recollection of long-term content knowledge (Carrier et al., 2014; Dillon & Scott, 2002; Falk & Dierking, 2010), and promote pro-environmental attitudes and behaviors (Ballantyne & Packer, 2005; Bogner, 1998). Research suggests that these synergistic benefits of OSE can result in retention of program content knowledge as well as pro-environmental attitudes up to three months after an OSE experience (Dettmann-Easler & Pease, 1999; Stern, Powell, & Ardoin, 2008). Previous qualitative research focused on the persistence of outcomes demonstrates that OSE experiences can generate vivid memories and perceived pro-environmental attitudes that persist up to a year following an intervention (Farmer, Knapp, & Benton, 2007). More recent research focused on the efficacy of outdoor learning highlights its role in improving student scores on academic assessments across multiple disciplines including science (Dillon et al., 2016). Carrier and colleagues (2014) found adults were more likely to recall science lessons from their childhood when the lessons occurred outside. Similarly, although EE traditions often emphasize affective learning (Iozzi, 1989; Littledyke, 2008), knowledge-based SE approaches may reinforce EE outcomes. Knowledge alone does not lead to conservation behaviors, but it does play a role (Kollmuss & Agyeman, 2002). Similarly,

knowledge alone is not a direct driver of behavior, but is essential to sound environmental decision-making (Frisk & Larson, 2011). Further, significant life experience research has identified knowledge-based activities including relevant readings and coursework as influential in life-long environmental engagement (Chawla, 1998; Tanner, 1980).

Early interventions are most likely to promote long-term gains in science and environmental literacy. Early learning experiences may change general attitudes and orientations including science interest and motivation (Bruce, Bruce, Conrad, & Huang, 1997; Eshach & Fried, 2005; Tyler-Wood, Ellison, Lim, & Periathiruvadi, 2012) and environmental sensitivity (Chawla, 1998; Peterson, 1982), which may lead to life-long patterns in behaviors such as pursuing a STEM major in college (Maltese & Tai, 2010; Prévot, Clayton, & Mathevet, 2018) and environmental action (Lester, Ma, Lee, & Lambert, 2007), respectively. For instance, childhood SE experiences may lead children to develop positive attitudes toward and interest in science (Eshach & Fried, 2005; Randler & Hulde, 2007), which promote long-term engagement with science (Crawley & Black 1992; Maltese & Tai, 2010). Within the context of EE, interventions early in life play an important role in the development of "life-long attitudes, values, and patterns of behavior toward natural environments" (Wilson, 1996, p. 2). Wells and Lekies (2006) suggest participation in nature-based activities as a child leads to pro-environmental attitudes and to some degree, pro-environmental behavior among adults. Heberlein (2012) strengthens the argument for working with children by suggesting that their attitudes are more susceptible to change than those of adults.

What is less understood is the degree to which short-term synergistic benefits of blending SE and EE approaches persist as learners' age. Much of the previous research on long-term impacts of SE and EE has focused on single domains, such as the perceived benefits of

childhood outdoor experiences on life-long environmental engagement (Chawla, 1999; Wells & Lekies, 2006) or early science interventions in building science competencies that translate to sustained interest and motivation regarding science (Eshach & Fried, 2005; Tyler-Wood et al., 2012). Research focused on citizen science efforts that include elements of both SE and EE demonstrate the short-term synergistic potential of OSE (Lewandowski & Oberhauser, 2017; Schuttler, Sorensen, Jordan, Cooper, & Shwartz, 2018), but additional research is needed to explore how these relationships may continue to support one another over time. A review of nature-based citizen science literature conducted by Schuttler and colleagues (2018) highlights SE outcomes such as increased science knowledge, and EE outcomes including increased engagement with nature and the development of an emotional connection with nature, but Schuttler et al. found no studies that examine these variables over time. While OSE may simultaneously build science efficacy and connection to nature (Carrier et al., 2014), we do not know the degree to which that experience will continue to lead to long-term outcomes such as interest in science careers or support for conservation. Identifying the degree to which key childhood experiences reinforce both SE and EE outcomes may shed light on how to maximize early interventions to foster a citizenry that has the scientific know-how and deep commitment to addressing environmental challenges.

This study seeks to improve our understanding of the mutualistic and long-term impacts of SE, EE, and OSE through a case study of high school students in western North Carolina. We measured the presence of potential intermediate affect-related outcomes (i.e., science confidence, enjoying time outdoors) and long-term behavioral outcomes (i.e., pursuit of a STEM major in college, support for local natural resources) from differing education programs. This approach differs from the methodology of several retrospective studies, which have asked adult

participants to self-identify the linkages between experiences and their commitment to the environment as demonstrated by career choice or specific actions (Chawla, 1999, 2007; James, Bixler, & Vadala, 2010; Palmer, Suggate, Robottom & Hart, 1999; Tanner, 1980). These studies may be subject to recall and selection biases, as long-term retrospective recall has been identified as a poor measurement of actual events (Golden, Wrangham, & Brashares, 2013). The present study reduces recall bias by engaging adolescents, versus adults, who are closer in age to participation in the educational programs. It limits selection bias by engaging a broad sample of high school students who were not chosen based on exhibiting extraordinary interest and engagement with the environment. We tested five hypotheses:

- H_1: Participation in a multi-year long SE program in high school will be positively related to the intention to pursue a STEM major in college, as mediated by individuals' science confidence.
- H_2: Participation in a multi-year long EE program will be positively related to support for local natural resources, which will be mediated by enjoying time outdoors.
- H_3: Participation in a yearlong OSE program in fifth grade will be positively related to the intention to pursue a STEM major in college and support for natural resources in high school, which will be mediated by science confidence and enjoying time outdoors, respectively.
- H_4: Enjoying time outdoors will strengthen the positive relationship between science confidence and the intention to pursue a STEM major in college.
- H_5: Science confidence will strengthen the positive relationship between enjoying time outdoors and support for natural resources.

Materials and Methods

Sampling

This study sampled high school students, as this group includes emerging adulthood developmental stages, when identities and worldviews are beginning to solidify and influence life paths and career trajectories (Arnett, 2000; Kroger, Martinussen, & Marcia, 2010). Additionally, the high school years (i.e., ages 14-18) are proximate enough to childhood that the recalled memories of childhood experiences may be more accurate than those of adults (Brewin, Andrews, & Gotlib, 1993; Halverson, 1988; Stevenson et al., 2014). We surveyed students from two high schools in Transylvania County located in western North Carolina through May and June of 2017. The high schools were selected because the students in these schools would have participated in the OSE program included in this study if they lived in the area during fifth grade, as well as had opportunity to participate in the EE and SE programs of interest. The guidance counseling office at each high school emailed their respective student bodies with a request to complete our survey. In addition, a student volunteer at one of the high schools visited individual classes to encourage students to complete the survey. The possible sample included 1,068 students (731 at school A and 337 at school B), with a total of 186 students responding from school A (25% response rate) and 45 students responding from school B (13% response rate) for a total of 231 responses (22% response rate). Our sample included ninth-grade students (n=51), tenth-grade students (n= 55), eleventh-grade students (n=70), and twelfth-grade students (n=55). A majority (64.1%) of the responding students identified as female (n=148), 32.5% identified as male (n=75), and 3.5% identified as other (n=8). The sample was primarily comprised of students identifying as White (n=186, 85.7%), with fewer Hispanic (n=4, 1.8%), Black (n=4, 1.8%), Asian (n=3, 1.4%), Native American (n=2, 0.9%), and mixed ethnicity students (n=17,

12.8%). Due to the small sample size race was broken into two categories in our analysis with students identifying as White being categorized as White and all other students being categorized as non-White. The socio-economic status of the schools was evaluated by determining the percentage of students eligible for free or reduced-price lunch (Nicholson, Slater, Chriqui, & Chaloupka, 2014). School A had 291 students eligible for free or reduced-price lunch, accounting for nearly 40% of the student population, whereas school B had 148 eligible students, accounting for nearly 44% of the student population.

Choice of activities

For this study, we assessed whether students participated in programs exemplifying SE, EE, and OSE. The three programs we asked students about were Time 4 Real Science (SE), scouting (i.e., Boy Scouts/Girl Scouts; EE), and Muddy Sneakers (OSE) (see Table 1).

Time 4 Real Science is an after-school SE program for high school students, representing a partnership between the local school district and the county 4H Youth Development program. Participants are ninth through twelfth graders who spend 250 hours during and after school conducting scientific research in partnership with teachers and volunteer scientists from the community (Time 4 Real Science, 2019). Participation in the Time 4 Real Science Program varies so some of the students may have been actively involved in the program at the time they completed the survey for this study.

In this study, scouting includes participating in either the Boy Scouts of America or the Girl Scouts of the USA. Individuals can participate in scouting from kindergarten through high school (Boy Scouts of America, 2019; Girl Scouts, 2019). Scouts cover a wide range of topics with emphasis on providing “leadership development experiences” (Girl Scouts, 2019) as well as youth development and character building (Boy Scouts of America, 2019). Both organizations

offer several experiences related to enjoying and appreciating natural resources (Boy Scouts of America, 2019; Girl Scouts, 2019). It is possible that participants in this study were actively involved with Scouts at the time they completed the survey, or that their involvement ended several years prior.

Muddy Sneakers teaches fifth-grade science curriculum through experiential learning in local natural settings. The program is integrated into participating fifth grade public schools in the western and Piedmont regions of the Carolinas. Students participating in the program spend six to ten full school days over the course of the school year in local natural areas engaging in nature-based scientific inquiry focused around the core concepts of the state science curricula (Muddy Sneakers, n.d.). As Muddy Sneakers was operating in all of the Transylvania County elementary schools at the time when the respondents were in fifth grade, our high school study participants likely participated in Muddy Sneakers if they attended one of the county's elementary schools. Participation in the Muddy Sneakers program would have concluded four to seven years before the survey for this study was administered.

Of the three programs, Muddy Sneakers is the only program that is mandatory as it is incorporated into the normal school day. Time 4 Real Science and scouting are both voluntary programs that students can sign up for outside of normal school hours. Though this does represent program variability, it offers an opportunity to contextualize how OSE among a general student population (i.e., not self-selected) may promote SE and EE outcomes as compared with those who self-select, who we might expect to report greater scores on respective outcome variables. Some respondents participated in more than one program; in such instances our study counted them for each program in which they participated.

We chose these programs for both their availability within the study area as well as their inclusion of approaches linked to our variables of interest. Here, we outline distinctive approaches to which the literature points as emblematic of SE or EE. Note that these approaches are not mutually exclusive (e.g., SE can occur outdoors, EE can employ SE practices), but rather reflect associated emphases from these educational traditions (Gough, 2002; Wals et al., 2014). Time 4 Real Science includes key attributes of impactful SE: starting during childhood (Eshach & Fried, 2005; Maltese & Tai, 2010; Tyler-Wood et al., 2012), allowing for student-directed learning where students can pursue experiences that interest them, and allowing students to make direct connections to their own lives (Carrier & Stevenson, 2017; Dierking, Falk, Rennie, Anderson, & Ellenbogen, 2003; Lawson et al., 2018; Lindemann-Matthies, 2005; Renninger, 2006) (Table 2). Key outcomes of the Time 4 Real Science program are to develop science-related skills and prepare students to become scientists. Time 4 Real Science has been active in the study area since 2006 and partners with the 4H youth development program. Scouting includes key attributes of impactful EE: starting during childhood (Braun & Dierkes, 2017; Wells & Lekies, 2006), using outdoor settings (Braun & Dierkes, 2017; Cronin-Jones, 2000; Martin, 2003), providing opportunities for participants to interact with positive role models (Chawla, 1999; Tanner, 1980), and having longer duration or repeated interventions (Bogner, 1998; Braun & Dierkes, 2017; Cronin-Jones, 2000; Rickinson, 2001; Stern et al., 2008) (Table 2). Scouts have been active in the study area for 100 years (Boy Scouts of America: Daniel Boone Council, 2020). Key outcomes associated with scouting include character development, hands-on learning, and building an appreciation for the natural world. Muddy Sneakers includes all of the attributes listed for both Time 4 Real Science and scouting (Carrier & Stevenson, 2017; Carrier et al., 2014; Priest, 1986) (Table 2). Key outcomes associated with Muddy Sneakers

include teaching state science curriculum through outdoor experiences and developing an affective relationship with local natural resources.

Survey instrument

The survey instrument included questions focused on conservation and science attitudes, as well as questions about participation in specific SE, EE, and OSE programs. Respondents self-reported participation in Time 4 Real Science (SE), scouting (EE), and Muddy Sneakers (OSE) programming. We measured the intermediate SE outcome "science confidence" with a scale consisting of nine questions previously used with adolescents (Unfried, Faber, Stanhope, & Wiebe, 2015). The scale displayed acceptable reliability (Cronbach's alpha = 0.94) and a principal component factor analysis indicated all items were associated with a single factor with factor loadings > 0.4 (Table 3) (Comrey & Lee, 2013). The scores for the nine questions were added up for a maximum composite score of 45. We used "intention to pursue a science major in college" as a long-term SE outcome. We asked participants to indicate whether they planned to go to college and if so, what was their intended major. Respondents selected from a list of common majors, and we collapsed those choices into STEM (math, physical sciences, biological sciences, and medicine) and non-STEM majors (English, economics, education, psychology, communications, and history). We measured the intermediate EE outcome enjoying time outdoors with a single question: "Are you someone who enjoys spending time in the outdoors?" and respondents indicated their level of agreement by selecting one of five responses on a Likert scale ranging from "not at all" to "very much." The long-term EE outcome was measured by asking individuals "Do you think Transylvania County's natural resources are important to the community?", which was scored using a five-point Likert scale ranging from "not at all" to "very much." We used a single item to measure "enjoying time outdoors" and "support for local

natural resources" as they captured what we were interested in and contributed to our goal of a parsimonious survey instrument. Students also self-reported grade level, gender, and race. The final survey instrument drew from previously validated instruments and was subject to expert review, as well as review by high school students to ensure its appropriateness for our target population.

Data analysis

We analyzed the data using STATA software, version 14.2. We tested hypotheses 1- 3 using stepwise multiple linear regression to conduct mediation analyses using the Sobel Goodman mediation test, following guidelines laid out by MacKinnon, Warsi and Dwyer (1995). We conducted mediation analyses in three steps: 1) testing in sequence the relationship between each program (Time 4 Real Science, Scouts, and Muddy Sneakers) and its relationship with intermediate outcomes (science confidence, enjoying time outdoors); 2) testing the relationship between each program and long-term outcomes (intention to pursue a STEM major, support for local natural resources); and 3) testing the relationship between each program and long-term outcomes, controlling for intermediate outcomes (Table 4). We first regressed science confidence (Step 1A, Table 6) and enjoying time outdoors (Step 1B, Table 7) on participation in the three programs. Second, we regressed intention to pursue a STEM major (Step 2A, Table 6) and support for local natural resources (Step 2B, Table 7) on participation in the three programs. Third, we regressed intention to pursue a STEM major (Step 3A, Table 6) and support for local natural resources (Step 3B, Table 7) on science confidence, enjoying time outdoors, and participation in the three programs.

We tested hypotheses 4 and 5 using stepwise linear regression to conduct moderation analyses in three steps: 1) testing in sequence the relationship between each program and long-

term outcomes, controlling for intermediate outcomes; 2) testing the relationship between each program and long-term outcomes, controlling for both SE and EE intermediate outcomes; and 3) testing the relationship between each program and long-term outcomes, controlling for both SE and EE intermediate outcomes, as well as the interaction between the two intermediate outcomes (Table 5). We first regressed science confidence (Step 1C, Table 8) and enjoying time outdoors (Step 1D, Table 9) on participation in the three programs. Second, we regressed intention to pursue a STEM major (Step 2C, Table 8) and support for local natural resources (Step 2D, Table 9) on science confidence, enjoying time outdoors, and participation in three programs. Third, we regressed intention to pursue a STEM major (Step 3C, Table 8) and support for local natural resources (Step 3D, Table 9) on science confidence, enjoying time outdoors, science confidence*enjoying time outdoors, and participation in the three programs. Examining the moderating effects of intermediary outcomes allows us to explore the moderating potential of SE intermediate outcomes (science confidence) on EE long-term outcomes (support for local natural resources) and EE intermediate outcomes (enjoying time outdoors) on SE long-term outcomes (intention to pursue a STEM major). In all regression models, we controlled for demographics including the high school attended, grade level, gender, and race.

Results

Nearly three-quarters of the students surveyed participated in Muddy Sneakers (OSE program) (n = 170, 73.59%), with fewer Scouts (EE Program) (n = 53, 22.94%) and Time 4 Real Science participants (SE program) (n = 21, 9.09%). There was overlap between the three groups with 16 students participating in both Muddy Sneakers and Time 4 Real Science, 36 students participating in Muddy Sneakers and scouts, one student participating in Time 4 Real Science and scouts, and two students participating in all three programs. Aggregate mean scores for

students' enjoyment of time outdoors was 3.85 out of 5.00 (sd = 1.11), and confidence in science was 29.40 out of 45.00 (sd = 8.18). Few students planned to major in science (n = 71, 32.13%). Support for local natural resources was 4.57 out of 5.00 (sd = 0.78).

We found partial support for hypothesis 1, as participation in the SE program Time 4 Real Science predicted the intermediate SE outcome science confidence (B = 5.529; p = 0.004) (Step 1A, Table 6, Figure 1), and science confidence predicted the long-term SE outcome interest in pursuing a STEM major (B = 0.030; p < 0.001) (Step 3A, Table 6, Figure 1). Specifically, students participating in Time 4 Real Science (SE program) were 18.09% more confident on average than those that did not participate (SE = 1.908). However, science confidence did not mediate the relationship between Time 4 Real Science and interest in pursuing a STEM major, as there was no relationship between participation in Time 4 Real Science and intention to pursue a STEM major in college (Step 2A, Table 6).

We did not detect support for hypothesis 2, with no relationship between participation in the EE program scouts and the intermediate EE outcome enjoying time outdoors (Step 1B, Table 7, Figure 1) or the long-term EE outcome support for local natural resources (Step 2B, Table 7, Figure 1).

We found partial support for hypothesis 3, as participation in the OSE program Muddy Sneakers served as a weak predictor for the intermediate EE outcome enjoying time outdoors (B = 0.324; p = 0.065) (Step 1B, Table 7, Figure 1), and enjoying time outdoors predicted the long-term EE outcome appreciation for local natural resources (B = 0.279; p = 0.016) (Step 3B, Table 7, Figure 1). Specifically, students participating in Muddy Sneakers reported enjoying time outdoors an average of 10.68% (SE = 0.175) more than those who did not participate and individuals that enjoyed time outdoors were on average 5.01% (SE = 0.046) more supportive of

local natural resources. We did not detect a relationship between Muddy Sneakers participation and SE outcomes (Step 1A and 2A, Table 6, Figure 1).

We did not find support for hypothesis 4, as the moderating relationship between enjoying time outdoors and the relationship between science confidence and intention to pursue a STEM major was marginal (B = 0.005; p = 0.091) (Step 3C, Table 8, Figure 1). We also failed to detect support for hypothesis 5, the moderating effects of science confidence on the relationship between enjoying time outdoors and support for local natural resources (Step 3D, Table 9, Figure 1).

Although we did not have hypotheses associated with demographic control variables, several relationships were detected. Girls expressed a higher level of intention to choose a STEM major in college than boys across models 2A (B = 0.163; p = 0.019), 3A (B = 0.126; p = 0.035) (Table 6), and 3C (B = 0.123; p = 0.039) (Table 8). Students attending high school A and girls were more supportive of local natural resources than boys across model 2B (B = 0.252; p = 0.021), 3B (B = 0.241; p = 0.027) (Table 7), and 3D (B = 0.222; p = 0.040) (Table 9). Given that boys have been shown to demonstrate greater interest and engagement with science than girls during middle school (Catsambis, 1995), and some studies have shown that OSE may be effective at engaging girls (Tyler-Wood et al., 2012), we also tested for an interaction between girls and the OSE intervention. However, we found no moderating relationship of OSE between gender and science confidence (B = 0.951; p = 0.751) or gender and intention to pursue a STEM major (B = 0.143; p = 0.366). Although the relationships were weak, younger students expressed greater enjoyment of time outdoors (B = -0.129; p = 0.066) (Step 1B, Table 7) and students identifying as non-white expressed lower levels of enjoyment of time outdoors and support for local natural resources (B = -0.264; p = 0.086) (model 3D, Table 7).

Discussion

Local experiences in natural settings, repeated interventions over the course of the school year, and a focus on young students (fifth grade) may explain why Muddy Sneakers participants reported slightly higher enjoyment of time outdoors and greater propensity to consider local natural resources important four to seven years after their OSE experience. A review of research focused on K-12 EE outcomes between 1994-2013 highlighted there were only six studies (18%) collecting followup data more than six months post intervention (Ardoin, Bowers, Roth, & Holthuis, 2018). Our results demonstrating the persistence of positive conservation-related attitudes four to seven years after participation in the Muddy Sneakers program align with previous research demonstrating persistence of similar EE outcomes three months after an OSE experience (Dettmann-Easler & Pease, 1999; Stern et al., 2008). Previous research highlights that participating in OSE instills enjoyment of time outdoors (Ewert, Place, & Sibthorp, 2005), which could contribute to the development of an eco-centric versus an anthropocentric worldview and subsequent support for conservation (Ewert et al., 2005; Wells & Lekies, 2006). Some attributes of Muddy Sneakers that likely contribute to the program's effectiveness at generating these long-term EE outcomes include the young age at which the intervention occurs (Braun & Dierkes, 2017; Chawla, 1999; Dillon et al., 2016; Tanner, 1980; Vadala et al., 2007; Wells & Lekies, 2006), the use of local outdoor settings (Martin, 2003; Rios & Brewer, 2014), longer duration and repeated interventions (Bogner, 1998; Braun & Dierkes, 2017; Cronin-Jones, 2000; Rickinson, 2001), and use of small group sizes, which may increase the potential for an instructor to serve as a role model and provide opportunity for deep affective connections to local natural resources (Chawla, 1999; Sivek, 2002; Tanner, 1980).

This study suggests previously identified OSE impacts on interest in science may diminish over time without recurring interventions. Previous studies investigating science outcomes immediately following an OSE experience identified increased science motivation and interest (Dettweiler, Ünlü, Lauterbach, Becker, & Gschrey, 2015; Zoldosova & Prokop, 2006), and increased science content knowledge related to environmental science topics (Cronin-Jones, 2000). While increased interest in science and gains in science knowledge may result in science confidence, maintaining science confidence likely relies on continued interest and regular gains in content knowledge. Previous research demonstrating students' interest and performance in science declines throughout adolescence (Bøe, Henriksen, Lyons, & Schreiner, 2011; Linn, Lewis, Tsuchida, & Songer, 2000) may help explain why we did not find a relationship between participation in OSE and science confidence or interest in pursuing a STEM major several years later. It is possible that any gains in science confidence associated with childhood OSE may have eroded without reinforcement throughout adolescence. Future research should investigate whether repeated OSE interventions may help these outcomes persist over time.

Participation in SE was associated with science confidence, but future research with participants who are not self-selecting and over longer time periods is needed to understand how this may translate to persistent interest and participation in STEM. Additionally, the small sample size for this group (n = 21) makes it difficult to draw any inferences regarding our results. Time 4 Real Science is an after-school program for high school students that is focused on improving students' science-related skills by pairing them with scientists from their community who help them conduct a scientific research project. Because Time 4 Real Science occurs during high school, science confidence effects were still short-term relative to those measured for Muddy Sneakers. As participation in Time 4 Real Science is voluntary, in contrast to Muddy

Sneakers, it is possible that higher science confidence among Time 4 Real Science students reflected self-selection bias in addition to effects from the program (Aschbacher, Li, & Roth, 2010). However, the lack of relationship between Time 4 Real Science participation and the choosing of a science major suggests that participation did not translate that confidence towards the intention to pursue a STEM major. Another aspect to consider when comparing potential long-term impacts of OSE on science and environmental engagement is that our measure of engagement with the environment (i.e., support for local natural resources) required less personal commitment than our measure of engagement with science (i.e., choosing a STEM major). Further, the item we used could be interpreted as how much others (i.e., the community) value natural resources rather than self. However, the significant relationship found between participation in OSE and the support for natural resources suggests that aspects of the program likely fostered some sort of lasting connection with local natural resources. Future research should explore how science confidence and interest may relate to long-term science engagement outside of career choice (e.g., science hobbies; Alexander, Johnson & Kelley, 2012; Dabney et al., 2012; Jones, Corin, Andre, Childers, & Stevens, 2017) and seeking scientific evidence in decision making (Bell & Lederman, 2000). Future research should also seek to develop a more nuanced understanding of how OSE in childhood may foster lasting connections with local natural resources.

High variability in scouting programming may explain the surprising lack of relationships between scouting participation and enjoyment of time outdoors or support for local natural resources. Although scouts have key attributes linked to EE, participants can choose a participation approach that spans 135 Boy Scout merit badges (Boy Scouts of America, 2019) and over 230 Girl Scout badges (Girl Scouts, 2019), many of which are not directly related to

environmental education. Arguably, scouting does aim to promote substantial experiences with the outdoors (Boy Scouts of America, 2019; Girl Scouts, 2019), but at least in this case, those collective experiences may not be enough to promote enjoyment of time outdoors or appreciation for local natural resources. In contrast, we have a firm understanding of the programmatic attributes of the OSE experience related to this study. Future research should continue to explore impacts of participation in scouts, while accounting for the type of participation individuals choose.

The weak moderating relationships we identified between SE and EE outcomes suggests that future research should continue to explore the potential for long-term moderating benefits of OSE on engagement with both science and the environment. Previous research suggests that OSE can promote both science learning and environmental engagement in the short term (Stern et al., 2008). Some research suggests that these benefits may be synergistic, where learning science content may promote further environmental engagement (Littledyke, 2008; Wals et al., 2014), and learning outdoors may enhance science content knowledge and skills more than learning in settings not explicitly outdoors (Carrier et al., 2014; Cronin-Jones, 2000; Rios & Brewer, 2014). Though the interactions we tested were not significant, similar studies with larger sample sizes may increase the chances of detecting these relationships, supporting the notion that OSE, or other interventions providing opportunity for engagement with science in the outdoors (e.g., nature-based citizen science; Schuttler et al., 2018), may work to strengthen life-long engagement with both science and the environment.

The positive relationship between female gender and commitment to STEM majors demonstrated in our study may be explained by evidence that OSE contributes to female student engagement with science. Studies from diverse fields related to conservation and environmental

education have documented more pro-environmental attitudes and behaviors among females as compared to males (Arnocky & Stroink, 2011; Karpiak & Baril, 2008; Zelezny, Chua, & Aldrich, 2000), which our study mirrored. However, research around the gender STEM gap suggests that girls are consistently less interested in science and less likely to pursue majors and careers, particularly as they age (Brotman & Moore, 2008; Tyler-Wood et al., 2012; Wang & Degol, 2017). Our results suggest a shift in female patterns of STEM participation, perhaps brought on by the numerous efforts in recent decades to mitigate a gender gap in STEM fields (Brotman & Moore, 2008; Holman, Stuart-Fox, & Hauser, 2018; Wang & Degol, 2017). Girls may also gain more interest in STEM majors as a result of OSE interventions (Tyler-Wood et al., 2012; Zoldosova & Prokop, 2006), although we did not find that relationship in our study. The unusually high interest in STEM majors among girls in our study is encouraging in light of efforts to mitigate STEM gender gaps, and our study highlights a need to monitor this issue as educational interventions attempt to address it and gender roles shift over time.

Other differences detected based on age and ethnicity are consistent with previous findings and highlight a need to improve SE and EE curricula for older and more diverse youth. Several studies suggest younger students are more engaged with science (Baram-Tsabari & Yarden, 2009; Potvin & Hasni, 2014; Simpson & Oliver, 1985) and exhibit a greater degree of environmental concern (Buttel, 1979; Liefländer & Bogner, 2014; Stevenson, Peterson, Bondell, Mertig, & Moore, 2013). The parallel findings in our study suggest continued efforts are needed to keep older students engaged in science and the environment. Encouraging efforts with older students include programs like Time 4 Real Science, and our results suggest they do work to boost science confidence. Similarly, non-White people, particularly those identifying as African American, are underrepresented in outdoor recreation (Schwartz & Corkery, 2011), as well as

conservation majors (Porter & Umbach, 2006) and careers (Blockstein, 1990; Lawrence, Holland, & Morrin, 1993). Recent boosts in efforts to diversify outdoor recreation and conservation fields are also encouraging (Diversify Outdoors, 2018; Outdoor Afro, 2019), and techniques such as hiring diverse staff who may serve as potential role models (Shin, Levy, & London, 2016) and removing potential barriers (Balcarczyk, Smaldone, Selin, Pierskalla, & Maumbe, 2015; Foster, Blair, Bennett, Bynum, & Sterling, 2014; Tsui, 2007) may help strengthen underrepresented individuals' sense of belonging in recreation, conservation, and STEM fields. Our results suggest that SE and EE communities working with children should employ these strategies to ensure diverse stakeholders are engaged with science, the environment, and building a sustainable and just future.

Conclusion

This study suggests childhood OSE may help build life-long environmental engagement by promoting support for local natural resource protection up to seven years after program participation. Although we did not find parallel long-term outcomes related to science engagement, future research should continue to explore the short-term science-related benefits of OSE and the conditions under which those may persist. Periodic science-based interventions (e.g., Time 4 Real Science or similar programs) may reinforce the short-term gains related to science confidence others have found associated with childhood OSE (Cronin-Jones, 2000; Dettweiler et al., 2015; Zoldosova & Prokop, 2006). Though it should be repeated with larger sample sizes, our analytical approach of quantitatively linking experiences with intended behaviors and commitments provides new support for the notion that such experiences serve as a mechanism for the persistence of OSE outcomes. Future research should explore other SE outcomes such as content knowledge or skills to understand how OSE may impact science

engagement over time. Additionally, our findings regarding the synergistic relationship between SE and EE outcomes hint at a potential relationship that may aid in the development of educational interventions that work towards addressing issues associated with the compounding problems of disinterest in science and a disconnection from the natural world.

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Table 1. Program descriptions, participation age, duration, and enrollment type
This table provides descriptions of the programs included in this study.

Programs	Program description	Participation age range	Duration	Voluntary/integrated
Time 4 Real Science (SE)	After school research-oriented SE program	14-18 year olds	250 hours	Voluntary opt-in enrollment
Scouting (EE)	After school EE focused program	5-18 year olds	Dependent on individual but typically meet once a week	Voluntary opt-in enrollment
Muddy Sneakers (OSE)	In school OSE in a local natural area	10-11 year olds	6-10 school days	Integrated into school field trips for all fifth graders

Table 2. Key attributes supporting educational approaches
This table highlights key attributes related to each program type.

Educational Approaches	Best Practices	Supporting Literature
Science Education	Connection to students' lives	(Carrier & Stevenson, 2017)
	Childhood experiences	(Eshach & Fried, 2005; Maltese & Tai, 2010; Stake & Mares, 2001; Tyler-Wood et al., 2012)
	Free-choice learning and learner-centered environments	(Ballantyne & Packer, 2005; Carrier & Stevenson, 2017; Dierking et al., 2003; Renninger, 2006)
	Longer duration and/or repeated interventions	(Carrier & Stevenson, 2017)
Environmental Education	Childhood experiences	(Braun & Dierkes, 2017; Chawla, 1999; Dillon et al., 2016; Tanner, 1980; Vadala, Bixler, & James, 2007; Wells & Lekies, 2006)
	Outdoor settings	(Ballantyne & Packer, 2002; Carrier, 2009)
	Positive role models	(Chawla, 1999; Sivek, 2002; Sward, 1999; Tanner, 1980)
	Longer duration and/or repeated interventions	(Bogner, 1998; Braun & Dierkes, 2017; Cronin-Jones, 2000; Stern et al., 2008)
Outdoor Science Education	All of the above	All of the above

Table 3. Principal component factor analysis of science confidence scale items
These items come from a previously validated scale (Unfried et al., 2015). Response items included: Strongly agree, Agree, Neither agree or disagree, Disagree, Strongly disagree.

Science confidence items	Factor
I am confident in science classes	0.74
I would consider a career in science	0.87
I expect to use science when I graduate from school	0.91
Knowing science will help me earn a living	0.87
I will need science for my future work	0.88
I know I can do well in science	0.79
Science will be important to me in my life's work	0.91
I can handle most subjects well, but I struggle in science	0.48
I am sure I could do advanced work in science	0.85

Chronbach's alpha = 0.94

Table 4. Stepwise mediation analysis
This table provides a step-by-step roadmap of the mediation analyses.

	Description of Analysis Steps	Intent to Pursue STEM Major (Analysis A)	Support for Local Natural Resources (Analysis B)
Mediation Analysis	**Step 1:** Test if program participation predicts intermediary outcome	OSE + SE + EE = Science Confidence	OSE + SE + EE = Enjoying Time Outdoors
	Step 2: Test if intermediate outcome predicts long-term outcome	OSE + SE + EE = Intent to Pursue STEM Major	OSE + SE + EE = Support for Local Natural Resources
	Step 3: Test if program participation predicts long-term outcome when controlling for intermediate outcome	OSE + SE + EE + Science Confidence = Intent to Pursue STEM Major	OSE + SE + EE + Enjoying Time Outdoors = Support for Local Natural Resources

Table 5. Stepwise moderation analysis
This table provides a step-by-step road map of the moderation analysis.

	Description of Analysis Steps	Intent to Pursue STEM Major (Analysis C)	Support for local Natural Resources (Analysis D)
Moderation Analysis	**Step 1:** Test if program participation predicts long-term outcome when controlling for intermediate outcome	OSE + SE + EE + Science Confidence = Intent to Pursue STEM Major	OSE + SE + EE + Enjoying Time Outdoors = Support for Local Natural Resources
	Step 2: Test if program participation predicts long-term outcome when controlling for both SE and EE intermediate outcomes	OSE + SE + EE + Science Confidence + Enjoying Time Outdoors = Intent to Pursue STEM Major	OSE + SE + EE + Science Confidence + Enjoying Time Outdoors = Support for Local Natural Resources
	Step 3: Test if program participation predicts long-term outcome when controlling for both SE and EE intermediate outcomes and the interaction between intermediate outcomes	OSE + SE + EE + Science Confidence + Enjoying Time Outdoors + Science Confidence*Enjoying Time Outdoors = Intent to Pursue STEM Major	OSE + SE + EE + Science Confidence + Enjoying Time Outdoors + Science Confidence*Enjoying Time Outdoors = Support for Local Natural Resources

Table 6. Mediation analysis for factors predicting intention to choose a STEM major
This table shows the mediation analysis results for factors predicting the intention to choose a STEM major.

	Science Confidence Step 1A			Intention for STEM Major Step 2A			Intention for STEM Major Step 3A		
	Beta	**Std. Beta**	***p***	**Beta**	**Std. Beta**	***P***	**Beta**	**Std. Beta**	***p***
Muddy Sneakers	1.240	0.067	0.325	-0.009	-0.008	0.909	-0.044	-0.041	0.506
Scouts	1.410	0.072	0.290	0.006	0.005	0.945	-0.034	-0.030	0.628
Time 4 Real Science	5.529	0.196	0.004**	0.081	0.050	0.474	-0.079	-0.049	0.424
Science Confidence							0.030	0.523	<0.001***
High School	0.428	0.021	0.761	-0.034	-0.029	0.694	-0.043	-0.037	0.554
Grade	-0.690	-0.093	0.169	-0.020	-0.046	0.512	-0.002	-0.004	0.947
Gender	1.321	0.077	0.248	0.163	0.164	0.019*	0.126	0.127	0.035*
Race	0.894	0.037	0.585	0.010	0.007	0.920	-0.009	-0.006	0.918
Intercept	27.949		0.000	0.302		0.054	-0.549		0.001
P	0.043*			0.431			<0.001***		
R^2	0.034			<0.001			0.264		
N	223			213			213		

Notes: Gender (Male = 0, Female = 1), Race (White = 0, non-White = 1)
$^{+}$ $p \leq 0.1$; * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

Table 7. Mediation analysis for factors predicting support for local natural resources
This table shows the mediation analysis results for factors predicting the support of local natural resources.

	Enjoying Time Outdoors Step 1B			**Support for Local NR Step 2B**			**Support for Local NR Step 3B**		
	Beta	**Std. Beta**	***p***	**Beta**	**Std. Beta**	***p***	**Beta**	**Std. Beta**	***p***
Muddy Sneakers	0.324	0.128	0.065^{+}	0.279	0.155	0.021*	0.243	0.135	0.044*
Scouts	-0.003	-0.001	0.986	0.100	0.053	0.431	0.101	0.053	0.424
Time 4 Real Science	0.160	0.041	0.547	0.325	0.118	0.076^{+}	0.307	0.111	0.090^{+}
Enjoy Time Outdoors							0.112	0.157	0.016*
High School	-0.041	-0.015	0.836	-0.334	-0.168	0.014*	-0.329	-0.166	0.014*
Grade	-0.129	-0.126	0.066^{+}	0.027	0.038	0.566	0.042	0.057	0.380
Gender	0.104	0.044	0.514	0.252	0.151	0.021*	0.241	0.144	0.027*
Race	0.105	0.031	0.647	-0.240	-0.101	0.126	-0.251	-0.105	0.105
Intercept	3.905		<0.001	4.485		<0.001	4.049		<0.001
P	0.263			<0.001***			<0.001***		
R^2	0.009			0.081			0.101		
N	223			223			223		

Notes: Gender (Male = 0, Female = 1), Race (White = 0, non-White = 1)
$^{+}$ $p \leq 0.1$; * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

Table 8. Moderation analysis for factors predicting intention to choose a STEM major
This table shows the moderation analysis results for factors predicting the intention to choose a STEM major.

	Intention for STEM Major Step 1C			Intention for STEM Major Step 2C			Intention for STEM Major Step 3C		
	Beta	**Std. Beta**	***p***	**Beta**	**Std. Beta**	***p***	**Beta**	**Std. Beta**	***p***
Muddy Sneakers	-0.044	-0.041	0.506	-0.045	-0.042	0.500	-0.042	-0.039	0.528
Scouts	-0.034	-0.030	0.628	-0.033	-0.029	0.633	-0.025	-0.022	0.717
Time 4 Real Science	-0.079	-0.049	0.424	-0.079	-0.049	0.425	-0.087	-0.054	0.380
Science Confidence	0.030	0.523	<0.001***	0.030	0.521	0.000***	0.013	0.222	0.236
Enjoy Time Outdoors				0.004	0.009	0.890	-0.126	-0.289	0.121
Science Confidence *Enjoy Time Outdoors							0.005	0.480	0.091^{+}
High School	-0.043	-0.037	0.554	-0.043	-0.037	0.556	-0.032	-0.027	0.660
Grade	-0.002	-0.004	0.947	-0.001	-0.003	0.958	-0.004	-0.010	0.870
Gender	0.126	0.127	0.035*	0.126	0.126	0.036*	0.123	0.124	0.039*
Race	-0.009	-0.006	0.918	-0.009	-0.006	0.917	-0.010	-0.007	0.908
Intercept	-0.549		<0.001	-0.560		0.003**	-0.103		0.752
P	<0.001***			<0.001***			<0.001***		
R^2	0.264			0.260			0.267		
N	213			213			213		

Notes: Gender (Male = 0, Female = 1), Race (White = 0, non-White = 1)
$^{+}$ $p \leq 0.1$; * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

Table 9. Moderation Analysis for factors predicting support for local natural resources
This table shows the moderation analysis results for factors predicting support for local natural resources.

	Support for local NR Step 1D			Support for local NR Step 2D			Support for local NR Step 3D		
	Beta	**Std. Beta**	***p***	**Beta**	**Std. Beta**	***p***	**Beta**	**Std. Beta**	***p***
Muddy Sneakers	0.243	0.135	0.044*	0.233	0.129	0.052	0.233	0.130	0.051^{+}
Scouts	0.101	0.053	0.424	0.081	0.043	0.516	0.092	0.048	0.462
Time 4 Real Science	0.307	0.111	0.090^{+}	0.235	0.085	0.199	0.226	0.082	0.217
Enjoy Time Outdoors	0.112	0.157	0.016*	0.090	0.127	0.056	-0.083	-0.117	0.565
Science Confidence				0.014	0.139	0.038*	-0.010	-0.101	0.616
Science Confidence *Enjoy Time Outdoors							0.006	0.390	0.205
High School	-0.329	-0.166	0.014*	-0.366	-0.169	0.012*	-0.320	-0.161	0.017*
Grade	0.042	0.057	0.380	0.049	0.066	0.307	0.045	0.062	0.343
Gender	0.241	0.144	0.027*	0.225	0.135	0.037*	0.222	0.133	0.040*
Race	-0.251	-0.105	0.105	-0.261	-0.110	0.090^{+}	-0.264	-0.111	0.086^{+}
Intercept	4.049		<0.001	3.751		<0.001	4.365		<0.001
P	<0.001***			<0.001***			<0.001***		
R^2	0.101			0.115			0.117		
N	223			223			223		

Notes: Gender (Male = 0, Female = 1), Race (White = 0, non-White = 1)
$^{+}$ $p \leq 0.1$; * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

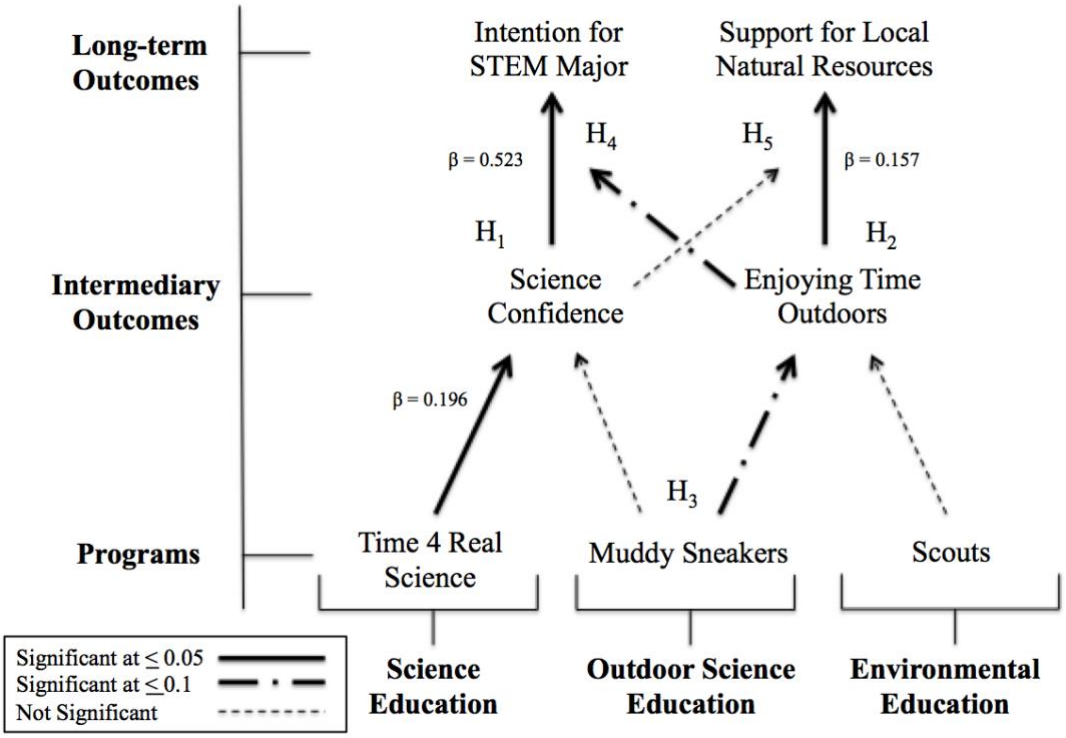

Figure 1. Programs, outcomes, and their relationships
This figure is a conceptual model of our mediation and moderation findings. Standardized beta coefficient values (β) are provided for significant hypothesized relationships.

CHAPTER 3: Outdoor Activity Participation Improves Adolescents' Mental Health and Well-being During the COVID-19 Pandemic

This chapter has been published in the *International Journal of Environmental Research and Public Health:*

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Abstract

COVID-19 is reshaping human interactions with the natural environment, potentially generating profound consequences for health and well-being. To assess the effects of COVID-19 on the outdoor recreation participation and subjective well-being of adolescents, as well as how participation in outdoor activities may mitigate declines in subjective well-being, we used a Qualtrics XM panel to conduct a nationally representative survey of youth ages 10–18 across the United States (n = 624) between 30 April and 15 June 2020. Survey questions focused on frequency of participation in outdoor activities before and during the pandemic, as well as changes in subjective well-being. Paired t-tests revealed decreases in both outdoor recreation participation (64% reported declines) and subjective well-being (52% reported declines). A regression model examining correlates of changes in subjective well-being (R^2 = 0.42) revealed strong associations with changes in outdoor play (B = 0.44, p < 0.001) and nature-based (B = 0.21, p = 0.016) activities. Adolescents from all backgrounds who participated in these activities during the pandemic reported smaller declines in subjective well-being. Results highlight the critical role that time outdoors and time in nature play in bolstering adolescents' resilience to stressors such as the COVID-19 pandemic and underscore the need to facilitate outdoor recreation opportunities for youth during times of crisis.

Introduction

Global change threatens the resilience of socio-ecological systems, including human health and well-being. Impacts from land-use change, climate change, ecosystem degradation, and global health crises are evident in the increased risk of exposure to infectious disease, water scarcity, food scarcity, natural disasters, and population displacement [1]. In the context of human health, resilience can be defined as the ability to maintain a high-level of well-being by coping and adapting to adverse social and environmental changes [2–5]. Subjective well-being (SWB), defined as a sense of life satisfaction, positive affect, and low negative affect [6,7], is one measure of mental health that may promote resilience to these challenges [2,3,8,9]. Often referred to as a measure of happiness [10], SWB is recognized as the primary measure of hedonic well-being [7] and is frequently employed as an indicator of mental health [11,12]. Understanding the factors that contribute to SWB during a crisis is an important step in identifying strategies to build resilience as global change progresses. Adolescents (youth who are 10–19 year olds [13]) may be particularly susceptible to the impacts of global change as they are acutely impacted by stressors associated with emergencies and disasters [14]. Accordingly, understanding factors that contribute to maintaining the SWB of adolescents in times of stress may be important for promoting the resilience of current and future generations in the face of global change.

The COVID-19 pandemic has become a profound human health stressor associated with global change. While the direct effects of contracting COVID-19 can result in a range of physical health complications including death, the virus also impacts the mental well-being of those not infected [15–18]. Health initiatives such as physical or social distancing and quarantine intended to curtail the spread of COVID-19 require people to refrain from activities deemed non-essential.

While these practices are necessary for protecting public health [19], they put additional stress on adolescents by changing routines and reducing social interactions during a key life stage [20]. Research on the mental health impacts of the 2009 H1N1 pandemic found that nearly one third of youth who experienced isolation or quarantine met the criteria for a PTSD (post-traumatic stress disorder) diagnosis [21]. Preliminary reports on the mental health impacts of COVID-19 in China highlight a rise in psychological disorders, increased anxiety, depression, and stress [22–24]. Following a pandemic, a diagnosis of a psychological disorder in a parent is frequently mirrored in their children [21]. These are concerning developments, as the impact of stress on adolescents has been identified as having lasting repercussions, including greater susceptibility to stress later in life [25].

Participation in outdoor activities has potential for bolstering adolescent's resilience to environmental stressors, including those associated with COVID-19 [26]. Differences between outdoor activities likely have an impact on their effects on SWB. Exposure to nature is one key aspect of participation in outdoor activities that provides a range of health benefits, including relief from stress [27–32]. Nature may promote resilience among adults by facilitating restoration from stress [33] and buffering against negative health outcomes associated with stress [34]. Health benefits associated with exposure to nature include improved physical health [35,36], but the majority of the findings center on improved mental well-being [37–43]. Although most of the aforementioned studies focus on adult subjects, exposure to nature may have an even more profound effect on children and adolescents [44,45].

Outdoor activities also provide adolescents with an opportunity to engage in physical fitness, which plays an important role in maintaining physical and mental well-being [46,47]. Research exploring life satisfaction points to declines in participation in physical activity as

being linked to declines in life satisfaction [48–50]. Previous research also demonstrates that an increase in the frequency and duration of moderate-intensity physical activity is positively associated with SWB [51]. Emergent research aimed at exploring physical activity during COVID-19 suggests children and adolescents may be spending less time engaging in physical activities and more time engaging in sedentary activities [52], which have been shown to negatively affect the physical and mental well-being of adolescents [46]. Studies exploring connections between physical activity and exposure to nature demonstrate that these two factors work synergistically to provide greater positive impacts on physical and mental health than physical activity alone [53], highlighting the potential benefits of adolescent outdoor activities that incorporate physical activity in the form of outdoor play.

Outdoor activities also play a pivotal role in the development and maintenance of social capital and cohesion, which can influence mental health for both adolescents and adults [54]. Individuals who are socially isolated are physically and psychologically less healthy [54] and more susceptible to stress [55]. Research on the role of social capital in promoting the use of green space and physical activity points to social relationships as a key factor encouraging the use of green space [56] and participation in physical activities [57]. Social interactions with immediate family have been identified as particularly beneficial, with increases in time spent with family resulting in increased SWB [58]. Within the context of COVID-19, adolescents are primarily limited to social interactions with direct family members, demonstrating the potential importance of family-centered outdoor activities that provide social interaction, build social capital, and facilitate exposure to nature and physical fitness.

Given these benefits of outdoor recreation, early reports suggesting the COVID-19 pandemic has reduced participation in outdoor activities [18,52] are troubling. Yet, the negative

trends in participation rates can be responsibly reversed since exposure to the virus is less likely in outdoor spaces compared to indoor spaces [59]. Prior to the pandemic, adolescents could participate in a variety of recreational activities through community recreation programs, schools, and organized sports [60]. Participation in these activities expose adolescents to nature, physical activity, and social interactions that can generate multiple health benefits [28]. During the pandemic, however, these activities have likely been impacted by social distancing guidelines, potentially limiting adolescent's ability to benefit from health-buffering factors during a time of increased stress [16]. In many cases, outdoor activity participation may have decreased due to school, park, and outdoor recreation space closures, as well as cancelled team sports and activity classes [52,61]. However, evidence suggests that other outdoor activities (e.g., neighborhood walks, visiting local parks) may have increased as some people seek ways to get out of their homes and safely interact with others [62].

While the stress of COVID-19 is likely negatively affecting all adolescents to some degree [63], some are at a greater risk from the effects of the pandemic than others [64]. For instance, health data reveal higher COVID-19 infection rates in Black communities compared to other demographic groups [65,66]. Disparities in infection rates may be exacerbated by disparities in outcomes from social distancing efforts such as intensifying food insecurity and declining educational outcomes among underserved communities when schools are moved online [64]. Prior to the pandemic, girls, Black youth, and older adolescents spent less time outside and more time on electronic devices, highlighting potential trends that may persist during the pandemic [67]. Additionally, adolescents in urban environments are at a higher risk for viral infection, and there are fewer opportunities for exposure to nearby nature [26,68], which has been identified as a significant factor in children's ability to cope with stress [44,45]. The

perceived quality of nearby nature has also been shown to play an important role in the effectiveness that time outside has on mental well-being, highlighting additional inequities in opportunities for exposure to the benefits of time in nature [69]. Moreover, the greater density of people seeking nearby nature in urban areas may further restrict access to outdoor recreation opportunities due to social distancing policies, park closures, and citywide lockdowns in areas with high infection rates [61,70].

Characterizing changes in outdoor activity participation, across landscapes and demographic groups (age, race, household-income, community type, and region of the country), is critical to understanding the potentially inequitable impacts of COVID-19 on adolescents SWB. We explored answers to these questions with a nationally representative survey that measured adolescent outdoor activity participation and SWB both before and during the COVID-19 pandemic. We tested several hypotheses. First, (H1) we predicted that adolescent SWB decreased as COVID-19 emerged, likely due to the wide array of stressors associated with a global health crisis [14,21,71,72]. Next, (H2) we hypothesized that adolescent participation in outdoor activities (outdoor play activities, nature-based activities, and outdoor family activities) decreased during the COVID-19 pandemic [52]. Finally, we expected to see relationships linking participation in outdoor activities with higher levels of SWB. As time outdoors may buffer against stress, we hypothesized that (H3) adolescents with high outdoor activity participation levels pre-COVID-19 experienced a smaller decrease in SWB, and that (H4) adolescents who maintained higher levels of participation in outdoor activities during COVID-19 experienced a smaller decline in SWB.

Materials and Methods

Data collection

The sample for this study was prepared using an online panel provided by Qualtrics XM through a stratified convenience sampling approach. We chose to use a Qualtrics panel because it allowed for demographic quotas and, when compared to other online panel providers, Qualtrics samples come closest to a national probability sample in terms of demographic representativeness [73]. Qualtrics also allows for rapid data collection—a critical need in our COVID-19-focused study—as it compiles panel respondents recruited from a range of other firms [73]. The Qualtrics panel provided for this study drew from a national pool (50 states, Puerto Rico) with demographic quotas for gender (male, female, non-binary and other), race (White, Black, Hispanic, Asian/Pacific Islander, Native American, other), and community type (rural area, small city or town, suburb near a large city, and large city) representative of the 2019 U.S. census data. Sampling was restricted to parents and their children between the ages of 10–18 years old. We chose this age range because adolescents are particularly susceptible to stress linked to global health crises [14,74], and old enough to understand the survey.

Data collection began 30 April 2020 and closed 15 June 2020. Data were collected through separate but linked parent and child survey instruments that were created and administered using the Qualtrics platform. Surveys were administered to qualifying parents who completed the parent version of the survey before being prompted to hand their device to their qualifying child to complete the adolescent version of the survey. Prior to starting the survey, parents were provided with a linked and downloadable consent form acknowledging their consent to participate and their consent for their child to participate. Adolescents were also

provided with an age-appropriate assent form acknowledging their consent to participate. 2.2. *Survey instrument*

The adolescent survey instrument included 21 self-reported items comprising four main constructs, pre and post COVID-19 SWB, pre and post COVID-19 mental health, pre and post COVID-19 outdoor activity participation, and a single item eliciting information about the causal relationship between outdoor activity participation and SWB. Within the context of this study pre COVID-19 refers to the period before the virus impacted the daily lives of respondents, whereas post COVID-19 refers to the period when the survey was completed (1–3 months into the pandemic). In addition to these constructs, adolescents were also asked demographic questions including age, gender, and race. Demographic information gathered from the parent survey included household income, community type, and state of residence.

The four-item SWB construct used for this study was a modified version of the World Health Organization's (WHO) five-item subjective health and well-being scale [75–77], which has been used internationally for measuring the SWB of both children and adults [77]. The scale represents a unidimensional measurement of health with high predictive validity [77]. We made several careful modifications. First, as we were interested in SWB before and during COVID-19, we modified the question stem to assess respondents' health prior to being asked to practice social distancing as well as after: "How did you feel both before and after you were asked to practice social distancing because of the coronavirus outbreak?" In addition, as this survey was aimed at adolescents, we omitted one item and modified the wording on the remaining items to be appropriate for younger audiences (see Table 1 for final item wording). Lastly, to reduce the burden on respondents, we modified the response items to be four-point Likert scales including the responses "at no time", "some of the time", "most of the time", and "all of the time". While

measures of SWB might be impacted by the momentary mood of the respondent at the time of their response, previous research highlights that the use of a multi-item scale is less susceptible to such distortion [78,79]. Measures of recalled mood and emotions are relatively stable and reliable over periods of time ranging from 2 weeks to 2 months [78,80], which was just short of the approximate time frame required for adolescents to recall pre-pandemic SWB in our study. Although acute events experienced by individuals (e.g., getting a bad grade/marks on a test) may impact reported SWB, these individual events do not impact inferences drawn from the overall sample unless they are experienced systematically by relatively large numbers of respondents.

The pre and post COVID-19 self-rated mental health construct we used was a modified version of the scale used in the Behavioral Risk Factor Surveillance System survey [81]. The scale represents an efficient indicator of mental health and has been used to assess population mental health as well as the risk of adverse mental health outcomes [82]. Our version of the scale was modified to assess respondents' health prior to being asked to practice social distancing as well as after: "How would you rate your health both before and after you were asked to practice social distancing because of the coronavirus outbreak?" The response items for this scale comprised five-point Likert scales including "Terrible, Poor, Average, Good, and Excellent".

Outdoor activity items were focused on determining frequency of participation in specific outdoor and nature-related activities. Adolescents were asked "How often did you participate in the following activities this time last year and now, after you have been asked to practice social distancing because of the coronavirus outbreak?" Both the retrospective and current iteration of the items used a three-point Likert scale with the responses "Never", "Every now and then", and "Often". A short response scale was used for this construct as our research questions are focused on determining directional trends rather than specific measures of intensity or extremity [83]. We

included five “outdoor play” activities that could be done in any type of outdoor environment (playing sports outside, bicycling outside, going for walks or runs outside, swimming outside, skating), eight “nature-based activities” confined to more natural settings (camping, wildlife viewing, hiking, paddling, hunting, fishing, playing in the woods, collecting natural items), and a single item measuring “outdoor family activities” (spending time with my family outdoors), for a total of 14 different activities. These activities were selected based on retrospective qualitative interviews conducted with young adults (18–35 years old) during the summer of 2019. During these interviews, respondents shared the childhood experiences that shaped their connection to nature. Activities were also selected based on previous studies focused on adolescent participation in outdoor and physical fitness activities [49], including those that noted the importance of distinguishing between outdoor play and nature-based activities [84]. We also included a more general outdoor activity item that used the same question stem as the previous outdoor activity items but referred to participation in “some sort of outdoor activity” rather than a specific activity. Both the retrospective and current aspects of this item used a five-point Likert scale consisting of the responses “less than one time per month”, “1–2 times per month”, “1 time per week”, “2–4 times per week”, and “5 or more times per week”.

The single item: “Has spending time outdoors in nature helped you deal with the stress caused by practicing social distancing because of the coronavirus outbreak?” was also included in order to assess face validity of a causal relationship between outdoor activity participation and SWB. The item included a five-point Likert response scale comprised of “Not at all”, “Somewhat”, “Definitely”, and “Does not apply, as I haven’t spent much time outdoors since I was asked to practice social distancing”.

Data Analysis

Data preparation

We used listwise deletion to remove 257 responses that were either straight-line responses (answering the same for all questions) or nonsensical text responses (related to open text questions), resulting in a final sample of 624. When a survey response was removed from the sample, the corresponding parent or child survey was also removed. Parent and child surveys were linked using Qualtrics embedded dyad codes. All items were analyzed based on coding described above with the following exceptions. The response scale for the general outdoor activity item was recoded so that "less than one time per month" = 0.25, "1–2 times per month" = 0.5, "1 time per week" = 1, "2–4 times per week" = 3, and "5 or more times per week" = 5. We recoded these values to approximate the actual number of outdoor activities adolescents participated in during the week. The response scale for the item "Has spending time outdoors in nature helped you deal with the stress caused by practicing social distancing because of the coronavirus outbreak?", was also recoded so that the responses "Not at all" and "Does not apply" were grouped together as "No", while the responses "Somewhat" and "Definitely" were grouped together as "yes". This helped to streamline the analysis and clarify directionality of the relationship between outdoor activity participation and SWB. Children identifying as more than one race were grouped into a single "two or more races" category. State of residence data were broken into 4 geographic regions delineated by the U.S. Census Bureau, with Alaska and Hawaii being added to the West region and Puerto Rico being added to the South region (South: AL, AR, DC, FL, GA, KY, LA, MD, MS, NC, OK, PR, SC, TN, TX, VA, WV) (Northeast: CT, DE, ME, MA, NH, NJ, NY, PA, RI, VT) (Midwest: IL, IN, IA, KS, MI, MN, MO, NE, ND, OH, SD,

WI) (West: AK, AZ, CA, CO, HI, ID, MT, NV, NM, OR, UT, WA, WY) [85]. The cleaned dataset was analyzed with Stata 14.1.

Activity grouping and SWB scale analysis

We used exploratory factor analysis (principal component factor analysis, or PCF) with an orthogonal varimax rotation to assess the dimensionality and internal consistency of our modified four-item WHO SWB scale (Table 1). The analysis supported a unidimensional factor structure that explained 70% of the variance. The scale also demonstrated high internal consistency ($\alpha = 0.852$) and acceptable convergence (all items loaded with eigenvalues >0.8). We selected outdoor recreation activities for each grouping a priori, and assessed the validity of these groupings using PCF to examine the structure of all individual pre COVID-19 activities (Table 2). The analysis supported a two-factor structure explaining 55% of the variance. These factors were outdoor play activities (5 items, $\alpha = 0.784$), and nature-based activities (8 items, $\alpha = 0.876$). The single-item outdoor family activities was also included as an activity group although it was not included in the factor analysis. Both activity groupings displayed acceptable convergence (all activities loaded with eigenvalues > 0.5). We created composite scores for each activity grouping by averaging responses.

Hypothesis testing

To address our first two hypotheses, we used paired sample t-tests to compare pre and post-COVID-19 levels of SWB and self-reported mental health. We also used paired sample t-tests to compare pre and post COVID-19 activity scores for the three types of outdoor activities (outdoor play, nature-based, and outdoor family) and general outdoor activity participation. We used the Bonferroni correction to address family-wise error rates associated with conducting multiple tests of significance [86]. To evaluate our third and fourth hypotheses exploring the

relationship between outdoor activity participation and change in SWB, we used a multiple linear regression model. We modeled change in SWB for each adolescent respondent as a function of their pre outdoor play activity score, pre nature-based activity score, pre outdoor family activity score, change in outdoor play activity score, change in nature-based activity score, and change in outdoor family activity score. Our model also included the pre-COVID-19 SWB score to control for a potential ceiling effect where respondents with low initial SWB scores have less room for declines than those with high initial SWB scores [87]. We also controlled for household income, gender (with males as the reference group), race (with White as the reference group), community type (with suburbs near a large city as the reference group), and geographic region (with South as the reference group). We selected these reference groups as they represent the groups with the highest sample size in their respective categories. We conducted a post hoc power analysis of our multiple linear regression using the G*power 3.1 statistical package [88]. This test yielded a value of approximately 1.00 for the power of the omnibus F test, indicating a near 0% chance of a false negative result.

To explore the potential for a causal relationship, we used a one-way ANOVA to model change in SWB by perception of whether outdoor activity participation helps with stress. We also ran a second one-way ANOVA modeling change in self-reported mental health by the same outdoor time and stress question.

Results

Sample

Our sample (n = 624) was comprised of an equal gender ratio, was 59.8% White, and included adolescents ranging from 10–18 years old with relatively equal splits across ages. Household income was normally distributed, and the Southern region of the United States had

the greatest number of respondents, with suburbs of large cities being the most common community type (Table 3).

Subjective well-being and mental health scores

We found support for H1 as adolescents reported a 23.0% decline in SWB scores (pre-COVID-19 M = 2.21, SD = 0.62; post-COVID-19 M = 1.75, SD = 0.75; $t(623) = 14.87$, $p < 0.001$; Table 4) and a 9.3% decline in self-reported mental health scores during the pandemic (pre COVID-19 M = 4.31, SD = 0.80; post COVID-19 M = 3.92, SD = 0.96; $t(623) = 10.92$, $p < 0.001$; Table 4). Overall declines in SWB were reported by 51.6% of adolescents, with 6.1% reporting increases. Overall declines in self-reported mental health were reported by 34.9% of adolescents, with 6.7% reporting increases.

Outdoor activity scores

Declines across all outdoor activity groups support H2 as outdoor play activities dropped by 41.6%, nature-based activities dropped by 39.7%, and outdoor family activities dropped by 28.6% (Table 4, Figure 1). Declines in general outdoor activity participation during the pandemic were reported by 52.4% of adolescents, resulting in a 21.6% decrease in outdoor activity participation (pre COVID-19 M = 3.68, SD = 1.17; post COVID-19 M = 2.89, SD = 1.45; $t(623) = 11.82$, $p < 0.001$; Table 4). During COVID-19, 59.9% of adolescents reported participating in an outdoor activity once per week or less, 40.2% participated once every two weeks or less, and 27.4% participated once a month or less.

Linear regression model

We found partial support for H3, as individuals who participated in more outdoor play activities pre COVID-19 were more resistant to negative changes in their SWB score during the

pandemic (B = 0.30, p < 0.001; Table 5). We did not detect relationships between pre-COVID-19 activity levels and change in SWB associated with nature-based or outdoor family activities.

We found partial support for H4, as declines in outdoor play and nature-based activities during the pandemic were associated with declines in SWB scores. Continued participation in outdoor play activities (B = 0.44, p < 0.001; Table 5, Figure 2a) and nature-based activities (B = 0.21, p = 0.016; Table 5, Figure 2b) buffered adolescents against the negative impacts of COVID-19 on SWB. For both of these activity groups, high levels of participation were associated with post-COVID-19 SWB levels approximating those experienced in a pre-COVID-19 context. We did not detect a relationship between participation in outdoor family activities and SWB (B = 0.06, p = 0.123; Table 5, Figure 2c), but the non-significant relationship had the same valence as those detected for other activity types. The relationship between outdoor activity participation and SWB was positive for all activity groups both before and after COVID-19. Demographic variables (gender, age, race, household income, community type, and geographic region) were not significant in this model, however effects appeared to be slightly more magnified for adolescents in urban communities (B = −0.10, p = 0.140).

During the pandemic, 76.4% of adolescents reported that spending time outside in nature helped them deal with the stress caused by practicing social distancing. Furthermore, the adolescents who said time outdoors helped them cope with pandemic-related stress reported less pronounced declines in SWB (M = −0.39, SD = 0.73) than those who did not recognize these benefits (M = −0.70, SD = 0.87) (F(1622) = 17.72, p < 0.001). Similar patterns were observed with respect to self-reported changes in mental health: adolescents who said time outdoors helped them cope reported less pronounced declines in SRMH (M = −0.35, SD = 0.89), than those who did not recognize these benefits (M = −0.54, SD = 0.90) (F(1622) = 5.18, p = 0.023).

Discussion

Our study revealed declines in SWB and outdoor activity participation that may be casualties of community health initiatives aimed at reducing the spread of COVID-19. Adolescents' SWB dropped during the pandemic, as did participation in outdoor activities. Adolescents with high participation rates in outdoor play activities prior to the pandemic had smaller decreases in their SWB, and those that continued to participate in outdoor play and nature-based activities during the pandemic were buffered against declines in SWB. Adolescents who reported that spending time outdoors in nature helped them deal with the stress associated with the pandemic experienced smaller declines in both their SWB and their self-reported mental health.

Declines in adolescents SWB identified in this study highlight an underlying and largely unexplored COVID-19 related health risk. Our SWB findings support previous research pointing to the negative impacts of pandemics, natural disasters, and large-scale emergencies on the mental health of adolescents [14,21], further elucidating risks posed by the expanding scale and frequency of global change events [1]. This is concerning, as decreases in adolescents SWB hamper social, emotional, and academic development [89]. Additionally, an increase in stress and trauma at a young age can have long-term impacts that affect SWB later in life [25,90], and may lead to other health disorders [91], hinting at the potential for a health crisis that may unfold for years to come. The potential impacts of declines in SWB measured in this study lend further support to the importance of identifying and promoting resilience-enhancing factors that allow adolescents to better cope and adapt to global change events [4].

The decline in adolescents' outdoor activity participation may be an artifact of where and how adolescents engage in outdoor activities, as pandemic related closures reduce access to

recreation spaces and remove outdoor activities built into daily routines. Some outdoor play and outdoor family activities were likely accessible to adolescents before and during the pandemic, as they can be conducted near home while maintaining social distancing. Despite this, concerns regarding the safety of all outdoor activities may have contributed to the decline in participation, as well as closures or overcrowding in available public outdoor spaces [18,61,70]. Safety concerns coupled with the loss of structured recreation opportunities (e.g., school sports) may help explain the large decline in outdoor play activities. Other research has indicated a drop in physical activity and a rise in sedentary behaviors when school is not in session [92]. The smaller decline in outdoor family activities may be attributed to the broad nature of this outdoor activity group, as well as the relative safety of recreating with family units versus the risks associated with interacting with other individuals. Declines in nature-based activities could be explained by limited access to natural areas due to park closures [70] and the increased risk associated with traveling further to reach natural areas [93]. The low participation rates in nature-based activities versus other activity groups even before the pandemic, may also point to barriers such as access to natural areas, which may have been exacerbated during the pandemic [61]. Declines across all outdoor activities identified in this study represent disturbing trends with potentially long-term adverse effects [52], as adolescence is a key life stage where lifestyle habits develop and shape outdoor recreation patterns and preferences in adulthood [94–96]. Offering and promoting recreational opportunities that facilitate COVID-19 appropriate outdoor activities at or near home (e.g., keeping municipal park spaces open, closing city streets for pedestrian use) may improve participation rates [70,97], particularly while recreation opportunities adolescents routinely participate in (e.g., school programs, organized sports, clubs and summer camps) are

unavailable. Such programs could build on other research highlighting the health benefits of "nearby nature" and outdoor recreation experiences [44,45,98].

Our results indicate that frequent participation in outdoor play activities prior to the pandemic provided lasting resilience against drops in SWB during the pandemic. Several studies with adults suggest that regular outdoor recreation may provide mental resiliency to stress [18,99]. For instance, an experimental study in the United Kingdom found that adults participating in a 10-week outdoor walking program had improved mental health for at least one year [100]. Another study found that regular outdoor recreation in both neighborhoods and nearby natural areas was associated with long-term well-being and psychological resilience [99]. Our results indicate that similar trends may hold for adolescents, with those who participate in frequent outdoor play having increased resiliency to declines in SWB under stress. Future research should continue to explore this possibility, as well as measure, and mitigate detrimental impacts of pre-existing outdoor play deficits on SWB [101]. As continued participation in each of the outdoor activity groups provided some relief from negative impacts on SWB during the pandemic, adolescents may reap the benefits of outdoor activity participation regardless of pre COVID-19 outdoor activity participation.

Differences in levels of exposure to nature, physical activity, and social interactions between outdoor activity types may account for the variation in each activity's capacity to buffer against declines in SWB during the pandemic. Continued participation in outdoor play and nature-based activities during the pandemic buffered adolescents against declines in their SWB, resulting in post COVID-19 SWB scores similar to pre COVID-19 scores. Outdoor play was particularly effective at reducing the decline in SWB, nearly doubling the efficacy of nature-based activities. Outdoor play activities tend to be more accessible than nature-based activities

and are therefore engaged in more frequently. These activities also provide the potential for exposure to nature and are often more physical fitness oriented. Prior to COVID-19, outdoor play activities also provided adolescents with opportunities for social interaction [56,102]. Social interactions likely persist during the pandemic, but they may be limited to family and small groups of neighbors [62]. In contrast, participating in nature-based activities during the pandemic is less frequent for adolescents and may be limited to immediate family. Outdoor family activities are not mutually exclusive and can include any of the other activities but within a family context. However, the weaker relationship between outdoor family activities and SWB may be due to being isolated with family during the pandemic, resulting in an increased amount of time being spent together, which some studies have shown has heightened family-level stress in the context of the COVID-19 pandemic [103,104]. Accordingly, although outdoor family activities are important [54], within the context of COVID-19 it may be beneficial to spend time away from family. These differences between activity groups help to explain the effectiveness of outdoor play activities during COVID-19 and demonstrate the potential of nature-based and outdoor family activities for improving SWB outside of the COVID-19 context.

Our findings suggest COVID-19 negatively impacts adolescents SWB and outdoor activity participation regardless of race, gender, age, household income, community type, and geographic region. Further, we did not find significant disparities in activity participation or SWB based on these demographics. We find this latter result particularly surprising and encouraging, given the well-documented disparities in both access to nature [68,105] and more serious health impacts of COVID-19 felt by Black, Hispanic, and other racial and ethnic minority communities [65]. However, restrictions on outdoor activities related to COVID-19 have been largely geographic rather than demographic (e.g., entire states imposing mobility restrictions),

and previous research indicates that demographic variables have a relatively weak impact on life satisfaction compared to environmental factors [106]. Although all adolescents have been affected by COVID-19, outdoor activity-focused interventions might help promote SWB for all, demonstrating a need to promote adolescent participation in such activities and increase equitable access to nature and recreational spaces [107,108]. This appears to be particularly true for nature-based activities, as pre COVID-19 participation rates were less than half that of the next closest activity group. Initiatives such as Blue Sky Funders Forum's Rethink Outside [109] and Sierra Club's Outdoors for All [110] are working towards this goal, but additional research highlighting nature as essential to human health and well-being is needed to leverage the potential of such initiatives.

Recommendations for future research

This study highlights a need for additional research exploring the potential for outdoor activities as a means of building adolescents' resilience against global change events. Future studies should continue to aim for large, representative samples and consider including respondents outside of the United States. These additions would highlight pandemic impacts on youth in other regions and illustrate how trends found here may hold or change across cultural contexts. Additionally, research on how these trends may change as the pandemic progresses could shed light on both the immediate and cumulative benefits of outdoor activities on SWB during times of crisis. Continued exploration of different types of outdoor activities and their health benefits, the "dosage" of nature required to generate benefits [30], as well as motivations for participation in such activities would also be valuable, both during times of stress and times of relative normalcy. As recalled measures of mood, emotions, and SWB can diminish in intensity and become unstable over longer periods of time [80,111], longitudinal studies that

feature moment-in-time SWB assessments and integrate other measures of psychological well-being could facilitate tracking of mental health outcomes. Studies focused on other outcomes such as physical health would also contribute to our understanding of the impacts of pandemics and broader global change events. Additionally, the incorporation of qualitative methods in future studies may provide a deeper understanding of the salutogenic aspects of outdoor activity participation not evident in self-report survey responses.

Conclusion

This study provides evidence that raises concerns regarding declines in adolescent SWB and mental health associated with the COVID-19 pandemic [15,16]. However, results also demonstrate the potential effectiveness of outdoor activity-based interventions in promoting improved SWB for all adolescents regardless of their demographic background [26]. In addition to highlighting the importance of engaging in outdoor activities during COVID-19, this study also illuminates the potential value of outdoor activities as a proactive means of building resilience to stressors associated with future public health challenges and other global change events. As the magnitude and frequency of global crises increases [1], adolescents will face ongoing exposure to stressors that negatively impact their SWB. Facilitating adolescent participation in outdoor activities through policy and infrastructure development, particularly activities that provide opportunities for exposure to nature, physical activity, and social interaction, can be a key step in promoting adolescent health and resiliency during times of crisis.

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Table 1. Principal component factor analysis for pre COVID-19 pandemic subjective well-being items

Item	SWB means	SWB factor loadings
SWB scale	2.21	
Cheerful and in good spirits	2.25	0.87
Calm and relaxed	2.13	0.84
Active and full of energy	2.60	0.82
Interested and curious about the world around me	2.19	0.80
Eigenvalue		2.78
% of variance explained		70%
Chronbach's alpha		0.85

Response scale items included: At no time=0, Some of the time=1, Most of the time=2, All of the time=3.

Table 2. Principal component factor analysis of adolescent pre COVID-19 pandemic outdoor activity participation items

Item	Activity means	Nature-based factor	Outdoor play factor
Nature-based Activity Scale	**0.68**		
Paddling (canoeing, kayaking)	0.51	0.76	0.21
Hunting	0.36	0.76	0.03
Camping	0.71	0.73	0.21
Fishing	0.66	0.72	0.16
Wildlife viewing	0.81	0.70	0.24
Hiking	0.82	0.67	0.28
Collecting (flowers, bugs, rocks, feathers, shells, leaves, seeds)	0.71	0.64	0.27
Playing in the woods (building forts, playing games in the woods)	0.88	0.55	0.50*
Outdoor Play Activity Scale	**1.20**		
Bicycling outside	1.22	0.23	0.76
Going for walks or runs outside	1.36	0.18	0.74
Playing sports outside	1.42	0.05	0.71
Swimming outside	1.16	0.17	0.67
Skating (skateboard, rollerblades, scooter)	0.84	0.42*	0.67
Eigenvalues		5.64	1.54
% of variance explained		43%	12%
Chronbach's alpha		0.88	0.78

Response scale items included: Never=0, Every now and then=1, Often=2. * Cross-loaded items.

Table 3. Sample demographics (N=624)

Variable		N	%
Gender	Male	306	49.0%
	Female	314	50.3%
	Non-binary	3	0.5%
Race	White	373	59.8%
	Black	71	11.4%
	Hispanic	78	12.5%
	Asian/Pacific Islander	42	6.7%
	Native American	6	1.0%
	Other	6	1.0%
	Two or more races	45	7.2%
Age	10 years	78	12.5%
	11 years	70	11.2%
	12 years	63	10.1%
	13 years	79	12.7%
	14 years	77	12.3%
	15 years	53	8.5%
	16 years	81	13.0%
	17 years	76	12.2%
	18 years	47	7.5%
Community	Rural area	126	20.2%
	Small city or town	126	20.2%
	Suburb near a large city	228	36.5%
	Large city	144	23.1%
Region	South	252	40.4%
	West	136	21.8%
	Midwest	106	17.0%
	Northeast	130	20.8%

The category “prefer not to answer” is not included in this table for gender, race, and income resulting in the % for those categories not adding up to 100.

Table 4. Paired sample t-tests for pre and post COVID-19 pandemic subjective well-being scores, mental health scores, and outdoor activity scores.

Variable	Pre COVID-19		Post COVID-19		Paired t Test	
	Mean	SD	Mean	SD	*t*	*p*
Subjective well-being	2.21	0.616	1.75	0.750	14.870	<0.001
Mental health	4.31	0.798	3.92	0.965	10.919	<0.001
Outdoor play activities	1.20	0.545	0.68	0.566	18.333	<0.001
Nature-based activities	0.68	0.540	0.41	0.492	13.526	<0.001
Outdoor family activities	1.38	0.636	1.02	0.799	10.156	<0.001
General Outdoor activities	3.68	1.174	2.89	1.453	11.819	<0.001

Response scale items for SWB included: At no time = 0, Some of the time = 1, Most of the time = 2, All of the time = 3. Response scale items for Mental health included: Terrible = 1, Poor = 2, Average = 3, Good = 4, Excellent = 5. Response scale items for outdoor activity groups included: Never = 0, Every now and then = 1, Often = 2. Response scale items for general outdoor activities included: Less than one time per month = 0.25, 1–2 times per month = 0.5, 1 time per week = 1, 2–4 times per week = 3, 5 or more times per week = 5. All *t*-tests were significant after Bonferroni correction to family-wise error rates ($p = 0.008$) [86].

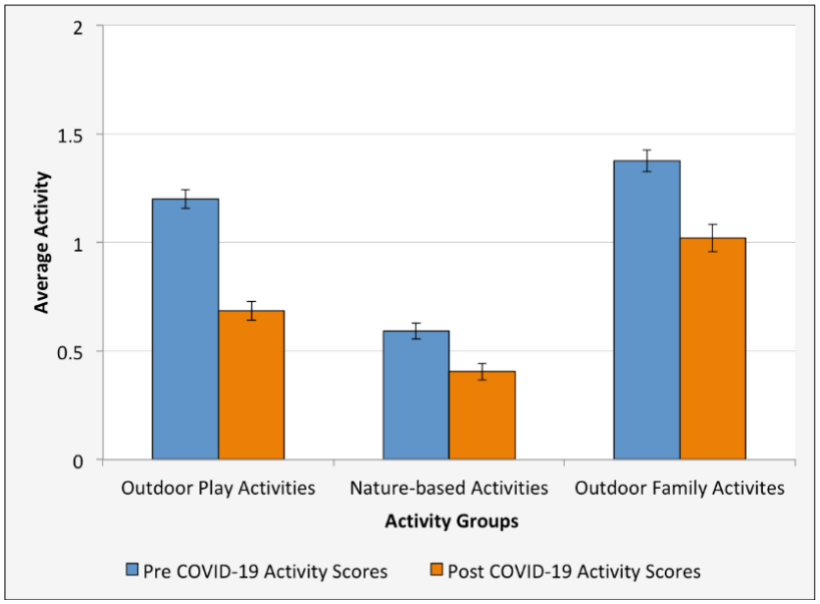
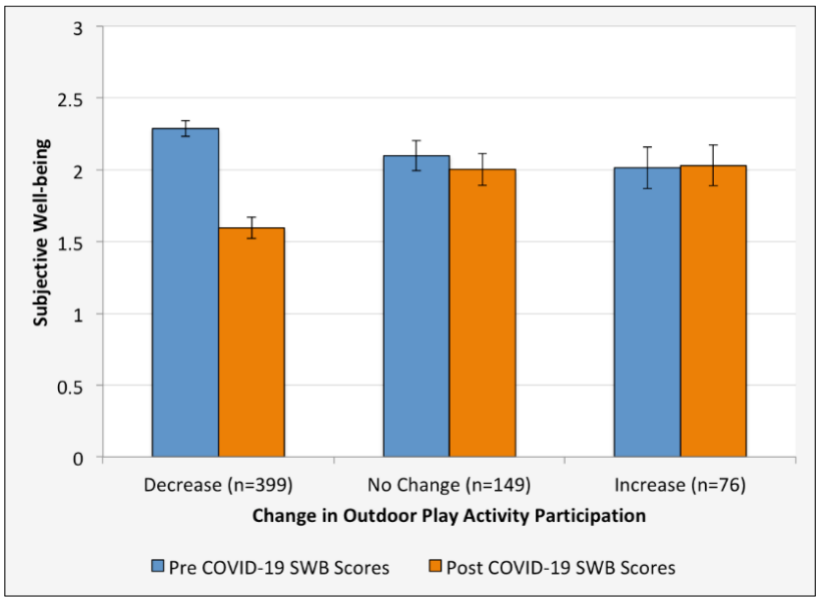
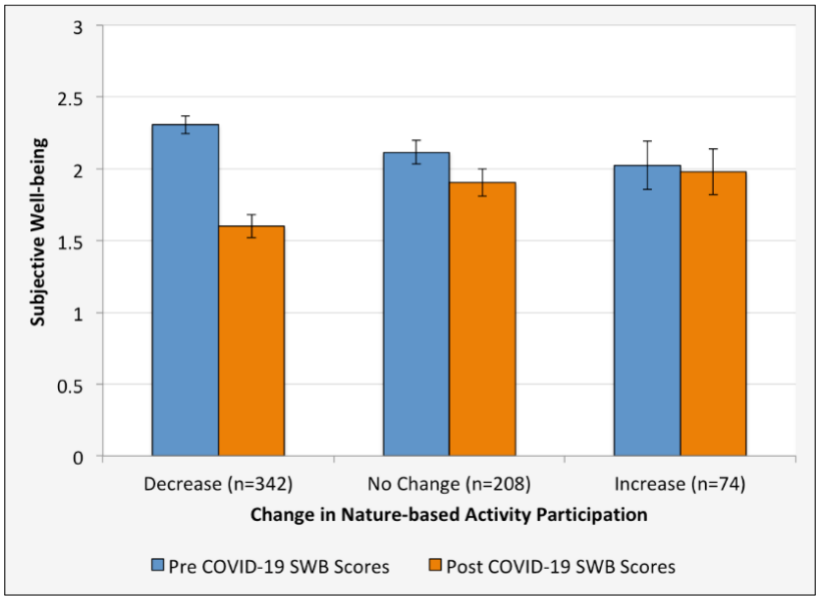


Figure 1. Changes in outdoor activity participation rates (by type of outdoor activity) pre- and post-COVID-19 pandemic for adolescents in the United States (N = 624). Mean activity scores ranged from 0 (never participate) to 2 (often participate).

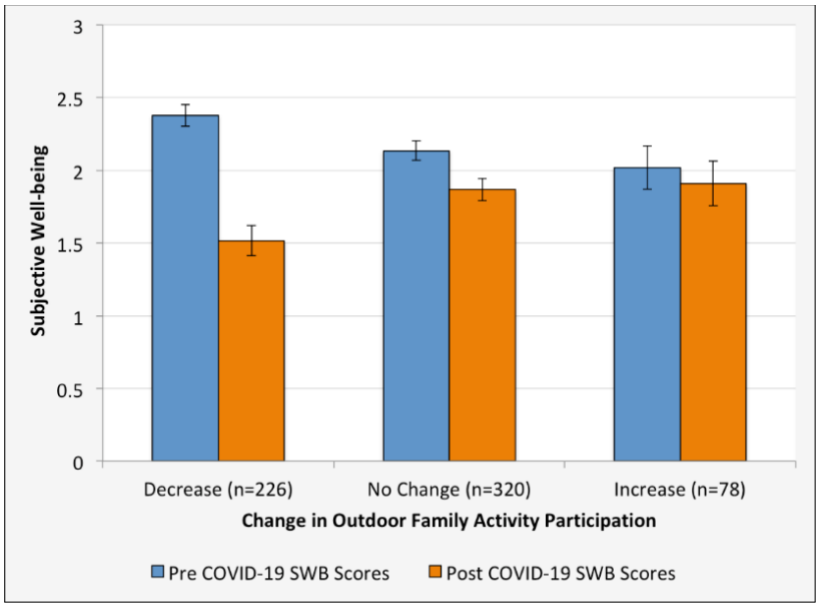
Figure 2. Changes in subjective well-being scores by changes in rates of outdoor play activity (a), nature-based activity (b), and outdoor family activity (c) participation pre and post COVID-19 pandemic for adolescents in the United States (N = 624). Mean activity scores ranged from 0 (at no time) to 3 (all of the time). This figure is made up of three graphs (a, b, and c).


3
2.5
2
1.5
1
0.5
0
Subjective Well-being
Decrease (n=399)
No Change (n=149)
Increase (n=76)
Change in Outdoor Play Activity Participation
Pre COVID-19 SWB Scores
Post COVID-19 SWB Scores

(a)


3
2.5
2
1.5
1
0.5
0
Subjective Well-being
Decrease (n=342)
No Change (n=208)
Increase (n=74)
Change in Nature-based Activity Participation
Pre COVID-19 SWB Scores
Post COVID-19 SWB Scores

(b)


3
2.5
2
1.5
1
0.5
0
Subjective Well-being
Decrease (n=226)
No Change (n=320)
Increase (n=78)
Change in Outdoor Family Activity Participation
Pre COVID-19 SWB Scores
Post COVID-19 SWB Scores

(c)

Table 5. Linear Regression depicting factors associated with change in subjective well-being scores pre and post COVID-19 for adolescents in the Unites States (N = 624).

Difference in SWB Score (Post-Pre)	*B*	Standard Error	Standard Beta	*p*
Pre COVID-19 SWB score	−0.44	0.04	−0.35	0.000 ***
Pre COVID-19 participation in play-based activities	0.30	0.08	0.21	0.000 ***
Pre COVID-19 participation in nature-based activities	−0.08	0.07	−0.06	0.271
Pre COVID-19 participation in outdoor family activities	−0.02	0.05	−0.01	0.714
Change in play-based activity participation during COVID-19	0.44	0.07	0.40	0.000 ***
Change in nature-based activity participation during COVID-19	0.21	0.09	0.14	0.016 *
Change in outdoor family activity participation during COVID-19	0.06	0.04	0.07	0.128
Gender	−0.01	0.05	−0.01	0.804
Age	−0.00	0.01	−0.00	0.941
Income	0.00	0.02	0.00	0.913
Race: White (reference group)				
Black	0.03	0.08	0.01	0.713
Hispanic	0.06	0.08	0.02	0.478
Asian/Pacific Islander	0.02	0.10	0.01	0.832
Native American	−0.31	0.25	−0.04	0.219
Other	−0.29	0.25	−0.04	0.246
Prefer not to answer	−0.20	0.35	−0.02	0.572
Identify as more than one race	0.02	0.10	0.01	0.851
Community type: Suburbs near a large city (reference group)				
Rural area	−0.07	0.07	−0.04	0.313
Small city or town	0.00	0.07	0.00	0.974
Large city	−0.10	0.07	−0.05	0.141
Geographic region: South (reference group)				
West	−0.05	0.07	−0.03	0.414
Midwest	−0.03	0.07	−0.01	0.723
Northeast	0.03	0.07	−0.01	0.687
Intercept	0.59	0.14		0.000 ***

All change scores represent average post-pre scores. Reference groups were selected based on the largest categories for each respective variable. Gender: Male = 0, Female = 1, Non-binary = 2, Prefer not to answer = 4. Age: 10 = 1, 11 = 2, 12 = 3, 13 = 4, 14 = 5, 15 = 6, 16 = 7, 18 = 9. Income: Less than USD 30,000 = 1, USD 30,000–USD 49,999 = 2, USD 50,000–USD 74,999 = 3, USD 75,000–USD 99,999 = 4, USD 100,000–USD 149,999 = 5, USD 150,000 or more = 6, Prefer not to answer = 7. N = 624, R2 = 0.421, Adjusted R2 = 0.399, * $p < 0.05$; *** $p < 0.001$.

CHAPTER 4: Connection to Nature Boosts Adolescents' Mental Well-being During the COVID-19 Pandemic

Abstract

This research explores COVID-19 related changes in adolescents' connection to nature and its role in maintaining mental well-being before and during the pandemic. Data collection occurred through a nationally representative survey of adolescents across the United States (n = 624) between 30 April and 15 June 2020. Survey items focused on connection to nature, mental well-being, and participation in outdoor activities before and during the pandemic. Paired sample t-tests revealed declines in connection to nature, mental well-being, and frequency of participation in outdoor activities. Mediation analyses comparing connection to nature's mediating role between outdoor activity participation and mental well-being before and during the pandemic indicate that connection to nature played an important role in driving improved mental well-being, however, during the pandemic the direct effect of particiaption in outdoor activities increased, accounting for a greater impact on mental well-being than before the pandemic. This study expands our understanding of connection to nature's role in enhancing mental well-being benefits associated with nature contact.

Introduction

The COVID-19 pandemic has had a profound impact on people around the world. In addition to the range of physical health complications associated with contracting the coronavirus, the pandemic has also impacted mental well-being by changing daily routines and increasing stress and uncertainty (Cullen et al., 2020; Galea et al., 2020; Holmes et al., 2020; Meyer et al., 2020). This may be particularly true for adolescents (Muñoz-Fernández & Rodríguez-Meirinhos, 2021), the group of youth who are 10–19 years old (World Health Organization, 2020). Because adolescents' daily routines have become increasingly organized and scheduled in recent years (Clements, 2004; Prince et al., 2013; Skar et al., 2016), disruptions to daily life may hold potential for high levels of pandemic-related stress. Such disruptions may have long-term impacts on adolescent development and well-being, as adolescence is a key developmental stage when activity patterns develop and solidify, setting trends that persist into adulthood (Chawla, 1999, 2015; Kahn & Kellert, 2002; Kuo et al., 2019; Pensini et al., 2016; Wells & Lekies, 2006). Research exploring impacts associated with the pandemic show that adolescents increased their participation in sedentary activities (Dunton et al., 2020) and decreased participation in outdoor activities, resulting in declines in their overall mental well-being (Jackson et al., 2021). Adolescence is also recognized as a life stage when individuals are more susceptible to the impacts of trauma and stress. (De Bellis & Zisk, 2014; Lupien et al., 2009). Increased stress during adolescence can predispose individuals to greater susceptibility to stress later in life (Lupien et al., 2009), potentially contributing to the development of stress-related health disorders (Rasheed, 2016). Further exploration of these impacts may provide insights into how best to support adolescents during times of increased stress.

One important and understudied aspect of the pandemic is its impact on adolescents' connection to nature. Defined as a cognitive, affective, and experiential relationship with nature, a connection to nature develops through regular contact with nature (Martin et al., 2020; Mayer & Frantz, 2004; Nisbet et al., 2009). A strong connection to nature is linked to participation in more outdoor activities (Martin et al., 2020; Mayer & Frantz, 2004; Wolsko & Lindberg, 2013) and a commitment to environmental conservation (Chawla & Cushing, 2007; Mackay & Schmitt, 2019; Nisbet et al., 2009; Whitburn et al., 2019). Exposure to outdoor environments during childhood is recognized as a key antecedent to the development of a connection to nature (Chawla, 1999; Cheng & Monroe, 2012; Wells & Lekies, 2006), and there is evidence that once developed, connection to nature is relatively stable. For instance, research investigating fluctuations in adult attitudes towards appreciation for nature and environmental protection indicate such attitudes were stable over a span of more than two years (Kaiser et al., 2014). In part, this may be because the link between nature-based activities and connection to nature is self-reinforcing. For example, participation in outdoor and nature-related activities contributes to the development of a connection to nature (Martin et al., 2020; Mayer & Frantz, 2004), which in turn serves as a motivator for continued time spent in nature (Colléony et al., 2017; Rosa et al., 2019; Wolsko & Lindberg, 2013). Accordingly, developing a connection to nature through outdoor experiences early in life may have lifelong benefits (Pensini et al., 2016).

Contact with nature has also been shown to enhance health and well-being (Martin et al., 2020; Mayer et al., 2009; Whitburn et al., 2019). Well-being benefits associated with exposure to nature include improved physical health (Annerstedt & Währborg, 2011; Bowler et al., 2010; Frumkin et al., 2017; Mitchell & Popham, 2008); however, a majority of findings relate to improved mental well-being (Barton & Pretty, 2010; Berto, 2014; Hartig et al., 1997; Hinds &

Sparks, 2008; Mayer et al., 2009; Nisbet et al., 2011; Pearson & Craig, 2014). Mental well-being benefits linked to contact with nature such as restoration from stress (Hartig et al., 2003; Ulrich et al., 1991) and increased resilience to negative health outcomes associated with stress (Berman et al., 2012; van den Berg et al., 2010) are of great interest (Frumkin et al., 2017), particularly during the pandemic (Jackson et al., 2021; Samuelsson et al., 2020). While individuals can obtain these well-being benefits from exposure to nature without a connection to nature (Bratman et al., 2015, 2019; Kuo, 2015), previous research points to the development of a psychological connection to nature as important for realizing the full potential of contact with nature (Cheng & Monroe, 2012; Martin et al., 2020; Soga et al., 2018). Research exploring connection to nature's role in driving improved health and well-being highlight its potential for improving mental health (Capaldi et al., 2014; Chawla et al., 2014; Pensini et al., 2016). However, the specific impacts of connection to nature on mental health and well-being remain uncertain (Dean et al., 2018).

Fluctuations in connection to nature during the COVID-19 pandemic may provide insights into the stability of adolescent connection to nature during a time when participation in outdoor and nature-related activities has declined (Dunton et al., 2020; Jackson et al., 2021). Investigating impacts to connection to nature also allows for further exploration of the role that connection to nature plays in enhancing the mental well-being benefits associated with nature contact, providing insights into connection to nature's capacity to improve adolescents' resilience during the pandemic. Previous studies investigating the relationship between nature contact, connection to nature, and mental well-being demonstrate that connection to nature mediates the relationship between nature contact and improved mental well-being (Martin et al., 2020; Mayer et al., 2009; Wolsko & Lindberg, 2013). Evaluating connection to nature's

mediating role both before and during the pandemic provides a unique and novel approach to understanding the degree to which this mediating effect may fluctuate in predicting mental well-being during the pandemic.

While the pandemic is likely impacting all adolescent's contact with nature, connection to nature, and mental well-being to some degree, its effects may be more pronounced for certain demographic groups (Dorn et al., 2020). Characterizing these effects across demographic groups (gender, age, race, household-income, community type, and region of the country) is critical to understanding inequities in access to nature and how such inequities may impact mental well-being. Research exploring trends in outdoor activity patterns in the Unites States prior to the pandemic showed girls, Black youth, and older adolescents spent less time outside and more time on electronic devices (Larson et al., 2019), underscoring trends that may be exacerbated during the pandemic. Additionally, adolescents in urban environments are at a greater risk of contracting COVID-19, and there is less nearby nature available compared to more rural environments (Rigolon et al., 2018; Samuelsson et al., 2020). The greater density of people seeking nearby nature in urban areas may further limit access to outdoor leisure opportunities due to social distancing policies, park closures, and citywide lockdowns in areas with high infection rates (Freeman & Eykelbosh, 2020; Slater et al., 2020).

This study addresses gaps in our understanding of the impacts of the COVID-19 pandemic on adolescent connection to nature by testing the following hypotheses. First, in line with previous studies (Jackson et al., 2021), (H1) we hypothesized that adolescent activity patterns and well-being declined during the pandemic along with connection to nature. Next, (H2) we hypothesized that adolescent declines in mental well-being would be predicted by declines in connection to nature. Because a connection to nature may enhance mental well-being

benefits associated with outdoor and nature-related activity participation (Martin et al., 2020), (H3) we also hypothesized that connection to nature mediates the relationship between participation in outdoor activities and mental well-being during the COVID-19 pandemic so that higher levels of connection to nature mitigate decreases in mental well-being. Additionally, as connection to nature is thought to be a relatively stable trait that supports well-being, (H4) we hypothesized that connection to nature will play a more important role in driving improved mental well-being during the COVID-19 pandemic. In addition to addressing these hypotheses, we also explored differences in connection to nature across age, race, gender, annual household income, and community type, as they represent demographic variables of interest that may highlight inequities in connection to nature.

Materials and Methods

Data collection

Our study was conducted with an online panel provided by Qualtrics XM through a stratified convenience sampling approach. We used a Qualtrics panel as it allowed for demographic quotas and, when compared to other online panel providers, Qualtrics samples came closest to a national probability sample in terms of demographic representativeness (Boas et al., 2020). Qualtrics also allows for quick data collection—a critical need in our COVID-19-focused study—as it compiles panel respondents recruited from a range of other firms (Boas et al., 2020). The Qualtrics panel provided for this study drew from a national pool (50 states, Puerto Rico) with demographic quotas for gender (male, female, non-binary and other), race (White, Black, Hispanic, Asian/Pacific Islander, Native American, other), and community type (rural area, small city or town, suburb near a large city, and large city) representative of the 2019 U.S. census data. Sampling was restricted to parents and their children between the ages of 10-18

years old. We chose this age range because adolescents are particularly susceptible to stress linked to global health crises (Danese et al., 2020; Schwarz & Perry, 1994), and old enough to understand the survey.

Data collection began April 30, 2020, and closed June 15, 2020. Data were collected through separate but linked parent and child survey instruments that were created and administered using the Qualtrics platform. Surveys were administered to qualifying parents who completed the parent version of the survey before being prompted to hand their device to their qualifying child to complete the adolescent version of the survey. Prior to starting the survey, parents were provided with a linked and downloadable consent form acknowledging their consent to participate and their consent for their child to participate. Adolescents were also provided with an age-appropriate assent form acknowledging their consent to participate.

Survey instrument

The adolescent survey instrument included 30 self-reported items comprising three main constructs all assessed before (via participant recall) and during COVID-19: outdoor and nature related activity participation, connection to nature, and mental well-being. In addition to these constructs, adolescents were also asked demographic questions including gender, race, and age. Demographic information gathered from the parent survey included annual household income, community type, and state of residence.

Nature experience and outdoor play activity items focused on determining frequency of participation in specific nature experience and outdoor play activities. Adolescents were asked "How often did you participate in the following activities this time last year and now, after you have been asked to practice social distancing because of the coronavirus outbreak?". Both the retrospective and current iteration of the items used a three-point Likert scale with the responses

"Never", "Every now and then", and "Often". A short response scale was used for this construct as our research questions are focused on determining directional trends rather than specific measures of intensity or extremity (DeCastellarnau, 2018). We included seven nature experience activities confined to more natural settings (paddling, hunting, camping, fishing, hiking, wildlife viewing, and playing in the woods) and five outdoor play activities that could be carried out in less natural outdoor environments (bicycling outside, playing sports outside, going for walks or runs outside, swimming outside, and skating outside) for a total of 12 different activities (See Table 1 for list of activities). These activities were selected based on retrospective qualitative interviews conducted with young adults (18-35 years old) during the summer of 2019 focused on childhood experiences that shaped respondent's connection to nature, as well as several previous studies focused on adolescent participation in outdoor and physical fitness activities (Valois et al., 2004).

Connection to nature was measured using a modified version of the six-item nature relatedness scale, which incorporates items measuring the degree of nature relatedness to 'self' and 'experience' (Larson et al., 2019 Nisbet & Zelenski, 2013). Although a number of scales have been developed to measure constructs such as connectedness to nature (Mayer & Frantz, 2004), connectivity with nature (Dutcher et al., 2007), and environmental identity = (Clayton, 2003), the six-item nature-relatedness scale was selected for this study due to its brevity, acceptability for use with youth, and its previous applications in understanding differences in individuals connection to nature and subjective well-being (Nisbet et al., 2009, 2011; Nisbet & Zelenski, 2013; Zelenski & Nisbet, 2014). We made two additional modifications to the scale. First, as we were interested in connection to nature before and during COVID-19, we modified the question stem to assess respondents' connection to nature prior to being asked to practice

social distancing as well as after: “How much did you disagree or agree with the following statements, both before and after you were asked to practice social distancing because of the coronavirus outbreak?” Lastly, to reduce the burden on respondents, we modified the response items to be three-point Likert scales including the responses “disagree”, “neither/neutral”, and “agree”.

Mental well-being was measured using a modified four-item version of the World Health Organization’s (WHO) five-item subjective health and well-being index (De Souza & Hidalgo, 2012; McDowell, 2010; Topp et al., 2015), which has been used internationally for measuring the subjective well-being (SWB) of both children and adults (Topp et al., 2015). Often described as a measure of happiness, the WHO SWB index represents a unidimensional measure of an individual’s mental health with high predictive validity (Topp et al., 2015). While measures of SWB might be impacted by the momentary mood of the respondent at the time of their response, previous studies highlight that the use of a multi-item scale is less susceptible to such distortion (Diener, 2009; Kamman et al., 1979). Measures of recalled mood and emotions are relatively stable and reliable over periods of time ranging from 2 weeks to 3 months (Kamman et al., 1979; Levine et al., 2001), which was the approximate time frame required for adolescents to recall pre-pandemic SWB in our study. Although acute events experienced by individuals may impact reported SWB, these individual events do not impact inferences drawn from the overall sample unless they are experienced systematically by relatively large numbers of respondents. We made several careful modifications to the scale. First, as we were interested in SWB before and during COVID-19, we modified the question stem to assess respondents’ health prior to being asked to practice social distancing as well as after: “How did you feel both before and after you were asked to practice social distancing because of the coronavirus outbreak?” In addition, as this

survey was aimed at adolescents, we omitted one item and modified the wording on the remaining items to be appropriate for younger audiences (see Table 3 for final item wording). Lastly, to reduce the burden on respondents, we modified the response items to be four-point Likert scales including the responses “at no time”, “some of the time”, “most of the time”, and “all of the time”.

Data preparation and scale development

We used listwise deletion to remove 257 responses that were either straight-line responses (answering the same for all questions) or nonsensical text responses (related to open text questions), resulting in a final sample of 624 youth. Parent and child surveys were linked using Qualtrics embedded dyad codes. When a survey response was removed from the sample, the corresponding parent or child survey was also removed. Survey items were coded as follows: nature experience and outdoor play activity participation (Never = 0, Every now and then = 1, Often = 2), connection to nature (Disagree = -1, Neither/neutral = 0, Agree = 1), mental well-being (At no time = 1, Some of the time = 2, Most of the time = 3, All of the time = 4), gender (Male = 0, Female = 1, Non-binary = 2, I identify another way = 3, Prefer not to answer =4), race (White = 0, Black = 1, Hispanic = 2, Asian/Pacific Islander = 3 , Native American = 4, Other = 5, Prefer not to answer = 6, Two or more races = 7), age (10 =1, 11 = 2, 12 = 3, 13 = 4, 14 = 5, 15 = 6, 16 = 7, 17 = 8, 18 = 9), annual household income (Less than $30,000 = 1, $30,000 - $49,999 = 2, $50,000 - $74,999 = 3, $75,000 - $99,999 = 4, $100,000 - $149,999 = 5, $150,000 or more = 6, Prefer not to answer = 7), community type (Rural area = 1, Small city or town = 2, Suburb near a large city = 3, Large city = 4) and region of the country (South = 1, West = 2, Midwest = 3, Northeast = 4). Regions were determined by breaking state of residence data into geographic regions delineated by the U.S. Census Bureau, with Alaska and Hawaii being added

to the West region and Puerto Rico being added to the South region (South: AL, AR, DC, DE, FL, GA, KY, LA, MD, MS, NC, OK, PR, SC, TN, TX, VA, WV) (Northeast: CT, ME, MA, NH, NJ, NY, PA, RI, VT) (Midwest: IL, IN, IA, KS, MI, MN, MO, NE, ND, OH, SD, WI) (West: AK, AZ, CA, CO, HI, ID, MT, NV, NM, OR, UT, WA, WY) (U.S. Census Bureau, 2020). The cleaned dataset was analyzed with Stata 14.1.

We selected outdoor and nature related activities for each grouping *a priori* and assessed the validity of these groupings using exploratory factor analysis (principal component factor analysis, or PCF) with an orthogonal varimax rotation to assess the dimensionality and internal consistency of all individual pre COVID-19 activities (Table 1). The analysis supported a two-factor structure explaining 56% of the variance. These factors were 'nature experience activities' (7 items, $\alpha = 0.86$) and 'outdoor play activities' (5 items, $\alpha = 0.78$). All activity groupings displayed acceptable convergence (all activities loaded with eigenvalues > 1.0). We created composite scores for each activity grouping by averaging responses. PCF was also used to assess the dimensionality and internal consistency of our modified before COVID-19 six-item nature relatedness scale (Table 2). The analysis supported a unidimensional factor structure explaining 63% of the variance. The scale also demonstrated high internal consistency ($\alpha = 0.88$), and acceptable convergence (all items loaded with eigenvalues >1.0). All six items were averaged to create before and during COVID-19 connection to nature composite scores. We again used PCF to assess the dimensionality and internal consistency of our modified before COVID-19 four-item WHO SWB scale (Table 3). The analysis supported a unidimensional factor structure that explained 70% of the variance. The scale also demonstrated high internal consistency ($\alpha = 0.85$) and acceptable convergence (all items loaded with eigenvalues >1.0). All four items were averaged to create before and during COVID-19 mental well-being composite scores.

Hypothesis testing

To evaluate our first hypothesis, we ran paired sample t-tests to explore differences in nature experience and outdoor play activity groups, connection to nature, and mental well-being before and during COVID-19. We used the Bonferonni correction to address family-wise error rates associated with conducting multiple tests of significance (Bland & Altman, 1995).

To address our second and third hypothesis, we used stepwise multiple linear regression to conduct mediation analyses using the causal steps approach (Baron & Kenny, 1986). We created a total of four mediation models to determine whether connection to nature mediated the relationship between participation in activity groups and mental well-being both before and during COVID-19. Each mediation model was conducted in three steps: 1) testing in sequence the relationship between activity participation and its relationship with connection to nature scores (Figure 1, path A); 2) the relationship between activity participation and mental well-being (Figure 1, path C); and 3) testing the relationship between activity participation and mental well-being, controlling for connection to nature (Figure 1, path B and C'). Mediation models one and two explored the degree to which connection to nature scores mediated the relationship between participation in nature experience activities and mental well-being scores both before (model 1) and during (model 2) the pandemic. Mediation models three and four explored the degree to which connection to nature scores mediated the relationship between outdoor play activities and mental well-being scores before (model 3) and during (model 4) the pandemic. Step 3 measuring paths C and C' in models 2 and 4 addressed our second hypothesis, while the set of analyses as a whole addressed our third hypothesis. In addition to running stepwise multiple linear regressions to test H3, we also used 5000 bootstrapped repetitions of our sample to generate an empirically derived representation of the sampling distribution of the indirect

effect (path AB) for each model, increasing the power and accuracy of our inferences (Hayes, 2009, 2018; Preacher & Hayes, 2004). The indirect effect (path AB), sometimes referred to as the mediating effect, provides a measure of the degree to which a relationship is mediated and can be calculated by multiplying path A and path B, or by subtracting the total effect (path C) from the direct effect (path C') (Preacher & Hayes, 2004).

We controlled for gender (with males as the reference group), race (with white as the reference group), age, household income (with households making less than $30,000 as the reference group), community type (with rural areas as the reference group), and geographic region (with South as the reference group) in each model. We selected these reference groups as they represent the groups with the highest sample size in their respective categories with the exception of the variable household income and community type. Households' making less than $30,000 was selected as a reference group for household income because it was the base group for the category. Rural areas were selected as the reference group for community type as they represent the category that likely offers the greatest degree of nature contact for residents.

To address our fourth hypothesis, we calculated differences between before and during COVID-19 mediation analyses for each activity group by comparing mediation pathway coefficients using Z tests (Clogg et al., 1995). The formula $Z = \frac{B_1 - B_2}{\sqrt{(SEB_1)^2 + (SEB_2)^2}}$ was used with (B_1) representing the before COVID-19 unstandardized path coefficient and (B_2) representing the during COVID-19 unstandardized path coefficient and *SEB* representing the standard error of the unstandardized path coefficient. This allowed us to compare changes for each pathway between before and during the pandemic mediation analyses. The unstandardized coefficients for path A, B, C (total effect), C' (direct effect), and AB (indirect effect) from before the pandemic (model 1 and 2) were compared to the corresponding coefficients from during the pandemic (model 3 and

4). Finally, to see if differences in connection to nature varied across age, race, gender, annual household income and community type we also conducted a series of ANOVA tests with Bonferroni adjustments.

Results

Sample

Our sample (n = 624) was comprised of an equal gender ratio, was 60% White, and included adolescents ranging from 10–18 years old with relatively equal splits across ages. Household income was normally distributed, and the Southern region of the United States had the greatest number of respondents (40%), with suburbs of large cities being the most common community type (37%) (Table 3).

Activity participation, connection to nature, and mental well-being

We found support for H1, as adolescents reported a 41% decline in nature experience activities ($t(623) = 13.666$, $p < 0.001$; Table 5) and a 43% decline in outdoor play activities ($t(623) = 18.333$, $p < 0.001$; Table 5) during the pandemic. Similarly, we observed a 45% decline in connection to nature scores ($t(623) = 7.253$, $p < 0.001$; Table 5) and a 21% decline in mental well-being scores ($t(623) = 14.870$, $p < 0.001$; Table 5) during the pandemic. Declines in nature experience activities were reported by 55% of adolescents, with 11% reporting increases; declines in outdoor play were reported by 64% of adolescents, with 12% reporting increases. Declines in connection to nature were reported by 34% of adolescents, with 17% reporting increases. Declines in mental well-being were reported by 52% of adolescents, with only 10% reporting increases.

Mediation analyses

We found support for H2, as mediation analyses indicate direct relationships between during COVID-19 declines in mental well-being and declines in connection to nature when controlling for participation in either nature experience ($B = 0.41$, $p < 0.001$; Appendix Table 2) or outdoor play activities ($B = 0.33$, $p < 0.001$; Appendix Table 4).

We found support for H3, as both before and during COVID-19, connection to nature mediated the relationship between participation in both of the activity groups and mental well-being. Before the pandemic, connection to nature had the greatest impact on mental well-being when coupled with participation in nature experience activities, accounting for 70% of the total effect on mental well-being. Connection to nature played a reduced role in driving improved mental well-being for individuals participating in outdoor play activities before the pandemic, accounting for 32% of the total effect on mental well-being. Before COVID-19, there was no direct relationship between participation in nature experience activities and mental well-being scores when controlling for connection to nature ($B = 0.07$, $p = 0.153$; Figure 3, Appendix Table 2), indicating that connection to nature fully mediated the relationship between nature experience activities and mental well-being scores before the pandemic. There was a direct relationship between participation in outdoor play activities and mental well-being scores when controlling for connection to nature ($B = 0.26$, $p = <0.001$; Figure 4, Appendix Table 4), indicating that connection to nature partially mediated the relationship between nature experience activities and mental well-being scores before the pandemic.

During COVID-19, connection to nature had the greatest impact on mental well-being when coupled with participation in nature experience activities, accounting for 45% of the total effect on mental well-being. Connection to nature played a reduced role in driving improved

mental well-being for individuals participating in outdoor play activities, accounting for 27% of the total effect on mental well-being during the pandemic. There was a direct relationship between participation in nature experience activities and mental well-being scores when controlling for connection to nature (B = 0.39, p = <0.001; Figure 3, Appendix Table 2), indicating connection to nature partially mediated the relationship between nature experience activities and mental well-being scores during the pandemic. There was also a direct relationship between participation in outdoor play activities and mental well-being scores when controlling for connection to nature (B = 0.53, p = <0.001; Figure 4, Appendix Table 4), indicating connection to nature partially mediated the relationship between outdoor play activities and mental well-being scores during the pandemic.

Bootstrapping results provide further support for H3, as none of the confidence intervals for the indirect effect in any of our models included zero, indicating a significant indirect effect for each model (model 1: indirect effect = 0.160, 95% CI = [0.115, 0.212], z = 6.44, p = <0.0001), (model 2: indirect effect = 0.175, 95% CI = [0.123, 0.230], z = 6.30, p = < 0.0001), (model 3: indirect effect = 0.123, 95% CI = [0.077, 0.171], z = 5.08, p = <0.0001), (model 4: indirect effect = 0.145, 95% CI [0.093, 0.199], z = 5.36, p = <0.0001).

Comparing mediation coefficients before and during COVID-19

While there were differences between before and during COVID-19 mediation models, we did not find support for H4, as the indirect path between activity participation and mental well-being increased in both models but was not significantly different from before the pandemic in either the nature experience activities model (path B: z = -0.417, p = 0.338; Table 6; Figure 3) or outdoor play activities model (path B: z = -0.611, p = 0.271; Table 6; Figure 4). Significant differences between before and during COVID-19 mediation path coefficients were limited to

the direct path between activity participation and mental well-being, which increased during COVID-19 in models for nature experience activities (path C': z = -1.992, p = 0.023; Table 6; Figure 3) and outdoor play activities (path C': z = -2.063, p = 0.020; Table 6, Figure 4). While there were no other significant differences between before and during COVID-19 mediation coefficients, we did detect trends across models for both activity groups. The relationship between activity participation and connection to nature decreased in both the nature experience model (path A: z = 0.709, p = 0.239; Table 6; Figure 3) and outdoor play activities model (path A: z = 0.600, p = 0.274; Table 6; Figure 4). Similarly, the relationship between connection to nature and mental well-being increased in both the nature experience (path B: z = -1.063, p= 0.144; Table 6; Figure 3) and outdoor play activities model (path B: z = -1.111, p = 0.133; Table 6; Figure 4). The total effect (direct and indirect) between activity and mental well-being increased in both the nature experience model (path C: z = -1.182, p = 0.119; Table 6; Figure 3) and the outdoor play activities model (path C: z = -1.282, p = 0.100; Table 6; Figure 4).

Demographic differences in connection to nature

We observed demographic differences in connection to nature in both the regression models and the exploratory series of one-way ANOVA's, with regression models highlighting differences in age and community type and ANOVA's demonstrating differences in community type. We did not detect differences in connection to nature associated with race, gender, or annual household income before or during the pandemic.

Differences in connection to natures across age

Regression results show that older adolescents had higher connection to nature scores than younger adolescents before the pandemic when controlling for participation in both nature experience (B = 0.02, p = 0.041; model 1; Appendix Table 1) and outdoor play activities (B =

0.02, $p = 0.002$; model 3; Appendix Table 3). Older adolescents also had higher connection to nature scores during the pandemic when controlling for participation in outdoor play activities ($B = 0.02$, $p = 0.041$; model 4; Appendix Table 4).

Differences in connection to nature across community type

Differences in connection to nature associated with community type were evident in both the regression models and ANOVA analysis. Regression results indicate that during the pandemic, adolescents living in small cities and towns had lower connection to nature scores than those living in rural areas when controlling for participation in both nature experience ($B = -0.18$, $p = 0.015$; model 2; Appendix Table 2) and outdoor play activities ($B = -0.20$, $p = 0.005$; model 4; Appendix Table 4), and during the pandemic, adolescents living in rural communities had higher connection to nature scores than those in large cities when controlling for participation in nature experience activities ($B = -0.15$, $p = 0.049$; model 2; Appendix Table 2). ANOVA results correspond with our regression models, with Bonferroni post-hoc analysis showing that adolescents in rural communities had higher connection to nature scores than adolescents in small cities and towns ($B = 0.292$, $p = <0.001$) and large cities ($B = 0.29$, $p = <0.001$). The ANOVA post-hoc analysis also showed that adolescents' living in suburbs of large cities had higher connection to nature scores than adolescents in small cities and towns ($B = 0.23$, $p = 0.003$) and large cities ($B = 0.23$, $p = 0.003$).

Differences in mental well-being across community type during the pandemic

Our regression models show that during the pandemic adolescents living in small cities and towns had higher mental well-being scores than those living in rural areas when controlling for connection to nature and participation in both nature experience ($B = 0.20$, $p = 0.025$; model

2; Appendix Table 2) and outdoor play activities (B = 0.20, p = 0.023; model 4; Appendix Table 4).

Differences in mental well-being across age during the pandemic

Our regression models also show that during the pandemic older adolescents had lower mental well-being scores compared to younger adolescents when controlling for connection to nature and participation in nature experience (B = -0.03, p = 0.009; model 2; Appendix Table 2) and outdoor play activity (B = -0.02, p = 0.041; model 4; Appendix Table 4).

Discussion

Our findings indicate that during the COVID-19 pandemic, adolescent connection to nature, mental well-being, and participation in nature experience and outdoor play activities declined. We also found that declines in connection to nature predicted declines in mental well-being, with connection to nature mediating the relationship between participation in either activity group and mental well-being, both before and during the pandemic. Comparisons between the mediating role of connection to nature before and during the pandemic demonstrate that while connection to nature continues to play an important role in enhancing mental well-being, the role was reduced during the pandemic. The direct effect of participation in outdoor activities played an increased role in driving improved adolescent mental well-being during the pandemic compared to before the pandemic.

Declines in outdoor activity participation, connection to nature, and mental well-being observed in this study could be an unanticipated consequence of community health initiatives aimed at slowing the spread of the virus. Pandemic related changes to adolescent daily routines such as the closure of schools, public parks and recreation spaces, coupled with the cancellation of youth sports and clubs, have limited opportunities for adolescent contact with nature, as

evidenced by COVID-19 related declines in participation in outdoor activities (Jackson et al., 2021) and increases in sedentary activities (Dunton et al., 2020). As contact with nature diminished due to reduced participation in outdoor activities, connection to nature appears to have declined as well (Soga et al., 2021). The widespread decline in adolescent connection to nature found in this study suggests this trait might be less stable and more malleable in youth than it is in adults (Kaiser et al., 2014). If these adverse shifts in adolescents' daily routines continue following the pandemic, they may contribute to lower levels of outdoor activity participation that persist across the lifespan (Bocarro et al., 2008; Rosa et al., 2019; Scott & Willits, 1998), and further contribute to an 'extinction of (nature) experience' (Pyle 1993, Soga & Gaston 2016), highlighting the potential for long-term impacts to connection to nature and mental well-being.

The benefits of outdoor activities for mental well-being are well documented (Frumkin et al., 2017; Hartig et al., 2014; Wolsko & Lindberg, 2013), but our results advance understanding of connection to nature's role in driving that relationship. Participation in either nature experience or outdoor play activities contributed to adolescent connection to nature and well-being, with connection to nature further enhancing the direct effects of participation in outdoor activities both before and during the pandemic. Connection to nature's increased effect on mental well-being when associated with nature experience activities compared to outdoor play activities can likely be attributed to differences in the environments that individuals are exposed to during participation in these activities. Previous research demonstrates that differences in environments yield differences in well-being outcomes, with exposure to natural environments providing greater mental well-being benefits than urban environments (Bratman et al., 2019; Hartig et al., 2003; Ulrich et al., 1991). For example, Hartig et al. (2003) found that young adults experienced

greater stress reduction and directed attention restoration in natural settings compared to urban settings. While our study did not quantify differences in the quality or quantity of nature present during participation in outdoor activities, nature experience activities typically occur in more natural environments, while outdoor play activities can be conducted in nearly any outdoor space. These differences highlight the importance of natural settings in promoting connection to nature and improved mental health.

While the mediating effect of connection to nature on mental well-being decreased during the pandemic, connection to nature remained an important contributor to improved mental well-being. Changes in the degree to which connection to nature mediated the relationship between participation in outdoor activities and improved mental well-being are a result of an increase in the direct effect of outdoor activity participation on mental well-being. This increased direct effect may be a result of pandemic-related changes to daily routines that extend beyond reduced outdoor activity participation. For example, prior to the pandemic, participation in outdoor activities likely represented only a portion of adolescents' opportunities to engage in behaviors associated with improved mental well-being. Daily routines that contribute to mental well-being such as physical activity (García-Hermoso et al., 2020; Janssen & LeBlanc, 2010) and social interaction (Orben et al., 2020) were likely reduced as adolescents shifted to online classes and refrained from mundane excursions outside the home. During the pandemic, participation in outdoor activities may have represented one of the few opportunities' adolescents had to engage in such behaviors, increasing outdoor activities' direct role in driving improved mental well-being during the pandemic. It is also possible that connection nature indirectly fueled the link between outdoor activities and well-being by inspiring and reinforcing higher levels of outdoor activity participation. Although this study did not explore the potential bidirectional relationship

between connection to nature and contact with nature, previous studies have demonstrated connection to nature's role in driving continued contact with nature (Colléony et al., 2017; Wolsko & Lindberg, 2013).

Our findings suggest that although the pandemic impacted connection to nature and mental well-being for almost all adolescents, some groups were impacted more than others. The higher connection to nature scores found in older adolescents before and during the pandemic are similar to findings from an earlier study that found connection to nature declined in the early teenage years and then increased in the late teenage and early adult years (Hughes et al., 2019). Hughes et al. (2019) suggest that changes in connection to nature during adolescence may be a result of life-stage differences, with older adolescents having increased freedom and agency compared to younger adolescents, potentially facilitating the development of connection to nature. Despite older adolescents having higher connection to nature scores, they also exhibited lower mental well-being scores compared to younger adolescents, demonstrating that other factors may outweigh the mental well-being benefits associated with connection to nature. This is further supported by emergent research indicating that older adolescents experienced increased anxiety during the pandemic (Smirni et al., 2020), which may be at least partially due to uncertainties regarding college and work following secondary school (Lee, 2020).

Inequities in connection to nature were particularly evident across different community types, with adolescents living in small cities and towns and large cities experiencing greater declines in connection to nature compared to adolescents in rural areas and suburbs of large cities. Differences between community types can likely be attributed to reduced access to nature due to increased risk of infection in urban areas early in the pandemic (Cuadros et al., 2021), the reduced access to natural spaces in more urban areas (Cox et al., 2017; Samuelsson et al., 2020),

and increased crowding in urban outdoor areas that remained open (Freeman & Eykelbosh, 2020; Slater et al., 2020). Despite having higher connection to nature scores than adolescents from small cities and towns, adolescents in rural areas also exhibited reduced mental well-being scores compared to those in small cities and towns during the pandemic. This particular finding aligns with previous research that suggests connection to nature may be associated with increased stress, anxiety, and depression due to increased environmental awareness and concern within the context of increasing environmental degradation (Dean et al., 2018). Despite this finding, the bulk of our results point to a positive relationship between connection to nature and improved mental well-being. Increasing and promoting access to nearby nature is one approach that may ameliorate inequitable trends in connection to nature, and mental well-being during the pandemic (Soga et al., 2021), as well as times of relative normalcy.

Recommendations for future research

This study highlights a need for additional research exploring connection to nature's role in enhancing the mental well-being of adolescents. In addition to conducting similar studies with large representative samples, future efforts should also consider including respondents from outside of the United States to explore pandemic related impacts across cultural contexts. Additional research on how these trends may change as a pandemic or similar global stressor event progresses could shed light on both the immediate and cumulative benefits of outdoor activity participation and connection to nature for mental well-being during times of crisis. Future studies should also explore the bi-directional relationship between outdoor activity participation and connection to nature, as a deeper understanding of the drivers of adolescent nature engagement may illuminate strategies for increasing participation in activities that positively impact mental well-being. A better understanding of what specific activities contribute

to a connection to nature and improved mental well-being would be valuable both within the context of COVID-19, as well as more broadly in efforts to address the growing disconnect between humans and nature (Soga & Gaston, 2016).

Future research should also explore different study designs, as well as different measures of psychological well-being. While this study relied on short-term recall of respondents' mental well-being before the pandemic, recalled measures of mood, emotions, and subjective well-being can become unstable over longer periods of time (Kim-Prieto et al., 2005; Levine et al., 2001). Longitudinal studies that assess mental well-being at individual moments in time could address this limitation. Continued exploration of changes in the relationship between outdoor activity participation, connection to nature, and mental well-being beyond the COVID-19 pandemic is also important, as environmental determinants of health are nonstationary and continued exploration of these variables may increase the efficacy of future health intervention measures (Kwan, 2021). Future studies could also explore pandemic related impacts to connection to nature, outdoor activity participation, and mental well-being through a qualitative lens, as it may provide a deeper understanding of the mechanisms driving observed relationships.

Conclusion

This study provides evidence supporting the value of connection to nature in maintaining adolescents' mental well-being before and during the COVID-19 pandemic. Our findings indicate that declines in adolescent mental well-being can be reversed through increased participation in outdoor activities, which contribute to improved mental well-being and the development of a connection to nature. The development of a connection to nature further enhances mental well-being by mediating the relationship between outdoor activity participation and mental well-being. While we found that connection to nature enhanced mental well-being for

both nature experience and outdoor activities, our findings indicate that connection to nature played a larger role in driving improved mental well-being for nature experience activities compared to outdoor play activities. The decreased indirect effect of connection to nature found during the pandemic appears to be a result of an increased importance in outdoor activity participation in the absence of other recreation alternatives, rather than a decrease in connection to nature's importance. Efforts to improve adolescent mental health and well-being, especially during times of crisis, could focus on promoting and improving access to nearby nature, allowing for increased outdoor experiences that helps to fuel connection to nature.

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Table 1. Principal component factor analysis of adolescent nature experience and outdoor play activity participation items before COVID-19
This table shows the principal factor analysis results used to delineate activity groups before COVID-19.

Items	Activity means	Nature experience Factor loadings	Outdoor play Factor loadings
Nature experience activities before COVID-19	**0.68**		
Paddling (canoeing, kayaking)	0.51	**0.78**	0.21
Hunting	0.36	**0.78**	0.03
Camping	0.71	**0.74**	0.22
Fishing	0.66	**0.73**	0.17
Hiking	0.82	**0.67**	0.29
Wildlife viewing	0.81	**0.69**	0.25
Playing in the woods (building forts, playing games in the woods)	0.88	**0.54***	0.51*
Outdoor Play Activities before COVID-19	**1.2**		
Bicycling outside	1.22	0.22	**0.76**
Playing sports outside	1.42	0.07	**0.70**
Going for walks or runs outside	1.36	0.17	**0.75**
Swimming outside	1.16	0.16	**0.67**
Skating (skateboard, rollerblades, scooter)	0.84	0.42	**0.61**
Eigenvalues		5.23	1.52
% of variance explained		31.5%	24.8%
Chronbach's alpha		0.86	0.78
Note: Response scale items included: Never=0, Every now and then=1, Often=2. * Cross-loaded items			

Table 2. Principal component factor analysis of adolescent nature relatedness items before COVID-19
This table shows the principal component factor analysis results for the abbreviated nature relatedness scale before COVID-19.

Items	NR means	NR factor loadings
Nature relatedness scale before COVID-19	**0.38**	
My relationship to nature is an important part of who I am.	0.24	0.85
I feel very connected to all living things and the Earth.	0.28	0.85
My favorite places are outside in nature.	0.36	0.82
I think about how what I do affects the Earth.	0.31	0.79
I spend time outdoors whenever I can.	0.45	0.77
I enjoy being outside in nature.	0.65	0.71
Eigenvalue		3.81
% of variance explained		63%
Chronbach's alpha		0.88
Note: Response scale items included: Disagree=-1, Neither/neutral=0, Agree=1		

Table 3. Principal component factor analysis for adolescent subjective well-being items before COVID-19

Items	SWB means	SWB factor
SWB scale before COVID-19	**2.21**	
Cheerful and in good spirits	2.25	0.87
Calm and relaxed	2.13	0.84
Active and full of energy	2.60	0.82
Interested and curious about the world around me	2.19	0.80
Eigenvalue		2.78
% of variance explained		70%
Chronbach's alpha		0.85
Note: Response scale items included: At no time=0, Some of the time=1, Most of the time=2, All of the time=3.		

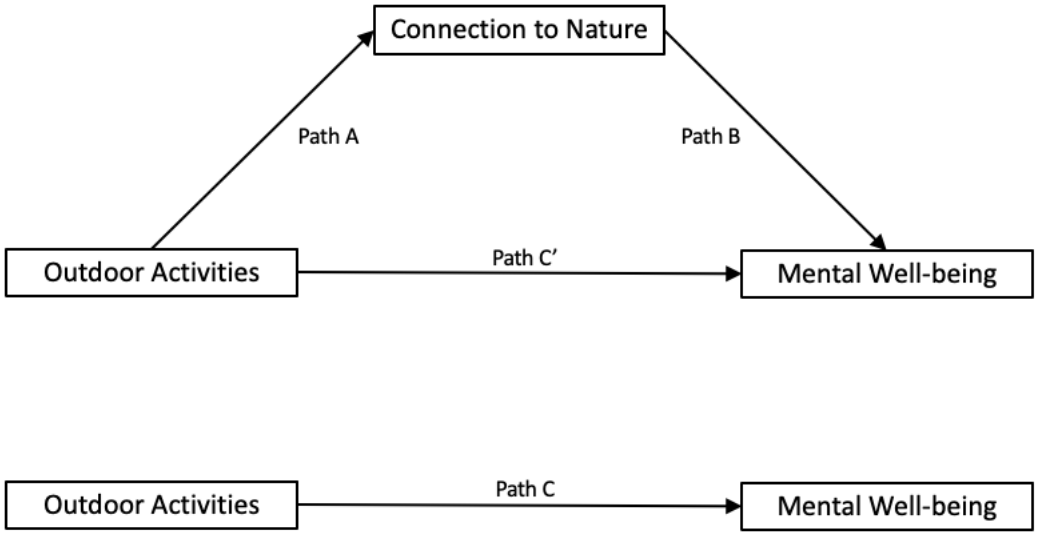

Figure 1. Conceptual mediation model
This figure illustrates the causal steps approach to mediation used in this study.

Table 4. Sample Demographics (*N*=624)
This table shows the demographic breakdown of the sample.

Variable		*N*	%
Gender	Male	306	49.0%
	Female	314	50.3%
	Non-binary	3	0.5%
Race	White	373	59.8%
	Black	71	11.4%
	Hispanic	78	12.5%
	Asian/Pacific Islander	42	6.7%
	Native American	6	1.0%
	Other	6	1.0%
	Two or more races	45	7.2%
Age	10 years	78	12.5%
	11 years	70	11.2%
	12 years	63	10.1%
	13 years	79	12.7%
	14 years	77	12.3%
	15 years	53	8.5%
	16 years	81	13.0%
	17 years	76	12.2%
	18 years	47	7.5%
Income	Less than $30,000	60	9.6%
	$30,000 - $49,999	87	13.9%
	$50,000 - $74,999	114	18.3%
	$75,000 - $99,999	114	18.3%
	$100,000 - $149,999	136	21.8%
	$150,000 or more	94	15.1%
Community	Rural area	126	20.2%
	Small city or town	126	20.2%
	Suburb near a large city	228	36.5%
	Large city	144	23.1%
Region	South	252	40.4%
	West	136	21.8%
	Midwest	106	17.0%
	Northeast	130	20.8%

Note: The category *prefer not to answer* is not included in this table for gender, race, and income resulting in the % for those categories not adding up to 100.

Table 5. COVID-19 related changes in adolescent nature experience and outdoor play activity groups, connection to nature, and mental well-being
This table shows the paired sample t-test results related to hypothesis 1.

Variable	Before COVID-19		During COVID-19		Paired *t* test	
	Mean	SD	Mean	SD	*t*	*p*
Nature experience activities (range 0-2)	0.68	0.55	0.40	0.50	13.666	**<0.001**
Outdoor play activities (range 0-2)	1.20	0.55	0.68	0.57	18.333	**<0.001**
Connection to nature (range -1-1)	0.38	0.56	0.21	0.61	7.253	**<0.001**
Mental well-being (range 0-4)	2.21	0.62	1.75	0.75	14.870	**<0.001**

Note: Response scale items for *Nature experience activities* and *Outdoor play activities*: Never = 0, Every now and then = 1, Often = 2. Response items for *Connection to nature* included: Disagree = 0, Neither/neutral = 1, Agree = 2. Response items for *Mental well-being* included: At no time = 0, Some of the time = 1, Most of the time = 2, All of the time = 3. All t-tests were significant after Bonferroni correction to family-wise error rates (p = 0.007) (Bland & Altman, 1995).

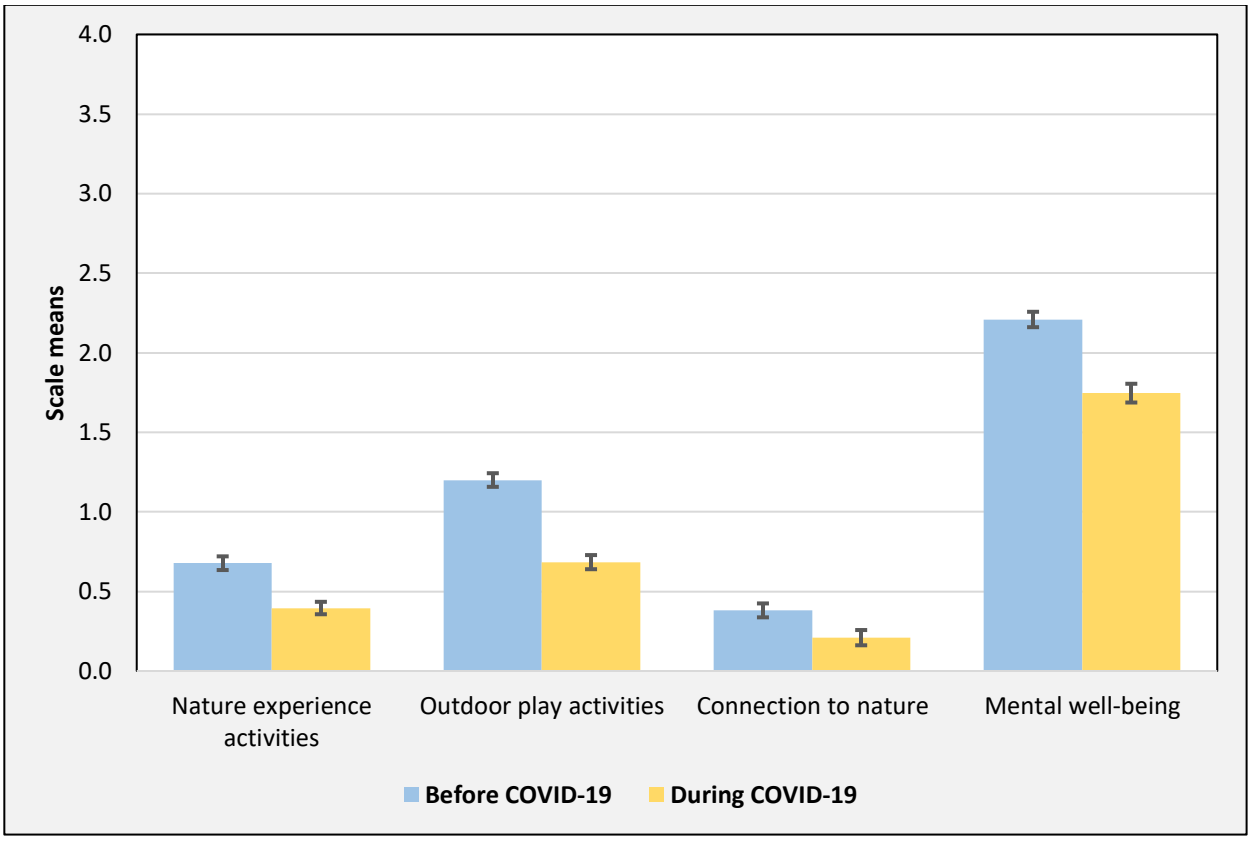

Figure 2. Adolescent participation in different types of activities, connection to nature, and mental well-being before and during the COVID-19 pandemic
Response scale items for *Nature experience activities* and *Outdoor play activities*: Never = 0, Every now and then = 1, Often = 2. Response items for *Connection to nature* included: Disagree = 0, Neither/neutral = 1, Agree = 2. Response items for *Mental well-being* included: At no time = 0, Some of the time = 1, Most of the time = 2, All of the time = 3. Error bars represent 95% confidence intervals.

Table 6. Differences in connection to nature mediation pathway coefficients before and during COVID-19

This table provides a comparison of the before and during COVID-19 mediation path coefficients.

Mediation pathway	Beta Before	Std. Error Before	Beta During	Std. Error During	Z-score	*p*
Nature experience activities						
Path A	0.46	0.04	0.42	0.05	0.709	0.239
Path B	0.34	0.05	0.41	0.05	-1.063	0.144
Path C' (Direct effect)	0.07	0.05	0.22	0.06	-1.992	0.023*
Path C (Total effect)	0.23	0.04	0.39	0.06	-1.182	0.119
Path AB (Indirect effect)	0.16	0.02	0.17	0.03	-0.417	0.338
Outdoor play activities						
Path A	0.48	0.04	0.44	0.04	0.600	0.274
Path B	0.26	0.05	0.33	0.05	-1.111	0.133
Path C' (Direct effect)	0.26	0.05	0.39	0.05	-2.063	0.020*
Path C (Total effect)	0.38	0.04	0.53	0.05	-1.282	0.100
Path AB (Indirect effect)	0.12	0.02	0.15	0.03	-0.611	0.271

Note: Path A = activity participation to connection to nature, Path B = connection to nature to mental well-being, Path C' = activity participation to mental well-being controlling for connection to nature, Path C = activity participation to mental well-being, Path AB = Path C' subtracted from Path C. $^{+}$ $p \leq 0.1$; * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.00$

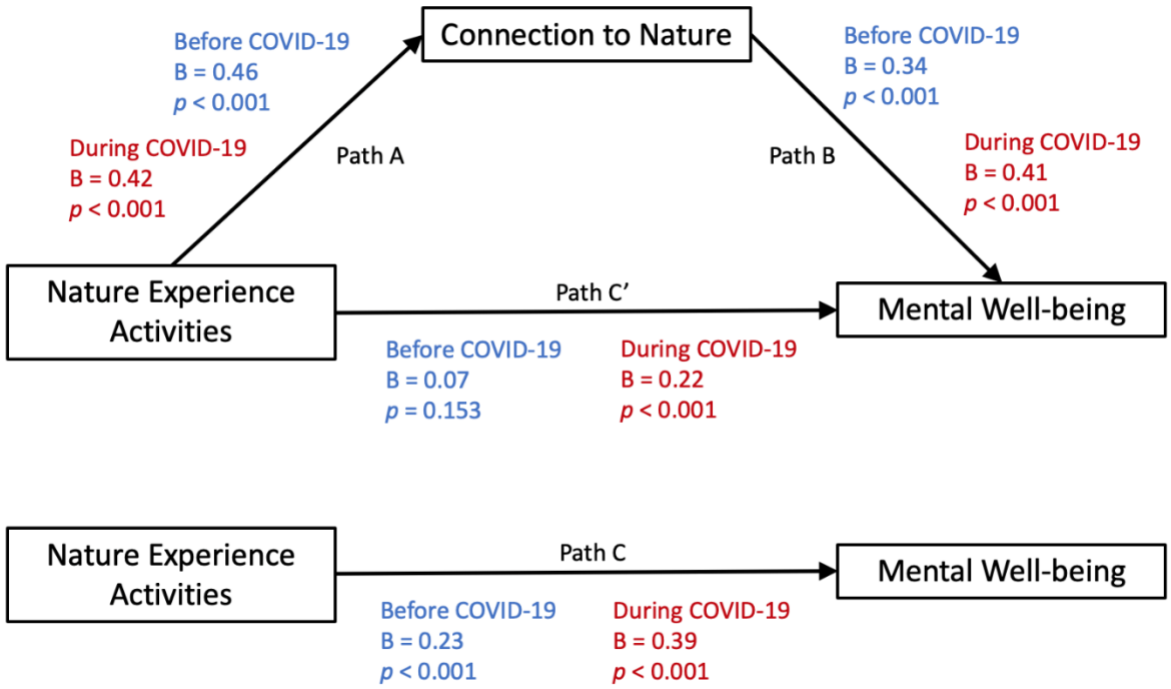

Figure 3. Connection to Nature as a mediator between nature experience activities and mental well-being before and during COVID-19

This figure illustrates the mediation path shifts associated with nature experience activity participation during COVID-19. Connection to nature accounted for 70% of nature experience activities total effect on mental well-being before the pandemic and 45% of the total effect during the pandemic.

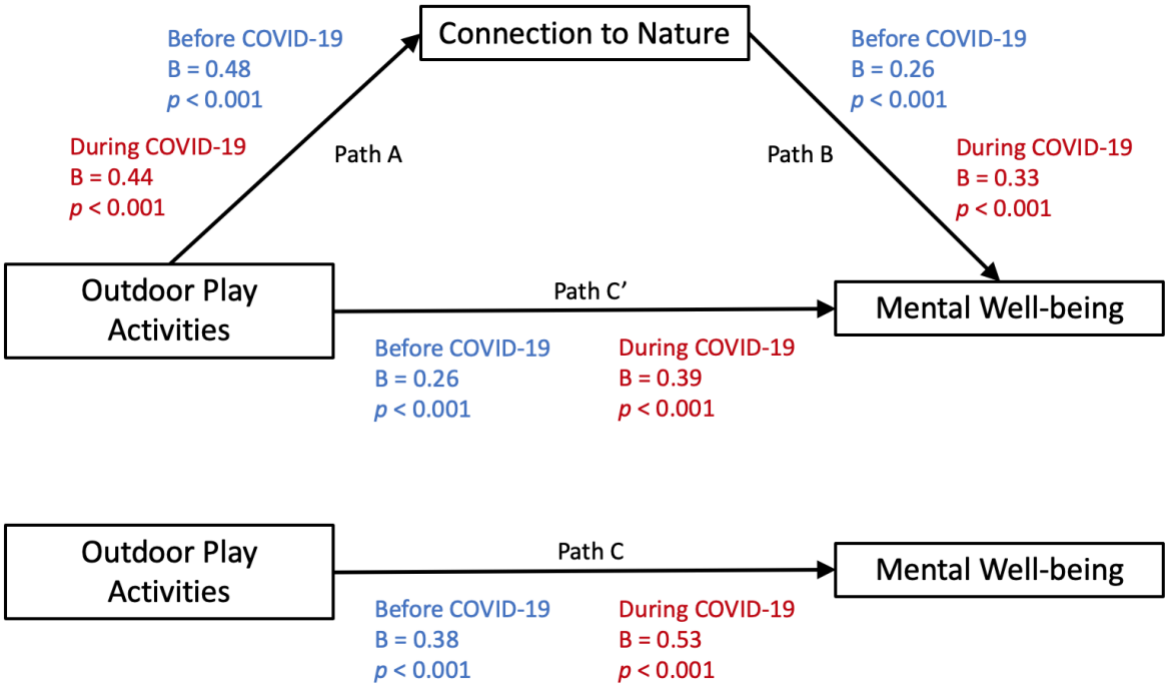

Figure 4. Connection to nature as a mediator between outdoor play activities and mental well-being before and during COVID-19

This figure illustrates the mediation path shifts associated with outdoor play activity participation during COVID-19. Connection to nature accounted for 32% of outdoor play activities total effect on mental well-being before the pandemic and 27% of the total effect during the pandemic.

APPENDIX

Table 1. Mediation model 1 exploring connection to nature's mediating effect between adolescent nature experience activity participation and mental well-being before COVID-19

This table shows the mediation results associated with nature experience activity participation before COVID-19.

	Connection to Nature before COVID-19 Path A			Mental Well-being before COVID-19 Path C			Mental Well-being before COVID-19 Path B and C'		
	Beta	**Std. Beta**	***p***	**Beta**	**Std. Beta**	***p***	**Beta**	**Std. Beta**	***p***
Nature Experience activities before COVID-19	0.46	0.46	0.001*	0.23	0.20	0.001*	0.07	0.06	0.153
Connection to Nature score before COVID-19							0.34	0.31	<0.001*
Race: White (Reference)									
Race: Black	-0.04	-0.02	0.583	0.29	0.15	<0.001*	0.30	0.16	<0.001*
Race: Hispanic	0.12	0.07	0.058	0.22	0.12	0.004*	0.18	0.10	0.016*
Race: Asian/Pacific Islander	0.12	0.05	0.16	0.02	0.01	0.877	-0.03	-0.01	0.792
Race: Native American	0.21	0.04	0.323	-0.12	-0.02	0.628	-0.19	-0.03	0.422
Race: Other	0.19	0.03	0.378	0.24	0.04	0.342	0.17	0.03	0.468
Race: Prefer not to answer	0.02	0.002	0.94	0.09	0.01	0.794	0.08	0.01	0.802
Race: Multi-race	0.12	0.06	0.139	0.18	0.08	0.055	0.14	0.06	0.121
Age	0.02	0.08	0.041*	-0.03	-0.13	0.001*	-0.04	-0.15	<0.001*
Gender	0.05	0.05	0.191	-0.11	-0.09	0.018*	-0.13	-0.11	0.004*
Income: < $30,000 (Reference)									
Income: $30,000 - $49,999	0.06	0.04	0.478	0.23	0.13	0.021*	0.21	0.12	0.028
Income: $50,000 - $74,999	0.01	0.01	0.875	0.08	0.05	0.403	0.08	0.05	0.409
Income: $75,000 - $99,999	-0.06	-0.04	0.494	0.12	0.08	0.209	0.14	0.09	0.129
Income: $100,000 - $149,999	-0.03	-0.02	0.724	0.11	0.07	0.258	0.12	0.08	0.198
Income: $150,000 or more	0.06	0.04	0.485	0.17	0.10	0.105	0.15	0.09	0.139
Income: Prefer not to answer	0.01	0.003	0.929	0.05	0.013	0.765	0.04	0.01	0.776
Home density: Rural (Reference)									
Home density: Small city or town	-0.05	-0.03	0.472	0.05	0.03	0.543	0.06	0.04	0.394
Home density: Suburb	0.05	0.04	0.401	0.02	0.01	0.792	0.00	0.00	0.983
Home density: Large city	-0.01	-0.003	0.934	0.07	0.05	0.353	0.07	0.05	0.32
Region: South (Reference)									
Region: West	-0.02	-0.02	0.687	-0.05	-0.03	0.444	-0.04	-0.03	0.499
Region: Midwest	-0.02	-0.01	0.781	-0.06	-0.04	0.358	-0.06	-0.04	0.381
Region: Northeast	0.02	0.01	0.733	-0.06	-0.04	0.335	-0.07	-0.05	0.267
Intercept	-0.08		0.411	2.07		0.001	2.10		<0.001
Adjusted R^2			0.2063			0.0815			0.1572
N			624			624			624

Table 2. Mediation model 2 exploring connection to nature's mediating effect between adolescent nature experience activity participation and mental well-being during COVID-19

This table shows the mediation results associated with nature experience activity participation during COVID-19.

	Connection to Nature during COVID-19 Path A			Mental Well-being during COVID-19 Path C			Mental Well-being during COVID-19 Path B and C'		
	Beta	**Std. Beta**	***p***	**Beta**	**Std. Beta**	***p***	**Beta**	**Std. Beta**	***p***
Nature Experience activities during COVID-19	0.42	0.35	<0.001*	0.39	0.26	<0.001*	0.22	0.14	<0.001*
Connection to Nature score during COVID-19							0.41	0.34	<0.001*
Race: White (Reference)									
Race: Black	-0.15	-0.08	0.061	0.14	0.06	0.152	0.20	0.09	0.032*
Race: Hispanic	-0.01	-0.01	0.853	0.15	0.07	0.109	0.16	0.07	0.08
Race: Asian/Pacific Islander	-0.12	-0.05	0.209	-0.09	-0.03	0.466	-0.04	-0.01	0.733
Race: Native American	0.22	0.03	0.354	-0.22	-0.03	0.46	-0.31	-0.04	0.274
Race: Other	0.36	0.06	0.137	-0.21	-0.03	0.495	-0.35	-0.05	0.221
Race: Prefer not to answer	-0.38	-0.04	0.258	-0.07	-0.01	0.867	0.08	0.01	0.835
Race: Multi-race	-0.09	-0.04	0.347	0.03	0.01	0.807	0.06	0.02	0.563
Age	0.01	0.04	0.253	-0.02	-0.08	0.035*	-0.03	-0.10	0.009*
Gender	0.06	0.05	0.181	-0.05	-0.03	0.387	-0.07	-0.05	0.172
Income: < $30,000 (Reference)									
Income: $30,000 - $49,999	0.01	0.00	0.957	0.21	0.10	0.091	0.21	0.10	0.078
Income: $50,000 - $74,999	0.07	0.04	0.447	0.30	0.15	0.012*	0.27	0.14	0.016*
Income: $75,000 - $99,999	-0.04	-0.03	0.658	0.33	0.17	0.005*	0.35	0.18	0.002*
Income: $100,000 - $149,999	-0.03	-0.02	0.734	0.16	0.09	0.159	0.18	0.10	0.109
Income: $150,000 or more	0.02	0.01	0.834	0.24	0.12	0.056	0.24	0.11	0.051
Income: Prefer not to answer	0.09	0.02	0.565	0.17	0.04	0.396	0.13	0.03	0.484
Home density: Rural (Reference)									
Home density: Small city or town	-0.18	-0.12	0.015*	0.13	0.07	0.176	0.20	0.11	0.025*
Home density: Suburb	0.06	0.05	0.356	0.08	0.05	0.354	0.05	0.03	0.506
Home density: Large city	-0.15	-0.10	0.049*	-0.06	-0.03	0.552	0.00	0.00	0.965
Region: South (Reference)									
Region: West	0.01	0.01	0.857	-0.11	-0.06	0.181	-0.11	-0.06	0.141
Region: Midwest	0.01	0.00	0.911	-0.05	-0.03	0.543	-0.06	-0.03	0.497
Region: Northeast	0.02	0.02	0.706	-0.10	-0.05	0.211	-0.11	-0.06	0.148
Intercept	0.02		0.831	1.50		<0.001	1.49	.	<0.001
Adjusted R^2			0.1492			0.0798			0.1740
N			624			624			624

Table 3. Mediation model 3 exploring connection to nature's mediating effect between adolescent outdoor play activity participation and mental well-being before COVID-19

This table shows the mediation results associated with outdoor play activity participation before COVID-19.

	Connection to Nature before COVID-19 Path A			Mental Well-being before COVID-19 Path C			Mental Well-being before COVID-19 Path B and C'		
	Beta	**Std. Beta**	***p***	**Beta**	**Std. Beta**	***p***	**Beta**	**Std. Beta**	***p***
Outdoor Play activities before COVID-19	0.48	0.47	<0.001*	0.38	0.34	<0.001*	0.26	0.23	<0.001*
Connection to Nature score before COVID-19							0.26	0.23	<0.001*
Race: White (Reference)									
Race: Black	-0.07	-0.04	0.286	0.26	0.13	0.001*	0.28	0.14	<0.001*
Race: Hispanic	0.05	0.03	0.419	0.16	0.09	0.032*	0.15	0.08	0.045*
Race: Asian/Pacific Islander	0.12	0.05	0.154	0.01	0.00	0.951	-0.03	-0.01	0.791
Race: Native American	0.14	0.02	0.508	-0.19	-0.03	0.425	-0.22	-0.04	0.332
Race: Other	0.12	0.02	0.564	0.18	0.03	0.454	0.15	0.02	0.526
Race: Prefer not to answer	0.12	0.02	0.674	0.17	0.02	0.606	0.14	0.02	0.666
Race: Multi-race	0.11	0.05	0.164	0.18	0.08	0.048*	0.15	0.06	0.089
Age	0.02	0.11	0.002*	-0.03	-0.10	0.007*	-0.03	-0.13	0.001*
Gender	0.04	0.04	0.245	-0.10	-0.08	0.028*	-0.11	-0.09	0.012*
Income: < $30,000 (Reference)									
Income: $30,000 - $49,999	0.09	0.06	0.28	0.24	0.14	0.012*	0.22	0.12	0.02*
Income: $50,000 - $74,999	0.06	0.04	0.48	0.10	0.06	0.287	0.08	0.05	0.353
Income: $75,000 - $99,999	-0.03	-0.02	0.713	0.12	0.07	0.217	0.12	0.08	0.177
Income: $100,000 - $149,999	0.01	0.00	0.938	0.11	0.07	0.221	0.11	0.07	0.216
Income: $150,000 or more	0.09	0.06	0.307	0.17	0.10	0.098	0.14	0.08	0.144
Income: Prefer not to answer	0.00	0.00	0.998	0.02	0.01	0.895	0.02	0.01	0.892
Home density: Rural (Reference)									
Home density: Small city or town	-0.09	-0.06	0.17	0.04	0.02	0.619	0.06	0.04	0.409
Home density: Suburb	-0.01	-0.01	0.867	-0.01	-0.01	0.879	-0.01	-0.01	0.907
Home density: Large city	-0.03	-0.02	0.654	0.06	0.04	0.438	0.06	0.04	0.369
Region: South (Reference)									
Region: West	-0.03	-0.03	0.53	-0.07	-0.04	0.293	-0.06	-0.04	0.351
Region: Midwest	-0.06	-0.04	0.288	-0.10	-0.06	0.147	-0.08	-0.05	0.214
Region: Northeast	0.00	0.00	0.943	-0.08	-0.05	0.203	-0.08	-0.05	0.187
Intercept	-0.34		0.001	1.77		<0.001	1.85	.	<0.001
Adjusted R^2			0.2146			0.1539			0.1953
N			624			624			624

Table 4. Mediation model 4 exploring connection to nature's mediating effect between adolescent outdoor play activity participation and mental well-being during COVID-19

This table shows the mediation results associated with outdoor play activity participation during COVID-19.

	Connection to Nature during COVID-19 Path A			Mental Well-being during COVID-19 Path C			Mental Well-being during COVID-19 Path B and C'		
	Beta	**Std. Beta**	***p***	**Beta**	**Std. Beta**	***p***	**Beta**	**Std. Beta**	***p***
Outdoor Play activities during COVID-19	0.44	0.41	<0.001*	0.53	0.40	<0.001*	0.39	0.29	<0.001*
Connection to Nature score during COVID-19							0.33	0.27	<0.001*
Race: White (Reference)									
Race: Black	-0.11	-0.06	0.137	0.18	0.08	0.052	0.22	0.09	0.016*
Race: Hispanic	-0.04	-0.02	0.594	0.12	0.06	0.162	0.14	0.06	0.111
Race: Asian/Pacific Islander	-0.04	-0.02	0.697	0.02	0.01	0.855	0.03	0.01	0.767
Race: Native American	0.11	0.02	0.646	-0.37	-0.05	0.196	-0.41	-0.05	0.143
Race: Other	0.35	0.06	0.129	-0.16	-0.02	0.574	-0.28	-0.04	0.32
Race: Prefer not to answer	-0.40	-0.05	0.216	-0.15	-0.01	0.707	-0.02	0.00	0.959
Race: Multi-race	-0.03	-0.01	0.731	0.11	0.04	0.306	0.12	0.04	0.249
Age	0.02	0.08	0.041*	-0.02	-0.05	0.149	-0.02	-0.07	0.041*
Gender	0.04	0.03	0.369	-0.07	-0.05	0.205	-0.08	-0.06	0.12
Income: < $30,000 (Reference)									
Income: $30,000 - $49,999	0.00	0.00	0.962	0.20	0.09	0.088	0.20	0.09	0.079
Income: $50,000 - $74,999	0.07	0.05	0.417	0.29	0.15	0.009*	0.27	0.14	0.014*
Income: $75,000 - $99,999	-0.10	-0.06	0.289	0.25	0.13	0.026*	0.29	0.15	0.01*
Income: $100,000 - $149,999	-0.06	-0.04	0.466	0.11	0.06	0.341	0.13	0.07	0.236
Income: $150,000 or more	0.00	0.00	0.976	0.21	0.10	0.083	0.21	0.10	0.074
Income: Prefer not to answer	-0.02	0.00	0.91	0.02	0.00	0.915	0.03	0.01	0.888
Home density: Rural (Reference)									
Home density: Small city or town	-0.20	-0.13	0.005*	0.13	0.07	0.142	0.20	0.11	0.023*
Home density: Suburb	0.02	0.01	0.806	0.06	0.04	0.481	0.05	0.03	0.508
Home density: Large city	-0.15	-0.10	0.036	-0.03	-0.02	0.739	0.02	0.01	0.82
Region: South (Reference)									
Region: West	0.02	0.01	0.799	-0.10	-0.06	0.17	-0.11	-0.06	0.136
Region: Midwest	-0.01	-0.01	0.837	-0.08	-0.04	0.338	-0.07	-0.04	0.349
Region: Northeast	0.04	0.03	0.47	-0.08	-0.04	0.324	-0.09	-0.05	0.223
Intercept	-0.10		0.33	1.28		<0.001	1.32		<0.001
Adjusted R^2			0.1927			0.1678			0.2242
N			624			624			624