Journal of Environmental Management 304 (2022) 114224

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Visualizing social-ecological intensities for management of recreation visitors in a multiuse system

Olivia A. DaRugna [a,1,*], Christopher J. Chizinski [b], Kevin L. Pope [c], Larkin A. Powell [b], Mark A. Kaemingk [d]

[a] Nebraska Cooperative Fish and Wildlife Research Unit, School of Natural Resources, University of Nebraska-Lincoln, Lincoln, NE, USA
[b] School of Natural Resources, University of Nebraska-Lincoln, Lincoln, NE, USA
[c] U.S. Geological Survey—Nebraska Cooperative Fish and Wildlife Research Unit, School of Natural Resources, University of Nebraska-Lincoln, Lincoln, USA
[d] Department of Biology, University of North Dakota, Grand Forks, ND, USA

ARTICLE INFO

Keywords:
Complex social-ecological systems
Ecological intensities
Management tool
Outdoor recreation
Social intensities

ABSTRACT

Accounting for the variation of visitor conflicts and ecological disturbance of outdoor recreation activities across space and time can cause difficulty for managers seeking to make decisions in social-ecological systems (SESs). We develop a method to quantify and visualize social and ecological intensities resulting from outdoor recreation. We demonstrate the utility of our method at Valentine National Wildlife Refuge, where we conducted onsite surveys for an entire year of recreationists participating in consumptive (i.e., hunting), intermediate-consumptive (i.e., fishing) and nonconsumptive (e.g., hiking) activities. We use survey results and combine them with expert consensus by engaging refuge managers and scientists (i.e., Delphi method) to chart patterns in social (e.g., visitor conflicts) and ecological (e.g., damages to natural resources) intensities across multiple spatial and temporal scales. We highlight unexpected patterns that are revealed by collectively considering multi-activity groups through space and time and combining different survey methods (onsite, Delphi method). Based on the consensus reached using the Delphi method, the consumptive group had the greatest potential for social conflicts and ecological disturbances. Social and ecological intensities (i.e., hotspots) of recreation varied across lake types and seasons, highlighting high-intensity areas and periods on the refuge. Accounting for diverse outdoor recreation activities and coinciding social and ecological intensities will allow managers of SESs the ability to concomitantly preserve ecological resources, prioritize conservation efforts, and minimize visitor conflicts. We demonstrate the utility and ease of use of this technique, which can be implemented by managers and scientists within their respective SES of interest.

1. Introduction

Many social-ecological systems (SESs) are managed to conserve the ecosystem and to provide the public with opportunities for recreation (Dearden, 2010). Achieving management goals that are compatible for both the social and ecological components is difficult and in some cases these goals may be competing. Management of SESs often focuses on the natural resources, and comparatively little effort is made to understand the social component of these important and complex systems (Eadens et al., 2009). Understanding the social component involves knowledge of the spatial and temporal distribution of recreational activities and the types of recreational activities that occur (Kulczyk et al., 2018). Recreational activities that overlap in space and time may lead to visitor conflicts (e.g., crowding conflicts) within and among recreational-activity groups and cause negative ecological disturbance (e.g., to wildlife; Leung and Marion, 2000; Miller et al., 2017). Ecological disturbances refer to any undesirable recreationists-related change of the biophysical natural resource (Leung and Marion, 2000). The quantified outcome of visitor conflicts and ecological disturbances is referred to as intensities and will likely be even more important to understand as visitor use (e.g., outdoor recreation) continues to increase on SESs (Cordell et al., 2008; U.S. Bureau of Land Management, 2019; U.S. Fish and Wildlife Service, 2016). Thus, management is becoming more difficult in some complex SESs that are receiving greater visitation and

* Corresponding author. Nebraska Game and Parks Commission, Lincoln, NE, 68503, USA.
E-mail address: olivia.darugna@nebraska.gov (O.A. DaRugna).
[1] Present address: Nebraska Game and Parks Commission, Lincoln, NE, 68503, USA.

https://doi.org/10.1016/j.jenvman.2021.114224
Received 27 May 2021; Received in revised form 4 November 2021; Accepted 30 November 2021

demands for recreation, such as National Wildlife Refuges (U.S. Fish and Wildlife Service, 2016). As visitor use increases, it will continue to become more difficult for some agencies to meet their goals and missions. For instance, the National Park Service has a mission to preserve natural and cultural resources and provide outdoor recreation and the National Wildlife Refuge System has a goal to provide wildlife-compatible public use (U.S. Department of the Interior, 2021; U. S. Fish and Wildlife Service, 2016). Managers must therefore understand which recreational activities are present and the potential social and ecological intensities resulting from these activities.

A lack of an adaptable tool that can be applied to a variety of SESs to assess sustainable human activities, such as outdoor recreation, contributes to the difficulty of managing these diverse areas that vary in human uses, types of ecosystems, size, and management. Typically, management in SESs occurs at different spatial scales such as managing for wildlife across the entire SES and managing for recreation use at a smaller subunit within the SES. Therefore, there is a need to develop an adaptable tool to understand social and ecological intensities of various activities at the appropriate management scales. Knowledge of both social and ecological components is necessary to provide an integrated systems approach to managing these complex SESs. Unfortunately, balancing the management needs of the social and ecological components is difficult with the limited resources, budgets, and personnel available (Leung et al., 2015). Herein, we aim to develop a method that requires minimal resources and can be easily used by SES personnel to quantify both social and ecological intensities of recreation use. We used the density of recreating parties and expert consensus to approximate visitor conflicts and ecological disturbances of various recreational activities to assess social and ecological intensities (i.e., hotspots) at multiple management scales. This process provides managers the ability to simultaneously manage for conserving ecological resources and providing outdoor recreation opportunities on SESs.

1.1. Conceptual background

1.1.1. Visitor conflicts

Visitor conflicts in outdoor recreation can be caused by a variety of differences within and among recreational groups. Conflicts can be caused by goal interference attributed to another recreationist's behavior through direct or indirect contact (Jacob and Schreyer, 1980). Jacob and Schreyer (1980) proposed four dimensions of conflict, which included activity style, resource specificity, mode of experience, and lifestyle tolerance. Conflicts from these four dimensions often occur among groups with differences of behavior standards for recreation, values and norms of resource use, and environment expectations for recreation experiences (Kil et al., 2012; Wang and Dawson, 2005). Direct contacts of recreational groups can lead to more goal interferences as parties compete for space and resources (Cole, 2001; Jacob and Schreyer, 1980). For example, encounters among consumptive groups (i.e., hunters) can lead to less satisfaction and more conflict as they may perceive a higher safety risk (Watkins and Poudyal, 2020). This can lead to displacement of consumptive groups as they avoid encounters with other consumptive groups (Schroeder et al., 2020). Conflicts may emerge from ecological impacts caused by different recreational activities, such as degradation of resources that influence recreation experiences (Jackson and Wong, 1982). Conflicts can also occur among groups participating in different types of recreational activities (Thapa and Graefe, 2004; Vaske et al., 1995). Several sources of conflict have been found among consumptive and nonconsumptive groups that includes disturbing wildlife, making noise, failing to be aware of others, and littering (Watkins and Poudyal, 2020). On the other hand, some recreational groups may be more tolerant to encounters with other types of recreational groups, such as different types of nonconsumptive activities (e.g., wildlife watching and hiking; Watkins and Poudyal, 2020).

Additionally, conflicts in outdoor recreation typically arise when groups have different norms and values towards natural resources and may occur when there is no direct conflict among groups (Vaske et al., 1995, 2007). For example, nonconsumptive groups may oppose the way the consumptive group uses natural resources and thus perceive social value conflict with the consumptive group without an encounter (Vaske et al., 1995). Conflict can be asymmetrical with one group perceiving a greater level of conflict compared to perceptions held by another group. For instance, nonconsumptive groups can perceive more conflict with consumptive groups, but not vice versa (Moore et al., 2017; Vaske et al., 1995; Watkins and Poudyal, 2020). As participation in consumptive recreation continues to decline and participation in nonconsumptive recreation continues to increase, conflicts among these groups may become more asymmetrical (Bowker et al., 2012; Cordell et al., 2008). Management of recreational opportunities needs to account for the diverse recreational-activity groups, as overlap among consumptive and nonconsumptive groups generally leads to more social conflicts (Eadens et al., 2009).

1.1.2. Ecological disturbances

Recreational activities can have detrimental effects on the ecological systems, and thus be counter to management efforts that focus on conservation (Monz et al., 2010). Therefore, accounting for the potential ecological disturbances caused by all recreational-activity groups present on a SES is essential for management (Monz et al., 2013). Both consumptive and nonconsumptive groups can cause negative effects on the ecological system. For instance, areas with high concentrations of recreational-activity groups can lead to bank erosion along waterbodies, trampled vegetation, and other indirect disturbances on wildlife populations (Knight and Cole, 1995). The presence of recreational-activity groups can lead to displacing wildlife from essential habitats and water sources, disrupting important breeding behaviors and rearing of young, and interfering with their movement (Hammitt and Cole, 1998; Knight and Cole, 1995). Managers must understand potential ecological disturbances caused by a variety of recreational activities to effectively manage SESs to conserve the ecosystems and provide wildlife-compatible recreation opportunities for all users.

1.1.2.1. Consumptive recreation. Consumptive users tend to spread out and avoid interactions to prevent goal interference with target species and threats to safety (Schroeder et al., 2020; Vaske et al., 2000). The spread of recreationists may create more ecological disturbances due to an increase in off-trail use leading to vegetation trampling, degradation, or disturbance to sensitive species. The unpredictable spatial movement from off-trail use typically causes wildlife to flush more easily leading to increased energy expenditure (MacArthur et al., 1982; Taylor and Knight, 2003)). Additionally, consumptive groups can have direct population effects on game species through harvest and indirect effects on both game and non-game wildlife behavior as well as flora abundance (Kays et al., 2017; Knight and Cole, 1995).

1.1.2.2. Nonconsumptive recreation impacts. Nonconsumptive groups can also have detrimental effects on natural resources, such as disturbing wildlife during temporally important behaviors like breeding displays and feeding (Mallord et al., 2007; Marzano and Dandy, 2012; Remacha et al., 2016). A trail that receives heavy use from hikers can lead to wildlife being displaced from trail corridors, greater trail erosion and tree root exposure (Leung and Marion, 2000; Miller et al., 2001). Additionally, the introduction and spread of exotic and invasive species has been correlated to distance from a hiking trail, with more exotic plants occurring closer to trails (Tyser and Worley, 1992). Nonconsumptive groups, like hikers or photographers, may continually disturb wildlife and cause wildlife to abandon certain habitats, and thus becomes counter to the goal of providing wildlife-compatible recreation opportunities (Marzano and Dandy, 2012; Remacha et al., 2016).

1.1.3. Spatial and temporal scales

Visitor conflicts and ecological disturbances of recreation use are expected to vary across space and time and further escalate the challenges of managing SESs (Beeco et al., 2013; Schuster et al., 2006). The spatial and temporal variation of visitor conflicts and ecological disturbances of human use may be caused by changes in the type of recreational activities present, timing, and the frequencies of recreational-activity parties. Therefore, we would predict that the number and composition of groups at a site contribute to the level of visitor conflicts and ecological disturbances. For example, spatial and temporal overlap of consumptive (e.g., hunters) and nonconsumptive (e.g., bird watchers) groups may have a higher potential for visitor conflicts in contrast to a scenario in which only the nonconsumptive group are present (Eadens et al., 2009; Schuster et al., 2006). The frequencies and densities of recreational-activity parties will also affect the potential for visitor conflicts and ecological disturbances (Leung and Marion, 2000). The cumulative visitor conflicts and ecological disturbances from many recreational-activity parties present can belie the conflicts and disturbances caused by a single recreational-activity party (Dearden and Hall, 1983). Thus, managing for each recreational-activity group and party in isolation is insufficient for compatible management of complex SESs.

Knowledge of the spatial-temporal variation of social and ecological intensities of recreation use is important for planning and management of complex SESs. A thorough understanding of these dynamics requires incorporating the most appropriate spatial and temporal scales at which to measure intensities (Raudsepp-Hearne and Peterson, 2016). Different spatial and temporal management objectives (e.g., specific areas for hunting during the fall), patterns in human use (e.g., differences in visitation from weekends to weekdays), and biological considerations (e.g., wildlife more vulnerable to disturbance during breeding seasons) should be considered when selecting the appropriate spatial and temporal scales for measuring social and ecological intensities (Scholes et al., 2013). For example, SESs may have high social and ecological intensities of use in areas with recreation infrastructures (e.g., management units with bathrooms, roads, and trails) and during the summer when families vacation (Jones and Scott, 2006). Therefore, managers of these complex systems may want to examine intensities at the management-unit and season scales. Additionally, SESs that offer waterfowl hunting may want to consider differences in intensities of recreation use at different lake types (e.g., lakes with waterfowl hunting versus lakes without waterfowl hunting), and for various day types (e.g., hunting openers versus weekends). Such knowledge is becoming more important to understand as recreation use continues to increase, and recreational-activity groups compete for use of shared areas (U.S. Bureau of Land Management, 2019; U.S. Fish and Wildlife Service, 2016). Mapping the intensity of recreation use at different spatial and temporal scales is necessary to identify “hotspots” such as high-use areas near sensitive flora and fauna, and relatively low impacted areas, both areas of which could warrant prioritization of management efforts and resources (Smallwood et al., 2011).

1.2. Objectives

Our objectives were to 1) develop a method that quantifies the social and ecological intensities of recreation use at various spatial and temporal scales for a SES and 2) demonstrate the utility of assessing social and ecological intensities for a SES. Our method provides managers with an interdisciplinary tool for understanding the relatively understudied social component of these complex systems, which will aid in effectively reducing the potential intensity of recreation use. Furthermore, this method can easily be integrated across disciplines to understand the intensity of other human activities and support sustainable management of complex SESs.

2. Methods

2.1. Study area

We chose to develop and assess our method at Valentine National Wildlife Refuge (NWR), located in the Sandhills of Nebraska (Fig. 1) because it had many of the qualities that typify SESs that provide outdoor recreation opportunities. The refuge permits a wide range of recreational activities that can be categorized into consumptive (i.e., hunting), intermediate-consumptive (i.e., fishing; anglers can harvest or catch-and-release fish [Hunt et al., 2002]), or nonconsumptive (e.g., hiking) groups. Different recreational groups are expected to have different visitor conflicts and different ecological disturbances. Management of recreational-activity groups on Valentine NWR occurs at two spatial scales including management units (i.e., seven management units) and lake types (i.e., three fishing and hunting [fishing and waterfowl hunting permitted], six fishing [fishing permitted], and twenty-five no fishing or hunting [fishing and waterfowl hunting are not permitted]). Often management regimes at SESs, such as Valentine NWR, influence where and when certain recreational activities can occur. For instance, at Valentine NWR consumptive-recreational activities are permitted on all management units and the fishing and hunting lake type, but have temporal restrictions (i.e., regulated hunting seasons). The intermediate-consumptive recreational activities are only permitted at one management unit and two lake types (fishing and hunting, and fishing), nonconsumptive recreational activities are permitted at all management units and lake types, and neither has temporal restrictions (Kauffeld et al., 1999). Additionally, there are temporal influences on recreational activities, including seasons (e.g., winter, summer) and day types (e.g., weekday). Seasonal weather and social norms often influence recreational behavior, such as participating in ice fishing during winter or family vacations during summer (Jang, 2004). Day types may influence frequency of recreational activities, however, there are no restrictions for weekdays, weekends, or event days for when recreational activities can occur. Therefore, policies and social norms subject to spatial and temporal effects may influence the recreational activities present and their frequencies, and thus affect the social and ecological intensities of recreation use.

2.2. Recreational-activity surveys

To understand the types and frequencies of recreational activities that lead to varying levels of social and ecological intensities, we distributed vehicle-windshield surveys to recreational-activity parties throughout the course of a year (July 30, 2017 to July 26, 2018). We defined seven recreational activities that were permitted on Valentine NWR (Kauffeld et al., 1999). Parties selected all the recreational activities (hunting, fishing, environmental education, hiking, photography, touring, wildlife watching, or other) that they partook in for that given day, the lakes they visited, and recorded their party size. Parties returned completed surveys at one of four onsite-drop boxes or via the U. S. Postal Service with each survey prepaid, postmarked and addressed to the University of Nebraska-Lincoln. We recorded the date, time, and GPS location for each distributed vehicle-windshield survey.

Distribution of surveys was stratified by two-week periods (fourteen days; N = 26 total periods). Within each two-week period, days were further stratified by day type (weekday [Monday through Friday] and weekend [Saturday and Sunday]). Six weekdays and two weekend days were randomly sampled within each two-week sampling period. Each day was stratified into either a morning or an evening sampling period. Morning sampling periods began at sunrise and evening sampling periods began 8 h prior to sunset. Sampling routes were predefined; the start (and end) location and route direction (clockwise or counter-clockwise) were randomized for each sampling day. Additional “event” days were added to the sampling schedule that included holidays and hunting openers. We expected deviations from normal use during these

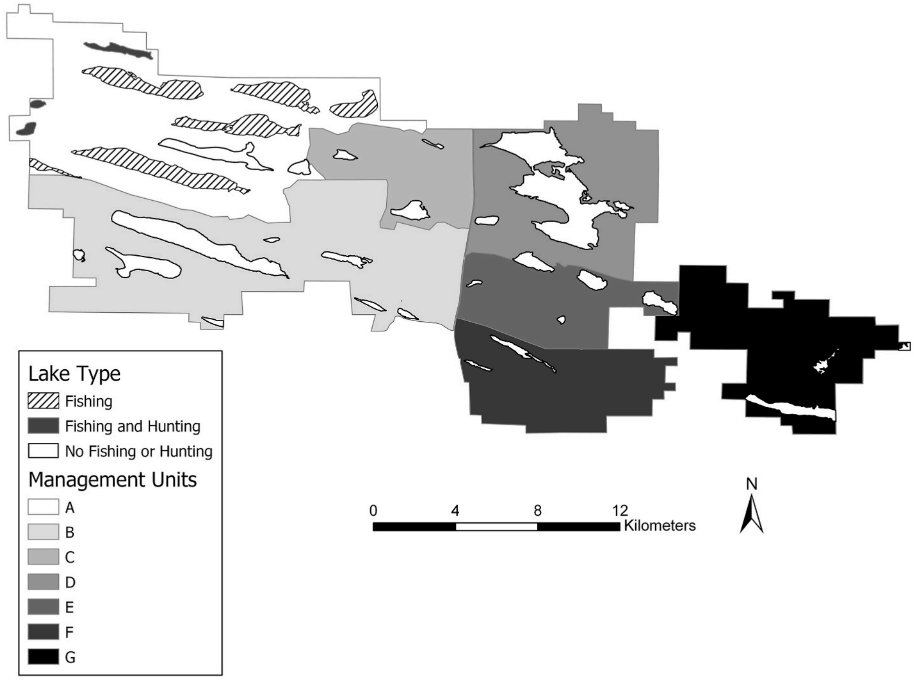

Fig. 1. Map of management units and lake types on Valentine National Wildlife Refuge, Nebraska during 2017–2018.

events and thus wanted to account for potential increased activity. We did not sample on scheduled days with foul weather (e.g., blizzards) and assumed no recreational activity occurred during these adverse weather conditions (Spinney and Millward, 2011).

We used the number of distributed surveys and number of returned surveys for each two-week sampling period to evaluate response bias to assess whether our returned surveys provided a representative sample of the temporal distribution (i.e., two-week sampling periods) of the recreational activities occurring on the refuge. Seasonality of different recreational activities (e.g., hunting permitted in fall, fishing when lakes are frozen in winter, wildlife watching in spring and summer during bird migrations and breeding displays) should indicate bias among the recreational-activity groups (Butler, 1994; Smallwood et al., 2011). For example, hunting has specific seasons and response-rate differences during these periods could reflect a misrepresentation of the consumptive group compared to the other recreational-activity groups. Thus, we attempted to evaluate response bias using a temporal approach that would expose seasonal deviates from a consistent response rate throughout the year.

The recreational activities were subsequently categorized based on a consumptive hierarchical gradient and assigned to one of three recreational-activity types: consumptive, intermediate-consumptive, or nonconsumptive. The consumptive group consisted of recreating parties that selected hunting, despite the other recreational activities selected. The intermediate-consumptive group consisted of the remaining parties that selected fishing, despite the other selected recreational activities. The nonconsumptive group consisted of the remaining parties that selected environmental education, hiking, photography, touring, wildlife watching, or other. We used GPS coordinates of the returned distributed vehicle-windshield surveys and the lakes selected by the party to assign each party to management units and lake types. Temporal scales included season and day type. Seasons were defined as winter (15 December to 22 March), spring (23 March to 14 June), summer (15 June to 21 September), or fall (22 September to 14 December). Days surveyed were subsequently categorized by day type, which included weekday, weekend day, or event day.

2.3. Delphi method

We used the Delphi method (Habibi et al., 2014; Okoli and Pawlowski, 2004) to quantify the social and ecological intensities of recreation use at Valentine NWR. The Delphi method is an iterative process that uses a series of questionnaires followed by expert feedback to collect and distill the anonymous judgements of experts until consensus is reached (Okoli and Pawlowski, 2004). The Delphi method, based on expert consensus, was used to assess daily potential visitor conflict values and daily potential ecological-disturbance values for consumptive, intermediate-consumptive and nonconsumptive groups. Such an approach is often used to facilitate problem solving and decision making, particularly in regards to environmental assessment and monitoring programs that lack information about a problem or phenomena (Nae-wen & Yue-hwa, 1999; Richey et al., 1985; Skulmoski et al., 2007; Verbos and Brownlee, 2017).

We selected ten experts based on their professional experience managing or researching natural resources and people (Habibi et al., 2014). Five experts were chosen based on their experience managing or conducting research at Valentine NWR. The remaining five experts were chosen to provide a diverse group of professionals from various natural resource disciplines (e.g., terrestrial, aquatic, game species, non-game species, or recreation management) to more fully capture the potential visitor conflicts and potential ecological disturbances of consumptive, intermediate-consumptive, and nonconsumptive groups. Each expert had a minimum of nine years professionally managing or researching natural resources and people. To prevent any personal bias towards a recreational-activity group, these experts personally participated in consumptive, intermediate-consumptive, and nonconsumptive recreational activities (Powell, 2003). Therefore, we expect that our expert panel provided a generalizable assessment of potential visitor conflicts and ecological disturbances (Okoli and Pawlowski, 2004).

Before beginning the questionnaire, experts were asked to envision a 129.5 ha (320-acre or half section) SES that included opportunities for consumptive, intermediate-consumptive, and nonconsumptive recreational activities. We intended to standardize the scenario at an appropriate spatial and temporal scale that was most manageable for all experts to assess (i.e., smaller than our study system and at the daily scale opposed to monthly or annual scale). Furthermore, our approach should also facilitate generalizing our results to other SESs that include consumptive, intermediate-consumptive, and nonconsumptive recreational activities. Experts completed a questionnaire about the daily potential visitor-conflict or ecological-disturbance value for each combination of consumptive, intermediate-consumptive, or nonconsumptive groups and their value-selection rationale. Daily potential visitor conflict refers to the varying levels of discord among parties (both within and among recreational-activity groups) that are recreating within a given spatial area on the same day. We defined daily potential ecological disturbance as the potential damages to natural resources that are caused by recreational-activity groups within the social-ecological system on the same day. The number of parties was held constant in our scenarios, but the composition varied (single or multiple recreational-activity groups). Experts were asked to use a continuous scale (0 = no potential, 10 = highest potential) with equal increments to assign a value for the daily potential visitor conflict or ecological disturbnace for each question.

We calculated the median and interquartile range (IQR) for questions after the first and second round of questionnaires (Argyrous, 2005; Murphy et al., 1998). The median and IQR are useful for scales with many values, and thus, more robust than mean, mode, and other measures of dispersion (Argyrous, 2005). Consensus is reached when the median value of each question has an IQR ≤2 (Scheibe et al., 1975; von der Gracht, 2012). Thus, each question with an IQR >2 was further assessed with additional rounds of questionnaires with the median provided as a controlled feedback. Three rounds of questionnaires is usually sufficient for reaching a consensus (Fan and Cheng, 2006). Therefore, by the third round if the IQR ≤2 is not reached then consensus will be reached based on the most frequent value assigned by the experts (Powell, 2003).

2.4. Quantifying social and ecological intensity

We used the expert-generated visitor-conflict and ecological-disturbance values to develop social and ecological intensity indices. The intensity indices provided insight to the range (minimum and maximum) of potential social and ecological intensities that occur over space (management unit, lake type) and time (season, day type), revealing opportunities to manage previously overlooked intensities. We used the concept of the marine potential conflict index presented by Freeman et al. (2016) to develop our equations for calculating 1) daily social intensity and 2) daily ecological intensity indices. Social and ecological intensity indices were developed to include disturbance-weighted densities.

$$Daily\ Social\ Intensity = P_t * S_t \quad (1)$$

where P_t = density of parties (number/100 km^2) based on returned surveys on a given day within a specified "area" (e.g., management unit or lake type); S_r = daily potential visitor-conflict value for the recreational-activity scenario based on the expert consensus values; and

$$Daily\ Ecological\ Intensity = (P_c * E_c) + (P_i * E_i) + (P_n * E_n) \quad (2)$$

where P_c = density of consumptive parties (number/100 km^2) based on returned surveys on a given day within a specified "area" (e.g., management unit or lake type); P_i = density of intermediate-consumptive parties (number/100 km^2) based on returned surveys on a given day within a specified "area" (e.g., management unit or lake type); P_n = density of nonconsumptive parties (number/100 km^2) based on returned surveys on a given day within a specified "area" (e.g., management unit or lake type); E_c = daily potential ecological-disturbance value of the consumptive-group scenario based on the expert consensus values; E_i = daily potential ecological-disturbance value of the intermediate-consumptive-group scenario based on the expert consensus values; E_n = daily potential ecological-disturbance value of the nonconsumptive-group scenario based on the expert consensus values.

To understand the social and ecological intensities at different spatial and temporal scales, we summed the daily social intensities for each season and each day type for each management unit and each lake type. We also summed the daily ecological intensities for each season and each day type for each management unit and each lake type.

2.5. Analysis

We analyzed temporal response bias using Kolmogorov-Smirnov 2-sample test to compare temporal (two-week periods) distributions between survey respondents and non-respondents (Seidel and Westphal, 2004). We used linear models to evaluate social and ecological intensities across space and time on Valentine NWR. We developed a set of models for social intensities and a set of models for ecological intensities of recreation use at the daily level (experimental unit; Table 1). The independent variables included one spatial scale (i.e., management unit or lake type) and one temporal scale (i.e., season, day type) and the dependent variables included social intensities or ecological intensities. We used an information theoretic approach (Akaike Information Criterion [AIC]) to evaluate model performance and selected the "best" model among the eight candidate models for social intensity and again for ecological intensity. We considered candidate models with ΔAIC ≤2 as important for explaining variation of social and ecological intensities of recreation use (Burnham and Anderson, 1998). We then visualized spatial and temporal intensity of the most supported models using heat maps. Analyses were performed in R (R Development Core Team, 2014).

3. Results

Surveys were received from 861 of the 2251 vehicle-windshield surveys distributed for a return rate of 38 percent. Results from the Kolmogorov-Smirnov test indicated a similar temporal distribution between respondents and non-respondents ($D = 0.26$, $p > 0.32$), and thus we did not detect a response bias. From the 861 vehicle-windshield surveys returned, there were 789 completed for a 35% functional return rate. The completed vehicle-windshield surveys were used for subsequent analysis.

Visitor-conflict values and ecological-disturbance values varied across recreational-activity questions. Expert consensus was reached

Table 1
All candidate models used to evaluate differences in social intensities (SI) and ecological intensities (EI) across space and time at Valentine National Wildlife Refuge, Nebraska during 2017–2018. Independent variables included spatial scales (lake type [LT] and management unit [MU]) and temporal scales (day type [DT] and season [SE]). Dependent variables were social intensities and ecological intensities.

Model	Model Equation
Social Intensities	
LT	SI ~ LT
MU	SI ~ MU
DT	SI ~ DT
SE	SI ~ SE
LT + DT	SI ~ LT + DT
MU + DT	SI ~ MU + DT
LT + SE	SI ~ LT + SE
MU + SE	SI ~ MU + SE
Ecological Intensities	
LT	EI ~ LT
MU	EI ~ MU
DT	EI ~ DT
SE	EI ~ SE
LT + DT	EI ~ LT + DT
MU + DT	EI ~ MU + DT
LT + SE	EI ~ LT + SE
MU + SE	EI ~ MU + SE

after two rounds of questionnaires for all visitor-conflict and ecological-disturbance values assigned to the recreational-activity questions (IQR ≤2.00). The recreational-activity question with only the consumptive group was assigned the greatest potential visitor-conflict (7.50) and ecological-disturbance (6.00) values. The recreational-activity question with only the nonconsumptive group was assigned the least potential visitor-conflict (1.50) and ecological-disturbance (1.50) values (Table 2).

3.1. Social intensity

The most supported model to explain social intensities included lake-type and season scales (Table 3). Social intensities of recreation use varied across the lake types and seasons (Fig. 2). The fishing and hunting lake type had the greatest social intensities (range: 0–2263) of all lake types across all four seasons with winter having the greatest intensities (mean = 489) and summer having the least intensities (mean = 188). Following the social intensities of the fishing and hunting lake type was the fishing lake type (range: 0–1114), with winter having the greatest intensities (mean = 204) and summer having the least intensities (mean = 49). The no fishing or hunting lake type received the least social intensity (range: 0–312) of all lake types across all four seasons with fall having the greatest intensities (mean = 19) and summer having the least intensities (mean = 1).

3.2. Ecological intensity

The most supported model to explain ecological intensities included lake-type and season scales (Table 3). Ecological intensities of recreation use varied across the lake types and seasons (Fig. 2). The fishing and hunting lake type had the greatest ecological intensities (range: 0–2263) of all lake types across all four seasons, with winter having the greatest intensities (mean = 480) and summer having the least intensities (mean = 195). The ecological intensities of the fishing and hunting lake type was followed by the fishing lake type (range: 0–759), with winter having the greatest intensities (mean = 199) and summer having the least intensities (mean = 52). The no fishing or hunting lake type received the least ecological intensity (range: 0–250) of all lake types across all four seasons with fall having the greatest intensities (mean = 15) and summer having the least intensities (mean = 1).

Table 2
The expert consensus median values for the daily potential visitor conflicts and daily potential ecological disturbances caused by the given recreational-activity groups and the rationale provided by the experts for the value selection.

Recreational-activity groups	Median Value	Rationale
Visitor Conflict		
Consumptive only	7.5	Hunters actively try to avoid other hunting parties due to dangerous activity and competition for resources.
Intermediate-consumptive only	4.0	May have little conflict if trying to fish same area or use the boat ramp.
Nonconsumptive only	1.5	Low competition for space or resources.
Consumptive and intermediate-consumptive	6.0	Anglers may become uncomfortable if hunters shoot near the lake, and hunters may be upset if anglers scare their target species.
Consumptive and nonconsumptive	6.0	Could disturb the wildlife the other groups seek to hunt or photograph.
Intermediate-consumptive and nonconsumptive	2.0	Little interaction among groups with no threat to safety.
Consumptive, intermediate-consumptive and nonconsumptive	6.0	Each group has a different goal, and thus has a potential for conflict, especially if competing for the same space or resources.
Ecological Disturbances		
Consumptive	6.0	Harvest-oriented goal can impact populations or displace wildlife.
Intermediate-consumptive	4.0	Could cause impacts along banks, pollution from gas leaks, littering, or disturbance to wildlife.
Nonconsumptive	1.5	Potential to disturb wildlife.

Table 3
Model selection results for Akaike's Information Criteria (AIC), to evaluate social intensities and ecological intensities at different spatial and temporal scales at Valentine National Wildlife Refuge, Nebraska during 2017–2018. Models include spatial scales (lake type [LT] and management unit [MU]) and temporal scales (day type [DT] and season [SE]).

Model	k	AIC	ΔAIC	*w*AIC
Social Intensities				
LT + SE	7	7478	0	1
LT + DT	6	7489	10	0
LT	4	7498	19	0
MU + SE	11	10,229	2751	0
MU + DT	10	10,237	2758	0
MU	8	10,260	2781	0
SE	5	23,432	15,953	0
DT	4	23,428	15,960	0
Ecological Intensities				
LT + SE	7	7459	0	1
LT + DT	6	7471	12	0
LT	4	7478	19	0
MU + SE	11	9888	2429	0
MU + DT	10	9888	2429	0
MU	8	9908	2449	0
SE	5	23,390	15,930	0
DT	4	23,397	15,938	0

4. Discussion

We provide an integrative method that can be broadly applied to international systems to visualize the complex relationships of a SES. Applying this method should minimize unintended consequences and promote better use of limited management resources. Our method allows managers to visualize what is happening in a complex and sometimes messy system, and hone in on a particular social and ecological component within certain spatial and temporal scales. We developed this integrative method to 1) collectively include both social and ecological components, 2) recognize that composition of users is important, 3) consider the spatial and temporal management scales, 4) and factor in the density of diverse users into management. We combined these typical system components in a method that can be visualized and easily applied across diverse SESs.

4.1. Benefits and challenges of considering social and ecological components

We demonstrated the applicability of our tool at Valentine NWR where we discovered a few surprises in our results that would have been easily overlooked if we had not collectively considered both social and ecological components of the SES. For example, intensities may be highest when only one group is present as opposed to two or more groups. We also acknowledge a few challenges and assumptions of our study that should be considered when incorporating social and ecological components into future assessments. First, we assigned a primary activity along a consumptive hierarchical gradient when some parties (23%) participated in more than one activity. We acknowledge recreationists may have selected a different primary activity than what we assigned. However, the different recreational groups (i.e., consumptive, intermediate-consumptive, and nonconsumptive) typically have different social value norms, attitudes towards wildlife, and views on how a resource should be used (Manfredo et al., 2009; Teel and Manfredo, 2009; Vaske et al., 1995). Therefore, we anticipate that these categories likely represent each party and group, regardless if they participated in multiple types of recreational activities. Second, we measured non-response bias based on differences in temporal patterns in

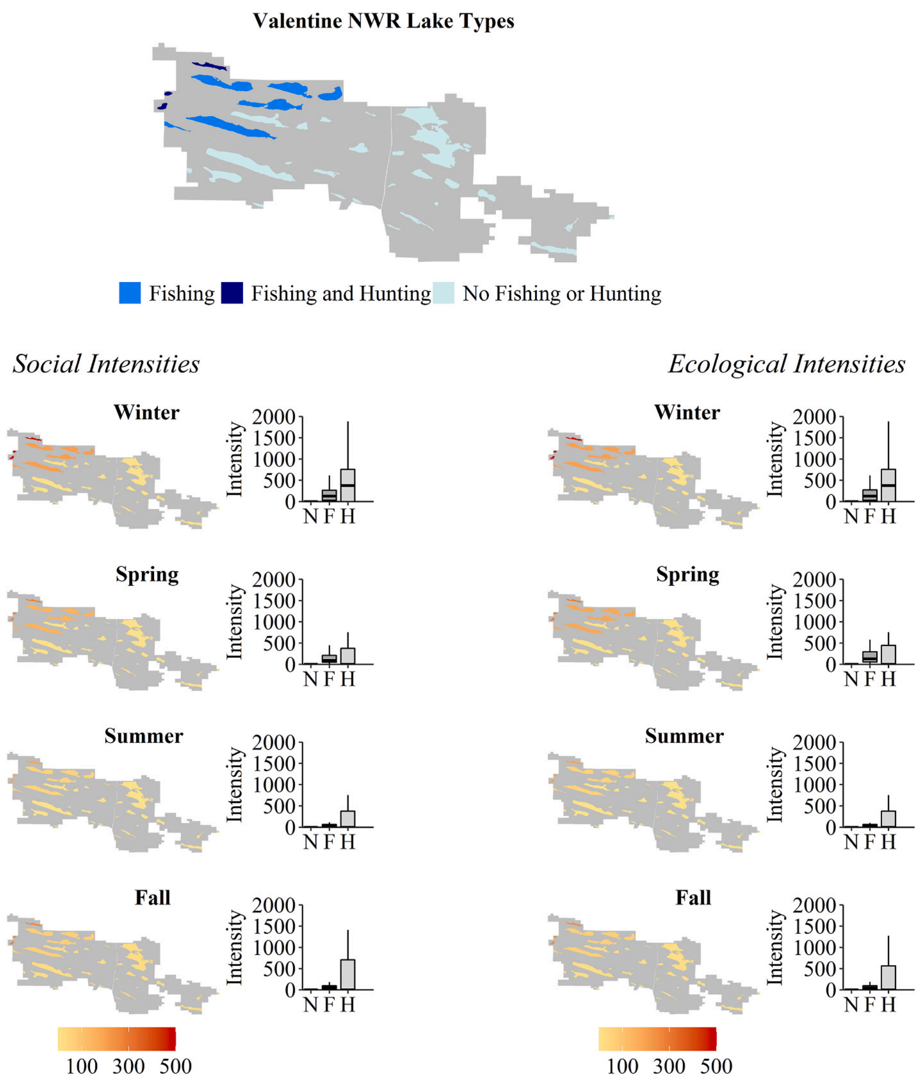

Fig. 2. Social intensities and ecological intensities across lake types and seasons at Valentine National Wildlife Refuge, Nebraska, during 2017–2018. The heat maps depict the seasonal average for social intensities across no fishing or hunting (N), fishing (F), and fishing and hunting (H) lake types. The greatest intensities occurred at the fishing and hunting lakes, followed by the fishing lakes and then the no fishing or hunting lakes. Box plot of social intensity and ecological intensity at the no fishing or hunting, fishing, and fishing and hunting lake types across winter, spring, summer and fall. The boxes denote the range from 25th to 75th percentile, dark horizontal lines denote the median, upper whiskers extend from the top of the box to the largest value at most 1.5 * IQR (interquartile range), and the lower whiskers extend to the lowest value no further than 1.5 * IQR.

response rates that were expected to align with our activity groups. For example, hunting is restricted to primarily fall months and fishing primarily occurs during winter months due to high densities of aquatic vegetation (Paukert et al., 2002). These patterns matched our personal observations when distributing our windshield surveys, although it is possible that we missed some pertinent information with our 35% functional return rate. Third, we only evaluated visitor conflicts, however there are other social components like economic impact that can be evaluated using our method to understand social intensities. Finally, we used the Delphi method to gather information from experts, which was beneficial for determining the visitor-conflict values and ecological-disturbance values. We acknowledge a different composition of scientists, natural resource managers, and other relevant experts may produce slightly different daily potential visitor-conflict and ecological-disturbance values, even though we followed previous recommendations and protocols to include a heterogeneous group of natural resource professionals (Batavia et al., 2020; Okoli and Pawlowski, 2004).

4.2. Composition of recreational activities

The composition of recreational-activity groups is an important predictor of social and ecological intensities. Areas that are managed for and attract multiple recreational-activity groups are expected to have the greatest potential for social and ecological intensities (Miller et al., 2017; Monz et al., 2013). However, counter to previous studies, we determined the greatest potential for social intensity occurs when only the consumptive group is present. The consumptive group may need more space to recreate due to intraspecific competition for limited resources (Eagles et al., 2002; Schroeder et al., 2020). Thus, greater densities of consumptive parties may cause more visitor conflicts among parties and greater ecological disturbance as consumptive parties seek to harvest natural resources. Although an overlap of consumptive and nonconsumptive groups can lead to some visitor conflicts and ecological disturbances, these two recreational-activity groups seek different experiences and potentially different resources (e.g., hunting deer versus photographing scenery; Vaske et al., 1982), thus alleviating the potential for the greatest visitor conflicts and ecological disturbances. It may be necessary to assess these densities for each complex system because the greatest source of social and ecological intensities may be context dependent.

4.3. Spatial and temporal management scales

We discovered that lake type and season were the most influential scales for predicting social and ecological intensities. The influence of lake type could be due to management regulation zoning that is specific to each recreational activity, such as waterfowl hunting being only permitted at the fishing and hunting lake type, and fishing being only permitted at the fishing and hunting and fishing lake types. Zoning recreational activities to different areas of the refuge could influence the intensities (Miller et al., 2017). We would predict that changes to these spatial zoning regulations would substantially alter the intensities at Valentine NWR. For example, allowing all activities on all lakes would lead to a more dispersed and different social and ecological intensities.

The influence of season could be due to the different recreational activities occurring most often during different seasons (e.g., hunting in fall, fishing in winter). We would predict that changes to management regulations, such as temporal zoning, would also alter intensities across seasons. For instance, extending the hunting seasons into spring and summer could increase the intensities during these seasons to similar intensities seen in the fall. Temporal zoning, which limits use on certain days, seasons, or other temporal scales can influence recreation use on SESs (Manning and Anderson, 2012). The spatial (i.e., lake type) and temporal (i.e., season) scales at which regulations are applied (e.g., fishing lakes, hunting season) was the most revealing for social and ecological intensities.

4.4. Densities of recreational-activity groups

Understanding the density of recreational-activity groups present is also important for understanding the mechanisms contributing to variation of social and ecological intensities at different spatial and temporal scales, such as lake types and seasons at Valentine NWR. The consumptive group had the greatest potential for visitor conflicts and ecological disturbances; however, due to the temporal restrictions (i.e., fall hunting seasons) and lower frequencies of consumptive parties, this recreational-activity group mostly contributed to the social and ecological intensities during fall at all lake types. Winter had the greatest social and ecological intensity indices at the fishing and hunting and fishing lake types. Compared to the consumptive group, the high densities of the intermediate-consumptive group offset the groups' lower potential visitor conflicts and ecological disturbances. Even though two different areas and seasons may have similar values for social and ecological intensities, the similar values may be caused by different compositions and frequencies of recreational-activity groups. Thus, to effectively manage for recreational activities, it is important to understand all the components that contribute to these social and ecological intensities.

The fishing and hunting lake type had the greatest social and ecological intensity values for all seasons. The small spatial area of the three lakes that comprise this lake type contributed to these large social and ecological intensity index values. Winter, by far, had the greatest values for social and ecological intensity at this lake type, likely due to greater densities of intermediate-consumptive parties. The spring and fall social and ecological intensity values at the fishing and hunting lake type were similar, however the composition of recreational-activity groups differed. During spring the fishing and hunting lake type was visited mostly by the intermediate-consumptive parties, whereas the fall had an even mix of consumptive and intermediate-consumptive parties. Therefore to alleviate the social and ecological intensities at this lake type, managers could open more lakes to fishing to disperse the intermediate-consumptive group across a larger spatial area and designate certain lakes to only hunting to further alleviate the intensities caused by the overlap of consumptive and intermediate-consumptive groups during fall (Marion, 2016).

4.5. Management implications

Management often seeks to offer diverse opportunities for users (Manning and Anderson, 2012), and our tool can provide managers with the knowledge needed to understand where and when to provide certain opportunities. For instance, the social and ecological intensity values at Valentine NWR were the least at the no fishing or hunting lake type across all seasons, which could indicate this lake type is important for providing reduced visitor conflicts and minimal ecological-disturbance recreational opportunities, such as nonconsumptive recreational activities. Managers can focus efforts on these areas of low values for social and ecological intensity to provide opportunities for the growing demands for diverse nonconsumptive opportunities, like wildlife watching and photography (Marion, 2016; U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau, 2018). However, this should be planned in conjunction with ecological evaluations to prevent further degradation of the ecosystem (van Riper et al., 2012). At Valentine NWR there was little seasonal social or ecological variation for the no fishing or hunting lake type; therefore, there should be little impact to seasonally important ecological processes, such as breeding bird displays during spring. We demonstrated how our method can be used to understand where and when intensities occur to help managers provide more rewarding opportunities for a diversity of users.

Mapping values for both social and ecological intensity of recreation use provides managers an important tool in developing and managing recreation zones for specific recreational-activity groups (Eadens et al., 2009; van Riper et al., 2012). This information can be used in conjunction with maps of sensitive species to understand areas where the species are most vulnerable to disturbance or destruction (Peterson et al., 2020). This is particularly important in areas where consumptive groups occur due to their elevated visitor conflicts and ecological disturbances, which could lead to interference of recreation or conservation management objectives (Eadens et al., 2009).

Our tool is useful for highlighting areas and times that may require special allocation of resources and management to minimize social and ecological intensities. This approach and information is currently lacking for managers that are responsible for management of compatible uses on complex SESs. Our method is beneficial because of its simplicity and ability to detect potentially problematic areas and times, with direct application to sustainable management of SESs. We treat recreational activities that overlap spatially and temporally as potentially having visitor conflicts and cumulative ecological disturbances. However, this method does not imply that all overlap of recreational-activity groups constitutes actual cumulative disturbances. We did not measure actual visitor conflicts or ecological disturbances of the recreational-activity groups. This method promotes a more systems-level approach and narrows in on potential zones and times where most intensities are expected to occur.

4.6. Conclusions

We provide an interdisciplinary tool that can be applied to other SESs in need of finding a balance to conserve ecological components and provide compatible human activities. This tool can be used on smaller SESs, such as city parks to understand the potential intensity of a single activity, such as dog walking, may have on other groups or on a restored prairie. This tool can also be applied to larger SESs, like National Parks, to evaluate the potential social and ecological intensities of different visitor groups across different spatial and temporal scales. Tourist agencies can use the results to know when to hire seasonal workers during times of highest social and ecological intensity. Additionally, landscape architects can use our tool to help design physical structures and spatial layouts to potentially alleviate intensities and contribute to a more sustainable SES.

Credit author statement

Olivia A. DaRugna: Conceptualization, Data curation, Formal analysis, Investigation, Visualization, Writing – original draft, Writing – review & editing. **Christopher J. Chizinski**: Formal analysis, Funding acquisition, Methodology, Visualization, Writing – review & editing. **Kevin L. Pope**: Conceptualization, Funding acquisition, Methodology, Project administration, Resources, Supervision, Writing – original draft, Writing – review & editing.**Larkin A. Powell**: Methodology, Writing –

original draft, Writing – review & editing. **Mark A. Kaemingk**: Conceptualization, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing.

Funding

This project was funded by Federal Aid in Sport Fish Restoration project F-182-R, which was administered by the Nebraska Game and Parks Commission. The Institutional Review Board for the Protection of Human Subjects approved the research protocol (IRB Project ID 14051). C. J. Chizinski was supported by Hatch funds through the Agricultural Research Division at the University of Nebraska-Lincoln and by Federal Aid in Wildlife Restoration project W-120-T, administered by the Nebraska Game and Parks Commission.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We thank Jerry Ryschon for assistance in the field. We are grateful to all the recreationists who completed our survey. We also thank Juan-carlos Giese and Mel Nenneman for access to the Valentine National Wildlife Refuge and their efforts in support of this research, and Christine Bender, Caryl Cashmere, Wilma Gerena, Richard Holland, and Keith Hurley for their assistance. We thank all the Delphi experts for their time and input throughout the process. The survey described herein was organized and implemented by the University of Nebraska and was not conducted on behalf of the U.S. Geological Survey. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government. The Nebraska Cooperative Fish and Wildlife Research Unit is jointly supported by a cooperative agreement among the U.S. Geological Survey, the Nebraska Game and Parks Commission, the University of Nebraska, the U.S. Fish and Wildlife Service, and the Wildlife Management Institute.

References

Argyrous, G., 2005. Statistics for Research, second ed. Sage Publications.

Batavia, C., Penaluna, B.E., Lemberger, T.R., Nelson, M.P., 2020. Considering the case for diversity in natural resources. Bioscience 70 (8), 708–718. https://doi.org/10.1093/biosci/biaa068.

Beeco, J.A., Hallo, J.C., English, W.R., Giumetti, G.W., 2013. The importance of spatial nested data in understanding the relationship between visitor use and landscape impacts. Appl. Geogr. 45, 147–157. https://doi.org/10.1016/j.apgeog.2013.09.001.

Bowker, J.M., Askew, A.E., Cordell, H.K., Betz, C.J., Zarnoch, S.J., Seymour, L., 2012. Outdoor Recreation Participation in the United States - Projections to 2060: a Technical Document Supporting the Forest Service 2010 RPA Assessment. Gen. Tech. Rep. SRS-160. U.S. Department of Agriculture Forest Service, Southern Research Station, Asheville, NC.

Burnham, K.P., Anderson, D.R., 1998. Practical use of the information-theoretic approach. In: Model Selection and Inference. Springer, pp. 75–117.

Butler, R., 1994. Seasonality in tourism: issues and problems. In: Seaton, A.V. (Ed.), Tourism: the Status of the Art. Wiley, pp. 332–339.

Cole, D.N., 2001. Visitor Use Density and Wilderness Experiences: A Historical Review of Research the Concept of Recreation Carrying Capacity, vol. 20. USDA Forest Service Proceedings RMRS-P, pp. 11–20.

Cordell, H.K., Betz, C.J., Green, G.T., 2008. Nature-based outdoor recreation trends and wilderness. Int. J. Wilderness 14 (2), 7–10.

Dearden, P., 2010. Social-ecological systems. In: Mitchell, B. (Ed.), Resource and Environmental Management in Canada: Addressing Conflict and Uncertainty, fourth ed. Oxford University Press, pp. 363–393.

Dearden, P., Hall, C., 1983. Nonconsumptive recreation pressures and the case of the Vancouver Island Marmot (Marmota vancouverensis). Environ. Conserv. 10 (1), 63–66. https://doi.org/10.1017/S0376892900011899.

Eadens, L.M., Jacobson, S.K., Stein, T.V., Confer, J.J., Gape, L., Sweeting, M., 2009. Stakeholder mapping for recreation planning of a Bahamian National Park. Soc. Nat. Resour. 22 (2), 111–127. https://doi.org/10.1080/08941920802191696.

Eagles, P.F.J., McCool, S.F., Haynes, C.D., 2002. In: Phillips, A. (Ed.), Sustainable Tourism in Protected Areas: Guidelines for Planning and Management, vol. 8. IUCN. https://doi.org/10.1111/j.1755-3768.1951.tb07631.x.

Fan, C.K., Cheng, C., 2006. A study to identify the training needs of life insurance sales representatives in Taiwan using the Delphi approach. Int. J. Train. Dev. 10 (3), 212–226.

Freeman, M.C., Whiting, L., Kelly, R.P., 2016. Assessing potential spatial and temporal conflicts in Washington's marine waters. Mar. Pol. 70, 137–144. https://doi.org/10.1016/j.marpol.2016.04.050.

Habibi, A., Sarafrazi, A., Izadyar, S., 2014. Delphi technique theoretical framework in qualitative research. Int. J. Eng. Sci. 3 (4), 8–13.

Hammitt, W.E., Cole, D.N., 1998. Wildland Recreation: Ecology and Management, second ed. John Wiley and Sons, New York, p. 361 (Hampton).

Hunt, L., Haider, W., Armstrong, K., 2002. Understanding the fish harvesting decisions by anglers. Hum. Dimens. Wildl. 7 (2), 75–89. https://doi.org/10.1080/10871200290089355.

Jackson, E.L., Wong, R., 1982. Perceived conflict between urban cross-country skiers and snowmobiles in Alberta. J. Leisure Res. 14, 47–62.

Jacob, G.R., Schreyer, R., 1980. Conflict in outdoor recreation: a theoretical perspective. J. Leisure Res. 12, 368–380.

Jang, S.C., 2004. Mitigating tourism seasonality: a quantitative approach. Ann. Tourism Res. 31 (4), 819–836.

Jones, B., Scott, D., 2006. Climate change, seasonality and visitation to Canada's National Parks. J. Park Recreat. Adm. 24 (2), 42–62.

Kauffeld, J., Garza, B., McPeak, K., Lindvall, M., Sellers, J., Len, M., Staller, D., 1999. Valentine National Wildlife Refuge Comprehensive Conservation Plan (Issue September).

Kays, R., Parsons, A.W., Baker, M.C., Kalies, E.L., Forrester, T., Costello, R., Rota, C.T., Millspaugh, J.J., McShea, W.J., 2017. Does hunting or hiking affect wildlife communities in protected areas? J. Appl. Ecol. 54 (1), 242–252. https://doi.org/10.1111/1365-2664.12700.

Kil, N., Holland, S.M., Stein, T., 2012. Identifying differences between off-highway vehicle (OHV) and non-OHV user groups for recreation resource planning. Environ. Manag. 50 (3), 365–380. https://doi.org/10.1007/s00267-012-9892-8.

Knight, R.L., Cole, D.N., 1995. Wildlife responses to recreationists. In: Knight, R.L., Gutzwiller, K.J. (Eds.), Wildlife and Recreationists: Coexistence through Management and Research. Island Press, pp. 51–69.

Kulczyk, S., Woźniak, E., Derek, M., 2018. Landscape, facilities and visitors: an integrated model of recreational ecosystem services. Ecosyst. Serv. 31 (C), 491–501. https://doi.org/10.1016/j.ecoser.2018.02.016.

Leung, Y., Walden-Schreiner, C., Conlon, K., Miller, A.B., 2015. A simple method for monitoring dog leash compliance behavior in parks and natural areas. J. Outdoor Recreat. Tour. 9, 11–16.

Leung, Y., Marion, J.L., 2000. Recreation Impacts and Management in Wilderness: A State-Of-Knowledge Review, vol. 5. USDA Forest Service Proceedings RMRS-P-15, pp. 23–48. https://doi.org/10.1515/rtuect-2016-0010.

MacArthur, R.A., Geist, V., Johnson, R.H., 1982. Cardiac and behavioral responses of mountain sheep to human disturbance. J. Wildl. Manag. 46, 351–358.

Mallord, J.W., Dolman, P.M., Brown, A.F., Sutherland, W.J., 2007. Linking recreational disturbance to population size in a ground-nesting passerine. J. Appl. Ecol. 44 (1), 185–195. https://doi.org/10.1111/j.1365-2664.2006.01242.x.

Manfredo, M.J., Teel, T.L., Henry, K., 2009. Linking society and environment: a multi-level model of shifting wildlife value orientations in the Western United States. Soc. Sci. Q. 90 (2), 407–427.

Manning, R., Anderson, L., 2012. Managing Outdoor Recreation: Case Studies in the National Parks. CAB International, Oxfordshire, UK.

Marion, J.L., 2016. A review and synthesis of recreation ecology research supporting carrying capacity and visitor use management decision making. J. For. 114 (3), 339–351. https://doi.org/10.5849/jof.15-062.

Marzano, M., Dandy, N., 2012. Recreationist behaviour in forests and the disturbance of wildlife. Biodivers. Conserv. 21, 2967–2986. https://doi.org/10.1007/s10531-012-0350-y.

Miller, S.G., Knight, R.L., Miller, C.K., 2001. Wildlife Responses to Pedestrians and Dogs. Wildlife Society Bulletin (1973-2006) 29 (1), 124–132. http://www.jstor.org/stable/3783988.

Miller, A.D., Vaske, J.J., Squires, J.R., Olson, L.E., Roberts, E.K., 2017. Does zoning winter recreationists reduce recreation conflict? Environ. Manag. 59 (1), 50–67. https://doi.org/10.1007/s00267-016-0777-0.

Monz, C.A., Cole, D.N., Leung, Y.F., Marion, J.L., 2010. Sustaining visitor use in protected areas: future opportunities in recreation ecology research based on the USA experience. Environ. Manag. 45 (3), 551–562. https://doi.org/10.1007/s00267-009-9406-5.

Monz, C.A., Pickering, C.M., Hadwen, W.L., 2013. Recent advances in recreation ecology and the implications of different relationships between recreation use and ecological impacts. Front. Ecol. Environ. 11 (8), 441–446. https://doi.org/10.1890/120358.

Moore, S.A., Brown, G., Kobryn, H., Strickland-Munro, J., 2017. Identifying conflict potential in a coastal and marine environment using participatory mapping. Journal of Environmental Management 197, 706–718. https://doi.org/10.1016/j.jenvman.2016.12.026.

Murphy, M.K., Sanderson, C.F.B., Black, N.A., Askham, J., Lamping, D.L., Marteau, T., McKee, C.M., 1998. Consensus development methods, and their use in clinical guidelines development. Health Technol. Assess. 2 (3).

Nae-wen, K., Yue-hwa, Y., 1999. An evaluation system for national park selection in taiwan. J. Environ. Plann. Manag. 42 (5), 735–745. https://doi.org/10.1080/09640569910975.

Okoli, C., Pawlowski, S.D., 2004. The Delphi method as a research tool: an example, design considerations and applications. Inf. Manag. 42, 15–29.

Paukert, C.P., Willis, D.W., Holland, R.S., 2002. Sample size requirements for in situ vegetation and substrate classifications in shallow, natural Nebraska lakes. N. Am. J. Fish. Manag. 22 (4), 1329–1333.

Peterson, B.A., Perry, E.E., Brownlee, M.T.J., Sharp, E., 2020. The transient nature of concentrated use at a national park: a spatiotemporal investigation into visitor behavior. J. Outdoor Recreat. Tour. 31 (September), 100310. https://doi.org/10.1016/j.jort.2020.100310.

Powell, C., 2003. The Delphi technique: myths and realities. J. Adv. Nurs. 41 (4), 376–382.

R Development Core Team, 2014. R: A Language and Environment for Statistical Computing.

Raudsepp-Hearne, C., Peterson, G.D., 2016. Scale and ecosystem services: how do observation, management, and analysis shift with scale—lessons from Québec. Ecol. Soc. 21 (3). Retrieved December 21, 2019, from. http://www.jstor.org/stable/26296016.

Remacha, C., Delgado, J.A., Bulaic, M., Pérez-Tris, J., 2016. Human disturbance during early life impairs nestling growth in birds inhabiting a nature recreation area. PLoS One 11 (11), 1–16. https://doi.org/10.1371/journal.pone.0166748.

Richey, J.S., Mar, B.W., Horner, R.R., 1985. The Delphi technique in environmental assessment. I. Implementation and effectiveness. J. Environ. Manag. 21, 135–146.

Scheibe, M., Skutsch, M., Schofer, J., 1975. Experiments in Delphi methodology. In: Linst, H.A. (Ed.), The Delphi Method - Techniques and Applications. Addison-Wesley, pp. 262–287.

Scholes, R.J., Reyers, B., Biggs, R., Spierenburg, M.J., Duriappah, A., 2013. Multi-scale and cross-scale assessments of social – ecological systems and their ecosystem services. Curr. Opin. Environ. Sustain. 5 (1), 16–25. https://doi.org/10.1016/j.cosust.2013.01.004.

Schroeder, S.S., Fulton, D.C., Cornicelli, L., McInenly, L.E., 2020. Recreation conflict, coping, and satisfaction: Minnesota grouse hunters' conflicts and coping response related to all-terrain vehicle users, hikers, and other hunters. J. Outdoor Recreat. Tour. 30, 100282. https://doi.org/10.1016/j.jort.2020.100282.

Schuster, R.M., Hammitt, W.E., Moore, D.W., Schneider, I., 2006. Coping with stress resulting from social value conflict: non-Hunters' response to anticipated social interaction with hunters. Hum. Dimens. Wildl. 11 (2), 101–113. https://doi.org/10.1080/10871200600572417.

Seidel, M.-D.L., Westphal, J.D., 2004. Research impact: how seemingly innocuous social cues in a CEO survey can lead to change in board of director network ties. Strat. Organ. 2 (3), 227–270. https://doi.org/10.1177/1476127004045252.

Skulmoski, G.J., Hartman, F.T., Krahn, J., 2007. The Delphi method for graduate research. J. Inf. Technol. Educ. 6 (1), 1–21.

Smallwood, C.B., Beckley, L.E., Moore, S.A., Kobryn, H.T., 2011. Assessing patterns of recreational use in large marine parks: a case study from Ningaloo Marine Park, Australia. Ocean Coast Manag. 54 (4), 330–340. https://doi.org/10.1016/j.ocecoaman.2010.11.007.

Spinney, J.E.L., Millward, H., 2011. Weather impacts on leisure activities in halifax, nova scotia. Int. J. Biometeorol. 55 (2), 133–145. https://doi.org/10.1007/s00484-010-0319-z.

Taylor, A.R., Knight, R.L., 2003. Behavioral Responses of Wildlife to Human Activity: Terminology and Methods. Wildlife Society Bulletin (1973-2006) 31 (4), 1263–1271. http://www.jstor.org/stable/3784477.

Teel, T.L., Manfredo, M.J., 2009. Understanding the diversity of public interests in wildlife conservation. Conserv. Biol. 24 (1), 128–139.

Thapa, B., Graefe, A., 2004. Recreation conflict and tolerance among skiers and snowboarders. J. Park Recreat. Adm. 22 (1), 37–52.

Tyser, Robin W., Worley, C.A., 1992. Alien flora in grass- lands adjacent to road and trail corridors in Glacier National Park, Montana (U.S.A.). Conserv. Biol. 6 (2), 253–262.

U.S. Bureau of Land Management, 2019. BLM Recreation Strategy: Connecting with Communities. Retrieved December 21, 2019, from. http://tedcantle.co.uk/pdf/connectingwithcommunitiesTedCantleOct2009.pdf.

U.S. Department of the Interior, 2021. What We Do (U.S. National Park Service). National Parks Service. Retrieved August 21, 2021, from: https://www.nps.gov/aboutus/index.htm.

U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau, 2018. 2016 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. Retrieved December 21, 2019, from: https://www.census.gov/content/dam/Census/library/publications/2018/demo/fhw16-nat.pdf.

U.S. Fish and Wildlife Service, 2016. Annual Performance Report FY2015: National Wildlife Refuge System. Retrieved December 21, 2019, from. http://npshistory.com/brochures/nwr/app-2015.pdf.

van Riper, C.J., Kyle, G.T., Sutton, S.G., Barnes, M., Sherrouse, B.C., 2012. Mapping outdoor recreationists' perceived social values for ecosystem services at Hinchinbrook Island National Park, Australia. Appl. Geogr. 35 (1–2), 164–173. https://doi.org/10.1016/j.apgeog.2012.06.008.

Vaske, J.J., Donnelly, M.P., Heberlein, T.A., Shelby, B., 1982. Differences in reported satisfaction ratings by consumptive and nonconsumptive recreationists. J. Leisure Res. 14 (3), 195–206.

Vaske, J.J., Donnelly, M.P., Wittmann, K., Laidlaw, S., 1995. Interpersonal versus social-values conflict. Leisure Sci. 17 (3), 205–222. https://doi.org/10.1080/01490409509513257.

Vaske, J.J., Carothers, P., Donnelly, M., Baird, B., 2000. Recreation conflict among skiers and snowboarders. Leisure Sci. 22 (4), 297–313.

Vaske, J.J., Needham, M.D., Cline, R.C., 2007. Clarifying interpersonal and social values conflict among recreationists. J. Leisure Res. 39 (1), 182–195. https://doi.org/10.1080/00222216.2007.11950103.

Verbos, R.I., Brownlee, M.T.J., 2017. The Weather Dependency Framework (WDF): A tool for assessing the weather dependency of outdoor recreation activities. J. Outdoor Recreat. Tour. 18, 88–99.

von der Gracht, H.A., 2012. Consensus measurement in Delphi studies. Review and implications for future quality assurance. Technol. Forecast. Soc. Change 79 (8), 1525–1536. https://doi.org/10.1016/j.techfore.2012.04.013.

Wang, C., Dawson, C.P., 2005. Recreation conflict along New York's great lakes coast. Coast. Manag. 33 (3), 297–314. https://doi.org/10.1080/08920750590952027.

Watkins, C.E., Poudyal, N.C., 2020. Recreation group encounters and impacts on satisfaction in Tennessee wildlife management areas. Hum. Dimens. Wildl. https://doi.org/10.1080/10871209.2020.1854901.