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The Weather Dependency Framework (WDF): A tool for assessing the weather dependency of outdoor recreation activities☆

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ABSTRACT

This paper describes the creation of a Weather Dependency Framework (WDF) and its potential usefulness for managers and researchers. The WDF is a mechanism for understanding the multi-dimensional variables that influence the weather dependency of outdoor recreation activities. The need for this work was evident because of the growing number of studies probing the general influence of weather on outdoor recreation without an organizing framework for making sense of those influences. A modified Internet-based Delphi process employing a panel of 27 experts in the areas of weather, climate, outdoor recreation, and natural resource management was facilitated in the summer of 2015 to develop the WDF. Additionally, the panel of experts tested the WDF's potential usefulness by applying it to three outdoor recreation activities that represent a likely spectrum of weather dependency. The paper concludes by considering other possible applications as well as recommendations for the WDF's future development.

Management implications: The article suggests a new tool for managers and researchers interested in interpreting and understanding the weather dependency of outdoor recreation activities in a multitude of settings. The application of the WDF could enhance management and contribute to assessing the weather related needs and behaviors of recreationists by activity type to aid in effective protected area planning; predict recreation participation under specific weather conditions and for specific activities; inform natural resource and outdoor recreation managers about potential risks under certain weather conditions and for specific activities; plan site infrastructure improvements and adaptation; and conduct site assessments to aid festival and event planning in respective site selection. Overall, managers' resulting use of the WDF may lead to reconsidering programs and policies, recreation impact mitigation, inspire weather-based planning initiatives, and predict land access trends.

1. Introduction

The multi-dimensional influences of weather have been receiving increasing attention in the outdoor recreation literature (Verbos, Altschuler, & Brownlee, 2017). In a recent study, for example, weather was identified as a primary topic in 184 published research articles (Verbos, et al., 2017). This weather research appeared in 84 different journals and is important to outdoor recreation to facilitate effective and efficient weather-related decision-making (Becken, 2012a, 2012b), planning and management of weather-dependent activities (Scott & Lemieux, 2010), and future research (Gómez Martín, 2005; Gössling & Hall, 2006; Scott & Lemieux, 2010).

Despite the importance of weather to outdoor recreation, previous research has not addressed 'weather dependency,' a concept arising from the resource dependency literature. *Resource dependency* is human dependency on the natural environment and is characterized as the strength of linkages between social and ecological systems (Tidball & Stedman, 2012). Similarly, we define weather dependency as *the degree to which a specific outdoor recreation activity is reliant on particular weather and resulting conditions*. Most outdoor recreation activities are highly affected by weather and resulting conditions.

Despite outdoor recreationists' evident reliance on weather, we know little about the weather dependency of outdoor recreation activities. Studies investigating weather have typically only indirectly assessed weather dependency, such as the impact of decreased snowfall on downhill skiing (Hamilton, Rohall, Brown, Hayward, & Keim, 2003) and extended shoulder seasons' impacts on golf participation (Scott & Jones, 2006). Moreover, research has yet to address the

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comprehensive nature of variables influencing the weather dependency of outdoor recreation activities.

Given the increasing attention paid to weather research and limited studies on the weather dependency of outdoor recreation (Verbos, et al., 2017), it was deemed necessary to combine factors and variables into one framework that could aid researchers and managers in assessing the weather dependency of outdoor recreation activities. Consequently, this paper presents a Weather Dependency Framework (WDF) for outdoor recreation activities, and extends previous research by incorporating variables formerly scattered through various research into one framework. The purpose of developing the WDF was to create a useful tool for researchers and managers interested in interpreting and understanding weather dependency in a multitude of settings. We suggest the WDF as an orientation to the most salient factors and variables influencing weather dependency.

2. Review of relevant literature

Weather-related research is diverse and scattered, often intertwining with climate research. Therefore, we first focus on the distinction between weather and climate, making clear that while researchers have interchanged them, the concepts are distinct. We then examine weather dependency and offer a justification for the importance of understanding the weather dependency of outdoor recreation activities. Finally, we synthesize the prevalent weather-related factors and variables identified throughout outdoor recreation research to provide a background and rationale for including key concepts in the WDF. Throughout, we consider *outdoor recreation* to be active leisure time spent in the outdoors (Manning, 2011, p. 4).

2.1. Weather versus climate

Although inextricably linked, weather and climate are distinct: *climate* is the long-term average behavior of weather in a specific location, while *weather* is the daily variations in meteorological conditions (e.g., temperature, sun, cloud, rain; Scott & Jones, 2006). The review of relevant literature and the WDF focus on weather specifically.

Outdoor recreation studies involving weather and climate exist in disparate journals, siloed by disciplines that often interchange weather and climate. This makes sense because weather and climate are inherently linked and both significantly influence outdoor recreation. For example, research has linked weather and climate variability to golf participation (Scott & Jones, 2006), destination selection (Becken, 2012a, 2012b; Windle & Rolfe, 2013), and ski demand (Dawson, Scott, & Havitz, 2013). However, it is important to distinguish weather and climate as unique concepts despite this linkage. While key climate parameters have been investigated in the context of tourism for over 30 years (Scott et al., 2008), weather studies have only just begun to receive increasing attention over the last 10 years (Verbos, et al., 2017).

2.2. Weather dependency

We define weather dependency as *the degree to which a specific outdoor recreation activity is reliant on particular weather and resulting conditions,* and many outdoor recreation activities are highly weather dependent. For example, downhill skiing and golf are both reliant on precipitation and temperature (Dawson & Scott, 2013; Hamilton et al., 2003; Nicholls, Holecek, & Noh, 2008). Other research has connected the impacts of seasonal weather to national park visitation (Jones & Scott, 2006), and surfing behavior is linked to wind and related wave conditions (Barbieri & Sotomayor, 2013).

Despite these studies, we know little about outdoor recreationists' direct dependency on weather forecasts, motivations to engage in weather-sensitive activities, and cultural interpretations of weather (Scott, Lemieux, & Malone, 2011). For instance, Rutty and Andrey (2014) found skiers, snowboarders, and snowmobilers to be reliant on weather forecasts when planning winter recreation activities. These authors also found that the use of weather forecasts varied by recreation type (e.g., skier site selection vs. snowmobilers' use of radar imagery). Previous research also indicates a need to combine recreationists' motivations for participation in weather-sensitive activities with other variables such as season (Qu, Kim, & Im, 2011). As well, it is important to further understand how motivations influence travel behavior under weather conditions (Spencer & Holecek, 2007). Additionally, destination choice and choice models have begun to investigate the interactions between push and pull factors and the weather to understand travel destination selection (Matzarakis, Hammerle, Koch, & Rudel, 2012; van Nostrand, Sivaraman, & Pinjair, 2013; Smith, Li, Pan, Witte, & Doherty, 2015). While the studies conducted to date hint at links between weather-related variables and weather dependency, research has yet to explore explicitly the weather dependency of outdoor recreation activities. The WDF is one way to combine influential factors and variables into one framework, thereby specifically addressing weather dependency.

The limited existing research on the weather dependency of outdoor recreation points to gaps in the research, especially in the manner that researchers, managers, and recreationists conceptualize weather dependency. For example, in one study, ski-tourism industry authorities did not perceive the ski industry to be particularly weather dependent while local ski-tourism operators considered the industry to be highly weather dependent (Rauken & Kelman, 2012). Investigations of travel adaptations have relied on only two variables to understand weather dependency: 'engagement with weather and climate information' linked to 'behavioral reactions to weather' (Becken & Wilson, 2013). The reliance on two variables does not account for the numerous additional factors influencing weather dependency, such as the process of integration, and engagement with weather information or the effects of travel adaptations related to motivations of participation in weather dependent activities (Scott, Hall, & Gössling, 2012).

Additionally, the large majority of research that points to weather dependency has used secondary data to predict outdoor recreation participation. For example, secondary data have been used to investigate the role of weather in beach travel (Sabir, Van Ommeren, & Rietveld, 2013), regional tourism potential (Matzarakis, Hämmerle, Koch, & Rudel, 2012), the golf industry (Scott & Jones, 2007), and the vulnerability of the ski industry (Scott, McBoyle, Minogue, & Mills, 2006). Assessments concerning the weather dependency of outdoor recreation activities could benefit from multi-dimensional investigations incorporating a variety of variables.

There is a need to know more about recreationists' culturally bound interpretations of weather dependency. In work with arctic communities, Kajan (2014) found that adaptation strategies employed local and traditional knowledge to combat weather exposure. Karamustafa and colleagues (2012) also found that culturally defined risk perceptions influence weather dependency. A weather dependency framework could help elucidate important factors and variables that relate to culturally bound interpretations of weather.

2.3. Weather factors and variables

Outdoor recreation weather-related studies include a multitude of factors and variables. For example, in a previous study, the authors' uncovered seven weather-related factors and 32 variables investigated in the literature (Verbos, et al., 2017). First, the factor *site characteristics* includes the variables of site infrastructure (Barbieri & Sotomayor, 2013), community infrastructure (Bennett, Lemelin, Koster, & Budke, 2012), vulnerability (Espiner & Becken, 2014), adaptive capacity (Scott & Simpson, 2012), and resources to support extreme weather events (Scott & Lemieux, 2010). Second, the *trip characteristics* factor includes the variables transportation mode (Reddy, Nica, & Wilkes, 2012), length of stay (Barbieri &

Sotomayor, 2013), route traveled (i.e., distance, topography, and activity day; Lackstrom, Kettle, Haywood, & Dow, 2014). Third, research in the area of *resource characteristics* considers regional weather variability (Scott & McBoyle, & Minogue, 2007), resource dependency (Marshall, Tobin, Marshall, Gooch, & Hobday, 2013), natural environment (Pomfret, 2006), and management practices (Spector, Chard, Mallen, & Hyatt, 2012). Fourth, the factor *personal characteristics* includes experience-use history (Barbieri & Sotomayor, 2013), past-use history (Barbieri & Sotomayor, 2013), place attachment (Yang, Madden, Kim, & Jordan, 2012), quality and satisfaction of recreation experiences (Richardson & Loomis, 2005; Thapa, 2012), recreation specialization (Tsaur, Yen, & Chen, 2010), beliefs in climate change (Brownlee & Verbos, 2015), and recreation experience preferences (Denstadli, Jacobsen, & Lohmann, 2011). Fifth, natural seasonality (Jones & Scott, 2006) and institutional seasonality (Scott, Jones, & Konopek, 2007) are included in the factor *season*. Sixth, the factor *experiences with weather* includes weather perceptions (Andrade, Alcoforado, & Oliveira, 2011), expectations (Becken & Wilson, 2013), and preferences (Førland et al., 2013), encountered weather (Denstadli et al., 2011), behavioral reactions to weather, and weather and climate information (Becken & Wilson, 2013). The seventh and final factor is *weather conditions*, which includes variables such as temperature and precipitation (Matzarakis, Hämmerle, Koch, & Rudel, 2012), relative humidity (Becken, 2012a, 2012b), wind speed (Matzarakis et al., 2012), and Physiological Equivalent Temperature (PET; Höppe, 1999).

The above factors and variables provide a foundation for the creation of the WDF. Notwithstanding the variety of salient factors and variables, research has yet to combine these factors and variables into one framework to understand weather dependency. Consequently, we know very little about the weather dependency of outdoor recreation activities, which led to pivotal research questions.

2.4. Research questions

Based on the absence of a framework to understand weather dependency, we developed the following research questions.

1. What are important considerations (e.g., anchors, continuums, and utility) for developing a visual display that adequately represents the salient factors and variables influencing the weather dependency of outdoor recreation activities?
2. Where might different outdoor recreation activities fall on a continuum of weather dependency, given a place specific setting?
3. What are the potential applications of the WDF including its utility for managers and researchers?
4. What are the opportunities for future development of the WDF?

3. Research design and methods

Given the dispersed knowledge about weather within individual disciplines and the need to analyze differences and similarities from an interdisciplinary perspective, the Delphi method (Dalkey & Helmer, 1963; Strauss & Zeigler, 1975) was considered the best option to address these research questions. Delphi studies have been used to further understand business operations, climate change adaptation, educational processes, land-use conflicts, natural resource management, nature conservation, and tourism (e.g., Landeta, 2005; McKenna, 1994). The Delphi method can also be used in a variety of ways in the social sciences (Strauss & Zeigler, 1975), such as identifying the differences and similarities in park and protected area managers' values and management practices and priorities (Ruschkowski, Burns, Arnberger, Smaldone, & Meybin, 2013). Delphi studies have also defined financial funding mechanisms and identified necessary knowledge to implement funding tools for conservation professionals responsible for financing international protected areas (e.g., Ecuador, Peru, and Columbia; Mancheno, Mclaughlin, & Courrau, 2013). The Delphi method is typically used to address complex research problems that require the involvement of discipline-specific experts (Ruschkowski et al., 2013).

The Delphi method relies on a panel of experts to explore a subject matter, identify dissent, arrive at consensus, and provide final evaluations of a product (e.g., the WDF) through a systematic process of iterative and controlled feedback (Landeta, 2005; Ruschkowski et al., 2013; Strauss & Zeigler, 1975). The premise behind the Delphi method is the notion that two heads are better than one, and, therefore, obtaining information from a panel of experts is ideal (Landeta, 2005; Ruschkowski et al., 2013; Strauss & Zeigler, 1975). For the purposes of this study, the researchers used a modified, Internet-based Delphi method as a committee evaluation tool, soliciting input and output from the panel of experts. The method required the researchers to first identify the area of interest (e.g., weather dependency) and then select the panel of experts.

3.1. Expert selection

Panel selection was a critical component of the study design. Previous research has suggested panel size is less important than the qualifications of the experts (Wilhelm, 2001). Furthermore, Delphi method limitations can arise if the panel of experts is too homogenous or like-minded (Landeta, 2005; Ruschkowski et al., 2013; Strauss & Zeigler, 1975). Accordingly, panel selection included heterogeneous individuals with research expertise or field-based knowledge in weather, climate, outdoor recreation, and/or natural resource management. Inclusion criteria ensured the panel was composed of diverse and experienced professionals. The following criteria were used to select panel members: a) evidence of peer recognition as an expert in weather, climate, outdoor recreation, and natural resource management (e.g., peer-reviewed publications, books, book chapters), b) recent and multiple years of professional experience, c) educational training related to the relevant subject matter, and d) experience working with outdoor recreation providers and stakeholders (modified from Mancheno et al., 2013). The pool of experts was validated using member checking processes to ensure all potential experts fit the selection criteria. Twenty-seven experts participated in this four-round, modified, Internet-based Delphi process. Panelists ranged from social scientists and outdoor recreation planners with federal land management agencies to academic researchers and private industry outdoor recreation professionals across the U.S., Canada, and Scandinavia.

3.2. Data collection and analysis

Study data were collected and managed using Research Electronic Data Capture (REDCap) a software program hosted at the University of Utah.[1] We collected data by conducting a four-round Delphi process, and the data generated in each round were analyzed and served as the basis for developing the questions for the next round. The first three rounds of the Delphi process produced qualitative and quantitative data responses with the fourth round exclusively eliciting expert responses through open-ended questions.

We employed standard qualitative analysis-coding techniques to characterize and analyze the qualitative responses for each round (Cresswell, 2015). Structural coding was used to represent concept-based phrases for segments of data as it related to variables considered for inclusion in the framework. During the analysis process, we used peer debriefing to enhance the trustworthiness of the findings

[1] REDCap is a secure, Web-based application designed to support data capture for research studies, providing: a) an intuitive interface for validated data entry, b) audit trails for tracking data manipulation and export procedures, c) automated export procedures for seamless data downloads to common statistical packages, and d) procedures for importing data from external sources (CCTS, 2015; Harris et al., 2009).

(Cresswell, 2015).

The quantitative data was analyzed using SPSS and descriptive statistics. In rounds one and two, REDCap responses from experts were coded into categorical variables to produce outputs for inclusion (yes) and exclusion (no) of variables considered for the framework.

We conducted the Delphi process with one initial questionnaire based on a previous research synthesis (Verbos, et al., 2017) and three additional feedback cycles thereafter. During the first round, the panel of experts provided feedback on the definition of weather dependency, potential salient factors, and variables related to weather dependency; subsequent inclusions and exclusions; and operationalized definitions of the factors and variables. After we analyzed the first round of major findings, a synopsis of the results was returned to the Delphi panel for comments, accompanied by round-two questions. The third round allowed the panelists to test the developed framework by placing three outdoor recreation activities (hiking, backcountry skiing, and ungulate hunting) along the framework continuum. The fourth round of the Delphi process was conducted to gain further consensus among the experts.

The researchers embedded a forum for agreement and dissent into each round. Experts were encouraged to clarify contradictory statements and seek further consensus or to correct data that the researchers may have misinterpreted. Delphi participants were encouraged to comment on their peers' statements as well. Study participation varied between the rounds. This was an intentional choice on behalf of the researchers to ensure flexibility, thereby permitting participants to complete rounds, as they were able. Due to the cumulative nature of the Delphi method and the flexible research design, there were no foreseeable negative effects on the study results.

4. Results

The four-round Delphi process resulted in the development of the Weather Dependency Framework (see Fig. 1). The results section discusses the response rate, results from each round, the definitions of factors and variables included in the framework, and elements of the WDF. Experts selected rounds to participate in based on their availability, and subsequently, out of 27 experts, 21 (77%) participated in the first round of the Delphi study, 22 (81%) returned the second questionnaire, 24 (89%) participated in the third round, and in the last round 16 (59%) completed the questionnaire. The overall response rate of 80% was similar to other Delphi studies (e.g., Kaynak et al., 1994) and allowed for valid analysis.

4.1. Round #1 and #2 results

The results from round one included factors and variables contributing to the weather dependency of outdoor recreation activities, addition, and deletions of variables, and grouping and/or renaming of some variables or factors. Overall, round one results contributed significantly to the scope of the framework and were used to develop a visual representation of the WDF.

During round two, we provided panelists with a visual representation of the WDF. Round two results included comments regarding scale, anchors, reverse coding, and conceptual correlations of higher scores to higher levels of weather dependency and vice versa for lower levels of weather dependency. Visual aspects of the framework were adapted to enhance category separation and overall visual appeal. Lastly, we adapted the low end of weather dependency to zero. The panelists determined zero was easier to understand and interpret as no weather dependency. At the high end of weather dependency, an activity could receive 10 points for each of the 33 variables within the WDF to achieve an overall maximum possible score of 330. As a result, outdoor recreation activities can receive a score as low as a zero (i.e., no weather dependency) and as high as 330 (i.e., high or complete weather dependency).

4.2. Round #3 results

The results from round three included the panelists' comments related to testing the WDF. Topics discussed included reverse-coded items, re-evaluation of anchors, weather dependency contributions, and aggregate activity-based scores resulting from interactive placement of three activities on the WDF. The majority of panel feedback deemed the anchors adequate and appropriate, with limited comments for additional clarification. With realigned anchors, the panel agreed that higher scores indicated higher weather dependency and vice versa for low levels of weather dependency. Round three concluded with interactive placement of three activities—hiking, ungulate hunting, and backcountry skiing—by variable and factor according to levels of weather dependency. These three activities were selected to represent a likely spectrum of weather dependency. A place-based description accompanied each activity and illuminated key factors within the framework, thereby providing a context for each activity.[2]

4.3. Round #4 results

The fourth and final round results included suggestions for reverse coding, WDF applications, utility for natural resource managers and as a research framework, scale of management, and potential limitations. We synthesize and discuss these topics in the discussion section.

4.4. Salient factor and variable definitions

The definitions of the salient factors and variables included in the WDF were informed by the literature (for a review Verbos, et al., 2017) and adapted through the Delphi process. Panelists commented on the relevancy of each definition to weather dependency. Table 1 provides a definition of each variable as well as interpretations of the anchors contained within the WDF.

4.5. Scoring and using the WDF

The framework contains a comprehensive set of salient factors and variables, listed in the left column of the framework (see Fig. 2). Panelists assessed each activity and variable on a continuum from zero to 10, where zero indicates no weather dependency and 10 suggests the highest levels of weather dependency. The panelists gave each activity a variable level score, which added first to a factor level score, and second to a total overall score for the weather dependency of each activity.

Variables combine to form factors that receive a total weather dependency score for each factor. In this study, the researchers selected hiking, ungulate hunting, and backcountry skiing to represent a potential range of weather-dependent activities. Not surprisingly, hiking received the lowest score, 177.5 out of 330 from the panelists. By percentage, hiking is approximately 53.7% weather dependent, based on panelists' feedback. Next, ungulate hunting received 210.8, not that different from hiking at 63.8% weather dependent. Finally, backcountry skiing received a total score of 240.7, equating to 72.9% weather dependent (see Fig. 2 for totals and the final WDF). The scores in Fig. 2 are the average of the panelists' assessment of the three activities, given a detailed place-based descriptive setting. The researchers used a Related Samples Freidman's Two-Way ANOVA by Ranks to understand statistical significance between activity types for each variable and aggregate factors. The results suggest statistical differences between activity types for 17 of the 32 variables and four of the seven factors (see Fig. 2).

[2] We provided lengthy descriptions but in summary described the hiking activity as a 'weekend warrior' on the Appalachian Trail in Shenandoah National Park. We described the ungulate hunting and backcountry skiing setting as the southern Rocky Mountains in Utah, including the Uinta-Wasatch-Cache National Forest, which is characterized as a backcountry and middle country setting.

Weather Dependency Framework for Outdoor Recreation Activities

Factors and Variables of Weather Dependency	0 *Low Weather Dependency*	0 1 2 3 4 5 6 7 8 9 10	330 *High Weather Dependency*
Site Characteristics			
Site infastructure	More infastructure		Less infastructure
Resiliency to weather (adaptive capacity, vulnerability, resources to support extreme weather events)	High resiliency		Low resiliency
Management practices	Limited		Specific
Trip Characteristics			
Transportation mode	Multi-modal (including motorized)		Uni-modal (human-powered, non-motorized)
Length of stay	Shorter/Day trips		Extended
Route traveled (distance at stie and topography)	Simple route, limited topography		Extensive route, expansive topography
Planning (distance to site, group size, group type)	Limited planning		Extensive planning
Resource characteristics			
Regional variability	High predictability		Limited predictability
Resource dependency	Low		High
Natural environment (push factors)	Low motivation		High motivation
Natural environment (pull factors)	Low attraction		High attraction
Personal Characteristics			
Experience use history (EUH)	High EUH		Low EUH
Recreation specialization	Highly specialization		Low specialized
Past use history	Extensive		Limited
Place attachment	High place attachment		Low place attachment
Satisfaction (of recreation experiences)	Low		High
Recreation experience Preferences	Limited motivations		Multi-dimensional and diverse motivations
Season			
Natural seasonality	High predictability		Limited predictability
Institutional seasonality	High predictability		Limited predictability
Experiences with Weather			
Perceptions of weather	Insignificant		Highly influential
Expectations of weather	Low or unknown expecrations		Rigid expectations
Engagement with weather and climate information	Low engagement		High engagement
Weather preferences	Adaptable preferences		Stringent preferences
Encountered weather	Insignificant events		Significant events
Behavioral reactions to weather	Limited changes		Frequent changes
Weather Conditions			
Temperature	Insignificant		Highly significant
Relative humidity	Insignificant		Highly significant
Wind speed	Insignificant		Highly significant
Precipitation	Insignificant		Highly significant
Physiological equivalent temperature	Insignificant		Highly significant
Extreme weather events	Insignificant		Highly significant
Climate variability	Insignificant		Highly significant

Fig. 1. The weather dependency fraemwork for outdoor recreation activities.

Table 1
Factor and variable definitions integrated with weather dependency.

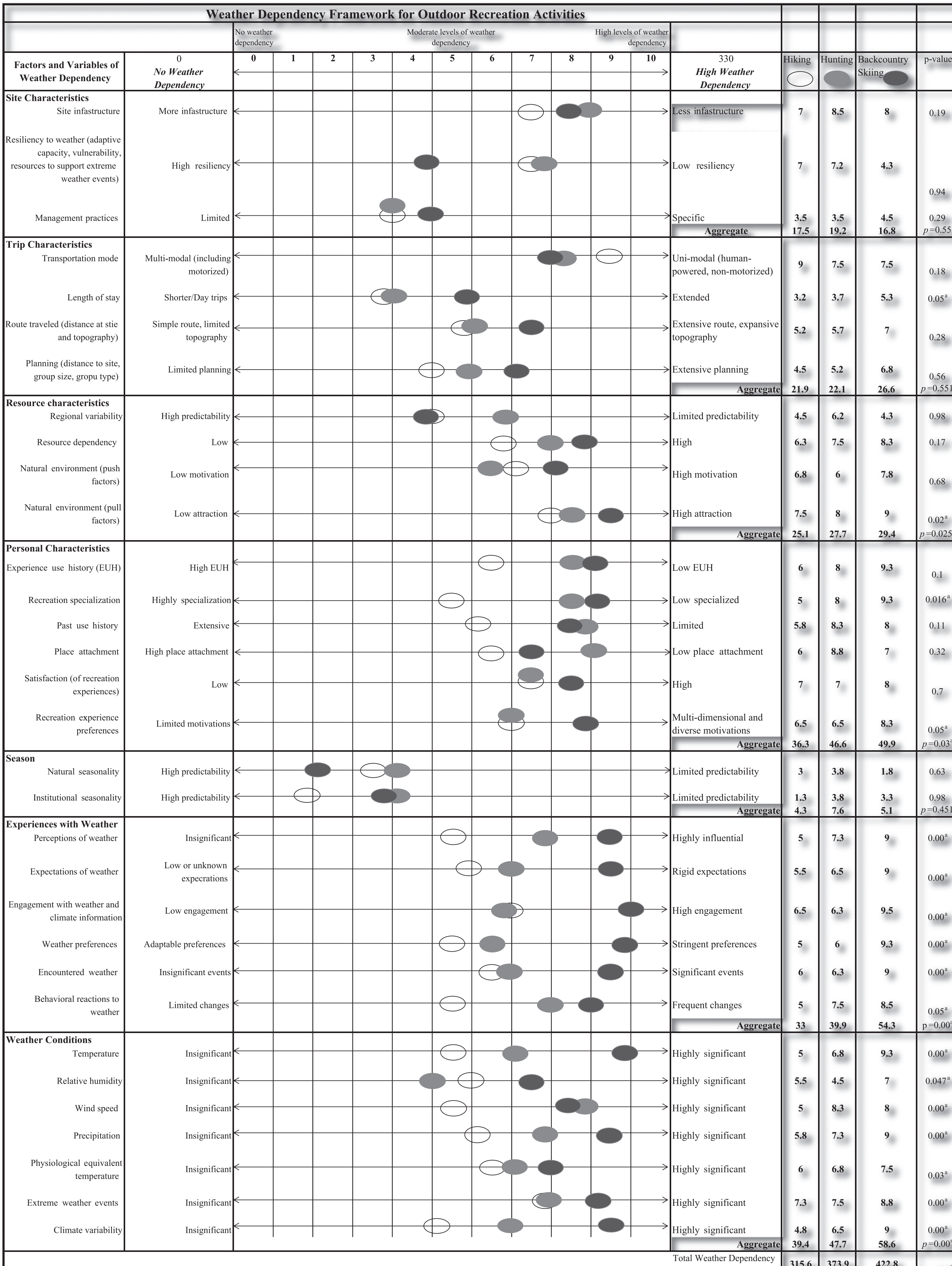
Factors and Variables[a]	*Variable Definitions and Citations*	*Anchor Explanations*		
		Low Levels of Weather Dependency[b]		*High Levels of Weather Dependency*[a]
Factor: Site characteristics				
Site Infrastructure	Fundamental operations and development specific to an area (i.e., roadways, restrooms, and visitors centers; Lemieux, Beechey, Scott, & Gray, 2011)	More	↔	Less
		Less infrastructure indicates a higher dependency due to higher exposure to weather conditions		
Resiliency to weather (adaptive capacity, vulnerability, resources to support extreme weather events)	*Adaptive Capacity* - The ability of a system to adjust, the 'system' referred to is the outdoor recreation and nature-based sector. *Vulnerability* - The degree to which a system is susceptible to adverse change (IPCC, 2015). *Resources to support extreme weather events* - Include the physical and built as well as data processing infrastructure (Scott & Lemieux, 2010)	High	↔	Low
		Low indicates a higher dependence due to limited capacity, high vulnerability, and limited resources to support extreme weather events		
Management Practices	Specific management practices in place at a specific recreation site. (Manning, 2011)	Limited	↔	Specific
		Specific indicates high weather dependency		
Factor: Trip characteristics				
Transportation mode	The mode of travel/transport used before and during recreation at a destination (Becken et al., 2003)	Multi-modal	↔	Uni-modal
		Uni-modal or human-powered, has high dependency on the weather to travel to, from, and within a recreation destination		
Length of stay	Defined by amount of time spent on-site or at the destination, during the current visit (Woodside, Caldwell, & Spurr, 2005)	Shorter/Day trips	↔	Extended Trips
		Extended trips suggests multi-day overnights, highly dependent on the weather and resulting conditions		
Route traveled (distance at site and topography)	Route traveled on-site or at a destination (Rogerson, 2009)	Simple	↔	Extensive
		route	↔	route
		Extensive routes indicates higher weather dependency		
Planning (distance to site, group characteristics such as group type and size)	A proxy for travel costs and travel time from residential city to destination location (Bigano, Hamilton, & Tol, 2006)	Limited	↔	Extensive
		Extensive planning contributes to higher weather dependency		
Factor: Resource characteristics				
Regional climate variability	Variations in the mean state and other statistics of the climate on all temporal and spatial scales (WMO, 2015)	High	↔	Limited
		Limited contributes to higher weather dependency		
Resource dependency	The strength of linkages between social and ecological systems (Tidball & Stedman, 2012)	Low	↔	High
		High resource dependency is reflective of high weather dependency		
Natural environment (push factors)	Push factors motivate travel (Pomfret, 2006)	Low	↔	High
		High indicates weather is an important push factor		
Natural environment (pull factors)	Pull factors influence destination selection (Pomfret, 2006)	Low	↔	High
		High indicates weather is an important pull factor		
Factor: Personal Characteristics				
Experience use history	Engagement in an activity and years of participation (Manning, 2011)	High	↔	Low
		Less contributes to higher weather dependency		
Recreation specialization	"A continuum of behavior from the general to the particular, reflected by equipment and skills used in the sport and activity setting preferences" (Bryan, 1977, p. 175)	High	↔	Low
		Low specialization indicates higher levels of weather dependency		
Past use history	Past experience at a particular site, including frequency of visitation and amount of time spent (Hammitt, Kyle, & Oh, 2009)	Extensive	↔	Limited
		Limited indicates higher weather dependency		
Place attachment	The emotional and symbolic, and functional attachment to a place (Manning, 2011)	High	↔	Low
		Low indicates higher weather dependency		

(continued on next page)

Table 1 *(continued)*

Factors and Variables[a]	***Variable Definitions and Citations***	***Anchor Explanations***		
		Low Levels of Weather Dependency[b]		***High Levels of Weather Dependency***[a]
Satisfaction (of recreation experiences)	"The congruence between expectations and outcomes" (Manning, 2011, p. 20)	Low	↔	High
		High indicates previous satisfaction and thus higher dependency on weather to simulate similar experiences		
Recreation experience preferences	Assess individual's motivations for recreation (Manning, 2011)	Limited	↔	Multi-dimensional
		Multi-dimensional, diverse motivations indicates a variety of motivations for participation and anyone could contribute to higher levels of weather dependency		
Factor: Season				
Natural Seasonality	Length and quality of recreation seasons (Jones & Scott, 2006)	High	↔	Limited
Institutional Seasonality	Characterized by systematic fluctuations of visitation around summer school holidays (Scott, Jones et al., 2007)	Limited indicates higher dependence on weather		
Factor: Experiences with Weather				
Perceptions of weather	Interpretations and responses to meteorological conditions (Gossling, Bredberg, Randow, Sandstrom, & Svensson, 2006)	Insignificant	↔	Highly Influential
		Highly Influential indicates higher levels of weather dependency		
Expectations of weather	Pre-determined understanding of conditions at a destination or recreation site (Hübner & Gössling, 2012)	Low	↔	Rigid
		Rigid expectations suggest higher weather dependency		
Weather preferences	Preferences for specific weather conditions. (Steen Jacobsen, J., Denstadli, J., Lohmann, M., Forland, 2011)	Adaptable	↔	Stringent
		Stringent preferences indicates high levels of dependency on weather		
Engagement with weather and climate information	Engagement with weather information (e.g., forecasts) prior to a trip, during-trip, and resultant plan (Becken & Wilson, 2013)	Low	↔	High
		High engagement indicates high levels of weather dependency		
Encountered weather	Experienced weather at recreation site (Denstadli et al., 2011)	Insignificant	↔	Significant
		Significant indicates high dependency on weather		
Behavioral reactions to weather	Changes in travel or destination selection based on actual or expected weather conditions (Becken & Wilson, 2013)	Limited	↔	Frequent
		Frequent reactions indicates higher weather dependency		
Factor: Weather Conditions				
Temperature	Internal energy that a substance contains (NOAA, 2015)	Insignificant	↔	Highly Significant
		Highly Significant indicates high weather dependency		
Relative humidity	Amount of atmospheric moisture relative to the amount that would be present if air were saturated (NOAA, 2015)	Insignificant	↔	Highly Significant
		Highly Significant indicates high weather dependency		
Wind speed	The rate air is moving horizontally (NOAA, 2015)	Insignificant	↔	Highly Significant
		Highly Significant indicates high weather dependency		
Precipitation	Rain, sleet, snow, hail, etc (NOAA, 2015)	Insignificant	↔	Highly Significant
		Highly Significant indicates high weather dependency		
Physiological Equivalent Temperature (PET)	Thermal comfort index using air temperature, relative humidity, wind speed, and cloud cover (Höppe, 1999)	Insignificant	↔	Highly Significant
		Highly Significant indicates high weather dependency		
Extreme weather events	Statistical reference to distribution at a place (IPCC, 2015)	Insignificant	↔	Highly Significant
		Highly Significant indicates high weather dependency		
Climate variability	Variations in the climate temporal and spatial scales (IPCC, 2015)	Insignificant	↔	Highly Significant
		Highly Significant indicates high weather dependency		

[a] Please contact the first author for an expanded list of definitions and related research.
[b] The definition of weather dependency is the degree that a specific outdoor recreation activity is reliant on particular weather and resulting conditions.



Factors and Variables of Weather Dependency	0 *No Weather Dependency*	330 *High Weather Dependency*	Hiking	Hunting	Backcountry Skiing	p-value
Site Characteristics						
Site infastructure	More infastructure	Less infastructure	7	8.5	8	0.19
Resiliency to weather (adaptive capacity, vulnerability, resources to support extreme weather events)	High resiliency	Low resiliency	7	7.2	4.3	0.94
Management practices	Limited	Specific	3.5	3.5	4.5	0.29
		Aggregate	17.5	19.2	16.8	*p*=0.55
Trip Characteristics						
Transportation mode	Multi-modal (including motorized)	Uni-modal (human-powered, non-motorized)	9	7.5	7.5	0.18
Length of stay	Shorter/Day trips	Extended	3.2	3.7	5.3	0.05[a]
Route traveled (distance at stie and topography)	Simple route, limited topography	Extensive route, expansive topography	5.2	5.7	7	0.28
Planning (distance to site, group size, gropu type)	Limited planning	Extensive planning	4.5	5.2	6.8	0.56
		Aggregate	21.9	22.1	26.6	*p*=0.551
Resource characteristics						
Regional variability	High predictability	Limited predictability	4.5	6.2	4.3	0.98
Resource dependency	Low	High	6.3	7.5	8.3	0.17
Natural environment (push factors)	Low motivation	High motivation	6.8	6	7.8	0.68
Natural environment (pull factors)	Low attraction	High attraction	7.5	8	9	0.02[a]
		Aggregate	25.1	27.7	29.4	*p*=0.025[a]
Personal Characteristics						
Experience use history (EUH)	High EUH	Low EUH	6	8	9.3	0.1
Recreation specialization	Highly specialization	Low specialized	5	8	9.3	0.016[a]
Past use history	Extensive	Limited	5.8	8.3	8	0.11
Place attachment	High place attachment	Low place attachment	6	8.8	7	0.32
Satisfaction (of recreation experiences)	Low	High	7	7	8	0.7
Recreation experience preferences	Limited motivations	Multi-dimensional and diverse motivations	6.5	6.5	8.3	0.05[a]
		Aggregate	36.3	46.6	49.9	*p*=0.03[a]
Season						
Natural seasonality	High predictability	Limited predictability	3	3.8	1.8	0.63
Institutional seasonality	High predictability	Limited predictability	1.3	3.8	3.3	0.98
		Aggregate	4.3	7.6	5.1	*p*=0.451
Experiences with Weather						
Perceptions of weather	Insignificant	Highly influential	5	7.3	9	0.00[a]
Expectations of weather	Low or unknown expecrations	Rigid expectations	5.5	6.5	9	0.00[a]
Engagement with weather and climate information	Low engagement	High engagement	6.5	6.3	9.5	0.00[a]
Weather preferences	Adaptable preferences	Stringent preferences	5	6	9.3	0.00[a]
Encountered weather	Insignificant events	Significant events	6	6.3	9	0.00[a]
Behavioral reactions to weather	Limited changes	Frequent changes	5	7.5	8.5	0.05[a]
		Aggregate	33	39.9	54.3	p=0.00[a]
Weather Conditions						
Temperature	Insignificant	Highly significant	5	6.8	9.3	0.00[a]
Relative humidity	Insignificant	Highly significant	5.5	4.5	7	0.047[a]
Wind speed	Insignificant	Highly significant	5	8.3	8	0.00[a]
Precipitation	Insignificant	Highly significant	5.8	7.3	9	0.00[a]
Physiological equivalent temperature	Insignificant	Highly significant	6	6.8	7.5	0.03[a]
Extreme weather events	Insignificant	Highly significant	7.3	7.5	8.8	0.00[a]
Climate variability	Insignificant	Highly significant	4.8	6.5	9	0.00[a]
		Aggregate	39.4	47.7	58.6	*p*=0.00[a]
		Total Weather Dependency Scores	315.6	373.9	422.8	*p*=0.00[a]

Fig. 2. The aggregate weather dependency framework for outdoor recreation activities. *Note:* [a] Indicates significance at the *p*=0.05 level for a Related Samples Freidmans's Two-Way ANOVA by Ranks. This test was selected based on the small sample size (n=14) and violation of the general linear model assumption of normality.

5. Discussion

The WDF has potential applications for social science researchers as well as natural resource managers. In the first section of this discussion, we offer potential applications of the WDF for social scientists. Second, we suggest promising implications for natural resource and outdoor recreation managers. To conclude the discussion, we present recommendations for future development of the WDF. Both the authors' insights and panelists' suggestions guide the discussion.

5.1. Social science research applications

One purpose of creating the WDF was to develop a tool for researchers to interpret and make sense of the weather dependency of outdoor recreation activities. The WDF could be viewed as a 'roadmap' to guide future research, as it contains identified variables of interest related to the weather dependency of outdoor recreation activities. For example, similar to sections of a roadmap, each variable represents a comprehensive area of research. Jones and Scott (2006) illustrate this point with their study about the relationships between specific weather conditions (e.g., temperature and precipitation) and golf participation. Temperature and precipitation are each variables representing potential areas of research within the WDF but could be paired to other variables as well. For example, researchers might use the WDF as a starting place to investigate the relationships between recreation specialization and resource dependency under specific weather conditions to make sense of the weather dependency of outdoor recreation participation for multiple activities. Many research examples exist as prospective applications of the WDF to aid in interpreting the weather dependency of outdoor recreation activities.

The WDF has the potential to predict recreation participation under weather conditions and for specific activities. For example, weather-dependent activity-based assessments could determine which outdoor recreation activities will suffer the most from changes in climate or cyclical meteorological events, such as El Niño. This could contribute to results about the most weather-dependent activities, as well as activity sectors that are less sensitive to weather. Predicting recreation participation under weather conditions might also provide the opportunity for researchers to understand how the WDF might be implemented as a decision-making tool for recreationists. Specifically, researchers might want to understand how weather and climate information is used to mitigate risk under certain weather conditions and for specific activities.

The WDF might also result in site assessments. Researchers conducting site assessments, using the WDF, could select specific elements from the framework. For example, site characteristics and personal characteristics could be used to determine the weather dependency of beach tourism, and recommend site infrastructure improvements for destination tourism operators based on the assessment results. More specifically, a site assessment could aid in festival or event planning site selection, based on areas where there is higher predictability in the weather for outdoor events. For instance, the winter Olympics site assessment could include specific elements of the WDF to plan for optimal venue conditions.

Besides site assessments, the WDF could potentially be used by social scientists interested in programmatic evaluations. Researchers might examine destinations as a part of strategic planning for programming under key weather conditions. Additionally, outdoor education research on adventure-based programs could use the WDF to determine student populations with the potential to disengage from course experiences based on certain weather. Adventure-based programs involving at-risk or adjudicated youth might conduct program evaluations to determine beneficial seasons to facilitate extended outdoor activity-based expeditions. These evaluations might be based on personal characteristics and optimal weather conditions to obtain desired program outcomes.

It is also important to note the dynamic nature of weather dependency and, consequently, the WDF. The researchers designed the WDF as a way to think about weather dependency and as a mechanism to compile and visually represent dynamic factors and variables influencing the weather dependency of outdoor recreation activities. This is important because some of the variables within the WDF may be highly contextual. Consequently, the weather dependency of skiing in the Rocky Mountains may not be equal to the weather dependency of skiing in the Adirondacks as a result of contextual site characteristics and weather conditions. Additionally, personal characteristics contribute to the weather dependency of outdoor recreation activities, including the variables experience use history, place attachment, and recreation specialization, each of which are circumstantial and vary according to place and population. Personal characteristics might also reflect a recreationists' individual resiliency or adaptive capacity, and might be further investigated to reflect the dynamic nature of weather dependency. The dynamic nature of weather dependency and consequently, the WDF, are reliant on these contextual elements.

5.2. Management applications

Natural resource managers of parks and protected areas might use the WDF as a planning tool. Parks and protected area planning requires diverse information about user groups, and the WDF might provide a greater sense of how each type of outdoor recreation activity is related to weather dependency factors and variables. Therefore, the WDF could become a method for managers to assess the weather-related needs and behaviors of recreationists by activity type with results contributing to planning efforts. Managers might plan for site characteristic adaptations or manage according to personal characteristics of certain recreation groups. For example, if a manager identifies that mountain bikers could be highly weather dependent, the manager could then examine site and resource conditions for susceptibility to weather-related changes asking the question *does site infrastructure, such as trails, require improvement to prevent resource degradation during recreation participation under certain weather conditions?* Answering this question through the lens of the WDF might allow managers to plan for mountain bikers' desired site characteristics and resource dependency under certain weather conditions. In general, the WDF could be used as a planning tool to assess a number of outdoor recreation activities for the purposes of supporting effective planning and management of parks and protected areas.

Natural resource managers may have the ability to increase or decrease weather dependency by manipulating certain variables within the WDF. For example, to increase weather dependency, natural resource managers could create more specific management practices, require extensive planning paperwork for permitted areas (e.g., distance, travel plans, group type, group size), or decrease site infrastructure to a specific area. Alternatively, to decrease weather dependency managers might increase site infrastructure (e.g., facilities such as warming huts or shelters), decrease trip length requirements for areas requiring permits, or allow multimodal transportation access where possible. As another example, managers might require recreationists to show evidence of certifications that would link individuals to higher levels of experience use history and recreation specialization and thereby lower levels of weather dependency.

The WDF has possible utility for outdoor recreation resort operators and managers. The WDF may allow for targeting populations and making management decisions about types and levels of infrastructure that could potentially be introduced into a specific area based on weather-dependent factors. Resort owners and managers may use the WDF to develop goals relative to sustainable development and policies, and projects for key destinations. For example, resorts might begin to develop weather resiliency by incorporating elements of the WDF into programming and management of activities.

At the activity level, the WDF could aid in understanding changes in demand for outdoor recreation. These changes in demand might allow managers to mitigate the impacts of recreation flow based on weather-related variables. For example, an impact of climate change for some regions will be decreasing snowfall; a mitigation strategy for resorts is to produce more snow. However, managers' first need to understand the increase in demand that results from the weather dependency of resort skiing. It may be the case that decreased snowfall in the backcountry is linked to an increase in demand for resort skiing or shift destination selection, which could be elucidated by the WDF.

Outdoor recreation managers could gather and provide weather-related information to visitors. Gathering information (e.g., data collection) on the variable personal characteristics in the WDF could benefit the development of effective programs in areas where the weather is a programmatic factor. For example, managers might assess the personal characteristics of visitors likely to attend a night sky program under certain weather conditions (e.g., percent cloud cover). Next, managers might gather information related to engagement with weather and climate information. Gathering information could aid in the development of communication strategies about weather-related considerations for outdoor recreation participation specific to park and protected area resources. For instance, parks and protected areas ideal for human-powered boating (i.e., sea kayaking and canoeing), might create tailored forecasts, based on gathered information, specific to resource characteristics or weather information applications that recreationists' can access during their trip.

Additionally, resource managers may benefit from gathering weather-related information from visitors in order to provide more effective programming for weather dependent outdoor recreation activities. For example, many visitors to parks and protected areas may select their visitation place and time-of-year based on weather conditions. Winter recreation in Yellowstone National Park is one example. Gathering weather-considered programming information, anecdotally or through a formal data collection effort, could benefit Yellowstone National Park winter recreationists. Programs might be tailored to key characteristics within the WDF such as trip and personal characteristics based on winter outdoor recreation activities such as snowmobiling, cross-country skiing, and snowshoeing. More broadly, this information from visitors could give parks and protected area managers the opportunity to predict visitation patterns based on levels of weather dependency at a specific park or resource unit. Managers' resulting use of the WDF may lead to reconsidering programs and policies, recreation impact mitigation, inspire weather-based planning initiatives, and predict land access trends.

5.3. Future development of the WDF

A variety of next steps might be considered to develop the WDF. Researchers might consider developing place-based activity assessments for multiple activities as well as quantifying and developing standard measurement techniques for specific variables of the WDF. We provide suggestions for interpreting dimensionality within the WDF and make recommendations for research to explore outdoor recreationists' perceptions of the WDF.

Primarily, there is a need to develop place-based activity assessments for multiple activities. As an example, researchers could assess the weather dependency of water sports comparing the differences between lake and whitewater recreationists' in eastern Kentucky. Developing place-based specific activity assessments might allow researchers to account for similarities in regional weather conditions and compare differences in the weather dependency of outdoor recreation activities, such as trip, personal, and resource characteristics. Related, future research could test the spatial transferability of the WDF by evaluating the same activity (e.g., mountaineering) across continents with distinct social and physical landscapes, such as Europe, Africa, and Asia.

Researchers could quantify the WDF by investigating the interrelationships between variables such as correlations, weights, and predictor variables of outdoor recreation behavior. Explorations of variable correlations might help to decrease the number of variables within the WDF, allowing the WDF to become more parsimonious. For example, if the variable 'encountered weather' is highly correlated to 'behavioral reactions to weather', researchers might suggest adapting the WDF to merge these variables with one another. Next, the framework currently does not weight variables by level of importance (e.g., if one variable is more significant for determining weather dependency for specific activities). By first determining which variables are most significant, based on activity type, weighting variables may aid researchers' interpretations of weather dependency. For example, recreation experience preferences (REP; i.e., motivations) might be more significant than specific weather conditions for certain activities. Therefore, weighting recreation preferences and weather conditions based on their respective level of significance could provide a more accurate representation of the weather dependency of outdoor recreation activities. Additionally, predicting outdoor recreation behavior based on weather-related factors is another beneficial outcome of quantifying the framework.

Researchers might employ multiple regression analysis to predict outdoor recreation behavior based on specific predictor variables or factors. For instance, based on the Related Samples Freidman's' Two-Way ANOVA by Ranks, the factor *experiences with weather* indicated overall significant differences between activity types for each variable within the factor. This might indicate that *experiences with weather* is potentially more predictive of outdoor recreationists' behavior than the factor *season*, which indicated there was not statistically significant differences between activity types. Future research might further investigate interrelationships and predictive power of factors and variables within the WDF.

Forthcoming research might seek to develop standard measurement techniques for specific variables within the WDF. Due to the varied and diverse nature of weather-related studies, many of the variables lack consistent measurement techniques. This includes most of the variables within the *experiences with weather* factor. Resource dependency and resiliency to weather are also variables lacking consistent measurement. Other variables require standard measurement techniques because previous research has relied on secondary data. For example, research on U.S. National Park attendance was based on monthly recreation visitation patterns and air temperature data to predict attendance shifts relevant to increases in average springtime temperatures (Buckley & Foushee, 2012). Findings such as these can be enhanced by incorporating other WDF factors and variables such as resource and site characteristics and their standard measurement techniques.

Since a panel of experts developed the WDF, recreationists' perceptions of weather dependency could contribute to a more in-depth understanding of the weather dependency of outdoor recreation activities. Researchers could investigate recreationists' perceptions of weather dependency through a variety of methods, including qualitative interviews or quantitative survey methods. Researchers could explore winter recreationists' perceptions of weather dependency in a highly weather sensitive place. Investigations might include weather sensitive activities such as downhill skiing, snowmobiling, snowshoeing, or backcountry skiing.

Lastly, researchers should be aware that presently the WDF could appear to be oversimplifying multi-dimensional items into unidimensional measurements, which is not the authors' intent. The aim is for the WDF to be implemented as a research tool to describe the salient factors and variables that contribute to the weather dependency of outdoor recreation activities. For example, researchers interested in the contributions of place attachment to the weather dependency of backcountry skiing, would employ the standard multi-dimensional measurements of place attachment (see Manning, 2011 for review). The premise is that if the framework included the dimensionality of each variable, it would become a cumbersome tool and therefore would be difficult to interpret and use effectively.

5.4. Implications for future research

Based on the previous discussion, there appear to be areas where future research with the WDF might focus. What we have done initially is to create the WDF and demonstrate its use with three outdoor recreation activities. Implications for future research presented here include testing the WDF with a multitude of other weather dependent activities, exploring variables unintentionally excluded, and validating of the WDF by assessing recreationists' perceptions of weather dependency.

Potential next steps of research could test the WDF with a multitude of other weather dependent activities. For example, whitewater sports such as canoeing and kayaking are dependent not necessarily on direct weather conditions but the resulting conditions of weather that significantly influence water flow. There also exist thresholds of use when water flow exceeds or diminishes optimal conditions, shifting recreation participation based on the resulting conditions of weather. Previous research has also noted that relationships exist between subdimensions of recreation specialization and place attachment for whitewater boaters (Bricker & Kerstetter, 2000); likely, weather dependency is another element influencing whitewater recreation. Therefore, future research might continue to test and add a variety of weather dependent activities to the WDF.

There are also possible variables and factors unintentionally excluded from the WDF. Future research could continue to develop and add these variables and factors to the WDF. Likewise, there are potentially variables included that are not as important as they initially seemed to be. For example, relative humidity is a weather condition that could be irrelevant in dry and arid climates. Future research might add variables and remove non-essential items through discovering if this framework makes sense to outdoor recreationists. One way to accomplish this is to explore the framework under a multitude of activity types in diverse settings. One suggestion we offer is to compare the weather dependency of recreationists by region. For example assessing recreationists' perceptions of weather dependency in the southeast as compared to their western counterparts.

Lastly, experts developed this framework, and the next logical sequence is to validate this by assessing outdoor recreationists' perceptions of weather dependency. For instance, researchers might assess winter recreationists' perceptions of weather dependency in highly weather sensitive activities and places, such as examining skiing or snowmobiling in the Rocky Mountains. Researchers might also consider comparing place-based assessments of the weather dependency of one activity across multiple regions, such as comparing big game hunters' perceptions of weather dependency in various regions of the United States including the Pacific Northwest, West, Northeast, and Southeast. Alternatively, place-based investigations might assess and compare recreationists' perceptions of the weather dependency of several outdoor recreation activities in one region.

6. Conclusion

The purpose of this study was to develop an interpretive framework to understand the weather dependency of outdoor recreation activities. The Weather Dependency Framework (WDF) contains the most salient factors and variables and three activity examples of how researchers and natural resource managers might use the framework. This WDF illustrates the diverse opportunities that exist for future research and as applications for outdoor recreation and natural resource managers. As the impact of weather on outdoor recreation continues to receive increasing attention, the WDF is a roadmap to understanding outdoor recreationists' reliance on weather and resulting conditions. If researchers and managers want to understand and investigate weather dependency, the Weather Dependency Framework is one place to begin.

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