Towards Evidence-Based Management: Integrating Institutional Analysis and Machine Learning for Enhanced Recreational Fisheries Monitoring and Decision-Making

by

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Abstract

This thesis consists of two separate studies, the first investigates the institutional framework and challenges in managing public recreational fisheries. It contrasts the existing system with an idealized agency structure model, highlighting deficiencies in monitoring, decision-making, and accountability. Semi-structured interviews inform the analysis, revealing a disconnect between monitoring practices and actionable triggers, leading to instability in decision-making. Inconsistent information flow and limited public involvement exacerbate accountability issues. The study proposes a framework rooted in evidence-based management, featuring clear objectives, triggers, and bidirectional information flow. The second study employs machine learning techniques to identify key variables influencing angler presence, revealing reservoir area as the most influential factor. Despite greater access to information and shifting social norms, recreational anglers have maintained their historical habits and current creel survey designs capture this. These insights contribute to understanding angler behaviour and emphasize the importance of evidence-based management in fisheries monitoring and decision-making processes.

Keywords: Recreational fisheries management; Decision-making; Evidence-based management; Machine Learning; Management structure; Creel surveys

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Chapter 1.

Background

Recreational fishing is the act of fishing for leisure, sport, or relaxation rather than for commercial purposes (FAO, 2012). Participants, commonly known as anglers, engage in recreational fishing for various reasons, including enjoyment of nature, social bonding, and the challenge of catching fish (Arlinghaus, 2006; Arlinghaus et al., 2017; Solomon et al., 2020). Recreational fishing contributes to economies through expenditures on fishing equipment, travel, accommodation, and related services (Arlinghaus et al., 2002; Hughes, 2014) as well as providing social benefits to individuals and communities (van Poorten et al., 2011; Arlinghaus et al., 2019; Brownscombe et al., 2019). Fisheries in North America are public resources that state, provincial, and federal governments manage in trust for the public (Nielsen, 1999). Therefore, managers' policy options may be limited by social norms that dictate acceptable behaviour (Solomon et al., 2020). Management often aims to maintain healthy fish populations and ecosystems while maximizing the social benefit to user groups (Beardmore et al., 2015). Recreational fisheries management involves various activities, including setting fishing regulations, monitoring fish populations, assessing habitat health, researching angler behaviour, and engaging stakeholders in decision-making processes (Cooke et al., 2013; Kvamsdal et al., 2016; Arostegui et al., 2021). Decisions regarding actions to be taken in recreational fisheries must consider social, ecological, legal, and political factors due to their complex and interdependent nature (Camp et al., 2020).

Recreational fishing is a complex social-ecological system that involves human communities, social structures, and the natural environment (Carruthers et al., 2019). These systems are often spread over very large areas, with many small waterbodies embedded in a landscape, making effective monitoring and managing difficult (Post et al., 2002). All social-ecological systems have sources of adaptive capacity and resilience that can maintain ecosystem services and human well-being through active ecosystem stewardship, even though they are vulnerable to changes (Chapin et al., 2010). Recognizing the complexity of social-ecological systems enables us to view individual recreational fisheries as part of a larger interconnected system. This approach helps to prevent management decisions that focus solely on individual fisheries and ignore their impact on the wider social-ecological system (Hunt et al., 2013; Pope et al., 2014; Arlinghaus et al., 2017).

The complexity of the social-ecological system inherently increases the complexity of management and decision-making. Globally, recreational fisheries governance is generally considered to be poorly managed in most countries (Potts et al., 2020). Primary obstacles include irregular monitoring of fish populations, unregulated fishing activities, and the heightened risk of overexploiting popular fisheries (Arlinghaus, 2005). Moreover, the intricate feedback mechanisms and diverse behaviours of anglers and fish populations introduce uncertainty into dynamics, posing significant challenges to conservation efforts (Kaemingk et al., 2021). To address these challenges, decision-makers in recreational fisheries must allocate resources towards comprehensive monitoring of all fishery aspects, encompassing both fishery-independent and -dependent data.

Fishery-independent data provides information on fish abundance, distribution, size, and age structure gathered through standardized procedures that are independent of fishing activities (National Research Council, 2006; Pennino et al., 2016). The ability of fishery-independent surveys to inform stock assessments and management decisions depends on their consistency over time and space (Vecchio et al., 2023). Long-term data collected using standardized methods is the best way to assess fish population dynamics. However, obtaining such data is rare and expensive (Pope et al., 2010). Alternatively, fishery-dependent surveys collect information on fishery metrics, including exploitation rate, effort, and harvest (Deroba et al., 2007; Mosel et al., 2015; Pope et al., 2017), and can sometimes additionally gather essential data on angler behaviour and satisfaction (Neiman et al., 2021). Creel surveys, or angler-harvest surveys, are an extremely common example of a fishery-dependent survey within recreational fisheries. These surveys involve direct communication with anglers and are often unique in space and time, not necessarily related to fishing pressure or fish abundance (Lynch et al., 2021).

Results from these surveys are often used to inform decision-making; however, this is not always the case (Cook et al., 2010). Managers often encounter problems with insufficient, excessively complicated, or inconsistent information, resulting in management plans that may be justified based on the manager's personal experience, anecdotal evidence, and conventional wisdom, rather than the most reliable evidence available (Pullin and Knight 2004; Cook et al. 2010; Dicks et al., 2014). Inefficient or ineffective collection of information, as well as inefficient management structures, can exacerbate the challenges faced by decision-makers in recreational fisheries management (Sutherland, 2022). Without accurate and timely data, managers may struggle to understand the status of fish populations, assess the impacts of fishing activities, and develop appropriate management strategies (Tallis et al., 2010; Friedlander et al., 2015). This can lead to suboptimal or even detrimental decisions, such as setting inappropriate catch limits, failing to address overexploitation, or neglecting the needs of stakeholders (Post et al., 2002; Arlinghaus, 2005; Lockwood et al., 2010). Presenting evidence to support management decisions can prevent ineffective strategies and minimize conflicts among stakeholders (Elmer et al., 2017). Therefore, it is essential to invest in efficient data collection methods and streamline management structures to enhance the effectiveness of recreational fisheries management.

The first study will examine the management structure of a typical fisheries jurisdiction. This analysis will include an evaluation of its organizational framework, decision-making processes, stakeholder engagement mechanisms, and resource allocation strategies. By identifying the strengths and weaknesses of the management structure, the research aims to identify areas for improvement to enhance the effectiveness and efficiency of recreational fisheries management. The second study explores a specific aspect of fisheries data collection, with a focus on the assessment of fishing effort. This will involve evaluating existing data on fishing effort, collected during creel surveys. This analysis aims to identify ways to improve the allocation of limited resources for surveys to increase their accuracy and efficiency. I provide valuable insights into the management structure of recreational fisheries jurisdictions and the optimization of data collection processes, which will ultimately help in making better-informed decisions in the field of sustainable recreational fisheries management.

Chapter 2.

Navigating Challenges in Recreational Fisheries Management: Insights from a Nebraska Case Study

2.1. Abstract

This study examines the institutional framework and challenges in the management of public recreational fisheries, using the Nebraska Game and Parks Commission in Nebraska, USA, as a case study. It seeks to identify institutional constraints and deficiencies within the existing system by contrasting a natural resource agency with an idealized agency structure model. We present an idealized management structure as one where the management process, consisting of objectives, triggers, and monitoring, supports the decision-making structure, which includes information flow and accountability. Semi-structured interviews were conducted with key individuals involved in recreational fisheries management and monitoring. An inductive approach was employed, identifying codes and themes based on interviews with individuals within the management agency. The case study revealed a scenario where monitoring is frequent but not supported by clear triggers for action or measurable objectives, resulting in an unstable foundation for the decision-making structure. Additionally, inconsistent information dissemination within this structure and insufficient public involvement contribute to accountability issues in decision-making. We found a misalignment between the actual management system and the expectations of an ideal natural resource agency structure, which should be rooted in evidence-based management, featuring well-defined objectives, triggers, and ongoing monitoring. We encourage further investigations to assess the prevalence of these challenges and gather best practices. Our proposed framework and management structure could allow agencies to make defensible management decisions by utilizing existing monitoring data effectively while leveraging internal and public input. Information should flow bidirectionally through the agency hierarchy to enable all levels to comprehend the basis of management decisions. Transitioning to evidence-based management, promoting information flow, and engaging agency members and external stakeholders can help agencies move toward more effective and collaborative resource management strategies.

2.2. Introduction

Managing recreational fisheries is complicated and requires a comprehensive approach from data collection to management decisions. Recreational fisheries have many constituent parts, including ecological and social dynamics and their interactions, making them a classic example of social-ecological systems (Arlinghaus et al., 2013). As the resource is often publicly owned and managed (especially in North America), governance of recreational fisheries can shift with changes in public desires and government priorities. Due to this inherent complexity, a clear, understandable, and functional framework is needed to push the system toward 'success,' as defined by the managing body. Evidence-based management is an example of a functional framework that uses reliable data to make informed decisions that reduce uncertainty for effective management (Dicks et al., 2014; Cooke et al., 2017). Though there are many approaches to evidence-based management, the critical components of the process include setting goals and objectives, implementing management actions, monitoring the outcomes of those actions, and determining if changes need to be made (Mikalsen & Jentoft, 2001; Fenichel et al., 2013; Cook et al., 2016).

Throughout North America, state and provincial agencies are generally responsible for managing fish and wildlife. Although each of these agencies are unique, they generally employ fish and wildlife professionals to monitor natural populations, enforce regulations on harvest, and make recommendations for new management actions and regulations to an oversight board, which is often, but not always, politically appointed or elected. Although the elements of an ideal management institution are well established (e.g., Lockwood et al., 2010; Cooke et al., 2019; Marentette & Zhang, 2022), the realities of managing within the backdrop of complex political and social systems may be underappreciated.

We present a fisheries management case study to illustrate the institutional structure and challenges inherent in managing public recreational fisheries. Our case study focuses on the Nebraska Game and Parks Commission operations and management processes in Nebraska, USA. To gain insights and improve our understanding of institutional constraints and shortcomings, we compare the realities of this system against the ideal of how natural resource agencies are structured. This work reports on those insights and provides recommendations on how to implement a more effective management structure that could improve transparency and achieve the objectives of recreational fisheries management more consistently.

2.3. Ideal Management Structure

Long-term management involves a continuous process of operations and decision-making structures that allow for adaptation and adjustments within the system. An ideal management structure (Figure 2-1) has a foundation of management processes that incorporate evidence-based management in decision-making (Sutherland, 2022). The pillars of evidence-based management include setting objectives, defining triggers, and ongoing monitoring. Each pillar provides valuable information that guides decisions to reduce uncertainty (Biggs et al., 2015; Arlinghaus et al., 2017; de Bie et al., 2018; Brownscombe et al., 2019). With a solid foundation, the decision-making structure uses this knowledge to make informed and defensible decisions. Information about the resource state can move up the hierarchy of responsibilities, whereas decision reasoning moves down this hierarchy, allowing all levels of the management team to remain engaged and involved in the resource management process.

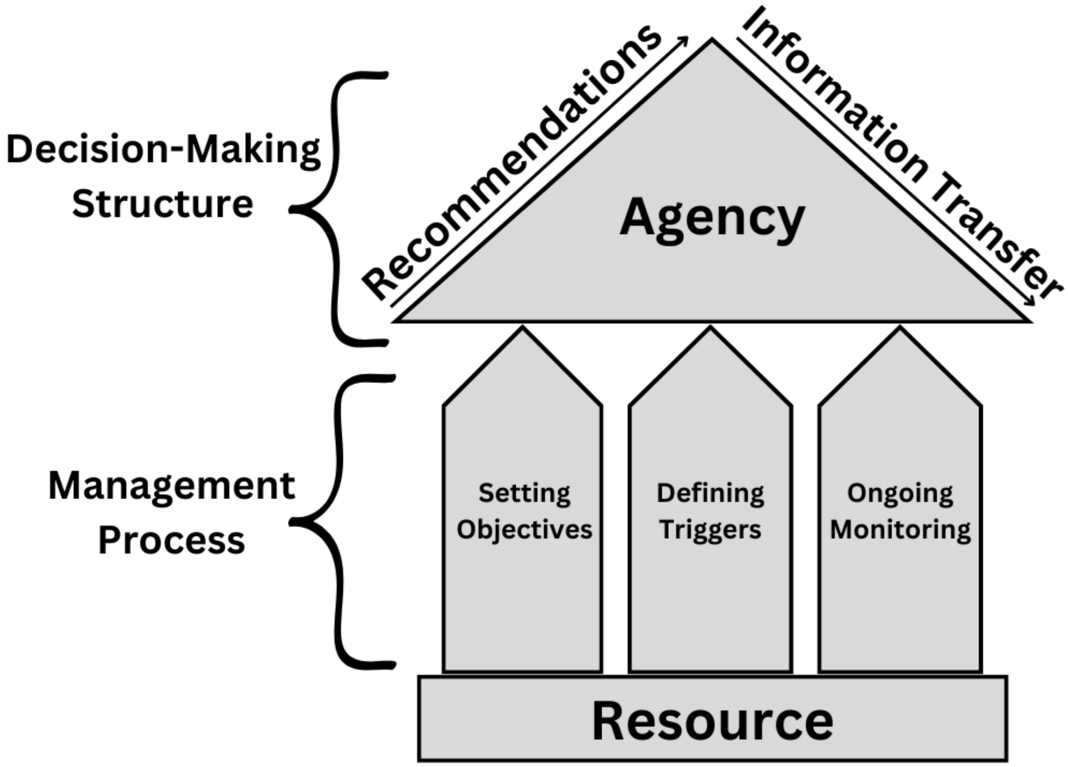

Figure 2-1. Idealized management structure: The foundation of evidence-based management consists of three pillars: objectives, triggers, and monitoring. Recommendations move upward through the hierarchy of responsibilities, with decision-makers being accountable to lower levels within the agency. Information flows bi-directionally within the pyramid.

2.3.1. Management process

A robust management framework establishes objectives to guide management direction and decisions. Objectives are clear, specific, and measurable reflections of these goals (Lackey, 1998). Importantly, objectives must be attainable (Hilborn, 2007; Brownscombe et al., 2019). In recreational fisheries, objectives often balance long-term ecological sustainability and human (angler) satisfaction (Birdsong et al., 2021). Although it seems simple, setting objectives is a fundamental challenge in recreational fisheries (Conroy & Peterson, 2013); a large hurdle specific to recreational fisheries is that there is no ubiquitous pricing system to value recreational factors such as ‘satisfaction’ (Lackey, 1998). Measuring satisfaction is complex because it is influenced by multiple fisheries attributes, including social and psychological experiences and attributes, and the importance of these attributes varies among anglers and fisheries (Beardmore et al., 2015). Working with this diversity of societal preferences and associated trade-offs can be challenging for managers (Mikalsen & Jentoft, 2001; Arlinghaus et al., 2019). Regardless of the challenges, management programs that lack objectives have the much larger issue of being unable to evaluate management decisions, making it difficult to defend decisions, adapt to change, mitigate risk, and improve performance (Barber & Taylor, 1990; van Poorten & MacKenzie, 2020; Marentette & Zhang, 2022).

An additional challenge is that the term ‘objective’ is often misused in resource management. What a managing body may call an ‘objective’ is often referred to in the literature as an ‘end objective’ representing the ultimate goals of management, such as maintaining the long-term sustainability of wild fish populations or providing enjoyable fishing opportunities. These end objectives (sometimes called ‘fundamental’ objectives; Conroy & Peterson, 2013) guide managers in planning, strategic development, and overall organizational activities (Lackey, 1998; Krueger & Decker, 1999; McDaniels et al., 2006; Pascoe et al., 2014; van Poorten & Camp, 2019; Marentette & Zhang, 2022). However, instead of just identifying end objectives, defining complementary ‘means objectives’ is often more practical. Means objectives refer to the specific actions and strategies employed to achieve end objectives, such as providing trophy fish or diverse fishing opportunities (Camp et al., 2013). Means objectives act as stepping stones to the end objectives by defining intermediate tasks necessary for goal attainment (Barber & Taylor, 1990).

Once means objectives are set, thresholds or triggers represent a quantifiable and measurable relationship with the desired system state and reflect what the management organization hopes to achieve and maintain over time. Triggers prompt action when exceeded and enable responsive modifications to management actions based on the results of the monitoring and evaluation process (Addison et al., 2016; Cook et al., 2016; Adkin et al., 2017). For example, a trigger might be a specified biomass of a target species, below which some management action is needed. Decision triggers ensure timely management action and allow agencies to focus on triggers most relevant to achieving the means objectives (Martin et al., 2009).

When predetermined means objectives and triggers have been established, managing bodies must track the effect of their management decisions by establishing a monitoring-and-evaluation system that consistently gathers relevant information on the social and ecological components of the fishery system (Hansen et al., 2015). Monitoring allows managing bodies to understand the current state of the system and how it reacts to regulation changes; thus, monitoring is considered the most important component of adaptive management (Walters, 2007; Camp et al., 2013) and other evidence-based management strategies (Cook et al., 2016) that are designed to understand and reduce uncertainty in fisheries management (Hansen et al., 2015). However, monitoring fisheries can be challenging due to infrequent surveys of fish populations and uncontrolled fishing effort (van Poorten & MacKenzie, 2020). Regardless, monitoring is essential, and agencies use many methods such as angler harvest surveys (creel surveys: Chizinski et al., 2014; Nieman et al., 2021), fishing licence sales trends (Fedler & Ditton, 2001; Kaemingk et al., 2021), fish population assessment surveys (Pope et al., 2010), and electronic monitoring (GPS tracking or electronic reporting: Behivoke et al., 2021; Dainys et al., 2022). Many agencies have established regular monitoring programs across landscapes to track populations over time to ensure thresholds are not exceeded (Lester et al., 2021; Bonar & Hubert, 2002).

2.3.2. Decision-making structure

Information derived from the management process, encompassing objectives, triggers, and monitoring, is the foundation for informed decision-making. The decision-making structure is influenced by the information communicated from the management process and the public values the agency is trying to satisfy. The governance system influences how information is communicated within the management agency and is used to match decisions to institutional goals (Arlinghaus et al., 2016; Brownscombe et al., 2019). In the context of recreational fisheries, the resource management system operates within a sphere deeply affected by stakeholders and user groups, often with substantial personal investment. Given that the resource is a public good and agencies are typically funded through taxpayer contributions and fishing license sales, public participation and accountability take on heightened importance in shaping management decisions (Post & Parkinson, 2012; van Poorten & Mackenzie, 2020).

Engaging stakeholders in management is a practical approach to proactively incorporating information about societal preferences (Lackey, 1998; Reed, 2008). Instead of solely seeking public comments at the end of the decision-making process, actively embedding the public throughout the entire process leads to more informed and effective outcomes (Pinkerton, 1994; Lynam et al., 2007; Cooke et al., 2013; Crandall et al., 2019, Camp et al. *in review*). Engaging the public from the outset allows for a better understanding of stakeholders' diverse interests, values, and expectations, thereby promoting transparency, accountability, and legitimacy in decision-making (Lockwood et al., 2010; Beardmore et al., 2015; Brownscombe et al., 2019). This involvement enhances acceptance and implementation of resulting decisions. Additionally, involving the public provides access to local knowledge, expertise, and perspectives that may not be readily available within traditional managerial frameworks (Reed, 2008; Turner et al., 2008).

Lastly, governance systems are supported by organizational frameworks that significantly affect policy actions and decision-making processes (Egeberg, 1999). The structure of an organization lays the foundation for making decisions and taking policy actions (Rahman et al., 2017). It requires well-defined roles and responsibilities, effective communication channels, and active stakeholder collaboration (Lockwood et al., 2010). However, a lack of transparency, clear communication, and accountability regarding how and why decisions are made within and among hierarchical levels in agency structures can lead to miscommunication and knowledge loss (Rahman et al., 2017; Yue et al., 2019). Therefore, effective management requires understanding the organizational structure and its consequences for policy management.

2.4. Methods

2.4.1. Study area

Nebraska serves as an example state for recreational fisheries management, shedding light on challenges that provincial and state agencies across North America may encounter. Nebraska comprises 618 public fishable reservoirs ranging from 400 m^2 to 121.41 km^2 (Kaemingk et al., 2019). These multi-species fisheries comprise more than 100 fish species targeted by anglers (Nebraska Game and Parks Commission, 2023). Reservoirs are stocked with several species; some are stocked annually to maintain recruitment and abundance, and others are stocked infrequently, forming self-recruiting populations (Nebraska Game and Parks Commission, 2023). Nebraska provides ample and varied fishing opportunities for anglers residing in all 93 Nebraska counties and visitors from other parts of the United States of America and from around the world (Nebraska Game and Parks Commission, 2023).

The Nebraska Game and Parks Commission has an extensive monitoring program that includes fishery-dependent and fishery-independent data collection. Fishery-dependent surveys include creel surveys, which collect information on the social component of the system, as well as the total harvest of different species. In Nebraska, creel surveys are formulated to provide insights about particular waterbodies within a given year. This may include details on the number of fish harvested, group sizes, and overall fishing quality (Nebraska Game and Parks Commission, 2023).

Fishery-independent surveys of fish use standardized methods to assess fish populations' relative abundance and structure. In Nebraska, fish surveys provide insights about a particular waterbody within a given year. This may include relative abundance, size structure, growth rate, and fish condition within a given population (Nebraska Game and Parks Commission, 2023)

The availability of fishery-dependent and fishery-independent monitoring data in Nebraska enables researchers to develop a comprehensive understanding of each recreational fishery and evaluate the outcomes of management practices. The agency's abundant data resources provide a best-case scenario for examining the management and decision-making processes in similar state and provincial management agencies.

2.4.2. Data collection and analysis

To investigate recreational fisheries management processes—specifically components of the management and decision-making structures in Nebraska — we employed a qualitative approach that used semi-structured group interviews to gather opinions and perspectives from relevant personnel (Creswell, 2014). Semi-structured interviews involve guided open-ended discussions with participants through predetermined questions (Kallio et al., 2016). This method allows for flexibility and adaptation during the interviews, enabling participants to elaborate on their experiences and explore unique lines of questioning (Dearnley, 2005).

2.4.3. Participants

Eligible interview participants were individuals whose job duties included monitoring and managing recreational fisheries. They possessed expertise in interpreting fisheries monitoring data, aggregating information from surveys, or utilizing briefing materials to make recommendations or decisions on future management policies. In Nebraska, this includes members of the Board of Commissioners, the Director, Administrators, District Biologists, Assistant District Biologists, and Academics (Table 2-1). These selection criteria ensured that participants had the necessary knowledge and experience to provide relevant insights into recreational fisheries management. Out of 35 individuals who were approached for the study, 20 (57%) participated in the semi-structured interviews.

Participants were categorized based on their roles within the management of Nebraska's recreational fisheries. Group interviews were conducted with participants within a category to facilitate open conversations and encourage participants to freely express their opinions without influence from superiors or other organizational levels. Interviews were limited to four individuals per session, resulting in seven separate semi-structured interviews.

Table 2-1. Interview participant management levels and the corresponding description of their roles in the decision-making structure.

Management Level	Number of Participants	Role Description
Board Member	3	The Board of Commissioners comprises private individuals serving as volunteers. The Governor of Nebraska appoints individuals to the board, which acts as the rulemaking body. Although board members are interested in hunting, fishing, or parks, they often lack a professional or technical background in resource management. Their primary role is to approve or deny recommendations regarding operations and budgets provided by Nebraska Game and Parks staff. Ultimately, the Board of Commissioners is the final decision-making authority regarding implementing regulations.

Director	1	The Director is hired through the Board of Commissioners and is a vital link between the agency and the commissioners. Responsibilities include overseeing agency operations and signing off on recommendations or official rulemaking processes. As a liaison, the Director facilitates effective communication between the agency and the governing body, ensuring that recommendations and decisions are conveyed appropriately.
Administrator	5	Administrators are decision-makers responsible for providing recommendations to the Board of Commissioners. Working primarily in an office-based setting, they collate data and recommendations from different state districts. Their perspectives and insights provide valuable information on the decision-making process at higher levels of administration.
District Biologist	2	District Biologists are responsible for compiling data and making recommendations to Administrators. They perform field duties, collecting data directly from the recreational fisheries in their respective districts. Each District Biologist is assigned to a specific geographic area within the state, providing on-the-ground insights into recreational fisheries management.
Assistant District Biologist	6	Assistant District Biologists are involved in data collection and provision. Assisting the District Biologists in their field duties, they contribute to collecting vital information about the recreational fisheries. Their involvement provides a perspective from individuals working closely with District Biologists and engaging in data-related tasks.
Academic	3	Though not directly involved in recreational fisheries management, Academics (individuals employed in academia) play a significant role in designing field studies, collecting and analyzing data, and providing reports and recommendations to the Administrators. Their expertise in research and data analysis contributes valuable insights to this study.

2.4.4. Interview questions

The interview questions (see Appendix B) focused on the structure and process of managing the recreational fisheries in Nebraska. The interviews covered various topics, including (1) attributes of the recreational fisheries, (2) end and means objectives for the Nebraska recreational fisheries, (3) the agency's monitoring and management approaches, (4) specific information on monitoring data and its value, and (5) informational flow. Additionally, a question regarding concerns about the fisheries' future was added after the initial interview to obtain more specific details and inform future resource allocation decisions.

2.4.5. Interviews

The online video conferencing platform Zoom™ was used to conduct the semi-structured group interviews in July 2022 (Assistant District Biologist, District Biologist, Administrator, Academic) and May and June 2023 (Director, Board Member). Group interviews were scheduled for 60 minutes, but actual interviews ranged from 67 to 82 minutes, allowing extra time for participant questions and project-related information. Interviews were recorded and transcribed via Zoom and then edited for analysis.

2.4.6. Analysis

Using the qualitative analysis software NVivo 12 (QSR International, 2018), transcriptions were coded into nodes to capture relevant information and identify emergent themes. A structured inductive coding approach was employed, starting with general codes from the question format and deriving further coding and themes from the data (Bingham & Witkowsky, 2022). Relevant information was identified by reading and re-reading the corrected transcription of each interview and then coded into similar responses from each interview. General themes based on interview questions, e.g., "Management Objective," "Triggers for Management Action," and "Management Process," were further subdivided into codes (Table 2-2). The codes were broken down into finer details to gather specific information and tease out nuance within the themes.

Table 2-2. Example of coding scheme to determine the "Management Objectives" theme.

Code	Code Level	Description
Management Objective	1	Instances that could be considered a management objective for the Nebraska government
Fish Population Health	2	Includes habitat, self-sustaining populations, fish abundance, and catch metrics
Angler Satisfaction	2	Included: angler satisfaction, diverse fishing opportunities, access to fishery, and trophy fish
Assumed Objectives	2	Objectives interpreted from the interviewee's statements
Angler Satisfaction	3	The reward that recreational anglers receive from their experiences
Cost Effective	3	Producing good results without costing much money
Diverse Fishing Opportunities	3	Providing diverse angling opportunities for many different species of fish to please different angler types

Fish Abundance and Catch metrics	3	Use of fish catch rates to determine the "health" of the system; used to standardize management objectives
Providing Trophy Fish	3	Specimens of game fish whose measurements (body length and weight) are much higher than the species' average
Self Sustaining populations	3	Populations that will continue without stocking
Individual ideal end objectives	2	From the question "What is the perfect fishery?"; personal end objectives around fisheries management
Access to fishery	3	How accessible is the fishery? Use of shore fishing, docks, boat ramps, etc.
Angler Satisfaction	3	The reward that recreational anglers receive from their experiences
Diverse fishing opportunities	3	Providing diverse angling opportunities and many different species of fish to please different angler types
Habitat Quality	3	What the surrounding area is like, including water quality
Healthy Populations	3	Specific to fish populations, healthy sizes and abundance
Self-sustaining populations	3	Populations that will continue without stocking
Trophy fish	3	Specimens of game fish whose measurements (body length and weight) are much higher than the species' average

2.5. Results

2.5.1. Management process

Management objectives: end and means objectives

The participants identified three central end objectives: healthy fish populations, angler satisfaction, and increasing the number of self-sustaining fish populations. Healthy fish populations and angler satisfaction had further means objectives such as diverse fishing opportunities and abundant trophy fish. The most frequently stated end objective across all participant categories was ‘healthy fish populations,’ which refers to high fish abundance and sufficient resources to support healthy growth rates and large sizes of target species.

Participants acknowledged the difficulty in measuring ‘angler satisfaction.’ In Nebraska, there is no formal way of recording or analyzing angler complaints or gauging satisfaction apart from informal comments encountered during creel surveys or other channels such as phone calls, emails, and text messages. These unstructured opinions create a proxy for angler satisfaction. Still, while they are not explicitly used to measure angler satisfaction, complaints alert staff to an issue that may need to be addressed.

Further, no standard measure of angler satisfaction was mentioned. As stated by one *District Biologist* participant, *"Angler input, you know, that is a big one. You start hearing a lot of complaints from fishermen that they want this, or they don't want that, or they want more of this and that. That definitely impacts your management decision on what you stock or what you put out there for regulation to try to protect what you have in your reservoirs."*

The means objective of 'diverse fishing opportunities' is closely tied to the angler satisfaction end objective. The diversity of angling opportunities across the landscape is designed to reflect and cater to the heterogeneity of the angler population. Nebraska's recreational fisheries primarily consist of human-constructed reservoirs with numerous stocked fish species; therefore, the agency can shape the fisheries' angling opportunities. One *Administrator* participant highlighted the agency's mission of introducing people to natural resources and promoting outdoor recreation rather than solely focusing on catching large fish or enforcing bag limits.

Many participants described 'trophy-sized fish' as a top priority. Certain reservoirs with the potential to produce trophy fish are more sought after by the public, increasing fishing effort in those areas. The agency considers trophy fish an asset because they can attract people from neighbouring states to come to Nebraska and fish, thereby increasing the economic values of these fisheries.

Finally, the end objective of 'increasing the number of self-sustaining populations' was recognized as highly beneficial for the agency, primarily due to its ability to diminish the requirement for expensive annual fish stockings. Deteriorating fish hatchery infrastructure and high costs associated with substantial upgrades served as compelling reasons to prioritize the maintenance of self-sustaining populations. Opting for self-recruiting populations rather than annual stocking substantially reduces expenses and staff resources. The significance of this aspect was particularly evident among higher-level authorities within the agency hierarchy, likely due to their direct involvement in budgeting and overall system responsibility.

Participants in the study highlighted the challenges associated with defining management objectives in natural resource management. It was noted that general fishery objectives are often lacking, although specific objectives may exist for individual waterbodies. One *Academic* participant stated, *"Most reservoirs don't have an official target that they're going for. The ones we've set are typically [set] because of brush fires that have occurred politically."* The *Director* participant expressed the view that the objective is to develop fisheries resources that provide various angling opportunities to meet the desires of anglers, which can vary significantly. However, they noted that no definite end or means objectives were established for this purpose.

Triggers for management action

During the interview, when asked about management triggers, the participants' responses were not precise or quantitative. Instead, they were more aligned with management priorities. Although the interview question explicitly referred to triggers, the responses given did not accurately depict the previously defined 'trigger.' The triggers for management action identified by the interview participants include invasive species (invasive species may disrupt ecosystems, harm other species, impact human activities, or create management difficulties), aquatic health (water quality and habitat degradation), political and angler pressure, and fishery-independent data.

All the participant groups agreed that the presence of invasive species is a clear trigger for management action. They acknowledged that invasive species have negative impacts on fisheries and that their presence requires immediate attention. Common carp (*Cyprinus carpio*) and white perch (*Morone americana*) were identified as invasive species that affect both large and small reservoirs. Their competition with stocked fish and the decline in water and habitat quality are urgent issues that need long-term management plans. Other factors that trigger management action include aquatic health, water quality, and habitat degradation. Invasive species, sediment loads in older reservoirs, and excessive nutrients were some of the factors highlighted in this category.

Angler input is an influential factor in management decisions. The satisfaction of anglers and their opinions regarding fishery conditions are considered vital. One *Assistant District Biologist* participant stated that public and angler concerns often lead to a closer look at specific species and bodies of water, acknowledging the challenge of managing for everyone's interests. Similarly, an *Administrator* participant mentioned that when people voice their concerns, a closer examination is conducted, which may result in changes. One *Academic* participant added that public opinion could drive a closer look at data, and managers must consider the opinions expressed. The *Director* also emphasized the significance of public input, conversations with anglers, and creel survey information, which often reflect anglers' wants and needs, especially in high-profile fisheries.

Data obtained from annual fish surveys conducted by the Assistant District Biologist and District Biologist roles are often used to trigger management actions. An *Assistant District Biologist* participant highlighted the importance of considering multiple indices, including catch rates, size structure, age structure, and signs of overcrowding or fish abundance decline. An *Administrator* participant further elaborated on the importance of analyzing short-term and long-term trends, highlighting the need for consistent trends over multiple years to indicate significant changes*: "You would want to look at short-term and long-term trends. You could have a two- to three-year decline, but overall, your 10-year trend is level or at an upward tick, whether it is catch rates or condition. So, for the most part, we probably start to become concerned when we see those trends continue for four- or five, six years in a row. It is not like we are always that slow to be reactive, but that gives a number of years of variability to say, 'Yeah, there is something going on,' no matter what our environmental conditions are."* These triggers and data sources demonstrate the complex nature of fishery management, requiring a comprehensive approach to ensure the health and sustainability of fish populations.

2.5.2. Monitoring: fishery-independent vs. fishery-dependent

Interviewees from all categories recognized the value of fishery-dependent surveys in gathering social data and gaining a comprehensive understanding of the social-ecological environment of a fishery. Specifically, fishery-dependent creel surveys are valued as a direct means of communication with anglers, serving various purposes such as gathering opinions on supplemental questions regarding infrastructure or proposed regulation changes and obtaining information on target species and harvest rates. Moreover, conducting creel surveys increases angler involvement and helps establish a connection with the organizations managing recreational fishing. Many participants across all levels indicated that this direct engagement with anglers provides unique and valuable perspectives, especially compared to channels like public meetings, which often suffer from low attendance of particularly engaged stakeholders.

Participants believed that fishery-dependent surveys also provide valuable information regarding fishing pressure. The *Director* participant explained that creel surveys are the only source of monitoring fishing effort, a key component of managing recreational fisheries, stating, *"I think it is a valuable source because I think we actually gain a lot from the creel survey. We don't get any other way to measure the amount of fishing pressure on different waterbodies. The amount of harvest is also an important part of that whole process."* The catch rate was the most valuable information obtained from creel surveys across all participants. Creel surveys are much more resource-intensive than fishery-independent fish surveys. Therefore, creel surveys are much less frequent and do not cover most waterbodies, resulting in inter-annual variation that can hinder accurate year-to-year comparisons, especially when significant temporal gaps exist. Though many participants consider creel surveys a desirable addition to the larger fishery management framework, they were not considered essential. All participants stated that they would choose fish surveys over creel surveys if they had to choose between them.

Although fishery-dependent surveys are regarded positively, the interviews highlighted the greater value of fishery-independent fish survey data. Fish surveys conducted annually by District Biologists and Assistant Biologists in Nebraska were deemed more reliable and of higher quality. Fishery-independent data provide quantifiable information on reservoir fish populations, and the availability of long-term data sets, such as those in Nebraska, offers historical data that serve as a "baseline" for evaluating current fisheries. These baseline data allow agency staff to identify whether fish populations increase or decrease over time. Consequently, fishery-independent annual data on relative abundance and size structure were prioritized over fishery-dependent data due to their reduced bias and greater frequency.

2.5.3. Decision-making structure

The decision-making structure in the Nebraska Game and Parks Commission (i.e., the 'roof' from Figure 2-1) has a specific hierarchy (Figure 2-2). Within this hierarchy are procedures for "elevating" management recommendations and an unspecified "culture" for information flow. Recommendations move up the pyramid from the Assistant District Biologist to the District Biologist in different regions across the state and are compiled by the Administration. The Director connects the agency

(Administrator, District Biologist, and Assistant District Biologist) to the Board of Commissioners who make the final regulatory decisions. Academics (Academic category) are outside the agency and make recommendations to the Administration based on their research. The broken arrows in the figure represent the missing pieces of information. In this case, anglers do not have formal recommendations, though they can provide input during public meetings and through contact at any level of the hierarchy. Finally, information does not transfer down the pyramid, only up, potentially leading to confusion regarding decision-making.

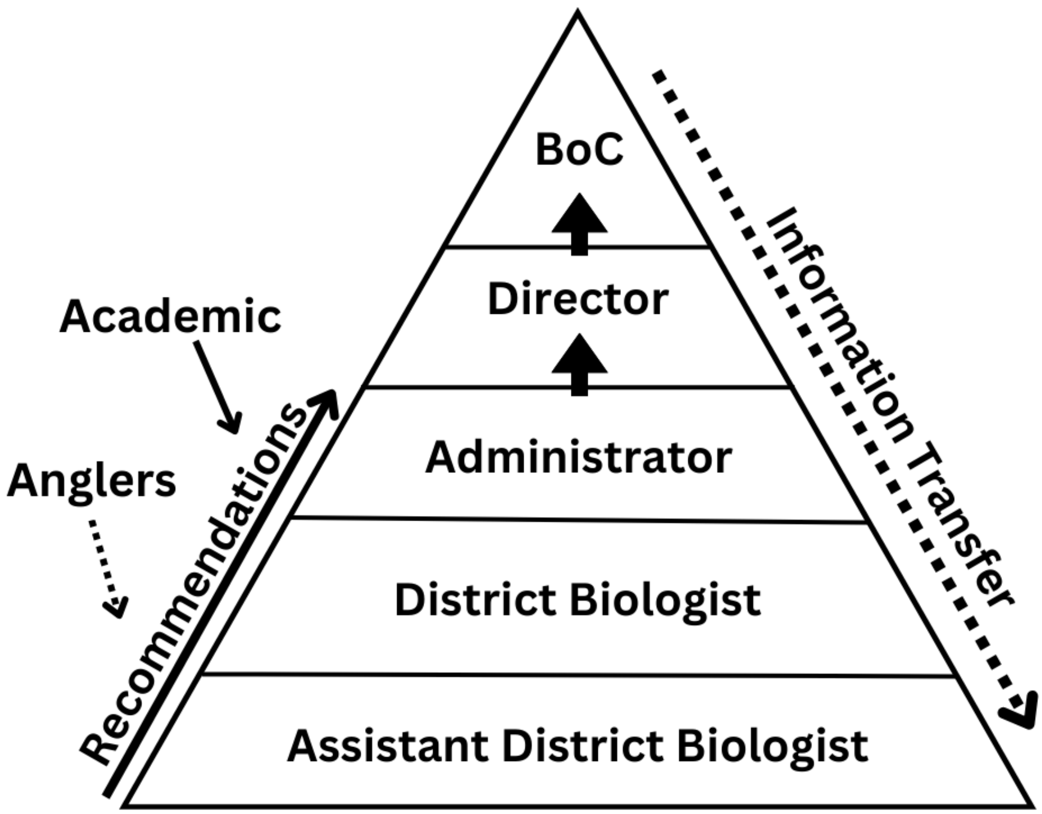

Figure 2-2. An in-depth depiction of the Decision-making structural hierarchy and information flow within the Nebraska Game and Parks Commission. External influences (such as anglers and academic sources) are represented by the outer lines (arrows), while arrows within the pyramid symbolize condensed recommendations flowing from agency personnel (Administrators, District Biologists, and Assistant District Biologists) to the Director, ultimately reaching the Board of Commissioners (BoC). Solid lines signify the presence of information, whereas dotted lines indicate areas where information is either absent or not formally integrated.

The Nebraska Game and Parks Commission incorporates multiple channels of information into decision-making, including public complaints, written reports, staff presentations, and internal meetings where staff members provide recommendations. Staff present the current state of the fishery and propose recommended changes to the *Board of Commissioners* at public hearings. Proposed recommendations are thoroughly reviewed before being presented at these public meetings for final approval. The *Board of Commissioners* receives information about these recommendations in three to four separate instances before the public meetings. Both written comments and in-person attendance by the public contribute to the decision-making process; even so, the board relies heavily on staff expertise.

Assistant District Biologist and *District Biologist* participants have the strongest connection to the resource by collecting data through field surveys and analyzing the outcomes. They hold annual meetings with the Administration to present survey results and discuss potential recommendations. *Assistant District Biologist* participants noted that their suggestions sometimes failed to reach the *Board of Commissioners*, and the reasons why were unknown to them. A specific case exemplifying this situation involved the use of creel surveys. They explained that the Administration had considered changing the length limit for muskellunge (*Esox masquinongy*) in a reservoir. However, analysis of the creel data showed that a negligible number of muskellunge had been harvested from the reservoir. Consequently, the *Assistant District Biologist* participants recommended maintaining a 40-inch (102 cm) minimum size limit. However, the Administration recommended a 50-inch minimum size limit, disregarding the insights provided by the creel data. This interaction between Assistant District Biologists and Administration raised questions regarding the influence and consideration of their recommendations. The conversation highlighted the frustration surrounding this discrepancy and lack of transparency and internal accountability, where the results of the creel surveys appeared to be overlooked or disregarded in the final decision-making process. This conversation also highlights the complexities and intricacies of making decisions.

Academic participants recognized the value of their recommendations, even if not all were implemented. They highlighted the potential for their research findings to be utilized beyond the state's boundaries. *Academic* participants acknowledged the necessity of adapting traditional approaches to incorporate rapidly changing environments due to climate change and emphasized the significance of data-driven decision-making in effectively addressing concerns.

Information Transfer

Upper levels of the agency structure perceive the dissemination of information as efficient and informative; however, participants further removed from the decision-making process (Assistant District Biologist and Academic) expressed uncertainties and concerns (Figure 2-2). These individuals, who have less direct involvement and control in the flow of information, highlighted potential gaps and uncertainties in their understanding of the decision-making process. They believed that the information they received from higher up the hierarchy was insufficient in depth and scope, contributing to confusion and potential misunderstandings regarding decisions that were made by other levels.

This issue of incomplete information transfer became apparent while examining perceptions regarding the level of data-oriented decision-making within the organization. This opinion that decisions were data-driven was held more strongly by higher levels in the organization. For instance, the *District Biologist* participants emphasized that fish sampling is pivotal in driving fisheries management in their district, indicating a strong emphasis on data-driven approaches. *Administrator* participants confirmed that management actions are based on survey results, reinforcing the organization's data-oriented approach. One *Assistant District Biologist* participant acknowledged that combining data indicators and angler behaviour is commonly used. However, some lower-level participants expressed concerns about the clarity of management decisions and their data-driven nature. One *Academic* participant suggested a tendency to rely on existing data to support current practices, stating, *"I think the knee-jerk reaction is that any time suggested management actions come from the public or the commissioners down to the managers, the biologists, the knee-jerk reaction is, let me look at the data to support what I have been doing."* This observation suggests a need for increased objectivity and reliance on data-driven approaches in decision-making processes.

Public Involvement

Since angler satisfaction is a high priority, *District Biologist* participants affirmed that they are willing to make swift changes to address any issues that ensure anglers are satisfied again. *Administrator* participants also recognized that when anglers raise concerns, it prompts a closer examination of historical data and potential management changes. Creel surveys were highlighted as a valuable means of formally connecting with anglers and gathering their opinions. One *Assistant District Biologist* participant mentioned, *"These creels are the only way that … we get … angler input …, other than our public meetings, and not everybody shows up to those, so they are pretty poor [in] attendance."*

Angler feedback greatly influences reservoir management decisions among all study participants. Notably, significant public interest or concerns can sway the board's decisions and affect recommendation approvals. Participants stressed the Nebraska Game and Parks Commission's duty as a public agency to serve the public and ensure angler satisfaction. The *Director* participant emphasized this role, stating that as a public agency, their mission is to serve the public, steward resources, and involve the public in their decision-making.

Information is collected from the public through various channels like phone calls, text messages, emails, remote meetings, and public Board of Commissioner meetings. However, there is not a formal means of collecting public input mentioned. Some participants noted that a small number of individuals in the state hold more sway, but their opinions are not assumed to represent the majority. Instead, the management team focuses on recurring trends and themes in public input, prioritizing ideas consistently raised by many different people rather than one-time remarks.

The source of the feedback matters, as the vocal minority often garners more attention. To ensure a comprehensive range of feedback, the *Board Member* group stated that they rely on the expertise of knowledgeable staff members who understand general preferences and concerns. *Assistant District Biologist* participants acknowledged that pleasing everyone is impossible but emphasized aligning changes with angler preferences. When concerns are voiced, especially by anglers, the management team conducts detailed investigations into specific species or water bodies. One *Assistant District Biologist* explained that public input, particularly from anglers, plays a crucial role in management decisions, and sometimes, the "squeaky wheel" gets more attention, allowing adjustments to meet their preferences. However, there's no efficient method for compiling or monitoring public remarks, and only a few people regularly voice their complaints.

Public communication

There was a common belief among the participants that a significant amount of information is shared with the public. For instance, district meetings that inform the public about the state of fisheries in each district were shifted to virtual platforms due to the COVID-19 pandemic. These meetings were attended by an average of 85 people, which is higher than the number of participants when meetings were held in person. The agency also provides a fishing forecast that summarizes the fish survey data from the previous year, which helps anglers target specific waterbodies based on their desired fish species. Furthermore, the agency makes stocking data, fish survey data, and program information easily accessible on the Nebraska Game and Parks Commission website.

Despite the accessibility of this information, the turnout for Board of Commissioner meetings, where decisions are made and in which the public can voice their concerns, remains relatively low. A meeting with five participants is considered a good turnout. These public hearings occur eight times annually at locations throughout the state. It is important to mention that written participation seems to be more prevalent than in-person attendance. Interestingly, recreational fishing in Nebraska has encountered very few controversies, which has led to a streamlined approval process for recommendations. This could be due to anglers being content with the fisheries, or to a politically inactive angler base at this point in the decision-making process.

2.6. Discussion

Overall, this case study revealed a situation where monitoring is frequent but is not balanced with clear triggers or measurable objectives, creating an unstable basis for the decision-making structure (Figure 2-3). Moreover, inconsistent dissemination of information within the decision-making structure and inadequate public involvement in decisions contribute to poor decision-making accountability.

2.6.1. Management process

We believe the case study presented could mirror other agencies managing recreational fisheries across North America. Monitoring is done regularly, data are collected annually, and resources are allocated to the highest-use areas. Monitoring efforts are maintained while means objectives and triggers remain undefined (Figure 2-3). Clear and measurable triggers can guide responsive action that ensures fish stocks' long-term viability (Brownscombe et al., 2019). Measurable objectives also assist in developing and implementing regulations for recreational fisheries, enabling policymakers to establish appropriate rules and enforce compliance effectively, thus building trust and encouraging stakeholder participation (Irwin et al., 2011; Camp et al., 2020; Solomon et al., 2020). Unclear objectives make monitoring progress and allocating resources challenging, potentially harming decision-making. This creates an unstable basis for managers to make decisions, increasing uncertainty and the probability of negative outcomes. When individuals within an organization are not all working towards the same goal, it can lead to confusion and inefficiencies (Gregory et al., 2012). Furthermore, measurable means objectives serve as a foundation for data collection and monitoring efforts, allowing managers to assess the status and trends of fish populations, angler behaviour, and ecological impacts (Lackey, 1998; Arlinghaus et al., 2016).

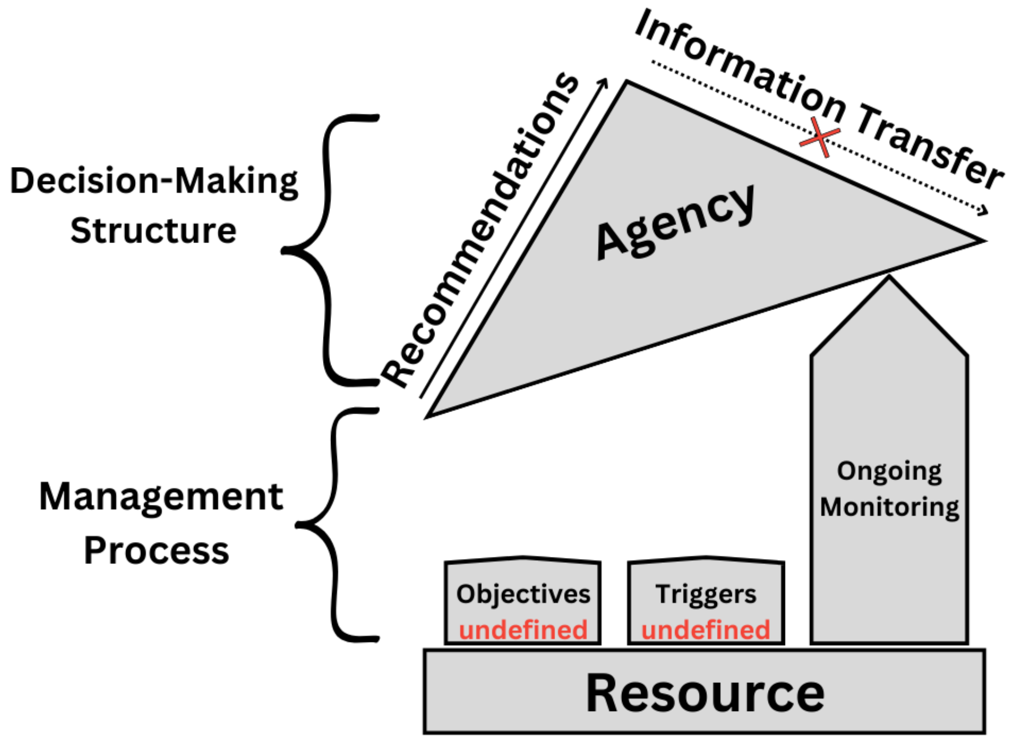

Figure 2-3. An illustration of the decision-making structure and management process in the Nebraska case study. Solid lines denote the presence of information, while dotted lines signify its absence. Information flows only upward through the pyramid. Notably, the management process lacks clearly defined objectives and triggers and predominantly relies on monitoring, resulting in an unstable decision-making structure.

The semi-structured group interviews identified that clear, measurable means objectives are missing from many management procedures. Interview participants revealed several fundamental objectives such as ‘angler satisfaction’ and ‘healthy fish populations’ but lacked any quantitative measure of these variables. Although there is an abundance of fisheries-independent and -dependent data, there is a lack of specific and measurable targets and thresholds. This absence of targets makes it difficult to determine when success has been achieved or if adjustments are needed, ultimately hindering the attainment of stated ‘goals.’ Without clear and well-defined fundamental objectives and accompanying means objectives, there is a risk of goal displacement, where priorities and focus deviate from the intended direction (Lackey, 1998). As demonstrated by the creel surveys, the absence of means objectives also leads to a lack of accountability within an agency and with public stakeholders. Means objectives that can be communicated effectively to the public ensure external transparency and enable meaningful public engagement in the decision-making processes related to fisheries management (Camp et al., 2013).

Every level of the organization mentioned angler satisfaction as a top priority; however, there was no indication of how it was measured. Creel surveys are commonly used to measure fishing effort and catch, but these in-person interviews also provide an opportunity to collect valuable social data (Nieman et al., 2021). Unfortunately, assessing satisfaction may be more complicated than asking anglers if they were satisfied (Arlinghaus & Mehner, 2005; Hunt et al., 2013; Arostegui et al., 2021; Birdsong et al., 2021). For example, Arlinghaus (2006), showed through angler interviews that angler satisfaction relies heavily on expectations based on past fishing experiences. Regardless, by recognizing angler satisfaction as another parameter to be evaluated in fisheries management, long-term data sets allow managers to view changes through time, aid in evaluating the success of management efforts, and identify areas that require improvement. Understanding angler satisfaction, particularly with their catch, is critical for policymakers and fisheries managers who aim to provide high-quality recreational fishing experiences. By analyzing catch outcomes for different species and their impact on satisfaction, managers can identify areas for improvement and enhance anglers' overall experience (Beardmore et al., 2015).

Like end and means objectives, triggers play a fundamental role in evidence-based management strategies in recreational fisheries, enabling managers to identify specific conditions or changes that require prompt action and timely responses (Hansen et al., 2015). Moreover, decision triggers assist management organizations in avoiding wasteful monitoring efforts when there is no intention to act (Lindenmayer et al., 2013). Although the fisheries-independent data did include some measurable indices for 'healthy fish populations,' specific quantifiable triggers that would prompt management action were absent. Agency staff stated they use long-term data to make decisions but did not provide specifics about triggers for population or size structure in those long-term data sets. This is a common issue; many agencies often lack the necessary internal processes and methods to create decision triggers (Martin et al., 2009; Biggs et al., 2015; de Bie et al., 2018). Adopting approaches that align with existing evidence-based frameworks and operational constraints can reduce uncertainty in decision-making (Addison et al., 2016). Extensive monitoring data could be formally integrated to create thresholds or triggers for management action (Biggs & Rogers, 2003; Martin et al., 2009; Connors & Cooper, 2014).

2.6.2. Decision-making structure

The decision-making structure within the agency currently exhibits a bottom-up flow of information, with limited information transfer in the top-down direction (Figure 2-3). Though the upper levels of the agency perceive the current information dissemination as efficient and informative, there are gaps in understanding and uncertainties among participants removed from the decision-making process. This highlights the necessity for comprehensive information dissemination at all levels of the organization to ensure transparency and accountability in decision-making. Improvements are needed to enhance accessibility and promote widespread information sharing within the agency. Encouraging transparency within an agency fosters trust among its members and acknowledges their contributions (Dawes, 2010).

When making final decisions, there may be other objectives that are not explicitly stated in the data presented by the agency. It is important to make these trade-offs clear and communicate their significance to all levels of the agency. There are times when factors other than the data matter, and if the agency communicates how the data are weighted against these factors, all levels will understand that their work has not been disregarded. When communication regarding recommendations or approvals is lacking, staff may feel demotivated and insignificant, resulting in a hostile work environment and poor work quality (Gregory et al., 2012). Providing sufficient information and encouraging discussions cultivates a positive working environment and avoids apathy (Ismail Al-Alawi et al., 2007). By addressing these gaps and uncertainties in information flow, the agency can foster a better understanding of the decision-making process and mitigate potential misunderstandings. Transparent information sharing, including data and contextual insights, can enable a more inclusive and collaborative environment where stakeholders at all levels feel empowered to contribute effectively to the organization's goals (De Vente et al., 2016).

Currently, public involvement in decision-making is limited to creel surveys, undocumented complaints, and participation in Board of Commissioners' meetings. Recreational fishing stakeholders, who are often close to the resource and decision-makers, would benefit from increased public involvement opportunities (Armitage et al., 2009). Efforts to engage the public are underway, but there is a need for increased participation and diversity in voices (Jentoft & McCay, 1995; Irvin & Stansbury, 2004). Extensive research consistently underscores the importance of public involvement in decision-making to ensure democratic accountability and legitimacy. By engaging the public, agencies can access diverse perspectives, expertise, and local knowledge, leading to better-informed decisions and increased public trust (Irvin & Stansbury, 2004; Rowe & Frewer, 2005).

The lack of a reliable system for collecting and recording public input hinders management agencies (Hendee et al., 2019). It makes identifying patterns in public sentiment, prioritizing issues, and allocating resources challenging (Wouters et al., 2011; Yang & Su, 2020). Additionally, it impedes the integration of meaningful suggestions or criticisms into decision-making processes (Abelson et al., 2003; Knobloch, 2022). A standardized approach to collecting and recording public input addresses these challenges. This can involve establishing digital platforms or online portals where the public can submit comments, suggestions, or concerns, allowing for centralized and accessible record-keeping (Rowe & Frewer, 2005; van der Does & Bos, 2021). These strategies would improve the quality of public input, enable comprehensive analysis, and demonstrate accountability to the public.

Agencies often have the pieces for effective and transparent management but lack integration. As a result, the public may lack sufficient information and volition to provide feedback on recreational fisheries management. There can be considerable differences in the opinions of anglers and fisheries managers concerning management decisions, which can lead to conflicts when decisions go against the views of anglers (Klefoth et al., 2023; Connelly et al., 2000). To address this issue, agencies can employ smaller decision-making bodies with closer relationships with anglers or utilize some type of co-management (Camp et al. *in review*). This approach ensures that all parties understand the advantages and drawbacks of various management strategies, including traditional and innovative methods.

Outside of true co-management, it is important to note that the agency still holds the responsibility to make the final decisions. To do this effectively, agencies could develop a comprehensive engagement plan that defines the roles and responsibilities of all participants, aligns with the project objectives, and encourages productive public participation (Wouters et al., 2011). By making participation opportunities more visible, creating transparent decision-making processes, and incorporating effective stakeholder input, agencies can achieve meaningful engagement and increase satisfaction with management (Crandall et al., 2019; Knobloch, 2022).

2.6.3. Limitations

It is important to acknowledge that this study has several limitations. Firstly, although the participants constituted a representative sample of the larger population, not all fisheries employees of the Nebraska Game and Parks Commission were included. For example, only two out of four District Biologists opted to participate, thereby limiting the voice of that participant category. There were also limitations in the scope of information gathered in the interviews. Finally, the management process, particularly in elected governments, is very complicated, and the findings presented here only cover a portion of the issues that agencies may face.

2.7. Conclusion

We used semi-structured group interviews with participants from the Nebraska Game and Parks Commission and others associated with decision-making in the Nebraska recreational fisheries. We aimed to gain insights and improve our understanding of institutional constraints and the overall management process of actively managed recreational fisheries. We found that the realities of the management system do not mesh with the expectations of how a natural resource agency could be structured (Figure 2-1). An ideal management structure has a strong base of evidence-based management, including clear objectives, defined triggers, and an ongoing monitoring process.

We suspect that Nebraska's approach to natural resource management is emblematic of a broader issue across North America, where substantial resources are allocated to monitoring, but a lack of clear objectives and triggers potentially undermines decision-making. We encourage researchers and agencies to conduct similar studies to examine how widespread these challenges are and to collect information on best practices. The presented framework can aid agencies interested in reducing uncertainty and making more robust, defensible decisions by moving towards an evidence-based management strategy that can more effectively use the monitoring data already available. Lastly, the public service employees at Nebraska Game and Parks take their role very seriously and work hard to serve public interests and maintain sustainable fisheries. This work is by no means intended to denigrate their efforts but to highlight the potential commonalities many agencies may face when managing complex social-ecological systems.

Chapter 3.

Exploring influential variables in angler presence from creel survey data using machine learning

3.1. Abstract

Creel survey designs based solely on location and time may miss factors influencing angler behaviour and impact effort estimates. This study employs machine learning techniques to identify the key variables influencing angler presence, aiming to inform fisheries monitoring, through stratified survey design. A random forest model was trained using Nebraska creel fisheries data from 2014 to 2023. Eight variables were extracted from the creel data—including reservoir area, year, month, day, time, wind, precipitation, and lightning—to compare with the total number of anglers. The fitted model explained 59.34% of the total variance in the data. Our results identified reservoir area as the most influential variable affecting predicted angler numbers, followed by temporal factors such as year, month, day, and time. Conversely, weather data were the least impactful overall. These findings confirm the value of existing creel survey designs. Further, they suggest that despite important changes to social norms and information availability, recreational anglers have not changed their patterns of where and when to fish.

3.2. Introduction

Recreational fisheries exert a growing pressure on many freshwater and marine ecosystems (Ihde et al., 2011), yet unlike commercial fisheries, recreational anglers are not mandated to report their catch (MacKenzie & Cox, 2013). This means that time, effort, and resources are allocated to surveying populations of anglers across multiple fisheries on their catch and effort data. To gather information, various methods have been devised, such as on-site interviews called creel surveys, or off-site methods, such as mail surveys and aerial surveys (Bernard et al., 1998; Douglas & Giles, 2001; Hartill et al., 2019). These survey tools are used by fisheries management agencies to gather essential data on angler behaviour and outcomes and derive estimates for management-relevant fishery metrics, including exploitation rate, effort, and harvest (Mosel et al., 2015; Pope et al, 2017; McCormick & Meyer, 2017). Each survey type has its strengths and weaknesses. For example, aerial and creel (in-person) surveys are expensive and require baseline information of temporal and spatial patterns of effort to aid in the stratification of sampling times and areas (creel) or extrapolation of counts (aerial; Hartill et al., 2016; Askey et al., 2018; Hartill et al., 2019). However, because of the direct contact with anglers and the breadth of information that can be obtained, creel surveys are widely considered the most efficient and reliable way for managers to gather data on the human aspect of recreational fisheries (Hartill et al., 2016; Kane et al., 2020). Creel surveyors, or "creel clerks," collect information such as the number of anglers present, fishing locations, duration of a fishing trip, target species, number of fish caught, and numbers harvested (Chiziniski et al., 2014). Depending on the survey goals, other supplemental questions related to economic or social impacts may be asked (Nieman et al., 2021).

Sampling designs are usually stratified to improve the accuracy and precision of effort and catch estimates while reducing staffing and improving logistics (Cochran, 1977; Pollock et al., 1994). In creel survey designs, stratification is determined by separating the season into time or spatial blocks with distinct patterns of fishing activity, and with little variation in activity within each block (Noble et al., 2007). Fishing effort may vary due to the interplay between fish-related factors such as behaviour, distribution, and migration and angler-related factors such as location, time, or fishing gear employed.

Traditionally the most common stratification in creel designs is based on spatial and temporal dimensions (month, week, day-of-week, time-of-day; Bernard & Bingham, 1998; Martin et al., 2015; Pope et al., 2017). Location and time are highly relevant factors that influence fishing activity. Different waterbodies or fishing spots within a waterbody may attract varying levels of angler interest, while fishing success can vary depending on the time of day, week, or month. Stratifying by temporal dimensions allows researchers to account for seasonal trends and daily patterns in fishing activity, such as changes in behaviour due to weather conditions or natural fish behaviour (Pope et al., 2010; Bently, 2017; Nisbet et al., 2021). This stratification format is relatively easy to measure and categorize, allowing surveyors to organize sampling efforts, collect data, and analyze the data efficiently. While this traditional format is widely used and effective, there is increasing recognition of the importance of considering additional factors, such as long-term weather conditions or angler characteristics, to provide a more comprehensive understanding of recreational fishing dynamics (Hunt, 2006; Tucker et al., 2024). As technology and methodologies evolve, there may be opportunities to incorporate these factors into creel survey designs to enhance their accuracy and utility for fisheries management.

Over the past three decades, recreational fisheries have undergone significant transformations, reflecting cultural shifts, technological advancements, and societal norms. One notable aspect of this change is the cultural shift surrounding recreational fishing. Once viewed as a solitary pursuit or a means of sustenance, fishing has evolved into a multifaceted leisure activity embraced by diverse demographics (Arlinghaus, 2006; Embke et al., 2020; Arlinghaus et al., 2021). Moreover, the landscape of recreational fishing has been fundamentally altered by the rapid integration of technology and the pervasive influence of social media (Brownscombe et al., 2019; Cooke et al., 2021). Generally, anglers now have access to cutting-edge fishing gear, navigational aids, and fish-finding technologies, enabling them to target species and explore previously inaccessible waters effectively. Simultaneously, social media platforms have revolutionized how anglers share their experiences, fostering online communities where fishing enthusiasts can exchange tips, showcase their catches, and connect with like-minded individuals worldwide (Lennox et al., 2022; Allison et al., 2023). As a result, factors that once explained the variation in fishing activity from years past may no longer be as applicable today (Lester et al., 2021; de Kerckhove et al., 2024). Traditional methods of stratifying creel survey designs based solely on location and temporal dimensions may overlook important influences shaping contemporary angler behaviour and therefore impact the accuracy or precision of fishing effort estimates. With the wealth of creel data that has been collected in some jurisdictions, there is an opportunity to evaluate our assumptions of spatio-temporal fishing patterns using recent data.

In this study, we employ machine learning to determine if contemporary patterns in fishing effort differ from our expectations. Prevailing expectations built over the last several decades of the 20th century are that more fishing will occur mid-day, on weekends and holidays, and in spring and summer months (Askey et al. 2018). If current patterns in fishing effort deviate from this expectation, findings can be used to develop updated stratification variables for estimating fishing effort, or for appropriately expanding effort counts.

3.3. Methods

This study focused on creel survey data collected by the Nebraska Game and Parks Commission since 2014. Data are limited to the open-water fishing season from April to October and include predictive variables such as waterbody name, waterbody area, year, month, day type, time of day, wind, precipitation, and lightning presence (Table 3-1). The total number of anglers in each survey is the output variable of interest and includes the total number of boat and bank anglers combined. It should be noted that each waterbody was not sampled every year.

Table 3-1. Variables used to predict the total number of anglers.

Predictor	Data Type	Variable Description
Hectares	Continuous	The surface area of a waterbody in hectares
Year	Categorical (10)	Year of the creel survey
Month	Categorical (7)	Month of the creel survey
Day	Categorical (2)	Weekday, or weekend/U.S. Holiday
Time	Categorical (17)	Time of creel survey
Wind	Categorical (4)	None, Light, Moderate, Heavy
Precipitation	Categorical (4)	None, Light, Moderate, Heavy
Lightning	Categorical (2)	Lightning absent or present

Random forest analyses employ bootstrap samples to build multiple trees, each growing from a randomized subset of predictors (Prasad et al., 2006). A random sample of *m* variables is selected from all candidate variables at each tree node. This sample is then used to determine how to split data to minimize variance within each group. Model prediction accuracy can be improved by adjusting the number of predictors. An ensemble of uncorrelated trees can reduce variance while maintaining prediction strength (Bharathidason & Jothi Venkataeswaran, 2014). After the forest is "grown", each tree is used to make predictions for the out-of-bag (OOB) data, meaning data that was not included in the original bootstrap dataset, to assess the model performance (Breiman, 2001). The predicted class for each observation is determined by taking a majority vote of the out-of-bag (OOB) predictions across the forest. In the case of ties, the class is randomly selected. For each observation, error rates are computed based on OOB predictions and averaged across all observations (Louppe, 2014). Because OOB observations are used to cross-validate the model accuracy and are not used to fit the tree data, testing data does not need to be held back to validate the model (Cutler et al., 2007).

Random forest is appropriate because of its ability to incorporate continuous and categorical variables while being easily interpretable and robust to noisy or irrelevant variables (Cutler et al., 2007; Louppe, 2014; Luan et al., 2020). It is particularly useful because it can detect patterns in data without making many parametric assumptions and can account for interactions between different variables that may affect the outcome (Qi, 2012).

Data were analyzed using the randomForest package (Liaw & Wiener, 2002) in R (R Core Team, 2024). Given that the output variable (total anglers) is continuous, a regression random forest model was employed with a 3:1 training and testing data split at each tree, respectively (Breiman, 2001; Louppe, 2014). No data transformation was necessary. Random forests have a limited set of tuning parameters to enhance prediction accuracy, including the number of trees grown (*n*), the number of random predictors sampled for splitting at each node (*P*), and the minimal size of terminal nodes (*m*; Liaw & Wiener, 2002; Prasad et al., 2006). The optimal number of trees in the forest was tested for model accuracy across 500, 1,000, and 10,000. As there was no significant variation in outcomes, 1,000 trees was chosen. To ensure the best fit of the data, *n* was initially varied on the dataset using a forest of 250 to identify the combination resulting in the lowest residual mean squared error before the final analysis.

Our goal was to identify the input variables with the largest impact on predictions. Variable importance was evaluated in two ways: the percent increase in mean squared error (%IncMSE) and the increase in node purity. Percent increase in mean squared error evaluates the importance of a predictor variable in a model for accurate prediction by randomly shuffling the values of that variable while keeping other variables constant and then measuring the increase in mean squared error. An increase in node purity measures the homogeneity of a target variable within a node by splitting a node based on a specific predictor variable. Splitting on a variable that results in a higher separation of classes or groups within the node leads to higher node purity, indicating that the variable plays a crucial role in partitioning the data in the tree.

3.4. Results

The data set used in the RF model included 14,243 records from Nebraska creel surveys. The best-performing node size (*m*) was ten and the best *P* was determined to be 4. The fitted model explained 59.34% of the variation in the data, with a mean absolute error of 4.97 (Table 3-2).

Table 3-2. Summary of statistical results from the random forest model fit to the creel data.

Parameter	Value
Mean squared error (MSE)	203.12
Mean absolute error (MAE)	4.97
R^2	0.589
Percent variance explained (PVE; %)	59.34
Out-of-bag error (OOBE)	367.95

The model underpredicted high effort observations, and overpredicted low effort observations (Figure 3-1). In general, the model was able to make better predictions of angler counts when the number of anglers was low. However, the predictive capacity of the model may be affected by the lack of differentiation between good angling days and poor angling days.

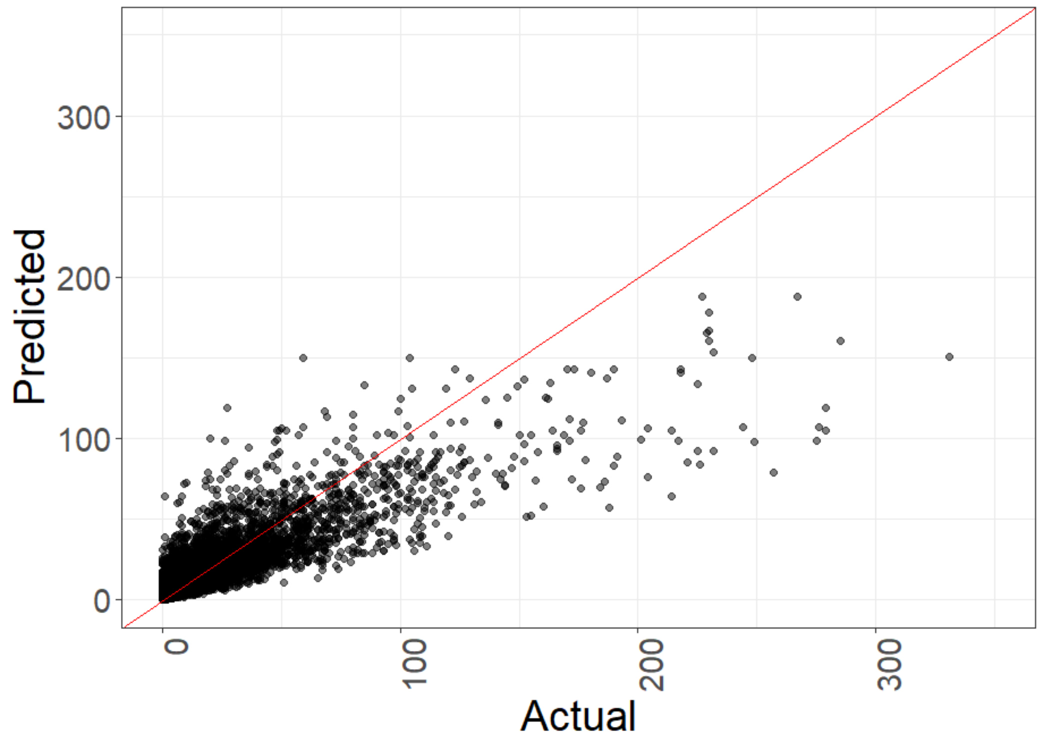

Figure 3-1. **Comparison of model predictive results with the original data. The red line represents the "perfect prediction line," where predicted values would lie if they were exactly equal to the actual values (1:1).**

Waterbody surface area (labelled *Hectares*) resulted in the highest percent increase in mean squared error and node purity (Figure 3-2). Time-related variables were grouped as the second most important variables across both metrics, though the order differed across metrics. Finally, weather states (Wind, Precipitation, and Lightning) were the least important in predicting angler counts.

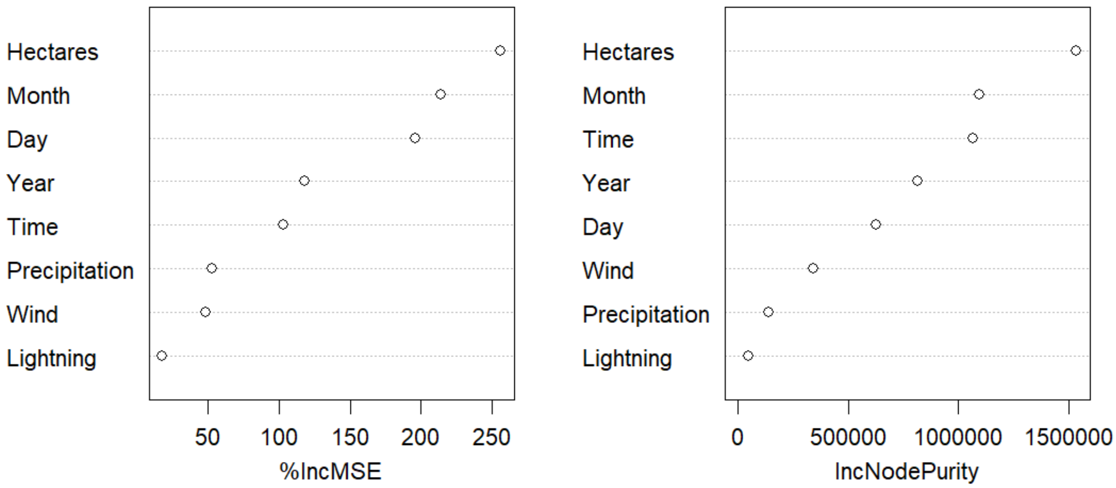

Figure 3-2. Variable importance for accurate predictions of total anglers using percent increase in mean squared error (%IncMSE) and increase in node purity (IncNodePurity)

Partial dependence plots demonstrate the relationships between each predictor variable and the predicted number of anglers present. Predicted fishing effort has generally declined over years, with 2020 as a notable exception (Figure 3-3).

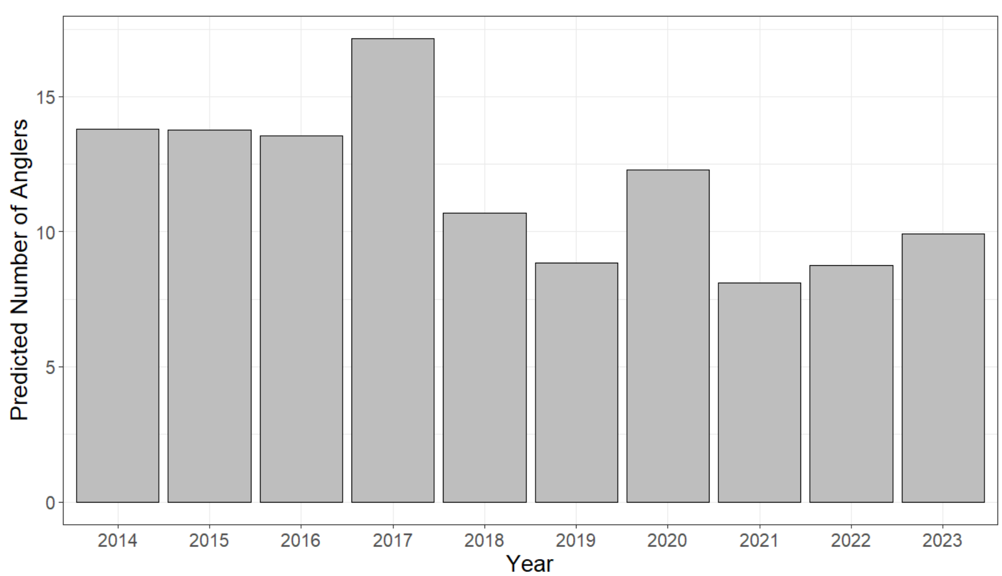

Figure 3-3. Partial dependence plots for variable "Year"

Predicted effort is also highest in the early summer months of May and June, declining thereafter (Figure 3-4). Effort is also notably higher on weekends and holidays than during days in the middle of the week.

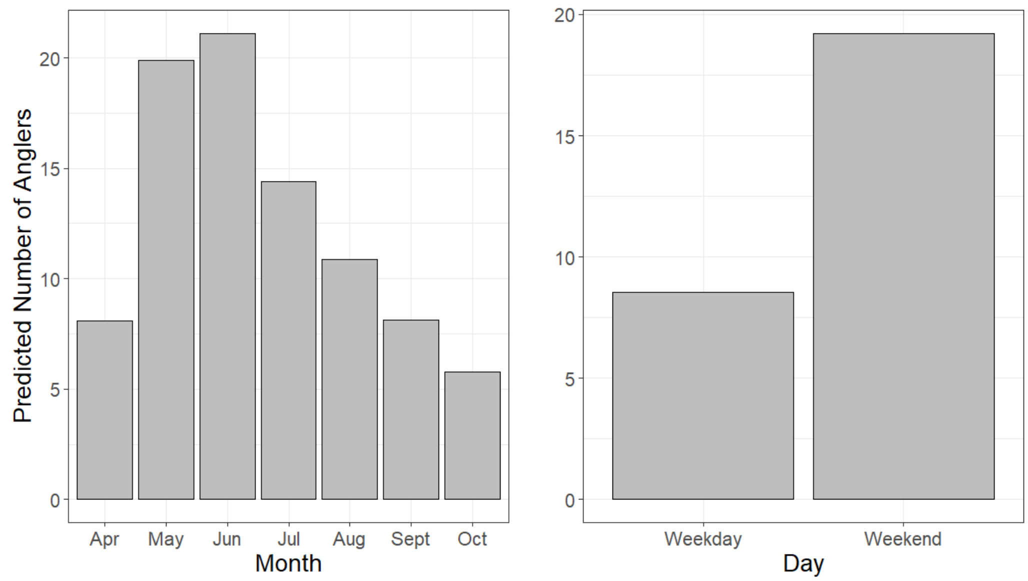

Figure 3-4. Partial dependence plots for variables "Month" and "Day"

The final temporal variable, time of day, the predicted fishing effort was highest between 10:30-11:30 and generally decreased throughout the day (Figure 3-5). Early morning (05:30-06:30) had the fewest predicted anglers.

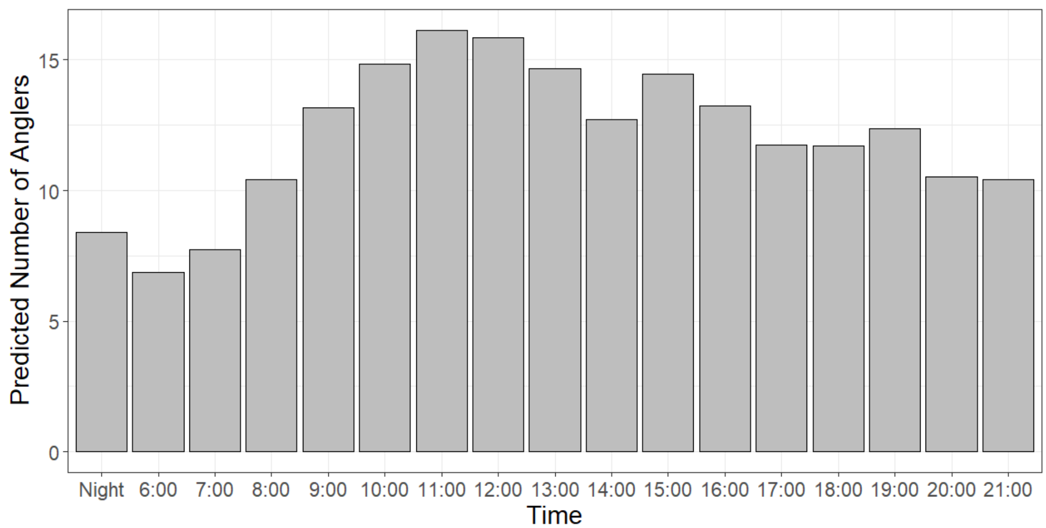

Figure 3-5. Partial dependence plot for the time of day. Daytime intervals are hourly starting at 05:30 and ending at 21:30. Night interval is between 21:30 and 05:30.

Partial dependence plots for weather exhibited a decreasing trend of predicted anglers with increased weather severity (Figure 3-6). Based on the partial dependence plot for precipitation, it appears that the presence of rain discourages fishing. When there was no precipitation, the predicted number of anglers was higher compared to when it was raining. The intensity of the precipitation did not seem to have a significant impact on angler presence. Similarly, the plot for wind shows that the predicted number of anglers decreased as the intensity of the wind increased. However, the decrease was not as sharp as with precipitation. Finally, the plot for lightning shows that the presence of lightning resulted in a slightly lower number of predicted anglers.

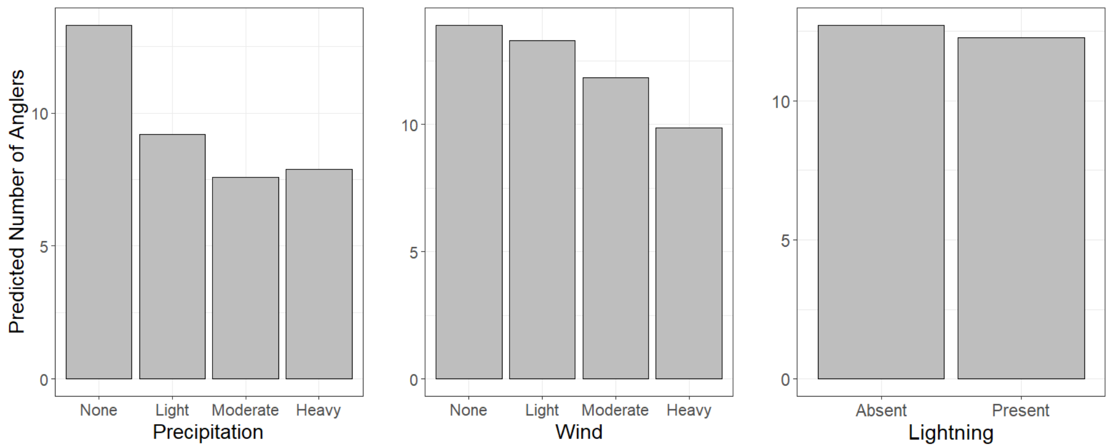

Figure 3-6. Partial dependence plots for weather variables.

Finally, waterbody surface area showed a general increase in predicted fishing effort with size, though there was one reservoir that was notably larger than the rest (Figure 3-7). From the discrete data, the continuous range of waterbody size was predicted, which reveals an overall pattern but not well-fitted results.

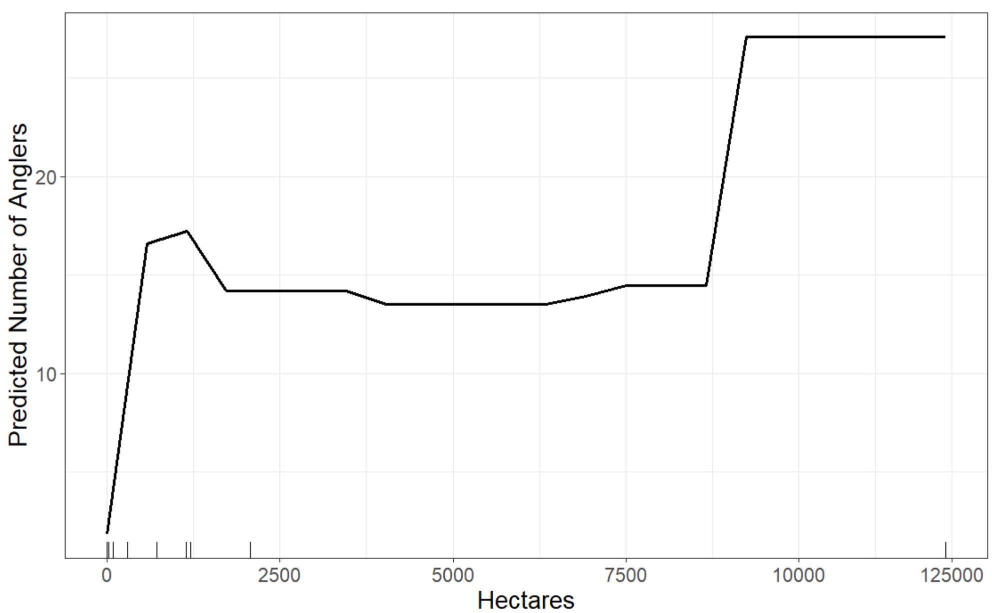

Figure 3-7. Partial dependence plots for continuous variable "Hectares" (reservoir size), ticks on the x-axis indicate ten instances of data present.

3.5. Discussion

Our findings highlight the critical role of reservoir size in predicting the presence of anglers, followed by temporal variables, with weather data being the least influential variable. In particular, the month was the most significant temporal factor, with either year or day type following suit, depending on the variable importance metric used. These results largely validate existing presumptions regarding the dynamics of fishing activities across time and space, yet also provide nuanced patterns on how effort varies within those variables. The model showed a tendency to underestimate high-effort observations while overestimating low-effort observations. This could be due to the absence of catch-related variables that may drive effort and which could aid in distinguishing between good and bad angler days. Good days tend to have many anglers whereas poor days have none. This discrepancy reduces the overall effectiveness of the model in explaining variance. Including temperature or catch rate data may help identify the reasons behind the disparity between good and poor angling days and could ultimately help reduce bias in the model's predictions.

Several studies have demonstrated that resource size is a crucial metric influencing ecological and social aspects of natural resources (e.g. Hunt, 2005; Kaemingk et al., 2019; Kane et al., 2022). This may be due to larger reservoirs' greater diversity in fishing opportunities, both in spatial complexity and fish community composition, which can attract more diverse anglers (Kaemingk et al., 2021). The Nebraska creel data included 22 reservoirs, 20 of which were less than 2500 ha in size. However, even within these smaller reservoirs, there was a general trend of increasing predicted anglers with waterbody size. In Nebraska, most of the population resides in the state's eastern half, while the larger bodies of water are in the western half (Kane et al., 2022). The predicted anglers' downturn could reflect a critical interaction between distance to population centres and the attractiveness of these large reservoirs (Post et al. 2008; Carruthers et al. 2019). This important potential interaction was not captured in our dataset.

Creel surveys are typically stratified by day type (weekday, weekend/holiday) and period (morning, afternoon), with multiple surveys occurring per week (e.g. Deroba et al., 2007; Chizinski et al., 2014; Kaemingk et al., 2020). Our results support categorizing surveys by day type as an appropriate approach for collecting data during peak and off-peak times throughout the survey. This stratification approach helps to reduce variance when patterns of effort are markedly different between strata and generally grouping sampling periods into strata will increase the accuracy of estimates. However, as the number of strata increases, the marginal increase in accuracy decreases, and scheduling staff becomes more difficult so the number of strata used should be carefully considered (Cochran 1977).

The time of day was the second-highest time variable for the increase in node purity. The number of predicted anglers varied throughout the day, with a sharp increase from 6:30 a.m. to its peak around 11 a.m., followed by a decrease. This pattern is likely influenced by factors such as sunrise and sunset and the timing of surveys. Most survey effort is focused on daytime periods, mainly for practical reasons such as logistics and safety. Depending on the sensory and foraging ecology of the target species, night fishing can be desirable to anglers (Cooke et al., 2017). As a result, managers may miss out on valuable harvest and effort data during this time.

To improve survey accuracy, it might be better to sample every few hours or focus on the busiest fishing times and use an appropriate expansion coefficient to calculate the total daily effort (Lester & Dunlop, 2004). This method works best if angler activity peaks around midday and follows a predictable pattern (Tucker et al., 2024). Alternatively, technology such as digital camera monitoring (e.g., Hartill et al., 2016; Stahr & Knudsen, 2018; Hartill et al., 2019; Dutterer et al., 2020; Eckelbecker et al., 2022) or other technology (van Poorten and Brydle, 2018; Johnston et al., 2022) could be used with current creel surveys to lengthen the time when anglers are monitored to capture more information on angler temporal patterns. Sampling and analyzing the entire day's data helps us understand daily fishing trends, consider practical constraints, compare surveys conducted at different times, and accurately estimate daily fishing activity levels.

Although the year was not high in variable importance, the partial independence plots showed an interesting trend. In 2017, the predicted number of anglers peaked, after which the predicted number of anglers declined overall. However, there was a rise in 2020, likely due to the COVID-19 pandemic, when recreational fisheries participation increased in the United States of America as people were looking for perceived ‘safe’ outdoor activities that reduced stress while maintaining social distance (Midway et al., 2021; Paradis et al., 2021). Despite this small rise, the average number of predicted anglers has been declining throughout the timeframe of our data. While participation and effort are two different things, both are important indicators of recreational fishing. In Nebraska, participation in recreational fishing has been declining (Hinrichs et al. 2020), consistent with fewer people purchasing fishing licenses in the United States (Pergams & Zaradic, 2008). This decrease may be linked to the predicted drop in angler counts.

Weather has been shown to have impacts on short-term decisions to go fishing in highly accessible fisheries (Griffin et al., 2021); however, the importance of weather on fishing effort in fishing sites with higher travel times is less well understood. In Nebraska, we did find that weather affected predicted angler counts, where more anglers were fishing in warmer, dryer, and calmer times. On this broader scale, it is likely that anglers adjust their site course based on weather predictions (Smith & Lamborn, 2024); however, once they are at a waterbody, many continue fishing in inclement weather. Additionally, the predicted angler count decreased slightly with stronger winds. Most of our study's reservoirs are small, so wind is not likely to be a significant factor. However, on larger reservoirs, wind can create larger waves that may negatively impact anglers (Hunt and Dyck, 2011). Even though the weather conditions during the surveys did not have a significant effect on the presence of anglers, changes in long-term weather patterns caused by increased variability due to climate change may impact factors such as ice quality, timing, and precipitation, which in turn can affect day fishing trips (Hunt, 2006; Hunt et al., 2016; Dundas & Haefen, 2019). Therefore, further research is needed to understand the relationship between anglers and weather conditions.

Our study, though insightful, is subject to several limitations, the most prominent of which is the reliance on existing creel data that are already stratified based on temporal factors. To maintain model simplicity, we deliberately restricted the selection of variables. However, for a more comprehensive understanding of angler behaviour, additional reservoir characteristics—such as proximity to population centers or local population density, accessibility, and available target species—could illuminate the site-specific characteristics anglers desire. Acknowledging the omission of the ice-fishing season, particularly in March and April, underscores potential biases in earlier-year predictions. Additionally, while our study did not delve into fish-species-specific information for each lake, the seasonal variability in fish catchability likely plays a role in determining angler activity (Deroba et al., 2007). Moreover, constraints within the creel survey data, such as collecting data exclusively during open-water seasons, primarily limiting observations to daylight hours, and excluding fish-specific data like seasonality, inevitably impact the ability of the model to capture subtle nuances in angler effort. Our attempt to explain the data solely through variables currently employed in creel design underscores the potential oversight of significant influencers shaping angler behaviour. It is worth noting that our model's predictive accuracy of 59.34% remains somewhat modest. This could partly be attributed to the prevalence of instances where no anglers were counted and the limited number of variables that drive effort incorporated in the analysis.

In terms of modernizing fisheries systems, do our survey structures require revision? Our findings indicate that while changes in fishing technology may affect effort, the timing of fishing remains consistent. This suggests that despite technological and social changes over the recent past, constraints related to working hours, summer holidays, and fish activity and availability to anglers are stronger drivers in when people can fish. Our research supports the continued use of traditional stratification methods based on temporal variables. Nonetheless, incorporating reservoir size into allocating creel survey effort regionally could enhance effectiveness. Future studies could explore creel stratification using a full year of unstratified data as a foundation for future designs. However, the resource-intensive nature of creel surveys makes such specialized studies improbable (Deroba et al., 2007; Hartill et al., 2019). Our results suggest that such efforts may not significantly alter the landscape of recreational fisheries monitoring. However, identifying variables influencing angler presence will be valuable for future creel designs. By intentionally designing creel surveys with stratification strategies that target specific questions, we can better understand fishing practices and make informed decisions for better fisheries management (Nieman et al. 2021). Ultimately, this approach can help to enhance resource utilization effectiveness and sustainability, which is important for the conservation and management of recreational fisheries on both local and global scales.

Chapter 4.

Conclusion

Recreational fishing exists within complex social-ecological systems, with interconnected human communities, social structures, and the natural environment. Proper management of recreational fishing requires a deep understanding of this complexity and the consideration of wider impacts. Robust management systems are essential for adjusting and adapting to the challenges posed by these complex systems. This requires a comprehensive approach that considers the various social and ecological factors that are at play, and that is adaptable to changing circumstances and new information.

These studies are separate in their methods and findings but contribute to the broader knowledge of recreational fisheries management and monitoring. In the first study, we conducted group interviews with individuals involved in managing recreational fisheries in Nebraska. We aimed to understand institutional constraints and improve management processes. We found that the current management system does not align with the literature expectations of a natural resource agency. An ideal management structure would have evidence-based management with clear objectives, triggers, and monitoring. Natural resource agencies should use evidence-based management, promote information sharing, and engage stakeholders and internal members. This would allow them to make transparent decisions that are defensible to the public and members of the agency. Unfortunately, managers often face challenges with insufficient, complicated, or inconsistent information across different data sources, leading to suboptimal decisions. Effective data collection and information transfer are essential for informed decision-making and minimizing conflicts among stakeholders. This research aims to evaluate and improve management structures and data collection processes to enhance the effectiveness and efficiency of recreational fisheries management, ultimately supporting sustainable practices.

Based on these findings, more research should be completed to look at the broader context across North America to determine if these findings are an isolated case. Conducting qualitative interviews or online survey studies across multiple agencies can provide us with a better understanding of how fisheries management operates. By identifying the weak areas in management agencies, we can make changes to improve management overall.

In the second study, we used a machine learning technique called random forest to identify the key variables that influence the presence of anglers. We analyzed the Nebraska creel survey data from 2014 to 2023 and found eight variables that may impact the total number of anglers, including reservoir area, year, month, day, time, wind, precipitation, and lightning presence. Our findings indicate that reservoir area is the most influential variable affecting predicted angler numbers, followed by temporal factors such as year, month, day, and time. Weather data, on the other hand, had the least impact on the overall results. These results confirm the importance of existing creel survey designs and suggest that recreational anglers have not significantly changed their fishing patterns despite changes in social norms and information availability. Constraints such as working hours, summer vacations, and fish activity strongly influence when people can fish. We suggest continuing the use of traditional stratification methods based on temporal variables. Yet, accounting for reservoir size could enhance the effectiveness of regional creel survey efforts. The limited variables contributing to understanding fishing effort likely increased the uncertainty in our model. More information on fish abundance, daily temperature, accessibility, and even specific fishing regulations would give us a clearer picture of what variables influence angler presence (Beard et al., 2003; Johnston et al., 2013; Carruthers et al., 2019).

In conclusion, these studies underscore the complexity of managing fishing activities within dynamic social-ecological systems. While each study offers unique insights into management structures and fishing effort determinants, they collectively emphasize the need for evidence-based management and efficient data collection processes. The challenges identified, such as insufficient information and inconsistent management approaches, highlight the importance of continuous improvement in fisheries management practices. Moving forward, further research across North America and beyond is warranted to validate findings and identify common trends or challenges. By addressing weak areas and enhancing our understanding of the factors driving fishing effort, we can strive towards more sustainable and effective recreational fisheries management practices that benefit both ecosystems and communities.

References

Abelson, J., Forest, P.-G., Eyles, J., Smith, P., Martin, E., & Gauvin, F.-P. (2003). Deliberations about deliberative methods: Issues in the design and evaluation of public participation processes. *Social Science & Medicine*, *57*(2), 239–251. https://doi.org/10.1016/S0277-9536(02)00343-X

Addison, P. F. E., Cook, C. N., de Bie, K., & Bennett, J. (2016). Conservation practitioners' perspectives on decision triggers for evidence-based management. *The Journal of Applied Ecology.*, *53*(5), 1351–1357.

Adkin, L. E., Hanson, L. L., Kahane, D., Parkins, J. R., & Patten, S. (2017). Can public engagement democratize environmental policymaking in a resource-dependent state? Comparative case studies from Alberta, Canada. *Environmental Politics*, *26*(2), 301–321. https://doi.org/10.1080/09644016.2016.1244967

Allison, C., Winkler, A. C., Childs, A.-R., Muller, C., & Potts, W. M. (2023). Can social media platforms be used to foster improved environmental behaviour in recreational fisheries? Fisheries Research, 258, 106544. https://doi.org/10.1016/j.fishres.2022.106544

Arlinghaus, R. (2005). A conceptual framework to identify and understand conflicts in recreational fisheries systems, with implications for sustainable management. Aquatic Resources, Culture and Development, 1(2), 145-174. 10.1079/cabireviews20063050513

Arlinghaus, R. (2006). On the Apparently Striking Disconnect between Motivation and Satisfaction in Recreational Fishing: The Case of Catch Orientation of German Anglers. *North American Journal of Fisheries Management*, *26*(3), 592–605. https://doi.org/10.1577/M04-220.1

Arlinghaus, R., Aas, Ø., Alós, J., Arismendi, I., Bower, S., Carle, S., Czarkowski, T., Freire, K. M. F., Hu, J., Hunt, L. M., Lyach, R., Kapusta, A., Salmi, P., Schwab, A., Tsuboi, J., Trella, M., McPhee, D., Potts, W., Wołos, A., & Yang, Z.-J. (2021). Global Participation in and Public Attitudes Toward Recreational Fishing: International Perspectives and Developments. Reviews in Fisheries Science & Aquaculture, 29(1), 58–95. https://doi.org/10.1080/23308249.2020.1782340

Arlinghaus, R., Abbott, J. K., Fenichel, E. P., Carpenter, S. R., Hunt, L. M., Alós, J., Klefoth, T., Cooke, S. J., Hilborn, R., Jensen, O. P., Wilberg, M. J., Post, J. R., & Manfredo, M. J. (2019). Governing the recreational dimension of global fisheries. *Proceedings of the National Academy of Sciences*, *116*(12), 5209–5213. https://doi.org/10.1073/pnas.1902796116

Arlinghaus, R., Bork, M., & Fladung, E. (2008). Understanding the heterogeneity of recreational anglers across an urban-rural gradient in a metropolitan area (Berlin, Germany), with implications for fisheries management. *Fisheries Research*, *92*, 53–62. https://doi.org/10.1016/j.fishres.2007.12.012

Arlinghaus, R., & Mehner, T. (2005). Determinants of management preferences of recreational anglers in Germany: Habitat management versus fish stocking. *Limnologica*, *35*(1–2), 2–17. https://doi.org/10.1016/j.limno.2004.10.001

Arlinghaus, R., Mehner, T., & Cowx, I. G. (2002). Reconciling traditional inland fisheries management and sustainability in industrialized countries, with emphasis on Europe. Fish and Fisheries, 3(4), 261–316. https://doi.org/10.1046/j.1467-2979.2002.00102.x

Armitage, D. R., Plummer, R., Berkes, F., Arthur, R. I., Charles, A. T., Davidson-Hunt, I. J., Diduck, A. P., Doubleday, N. C., Johnson, D. S., Marschke, M., McConney, P., Pinkerton, E. W., & Wollenberg, E. K. (2009). Adaptive co-management for social–ecological complexity. *Frontiers in Ecology and the Environment*, *7*(2), 95–102. https://doi.org/10.1890/070089

Arostegui, M. C., Anderson, C. M., Benedict, R. F., Dailey, C., Fiorenza, E. A., & Jahn, A. R. (2021). Approaches to regulating recreational fisheries: Balancing biology with angler satisfaction. *Reviews in Fish Biology and Fisheries*, *31*(3), 573–598. https://doi.org/10.1007/s11160-021-09662-y

Askey, P., Ward, H., Godin, T., Boucher, M., & Northrup, S. (2018). Angler Effort Estimates from Instantaneous Aerial Counts: Use of High-Frequency Time-Lapse Camera Data to Inform Model-Based Estimators. North American Journal of Fisheries Management, 38, 194–209. https://doi.org/10.1002/nafm.10010

Barber, W. E., & Taylor, J. N. (1990). The Importance of Goals, Objectives, and Values in the Fisheries Management Process and Organization: A Review. *North American Journal of Fisheries Management*, *10*(4), 365–373. https://doi.org/10.1577/1548-8675(1990)010<0365:TIOGOA>2.3.CO;2

Beard, T. D., Cox, S. P., & Carpenter, S. R. (2003). Impacts of Daily Bag Limit Reductions on Angler Effort in Wisconsin Walleye Lakes. *North American Journal of Fisheries Management*, *23*(4), 1283–1293. https://doi.org/10.1577/M01-227AM

Beardmore, B., Hunt, L. M., Haider, W., Dorow, M., & Arlinghaus, R. (2015). Effectively managing angler satisfaction in recreational fisheries requires understanding the fish species and the anglers. *Canadian Journal of Fisheries and Aquatic Sciences*, *72*(4), 500–513. https://doi.org/10.1139/cjfas-2014-0177

Behivoke, F., Etienne, M.-P., Guitton, J., Randriatsara, R. M., Ranaivoson, E., & Léopold, M. (2021). Estimating fishing effort in small-scale fisheries using GPS tracking data and random forests. *Ecological Indicators*, *123*, 107321. https://doi.org/10.1016/j.ecolind.2020.107321

Bernard, D. R., & Bingham, A. E. (1998). The Mechanics of Onsite Creel Surveys in Alaska. Alaska Department of Fish and Game, Special Publication No. 98-1, Anchorage.

Bernard, D. R., Bingham, A. E., & Alexandersdottir, M. (1998). Robust Harvest Estimates from On-Site Roving–Access Creel Surveys. Transactions of the American Fisheries Society, 127(3), 481–495. https://doi.org/10.1577/1548-8659(1998)127<0481:RHEFOS>2.0.CO;2

Bharathidason, S., & Jothi Venkataeswaran, C. (2014). Improving Classification Accuracy based on Random Forest Model with Uncorrelated High Performing Trees. International Journal of Computer Applications, 101(13), 26–30. https://doi.org/10.5120/17749-8829

Biggs, H. C., & Rogers, K. H. (2003). An adaptive system to link science, monitoring and management in practice. *The Kruger Experience: Ecology and Management of Savanna Heterogeneity*, 59–80.

Biggs, R. (Oonsie), Rhode, C., Archibald, S., Kunene, L. M., Mutanga, S. S., Nkuna, N., Ocholla, P. O., & Phadima, L. J. (2015). Strategies for managing complex social-ecological systems in the face of uncertainty: Examples from South Africa and beyond. *Ecology and Society*, *20*(1). https://www.jstor.org/stable/26269769

Bingham, A.J., & Witkowsky, P. (2022). Deductive and inductive approaches to qualitative data analysis. In C. Vanover, P. Mihas, & J. Saldaña (Eds.), Analyzing and interpreting qualitative data: After the interview (pp. 133-146). SAGE Publications.

Birdsong, M., Hunt, L. M., & Arlinghaus, R. (2021). Recreational angler satisfaction: What drives it? *Fish and Fisheries*, *22*(4), 682–706. https://doi.org/10.1111/faf.12545

Bonar, S. A., and W. A. Hubert. (2002). Standard sampling of inland fish: benefits, challenges, and a call for action. *Fisheries, 27*(3), 10–16.

Breiman, L. (2001). Random Forests. Machine Learning, 45(1), 5–32. https://doi.org/10.1023/A:1010933404324

Brownscombe, J. W., Hyder, K., Potts, W., Wilson, K. L., Pope, K. L., Danylchuk, A. J., Cooke, S. J., Clarke, A., Arlinghaus, R., & Post, J. R. (2019). The future of recreational fisheries: Advances in science, monitoring, management, and practice. Fisheries Research, 211, 247–255. https://doi.org/10.1016/j.fishres.2018.10.019

Camp, E. V., Lorenzen, K., Ahrens, R. N. M., Barbieri, L., & Leber, K. M. (2013). Potentials and Limitations of Stock Enhancement in Marine Recreational Fisheries Systems: An Integrative Review of Florida's Red Drum Enhancement. *Reviews in Fisheries Science*, *21*(3–4), 388–402. https://doi.org/10.1080/10641262.2013.838075

Camp, E. V., Kaemingk, M. A., Ahrens, R. N. M., Potts, W. M., Pine, W. E., Weyl, O. L. F., & Pope, K. L. (2020). Resilience Management for Conservation of Inland Recreational Fisheries. *Frontiers in Ecology and Evolution*, *7*, 498. https://doi.org/10.3389/fevo.2019.00498

Camp, E., van Poorten, B., Robinson, K., Harrison, H., Nguyen, V., Crandall, C., Lorenzen, K., Casola, W., Dedual, M., Klizentyte, K. (in Review) Integrating diverse stakeholder knowledge in recreational fisheries decision making.

Carruthers, T. R., Dabrowska, K., Haider, W., Parkinson, E. A., Varkey, D. A., Ward, H., McAllister, M. K., Godin, T., Van Poorten, B., Askey, P. J., Wilson, K. L., Hunt, L. M., Clarke, A., Newton, E., Walters, C., & Post, J. R. (2019). Landscape-scale social and ecological outcomes of dynamic angler and fish behaviours: Processes, data, and patterns. Canadian Journal of Fisheries and Aquatic Sciences, 76(6), 970–988. https://doi.org/10.1139/cjfas-2018-0168

Chapin, F. S., Carpenter, S. R., Kofinas, G. P., Folke, C., Abel, N., Clark, W. C., Olsson, P., Smith, D. M. S., Walker, B., Young, O. R., Berkes, F., Biggs, R., Grove, J. M., Naylor, R. L., Pinkerton, E., Steffen, W., & Swanson, F. J. (2010). Ecosystem stewardship: Sustainability strategies for a rapidly changing planet. Trends in Ecology & Evolution, 25(4), 241–249. https://doi.org/10.1016/j.tree.2009.10.008

Chizinski, C. J., Martin, D. R., Pope, K. L., Barada, T. J., & Schuckman, J. J. (2014). Angler effort and catch within a spatially complex system of small lakes. Fisheries Research, 154, 172–178. https://doi.org/10.1016/j.fishres.2014.02.013

Cochran, W. G. (1977). Sampling techniques, 3rd ed. John Wiley and Sons, Inc. New York

Connelly, N. A., Brown, T. L., & Knuth, B. A. (2000). Do Anglers and Fishery Professionals Think Alike? *Fisheries*, *25*(2), 21–25. https://doi.org/10.1577/1548-8446(2000)025<0021:DAAFPT>2.0.CO;2

Connors, B. M., & Cooper, A. B. (2014). Determining Decision Thresholds and Evaluating Indicators when Conservation Status is Measured as a Continuum. *Conservation Biology*, *28*(6), 1626–1635. https://doi.org/10.1111/cobi.12364

Conroy, M.J. and Peterson, J.T. (2013). Identifying and Quantifying Objectives in Natural Resource Management. In Decision Making in Natural Resource Management: A Structured, Adaptive Approach (eds M.J. Conroy and J.T. Peterson). https://doi-org.proxy.lib.sfu.ca/10.1002/9781118506196.ch3

Cook, C. N., M. Hockings, and R. W. Carter. (2010). Conservation in the dark? The information used to support management decisions. Frontiers in Ecology and the Environment 8:181–186.

Cook, C. N., de Bie, K., Keith, D. A., & Addison, P. F. E. (2016). Decision triggers are a critical part of evidence-based conservation. *Biological Conservation, 195,* 46–51. https://doi.org/10.1016/j.biocon.2015.12.024

Cooke, S. J., Lapointe, N. W., Martins, E. G., Thiem, J. D., Raby, G. D., Taylor, M. K., Beard, T. D., & Cowx, I. G. (2013). Failure to engage the public in issues related to inland fishes and fisheries: Strategies for building public and political will to promote meaningful conservation. *Journal of Fish Biology, 83*(4), 997–1018. https://doi.org/10.1111/jfb.12222

Cooke, S., Lennox, R., Bower, S., Horodysky, A., Treml, M., Stoddard, E., Donaldson, L., & Danylchuk, A. (2017). Fishing in the dark: The science and management of recreational fisheries at night. Bulletin of Marine Science, 93(2), 519–538. https://doi.org/10.5343/bms.2015.1103

Cooke, S. J., Suski, C. D., Arlinghaus, R., & Danylchuk, A. J. (2013). Voluntary institutions and behaviours as alternatives to formal regulations in recreational fisheries management. Fish and Fisheries, 14(4), 439–457. https://doi.org/10.1111/j.1467-2979.2012.00477.x

Cooke, S. J., Twardek, W. M., Reid, A. J., Lennox, R. J., Danylchuk, S. C., Brownscombe, J. W., Bower, S. D., Arlinghaus, R., Hyder, K., & Danylchuk, A. J. (2019). Searching for responsible and sustainable recreational fisheries in the Anthropocene. *Journal of Fish Biology, 94*(6), 845–856. https://doi.org/10.1111/jfb.13935

Cooke, S. J., Wesch, S., Donaldson, L. A., Wilson, A. D. M., & Haddaway, N. R. (2017). A Call for Evidence-Based Conservation and Management of Fisheries and Aquatic Resources. *Fisheries*, *42*(3), 143–149. https://doi.org/10.1080/03632415.2017.1276343

Cooke, S. J., Venturelli, P., Twardek, W. M., Lennox, R. J., Brownscombe, J. W., Skov, C., Hyder, K., Suski, C. D., Diggles, B. K., Arlinghaus, R., & Danylchuk, A. J. (2021). Technological innovations in the recreational fishing sector: Implications for fisheries management and policy. Reviews in Fish Biology and Fisheries, 31(2), 253–288. https://doi.org/10.1007/s11160-021-09643-1

Crandall, C. A., Monroe, M., Dutka-Gianelli, J., & Lorenzen, K. (2019). Meaningful action gives satisfaction: Stakeholder perspectives on participation in the management of Marine Recreational Fisheries. *Ocean & Coastal Management, 179*: 104872. https://doi.org/10.1016/j.ocecoaman.2019.104872

Creswell, J. W. (2014). Research design: Qualitative, quantitative, and mixed methods approaches. Sage publications.

Cutler, D. R., Edwards Jr., T. C., Beard, K. H., Cutler, A., Hess, K. T., Gibson, J., & Lawler, J. J. (2007). Random Forests for Classification in Ecology. Ecology, 88(11), 2783–2792. https://doi.org/10.1890/07-0539.1

Dainys, J., Gorfine, H., Mateos-González, F., Skov, C., Urbanavičius, R., & Audzijonyte, A. (2022). Angling counts: Harnessing the power of technological advances for recreational fishing surveys. *Fisheries Research, 254,* 106410. https://doi.org/10.1016/j.fishres.2022.106410

Dawes, S. S. (2010). Stewardship and usefulness: Policy principles for information-based transparency. *Government Information Quarterly, 27*(4), 377–383. https://doi.org/10.1016/j.giq.2010.07.001

Dearnley C. (2005). A reflection on the use of semi-structured interviews. *Nurse researcher, 13*(1), 19–28. https://doi.org/10.7748/nr2005.07.13.1.19.c5997

de Bie, K., Addison, P. F. E., & Cook, C. N. (2018). Integrating decision triggers into conservation management practice. *Journal of Applied Ecology, 55*(2), 494–502. https://doi.org/10.1111/1365-2664.13042

Deroba, J. J., Hansen, M. J., Nate, N. A., & Hennessy, J. M. (2007). Evaluating Creel Survey Efficiency for Estimating Walleye Fishery Metrics in Northern Wisconsin Lakes. North American Journal of Fisheries Management, 27(2), 707–716. https://doi.org/10.1577/M06-126.1

de Kerckhove, Derrick, Caroline Tucker, Lee Gutowsky, George Morgan, Matthew Guzzo, and Vianey Leos Barajas. 2024. Optimizing Creel Surveys. In Understanding recreational fishers: disciplinary and interdisciplinary approaches for fisheries management, ed. Kevin L. Pope, Robert Arlinghaus, Len M. Hunt, Abigail J. Lynch, and Brett T. van Poorten. Springer Science & Business Media.

De Vente, J., Reed, M. S., Stringer, L. C., Valente, S., & Newig, J. (2016). How does the context and design of participatory decision-making processes affect their outcomes? Evidence from sustainable land management in global drylands. *Ecology and Society, 21*(2), 24. https://doi.org/10.5751/ES-08053-210224

Dicks, L. V., Walsh, J. C., & Sutherland, W. J. (2014). Organising evidence for environmental management decisions: A ‘4S’ hierarchy. *Trends in Ecology & Evolution, 29*(11), 607–613. https://doi.org/10.1016/j.tree.2014.09.004

Douglas, J., & Giles, A. (2001). The use of traffic counters to plan creel surveys: A case study of Lake Dartmouth, Victoria, Australia. Fisheries Management and Ecology, 8(6), 543–546. https://doi.org/10.1046/j.1365-2400.2001.00254.x

Dundas, S. J., & Von Haefen, R. H. (2020). The Effects of Weather on Recreational Fishing Demand and Adaptation: Implications for a Changing Climate. Journal of the Association of Environmental and Resource Economists, 7(2), 209–242. https://doi.org/10.1086/706343

Dutterer, A. C., Dotson, J. R., Thompson, B. C., Paxton, C. J., & Pouder, W. F. (2020). Estimating Recreational Fishing Effort Using Autonomous Cameras at Boat Ramps versus Creel Surveys. North American Journal of Fisheries Management, 40(6), 1367–1378. https://doi.org/10.1002/nafm.10490

Eckelbecker, R. W., Coleman, T. S., & Catalano, M. J. (2022). Incorporating Time-Lapse Digital Cameras into Creel Surveys at Three Alabama Reservoirs. North American Journal of Fisheries Management, 42(5), 1349–1358. https://doi.org/10.1002/nafm.10828

Egeberg, M. (1999). The study of public organizations: Issues and perspectives. *International Review of Administrative Sciences, 65*(2), 239-255. doi:10.1177/002085239906500207

Elmer, L. K., Kelly, L. A., Rivest, S., Steell, S. C., Twardek, W. M., Danylchuk, A. J., Arlinghaus, R., Bennett, J. R., & Cooke, S. J. (2017). Angling into the Future: Ten Commandments for Recreational Fisheries Science, Management, and Stewardship in a Good Anthropocene. Environmental Management, 60(2), 165–175. https://doi.org/10.1007/s00267-017-0895-3

Embke, H. S., Douglas Beard, T., Lynch, A. J., & Vander Zanden, M. J. (2020). Fishing for Food: Quantifying Recreational Fisheries Harvest in Wisconsin Lakes. Fisheries, 45(12), 647–655. https://doi.org/10.1002/fsh.10486

FAO (2012) Recreational Fisheries. FAO Technical Guidelines for Responsible Fisheries. No. 13. Rome, Italy

Fedler, A. J., & Ditton, R. B. (2001). Dropping Out and Dropping In: A Study of Factors for Changing Recreational Fishing Participation. *North American Journal of Fisheries Management, 21*(2), 283–292. https://doi.org/10.1577/1548-8675(2001)021<0283:doadia>2.0.co;2

Fenichel, E.P., Abbott, J.K., Huang, B., (2013). Modelling angler behaviour as a part of the management system: synthesizing a multi-disciplinary literature: Modelling angler behaviour. *Fish 14*: 137–157. https://doi.org/10.1111/j.1467-2979.2012.00456.x

Friedlander, A. M., Nowlis, J., & Koike, H. (2015). Improving fisheries assessments using historical data: stock status and catch limits. J.N. Kittinger, L. McClenachan, K.B. Gedan, L.K. Blight (Eds.), Marine Historical Ecology in Conservation: Applying the Past to Manage for the Future, University of California Press, Oakland, pp. 91-118

Gregory, R., Failing, L., Harstone, M., Long, G., McDaniels, T., & Ohlson, D. (2012). Structured Decision Making: A Practical Guide to Environmental Management Choices (1st ed.). Wiley. https://doi.org/10.1002/9781444398557

Griffin, K. J., Hedge, L. H., Warton, D. I., Astles, K. L., & Johnston, E. L. (2021). Modeling recreational fishing intensity in a complex urbanised estuary. Journal of Environmental Management, 279, 111529. https://doi.org/10.1016/j.jenvman.2020.111529

Hansen, G. J., Gaeta, J. W., Hansen, J. F., & Carpenter, S. R. (2015). Learning to Manage and Managing to Learn: Sustaining Freshwater Recreational Fisheries in a Changing Environment. *Fisheries, 40*(2), 56-64. 10.1080/03632415.2014.996804

Hartill, B. W., Payne, G. W., Rush, N., & Bian, R. (2016). Bridging the temporal gap: Continuous and cost-effective monitoring of dynamic recreational fisheries by web cameras and creel surveys. Fisheries Research, 183, 488–497. https://doi.org/10.1016/j.fishres.2016.06.002

Hartill, B., Rush, N., Armiger, H., & Bian, R. (2019). Aerial-access recreational harvest estimates for snapper, kahawai, red gurnard, tarakihi and trevally in FMA 1 in 2017-18.

Hartill, B., Taylor, S., Keller, K., & Weltersbach, M. S. (2019). Digital camera monitoring of recreational fishing effort: Applications and challenges. *Fish and Fisheries, 21,* 204–215. https://doi.org/10.1111/faf.12413

Hendee, J.C., Clark, R.N. and Stankey, G.H., (2019). A Framework for Agency use of Public Input in Resources Decision Making. In Land and Leisure (pp. 300-312). Routledge.

Hilborn, R. (2007). Defining success in fisheries and conflicts in objectives. *Marine Policy, 31*(2), 153–158. https://doi.org/10.1016/j.marpol.2006.05.014

Hinrichs, M. P., Price, N. B., Gruntorad, M. P., Pope, K. L., Fontaine, J. J., & Chizinski, C. J. (2020). Understanding Sportsperson Retention and Reactivation Through License Purchasing Behavior. Wildlife Society Bulletin, 44(2), 383–390. https://doi.org/10.1002/wsb.1088

Hughes, B. (2014). The Socioeconomic Values of Recreational Fishing. Fisheries, 39(7), 291–291. https://doi.org/10.1080/03632415.2014.926894

Hunt, L. (2005). Recreational Fishing Site Choice Models: Insights and Future Opportunities. Human Dimensions of Wildlife, 10(3), 153–172. https://doi.org/10.1080/10871200591003409

Hunt, L. (2006). The potential impacts of climate change on recreational fishing in Northern Ontario, Canada. Canada Commons. https://canadacommons.ca/artifacts/1214126/the-potential-impacts-of-climate-change-on-recreational-fishing-in-northern-ontario/1767223/

Hunt, L. M., & Dyck, A. (2011). The Effects of Road Quality and Other Factors on Water-Based Recreation Demand in Northern Ontario, Canada. Forest Science, 57(4), 281–291, https://doi.org/10.1093/forestscience/57.4.281

Hunt, L. M., Fenichel, E. P., Fulton, D. C., Mendelsohn, R., Smith, J. W., Tunney, T. D., Lynch, A. J., Paukert, C. P., & Whitney, J. E. (2016). Identifying Alternate Pathways for Climate Change to Impact Inland Recreational Fishers. Fisheries, 41(7), 362–372. https://doi.org/10.1080/03632415.2016.1187015

Hunt, L. M., Sutton, S. G., & Arlinghaus, R. (2013). Illustrating the critical role of human dimensions research for understanding and managing recreational fisheries within a social-ecological system framework. *Fisheries Management and Ecology, 20*(2–3), 111–124. https://doi.org/10.1111/j.1365-2400.2012.00870.x

Ihde, T. F., Wilberg, M. J., Loewensteiner, D. A., Secor, D. H., & Miller, T. J. (2011). The increasing importance of marine recreational fishing in the US: challenges for management. Fisheries Research, 108(2-3), 268-276.

Irvin, R.A. and Stansbury, J., (2004). Citizen participation in decision making: is it worth the effort?. *Public administration review, 64*(1), 55-65.

Irwin, B. J., Wilberg, M. J., Jones, M. L., & Bence, J. R. (2011). Applying structured decision making to recreational fisheries management. *Fisheries, 36*(3), 113–122. https://doi.org/10.1080/03632415.2011.10389083

Ismail Al-Alawi, A., Yousif Al-Marzooqi, N., & Fraidoon Mohammed, Y. (2007). Organizational culture and knowledge sharing: Critical success factors. *Journal of Knowledge Management, 11*(2), 22–42. https://doi.org/10.1108/13673270710738898

Jentoft, S., McCay, B., (1995). User participation in fisheries management: Lessons drawn from international experience. *Marine policy, 19*(3), 227-246

Johnston, F. D., Arlinghaus, R., & Dieckmann, U. (2013). Fish life history, angler behaviour and optimal management of recreational fisheries. *Fish and Fisheries*, *14*(4), 554–579. https://doi.org/10.1111/j.1467-2979.2012.00487.x

Kaemingk, M. A., Bender, C. N., Chizinski, C. J., Bunch, A. J., & Pope, K. L. (2021). Temporal invariance of social-ecological catchments. Ecological Applications, 31(2). https://doi.org/10.1002/eap.2272

Kaemingk, M. A., Chizinski, C. J., Allen, C. R., & Pope, K. L. (2019). Ecosystem size predicts social-ecological dynamics. Ecology and Society, 24(2), art17. https://doi.org/10.5751/ES-10961-240217

Kaemingk, M. A., Hurley, K. L., Chizinski, C. J., & Pope, K. L. (2020). Harvest–release decisions in recreational fisheries. Canadian Journal of Fisheries and Aquatic Sciences, 77(1), 194–201. https://doi.org/10.1139/cjfas-2019-0119

Kallio, H., Pietilä, A. M., & Johnson, M. (2016). Content analysis in qualitative research. Sage publications.

Kane, D. S., Kaemingk, M. A., Chizinski, C. J., & Pope, K. L. (2020). Spatial and temporal behavioral differences between angler-access types. Fisheries Research, 224, 105463. https://doi.org/10.1016/j.fishres.2019.105463

Kane, D. S., Pope, K. L., Koupal, K. D., Pegg, M. A., Chizinski, C. J., & Kaemingk, M. A. (2022). Natural resource system size can be used for managing recreational use. Ecological Indicators, 145, 109711. https://doi.org/10.1016/j.ecolind.2022.109711

Klefoth, T., Wegener, N., Meyerhoff, J., & Arlinghaus, R. (2023). Do anglers and managers think similarly about stocking, habitat management and harvest regulations? Implications for the management of community-governed recreational fisheries. *Fisheries Research, 260,* 106589. https://doi.org/10.1016/j.fishres.2022.106589

Knobloch, K. (2022). Listening to the Public: An Inductive Analysis of the Good Citizen in a Deliberative System. *Journal of Deliberative Democracy 18*(1). doi: https://doi.org/10.16997/10.16997/jdd.955

Krueger, C. C., and D. J. Decker. (1999). The process of fisheries management. Pages 31–59 in C. C. Kohler and W. A. Hubert, editors. Inland fisheries management in North America, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Kvamsdal, S. F., Eide, A., Ekerhovd, N.-A., Enberg, K., Gudmundsdottir, A., Hoel, A. H., Mills, K. E., Mueter, F. J., Ravn-Jonsen, L., Sandal, L. K., Stiansen, J. E., & Vestergaard, N. (2016). Harvest control rules in modern fisheries management. Elementa: Science of the Anthropocene, 4, 000114. https://doi.org/10.12952/journal.elementa.000114

Lackey, R. T. (1998). Seven pillars of ecosystem management. *Landscape and Urban Planning, 40*(1–3), 21–30. https://doi.org/10.1016/S0169-2046(97)00095-9

Lennox, R. J., Sbragaglia, V., Vollset, K. W., Sortland, L. K., McClenachan, L., Jarić, I., Guckian, M. L., Ferter, K., Danylchuk, A. J., Cooke, S. J., Arlinghaus, R., & Twardek, W. M. (2022). Digital fisheries data in the Internet age: Emerging tools for research and monitoring using online data in recreational fisheries. Fish and Fisheries, 23(4), 926–940. https://doi.org/10.1111/faf.12663

Lester, N. P., Sandstrom, S., De Kerckhove, D. T., Armstrong, K., Ball, H., Amos, J., Dunkley, T., Rawson, M., Addison, P., Dextrase, A., Taillon, D., Wasylenko, B., Lennox, P., Giacomini, H. C., & Chu, C. (2021). Standardized Broad-Scale Management and Monitoring of Inland Lake Recreational Fisheries: An Overview of the Ontario Experience. Fisheries, 46(3), 107–118. https://doi.org/10.1002/fsh.10534

Liaw, A., & Wiener, M. (2002). Classification and Regression by randomForest. 2.

Lindenmayer, D. B., Piggott, M. P., & Wintle, B. A. (2013). Counting the books while the library burns: Why conservation monitoring programs need a plan for action. *Frontiers in Ecology and the Environment, 11*(10), 549–555.

Lockwood, M., Davidson, J., Curtis, A., Stratford, E., and Griffith, R. (2010). Governance principles for natural resource management. *Society & Natural Resources, 23*(10), 986-1001. doi:10.1080/08941920802178247

Louppe, G. (2014). Understanding Random Forests: From Theory to Practice. https://doi.org/10.13140/2.1.1570.5928

Lynch, A. J., Sievert, N. A., Embke, H. S., Robertson, A. M., Myers, B. J. E., Allen, M. S., Feiner, Z. S., Hoogakker, F., Knoche, S., Krogman, R. M., Midway, S. R., Nieman, C. L., Paukert, C. P., Pope, K. L., Rogers, M. W., Wszola, L. S., & Beard, T. D. (2021). The U.S. Inland Creel and Angler Survey Catalog (CreelCat): Development, Applications, and Opportunities. Fisheries, 46(11), 574–583. https://doi.org/10.1002/fsh.10671

MacKenzie, C. J., & Cox, S. P. (2013). Building legitimacy of the recreational fishing sector in mixed commercial–recreational fisheries. Ocean & coastal management, 75, 11-19

Marentette, J. R., & Zhang, F. (2022). From means to ends: insights into the operationalization and evaluation of sustainable fisheries. *Marine Policy, 141,* 105087.

Martin, D. R., Chizinski, C. J., & Pope, K. L. (2015). Reservoir Area of Influence and Implications for Fisheries Management. North American Journal of Fisheries Management, 35(2), 185–190. https://doi.org/10.1080/02755947.2014.975299

Martin, J., Runge, M. C., Nichols, J. D., Lubow, B. C., & Kendall, W. L. (2009). Structured decision making as a conceptual framework to identify thresholds for conservation and management. *Ecological Applications, 19*(5), 1079–1090. https://doi.org/10.1890/08-0255.1

McCormick, J. L., & Meyer, K. A. (2017). Sample Size Estimation for On-Site Creel Surveys. North American Journal of Fisheries Management, 37(5), 970–980. https://doi.org/10.1080/02755947.2017.1342723

McDaniels, T., Longstaff, H., & Dowlatabadi, H. (2006). A value-based framework for risk management decisions involving multiple scales: a salmon aquaculture example. *Environmental science & policy, 9*(5), 423-438.

Midway, S. R., Lynch, A. J., Peoples, B. K., Dance, M., & Caffey, R. (2021). COVID-19 influences on US recreational angler behavior. PLOS ONE, 16(8), e0254652. https://doi.org/10.1371/journal.pone.0254652

Mikalsen, K. H., & Jentoft, S. (2001). From user-groups to stakeholders? The public interest in fisheries management. *Marine Policy, 25*(4), 281-292.

Mosel, K. J., Isermann, D. A., & Hansen, J. F. (2015). Evaluation of Daily Creel and Minimum Length Limits for Black Crappie and Yellow Perch in Wisconsin. North American Journal of Fisheries Management, 35(1), 1–13. https://doi.org/10.1080/02755947.2014.963752

National Research Council. (2006). Review of Recreational Fisheries Survey Methods. The National Academies Press. https://doi.org/10.17226/11616

Nebraska Game and Parks Commission. (2023). Fishing. Retrieved from https://outdoornebraska.gov/fish/

Nebraska Game and Parks Commission. (2023). Fish stocking database. Retrieved from https://outdoornebraska.gov/conservation/fisheries-management/fish-stocking-program/fish-stocking-database/

Nebraska Game and Parks Commission. (2023). Fish sampling reports. Retrieved from https://outdoornebraska.gov/guides-maps/fishing-guides-reports/fish-sampling-reports/

Nielsen, L. A. (1999). History of inland fisheries management in North America. Inland fisheries management in North Am*erica, 2nd edition. American Fisheries Society, Bethesda, Maryland, 3-30.*

Nieman, C. L., Iwicki, C., Lynch, A. J., Sass, G. G., Solomon, C. T., Trudeau, A., & van Poorten, B. (2021). Creel Surveys for Social-Ecological-Systems Focused Fisheries Management. Reviews in Fisheries Science & Aquaculture, 29(4), 739–752. https://doi.org/10.1080/23308249.2020.1869696

Nisbet, M. T., Myers, R. A., Binion, G. R., & McDonald, D. (2021). Using Creel Data to Evaluate Blue and Channel Catfish Aggregate Harvest Regulations for Texas Reservoirs. North American Journal of Fisheries Management, 41(S1). https://doi.org/10.1002/nafm.10568

Noble, R. L., Austen, D. J., & Pegg, M. A. (2007). Fisheries management study *design considerations. Analysis and interpretation of freshwater fisheries data. American Fisheries Society, Bethesda, Maryland, 31-49.*

Pascoe, S., Brooks, K., Cannard, T., Dichmont, C. M., Jebreen, E., Schirmer, J., & Triantafillos, L. (2014). Social objectives of fisheries management: What are managers' priorities?. *Ocean & Coastal Management, 98*: 1-10.

Pennino, M. G., Conesa, D., López-Quílez, A., Muñoz, F., Fernández, A., & Bellido, J. M. (2016). Fishery-dependent and -independent data lead to consistent estimations of essential habitats. ICES Journal of Marine Science, 73(9), 2302–2310. https://doi.org/10.1093/icesjms/fsw062

Pergams, O., & Zaradic, P. (2008). Evidence for a Fundamental and Pervasive Shift Away from Nature-Based Recreation. Proceedings of the National Academy of Sciences, 105, 2295–2300. https://doi.org/10.1073/pnas.0709893105

Pollock, K.H., Jones, C.M. and Brown, T.L. (1994) Angler Survey Methods and Their Application in Fisheries Management. American Fisheries Society Special Publication 25.

Pope, K. L., Allen, C. R., & Angeler, D. G. (2014). Fishing for Resilience. Transactions of the American Fisheries Society, 143(2), 467–478. https://doi.org/10.1080/00028487.2014.880735

Pope, K. L., Lochmann, S. E., & Young, M. K. (2010). Methods for Assessing Fish Populations. Nebraska Cooperative Fish & Wildlife Research Unit—Staff Publications. 74. https://digitalcommons.unl.edu/ncfwrustaff/74

Pope, K. L., Powell, L. A., Harmon, B. S., Pegg, M. A., & Chizinski, C. J. (2017). Estimating the number of recreational anglers for a given waterbody. Fisheries Research, 191, 69–75. https://doi.org/10.1016/j.fishres.2017.03.004

Post, J. R., & Parkinson, E. A. (2012). Temporal and spatial patterns of angler effort across lake districts and policy options to sustain recreational fisheries. *Canadian Journal of Fisheries and Aquatic Sciences, 69*(2), 321–329. https://doi.org/10.1139/F2011-163

Post, J. R., Sullivan, M., Cox, S., Lester, N. P., Walters, C. J., Parkinson, E. A., Paul, A. J., Jackson, L., & Shuter, B. J. (2002). Canada's Recreational Fisheries: The Invisible Collapse? Fisheries, 27(1), 6–17. https://doi.org/10.1577/1548-8446(2002)027<0006:crf>2.0.co;2

Potts, W. M., Downey-Breedt, N., Obregon, P., Hyder, K., Bealey, R., & Sauer, W. H. H. (2020). What constitutes effective governance of recreational fisheries?—A global review. Fish and Fisheries, 21(1), 91–103. https://doi.org/10.1111/faf.12417

Prasad, A. M., Iverson, L. R., & Liaw, A. (2006). Newer Classification and Regression Tree Techniques: Bagging and Random Forests for Ecological Prediction. Ecosystems, 9(2), 181–199. https://doi.org/10.1007/s10021-005-0054-1

Pullin, A. S., and Knight. T. M. (2004). Support for decision making in conservation practice: an evidence-based approach. Journal for Nature Conservation 11: 83–90.

Qi, Y. (2012). Random Forest for Bioinformatics. In C. Zhang & Y. Ma (Eds.), Ensemble Machine Learning: Methods and Applications (pp. 307–323). Springer. https://doi.org/10.1007/978-1-4419-9326-7_11

QSR International Pty Ltd. (2018). NVivo (Version 12). https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home

Rahman, H. M. T., Ville, A. S. S., Song, A. M., Po, J. Y. T., Berthet, E., Brammer, J. R., Brunet, N. D., Jayaprakash, L. G., Lowitt, K. N., Rastogi, A., Reed, G., & Hickey, G. M. (2017). A framework for analyzing institutional gaps in natural resource governance. *International Journal of the Commons, 11*(2), 823–853. https://doi.org/10.18352/ijc.758

R Core Team (2024). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Reed, M. S. (2008). Stakeholder participation for environmental management: a literature review. *Biological Conservation, 141*(10), 2417-2431.

Rowe, G. & Frewer, L. J. (2005). A typology of public engagement mechanisms. *Science, Technology, & Human Values, 30*(2), 251–290. https://doi.org/10.1177/0162243904271724

Smith, J. W., & Lamborn, C. C. (2024). The influence of population growth and weather on the value of recreational angling trips within Utah (USA). Fisheries Research, 274, 106976. https://doi.org/10.1016/j.fishres.2024.106976

Solomon, C. T., Dassow, C. J., Iwicki, C. M., Jensen, O. P., Jones, S. E., Sass, G. G., Trudeau, A., van Poorten, B. T., & Whittaker, D. (2020). Frontiers in modelling social–ecological dynamics of recreational fisheries: A review and synthesis. *Fish and Fisheries, 21*(5), 973–991. https://doi.org/10.1111/faf.12482

Sutherland, W. J. (Ed.). (2022). Transforming Conservation: A Practical Guide to Evidence and Decision Making (1st ed.). Open Book Publishers. https://doi.org/10.11647/OBP.0321

Stahr, K., & Knudsen, R. (2018). Evaluating the Efficacy of Using Time-Lapse Cameras to Assess Angling Use: An Example from a High-Use Metropolitan Reservoir in Arizona. North American Journal of Fisheries Management, 38. https://doi.org/10.1002/nafm.10026

Tallis, H., Levin, P. S., Ruckelshaus, M., Lester, S. E., McLeod, K. L., Fluharty, D. L., & Halpern, B. S. (2010). The many faces of ecosystem-based management: Making the process work today in real places. Marine Policy, 34(2), 340–348. https://doi.org/10.1016/j.marpol.2009.08.003

Tucker, C. M., Collier, S., Legault, G., Morgan, G. E., & De Kerckhove, D. K. (2024). Estimating angler effort and catch from a winter recreational fishery using a novel Bayesian methodology to integrate multiple sources of creel survey data. Fisheries Research, 272, 106932. https://doi.org/10.1016/j.fishres.2023.106932

Turner, N. J., Gregory, R., Brooks, C., Failing, L., & Satterfield, T. (2008). From Invisibility to Transparency: Identifying the Implications. *Ecology and Society, 13*(2). https://doi.org/10.5751/ES-02405-130207

Walters, C. J. (2007). Is Adaptive Management Helping to Solve Fisheries Problems? AMBIO: A *Journal of the Human Environment, 36*(4), 304–307. https://doi.org/10.1579/0044-7447(2007)36[304:IAMHTS]2.0.CO;2

Wouters, M. & Hardie-Boys, N. & Wilson, C. (2011). Evaluating public input in national park management plan reviews Facilitators and barriers to meaningful participation in statutory processes. *Science for Conservation 308*. Department of Conservation, Wellington. 5-104.

van der Does, R. & Bos, D. (2021). What Can Make Online Government Platforms Inclusive and Deliberative? A Reflection on Online Participatory Budgeting in

Duinoord, The Hague. *Journal of Deliberative Democracy 17*(1), 48-55. doi: https://doi.org/10.16997/jdd.965

van Poorten, B. T., Arlinghaus, R., Daedlow, K., & Haertel-Borer, S. S. (2011). Social-ecological interactions, management panaceas, and the future of wild fish populations. Proceedings of the National Academy of Sciences of the United States of America, 108(30), 12554–12559. https://doi.org/10.1073/pnas.1013919108

van Poorten, B. T., & Brydle, S. (2018). Estimating fishing effort from remote traffic counters: opportunities and challenges. Fisheries Research, 204, 231-238.

van Poorten, B. T., & Camp, E. v. (2019). Addressing Challenges Common to Modern Recreational Fisheries with a Buffet-Style Landscape Management Approach. *In Reviews in Fisheries Science and Aquaculture 27*(4), 393–416. https://doi.org/10.1080/23308249.2019.1619071

van Poorten, B. T., & MacKenzie, C. J. A. (2020). Using Decision Analysis to Balance Angler Utility and Conservation in a Recreational Fishery. *North American Journal of Fisheries Management, 40(*1), 29–47. https://doi.org/10.1002/nafm.10377

Vecchio, J. L., Bubley, W. J., & Smart, T. I. (2023). Increased fishery-independent sampling effort results in improved population estimates for multiple target species. Frontiers in Marine Science, 10. https://doi.org/10.3389/fmars.2023.1192739

Ward, H. G. M., Allen, M. S., Camp, E. V., Cole, N., Hunt, L. M., Matthias, B., Post, J. R., Wilson, K., & Arlinghaus, R. (2016). Understanding and Managing Social–Ecological Feedbacks in Spatially Structured Recreational Fisheries: The Overlooked Behavioral Dimension. Fisheries, 41(9), 524–535. https://doi.org/10.1080/03632415.2016.1207632

Yang, Y., & Su, Y. (2020). Public Voice via social media: Role in cooperative governance during public health emergency. *International Journal of Environmental Research and Public Health, 17*(18), 6840. https://doi.org/10.3390/ijerph17186840

Yue, C. A., Men, L. R., & Ferguson, M. A. (2019). Bridging transformational leadership, transparent communication, and employee openness to change: The mediating role of trust. *Public Relations Review, 45*(3), 101779. https://doi.org/10.1016/j.pubrev.2019.04.012

Appendix A.

Interview Participant Consent Form

SFU RESEARCH ETHICS

Application number: 30000930

Consent Form

STUDY TITLE

Optimizing Monitoring Efficiency in Recreational Fisheries

STUDY TEAM

Principal Investigator: Professor Brett van Poorten, Resource and Environmental Management Department,

Student Lead: Kelcy Tousignant, Candidate: Masters in Resource Management,

External Research Collaborator: Kevin Pope Ph.D., Nebraska Cooperative Fish, and Wildlife Unit, University of Nebraska-Lincoln. Dr. Pope will help facilitate and organize focus group sessions

INVITATION AND STUDY PURPOSE

Why are you invited to take part in this study? Why are we doing this study?

- You are being invited to take part in this focus group because you are involved in the planning and decision-making of inland recreational fisheries. The focus group intends to inform a future model that will be used to determine the optimal creel monitoring frequency of inland recreational fisheries
- This research aims to understand the decision process of fisheries managers and integrate this into a monitoring plan to improve the resilience and performance of a recreational fisheries landscape. We are inviting people like you who have experience managing recreational fisheries to help us.

VOLUNTARY PARTICIPATION AND WITHDRAWL

You are invited to participate in a focus group regarding the management and monitoring of recreational fisheries.

- Your participation is voluntary. You have the right to refuse to participate in this study.
- If you decide to participate, you may withdraw from the study without any negative consequences to the education, employment, or other services to which you are entitled or are presently receiving.
- Following the focus group, you will have two weeks to add or withdraw any information you have given. After two weeks information cannot be removed as no references will be made to which individuals gave what responses.
- All responses in the focus group will be kept confidential.

1

Consent Form-- version 2 dated 4 April 2021

STUDY PROCEDURES

What happens if you say, "Yes, I want to participate in the focus group"?

If you say 'Yes,' here is how we will do the study:

- We will ask you to participate in a recorded Zoom meeting.
- You will be asked to participate for one hour.
- We will ask you about how and why fishery management decisions are made, what may cause a regulation change, and how you will monitor regulation changes through time.
- If you decide to take part in this research study, you will be recorded, and your responses will be compiled later. Your identity will be kept confidential, and no responses will be tied back to any individual.

CONFIDENTIALITY

- Your confidentiality will be respected. Information that discloses your identity will not be released. Insights gained from the focus group will inform future areas of study but will not be directly linked to individuals.
- Participants will not be identified by name in any reports of the completed study.
- As the study is a focus group, full confidentiality cannot be maintained in a group setting. We ask participants not to discuss the content of the focus group with people outside the group; however, we can't control what participants do with the information discussed.
- Recorded transcripts from the focus groups will be stripped of participants' names.
- Participants can use aliases during the focus group if they choose.
- Participants can leave their cameras off during the Zoom focus group.

DATA SECURITY

- The recorded Zoom sessions and complied answers will be kept for a maximum of 2 years.
- The data will be stored on Kelcy Tousignant's personal SFU OneDrive account which is password protected and requires a multi-factor identification code.
- Any data you provide may be transmitted and stored in countries outside of Canada, as well as in Canada. It is important to remember that privacy laws vary in different countries and may not be the same as in Canada.

FUTURE USE OF THE RESEARCH DATA

- The information gained from the focus group will inform a future anonymous stated choice survey that you may be asked to participate in.

STUDY RESULTS

- The results of this study will be reported in a graduate thesis and may also be published injournal articles and books.
- The main study findings may be presented at academic conferences**.**

CONTACT FOR INFORMATION ABOUT THE STUDY

Who can you contact if you have questions about the study?

- Student Lead: Kelcy Tousignant

CONTACT FOR COMPLAINTS

Who can you contact if you have complaints or concerns about the study?

- If you have any questions or concerns about the focus group, your participation, your consent, or other general inquiries please contact Kelcy Tousignant
- If you have any concerns about your rights as a research participant and/or your experiences while participating in this study, please contact the SFU Office of Research Ethics

PARTICIPANT CONSENT AND SIGNATURE

Taking part in this study is entirely up to you. You have the right to refuse to participate in this study. If you decide to take part and later change your mind, you can withdraw from the study at any time without giving a reason and without any negative impacts.

- Your signature below indicates that you have received a copy of this Consent Form for your records.
- Your signature indicates that you consent to participate in this study.
- You do not waive any of your legal rights by participating in this study.

Participant Name: ....

Participant Signature: ....

Date (yyyy/mm/dd): ....

Appendix B.

Semi-structured Interview Questions

SFU RESEARCH ETHICS

Application number: 30000930

Structured-Interview Questions

General information about Nebraska Fisheries

1. What are the main "types" of reservoirs you would potentially monitor/manage differently? (Small, medium, large?)

2. What top three species are you concerned with (most concerned to least)?

3. What top three reservoirs are you most concerned with?

4. What reservoir is a good example of a prototype fishery?

Monitoring Data

5. What are the main sources of monitoring data you use to make management decisions?
    a. Why are you doing these chosen surveys?
    b. Do their results change management actions? – do you make/implement management actions based on survey results?

Triggers for Management Actions

6. How do you define a declining fishery?

7. What are general triggers you would see that would cause you to implement a management action?
    a. What are the most critical indicators/triggers?

       ** management target:

8. What are the top 2-3 triggers you would see in **creel survey data** that would cause you to start a management action?
    b. Are there other data sources that you would combine with the creel data to make your decisions?

Resulting Management Actions

1

9. What management actions would you take in a response to a declining fishery?

10. How long do you anticipate the management action to take place to resolve the issue? How would you detect that the issue is resolved?
    a. AIM: *To identify how a management action would be deemed 'successful'.*

11. Top three concerns for managing your fishery?

12. What would you see as the perfect fishery?
    a. AIM: *Determine their goal or management objective.*

Appendix C.

Codebook

Code Level	Name	Description
1	Covid	Mentions of Covid-19
1	Fish Management	Fish management procedures in Nebraska
2	Creel Surveys	Mentions of creel surveys
3	Frequency of Creel Surveys	How often creel surveys are performed
3	Value of Creel Surveys	What individuals think of creel surveys and their value
2	Examples	examples of management actions that have been put in place
3	Bag limit changes	Examples of bag limit changes
3	habitat change	Examples of habitat changes
3	other	Other examples of fish management
3	Slot limit changes	Examples of slot limit changes
3	stocking	Examples of stocking frequency or quantity changes
2	How does management work	big picture catch all on people's opinions on how fish management works in Nebraska
2	Information Flow	the information transfer
2	length of assessment after mgmt. change	How long a waterbody or area is monitored after a management/regulation change to determine if the change is positive, or needs to be corrected
1	Management Concerns	General concerns management currently has
2	Fishing Pressure	the amount of fish on a reservoir
2	Prioritizing resources	Ability to distribute resources, how to prioritize them
1	Standardized Surveys	details of their standardized surveys, how they are run, frequency, what they look for in them
2	Consistency and Timing	How often standardized surveys are conducted and what time of year they are conducted
2	Gear types and fish targets	What tools are used in standardized surveys and what tools are used for specific fish species
1	Management Objective	items that could be considered a management objective for the Nebraska government
2	Angler Satisfaction	included: angler satisfaction, diverse fishing opportunities, access to fishery, and trophy fish
2	Assumed Objectives	objectives taken from other questions, for instance, what is an indicator of a declining fishery? If the opposite is true, then it meets the objective. Objectives I have interpreted from the interviewee's answers
3	Angler Satisfaction	the reward that recreational anglers receive from their experiences

3	Cost Effective	producing good results without costing a lot of money
3	Diverse Fishing Opportunities	providing diverse angling opportunities, and many different species of fish to please different angler types
3	Fish Abundance and Catch metrics	use of fish catch rates to determine the "health" of the system. used to standardize management objectives
3	Providing Trophy Fish	Specimens of game fish whose measurements (body length and weight) are much higher than the species' average
3	Self-Sustaining populations	populations that will continue without stocking
2	Fish Population Health	includes: habitat, self-sustaining populations, fish abundance and catch metrics,
2	Individual ideal goals	from the question "What is the perfect fishery?"; personal goals around fisheries management
3	Access to fishery	how accessible is the fishery? use of shore fishing, docks, boat ramps, etc.
3	Angler Satisfaction	the reward that recreational anglers receive from their experiences
3	Diverse fishing opportunities	providing diverse angling opportunities, and many different species of fish to please different angler types
3	Habitat Quality	what the surrounding area is like and the level of water quality
3	Healthy Populations	specific to fish populations, good sizes and abundance
3	Self-sustaining populations	populations that will continue without stocking
3	Trophy fish	Specimens of game fish whose measurements (body length and weight) are much higher than the species' average
2	Setting Objectives	How are management objectives set
1	Political Pressure	Instances of politics influencing management decisions, structure, or relationships
1	Triggers for Management Action	a change that would instigate a management action (i.e catch limits, fishing effort limits, restrictions on the size of fish that can be caught or retained, gear restrictions, or access controls (e.g. licences))
2	Combo of data and angler input	both angler input and standardized data are combined to trigger a management action.
2	Creel Specific Trigger	triggers that are specifically seen in creel surveys
3	Angler Comments	additional information provided by an angler, including general comments, answers to opinion questions and additional qualitative data
3	Catch rates for target species	Catch per angler hour for each target species
3	Fishing Pressure	hours spent fishing
3	Length at harvest	length of fish at the time of harvest. maybe an indicator of the number of "trophy"-sized fish

2	Habitat degradation	decrease in habitat quality either by biotic (algal blooms, eutrophication, invasive species) or abiotic (reservoir deterioration)
2	Invasive Species Presence	the presence of invasive or nuisance species in a waterbody
2	opinion Management Actions based on Data	asking if management actions are solely based on data collected from standardized surveys or from creel surveys
3	Middle-ground mgmt. use data	it is less clear how it is being used
3	No mgmt. use data	management actions not based on data
3	Yes mgmt. use data	management actions are based on data
2	Political or Angler Pressure for Management Action	specific pressure from the government or from constituents to change policy, or enact policy
3	look closer at the data	political pressure leads to biologists looking closer at the data to either confirm or deny public opinions
3	no, they don't impact	political or angler opinions don't impact management decisions
3	yes, they impact	political or angler opinions greatly impact management decisions
2	Standardized data	data gathered uniformly over many years by a group of professionals
3	Fish abundance and condition	looking at the "health" of the population. Good-sized fish not stunted. Population size that can support the growth of trophy-sized fish. Not too few, not too many. Includes CPUE. Gathered from standardized surveys
4	examples	examples of actions taken based on abundance and condition
4	Size structure changes	looking at previous surveys and observing how the length-at-age has changed, declining, or increasing, stable. Have the large fish been taken out, or are there too many small fish to support the growth of larger fish