Social-Ecological Institutional Fit in Volunteer-Based Organizations: A Study of Lake Management Organizations in Vilas County, Wisconsin, U.S.A.

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RESEARCH ARTICLE

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DANE WHITTAKER
ALISE CRIPPEN
CORINNE JOHNSON
MARCO A. JANSSEN

Author affiliations can be found in the back matter of this article

ABSTRACT

How do the social and ecological attributes of social-ecological systems enable outcomes of those systems? The high concentration of lake organizations in northern USA enables us to study social, institutional, and ecological attributes that correlate with performance of common pool resource governance—institutional fit. In the summer of 2019, we performed an in-depth comparative study of thirty-one lake organizations in Vilas County, Wisconsin using data collected through semi-structured interviews, websites, and agency databases. 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 systems. The Ostrom institutional design principles played an important role in SES governance outcomes where there was low-resource dependence. We found that different combinations of design principles, social, and ecological conditions led to the same lake SES outcomes—equifinality. Although we expected that there were no panaceas for lake governance, we were surprised by the high diversity in organizational goals and the relative low diversity of rules in use.

CORRESPONDING AUTHOR:
Dane Whittaker
School of Sustainability, Arizona State University, USA
d.whittaker@asu.edu

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INTRODUCTION

Environmental governance regimes often ignore the institutional, social, and ecological conditions known to be pivotal to social-ecological system (SES) sustainability (Leslie et al., 2015). Ostrom observed an overuse of one-size-fits-all SES governance solutions, and called for the study of the institutional, social, and ecological conditions of systems to understand what works contextually and move beyond panaceas (Ostrom, 2007). She argued the goal of sustainability science research is to understand the combinations of conditions that more often lead to sustainable outcomes overcoming collective action dilemmas and preventing disastrous results (Ostrom, 2007). In this study, we contribute to these sustainability science goals by showing how combinations of institutional, social, and ecological conditions, or institutional fit, are key to understanding sustainable outcomes and that there are multiple pathways to those outcomes.

Institutional fit is conditions' congruence with the rules and norms governing a system. There are three types of institutional fit—ecological, social, and social-ecological (Epstein et al., 2015). Ecological fit is evaluated by asking whether the rules and norms effectively address the biophysical challenges. Social fit occurs when the rules and norms align with the preferences, values, and needs of the people involved. Social-ecological fit combines these two to ask which institutions are likely to lead to sustainable social-ecological systems (Epstein et al., 2015). In other words, social-ecological fit is the combinations of institutions, social, and ecological conditions that lead to success in a social-ecological system. Assessments made solely on ecological or social data may lead to divergent conclusions (Leslie et al., 2015; Barnett et al., 2020).

SES fit is used to help understand the conditions in which an institution leads to greater SES sustainability. To do this, a measure or measures of success and the conditions that contribute to that success must be defined (Epstein et al., 2015). The challenges of SES fit include how the system and success are defined, the conditions that are included or not, and success defined based on one set of criteria (Epstein et al., 2015). Most studies rely on the researcher to define success and only use one measure of success, missing the multiple uses that emerge in SESs and differing drivers of outcomes or dimensions of success (Agrawal & Benson, 2011; Epstein et al., 2015; Barnett et al., 2020). In our study we compare the conditions that lead to various outcomes as defined by the people who are part of the SES.

Large-n comparisons and meta-analyses are needed to understand how institutions influence SES outcomes (Barnett et al., 2020; Cumming et al., 2020). These studies help to identify trends in the conditions and institutional arrangements that lead to SES sustainability, or SES fit. In large-n secondary case comparative studies, there are three types of bias that are common: investigator bias introduced by missing conditions, procedural bias stemming from coding errors, and substantive bias from the way individual conditions are weighted and alternative explanations (Barnett et al., 2016). Conducting standardized fieldwork is an approach for generating complete, consistent, comparable data to advance our understanding of common pool resource governance and overcome data comparability challenges (Barnett et al., 2016; Barnett et al., 2020). We compare organizations—using crisp-set qualitative comparative analysis as recommended by Epstein et al (2015)—that manage the same resource type but operate with different goals in different conditions. We integrate qualitative and quantitative datasets (Leslie et al., 2015) and explore different outcomes (Agrawal & Benson, 2011) to understand SES fit.

Traditional commons research focuses on social-ecological systems where the resource users are reliant on the resource for their livelihoods. These user groups 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). Through a large-n secondary case comparison, Ostrom and her colleagues identified eight institutional design principles (IDPs) that are associated with the persistence of community-based resource management (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. Follow up studies support the IDPs role in SES sustainability (Agrawal & Chhatre, 2006; Baggio et al., 2016; Cox et al., 2010; Shin et al., 2020); however, additional, rigorous studies of the institutional design principles are needed to understand their validity and generalizability (Araral, 2014). Our study confirms that the design principles play a greater role in some SES outcomes than others, explores their impact on SES outcomes for volunteer-based organizations without high resource dependence, and addresses data completeness and consistency concerns through primary data collection.

We explore SES fit and the validity and generalizability of the institutional design principles by comparing thirty-one Vilas County, Wisconsin, USA volunteer-based lake organizations using data collected through semi-structured interviews, websites, and agency databases. Vilas County is home to more than 1,300 lakes and 115 lake organizations providing an opportunity to compare conditions and outcomes across a landscape of lake SESs (Stedman, 2006). In this study, we explore how the combinations of ecological, 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. Few studies collect primary data about the institutional design principles (Agrawal & Chhatre, 2006; Shin et al., 2020).

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

METHODS & DATA

We conducted semi-structured interviews during the summer of 2019 to collect data about thirty-one lake organizations that conserve thirty-nine lakes in Vilas County, Wisconsin, USA. We integrated primary qualitative data with with secondary quantitative data derived from multiple sources. These sources included the Wisconsin Department of Natural Resources (WI DNR), University of Wisconsin Extension lakes program (UW-Ext), 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 assess SES institutional fit.

CASE SELECTION

The lakes and organizations in this study are in Vilas County, Wisconsin, USA (***Figure 1***). Vilas County is in the Northern Highland Lakes District, which is characterized by a patchwork of lakes and wetlands. Vilas County is home to more lakes than any other county in Wisconsin. It has 1,320 of Wisconsin's 15,000 lakes (Gabriel & Lancaster, 2004; Wisconsin Lakes Partnership, 2018), and there are 115 lake conservation organizations in Vilas County. Additionally, there is extensive existing data about both the social and ecological conditions in Vilas County and the Northern Highland Lakes District as they have been studied for decades by the WI DNR, UW-Ext, USGS, NTL LTER, and Jones Lab. The number of Vilas County lake SESs with available data afforded us a set of comparable cases with a variety of institutional arrangements, social and ecological conditions, and outcomes.

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 (Gabriel & Lancaster, 2004). A lake district is a 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, and may own public infrastructure or expensive equipment (Gabriel & Lancaster, 2004). Collective action problems are common in lake organizations since a small number of highly committed individuals do most of the work. 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).

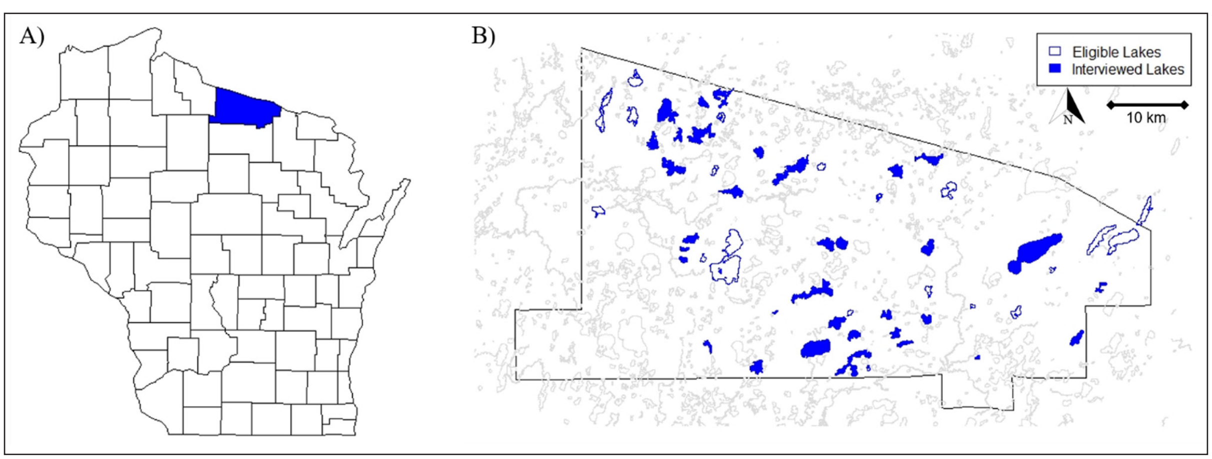

Figure 1 Our sample lakes in Vilas County, Wisconsin. **A)** Vilas County is in the Northern part of Wisconsin on the border of Michigan. **B)** The sixty-two Vilas County lakes outlined in blue were eligible for our study. The lakes filled in blue are the thirty-nine lakes managed by the thirty-one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

Vilas County lake organizations were eligible for our study (***Figure 1B***) if they fit 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 the negative effects of over exploitation. Second, we included lakes with lake organizations that manage three or fewer lakes to select organizations managing similar SESs. Finally, we selected lakes that are managed by the WI DNR for their data availability. After applying these filter criteria, there were fifty-two eligible volunteer-based lake organizations that manage sixty-two lakes.

PRIMARY DATA COLLECTION

We interviewed thirty-one of the fifty-two eligible organizations; the organizations manage a total of thirty-nine lakes. 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 group interviews lasted one to two hours and were conducted in community centers, homes, and once on a boat.

We used a semi-structured interview methodology. Each participant filled out a questionnaire about changes to the lake (Appendix 1), and then the group was asked a series of questions about their use of the IDPs (Appendix 2). The questions asked were consistent, but their order and wording varied slightly following the flow of the conversation. 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 were procedural, stemming from unclear definitions (Barnett et al., 2016). We refined the definitions for more consistency during the first week.

SOCIAL-ECOLOGICAL OUTCOMES

As noted by Agrawal and Benson (2011), people living around the lakes have different uses and desired outcomes for the SES. As a result, lake organizations have a range of social and ecological goals. ***Figure 2*** shows the goals stated during interviews by the lake organization leaders. We used constant comparison, a method whereby each statement

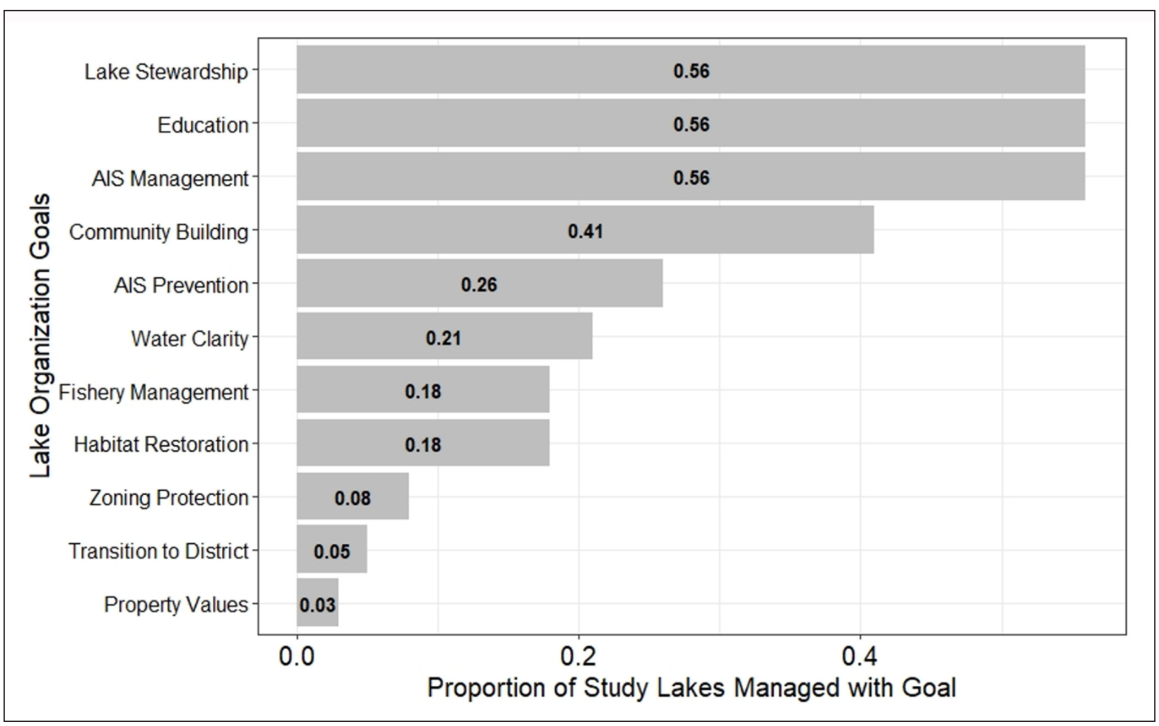

Figure 2 The eleven stated lake organization goals and the proportion of the thirty-nine lakes managed with each goal. Source: 2019 Interview Dataset.

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 leaders' responses.

Of the eleven goals, lake stewardship, education, and aquatic invasive species management were most common; organizations stated these goals for 56% of the thirty-nine studied lakes. The next three goals, stated for 20% or more of the lakes, were 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 of lake organizations in Wisconsin.

In ***Table 1***, we map the goals to measurable 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 stated to reach a particular lake SES outcome. We used data available via the WI DNR, UW-Extension Lakes Program, and our 2019 Interview Dataset in this step, and mapped the seven most common of the eleven goals to outcomes in ***Table 1*** (See Appendix 4 for details). Habitat restoration, zoning protection, transition to a lake district, and property value goals are not included in this study.

The outcomes in ***Table 1*** are used in our analysis of the ecological, social, and institutional conditions that lead to lake SES outcomes. We use user-defined goals, but our choice of outcome measures is constrained by data availability, as observed by Barnett et al (2020). 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 ecological, social, and institutional conditions listed in ***Table 2*** are the product of a three-step selection process. First, we included the IDPs (Ostrom, 1990). Second, there were conditions that the lake organization leaders described in the interviews, like Eurasian water milfoil and participation in the organization. Finally, we sought input from a group of freshwater ecologists and a WI DNR fish biologist for technical conditions like conductance and total phosphorous. Through an iterative process of analyzing different outcomes in dialogue with our cases and the experts, we identified the variables in ***Table 2*** as most useful to understand our outcomes.

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 ecological, social, and institutional conditions we used are categorical. For the remaining seven conditions, we evaluated the distribution (see Appendix 5 for details). We used the median to convert them into dichotomous variables, which is essential for the analysis method we used, crisp-set qualitative comparative analysis. 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. QCA is well-suited for evaluating conditions that lead to success in SESs (Baggio et al., 2016; Epstein et al., 2015). It is a mid-sized-n comparative method that uncovers the

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 DNR
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

Table 1 The mapped outcomes and dichotomization of seven of the goals mentioned by lake organizations during the 2019 interviews. Appendix 5 shows the distribution of continuous variables.

CONDITION	PRESENT (1)	ABSENT (0)	SOURCE
Ecological			
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 (µS/cm)	≥69	<69	NTL LTER
Total Phosphorous (µg/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

Table 2 The dichotomized ecological, social, and institutional conditions and their data sources. The dichotomization of continuous variables uses the median value. See Appendix 5 for plots.

combinations of conditions that lead to SES outcomes. 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 & Ragin, 2009).

There are three types of QCA analyses: crisp set, fuzzy set, and multi-variate (Rihoux & Ragin, 2009). Crisp set QCA (csQCA), the method we employ, uses dichotomized variables. All continuous and categorical variables are coded as present or absent. Based on our sensitivity analysis (Appendix 8), 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.

Following the standards in the csQCA methodology, we conducted a two-step analysis using the fsQCA 3.0 software developed by Ragin and Davey. First, we identified the necessary conditions for each outcome. A necessary condition is always present when the outcome occurs (Cebotari & Vink, 2013; Rihoux & Ragin, 2009). 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 and Vink, 2013). Second, we identified sufficient conditions. We used the default values in our sufficiency analysis where combinations with a consistency score equal to or greater than 0.80 are kept (Rihoux & Ragin, 2009). fsQCA 3.0 uses the Quine-McCluskey algorithm to simplify combinations of sufficient conditions (McCluskey, 1956).

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

RESULTS

We evaluated the necessity of the causal conditions (***Table 2***) for the seven outcomes (***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.

Lake depth (DEEP) is necessary for very high water clarity. Johnston and Shmagin found lake depth is the single best predictor of water clarity (Johnston & Shmagin, 2006). Lake depth is tied to phosphorous cycling in the lakes and groundwater fluxes (Johnston & Shmagin, 2006). 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 ecological, social, and institutional conditions that lead to the seven lake SES outcomes (***Table 4***). In this analysis,

OUTCOME	NECESSARY CONDITIONS[1]	CONSISTENCY	COVERAGE
Very high water clarity	DEEP	1.00	0.36

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.

[1] For abbreviations see Appendix 6.

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

Table 4 The combinations of ecological, social, and institutional 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.

[1] For abbreviations see Appendix 6.

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, showing contextual variables play an important role or the theory of institutional fit.

For each of the outcomes, there are multiple combinations of factors that lead to success. 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 SES outcome. The coverage ranges from 0.72 to 0.97; 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 8).

Outcomes can also be conditions in lake SESs. Very high water clarity is an outcome that lake organizations care about, and it is also a condition that explains 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 from visiting boats. 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 out-competes other aquatic plants (Smith & Barko, 1990), 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-affected 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-affected 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 (UW-Extension Lakes, n.d.). Three combinations explain 72% of the cases where lake organizations participated in CBCW during the summer of 2019. The first combination includes lake organizations that employ graduated sanctions (SANC) to manage lakes with EWM (EWM) and 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 also employ graduated sanctions (SANC), but do not have Eurasian Watermilfoil (ewm). These lakes are large (SIZE) and have a low building density (dens). CBCW is a volunteer-based program; lakes with graduated sanctions have stronger rule enforcement and perhaps less free-riding. 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 developed institutions to address rule breaking and conflict. 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, ≥ 65%, is explained by four combinations of conditions. These pathways explain 86% of the cases where organization participation is high. The first pathway includes 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 (SIZE), accessible (road) 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 the outcome in 96% of the cases. 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 et al., 1990). Additionally, some of these lakes are deep (DEEP), which inhibits EWM growth for the same reason. The next combination is shallow (deep) 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 resulting in less vegetative growth. 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 rule enforcement may prevent EWM. The fourth and final combination of conditions for lakes 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 (Johnston & Shmagin, 2006), 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 a 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. 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 rules, like harvest limits, are enforced. The lakes with more adult walleye per acre tend to be environmentally favorable and either less developed or with graduated sanctions in place.

Comparing the combinations of conditions that lead to each SES outcome (***Table 5***), we found that the institutional design principles were important to explaining success. In only one outcome, receiving a lake management grant, did we see only IDPs explaining success. For the other six out comes, the social and ecological conditions contributed to success. Four of the outcomes relied on both social and ecological conditions and two of the outcomes were ecologically determined. These results contribute to the validity of the institutional design principles, show their generalizability to low resource dependent SESs, and support the research on SES fit.

DISCUSSION

Considering the institutional approaches that lake organizations take to overcome the collective action dilemmas they experience, our mid-sized-n comparison of lake SESs confirmed that institutional design principles play a role in the outcomes for volunteer-based organizations. Our study advances the understanding of the institutional design principles because we show the IDPs also apply to SES sustainability where resource dependence is low. In ***Table 6***, we summarize the institutional approaches taken by lake organizations to overcome different collective action dilemmas. While there is some overlap, the approach taken to overcome collective action dilemmas varies based on the outcome. csQCA was a useful method for understanding institutional fit by identifying the combinations of ecological, social, and institutional conditions that lead to various SES outcomes. We uncovered multiple combinations that lead to the outcomes, reinforcing the risk of panaceas and the value of institutional fit.

While all of the institutional design principles (IDPs) were important to explain the seven user-defined SES outcomes we investigated. Graduated sanctions, conflict resolution, and nested enterprises—in the form of town lakes committees and consultants—were the design principles that played a deciding role for success in the lake SESs we studied (***Table 6***). For example, the organizations which participate in the Clean Boats, Clean Waters monitoring and education program also employed graduated sanctions and low-cost conflict mechanisms such as annual meetings. For grant applications, which require specialized skills, lake organizations ask consultants and town lakes committees for help—nested enterprises. We also see that the ecological context plays a pivotal role in some of these outcomes, like walleye populations. Araral (2014) calls for more research to confirm the generalizability and validity of the design principles, we contribute to the growing number of meta-analyses that show their validity (Agrawal & Chhatre, 2006; Baggio et al., 2016; Cox et al., 2010; Shin et al., 2020). Additionally, we tested whether the institutional design principles, emerging from community-based resource management groups who have high-dependency on the resource for their livelihood (Ostrom, 1990), apply to volunteer-based organizations with low resource dependency. In the thirty-one lake SESs we studied, they do.

Asking the lake organization leaders how they define success exposed a greater variety of desired SES outcomes than we anticipated. Most studies of the commons have not considered the multiple outcomes that emerge in renewable resource management (Agrawal & Benson, 2011; Barnett et al., 2020). The Wisconsin lake SESs we studied which have multiple uses like boating, fishing, swimming, and biodiversity conservation. Because most studies only consider one measure of success, their SES outcomes may not be considered successful if a different set of evaluation criteria were used (Epstein et al., 2015). We found that the conditions that lead to success differed based on the outcome and that, like Baggio et al (2016) there were multiple configurations leading to success—equifinality.

SES OUTCOME	INSTITUTIONAL	SOCIAL	ECOLOGICAL
Clean Boats, Clean Waters Participation	Yes	Yes	Yes
AIS Treatment Grant Received	Yes	Yes	Yes
Eurasian Watermilfoil Absence	Yes	Yes	Yes
Adult Walleye/acre ≥ 1.42	Yes	Yes	Yes
Participation in Org ≥ 0.65	Yes		Yes
Very High Water Clarity	Yes		Yes
Lake Management Grant Received	Yes		

Table 5 The Institutional Design Principles helped explain all seven SES outcomes. Four of the outcomes included social and ecological conditions to fit the institutions, two only ecological conditions, and one outcome was not context dependent.

OUTCOME	COLLECTIVE ACTION DILEMMA	INSTITUTIONAL APPROACH	ECOLOGICAL CONTEXT
Lake Management Grant Received	Filling out grant paperwork takes considerable skill and time.	Organization hires a consultant or partnering with a network of peers (town lakes committee).	All lake types.
AIS Treatment Grant Received	Filling out grant paperwork takes considerable skill and time. Need must be established to receive grant, organizations can't pre-emptively apply.	Organization sets an AIS management goal creating focus or hires a consultant to help.	Lakes with aquatic invasive species, specifically eurasian water milfoil.
Clean Boats, Clean Waters Participation	Everyone benefits from volunteers monitoring the boat ramp. Lake residents don't want to be perceived as police by their neighbors.	Monitoring is carried out by volunteers in organizations that use graduated sanctions and have enacted low-cost conflict resolution mechanisms.	Large lakes with high building density, and they may have or not have aquatic invasive species present.
Participation in Org	Lake users can benefit from the management activities of the organization without participating.	Organization hires a consultant to create a lake management plan involving lake users or sets a participation goal to overcome free-riding.	A mix of large and small lakes as well as lakes that are either near or far from a road.
Eurasian Water Milfoil Absence	One person failing to clean their boat and trailer, can introduce an AIS that impacts the entire lake.	Organizations employ graduated sanctions.	Deep, low clarity lakes with lower nutrient and conductance are less favorable to EWM growth.
Very High Water Clarity	Water clarity is largely biophysically determined.	Some lake organizations set water clarity goals.	Deep, seepage or spring-fed lakes.
Adult Walleye/Acre	Individual behaviors like overharvesting and shoreline development on personal property impact walleye populations for the whole lake.	Organizations use graduated sanctions and, for a few of the lakes, directly provision fish via stocking.	Deep, nutrient rich lakes some of which have low building density.

Table 6 The collective action dilemmas faced by lake organizations, common institutional approaches for addressing the dilemmas, and the ecological context in which these approaches were applied.

We studied lakes with lake organizations in a small county with hundreds of lakes. The role of lake organizations in monitoring and sanctioning and the support from local, nested enterprises were important to the SES outcomes. It is unlikely that lakes without lake organizations would use the same approaches to overcoming the collective action dilemmas listed in ***Table 6*** and lakes located in counties with few lakes may not have the support network needed to achieve success in the same way. Future research should consider how polycentric governance can support local conservation groups in achieving sustainable outcomes.

SES fit was critical to explaining four of the seven outcomes we studied. Without including both the social and ecological conditions in which the institutions were set, we would not have been able to explain the outcomes. For two outcomes, only ecological fit was needed and for receiving a grant the rules were enough. Epstein et al.'s SES approach to institutional fit, though more intensive to study, provides a better understanding of a system. Our results show that context is critical to the outcomes of the system, and that context differs depending on the collective action dilemma and desired outcome. Vilas County, like other lake regions, is experiencing changing conditions like demographic changes, precipitation changes, warming water temperatures, and the introduction of new species. As the conditions evolve, the governance of lakes will need to evolve as well. Our conversations with lake organizations indicated that they are aware of the coming challenges, but future studies should look to how the governance of lakes adapts to changing conditions and how the user-defined goals for the lakes may change.

Qualitative comparative analysis is a well-suited method for evaluating conditions that lead to success in SESs (Epstein et al., 2015), and thus evaluating SES fit. QCA is a useful method for conducting structured comparison of similar cases to understand the components of the cases that lead to different outcomes (Ragin, 1987).

QCA considers combinations of conditions and allows for equifinality, which is consistent with the concept of institutional fit where the context is critical to the outcome.

Primary data collection through semi-structured interviews helped gather comparable, consistent data, whose availability can stymie secondary data analysis (Araral, 2014; Barnett et al., 2016). We also used selection criteria for lakes in the county that provided a mix of successful and not successful cases when measured by the different outcomes. We compared SESs dominated by the same resource—lakes—in close proximity to each other, and thus used more granular and specific variables than may be used to compare across regions or resource types. Consistent with Dressel et al's study (2018), our regional comparison exposed social and ecological challenges to fit that would not have been visible at a coarser resolution. A synthetic approach, like that employed by Leslie et al (2015) and recommended by Barnett et al (2020), to integrate quantitative social and ecological data to qualitative outcome and institutional data is useful when evaluating SES fit and IDP validity and would serve future researchers well.

CONCLUSION

Institutions are critical to the sustainability of natural resource systems, facilitating cooperation and helping the systems adapt to change (Cumming et al., 2020). We have learned that these systems are not social or ecological, but integrated social-ecological systems (Liu et al., 2007; Ostrom, 2007). To understand what leads to sustainable social-ecological systems, we must consider the institutional, social, and ecological conditions that help overcome collective action dilemmas and lead to various outcomes (Dressel et al., 2018; Epstein et al., 2015; Leslie et al., 2015; Ostrom, 2007). We found that not only must the social-ecological fit be considered, but that multiple pathways may lead to the same outcome and important contextual variables vary based on the outcome. As we learn more about the institutions that lead to SES sustainability, we must be careful to consider the conditions in which those institutions are successful.

ADDITIONAL FILES

The additional files for this article can be found as follows:

- **Appendices 1–8.** Appendices 1–8 include data collection instruments, code definitions, abbreviations, QCA models, and sensitivity analysis. DOI: *https://doi.org/10.5334/ijc.1059.s1*
- **Median Truth Table.** csQCA truth table using the median values. DOI: *https://doi.org/10.5334/ijc.1059.s2*
- **Mean Truth Table.** csQCA truth table using the mean values. DOI: *https://doi.org/10.5334/ijc.1059.s3*

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COMPETING INTERESTS

The authors have no competing interests to declare.

AUTHOR AFFILIATIONS

Dane Whittaker *orcid.org/0000-0001-9475-648X*
School of Sustainability, Arizona State University, USA
Alise Crippen *orcid.org/0000-0001-7944-1551*
School of Sustainability, Arizona State University, USA
Corinne Johnson *orcid.org/0000-0002-2255-5678*
School of Sustainability, Arizona State University, USA
Marco A. Janssen *orcid.org/0000-0002-1240-9052*
School of Sustainability, Arizona State University, USA

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