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Conditions for success in natural resource management by volunteer-based organizations: A study of lake management organizations in Vilas County, Wisconsin, USA.

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ABSTRACT

Lakefront property owners form volunteer-based organizations to conserve and manage lakes. In Vilas County, Wisconsin, U.S.A., 115 common pool resource management organizations are organized around lakes. Despite a robust literature on institutional design, few studies endeavor a mid-size comparison of resource management organizations in a single geographic context. We address this gap by comparing thirty-one Vilas County, Wisconsin lake organizations using data collected through semi-structured interviews, websites, and agency databases during the summer of 2019. We systematically compared the cases using crisp-set qualitative comparative analysis, specifically analyzing how the eight Ostrom institutional design principles lead to different outcomes for the lake social-ecological system. We find that the institutional design principles used were similar across the thirty-one organizations studied. This can partly be explained by the fact that the county and state agencies provide template rules for the bylaws of the organizations. Though the rules-in-use were consistent, the goals of the organizations differed. We found that the organizations have different preferences for how the lakes should be used and managed partly because lake organization members do not rely on lakes for their livelihood. What appeared to be a natural experiment to study institutional design, upon closer inspection, revealed diverse goals whose outcomes are influenced by combinations of environmental, social, and institutional conditions.

Keywords: community-based natural resource management, volunteer organization, comparative case study analysis, social-ecological system, lakes, Ostrom design principles, Institutional analysis and design framework, collective action, qualitative comparative analysis

INTRODUCTION

The majority of natural resource management responsibilities in the United States belong to federal and state agencies. These federal and state agencies, however, are increasingly relying on community-based resource management groups to achieve conservation and restoration goals (Armitage, 2005; Bruyere & Rappe, 2007). Community-based resource management encourages participation of communities and resource users in decision-making through the incorporation of local knowledge and institutions in management, regulatory, and enforcement practices for more sustainable resource management outcomes (Armitage, 2005). Local participation and knowledge accumulation are facilitated by organizations comprised of people who live around and appropriate the shared resource for different uses (Ostrom, 1990). When changes threaten a community's natural resource, resource users often respond by forming organizations to address the challenge (Gabriel & Lancaster, 2004; Korth & Klessig, 1990; Ostrom, 1990). These organizations emerge from the community with a goal for the resource in mind; they design their rules based on the cultural and biophysical context (Ostrom, 2009). Community-based organizations play a critical role in resource management as federal and state agency budgets shrink, and resource usage increases.

The budgets of federal resource management agencies have either remained constant or declined for the past several decades (Bruyere & Rappe, 2007). Although budgets shrank, outdoor recreation participation has increased, creating a gap in maintenance and services. Agencies rely on volunteers to fill this gap (Bruyere & Rappe, 2007). In 2012, the US Fish and Wildlife Service reported that 2.2 million volunteer hours, equivalent to 1,036 full-time employees, supplemented their 9,000-employee workforce by over ten percent (US Fish & Wildlife Service, 2013). The contributions from volunteers go beyond saving money for natural resource managers. Volunteers are deeply committed to the resources they help manage. They provide services like observing changes in natural resources and providing environmental education. As agencies recognize that "one size fits all" solutions are a poor match to the complexity of social-ecological systems (SES), volunteer-based organizations can help adapt rules to the resource and the community using the resource (Ostrom, 1990).

Volunteer-based organizations' role in community-based resource management comes with challenges. Community-based organizations already struggle with collective action problems such as: "coping with free-riding, solving commitment problems, arranging for the supply of new institutions, and monitoring individual compliance with sets of rules" (Ostrom, 1990). Volunteers care a lot about the state of the resource, but volunteers' livelihoods do not rely on the resource in question, exacerbating collective action problems. With these challenges—and no formal authority to overcome them—volunteer-based organizations struggle to meet their goals. Goals themselves present a challenge to volunteer-based natural resource management organizations. People's different uses of natural resources result in diversity in goals for resource management (Gabriel & Lancaster, 2004; Peterson et al., 2003). Collective action problems and variety of use are common issues faced by volunteer-based organizations managing shared resources.

There is a reasonable understanding of how a community of resource users overcomes the collective action problems experienced by volunteer-based organizations. Ostrom and her colleagues identified eight institutional design principles (IDPs) that are associated with the persistence of community-based resource management through a systematic case study review (Ostrom, 1990). The design principles are: 1) clearly defined boundaries, 2) congruence between appropriation and provision rules and local conditions, 3) collective-choice arrangements, 4) monitoring, 5) graduated sanctions, 6) conflict-resolution mechanisms, 7) minimal recognition of rights to organize, and 8) nested enterprises (Ostrom, 1990). Follow up community-based resource management studies support the IDPs with minor adaptations (Baggio et al., 2016; Cox, Arnold, & Villamayor Tomas, 2010). We adopt one of these adaptations by separating the first design principle 1) clearly defined boundaries into 1A) user boundaries—the boundaries between who can and cannot use the resource—and 1B) resource boundaries—clear boundaries defining the resource system (Agrawal, 2002; Cox et al., 2010).

In addition to the eight IDPs, Ostrom and her colleagues proposed the Institutional Analysis and Development framework (IADF) to analyze the outcomes of repetitive interactions by diverse people. The IADF is used to explore how institutions—the rules humans use to structure repetitive interactions—persist, dissolve, and evolve (Ostrom, 2005). According to the IADF, people with diverse interests interact in a social space; the external context shapes the interactions and social space (Ostrom, 2005). The external contexts that influence the social interactions include the attributes of the biophysical world, the structure of the community where the interactions occur, and the rules in use (Ostrom, 2005). These three external contexts affect the actions that people can take, the benefits and costs of the actions, and the potential outcomes. We call these external contexts, respectively, environmental, social, and institutional conditions and situate the eight institutional design principles in the IADF as the institutional conditions or rules in use. We use the IADF to evaluate the environmental, social, and institutional conditions that result in different outcomes through a systematic comparison of volunteer-based resource management organizations. Despite a robust literature on institutional design, few studies endeavor a mid-size comparison of resource management organizations in a single geographic context.

We address this gap by comparing thirty-one Vilas County, Wisconsin, USA lake organizations using data collected through semi-structured interviews, websites, and agency databases during the summer of 2019. In this study, we explore how the combinations of environmental, social, and institutional conditions lead to different outcomes in lake SESs. To do this, we collected primary data about the goals and conditions through semi-structured interviews with lake organization leaders. Most studies of the institutional design principles rely on secondary case study analysis, which presents data completeness and variable consistency challenges (Ratajczyk, 2016); there are few examples of studies that collect primary data (Agrawal & Chhatre, 2006; Shin et al., 2020). Vilas County is home to more than 1,300 lakes and 115 lake organizations (University of Wisconsin - Stevens Point, n.d.; Vilas County Tourism and Publicity, 2020). Vilas County's rare geology and geography—a high concentration of lakes and organizations in a small area—present a natural experiment where factors such as socio-political context and external regulations are held constant.

In the next section, we explain the methods used to collect primary data to compare thirty-one lake organizations in Vilas County, Wisconsin, USA using semi-structured interviews. We then present a systematic comparison of the thirty-one organizations using crisp-set qualitative comparative analysis and conclude with a discussion of the implications of our findings.

METHODS & DATA

We conducted semi-structured interviews during the summer of 2019 to collect data about thirty-one lake organizations that protect and rehabilitate thirty-nine lakes in Vilas County, Wisconsin, USA. We supplemented the data we collected with data published by multiple sources. These sources included the Wisconsin Department of Natural Resources (WI DNR), UW-Extension lakes program, United States Geological Survey (USGS), the North Temperate Lakes US Long-Term Ecological Research Network (NTL LTER), and the Jones Lab at the University of Notre Dame. We used constant comparison to analyze the goals mentioned in the summer of 2019 interviews. After processing the data, we used crisp-set qualitative comparative analysis to identify the conditions that led to the outcomes for the lake SESs.

Case selection

The lakes and organizations in this study are in Vilas County, Wisconsin, USA (Figure 1A). We chose Vilas County because of its geography and geology. Geographically it is very far North making the growing season short. Additionally, the soil is poor. These factors combined make the area uninteresting to the commercial agriculture industry. The absence of agriculture and the predominance of tourism results in support for conservation of the lakes with little consideration for competing uses.

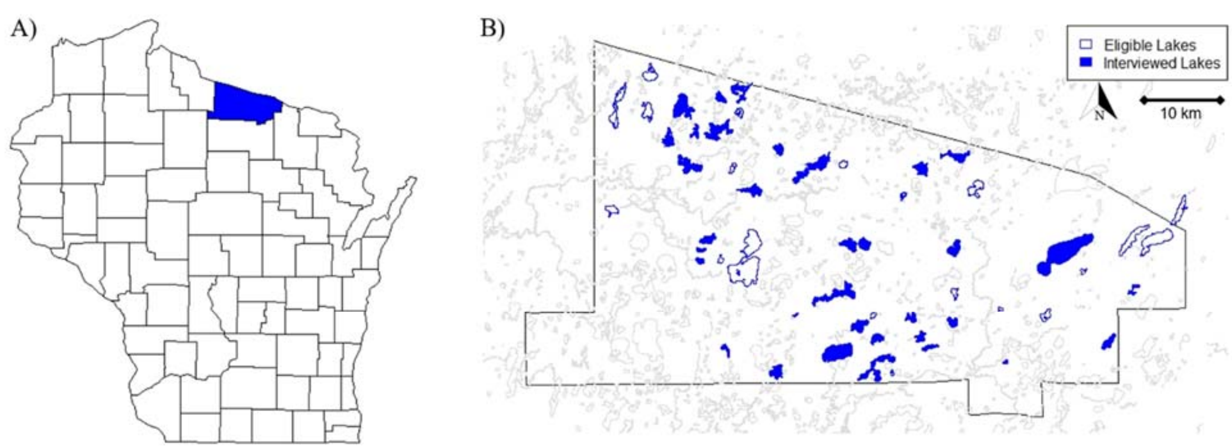

Figure 1. Our sample lakes in Vilas County, Wisconsin. A) Vilas County is in the Northern part of Wisconsin on the border of Michigan. B) The sixty-two Vilas County lakes outlined in blue were eligible for our study. The lakes filled in blue are the thirty-nine lakes managed by the thirty-one organizations we interviewed. Source: County Boundaries 24K and 24K Hydro Waterbodies (Open Water) published on dnrmaps.wi.gov.

An interesting geological feature is the number of lakes. Vilas County is home to more lakes than any other county in Wisconsin; it has 1,320 of Wisconsin's 15,000 lakes (Stedman, 2006). In addition to the 1,320 lakes in Vilas County, there are roughly 115 lake organizations. With a high concentration of lakes and organizations, Vilas County is an attractive location for a mid-sized case comparison.

Lake organizations, formed by lake users, have a variety of goals, including preventing or treating aquatic invasive species, maintaining or enhancing their fishery, protecting water quality, and member education (Gabriel & Lancaster, 2004). Lake organizations are one of two types: lake associations or lake districts. Lake associations are voluntary organizations made of lake property owners that range from informal, social organizations to incorporated non-profit organizations. Lake associations have no regulatory power over lake or land use activities; they use informal influence, volunteer time, and donations to contribute to the protection and rehabilitation of lakes (Gabriel & Lancaster, 2004; Wisconsin Lakes Partnership, 2018). A lake district is a specialized unit of government designed to protect and rehabilitate a lake or group of lakes. They can tax property in the district to levy funds for lake protection and rehabilitation. Lake districts have statutory responsibilities to the resource, local citizens, and taxpayers (Wisconsin Lakes Partnership, 2018). Lake districts manage projects that require a larger budget and can own public infrastructure or expensive equipment like weed harvesters and lake aerators (Gabriel & Lancaster, 2004). Both lake organizations types—lake associations and districts—are included in this study.

Collective action problems are common in community-based natural resource management groups like lake organizations. Like many volunteer-based organizations, a small number of highly committed individuals do most of the work. Lake organizations must design institutions that overcome these challenges and support the enforcement of rules without being perceived negatively by their neighbors. These challenges are exacerbated in regions where people live part-time. In Vilas County, 57.5% of lakefront houses are used "for seasonal, recreational, or occasional use" (Stedman, 2006). When these part-time residents are visiting their lake house, they want to relax. They do not want to contribute to management (Stedman, 2006).

We selected lakes and lake organizations (Figure 1B) using three criteria. First, we selected lakes with public access. Public access lakes have a boat ramp or landing where non-residents can access the lake for recreation, fishing, and other uses. Lakes that have public access are faced with greater collective action problems because there is potential for over-use and free-riding by non-residents who are less susceptible to resulting negative effects. Second, we included lakes with lake organizations that manage three or fewer lakes to study organizations that manage similar system complexity. Finally, we selected lakes that are managed by the WI DNR. There were fifty-two organizations that protect and rehabilitate sixty-two lakes eligible for this study after applying these three filter criteria.

Primary data collection

We interviewed thirty-one of the fifty-two eligible organizations, which protect and rehabilitate a total of thirty-nine lakes. To schedule the interviews, we contacted the primary contact listed on the UW-Extension Lakes Program website, lake organization websites, or provided by partners at the Vilas County Land & Water Conservation Department. Contacts from forty-one of the organizations responded. We asked the contact to invite one to four other members of the organization to the interview. The interviews lasted one to two hours and were conducted in community centers, lake organization member homes, and once on a boat.

We used a semi-structured interview methodology. Each interview started with the participants signing a letter of consent approved by the Arizona State University Internal Review Board. Next, each participant filled out a questionnaire about changes to the lake (Appendix 1). Most of the interview was a guided discussion about the lake organization structure and rules (Appendix 2). Each interview had the same facilitator and two notetakers. The notetakers took independent notes on the discussion.

Following each interview, the notetakers immediately coded the institutional design principles as present or absent based on their notes. Each notetaker coded independently, and then the two notetakers compared their decisions. When the notetakers disagreed, the facilitator made the final decision. The two design principles that had a high level of disagreement at the beginning of the data collection period were: monitoring and low-cost conflict resolution. The disagreements came from unclear definitions. We refined the definitions for more consistency during the first week. Once we reached an agreement on the codes, the notetakers entered the semi-structured interview data into a database.

Social-ecological outcomes

The people living around the lakes use the lakes in different ways. As a result, lake organizations have multiple social and environmental goals. Figure 2 shows the goals stated by the interviewed lake organization members. We used constant comparison, a process whereby each statement is compared with the other statements to determine whether it is the same or different (Glaser & Strauss, 1967). Using constant comparison, we identified eleven goals in the lake organization member responses noted during the 2019 semi-structured interviews.

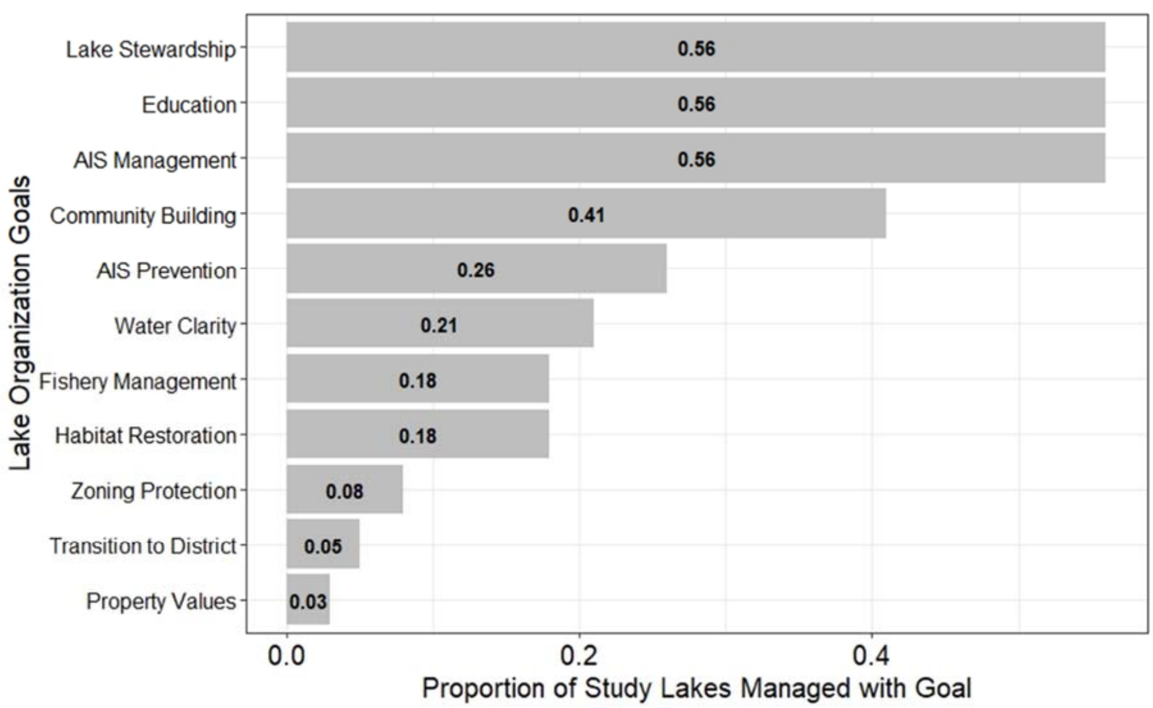

Figure 2. The eleven stated lake organization goals and the proportion of the thirty-nine lakes managed with each goal. Source: 2019 Interview Dataset.

Of the eleven goals, lake stewardship, education, and aquatic invasive species management were most common; organizations managed 56% of the thirty-nine lakes in the study with these goals. The next three goals, named by 20% or more of lakes, were focused on community building, aquatic invasive species prevention, and water clarity. These findings are consistent with Gabriel and Lancaster's survey results (Gabriel & Lancaster, 2004). The least common goals were transition to a lake district and to enhance property values, which included 5% or less of lakes. We were surprised to find that the lake organizations that we interviewed did not mention fishery protection and zoning issues as often as lake organizations in the 2004 Gabriel and Lancaster study.

In Table 1, we map the goals to outcomes for each lake. The goals stated by the lake organizations were general. When the participants described the steps they take to achieve their goals, it was clear that the more general goals were established to reach a particular lake SES outcome. We used data available via the WI DNR, UW-Extension Lakes Program, and our 2019 Interview Dataset. We focus on the common goals; we mapped seven of the eleven goals to outcomes in Table 1. We do not include habitat restoration, zoning protection, transition to a lake district, and property values in this study.

Table 1. The mapped outcomes and dichotomization of seven of the goals mentioned by lake organizations during the 2019 interviews. The data for the outcomes come from several public sources. Appendix 4 shows the distribution of continuous variables.

Goal	Outcome	Present (1)	Absent (0)	Source
Lake Stewardship	Lake Management Grant	Received	Not Received	WI DNR
Education	Clean Boats, Clean Waters (2019)	Participated	Did Not Participate	UW-Extension Lakes
AIS. Management	AIS Treatment Grant	Received	Not Received	WI DN R
Community Building	Participation in Organization	≥ 0.65	< 0.65	2019 Interview Dataset
AIS Prevention	Eurasian Watermilfoil (2019)	Present	Absent	WI DNR
Water Clarity	Very High Water Clarity	Very High	Moderate, Low	WI DNR
Fishery Management	Adult Walleye per Acre	≥ 1.42	< 1.42	WI DNR

We mapped seven lake organization goals to lake SES outcomes in Table 1 based on the interviewees' description of their goals. When talking about lake stewardship organizations mentioned general lake management and shoreline protection, lake organizations apply for lake management grants to understand and make improvements to the lake. Without a grant, they have no authority to make changes. Aquatic invasive species (AIS) treatment grants are specific to AIS management; they allow lake organizations to apply chemical and manual treatments to the lake. Education of members and lake users happens in many different ways; however, Clean Boats, Clean Waters (CBCW) is the most widely adopted and recorded approach. Through CBCW, volunteers educate lake users about the risks of AIS When lake organizations talked about community building, they mentioned increasing membership and neighborhood connections. Organization participation is a function of membership that controls for variations in the number of houses around a lake. Lake organizations are very concerned about EWM When they talked about AIS prevention, it was most often about EWM Water clarity is the only goal that is the same as its outcome. Fishery management like AIS prevention could be general, but lake organizations mentioned walleye most often; this is also a fish that the WI DNR manages through habitat improvement and by juvenile fish stocking. While lake organizations stated general goals, the way they described the steps they take to meet them made mapping a measured outcome straightforward.

The outcomes in Table 1 are used in our analysis of the environmental, social, and institutional conditions that lead to lake SES outcomes. We thought we might find a strong relationship between stating the goal and the outcome, but we did not find stating the goal to have a significant impact on its own (Whittaker, 2020). In the next section, we explore the conditions evaluated for the lake SES outcomes. Although we cannot conclude anything about outcomes from goal setting alone, we include goal setting as a condition in our analysis.

Environmental, social, and institutional conditions

The environmental, social, and institutional conditions listed in Table 2 are the product of a comprehensive, iterative selection process. First, we selected the theoretically relevant variables from the IADF and IDPs (Ostrom, 1990, 2005). We then included theoretically and empirically derived conditions from a literature review and the summer 2019 interviews, respectively. Through an iterative process of analyzing different outcomes in dialogue with our cases, we identified the following variables as most useful to understand our outcomes.

Table 2. The dichotomized environmental, social, and institutional conditions and their data sources. The dichotomization of continuous variables uses the median value. See Appendix 4 for plots.

Condition	Present (1)	Absent (0)	Source
Environmental			
Eurasian Watermilfoil (2019)	Present	Absent	WI DNR
Lake Type	Seepage, Spring	Drainage	WI DNR
Lake Size (ac)	≥ 377	< 377	WI DNR
Lake Depth (ft)	≥ 32	< 32	WI DNR
Distance from Road (ln(m))	≥ 6.58	< 6.58	USGS
Conductance (uS/cm)	≥ 69	< 69	NTL LTER
Total Phosphorous (ug/L)	≥ 12.4	< 12.4	Jones Lab, NTL LTER, WI DNR
Stock Walleye (since 2000)	Yes	No	WI DNR
Social			
Participation in Organization	≥ 0.65	< 0.65	2019 Interview Dataset
Building Density	≥ 16.58	< 16.58	USGS
Lake Organization Type	Lake District	Lake Assoc.	2019 Interview Dataset
Institutional			
Graduated Sanctions	Present	Absent	2019 Interview Dataset
Accessible Conflict Resolution	Present	Absent	2019 Interview Dataset
Exclusion	Present	Absent	2019 Interview Dataset
Work with Consultant	Yes	No	2019 Interview Dataset
Town Lakes Committee	Member	Not Member	2019 Interview Dataset
Outcome as a goal	Yes	No	2019 Interview Dataset

The data we used for the conditions come from several sources, including the WI DNR, USGS, NTL LTER, Jones Lab, and our 2019 Interview Dataset. Ten of the environmental, social, and institutional conditions we used are categorical. For the remaining seven conditions, we evaluated the distribution (Appendix 4). We used the median to convert them into dichotomous variables, which is essential for the analysis method we used. The condition "outcome as a goal" is drawn from the goals in Figure 2. A more detailed description and discussion of the conditions can be found in Whittaker (2020).

Analytical approach: crisp-set qualitative comparative analysis

We used crisp-set qualitative comparative analysis (QCA) to systematically compare the lake social-ecological systems. Charles C. Ragin developed QCA as a "synthetic strategy" to "integrate the best features of the case-oriented approach with the best features of the variable-oriented approach" (Ragin, 1987). According to Ragin, a case-oriented approach (qualitative) assesses a case holistically, while a variable-oriented approach (quantitative) separates the case into its parts. While QCA combines features of both approaches, it is more clearly a case-oriented, qualitative method. The replicability of QCA is a significant asset of this approach when compared to qualitative techniques without formalized rules of logic (Rihoux et al., 2012). Additionally, QCA is transparent about the choice of cases, variables, and the tools for analysis.

There are three types of QCA analyses: crisp set, fuzzy set, and multi-variate. Crisp set QCA (csQCA), the method we employ, uses dichotomized variables. All continuous and categorical variables are coded as present or absent. csQCA is most appropriate for our analysis because eight of the twelve factors we employ are dichotomous. Based on our sensitivity analysis (Appendix 7), we do not have cause to believe that varying degrees of the remaining four factors, used in fuzzy set and multi-variate QCA, would have a significant impact on the outcomes.

We used the fsQCA 3.0 software—developed by Charles Ragin and Sean Davey—to analyze the consistency of an outcome for a given set of conditions. We follow the convention where combinations with a consistency score equal to or greater than 0.80 are kept (Ragin & Davey, 2016). We then use the Quine-McCluskey algorithm, also called the tabulation method, to simplify the combinations to their minimal number of conditions (McCluskey, 1956).

We take an unconventional approach in this study, repeating csQCA's identification of necessary and sufficient conditions for multiple outcomes. Most studies identify necessary and sufficient conditions for a single outcome. In the following section, we will explain the environmental, social, and institutional conditions that lead to seven lake SES outcomes for the cases we compared.

RESULTS & DISCUSSION

We use crisp-set qualitative comparative analysis (csQCA) to compare the thirty-nine lakes whose lake organizations we interviewed. Following the standards in the csQCA methodology, we used a two-step analysis. First, we identified the necessary conditions for each outcome. Second, we identified sufficient conditions using the Quine-McCluskey algorithm for solution simplification.

A necessary condition is always present when the outcome occurs (Rihoux et al., 2012). We evaluated whether each condition is necessarily present, necessarily absent, or not necessary for each outcome. For a condition to be considered necessary, it should have a consistency score of greater than or equal to 0.90 (Cebotari & Vink, 2013). This score means that the condition is present or absent in 90% of the cases with that outcome.

We evaluated the necessity of the causal conditions in Table 2 for the seven outcomes in Table 1 and found lake depth is a necessary condition for very high water clarity (Table 3). Lake depth explains 36% of the cases with very high water clarity. There are no other necessary conditions.

Table 3. Necessary conditions by outcome. UPPERCASE means the variable is present; lowercase means the variable is absent. Conditions are considered necessary if they have a consistency value of 0.90 or higher.

Outcome	Necessary Conditions[1]	Consistency	Coverage
Very high water clarity	DEEP	1.00	0.36

[1]For abbreviations see Appendix 5

Lake depth (DEEP) is necessary for very high water clarity. This finding is consistent with a study by Johnston and Shmagin, where they found lake depth to be the single best predictor of water clarity. Lake depth is tied to phosphorous cycling in the lakes and groundwater fluxes (Johnston & Shmagin, 2006). These processes both affect the prevalence of algae and vegetation in the lake and thus the water clarity. Because the necessary conditions only start to explain lake SES outcomes, we next explore the sufficient conditions whose combinations lead to success in our sample.

The analysis of sufficiency identifies the combinations of environmental, social, and institutional conditions that lead to the seven lake SES outcomes (Table 4). In this analysis, the conditions sufficient to explain an outcome vary by the outcome assessed. For example, the conditions that explain receiving a lake management grant differ from the conditions that explain very high water clarity. For each of the outcomes, there are multiple combinations of factors that lead to success. Each line in Table 4 represents a combination of variables that lead to the outcome.

Table 4. The combinations of environmental, social, and institutions conditions that lead to the seven outcomes studied. Following the conventions of Boolean algebra, UPPERCASE letters mean the condition is present, and the value is "1." Lowercase letters represent absence, and the value is "0". The operators used are the logical "AND" represented by the multiplication symbol "*" and the logical "OR" represented by the addition symbol "+" (Rihoux et al., 2009). Each line represents a combination of variables that lead to the outcome.

Outcome	Combinations[1]	Consistency, Coverage
Lake Management Grant Received	[CONS] + [TLC*SANC*(stewg+dens)] + [tlc*STEWg*dens]	1, 0.97
AIS Treatment Grant Received	[DENS*road]*[(cons*AISMg)+CLAR] + [DENS*ROAD*AISMg*clar] + [EWM*road*clar*AISMg] + [EWM*CONS]	1, 0.88
Clean Boats, Clean Waters Participation	[EWM*SANC*ROAD]*[DENS+(SIZE*CONF)] + [ewm*sanc*SIZE*dens] + [road*SANC*CONF*SIZE]*[ewm+DENS]	1, 0.72
Participation in Org ≥ 0.65	[CONS*commg]*[(SANC*road)+(SIZE*EWM)] + [CONS*ROAD]*[(sanc*commg)+(sanc*SIZE)+(size*EWM)] + [cons*road*COMMg*SIZE] + [cons*commg*ROAD*SANC]	1, 0.86
Eurasian Watermilfoil Absence	[clar*dens]*[AISPg+(SANC*cond)+(TP*DEEP)] + [clar*tp*deep*cond*aispg] + [clar*DENS*SANC*COND] + [clar*sanc*AISPg] + [CLAR*tp*DEEP]*[SANC+cond] + [dens*tp]*[(cond*DEEP)+(clar*deep)]	1, 0.96
Very High Water Clarity	[DEEP*SEEP*(ROAD+CLARg)]	1, 0.88
Adult Walleye/acre ≥ 1.42	[clar*DEEP]*[(sanc*dens)+(cond*SANC)+(COND*sanc*STOCK)] + [clar*cond*dens*stock] + [CLAR*DEEP*COND*SANC]	1, 0.75

[1] Abbreviations used are available in Appendix 5.

The combinations that lead to the seven outcomes range in complexity and number. For example, very high water clarity has one pathway comprised of four conditions. High participation in the lake organization has four pathways with six conditions. All of the pathways have a consistency of 1. A consistency score of 1 means the cases that exhibit the conditions in that combination have the same outcome. The coverage ranges from 0.72 to 0.97, which means the pathways explain 72-97% of the studied cases with that outcome. The outcomes are somewhat sensitive to the way the variables have been dichotomized. When the conditions are dichotomized on the mean, rather than the median, the same conditions explain 63-94% of the outcomes (Appendix 7).

Outcomes can also be conditions in lake SESs. Very high water clarity is an outcome that lake organizations care about, and it also influences the appearance of EWM and adult walleye abundance outcomes. The interconnected nature of social-ecological systems blurs the line between cause and effect.

There are three combinations of conditions present when lake organizations receive a lake management grant. These combinations explained 97% of the cases when lake organizations received grants. The first combination is working with a consultant (CONS); consultants are paid through grants to conduct lake studies or prepare lake management plans for lake organizations. They provide scientific knowledge and have developed best practices based on experience with a variety of lake organizations. The second combination includes being a member of a Town Lakes Committee (TLC) and employing graduated sanctions (SANC) when there is no stewardship goal (stewg), or the building density is low (dens). Town lake committees can apply for grants on behalf of lake organizations and are forums for sharing information between organizations. Graduated sanctions (SANC) mean that organizations are sophisticated enough to enforce their rules and do it on a sliding scale, promoting learning. The third combination includes organizations that have a stewardship goal (STEWg), are not town lakes committee members (tlc), and have low building density (dens) around the lake. These organizations are focused on stewardship. Lake management grants provided by the WI DNR are the best method to protect and rehabilitate the lake. Receiving a lake management grant was achieved in three ways, which involve working with information aggregators—consultants and town lakes committees—and organizational sophistication shown through graduated sanctions and goal setting.

Lake organizations received aquatic invasive species (AIS) treatment grants when one of four combinations of conditions were present. These combinations described 88% of the cases when an AIS treatment grant was received. The four combinations fall into two groups, lakes with high building density (DENS) and lakes with Eurasian Watermilfoil (EWM). The first high building density combination is lakes that are close to a secondary road (road). These lakes are accessible, which may increase the non-resident traffic on the lake. Higher non-resident traffic would lead to a greater risk of the introduction of AIS during boat launching. The second high building density combination includes lake organizations with aquatic invasive species management goals (AISMg) that manage moderate to low clarity lakes (clar) that are not close to a secondary road (ROAD). These organizations need AIS treatment grants to reach their goals. For lake organizations with EWM, a rapidly spreading AIS that chokes out other plant life, one combination includes organizations with aquatic invasive species management goals (AISMg) managing lakes moderate to low clarity lakes (clar) near secondary roads (road). These accessible, EWM-plagued lakes need AIS treatment grants to meet their goals and prevent the spread of EWM The fourth combination includes organizations who work with consultants to manage EWM-plagued lakes. Consultants help lake organizations carry out the AIS treatment activities funded by the grants. Lake organizations dealing with EWM that set AIS management goals or partner with consultants receive AIS treatment grants to manage lakes that have high building density or are close to secondary roads.

Clean Boats, Clean Waters (CBCW) is an AIS education program carried out by volunteers who inspect boats at launch ramps across the state of Wisconsin. Three combinations explain 72% of the cases where lake organizations participated in CBCW during the summer of 2019. The first combination includes lake organizations employ graduated sanctions (SANC) to manage lakes with EWM (EWM) that are not close to secondary roads (ROAD). These conditions indicate that they already have an AIS, but they are committed to educating people about its spread through boat ramp monitoring and rule enforcement. The second combination includes organizations that employ graduated sanctions (SANC), but do not have Eurasian Watermilfoil (ewm). These lakes are large and have a low building density. CBCW is a volunteer-based program; lakes with graduated sanctions have stronger rule enforcement and perhaps stronger organizations. The third combination is large lakes (SIZE) near secondary roads (road) managed by organizations with graduated sanctions and conflict resolution. The size and accessibility of these lakes may put them at risk, so they participate in CBCW and have a sophisticated institutional structure. The lake organizations that participate in CBCW vary in structure as do the lakes they manage. Some organizations participate as a preventative measure; others have EWM and still participate. Some organizations supplement CBCW with graduated sanctions, and others do not.

High lake organization participation, $\geq$ 65%, is explained by four combinations of conditions. These pathways explain 86% of the cases where organization participation is high. First, lake organizations that partner with consultants (CONS) and do not have a community-building goal (commg). Members participate in surveys and workshops, like aquatic plant identification, during lake management studies by consultants. The resulting products are exciting and serve as strategy documents for the organization. These organizations, which manage large (SIZE) or accessible (road) lakes, might not have a community-building goal because they have high participation. The second combination includes lake organizations that work with consultants (CONS) and are not close to a secondary road (ROAD). The third combination is large, accessible lakes that have community building goals (COMMg). Finally, organizations that are not close to a secondary road (ROAD) and employ graduated sanctions (SANC) have high participation. The combinations that lead to high participation differ by lake size and accessibility. Common strategies like sophisticated organizational practices, partnering with a consultant, and goal setting, lead to high participation.

The absence of Eurasian Watermilfoil is the result of six combinations of conditions, which explain 96% of the cases where EWM was absent. The first combination includes lakes that have moderate to low water clarity (clar) and low building density (dens). Less light penetrates water with lower clarity, which inhibits EWM growth (Smith, Smith, Barko, & Barko, 1990). Additionally, some of these lakes are deep (DEEP), which inhibits EWM growth for the same reason. The next combination is shallow (deeps) lakes with moderate to low water clarity (clar). These lakes have low conductivity (cond) and total phosphorous (tp). Conductivity and total phosphorous are different measures of lake productivity; low conductivity and low phosphorous indicate low lake productivity. The third combination also includes moderate to low water clarity (clar) lakes managed by organizations with graduated sanctions (SANC) in place. These lakes also have high conductivity (COND) and high building density (DENS). Though the lake productivity and building density may be favorable to EWM, the graduated sanctions play a role in preventing EWM The fourth and final combination with moderate to low water clarity includes organizations that set AIS prevention goals (AISPg). The fifth combination is very high water clarity (CLAR), low total phosphorous (tp), deep (DEEP) lakes that either have low conductivity (cond) or graduated sanctions (SANC). Phosphorous is a nutrient that promotes EWM growth (Smith et al., 1990), so low levels of phosphorous in combination with the other factors prevent EWM presence. The final combination includes lakes with poor growing conditions for EWM that have low building density (dens). Eurasian Watermilfoil is prevented by unfavorable environmental conditions like low lake productivity and water clarity; graduated sanctions and goal setting also play a key role in preventing this aquatic invasive species.

Very high water clarity is the result of one combination, which explains 88% of the cases where water clarity is very high. The lakes in this group are deep (DEEP) and either seepage or spring lakes (SEEP). Both of these conditions are associated with phosphorous cycling in the lakes; deep, seepage or spring lakes have less phosphorous and, therefore, slower algae and plant growth (Johnston & Shmagin, 2006). These lakes were also far from a secondary road (ROAD), or the organization had a water clarity goal (CLARg). The lakes far from a secondary road may have less traffic, churning less sediment, or have more natural watershed leading to fewer runoff nutrients. Very high water clarity is a function of the hydrology in the lake; very clear lakes are deep, seepage or spring lakes.

The proportion of adult walleye per acre is higher in three combinations of conditions. These combinations explain 75% of the cases where the number of adult walleye per acre was equal to or higher than 1.42. In two of the combinations, the water clarity is low to moderate (clar). The first pathway is deep (DEEP), moderate to low clarity lakes. The low water clarity and depth make these good walleye lakes. Additionally, the walleye populations benefit from low building density (dens), graduated sanctions (SANC), high conductance (COND), and stocking (STOCK) in various cases. The second combination is low conductance (cond) lakes with low building density (dens) and organizations that do not stock (stock). These lakes have low productivity and are not deep; this goes against the understanding of what makes a good walleye lake. The low density and lack of stocking may mean these lakes are out of the way, without much fishing pressure. The third combination is clear (CLAR), deep (DEEP), high conductance (COND) lakes that employ graduated sanctions (SANC). The natural conditions in the lake are favorable to walleye, and the graduated sanctions mean that the harvest limits are probably enforced. The lakes with more adult walleye/acre tend to be environmentally favorable and either less developed or with graduated sanctions in place.

Trends across the seven outcomes show that some outcomes have a greater social and institutional impact, others have a greater environmental influence, and some are a blend. Receiving a lake management grant and having high participation are both heavily influenced by working with a consultant, graduated sanctions, and goal setting; these are social and institutional conditions. Adult walleye abundance and very high water clarity are influenced by environmental factors like lake productivity and lake depth, respectively. Finally, receiving an AIS treatment grant, CBCW participation, and EWM. prevention are a cross over. These three cross-over outcomes are management activities carried out by lake organizations to prevent and manage AIS Positive outcomes are a result of the natural conditions of the lake such as water clarity, social conditions like the building density, and institutional conditions like graduated sanctions.

CONCLUSION

We asked how the combinations of environmental, social, and institutional conditions lead to different outcomes for lake SESs with volunteer-based organizations. We found that multiple combinations can lead to the same outcome; these combinations vary in number and complexity by the outcome. The study of social-ecological systems acknowledges the interactions between environmental, social, and institutional factors. Some lake SES outcomes were influenced by environmental factors, others by social and institutional, and others by a combination. Outcomes that were also conditions, like water clarity, blurred the relationship between conditions and outcomes. Social-ecological research, which focuses on systems as a whole, must acknowledge the complex interactions between different types of conditions and the outcomes in the system.

While we expected to find different combinations that led to lake SES outcomes, we were surprised by the diversity in organizational goals. In community-managed common resources, there are often a few agreed-upon goals. The lake organizations we studied are volunteer-based, and most volunteers are secondary homeowners that spend most of their time elsewhere. Additionally, the members of the organizations' livelihoods do not rely on the lakes. These factors, in part, lead to diversity in use and goals for the lake and few direct partnerships between lake organizations. These bilateral partnerships are said to be too time-consuming. In addition to collective action challenges, volunteer organizations whose livelihoods are not dependent on the resource are challenged by diverse goals and limited time contributions from members.

We bounded our study of SES outcomes by the goals set by lake organizations. Lake organizations are one of several user-groups that use lakes, and goals differ by user-group. Managing lakes for different outcomes is challenging. One approach is to identify the underlying drivers that could maintain system resilience, no matter how success is defined. For example, one person may want to continue catching walleye, another may want to swim in clear water, and a third may want to maintain the value of their lakefront property. Though goals are diverse and motivated by different uses, there are underlying processes like shoreline development that could impact all the outcomes.

A case-based, systematic comparison presents challenges in preparing data, but it facilitates understanding the complex relationships in social-ecological systems. On the one hand, the approach we used to collect primary data for a moderate number of cases during one field season was effective for overcoming the challenges described by Ratajczyk with data completeness. On the other, we did not see the diversity in rules in use that we expected. The small geographic area and singular resource were conducive to complete and consistent data collection, but it also resulted in less institutional diversity. The well-established multi-level management of Wisconsin lakes and Vilas County, in particular, results in homogenous rules in use at the resource level. Additionally, with a sample of 31 organizations and 39 lakes, gathering secondary data on the environmental conditions of the lakes required compiling multiple secondary data sources. The reward of these challenges was seeing the similarities emerge. By examining a sample of similar organizations and geographically similar lakes, we identified the contextual nuances in the organizational structures and lakes. In a traditional case study, these would not have been identifiable as trends. In a traditional statistical approach, the context and the nuance of how the conditions combine would have been lost. Now that the pathways have been identified, other methods like case studies or statistical analysis can explore the nature and prevalence of these combinations of conditions.

Natural resource management is an essential and resource-intensive function. Innovative models of management are needed to adapt to increasing threats from climate change, land-use change, and invasive species to social-ecological systems. The lakes region in Vilas County, Wisconsin provides a collaborative model that relies on volunteer-based resource management; these solutions are not one size fits all. Conditions for success depend on the desired outcomes and the conditions present in the social-ecological system. Better understanding the dynamic nature of the environmental, social, and institutional context on outcomes is critical for designing social-ecological systems that remain resilient to the increasing challenges of the twenty-first century.

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APPENDICES

Appendix 1. Lake Changes Worksheet

1. For which lake(s) are you answering the questions below?
2. Please summarize how your lake changed over the past 10 years in 3-4 sentences.

In the following questions please check the box that most accurately describes the current state of the lake attribute listed and indicate whether it has increased (+), stayed the same (=), or decreased (-) over the past 10 years.

Attribute	Very Low	Low	Moderate	High	Very High	Change (+, =, -)
Water Clarity						
Amount of fish						
Diversity of fish						
Invasive plant prevalence						
Invasive animal prevalence						
Wildlife diversity						
Pollution levels						
Natural shoreline						
Property values						
Watershed quality						
Personal watercraft presence						
Fishermen presence						
Local visitors						
Wisconsin visitors						
Out-of-state visitors						
Volunteer turnout						
Annual meeting turnout						
Social event turnout						
Lake organization membership						
Housing density						
Amount of stocking						

3. Please list and indicate the state and change of any other attributes that you find important.
4. How does your lake organization compare on the attributes above to the other lake organizations in Vilas County? Please include the names of the organizations.

Appendix 2. Semi-Structured Interview Questions

SECTION1

What were the biggest changes you noticed in the past decade?

What do you think has caused the changes? Has your organization influenced the changes?

SECTION2

When did your lake organization form? Why did it form?

Have you considered being a lake district?

How many people are on your board?

Who lives around the lake? How many homes? What % in the lake organization?

Is there other development around the lake besides homes?

Are there other organizations you work with to manage the lake? County? DNR? (polycentricity)

How do people use the lake? Residents vs. non-residents?

What do you consider the lake?

What is your public landing like? Do you manage it? Improve it? (exclusion)

Are there rules about who can or cannot use the lake? (exclusion)

Do you participate in CBCW? AIS monitoring? Stocking? Shoreline improvement? (provision)

Are lake association members involved in rule making? Non-members? (collective choice)

Are there no wake times, special zoning requirements or other ordinances on your lake?

Has the organization suggested new ordinances or requested different catch limits? (collective choice)

What happens when someone doesn’t follow the rules of the lake? (monitoring, graduated sanc)

What happens when there is a conflict between lake users? DNR or township? (conflict)

What are the goals of the organization? How do you meet them?

Have you had any challenges carrying out your goals? (self-determination)

Are there ordinances or regulations that you’d like to change but haven’t been able to?

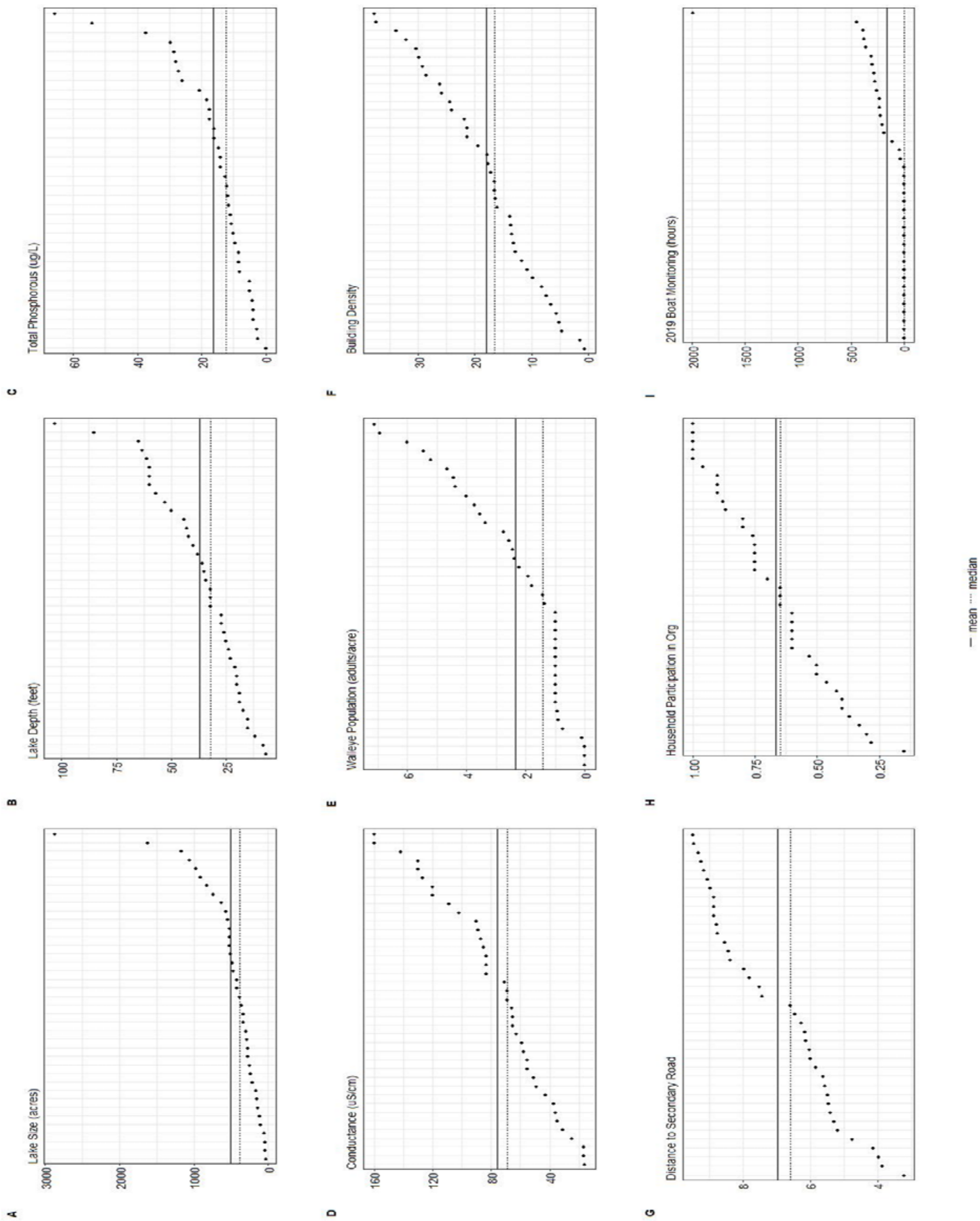
Have you been asked to perform certain activities by the DNR or your township?

Why do/don’t you stock fish in your lake? Would you stock/not stock in the future?

Appendix 3. Code Definitions for Organizational Goals

Goal	Definition	Typical Exemplars	Atypical Exemplars
Lake Stewardship (STEW)	General lake, shoreline, and watershed protection, monitoring, and management.	stewards of the environment, protect the natural shoreline	keep the lake healthy, keep management plan updated, prevent runoff
AIS Management (AISM)	Managing or controlling existing AIS populations.	AIS Management	contain milfoil with available resources, control EWM, adequate funds for management
Education (EDU)	Education and outreach goals for lake organization members and lake users.	Education, outreach	communication on lake, update website with info
Community Building (COMM)	Goals focused on building the community, promoting connection between neighbors, and goodwill.	increase membership, community building, neighborhood connections	keep volunteers, good life, increase membership
AIS Prevention (AISP)	Goal specifically mentions preventing AIS or protection the lake from AIS General lake protection is considered STEW.	AIS prevention, be alert for AIS	future camera installation
Water Clarity (CLAR)	Maintain, improve, or monitor lake water clarity.	preserve and maintain water quality and clarity, water clarity	water
Fishery Management (FISH)	Fishery improvement, monitoring, and management.	fishery management, fishery protection	good fishing
Habitat Restoration (HAB)	Habitat restoration or improvement. This can refer to wildlife or vegetation. Protection does not qualify.	habitat restoration, habitat improvement	helping the loons
Zoning Protection (ZONE)	Goals to prevent changes to zoning and land use activities.	zoning preservation	enforcing the deed restrictions
Transition to LD (T2LD)	Transition organization type from a lake association to lake district.	transition org from LA.	
Property Values (PROP)	Maintain or improve property values around the lake.	property values	

Appendix 4. Continuous Variable Dichotomization



Appendix 4. Continuous variables were dichotomized on the mean (solid line) and median (broken line).

Appendix 5. Condition and Outcome Abbreviations
The conditions used to understand the combinations that lead to outcomes for lake SESs. The condition and outcomes, values for which they are present, abbreviation used in Table 6 and Appendix 6, and data source.

	Present (1)	Abbreviation	Source
Environmental Conditions			
Eurasian Watermilfoil (2019)	Present	EWM	WI DNR
Lake Type	Seepage, Spring	SEEP	WI DNR
Lake Size (ac)	≥ 377	SIZE	WI DNR
Lake Depth (ft)	≥ 32	DEEP	WI DNR
Distance from Road (ln(m))	≥ 6.58	ROAD	USGS
Conductance (uS/cm)	≥ 69	COND	NTL LTER
Total Phosphorous (ug/L)	≥ 12.4	TP	Jones Lab, NTL LTER, WI DNR
Stock Walleye (since 2000)	Yes	STOCK	WI DNR
Social Conditions			
Participation in Organization	≥ 0.65	PART	2019 Interview Dataset
Building Density	≥ 16.58	DENS	USGS
Lake Organization Type	Lake District	LDST	2019 Interview Dataset
Institutional Conditions			
Graduated Sanctions	Present	SANC	2019 Interview Dataset
Accessible Conflict Resolution	Present	CONF	2019 Interview Dataset
Exclusion	Present	EXCL	2019 Interview Dataset
Work with Consultant	Yes	CONS	2019 Interview Dataset
Town Lakes Committee	Member	TLC.	2019 Interview Dataset
Outcome as a goal	Yes	*g	2019 Interview Dataset
Outcomes			
Lake Management Grant	Received	GRNT	WI DNR
Clean Boats, Clean Waters	Participated	CBCW	UW-Extension Lakes
AIS Treatment Grant	Received	APM	WI DNR
Participation in Organization	≥ 0.65	PART	2019 Interview Dataset
Eurasian Watermilfoil	Present	EWM	WI DNR
Very High Water Clarity	Very High	CLAR	WI DNR
Adult Walleye per Acre	≥ 1.42	ABUN	WI DNR

Appendix 6. QCA Models and Assumptions used in Sufficiency Analysis
Model: GRNT = f(CONS, TLC, SANC, STEWg, DENS)
Assumptions:
CONS (present)
TLC (present)
SANC (present)
STEWg (present)
DENS (present)
Model: APM = f(DENS, ROAD, CLAR, AISMg, CONS, EWM)
Assumptions:
DENS (present)
~ROAD (absent)
~CLAR (absent)
AISMg (present)
CONS (present)
EWM (present)
Model: CBCW = f(ROAD, EWM, SANC, CONF, SIZE, DENS)
Assumptions:
~ROAD (absent)
~EWM (absent)
SANC (present)
CONF (present)
SIZE (present)
DENS (present)
Model: PART = f(CONS, SANC, SIZE, COMMg, ROAD, EWM)
Assumptions:
CONS (present)
SANC (present)
EWM (present)
Model: ~EWM = f(CLAR, DENS, TP, SANC, DEEP, COND, AISPg)
Assumptions:
~CLAR (absent)
~DENS (absent)
~TP (absent)
SANC (present)
DEEP (present)
~COND (absent)
AISPg (present)
Model: CLAR = f(DEEP, SEEP, ROAD, CLARg)
Assumptions:
DEEP (present)
SEEP (present)
ROAD (present)
CLARg (present)
Model: ABUN = f(CLAR, DEEP, COND, SANC, DENS, STOCK)
Assumptions:

~CLAR (absent)
DEEP (present)
COND (present)
SANC (present)
~DENS (absent)
STOCK (present)

Appendix 7. Sensitivity analysis of the sufficient condition combinations.

Outcome	Combinations[1]	Consistency, Coverage
Lake Management Grant Received	[CONS] + [TLC*SANC*(stewg+DENS)]	1, 0.94
AIS Treatment Grant Received	[EWM*CONS] + [EWM*clar*AISMg] + [DENS*road*(cons+CLAR)] + [DENS*ROAD*AISMg*clar]	1, 0.88
Clean Boats, Clean Waters Participation	[ewm*sanc]*[(ROAD*SIZE)+(road*dens*CONF)] + [EWM*SANC]*[DENS+(ROAD*CONF)] + [SANC*conf*SIZE*DENS]	1, 0.73
Participation in Org ≥ 0.67	[CONS*COMMg]*[(SIZE*ROAD)+(size*road*EWM)] + [CONS*commg*road*EWM]*[SIZE+SANC] + [size*commg]*[(CONS*road*ewm)+(SANC*ROAD)] + [cons*COMMg*SIZE*road]	1, 0.84
Eurasian Watermilfoil Absence	[dens*tp]*[(cond)+(SANC*DEEP)] + [CLAR*tp*DEEP]*[(SANC*AISPg)+(cond)] + [clar*dens]*[(sanc*COND)+(SANC*cond)+(SANC*DEEP)] + [clar*sanc*cond*AISPg] + [clar*DENS*TP*SANC]	1, 0.93
Very High Water Clarity	[DEPTH*SEEP*(ROAD+CLARg)]	1, 0.75
Adult Walleye/acre ≥ 3	[clar*cond*stock]*[dens+SANC] [clar*DEEP*DENS*STOCK]*[COND+SANC] [clar*DEEP*dens*stock]	1, 0.63

LDST	EXCL	SANC	CONF	TLC	CONS	SIZE	DEEP	SEEP	DENS
0	0	1	1	0	1	1	1	1	1
0	0	1	1	1	1	1	0	0	0
0	1	0	0	1	1	1	1	0	0
1	0	0	1	1	1	1	1	0	1
0	0	1	0	0	1	1	1	1	1
0	0	0	0	0	0	0	0	0	1
0	0	0	0	1	0	1	0	0	0
0	1	0	0	1	1	1	1	0	0
0	1	0	0	0	1	0	1	0	0
0	0	1	1	0	1	1	1	1	0
0	0	1	0	1	1	0	0	0	1
0	1	0	0	0	1	1	1	0	0
0	0	0	0	0	0	0	0	0	0
0	0	1	1	1	1	1	0	0	0
1	0	0	1	0	1	1	1	0	0
1	0	1	1	0	1	1	1	0	1
0	0	1	1	0	1	1	0	0	1
0	1	1	1	1	0	0	0	0	1
0	1	1	1	1	0	0	0	0	0
0	0	0	1	0	1	0	0	0	1
0	0	1	1	1	1	1	1	0	0
0	1	1	0	1	0	1	1	1	1
0	0	0	0	0	1	0	0	0	1
0	0	0	1	1	1	1	1	0	0
0	0	1	0	1	0	1	1	0	1
0	1	1	0	1	0	0	1	1	1
0	1	0	0	0	1	0	0	0	0
0	1	0	0	0	1	0	0	1	1
0	0	0	0	0	0	0	0	1	1
1	0	0	1	1	1	0	1	1	0
0	0	0	1	0	0	1	1	1	1
0	0	1	0	0	1	0	0	1	1
1	0	0	0	1	1	1	1	0	1
1	0	0	0	1	1	1	1	0	1
0	1	1	1	1	0	0	1	0	0
0	0	0	0	1	1	0	0	1	0
0	0	1	1	1	1	0	0	0	0
0	0	1	0	1	0	0	1	0	0
0	1	1	1	0	0	0	1	1	1

GRNT	APM	PART	EWM	ABUN	CLAR	CBCW	COND	TP	ROAD
1	1	1	1	1	0	1	0	0	0
1	0	1	0	1	0	1	0	1	0
1	0	1	0	1	0	1	1	0	1
1	0	0	0	1	0	1	1	0	0
1	0	1	0	1	1	1	1	0	1
0	1	0	1	0	0	0	0	1	1
0	0	0	0	1	0	1	1	1	0
1	1	1	0	1	0	1	0	0	1
1	0	1	0	1	0	0	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	0	0	1	0	0	1
1	0	1	0	1	0	1	1	1	1
1	1	0	0	1	0	0	0	0	1
1	0	1	0	0	0	1	0	1	0
1	0	1	0	1	0	1	1	1	0
1	1	1	1	1	0	1	0	1	0
1	1	0	1	0	0	1	0	1	0
1	1	0	0	0	0	0	1	1	1
1	1	0	1	0	0	0	1	1	0
1	1	1	1	0	0	0	0	1	1
1	0	0	0	1	0	0	0	0	1
1	0	1	0	1	1	0	1	0	1
1	0	0	0	0	0	0	1	1	0
1	0	0	0	1	0	1	1	0	0
1	0	0	0	1	1	1	1	0	1
0	0	1	0	0	1	0	0	0	1
1	0	1	0	0	0	0	1	0	1
1	1	0	1	0	0	0	0	1	0
0	0	0	0	1	0	0	0	0	0
1	0	1	0	0	1	0	0	0	1
0	1	1	0	0	1	0	0	0	0
1	0	0	0	0	0	0	0	0	0
1	1	1	1	0	0	0	1	1	0
1	1	1	1	1	0	1	1	0	0
1	1	0	1	0	0	0	1	0	0
1	0	0	0	0	0	1	1	0	1
1	0	1	0	1	0	0	0	1	0
1	0	1	0	0	0	0	1	1	1
0	0	0	0	0	1	0	0	0	1

STOCK	STEWg	AISMg	EDUg	COMMg	AISPg	CLARg	FISHg
0	1	1	1	0	0	0	1
1	1	1	1	0	0	0	0
0	1	0	0	1	1	0	0
1	0	1	1	0	0	1	1
1	0	0	1	0	1	1	0
1	1	1	0	0	0	0	0
0	1	0	1	0	1	0	1
0	0	1	1	1	0	0	0
1	0	1	1	0	0	1	0
0	1	0	0	0	0	0	0
1	1	0	0	0	1	0	0
1	0	1	1	0	0	1	0
0	1	0	0	0	1	0	0
1	1	1	1	0	0	0	0
1	0	0	0	0	1	0	0
1	0	1	0	1	0	1	1
1	0	1	0	1	0	0	0
0	0	1	0	1	0	0	0
0	0	1	0	1	0	0	0
1	0	1	1	1	0	0	0
0	1	1	0	0	0	0	0
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1	1	0	1	1	1	0	0
0	0	0	1	1	1	0	1
0	0	1	1	1	0	0	0
0	1	0	1	0	1	0	0
1	0	1	1	0	0	1	0
0	0	1	1	0	0	0	0
0	1	0	1	1	0	0	0
0	1	0	0	0	0	0	0
0	1	0	0	1	0	1	1
1	0	0	0	1	0	1	1
0	1	1	0	0	0	0	0
0	1	1	0	0	0	0	0
1	0	1	0	1	0	0	0
0	1	1	1	1	0	0	0
1	1	1	1	0	0	0	0
1	1	0	1	0	0	0	0
0	1	0	1	1	0	0	0

LDST	EXCL	SANC	CONF	TLC	CONS	SIZE	DEEP	SEEP	DENS
0	0	1	1	0	1	0	0	1	1
0	0	1	1	1	1	0	0	0	0
0	1	0	0	1	1	1	1	0	0
1	0	0	1	1	1	1	1	0	1
0	0	1	0	0	1	1	1	1	1
0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	0	1	0	0	0
0	1	0	0	1	1	1	1	0	0
0	1	0	0	0	1	0	0	0	0
0	0	1	1	0	1	0	1	1	0
0	0	1	0	1	1	0	0	0	1
0	1	0	0	0	1	1	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	1	1	1	1	0	0	0	0
1	0	0	1	0	1	0	0	0	0
1	0	1	1	0	1	1	1	0	1
0	0	1	1	0	1	1	0	0	1
0	1	1	1	1	0	0	0	0	1
0	1	1	1	1	0	0	0	0	0
0	0	0	1	0	1	0	0	0	1
0	0	1	1	1	1	1	1	0	0
0	1	1	0	1	0	0	1	1	1
0	0	0	0	0	1	0	0	0	1
0	0	0	1	1	1	1	1	0	0
0	0	1	0	1	0	1	1	0	0
0	1	1	0	1	0	0	1	1	0
0	1	0	0	0	1	0	0	0	0
0	1	0	0	0	1	0	0	1	1
0	0	0	0	0	0	0	0	1	0
1	0	0	1	1	1	0	0	1	0
0	0	0	1	0	0	1	1	1	1
0	0	1	0	0	1	0	0	1	1
1	0	0	0	1	1	1	1	0	1
1	0	0	0	1	1	1	1	0	1
0	1	1	1	1	0	0	0	0	0
0	0	0	0	1	1	0	0	1	0
0	0	1	1	1	1	0	0	0	0
0	0	1	0	1	0	0	1	0	0
0	1	1	1	0	0	0	1	1	1

GRNT	APM	PART	EWM	ABUN	CLAR	CBCW	COND	TP	ROAD
1	1	1	1	1	0	1	0	0	0
1	0	1	0	1	0	1	0	0	0
1	0	1	0	1	0	1	1	0	1
1	0	0	0	1	0	1	1	0	0
1	0	1	0	0	1	1	1	0	1
0	1	0	1	0	0	0	0	1	1
0	0	0	0	1	0	0	0	1	0
1	1	1	0	1	0	1	0	0	1
1	0	0	0	0	0	0	1	0	1
1	1	1	1	1	1	1	0	1	1
1	1	1	1	0	0	1	0	0	1
1	0	0	0	0	0	1	1	1	1
1	1	0	0	1	0	0	0	0	1
1	0	1	0	0	0	1	0	1	0
1	0	1	0	1	0	1	1	1	0
1	1	1	1	1	0	1	0	0	0
1	1	0	1	0	0	1	0	0	0
1	1	0	0	0	0	0	1	1	1
1	1	0	1	0	0	0	1	1	0
1	1	1	1	0	0	0	0	1	0
1	0	0	0	1	0	0	0	0	1
1	0	1	0	1	1	0	1	0	1
1	0	0	0	0	0	0	0	1	0
1	0	0	0	1	0	1	1	0	0
1	0	0	0	0	1	0	1	0	1
0	0	1	0	0	1	0	0	0	1
1	0	0	0	0	0	0	1	0	1
1	1	0	1	0	0	0	0	0	0
0	0	0	0	1	0	0	0	0	0
1	0	1	0	0	1	0	0	0	1
0	1	1	0	0	1	0	0	0	0
1	0	0	0	0	0	0	0	0	0
1	1	1	1	0	0	0	1	1	0
1	1	1	1	1	0	1	1	0	0
1	1	0	1	0	0	0	1	0	0
1	0	0	0	0	0	0	1	0	1
1	0	1	0	1	0	0	0	0	0
1	0	1	0	0	0	0	1	1	1
0	0	0	0	0	1	0	0	0	1

STOCK	STEWg	AISMg	EDUg	COMMg	AISPg	CLARg	FISHg
0	1	1	1	0	0	0	1
1	1	1	1	0	0	0	0
0	1	0	0	1	1	0	0
1	0	1	1	0	0	1	1
1	0	0	1	0	1	1	0
1	1	1	0	0	0	0	0
0	1	0	1	0	1	0	1
0	0	1	1	1	0	0	0
1	0	1	1	0	0	1	0
0	1	0	0	0	0	0	0
1	1	0	0	0	1	0	0
1	0	1	1	0	0	1	0
0	1	0	0	0	1	0	0
1	1	1	1	0	0	0	0
1	0	0	0	0	1	0	0
1	0	1	0	1	0	1	1
1	0	1	0	1	0	0	0
0	0	1	0	1	0	0	0
0	0	1	0	1	0	0	0
1	0	1	1	1	0	0	0
0	1	1	0	0	0	0	0
1	1	0	1	0	1	0	0
1	1	0	1	1	1	0	0
0	0	0	1	1	1	0	1
0	0	1	1	1	0	0	0
0	1	0	1	0	1	0	0
1	0	1	1	0	0	1	0
0	0	1	1	0	0	0	0
0	1	0	1	1	0	0	0
0	1	0	0	0	0	0	0
0	1	0	0	1	0	1	1
1	0	0	0	1	0	1	1
0	1	1	0	0	0	0	0
0	1	1	0	0	0	0	0
1	0	1	0	1	0	0	0
0	1	1	1	1	0	0	0
1	1	1	1	0	0	0	0
1	1	0	1	0	0	0	0
0	1	0	1	1	0	0	0