VALUES-BASED COMMUNICATION STRATEGIES FOR PROMOTING CONSERVATION BEHAVIOR IN AQUATIC ECOSYSTEMS

BY

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DISSERTATION

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ABSTRACT

Aquatic invasive species (AIS) pose negative threats to social-ecological systems on a global scale. The risk of AIS transport by recreational anglers and boaters remains high, thus garnering research attention on how to encourage prevention behaviors. My dissertation seeks to build knowledge of the relationships among social psychological factors (e.g., values, risk perceptions) that shape human decision-making and messaging campaigns about AIS management in freshwater ecosystems. In my first study, I conducted a systematic review to understand how language was used in academic literature on AIS management over a 10-year period across the United States. I found that language use throughout 278 articles was predominantly negative and tied to social and ecological contexts surrounding biological invasions. These articles featured species-centered and human-centered message frames in relatively equal proportions. I also found that the use of terminology (e.g., 'invasive' vs. 'introduced') aligned with the stage of invasion, study objectives, and the biodiversity context of the study site. In my second study, I assessed the role of values and risk perceptions in predicting angler behavior through a survey of recreational anglers (n=788) across three U.S. states. Results of a manifest variable path model showed that risk perceptions directly predicted behavior, and that anglers' biospheric values were strong and foundational to AIS risk perceptions. Further, while personal risk perceptions were lower than social risk perceptions, they had a stronger relationship with AIS prevention behavior, in that high personal risk perceptions were associated with more frequent participation in prevention behavior. Building on these results in my third study, I surveyed recreationists across Illinois (n=507) and conducted a message experiment to test the efficacy of values-framed messages. I found that AIS outreach messages framed to reflect self-transcendent values were processed more deeply (i.e., resulted in high elaboration) by recreational water users, indicating

that values framing could be an effective tool for enhancing outreach messages. Together, the results of these three studies build theoretical knowledge of factors driving AIS-prevention behavior and inform communication strategies for promoting conservation initiatives that minimize the spread of AIS.

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CHAPTER 1: GENERAL INTRODUCTION AND REVIEW OF THE LITERATURE

1.1. Human Behavior and Aquatic Invasive Species

Aquatic invasive species (AIS) pose risks to social-ecological systems, with the potential to alter habitat, out-compete native species for food, and interfere with human activity (Gallardo et al., 2016). Eliminating a species once it has invaded is virtually impossible (Vander Zanden & Olden, 2008), thus preventing the spread of AIS is a priority for management agencies (Heck et al., 2016). Management interventions include regulations that minimizing the risk of invasion via shipping vectors (Firestone & Corbett, 2005) and the bait trade (Killian et al., 2012; Nathan et al., 2014). Additionally, aquatic recreationists may inadvertently transport AIS on watercraft and equipment moved from one waterbody to another (Connelly et al., 2016). Thus, AIS spread can also be prevented by encouraging aquatic recreationists to clean their watercraft and equipment after leaving a waterway (Pradhananga et al., 2015; Seekamp, Mayer, et al., 2016).

There have been a number of public outreach campaigns to raise awareness of the risks posed by AIS, and to encourage aquatic recreationists to clean their boat and equipment to be sure they are not spreading these species (Cole et al., 2016; Funnell et al., 2009). Past work has evaluated campaigns including “Stop Aquatic Hitchhikers!”, “Be a hero transport zero” and “Habattitude” (Kemp et al., 2017; Seekamp, McCreary, et al., 2016), and examined the efficacy of various sources in disseminating information regarding AIS, including movie theaters (Howell & Genskow, 2014; Shaw et al., 2014), aquarium and garden stores (Funnell et al., 2009), and media, events, and personal contacts (Cole et al., 2016). Thus, there is evidence that outreach campaigns have successfully raised awareness about AIS (Cole et al., 2016; Eiswerth et al., 2011; Seekamp, McCreary, et al., 2016). However, while participation in prevention behaviors has increased modestly, necessary levels for reducing the risk of AIS transport have not been met

(Cole et al., 2019). In other words, many people have become aware of the issue, but have not taken action. This phenomenon, referred to as the "knowledge-action gap" (Kollmuss & Agyeman, 2002), has sparked calls for research investigating the drivers of behavior relating to AIS and development of campaigns that move beyond knowledge and awareness to stimulate deeper psychological processes, such as values (Cole et al., 2019; van Riper et al., 2018).

1.2. Message Framing and Communication

Message framing is a means to make complex topics such as the spread of AIS more understandable and to help people develop their knowledge of the issue (Chong & Druckman, 2007; Geise & Baden, 2015). Communication research has multiple lines of work regarding message framing, most heavily emphasizing gain and loss framing (Shen & Bigsby, 2013), but also including narrative and statistical messages (Feeley et al., 2006; Kim et al., 2017) and disparity and progress frames (Nicholson et al., 2008). Message framing has been defined as specifically referring to gain and loss framing, which explores the effects of highlighting either the benefits one would receive from engaging in a behavior, or the costs they would experience from not participating (Shen & Bigsby, 2013). Though much work has been done in this area, meta-analysis has revealed that there is little to no effect in whether gain or loss frames are used, suggesting other types of framing should be pursued (O'Keefe & Jensen, 2009).

Normative framing is a robust area of research that has advanced the study of conservation behavior (Abrahamse & Steg, 2013; Niemiec et al., 2021; Shultz et al., 2008). Normative frames create social pressure to engage in desired behavior by highlighting how prevalent the behavior is or how it is expected by others. This type of framing has been successful in encouraging conservation behavior in the short term (Cialdini, 2003; de Groot et

al., 2013; Goldstein et al., 2008; Misra et al., 2013) and helping to understand science participation (Groves et al., 1992; Groves et al., 2000). However, there are also examples where normative framing has been unsuccessful (Silva & John, 2017; Wallen & Kyle, 2018). Furthermore, there is evidence that effects of normative framing may not be long lasting, as norms can quickly change and must be "activated" in a given situation to have an impact (Cialdini et al., 1991). Therefore, framing messages in line with more stable psychological processes, such as values, may have a longer lasting impact and is thus gaining traction as a method for stimulating public support of an issue in the long term (Nisbet & Mooney, 2007).

Message framing has been a center of debate among invasion biologists, wherein some researchers argue for using vivid language to engage the public whereas others suggest such language impedes scientific objectivity (Brown & Sax 2004, 2005; Cassey et al., 2005). Given the negative impacts that invasive species have on the environment, causing millions of dollars in impacts (Lovell et al., 2006), some researchers argue for adopting a position of advocacy regarding non-native species, even before the species is confirmed to be invasive (Larson, 2007; Lodge & Shrader-Frechette, 2003). With this approach, the use of metaphors is ideal as they allow the topic to be easily understandable and convey the importance of the work to general audiences (Kaufman et al., 2003; Verbrugge et al., 2016). Communication research has shown that metaphors have a high persuasive capacity (Sopory & Dillard, 2002), indicating that they could be used to generate support for AIS policy. On the other hand, some researchers argue that science must be framed objectively to gain public trust and avoid politicizing issues by advocating for policies (Kueffer & Larson, 2014). Further, some studies have shown that people react negatively to strong language, which ultimately erodes support for conservation goals (Keulartz & van der Weele, 2008). In other words, there is concern that messages that take a

strong stance against invasive species may cause reactance (Brehm, 1966) and result in people rejecting the message, deeming it biased and untrustworthy. Although some research has addressed the impacts of framing in science communication more broadly (Jang & Hart, 2015; Raymond et al., 2013; Spence & Pidgeon, 2010), this body of research has largely focused on understanding lay perspectives. Moreover, there remains a dearth of knowledge about how scientists use frames to influence the discourse of invasive species management.

1.3. Values

Understanding the values of recreational water users may help explain adoption of AIS-prevention behaviors. Values, defined as guiding principles in life (Rokeach, 1973), are enduring drivers of pro-environmental behavior (Steg and de Groot, 2012; Steg & Vlek, 2009; Stern et al., 1999). Thus, numerous theoretical frameworks to study values have been developed across the environmental social sciences (Chan et al., 2018; Dietz et al., 2005; Inglehart & Baker, 2000; Kenter et al., 2019; Schwartz, 1992; Steg et al., 2014; van Riper et al., 2018). People with strong biospheric values (i.e., concern with environmental production and unity with nature) are more likely to engage in behaviors that benefit the environment (Liobikiene & Juknys, 2016; Schultz et al., 2005). Past research has indicated a similar effect of altruistic values (i.e., equality, justice, and peace), in that people with high concern for others are more likely to engage in pro-environmental behavior (van Riper & Kyle, 2014); in contrast, egoistic values (i.e., power and influence) tend to be related to lower levels of engagement in conservation activities (de Groot & Steg, 2008). Though individual values have the potential to provide key information on deep drivers of behavior (Schwartz, 1992), they have received limited attention in the context of aquatic recreation and AIS (van Riper et al., 2020).

Values may also be applied in AIS outreach campaigns that seek to encourage AIS-prevention. Past work has indicated that value appeals are effective (Peloza & White, 2009), and that biospheric messaging is perceived as more relevant to campaigns about environmental issues, in contrast to other types of values (Hansla, 2011). Values framing can be further enhanced by identifying the values of a target audience and imbuing environmental outreach campaigns with content aligned with those values (Lagomarsino et al., 2020). For instance, to appeal to people who value the well-being of future generations, messages can seek to highlight how AIS prevention will protect desired fishing sites for future generations. The limited work that has tested values-alignment in messaging has focused on how attitudes are affected (Arp, 2018), as well as an audience's ability to discern argument strength (von Borgstede et al., 2014). Further research is needed to understand how values-aligned messages may affect beliefs, as well as the mechanisms through which such messaging has an influence. Thus, imbuing outreach messages with values in the context of AIS is a critically important area of study as it stands to generate key insights for mitigating and adapting to human impacts on the environment.

1.4. Risk Perceptions and Protection Motivation Theory

The study of risk is relevant to AIS given the widespread impacts that may result from a species introduction (Gallardo et al., 2016). Risk perceptions, defined as beliefs about the severity of possible harms to an entity (Rogers, 1975), have been shown to positively predict engagement in environmental behavior in a variety of contexts (Kothe et al., 2019; O'Connor et al., 1999). People tend to perceive risks to others (i.e., social risks) to be higher than risks to themselves (i.e., personal risks) (Smith & Leiserowitz, 2012; van der Linden, 2015; van Riper et al., 2016). There has been limited research on risk perceptions regarding AIS (Estevez et al.,

2015); however, relationships among social and personal dimensions of risk and angler behavior have yet to be studied.

Protection Motivation Theory posits that behavioral responses to threats are rooted in risk perceptions and efficacy, defined as one's perceived capacity to engage in a preventative behavior and their belief that the behavior will effectively reduce the risk threat (Rogers, 1975). There is a large body of work guided by this theory in the communication field (Mongeau, 2013), and a growing interest in applying Protection Motivation Theory to environmental issues (see Kothe et al., 2019 for a review). For instance, Protection Motivation Theory has been used to predict and measure responses to campaigns regarding earthquake preparedness (Mulilis & Lippa, 1990), water conservation (Kantola et al., 1983), and endangered species conservation (Shelton & Rogers, 1981). More recently, Protection Motivation Theory has been used as a framework for wildfire studies, providing a model for predicting whether homeowners will implement fire-protection measures (Hall & Slothower, 2009). The framework has not been applied to invasive species research, though past work has noted its relevance for understanding human interactions with invasive species (Hart & Larson, 2014; McLeod et al., 2015), especially given that most invasive species communication seeks to make people aware of risks. Further, research has yet to explore how risk and efficacy beliefs are impacted by values-framed messages. Building on these propositions, empirical testing of Protection Motivation Theory in response to AIS will provide insights on both angler behavior and communication strategies.

1.5 Elaboration Likelihood Model

Integrating perspectives from several fields and understanding responses to various message framing approaches requires a strong grounding in message processing and response

frameworks, such as the Elaboration Likelihood Model. The Elaboration Likelihood Model reflects how people process messages along a continuum from heuristic to systematic (Petty & Cacioppo, 1986) and is used the evaluation of behavior change approaches, including those in environmental contexts (Manca et al., 2019). Though addressing similar concepts as Kahneman's elastic capacity model (Kahneman, 1973), the elaboration likelihood model is a distinct line of work that focuses on persuasive outcomes (Petty et al., 1987). High elaboration is defined as systematic thinking about information relevant to the persuasive topic, whereas low elaboration is characterized by the use of mental shortcuts and heuristics to form opinions towards the message (Petty & Cacioppo, 1986). High elaboration is ideal because it tends to create stronger attitudes, and longer-term effects (O'Keefe, 2013). Thus, identifying ways to induce high elaboration is a key area of study.

High elaboration tends to occur when people are motivated to engage with the message. For instance, issue-involvement (i.e., personal relevance of an issue to one's life), has been shown to lead to high elaboration (Petty et al., 1983). Likewise, messages that are tailored to individual characteristics have induced high elaboration (Kroeze et al., 2006). Framing messages in line with values may have a similar effect, in that messages that resonate with their core principles may lead to motivation to explore the message, and thus high elaboration. However, it alternatively could result in low elaboration if people recognize the language as reflecting their values, trust the message, and move on without engaging in deep thinking. Thus, research is needed to understand the mental processing that occurs when people receive a message that aligns with their values.

The Elaboration Likelihood Model has been sparsely used to guide fisheries research, though its use to help solve recreation and tourism related problems has been suggested (Petty et

al., 1992). A handful of studies have made reference to the model in explaining angler behavior (Arlinghaus, 2005; Cooke et al., 2013) though few have used the model as a framework for research in testing the efficacy of angler outreach campaigns (e.g., Shaw et al., 2014). As a message processing theory, the Elaboration Likelihood Model is particularly appropriate for work bridging the gap between communication and fisheries research, as it provides an explanation for message responses.

1.6. Research Objectives and Dissertation Structure

The overarching objective of this dissertation was to understand relationships among message framing, social and ecological contexts, values, and risk perceptions to ultimately guide the design of outreach materials for engaging recreational water users in AIS risk prevention. Drawing on theories foundational to these relationships, including Protection Motivation Theory (Rogers, 1975), the Elaboration Likelihood Model (Petty & Cacioppo, 1986), and Value-Belief-Norm Theory (Stern, 1999), I developed three sub-objectives. First, I aimed to understand how message frames were used in academic writing, by characterizing language use in peer-reviewed articles published on non-native species management. Second, I sought to assess the drivers of AIS behavior among anglers by analyzing how values and risk perceptions predict this behavior. Finally, combining insights gained from the first two studies, my third objective was to assess the effectiveness of values-framing for AIS outreach materials. The problem of AIS is situated at the nexus of multiple disciplines, thus, to respond to my objectives, I adopted an interdisciplinary approach and extended theories from conservation psychology, communication, and invasion biology.

My dissertation is comprised of three studies that each contribute to the goal of understanding AIS communication and ultimately promoting conservation outcomes. In study one, I use a systematic literature review to understand how language is used in academic literature regarding invasive species management. After a systematic screening and selection process, 278 articles were selected for analysis, and coded to identify the language used, and the social and ecological characteristics of the study to assess their relationship. In my second study, I use a survey of recreational anglers (n=788) to understand the drivers of angler behavior relevant to the spread of aquatic invasive species. A manifest variable path model was used to assess relationships between individual values, risk perceptions, and pro-environmental behavior related to AIS. My final study aimed to apply insights gained from the first two studies by a message experiment testing the efficacy of values-framed messages. Illinois recreational water users were solicited through a Qualtrics panel (n=507). Each participant was asked to review a message and then report message evaluations and beliefs about AIS and prevention behaviors. Together, these three studies bridge the gap between conservation psychology, communication, and invasion biology, and provide suggestions for designing outreach materials that will be most effective in promoting conservation behavior.

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CHAPTER 2: WORDS MATTER: A SYSTEMATIC LITERATURE REVIEW OF COMMUNICATION IN NON-NATIVE AQUATIC SPECIES LITERATURE

2.1. Abstract

How scientists communicate can influence public viewpoints on invasive species. In the scientific literature, some invasion biologists adopt neutral language, while others use more loaded language, for example by emphasizing the devastating impacts of invasive species and outlining consequences for policy and practice. An evaluation of the use of language in the invasion biology literature does not exist, preventing us from understanding which frames are used and whether there are correlations between message framing in scientific papers and local environmental impacts associated with invasive species. Thus, we conducted a systematic literature review of 278 peer-reviewed articles published from 2008-2018 to understand communication styles adopted by social and natural scientists while reporting on aquatic non-native species research. Species-centered frames (45%) and human-centered frames (55%) were adopted to nearly equal degrees. Negative valence was dominant in that 81.3% of articles highlighted the negative risks and impacts of invasive species. Additionally, the use of terminology was found to broadly align with stage of invasion, in that "invasive" was most commonly used except when the research was conducted at early stages of invasion, when "non-native" was most commonly used. Terminology use therefore enables readers of scientific papers to infer the status and severity of ongoing invasions. Given that science communication within the peer-reviewed literature affects public understanding of research outcomes, these findings provide an important point of reflection for researchers.

2.2. Introduction

Biological invasions pose escalating threats to natural ecosystems, economies, and human well-being on a global scale (Pyšek et al., 2020), although impacts vary by taxon, ecosystem and region (Wolter & Röhr, 2010). There is a longstanding debate in invasion science of how to appropriately communicate about invasive species so as to shape public understanding of the issue (Brown & Sax, 2004, 2005; Cassey et al., 2005; Verbrugge et al., 2016; Clarke et al., 2020). Several papers (Larson et al., 2005; Janovsky & Larson, 2019), have analyzed the use of militaristic language (i.e., referring to a "battle" or "war" against invasive species), which seeks to emphasize the urgency of responding to the risks of invasive species. Although not necessarily supporting militaristic language, several researchers agree that within published literature, scientists should advocate for the control of non-native species, even if it remains uncertain whether the species has negative impacts (Lodge & Shrader-Frechette, 2003; Larson, 2007). By contrast, other researchers believe objectivity is most important, and have asserted that value-laden terms such as "battle" introduce bias that diminishes trust in science (Lackey, 2007; Keulartz & van der Weele, 2008). Further, when management decisions associated with non-native species are reported in the popular press, reporters often present counterarguments (Kueffer & Larson, 2014) that condemn such decisions accusing them to be arbitrary and xenophobic (Comaroff & Comaroff, 2010; Verbrugge et al., 2016; Sagoff, 2017). This reporting outcome is problematic because it creates controversy after management decisions are implemented and erodes support for the scientific process. In short, the way scientific results are communicated strongly affects public understanding of research outcomes and is thus important to study (Nisbet & Scheufele, 2009; Fischhoff, 2013).

Investigations of language use in literature can prove insight into the reasons *why* different framings are used across the social and natural sciences. It is possible that loaded language, such as militaristic framing, is a response to the degree of risk associated with invasive species (Otieno et al., 2014), whereas less provocative scientific communication styles may be adopted when the likelihood of invasions is lower, or when a management approach shifts from eradication to resilience (Druschke et al., 2016). Another possibility is that scientists may adopt vivid language to engage and capture the attention of readers (Simberloff, 2006), without considering potential consequences of their language use. Militaristic framing remains common in news coverage (Clarke et al., 2020), lending support to the idea that such vivid language is believed to be appealing to the public. Evaluating the reasons why researchers across different fields of study communicate in specific ways highlights disciplinary norms of language use and the potential consequences that ensue from such word choices.

There are three fundamental facets of invasive species communication. First, scientific results – among all other forms of information – are interpreted through message frames (Nisbet & Mooney, 2007). While framing underpins long-standing debates among invasion biologists over the merits of dramatic vs. less dramatic language, a comprehensive assessment of message framing related to aquatic non-native species has yet to be conducted. Message framing is defined as a phenomenon that occurs as people develop an understanding of a concept and communicate their interpretation (Chong & Druckman, 2007). Although frames are often expressed and processed subconsciously, they can be intentionally invoked to make concepts comprehensible to a specific audience or to persuade people to change their behavior (Lakoff, 2010). For example, framing of environmentalism has become particularly important to shape how information is exchanged because this topical area is increasingly politicized (Druckman,

2017) and interpreted using incomplete knowledge and heuristics (Preston et al., 2015). Different opinions on the dangers of biological invasions and the role of scientists (Young & Larson, 2011) have resulted in divergent message frames used in both academic literature and environmental outreach. For instance, narratives that position organisms as active agents of change are particularly adept at cultivating higher risk perceptions and greater willingness to take action (Hart & Larson, 2014). Although past work has identified common frames used to discuss non-native species (e.g., Clarke et al., 2020), it has not quantified patterns in frame use and investigated the possible reasons why particular language is chosen.

A second fundamental facet of communication is valence – defined as the positive, neutral, or negative tone adopted – which is considered highly influential in shaping judgement and behavior (Russell, 2003). Articles written with a positive valence may celebrate biodiversity brought about by new species (Keulartz & van der Weele, 2008; Schlaepfer, 2018) or highlight learning opportunities provided by non-native species (Larson, 2010). Ostensibly neutral valences position humans as passive observers as nature takes its course (Kueffer & Larson, 2014; Shackleton et al., 2019), while negative valences highlight the problems posed by invasive species and may frame them as being inherently "bad" and management efforts as "waging war" against biological invasions. Previous research on the effects of valence is mixed, in that positively positioned information has been more persuasive (Muchnik et al., 2013) and encouraged trustworthiness (Lim & van der Heide, 2014), whereas negative comments have caused reactance or unpleasant motivational arousal (East et al., 2008). Further, repeated exposure to communication campaigns can lead to message fatigue, a negative response to the messages based on perceived overexposure, redundancy, tedium, and a feeling of being burned (So et al., 2017). The risk of message fatigue can be mitigated by using messages that take a

more positive approach (Guan & Monahan, 2017). However, there are competing arguments that negative information is more memorable (Baumeister, 2001) and helps contribute to higher risk perceptions (Otieno et al., 2014). Although there are divergent opinions among scientists on whether it is their role to advocate for particular management outcomes (Young & Larson, 2011), the way scientists communicate, even if opting to be as objective as possible, influences public understanding of research results (Nisbet & Scheufele, 2009; Fischhoff, 2013). Thus, considering how valence is used in peer-reviewed literature is an important point for research and reflection.

Lastly, terminology and the associated definitions of key concepts are central to non-native species communication. Debate among scientists regarding the precise uses of various terms, including "invasive," has been ongoing for decades (Colautti & MacIsaac, 2004; Copp et al., 2005; Blackburn et al., 2011). For instance, many terms are used to describe a species that exists outside of the region in which it evolved. These terms include non-native, foreign, nonindigenous, alien, exotic, invasive, and exotic. Some of these terms are technically incorrect and others can easily be misinterpreted, thus impeding collaboration among scientists and stakeholder understanding of invasive species prevention and management (Richardson et al., 2000). Invasion science is generally replete with value-laden differences in communication strategies (Kapitza et al., 2019), and consistency in the conceptualization of key terms will increase the likelihood that all relevant perspectives are considered, mutual acceptability is increased, and misunderstandings are avoided (Coulatti & Richardson, 2009; Iannone et al., 2021).

2.2.1. Conceptual Model that Guided this Study

Messaging frames, valence and terminology used in the invasion science literature may be influenced by a variety of factors (Figure 2.1). Included among these factors are: (1) the disciplinary approach, (2) the study focus, (3) the stage of invasion describing the study population, (4) the transportation vector addressed, and (5) the biodiversity context in which the study is based. Empirical insights into the relationships across these characteristics will illuminate the underlying reasons why different communication strategies are used throughout the aquatic invasive species literature.

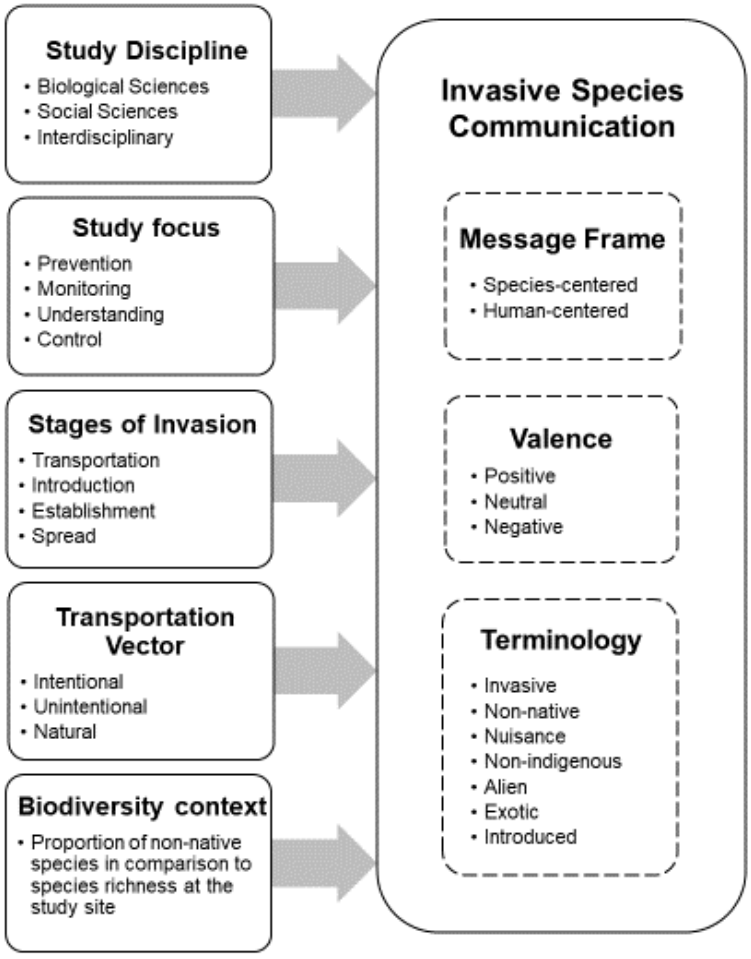

Figure 2.1. Illustration of relationships explored in this study, including five explanatory variables (i.e., study discipline, study focus, stages of invasion, transportation vector, and biodiversity context) that influenced three facets of invasive species communication (i.e., message frame, valence, terminology).

Characteristics of authors conducting and publishing research on non-native species may also influence the frameworks adopted, and, in turn, their strategy for communicating scientific results. Indeed, previous research has indicated that communication is influenced by the professional background of scientists and worldviews that emerge from different disciplines (Hakkarainen et al., 2020). For instance, the use of militaristic frames in studies of invasive species was shown to be absent among coastal restoration managers because their management goals did not include eradication (Druschke et al., 2016). Another study assessed the use of militaristic language in work with invasive species across several influential journals and found that applied journals tended to use less militaristic language than basic science journals (Janovsky & Larson, 2019). These professional backgrounds, including disciplinary approaches adopted in the study, may translate into different communication strategies.

The objectives or goals of a scientific article, referred to in this paper as "study focus," can also affect its communication style. Previous research on non-native species has been motivated by a variety of concerns that can be categorized into four areas of inquiry. First, many studies have sought to assess the risk of invasive species transport or determine the most effective prevention methods (Byers et al., 2013; Davidson et al., 2016; June-Wells et al., 2013). Second, researchers have monitored and detected aquatic invasive species through a variety of research methods, including environmental DNA (eDNA), citizen science, and remote sensing (Larson et al., 2020), with eDNA studies increasing in popularity (Rees et al., 2014; Klymus et al., 2017). Third, researchers have expressed a goal of understanding non-native species, including their relationships with other species and impacts on ecosystems (Lawrence et al., 2014). Finally, the extant literature has determined the effectiveness and suitability of management or control strategies (Sembera et al., 2018). These key goals in scholarship have

indicated that study focus is often closely linked to the stage of invasion most relevant to the study. For instance, studies focused on assessing the risk of invasion or evaluating prevention techniques are typically undertaken in response to a population of non-native species at the transport stage of invasion. In contrast, researchers tend to embark on studies evaluating control options for non-native species when a population is at the establishment or spread stage of invasion. Consequently, communication style adopted by an article reporting research results may be related to the research focus.

Previous research has underscored the importance of recognizing stages of invasion to unify approaches to understanding invasions and the ways they are discussed (Blackburn et al., 2011). Researchers have argued for bridging language gaps between disciplines and standardizing language use across stage of invasion (Colautti & MacIsaac, 2004). Each population of a species can be classified as existing along a gradient from *transportation* to *spread*, with designated terminology to be used at each stage (Robinson et al., 2016). At the *transportation* stage of invasion, whereby species move to a new location, the neutral term "non-native" is most appropriate, given the uncertainty of the species survival and impacts. The terms "introduced" and "established" directly correspond to the second and third stages of invasion: *introduction*, involving the arrival and release of species in a new location, and *establishment* when the introduced species survives and reproduces. Finally, when species *spread* aggressively beyond their established range or begin causing negative ecological or economic impacts, they are dubbed "invasive" (Lockwood et al., 2013). These terms and stages are tied to particular locations; for instance, a species may be at the *introduced* stage in one lake, while in a different lake, a different population of the same species is at the *spread* stage. Thus, language use may be related to differences in the abundance of species at each stage of invasion across a region.

Transportation vectors, defined as the mechanism by which species are carried along a pathway, may affect the way that researchers communicate about non-native species in the literature. For instance, intentional vectors, such as biocontrol, fish stocking (Gozlan, 2008), and the aquarium trade (Padilla & Williams, 2004), may result in more positively valanced language given the benefits of introducing these species (Carey et al., 2011). By contrast, unintentional vectors, such as ballast water (Bailey, 2015) and recreational equipment (Clarke Murray et al., 2011) may result in more negatively valenced language that highlights the need for humans to be aware of their unintentional impacts (Lauber et al., 2020).

Finally, scientists develop their communication styles in the specific social and ecological environment in which their study sites and own experiences are situated. There is spatial variation in the fraction of local species richness from non-native species, the degree of impacts attributable to these organisms and the corresponding policy efforts. Researchers are personally exposed to variation in the strength and impacts of non-native species, which may affect their language in scientific studies. Specifically, the use of strong language may be a response to the degree of risk associated with invasive species in the region given the relationship between risk perceptions and message framing (van ‘t Riet et al., 2016). Whereas concerns about objectivity may be less pressing when risks are higher, it may be easier to adopt a less alarming viewpoint and communication style when a researcher works in a context with lower risk. As such, an argument could be made that stronger language is necessary to induce change. Finally, many invasive species managers report being limited by funding (Beaury et al., 2020) with the understanding that the capacity to enact and enforce policies varies by region (Peters & Lodge, 2009), leading to further spatial differences in communication approaches.

2.2.2. Study Objectives

We conducted a systematic review of aquatic non-native species literature to explore the message frames, valence, and terminology used in research, as well as the reasons why these communication strategies were adopted. Aquatic invasive species cause significant ecological impacts (Gallardo et al., 2016) inflicting costs of at least US$345 billion annually (Cuthbert et al., 2021), but concurrently contain many species that serve important human needs, such as recreational fishing (Carey et al., 2011; Moore, 2012; Fabrizio et al., 2021), making them an ideal context for understanding both positive and negative perceptions. We limited our review to the United States to minimize cultural difference in language use and focus our scope on the role of study characteristics and geographical factors. Given that the vast majority of news articles discussing non-native species comment on management actions (Clarke et al., 2020), we sought peer-reviewed articles that pertained to management, thereby generating implications directly relevant to public messaging, such as communicating management plans, raising awareness of risk, and influencing recreationist behavior. This systematic literature review was guided by the following objectives: 1) Characterize invasive species communication across message frames, valence and terminology in peer-reviewed articles published on non-native species management in the United States from 2008-2018; 2) Define the effects of study discipline, study focus, stage of invasion, and transportation vector on message frames; 3) Quantify the effects of study discipline, study focus, stage of invasion, and transportation vector on valence; and 4) Analyze the relationships among study discipline, study focus, stage of invasion, transportation vector, and terminology. We seek to provide insights into communication and message framing in research conducted by scientists from multiple disciplines that are advancing the study of biological invasions.

2.3. Methods

2.3.1. Search Criteria and Article Identification

This systematic literature review (Gough et al., 2012) involved an examination of peer-reviewed articles discussing aquatic non-native species from a variety of disciplinary perspectives (Figure 2.2). We selected Thomson Reuters Web of Science and Scopus databases because of their common use in systematic reviews (Mongeon & Paul-Hus, 2016), and searched them on July 3, 2018 using a search string that included seven keywords commonly used to report invasive species research (Colautti & MacIsaac, 2004), as well as additional terms to target aquatic species and ecosystems and research that addressed management implications. Specifically, the sets of keywords were:

- invasive species AND (management OR conservation) AND aquatic
- non-native species AND (management OR conservation) AND aquatic
- introduced species AND (management OR conservation) AND aquatic
- alien species AND (management OR conservation) AND aquatic
- exotic species AND (management OR conservation) AND aquatic
- non-indigenous species AND (management OR conservation) AND aquatic
- nuisance species AND (management OR conservation) AND aquatic

In addition to searching keywords in the topic (TS), the search strings specified the language to be English and the country (CU) to be the United States. We limited articles to English-language studies from the United States (including Puerto Rico) given the focus on communication; accounting for cultural differences or variation across languages was outside the scope of this study. Additionally, we used a 10.5-year time from January 2008 through July 2018. The ten-

year timeframe was chosen to provide a snapshot of recent articles published after considerations around language were brought to light (e.g., Brown & Sax, 2004).

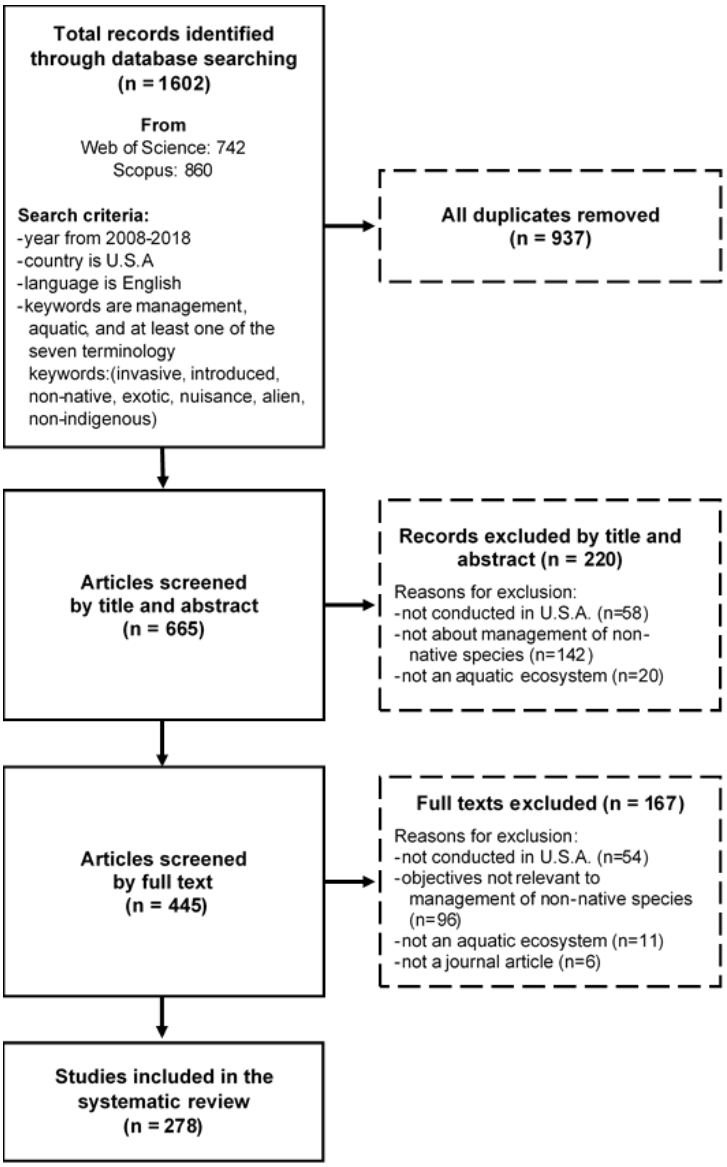

Figure 2.2. Flow diagram detailing the article search and screening process for a systematic review of aquatic non-native species management

In the first stage of screening, we read 665 titles and abstracts to determine whether the following criteria were met: (1) conducted in the United States; (2) speaks to management of

non-native species; 3) studies an aquatic ecosystem. The 445 articles that met the first stage of screening criteria were advanced to the second stage of screening. During the second stage of screening, we read the full article, and articles that did not meet the following criteria were excluded: (1) conducted in the United States, (2) study objectives pertain to management of non-native species; 3) the study ecosystem is aquatic; 4) peer-reviewed article that is article-length and not a book. The final pool included 278 articles, distributed across the 10.5-year window used for the review (Figure 2.3). Screening and management of the articles was conducted using EPPI Reviewer 4 software (Thomas et al., 2010).

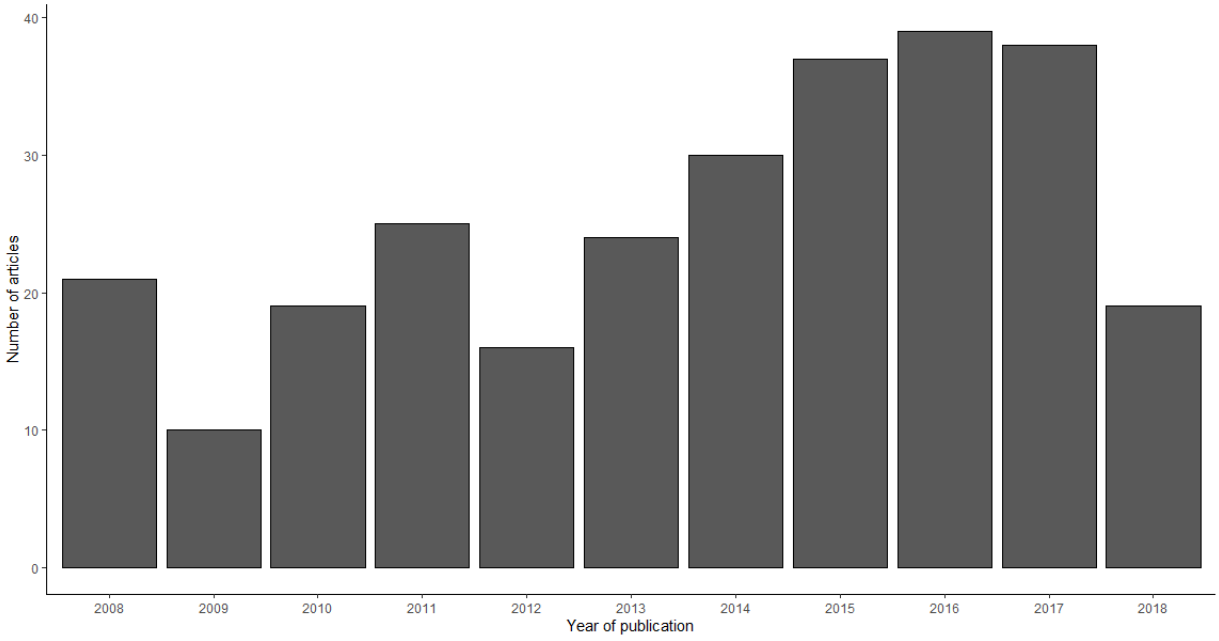

Figure 2.3. Publication year of 278 articles published from January 2008 through July 2018 that assessed non-native aquatic species management in the United States

2.3.2. Coding Process

To provide an overview of the types of studies included in the review, we recorded key characteristics of each study, including location of the study site, species studied, journal outlet, and affiliation of the lead author. Our systematic review unearthed published studies that were conducted across the United States (Figure 2.4). Species of study were grouped into the broad categories of plants (37%) and animals (45%), with 17% featuring both plants and animals.

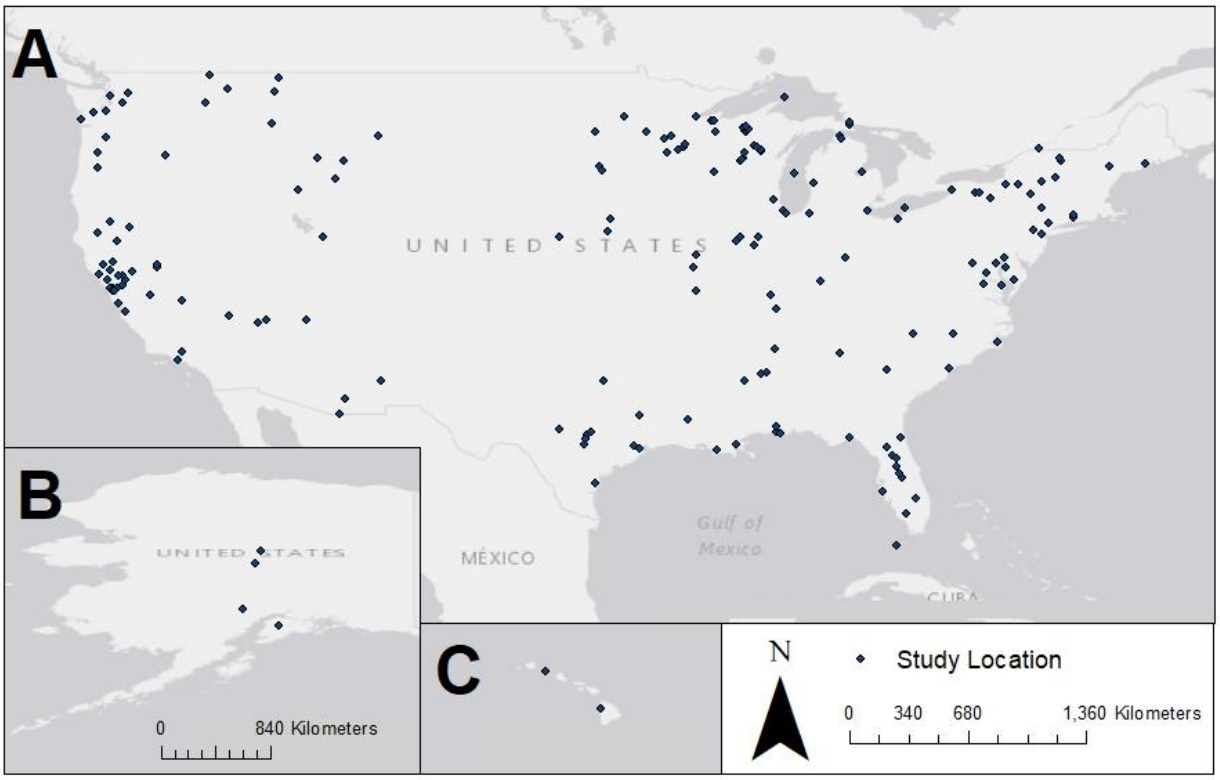

Figure 2.4. Geographic locations of study sites across 278 articles that reported on findings from aquatic non-native species research. Each point represents one study and shows its location in relation to other studies across (A) the contiguous United States, (B) Alaska and C) Hawaii.

In line with the study objectives, we coded each article for the seven features in our conceptual model (Figure 2.1). First, we coded each article for three facets of communication:

message frame, valence and terminology. Message frame was categorized as either human-centered or species-centered (Table 2.1).

Table 2.1. Message frames and valences that were coded from peer-reviewed articles about non-native aquatic species management

	Definition	Example
Message frame		
Human-centered	Research focused on the human drivers or causes of species introductions or centered on human responsibilities for taking action	Zebra mussels are spread by recreational boaters
Species-centered	Research focused on the species themselves as drivers, at times anthropomorphizing the species; no discussion of human influences	Zebra mussels filter water and reduce food availability lower in the food web
Valence		
Positive	Benefits of the study species are discussed or predicted	Zebra mussels filter algae and make water clearer
Neutral	Both positive and negative impacts, or no effects at all, are described	Zebra mussels make water clearer, but also reduce food availability for desirable species in the food web
Negative	A study species is described as problematic or its negative effects are detailed	Zebra mussels make water clearer but also reduce food availability for desirable species in the food web

Specifically, two independent coders identified the message frame adopted in the introduction section of each article, using the following definitions: *Human-centered frames* were those that focused on the human drivers or causes of species introductions or centered human responsibility for taking action, whereas *species-centered frames* were those that did not discuss human

influences on species introductions but focused on the species themselves as the drivers, at times anthropomorphizing the species. These codes were mutually exclusive, in that whenever human influence was mentioned, the article was classified as human-centered. To assess agreement between coders, we used Cohen's Kappa (κ) a measure of interrater reliability (McHugh, 2012), which indicated substantial agreement ($\kappa = 0.760$; percent agreement = 89%). For each article with an initial disagreement on code (n=31), the coders discussed the article until an agreement was reached.

Each article was next categorized according to its positive, negative or neutral valence. Specifically, the introduction section was coded as expressing positive valence when the benefits of a study species were discussed or predicted, whereas negative valence was indicated when the study species was described as problematic or its negative effects were detailed. The article was coded as having neutral valence if there were both positive and negative impacts described, or no effects at all. Again, two independent coders identified the valence; interrater reliability indicated substantial agreement ($\kappa = 0.620$; percent agreement = 88%), and when there was disagreement on valence (n=33), the article was discussed until agreement was reached. Terminology was assessed quantitatively. The text of each article, excluding the references, was searched for seven common terms used to refer to aquatic non-native species (i.e., alien, exotic, introduced, invasive, non-indigenous, nuisance, non-native), and the number of times each term appeared in the article was tallied.

Second, data reflecting four explanatory variables – study discipline, study focus, stage of invasion, and transportation vector – were extracted from each article. Study discipline was classified by identifying whether the disciplinary orientation and methods used were in line with the biological sciences, social sciences or an interdisciplinary approach. Data drawn from plants,

animals or ecosystems were classified as *biological sciences,* whereas data drawn from humans (e.g., methods involving surveys or interviews) were classified as *social sciences*. Study focus was derived from the stated objective of the paper and categorized as: *prevention* when objectives related to risk assessments or analysis of prevention measures; *monitoring* when objectives dealt with detecting or identifying non-native species; *understanding* when objectives pertained to analyzing the impacts or ecological characteristics of a species; and *control* when objectives related to the evaluation of management or control methods. Stage of invasion was identified based on the description of the study population provided in the introduction or methods of the paper. In some cases, the stage of invasion was explicitly stated; when it was not stated, articles were coded as *transportation* if the species was in the process of moving to a new location, *introduction* if the species had been released at a new location, *establishment* if the species had survived at the new location or *spread* if the species had spread beyond the initial point of introduction (Blackburn et al., 2011). Articles that could not be classified as occuring at one particular stage or for which stage of invasion was entirely irrelevant were coded as a fifth category. Finally, transportation vector was classified as natural, human-intentional and/or human-unintentional (Lockwood et al., 2013). Specifically, a vector was coded as *natural* if the study population was transported by dispersal patterns not directly mediated by humans, *human-intentional* if invasive species were transported deliberately by humans (e.g., stocking, biocontrol, aquaculture), and *human-unintentional* if the study population was transported accidentally by humans (e.g., ballast water, recreational equipment). Full details on the coding approach are available in the supplementary information.

Finally, we collected information on biodiversity context. We defined biodiversity context as watershed-level estimates of the percent of aquatic species classified as non-native

where the study was conducted. We determined native and non-native species occurrence within watersheds of the contiguous United States using the NatureServe Central Database, the United States Geological Society (USGS) Non-indigenous Aquatic Species Database, the Early Detection and Distribution Mapping System (EDDMapS) and the USGS Biodiversity Serving Our Nation (BISON) database. These databases contained native and non-native species occurrences (defined as a species introduced from outside its native range) that were sourced from the literature, museums, databases, monitoring programs, state and federal agencies, professional communications, online reporting forms, and hotline reports. Occurrence records were georeferenced to watersheds according to USGS hydrological unit code 8 (HUC 8) using ArcGIS (v. 10.3.1).

2.3.3. Analysis

Quantitative analyses were performed to define relationships between language use and the selected characteristics in the included articles. First, predictors of message frame were assessed using multinomial logistic regression with study discipline (i.e., biological science, social science, and interdisciplinary), study focus (i.e., prevention, monitoring, understanding, or control), invasion stage (i.e., transportation, introduction, establishment, or spread) and transportation vector (i.e., natural, unintentional, intentional, both, all, or not mentioned) as fixed effects. The model did not exhibit large overdispersion (residual deviance = 243, with 226 degrees of freedom). Second, predictors of valence (i.e., biological, interdisciplinary or social) were assessed using multinomial logistic regression with the same fixed effects used in the message frame model. Because only one study was coded as positively valanced, that study was excluded from analysis. Thus, the dependent variable was a binary categorical variable; studies

were either negative or neutral. This model also did not exhibit large overdispersion (residual deviance 212 on 224 degrees of freedom). Finally, the use of terminology was modeled as a function of four explanatory variables (i.e., study focus, study discipline, stage of invasion, and transportation vector) using multivariate redundancy analysis (RDA) in the R package 'vegan' (Oksanen et al., 2020). Because most papers did not use all terms, we used the Hellinger distance function to account for the many zeros in the dataset (Legendre & Gallagher, 2001). The correlation biplot was based on the covariance matrix and omitted the reference levels of the explanatory variables to avoid collinearity (Zuur et al., 2007). To test the hypothesis that the four variables explained a larger degree of variation than a random contribution, an ANOVA like permutation test for RDA was performed (Oksana et al., 2020). All analysis was conducted in the R programming language version 4.1.2.

Lastly, we tested whether language use in articles was associated with the biodiversity context in which the study was conducted. Comparisons of the percent of non-native species and types of message frames and valence were assessed using Wilcoxon rank sum tests with continuity correction and the relationship between percent non-native species and the overall article frequency of invasive species terminology (number of occurrences of the words: invasive, introduced, exotic, non-native, alien, nonindigenous, nuisance) was evaluated using simple linear regression.

2.4. Results

The articles included in this systematic review exhibited diverse patterns in message framing, valence and terminology. An approximately equal number of articles were classified as using species-centered language (45.0%) versus human-centered language (55.0%). Valence was

predominately negative (81.3%) across articles, with only one study framed positively (0.4%), and the remainder framed neutrally (18.3%). Finally, the term "invasive" was used most often in the published literature; 95.3% of the articles included this term on at least one occasion. Many articles also included the term "introduced" (70.5%), "non-native" (57.9%), "nuisance" (29.9%), "exotic" (27.7%), "non-indigenous" (23.4%), and "alien" (10.4%).

Examining study discipline, we found that biological sciences (84.5%) was dominant, with a minority of studies drawing on environmental social science (12.6%) and interdisciplinary methods (2.9%). Study focus was split among prevention (25.2%), monitoring (9.4%), understanding species impacts (31.3%), and control of the species (27.0%). A majority of articles (61.5%) were conducted during the spread stage of invasion, with fewer results published on the transport (5.4%), introduction (10.8%) or establishment (14.0%) stages. Stages of invasion were not relevant for several articles (8.3%); this category was excluded from further analysis. Intentional and unintentional spread were each discussed in approximately one quarter (24.1%) of the articles. Many studies (37.1%) did not report transportation vector, 9.0% covered multiple types of vectors, and only 5.8% focused on natural dispersal rather than human causes.

Both transportation vector ($\chi^2(5) = 38.600$; $p<.001$) and study focus $\chi^2(3) = 15.616$; $p<.001$) significantly predicted message frames. Message frame, transportation vector and study focus showed strong associations within the published literature ($\chi^2(13) = 89.756$; $p<.001$). Specifically, species-centered frames were used more frequently when the study focus was *understanding* impacts or *control*, whereas human-centered frames were used more frequently when the study focus was *prevention* (Table 2.2).

Table 2.2. Predictors of human-centered (reference level) vs. species-centered framing in peer-reviewed articles focused on non-native aquatic species management. Significant results are highlighted in bold.

Variable	B	Standard error	Z	p	Exp(B)
Intercept	0.272	0.954	.286	0.775	1.313
Study discipline[1]					
Interdisciplinary	-0.315	1.168	-0.270	0.787	0.730
Social sciences	0.381	0.832	0.457	0.647	1.463
Study focus[2]					
Monitoring	-0.920	0.626	-1.469	0.142	0.398
Understanding	**-1.187**	**0.488**	**-2.433**	**0.015**	**0.305**
Control	**-1.886**	**0.496**	**-3.804**	**<0.001**	**0.152**
Stage of invasion[3]					
Introduction	0.074	1.034	0.072	0.943	1.077
Establishment	-0.287	0.967	-0.297	0.766	0.750
Spread	-0.340	0.886	-0.384	0.701	0.712
Transportation vector[4]					
Natural	0.999	0.591	1.690	0.091	2.716
Human (unintentional)	**2.159**	**0.479**	**4.503**	**<0.001**	**8.660**
Human (intentional)	**2.014**	**0.400**	**5.043**	**<0.001**	**7.494**
Human (Both)	**1.616**	**0.780**	**2.071**	**0.038**	**5.033**
All	2.198	1.156	1.902	0.057	9.005

[1]Biological sciences served as the reference level
[2]Prevention served as the reference level
[3]Transportation served as the reference level
[4]Vector not mentioned served as the reference level
Note: Results: $\chi^2(13) = 89.756$; $p < .001$; Nagelkerke's Pseudo $R^2 = 0.416$.

We found a strong relationship between frame use and transportation vector. Human-centered frames were more common when human vectors were emphasized; when no vectors were emphasized, the species-centered frame dominated (Figure 2.5). Likewise, species-centered messaging became more common with increasing stages of invasion, though this was not a statistically significant result of the logistic regression. Additionally, species-centered frames were more likely to be used in research conducted in watersheds containing proportionally more non-native species (Figure 2.6A; W=3929.5, p=0.027, Wilcox test).

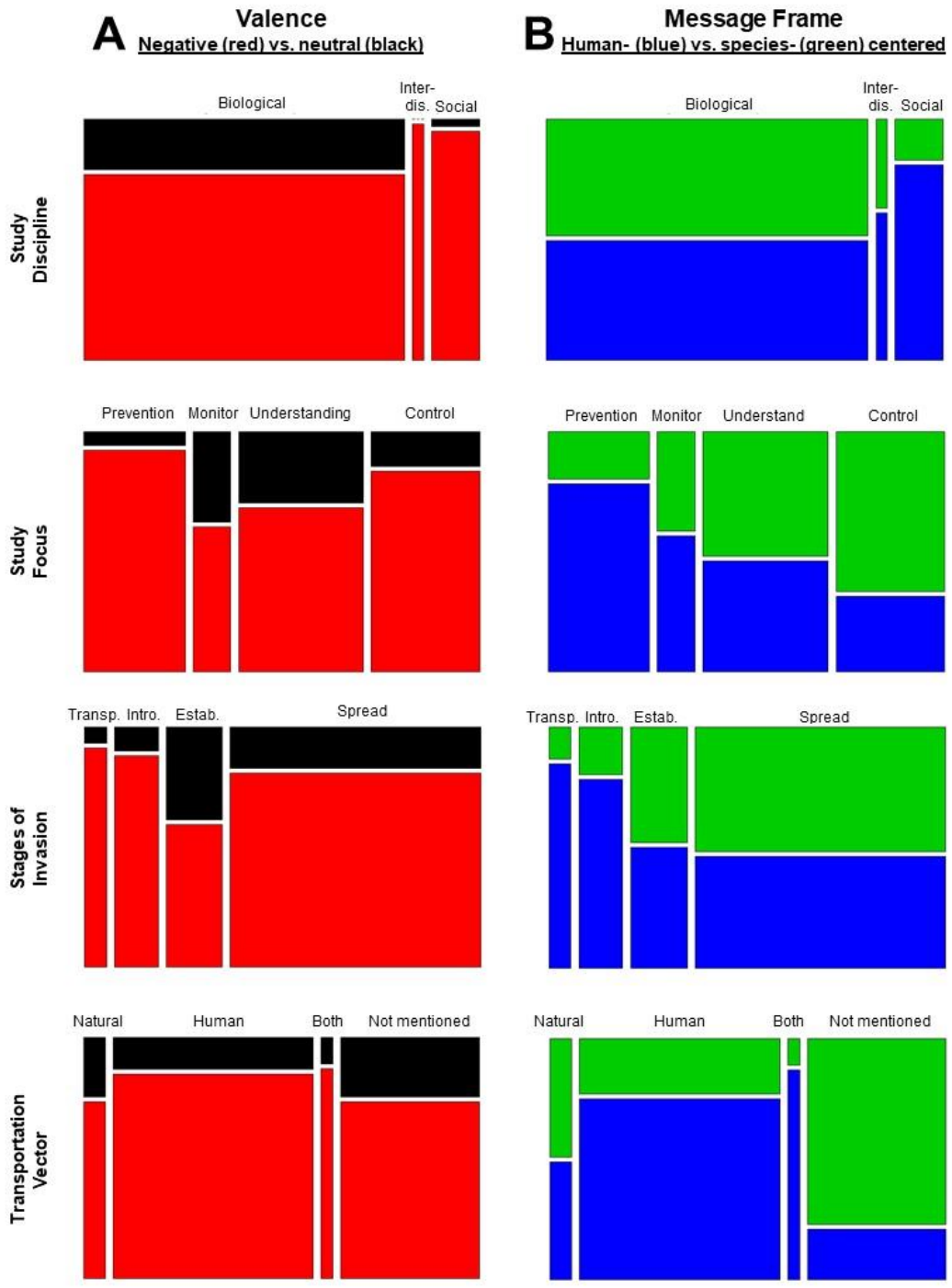

Figure 2.5. Comparison of (A) negative (red) vs. neutral (black) valence, and (B) human-centered (blue) vs. species-centered (green) message frames according to four study attributes including study discipline, study focus, stages of invasion, and transportation vector. Width of each column indicates the proportion of studies falling into each category. Comparisons between negative vs. neutral valence and human vs. species centered frames are likewise indicated proportionally in each graph.

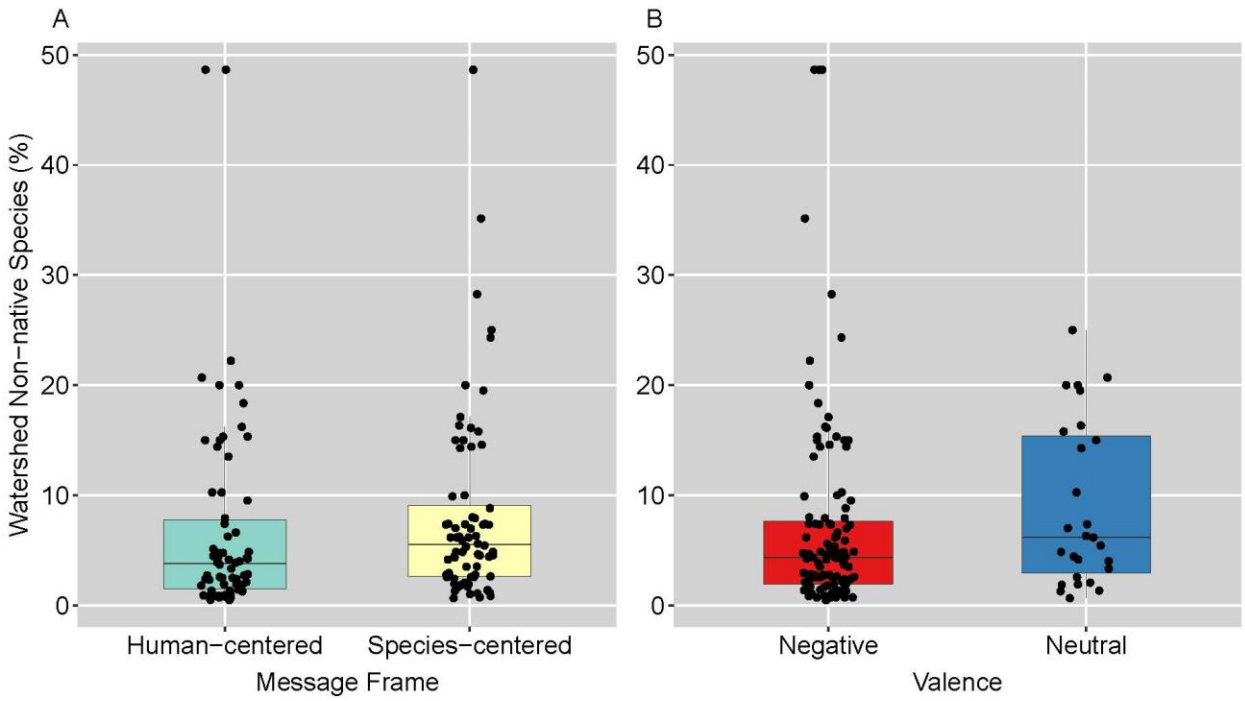

Figure 2.6. Relationship between non-native species richness (% of total species) in watershed of the study site and language use within the study, including message frame (A) and valence (B)

Negative valence was used more often for studies that focused on preventing the spread of invasive species or the evaluation of control options, in contrast to monitoring studies (Figure 2.5). This result was supported by the logistic regression model ($\chi^2(13) = 29.238$; $p = .006$; Nagelkerke's Pseudo $R^2 = 0.181$), in which study focus was a significant predictor ($\chi^2(3) = 10.660$; $p = .014$). That is, a neutral valence was more likely to be adopted when the study focus was monitoring or understanding the species, in contrast to studies with a focus on risk assessment that used predominantly negative valences (Table 2.3). Stage of invasion, transportation vector and study discipline had no influence on valence. Though the stage of invasion was not a significant predictor in the logistic regression model, there was a pattern in which negative language was used proportionally more often in studies examining establishment

and spread, compared to transport and introduction (Figure 2.5). Finally, we found no evidence that articles were more likely to portray non-native species negatively when conducted in watersheds containing more non-native species (Figure 2.6B; W=1235.5, p=0.099, Wilcox test).

Table 2.3. Predictors of negative (reference level) vs. neutral valence in peer-reviewed articles regarding non-native aquatic species management. Significant results are highlighted in bold.

Variable	B	Standard error	Z	p	Exp(B)
Intercept	2.394	1.191	2.010	0.044	10.959
Study discipline[1]					
Interdisciplinary	14.243	956.232	0.015	0.988	1533180
Social sciences	0.130	1.111	0.117	0.907	1.139
Study focus[2]					
Monitoring	**-1.926**	**0.731**	**-2.637**	**0.008**	**0.146**
Understanding	**-1.462**	**0.642**	**-2.275**	**0.023**	**0.232**
Control	-0.719	0.679	-1.059	0.290	0.487
Stages of invasion[3]					
Introduction	0.499	1.305	0.382	0.702	1.647
Establishment	-0.970	1.182	-0.821	0.412	0.379
Spread	-0.075	1.138	-0.066	0.948	0.928
Transportation vector[4]					
Natural	0.120	0.667	0.180	0.857	1.128
Human (unintentional)	0.364	0.551	0.660	0.509	1.439
Human (intentional)	0.228	0.430	0.528	0.597	1.255
Human (Both)	1.308	1.144	1.143	0.253	3.698
All	0.387	1.192	0.324	0.746	1.472

[1]Biological sciences served as the reference level
[2]Prevention served as the reference level
[3]Transportation served as the reference level
[4]Vector not mentioned served as the reference level
Note: Results: ($\chi^2(13) = 29.238$; p=.006; Nagelkerke's Pseudo $R^2 = 0.181$).

Relationships between terminology and the four predictor variables were assessed through RDA, where the first two axes explained 13% of the variation in terminology use ($F_{13,224} = 3.3$, p=0.001, Figure 2.7). Of the total variation explained, stages of invasion (39%) and study focus (31%) contributed the most to explaining patterns in terminology (Table 2.4). As shown in

the correlation triplot (Figure 2.7), studies that looked at the *establishment* stage of invasion and had the study focus to *understand* used the term "non-native" more often and the term "invasive" less often. By comparison, studies that had the study focus to analyze *control* measures or that looked at the stage of *spread* were more likely to use the terms "invasive" and less likely to use the term "non-native." Use of the term "introduced" correlated with intentional human introductions and the term "non-indigenous" with unintentional human introductions. Studies that looked at the *introduction* stage of invasion used the terms "introduced" and "non-indigenous" more commonly than studies addressing other stages of invasion. The overall frequency of non-native terminology used in each article was positively related to the percent of non-native species in the watershed where the study was conducted (Figure 2.8; F=5.4, p=0.022), although considerable variation in this relationship existed.

Table 2.4. Permutation test and marginal effects of four explanatory variables on terminology use. The total sum of all Eigenvalues is 0.055. Significant results are highlighted in bold.

Variable	df	Variance	F	p	Eigenvalue using only one explanatory variable	Eigenvalue as %
Study discipline[1]	2	0.002	0.7	0.702	0.000	0.00
Study focus[2]	**3**	**0.014**	**3.5**	**<0.001**	**0.019**	**0.34**
Stages of invasion[3]	**3**	**0.017**	**4.2**	**<0.001**	**0.023**	**0.41**
Transportation vector[4]	**5**	**0.013**	**2.0**	**0.009**	**0.010**	**0.18**
Residual	224	0.298				

[1]Biological sciences served as the reference level
[2]Prevention served as the reference level
[3]Transportation served as the reference level
[4]Vector not mentioned served as the reference level

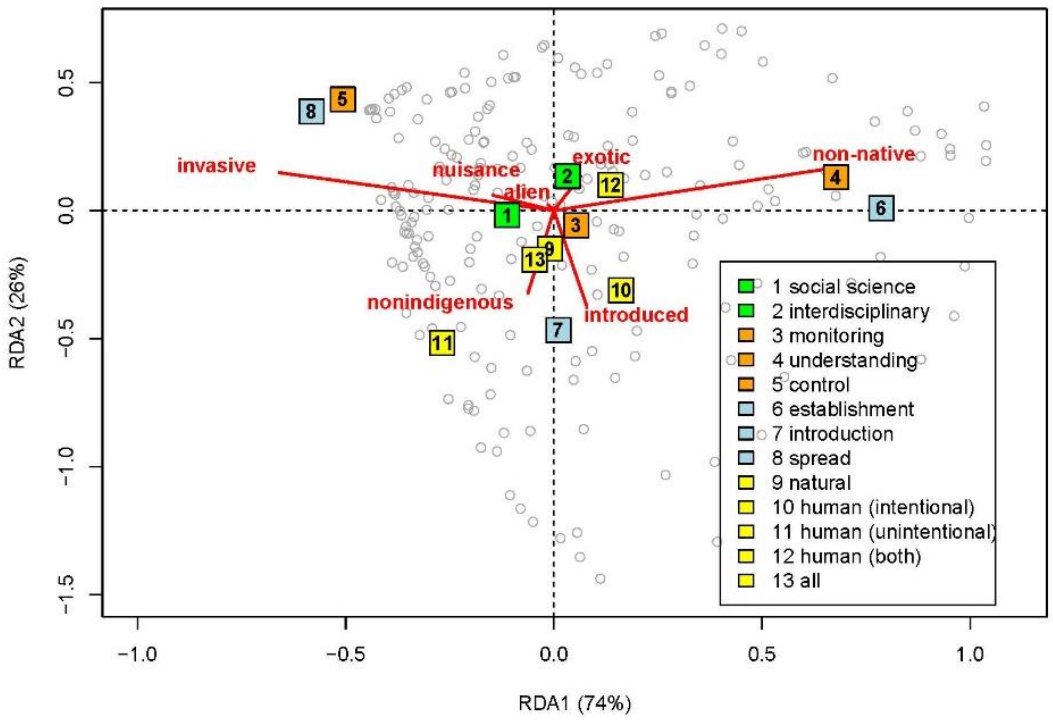

Figure 2.7. Redundancy analysis (RDA) of the terminology used in scientific publications (grey circles) concerned with invasive species management in the United States from 2008-2018. Eigenvectors (site scores) are scaled to their square-root. In total, 13.3% of variance is explained. Corresponding reference levels and further statistics are listed in Table 2.4.

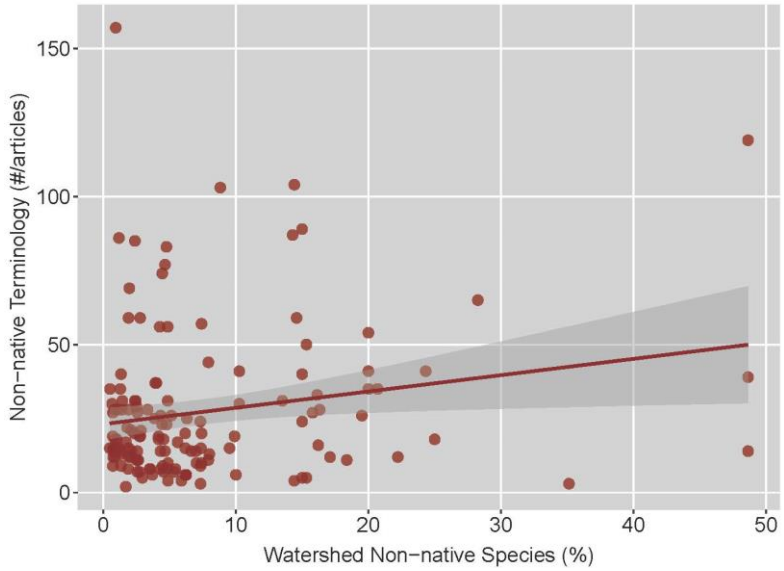

Figure 2.8. Relationship between non-native terminology used in each study and proportion of non-native species at the study site, assessed at the watershed level

2.5. Discussion

Our study aimed to quantify patterns and drivers of language use in the scientific aquatic non-native species literature in the United States. We discovered considerable variation in communication strategies used by scientists, including message frame, valence, and terminology. We contend that the factors explaining variation in communication patterns can be better understood through knowledge of message framing. Specifically, we observed that species-centered vs. human-centered frames strongly related to transportation vector and study focus, indicating that the role of humans tends to be highlighted when there is greater urgency in preventing the spread of non-native species, whereas the role of the species itself is centered when transportation vectors are not mentioned and the focus is on control. Aligned with previous research (Clarke et al., 2020), we found negative valences to be most common. Additionally, terminology use corresponded with stage of invasion, indicating that researchers are following guidance by past work to use standardized and consistent language, specifically relying on more general terms like "non-native" at earlier stages of invasion, and only classifying species as invasive after accelerating spread or clear impacts are occurring (Coulatti & MacIsaac, 2004; Blackburn et al., 2011).

We found researchers adopted message framing that aligned with a stated study focus. When an objective pertaining to risk assessment or a focus on prevention was expressed, human-centered frames were more common, corresponding to the important role humans play in curbing the spread of invasive species (Tabak et al., 2017). The importance of self-efficacy (i.e., beliefs that one has the ability to complete an action; Bandura, 1977) in enabling people to engage in preventative measures is well-documented in the literature (Niemiec et al., 2017; Landon et al., 2018; Mankad & Loechel, 2020), which underscores the importance of human-centered frames

that emphasize the role of humans in biological invasions. By contrast, when the focus of research was to understand a species or to analyze control measures, species-centered frames dominated the narrative adopted in reporting results. This finding aligns with past research suggesting that species-centered frames are likely to activate risk perceptions and engagement in preventative behaviors (Hart & Larson, 2014). Thus, because past work indicates the ability of both species- and human-centered frames to heighten risk perceptions, more research is needed to understand public responses to these frames and their success in changing behavior in positive ways. Such research (e.g., Clarke et al., 2020; Orth et al., 2020) should focus on analysis of science communication outside of traditional scientific papers or in press releases by scientific organizations because it is unlikely that the public or policy makers are readers of scientific papers.

The finding that negative valences were predominant in scientific papers is not surprising given the focus of the literature review on non-native species management, rather than targeting bodies of work on, for instance, stocking fish for capture fisheries. Accordingly, our selection of keywords (e.g., "invasive") may not always be used in studies of introduced species that are beneficial, although this is very unlikely to be the case given the need to comment on the negative impacts of non-native species even when reporting positive outcomes (e.g., Johnson et al., 2009; Aas et al., 2018). Despite this, we recognize that studies on the positive effects of non-native species may be underrepresented in our search (e.g., Carey et al., 2011). Emphasizing the negative impacts associated with invasive species seems to be perceived by invasion biologists as necessary—or at least helpful—to inform readers and generate support for preventing or controlling invasive species. However, there is a risk associated with an overabundance of negative language: as negative valences are translated into public news media, extreme

negativity can lead to feelings of helplessness and disinterest in management initiatives (Clarke et al., 2020). This is particularly worrisome given recent evidence that invasive species can, in some instances, play positive roles for local livelihoods and human well-being (Shackleton et al., 2019), and in other instances, not have measurable ecological or social impacts (e.g., Wolter & Röhr 2010).

The use of terminology broadly aligned with recommendations in previous research to be deliberate about defining concepts and study contexts in invasion biology (Colautti & MacIsaac, 2004; Copp et al., 2005). "Invasive" was the most frequently used term across all study attributes except when it was appropriate by definition to use "non-native." Specifically, the use of "non-native" rather than "invasive" aligned with stages of invasion such as establishment, where the species had yet to meet the requirements to be classified as invasive, defined as a species causing negative ecological or social impacts (Blackburn et al., 2011). Terms that were synonymous with "non-native," including "exotic," "alien," and "non-indigenous" were rarely used. In summary, invasive species researchers have responded to past calls for clarity in research (Richardson et al., 2000; Colautti & MacIsaac, 2004; Blackburn et al., 2011), and are using consistent terms aligned with stages of invasion.

Language use showed some evidence of being related to the regional biodiversity context in which the study was conducted. Specifically, in watersheds containing relatively more non-native species, studies were more likely to use species-centered frames. Past work has shown species-centered frames to be more effective in raising stakeholder engagement in preventative behaviors (Hart & Larson, 2014), thus the correlation between this framing and increasing dominance of non-native species is notable. Additionally, there was a positive relationship between non-native species richness and overall use of non-native terminology. Researchers may

be reflecting the degree of risk perceived in the study region with language that highlights these risks more clearly. Ultimately, higher-risk areas may warrant stronger language to better convey the need for greater management attention and heightened public awareness.

A strikingly small proportion of studies within the biological invasion literature were conducted through an environmental social science lens. Given the role of recreationists in non-native species transport (Johnson et al., 2009; Rothlisberger et al., 2010; Cole et al., 2019; Golebie et al., 2022) and complex and often controversial views about non-native species (Schlaepfer et al., 2011; Russell & Blackburn, 2017; Schlaepfer, 2018), there is a strong need for more social science research (e.g., Kochalski et al., 2019; Shackleton et al., 2019). The social science studies included in the review exclusively used negative valences, with a strong emphasis on human-centered frames. Use of human-centered frames was logical, given that social science seeks to understand the thoughts, feelings and actions of humans. Negative valences may have dominated given that the studies in our review predominantly investigated boater and angler transport of invasive species, and thus stressed the negative impacts of invasive species that could be averted by human action. Additionally, raising self-efficacy, the awareness of how individuals can play a role in invasive species spread, is an important step in encouraging people to take action. However, these results reveal an untapped area of inquiry on relationships between humans and non-native species. Several research questions should be addressed: In what ways are invasive species meaningful to humans? What are stakeholder preferences for invasive species management? On what information do people base these beliefs? Which non-native species are perceived as beneficial rather than harmful, and in what socioeconomic or cultural contexts? How can managers nudge recreationists and other people (e.g., aquarium fish holders, see Wolbers & Donnelly, 2019) to refrain from further spreading non-native fishes and

which messages frames are most effective in such communication strategies (e.g., Shaw et al., 2021)? Answering these questions will enhance invasive species management practices by deepening knowledge of how people do (or do not) support decision-making outcomes.

2.6. Conclusion

In conclusion, our work quantifies how published literature on aquatic non-native species research conveys varied message framing, valence and terminology. We show that authors of peer-reviewed journal articles are effectively using standardized terminology established in past work. For instance, we found limited evidence for inflammatory or exaggerative framings being dominant within peer-reviewed published literature between 2008-2018. Additionally, message frames evoked in these articles are correlated with study focus and local biodiversity context, indicating that language use is tailored to contextual conditions. We encourage researchers to be aware of how their language might be influenced by such factors and actively consider whether communication choices match the study goals. Future work should seek to evaluate language use in public-facing communication to identify relationships between public and academic communication, as well as the impacts of communication style on public perceptions of invasion biology research. Understanding the role of science communication more broadly in public understanding of invasion biology and support for management decisions is an important direction for future research.

2.7. References

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CHAPTER 3: REDUCING INVASIVE SPECIES TRANSPORT AMONG RECREATIONAL ANGLERS: THE IMPORTANCE OF VALUES AND RISK PERCEPTIONS

3.1. Abstract

The behavioral patterns of recreational anglers are an increasingly common focus of fishery management agencies, particularly due to the unintentional spread of aquatic invasive species (AIS). Previous research in this area has focused on understanding stakeholder awareness, use patterns, and beliefs. Although informative, these drivers of behavior are easily shifted by new information and thus potentially less influential for encouraging long-term behavior change. There is a pressing need to account for the effects of human values in management AIS because values are a fundamental driver of behavior that changes slowly over time and represents a core basis for angler decision-making. Therefore, this study assessed the relationships among values, risk perceptions, and reported AIS prevention behavior to inform management decisions aimed at minimizing angler transport of AIS. We generated a dataset from a mixed-mode survey of license holding recreational anglers from counties adjacent to the Great Lakes in three US states (n=788). Results from a structural equation model revealed that biospheric values positively predicted social and personal risk perceptions. Personal risk perceptions in turn positively predicted private and public dimensions of reported behaviors related to reducing the spread of AIS. Efforts to reduce the spread of AIS within the study context would be best served by emphasizing the personal impacts rather than broader social and ecological consequences from biological invasions. Agencies should also shift their attention to

thinking about the role of values in explaining how people process and respond to environmental threats and degradation from AIS.

3.2. Introduction

As one of the strongest drivers of environmental change (Pyšek & Richardson, 2010), aquatic invasive species (AIS) are organisms that have been introduced outside of their native range, survived, reproduced, and started spreading beyond the initial point of introduction, often causing negative effects throughout the process (Blackburn et al., 2011). These negative impacts range from altering habitat, to out-competing native species for food and interfering with human activity (Gallardo et al., 2016). The Great Lakes are a hotspot for species invasions due to international shipping, which brings organisms from places around the world in ships' ballast water that is discharged upon arrival into a port (Keller et al., 2011; Escobar et al., 2018). Once species have become established in new ecosystems, reversing an invasion is virtually impossible (Vander Zanden & Olden 2008); thus, preventing the spread of AIS is a crucial priority for fishery management agencies (Heck et al., 2016).

While regulations have been designed to minimize future biological invasions from shipping (Firestone & Corbett, 2005), as well as the bait trade (Kilian et al., 2012; Nathan et al., 2014), resource managers in the Great Lakes region have also been concerned about individual angler behavior that is exacerbating the spread of AIS (Heck et al., 2015; Pradhananga et al., 2015). In particular, recreational anglers pose a risk of unintentionally transporting AIS as they travel between waterbodies (Kilian et al., 2012; Ready et al., 2018). For instance, the spread of zebra mussels *Dreissena polymorpha* and quagga mussels *Dreissena bugensis* across the United States has been attributed to recreational boaters and anglers (Hickey, 2010), as well as the

secondary spread of Great Lakes invaders such as rainbow smelt *Osmerus mordax* and spiny waterflea *Bythotrephes longimanus* as anglers move from the Great Lakes to inland waterbodies (vander Zanden & Olden, 2008). Consequently, resource management agencies have increasingly directed attention to environmental education that encourages anglers to take precautions (e.g., cleaning boats and/or equipment) after leaving bodies of water to reduce the likelihood of AIS transport.

Outreach campaigns have been developed and implemented to encourage aquatic recreationists to check their equipment before entering new waterways and remove any plants, mussels, or other organisms they find (Cole et al., 2016; Funnell et al., 2009; Seekamp, McCreary, et al., 2016). The "Stop Aquatic Hitchhikers!" (stopaquatichitchhikers.org) campaign sponsored by the Aquatic Nuisance Species task force, for example, encourages anglers to "clean, drain, dry" their boats to prevent the spread of AIS, and uses slogans such as "protect our natural state" and "be a good steward." On the state level, Illinois' "Be a Hero, Transport Zero" campaign (transportzero.org) offers similar instructions for anglers to "remove, drain, dry." The Be a Hero campaign produced informational materials, including brochures that are disseminated at fishing events, and constructed boat washing stations at lakes in northern Illinois. Previous research has evaluated the efficacy of these campaigns (Kemp et al., 2017) and indicated that they have successfully raised awareness of AIS among anglers (Eiswerth et al., 2011). Slogans associated with these campaigns were recognized by 59% (Stop Aquatic Hitchhikers) and 25% (Be a Hero) of boaters who responded to one AIS survey (Cole et al., 2016), indicating that outreach was successfully reaching a large proportion of the boating population. Likewise, respondents to another angler survey reported agreement with the statements that AIS "are easily transferred from one lake to another" and "can interfere with water-based recreation like

swimming, fishing, and boating" (Eiswerth et al., 2011). These findings suggest there is relatively high awareness of how AIS have spread and why they are problematic.

Although awareness of AIS is increasing among anglers, their adoption of actions to prevent the spread of AIS have not followed suit. Research has shown that engagement in AIS prevention behaviors was the same across regions that had different levels of investment in AIS outreach (Cole et al., 2016), which calls to question the efficacy of information campaigns on behavioral performance. Additionally, inconsistencies of angler participation in prevention behaviors can further exacerbate the risk of AIS transport. Specifically, there are multiple required steps in angler prevention of AIS transport (e.g., cleaning the boat, draining it of water, and allowing it to try), and many anglers report performing one, but not all, necessary steps. For instance, one study in the Great Lakes region found that a majority of anglers completed the simplest step of draining their boat after each fishing trip, however only 5% also completed the four other recommended actions: inspecting their boat for attached animals, removing any plants, animals, or mud, washing with hot water or disinfecting, and allowing their boat to dry before traveling to a different water body (Connelly et al., 2016). A similar study of anglers in Illinois found that although many anglers reported always taking at least one step to prevent AIS spread, 62% had at least occasional fishing trips where they did not take any steps, leading to a high risk of AIS transport (Cole et al., 2019). In other words, many anglers have become aware of AIS and realized there are preventative steps they should be taking, but are not completing all of the steps, or are not completing them on a regular basis. This phenomenon, referred to as the "knowledge-action gap" (Kollmuss & Agyeman, 2002), has sparked calls for research investigating deeper psychological processes that affect AIS-relevant behavior (Cole et al., 2019), including values (Estevez et al., 2015) and risk perceptions (Hart & Larson, 2014).

Values are a key element in understanding behavior that benefits the environment (Steg & Vlek, 2009), and thus have been studied across disciplines with guidance from numerous theoretical frameworks (Steg et al., 2014; Chan et al., 2018; van Riper et al., 2018; Kenter et al., 2019). Values, defined as guiding principles in life (Rokeach, 1973), inform the study of environmentally-relevant behaviors on a deep level (Stern et al., 1999; Steg & de Groot 2012). People with strong biospheric, altruistic, and egoistic values hold guiding principles around nature preservation, social equality, and self-interest, respectively (Schwartz, 1992). Past work has shown that biospheric values, in particular, play a prominent role in predicting behavior, in that people who are driven by environmental concern are more likely to participate in behaviors that benefit the environment (Schultz et al., 2005; Liobikiene & Juknys, 2016). Altruistic values also lead to pro-environmental and pro-social beliefs, whereas egoistic values decrease the likelihood of environmental outcomes (de Groot & Steg, 2008). Human values have received limited attention within the study of recreational angling despite their potential to provide insights on the underlying reasons why behavioral patterns exist (van Riper et al., 2020).

The study of ecological risk in fisheries management has received widespread attention given the difficulties of implementing strategies that reduce threats from species invasions (Drake & Mandrak, 2014; Gallardo & Aldridge, 2018). Risk perceptions represent beliefs about the severity of possible harms to an entity (Rogers, 1975), such as beliefs about the severity of food web disruptions that could be caused by a new AIS within the Great Lakes fishery. Higher perceived risks have been shown to positively predict engagement in environmental behavior in a variety of contexts (O'Connor et al., 1999; Kothe et al., 2019). People tend to respond differently to risks that may affect themselves versus risks that affect the broader world including social and environmental concerns (Smith & Leiserowitz, 2012), generally perceving risks to

others (i.e., social risks) to be higher than risks to themseleves (i.e., personal risks) (van der Linden, 2015; van Riper et al., 2016). Risk perceptions specifically focused on preferences for AIS management have received previous research attention (e.g., Estevez et al., 2015); however, the effects of different types of risk perceptions on angler behavior have yet to be determined.

The goal of this study was to define the roles of individual values and perceived risks of biological invasions on the behaviors of recreational anglers related to the spread of AIS. Specifically, we addressed three research questions: 1) What are the relationships between values and risk perceptions among Great Lakes anglers? 2) What are the relationships between risk perceptions and reported behavior related to the spread of AIS for Great Lakes anglers? and 3) How do the relationships among values, risk perceptions, and reported behavior vary by fishing site within the Great Lakes? To respond to these research questions, we tested a manifest variable path model including multiple hypotheses informed by previous research (Figure 3.1). When combined, answers to our three research questions can aid in the goal of encouraging long-term behavior change to curb angler spread of AIS within the Great Lakes and beyond.

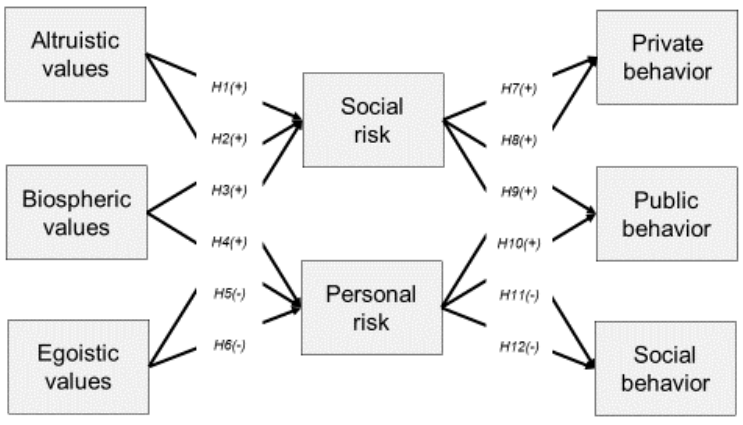

Figure 3.1. Hypothesized model showing predicted relationships between values, risk perceptions, and three dimensions of reported angler behavior.

3.3. Methods

3.3.1. Context of Recreational Angling in the Great Lakes Region

In the Great Lakes region, fishing environments can broadly be categorized as the Great Lakes themselves and their tributaries, or as inland waterways that include smaller lakes, rivers, and streams. Past work has highlighted differences among anglers according to fishing site (Ward et al., 2013; Dabrowska et al., 2017). Anglers fishing in different types of environments may have different beliefs and behavior related to AIS given variation in regulations observed, outreach efforts, and social-ecological conditions experienced. For instance, anglers who fish exclusively in the Great Lakes and its tributaries may be aware of existing degradation from AIS (Escobar et al., 2018) and thus perceive more risk than anglers who exclusively fish in inland waterways that have not been invaded by AIS. Additionally, anglers who frequent both Great Lakes and inland waterways are a particularly important group; boaters moving between multiple waterbodies in short timeframes, referred to as "transient boaters" pose the most risk for transporting AIS (Witzling et al., 2016), even if they take some preventative measures (Cole et al., 2019). However, avid transient boaters may also be aware of the issue given more exposure to a variety of AIS messages posted at different sites or through different mediums (Seekamp, Mayer et al., 2016). Because signage at fishing sites is a common method for communicating about AIS, message design can be validated or enhanced by understanding the beliefs and actions of anglers who fish in inland waterways versus the Great Lakes. Thus, understanding differences among anglers who fish different environments allows managers to better understand the risks of AIS transport, as well as the messaging needs at Great Lakes and inland waterways fishing sites.

3.3.2. Data Collection

Data were collected through a mailback survey of anglers in the Great Lakes region conducted May-October 2019. The target population was United States anglers who fish on Lake Michigan, Lake Ontario (and associated tributary streams and rivers), and nearby inland waterways. Survey recipients were randomly selected from lists of licensed anglers in counties adjacent to Lake Michigan or Lake Ontario. A sample of 1,200 anglers was randomly selected from each of three license lists – Illinois, Michigan, and New York – for a total of 3,600 anglers that were invited to participate. The survey was administered over the course of 14 weeks, and included an introductory letter, three mailings of the survey, and two reminder postcards, in line with standard guidelines by Dillman et al. (2014). In addition to the hard-copy questionnaire and postage paid envelope, participants also had the option to access the survey via an online link that was shared in each mailing. Respondents were each provided a unique numerical code to enter on the survey home page, which allowed us to track response rates and avoid duplicate responses from the same individual. A total of 788 anglers completed the survey via mail (n=669) or internet (n=119), resulting in a response rate of 22%. To assess potential sampling bias, we compared our sample with anglers from Michigan, New York, and Illinois in a past study (Connelly et al., 2014) and found no difference in gender ($\chi^2 = 2.1942$; $p = .139$). We also assessed days fished between our sample and a study of anglers in the Great Lakes region (Ready et al. 2012) and found no significant difference (t-stat($df = 4296$) =.7186; $p = .472$). Survey items were drawn from past research and finalized through two rounds of pilot testing, including a verbal protocol assessment (n = 6) and an online pilot test (n = 102).

3.3.3. Measures

We measured three types values including biospheric, altruistic, and egoistic established in previous research (Stern et al., 1999), and positioned as predictors of risk perceptions in environmental contexts (Slimak & Dietz, 2006). Three items reflected each type of value, and responses were measured on a nine-point scale ranging from 'opposed to my values' (1) to 'of supreme importance' (9).

We measured both personal and social risk perceptions (Leiserowitz, 2006; Brody et al., 2008; van der Linden, 2015). Past work has characterized personal risk perceptions as the seriousness of a threat to one's own health, financial wellbeing, and local environment, and social risk perceptions as seriousness of threat to the health, economy, and environment in broader society (Bord et al., 2000; Brody et al., 2008; Kellstedt et al., 2008; Milfont, 2012). We tailored these items to the context of AIS. Specifically, personal risk perceptions were measured as the seriousness of threat from AIS to the respondent's fishing experience, financial well-being, and the environment where they fished. Social risk perceptions were measured as the seriousness of threat from AIS to the Great Lakes fishery, the economy in the Great Lakes region, and the environment in the Great Lakes region. Respondents were asked to report the level of threat AIS each survey item on a five-point scale ranging from "low threat" (1) to "high threat" (5).

We examined three types of reported behavior established in previous research (Stern, 2000; Larson et al., 2015) and tailored to the topic of AIS. First, 'private sphere' behaviors included activities that affect one's own impact on the environment, such as cleaning one's boat to minimize risk of AIS transport. Second, behaviors in the 'public sphere,' were considered to have an impact beyond the individual, generally by aiming to affect policy, such as writing

letters to government officials in support of AIS control policies. Third, behaviors in the 'social sphere' involved others through actions like telling community members about the risks of invasive species and encouraging friends to attend AIS-related events. Private sphere behaviors such as boat washing have received the most attention in previous research given their tangible impact (Pradhananga et al., 2015; Kemp et al., 2017), though public and social sphere behaviors may have far-reaching impacts by affecting environmental policy and increasing participation in AIS prevention by other people (Ertz et al., 2016). Thus, all three dimensions were measured. Survey items asked respondents to consider their behavior over the past 12 months and report their frequency of engagement in each behavior on a five-point Likert scale from "never" (1) to "very often" (5).

Fishing site was assessed by asking respondents to select where they spent most of their time fishing from a list of the Great Lakes and descriptions of Great Lakes tributaries, inland lakes, and inland rivers/streams. Respondents who selected at least one Great Lake and/or Great Lakes tributary were categorized as "Great Lakes and Tributaries" (n=172), respondents who selected inland lakes and/or inland rivers and streams were categorized as "inland waterways" (n=203) and respondents who selected from both categories of answers were categorized as "mixed-site" (n=382). Respondents who did not respond to the fishing site question (N=31) were removed from further analysis.

3.3.4. Analysis

Structural equation modeling (Kline ,2011) was used to test relationships among values, risk perceptions, and reported behavior. Specifically, a two-step structural regression modeling procedure outlined by Anderson and Gerbing (1988) was used. First, the validity and reliability

of survey scales were evaluated using confirmatory factor analysis with a maximum likelihood estimation procedure. We assessed factor loading scores on each dimension, retaining items with standardized factor loading scores above 0.40 and ensuring no cross-loading of items (Hair et al., 2011). To test for internal consistency, we examined Cronbach's alpha as a measure of scale reliability; coefficients greater than 0.60 were accepted (Cortina, 1993). Past work has emphasized the importance of including multiple measures of reliability, because Cronbach's alpha relies on assumptions such as uncorrelated errors and tau-equivalence (Trizano-Hermosilla & Alvarado, 2016). Therefore, we also assessed Composite Reliability, which was considered acceptable given values exceeding 0.60 (Bagozzi & Yi, 1988). All final scales met these two thresholds (Table 3.1).

Our hypothesized reported behavior scale with a three-dimensional configuration demonstrated good model fit but poor reliability. Therefore, we used exploratory factor analysis to improve our hypothesized factor structure. We chose principal axis factoring, because it corrected for measurement error and varimax rotation because it minimized the correlation among the latent variables. This analysis resulted in a two-factor solution that accounted for 54% of the total variance: private behavior (α = .657; Ω = .642) and public behavior (α = .726; Ω = .731). One item ("worked with others to minimize impacts from aquatic invasive species") did not load onto either dimension and was therefore dropped from the final model.

Table 3.1. Means, standard deviations, measures of internal consistency including Cronbach's alpha (α) and composite reliability (Ω), and factor loading scores (λ) for scale items measuring reported behavior, risk perceptions, and values.

Reported behavior[1]	λ	**All anglers** M (SD)	**Great Lakes** M (SD)	**Inland** M (SD)	**Mixed-site** M (SD)
Private sphere behaviors (α = 0.657; Ω = 0.642)					
Looked up information about aquatic invasive species	0.665	2.03 (1.06)	2.07 (1.11)	1.82 (0.97)	2.13 (1.06)
Avoided purchasing products that contribute to the spread of aquatic invasive species	0.540	2.91 (1.80)	2.94 (1.80)	2.66 (1.74)	3.03 (1.65)
Took measures (e.g., washed boat or equipment) to personally reduce the spread of aquatic invasive species	0.435	2.99 (1.66)	2.91 (1.64)	2.64 (1.64)	3.19 (1.65)
Talked to other people in my community about AIS	0.695	2.22 (1.25)	2.16 (1.19)	1.89 (1.15)	2.43 (1.29)
Public sphere behaviors (α = 0.726; Ω = 0.731)					
Participated in a policy process (e.g., voting) related to AIS	0.649	1.67 (1.20)	1.69 (1.18)	1.47 (1.02)	1.77 (1.28)
Donated money with the intention of reducing impacts from AIS	0.570	1.56 (0.98)	1.64 (1.04)	1.50 (0.97)	1.56 (0.97)
Wrote a letter, sent an email, or signed a petition about AIS	0.664	1.29 (0.77)	1.26 (0.72)	1.17 (0.63)	1.36 (0.85)
Encouraged other people to attend an event related to AIS	0.706	1.32 (0.79)	1.32 (0.82)	1.23 (0.67)	1.37 (0.82)
Risk Perceptions[2]					
Personal risk (α = 0.734; Ω = 0.748)					
Your fishing experience	0.768	3.92 (1.24)	3.87 (1.27)	3.75 (1.33)	4.04 (1.17)
Your financial well-being	0.472	2.29 (1.33)	2.46 (1.42)	2.19 (1.30)	2.26 (1.30)
The environment where you fish	0.878	3.96 (1.20)	3.98 (1.14)	3.66 (1.28)	4.10 (1.15)
Social risk (α = 0.882; Ω = 0.885)					
The Great Lakes fishery	0.815	4.39 (.99)	4.31 (1.07)	4.24 (1.10)	4.50 (0.87)
The economy in the Great Lakes region	0.825	4.09 (1.13)	4.05 (1.18)	3.95 (1.16)	4.17 (1.07)
The environment in the Great Lakes region	0.905	4.24 (1.03)	4.17 (1.09)	4.13 (1.06)	4.34 (0.98)

Table 3.1. (cont.)

	λ	**All anglers** M (SD)	**Great Lakes** M (SD)	**Inland** M (SD)	**Mixed-site** M (SD)
Values[3]					
Biospheric values (α = 0.887; Ω = 0.891)					
Protecting the environment: preserving nature	0.838	7.55 (1.60)	7.46 (1.69)	7.38 (1.64)	7.68 (1.53)
Unity with nature: fitting into nature	0.887	7.02 (1.86)	6.94 (1.96)	6.95 (1.91)	7.09 (1.79)
A world of beauty: beauty of nature and the arts	0.839	7.15 (1.87)	6.94 (2.06)	7.09 (1.93)	7.28 (1.74)
Altruistic values (α = 0.858 ; Ω = 0.863)					
Equality: equal opportunity for all	0.839	7.12 (2.02)	6.94 (2.14)	7.04 (2.08)	7.25 (1.93)
Social justice: correcting injustice, care for others	0.885	6.89 (2.12)	6.66 (2.20)	6.84 (2.16)	7.02 (2.05)
A world at peace: free of war and conflict	0.741	7.12 (2.12)	6.96 (2.24)	7.26 (2.07)	7.13 (2.08)
Egoistic values (α = 0.730 ; Ω = 0.727)					
Authority: the right to lead or command	0.760	5.90 (2.06)	5.82 (2.15)	5.83 (2.13)	5.98 (1.99)
Social power: control over others, dominance	0.555	3.38 (2.27)	3.58 (2.43)	3.49 (2.21)	3.23 (2.22)
Influential: having an impact on people and events	0.750	5.40 (2.09)	5.36 (2.19)	5.25 (2.10)	5.51 (2.04)

[1]Scales ranged from 1 (Never) to 5 (Very Often); confirmatory factor analysis indicated good model fit (χ^2 = 73.557, df = 19, p <0.001; RMSEA = 0.062 (90% CI: 0.048-0.077); CFI = 0.958; TLI = 0.938; SRMR = 0.035).

[2]Scales ranged from 1 (Low Threat) to 5 (High Threat) and reflect perceived seriousness of threat invasive species are to each of the six items; confirmatory factor analysis indicated good model fit (χ^2 = 51.668, df = 8, p <0.001; RMSEA = 0.086 (90% CI: 0.065-0.109); CFI = 0.980; TLI=0.963; SRMR = 0.023).

[3] Scales ranged from 1 (Opposed to my values) to 9 (Of Supreme Importance); confirmatory factor analysis indicated good model fit (χ^2 = 90.679, df = 24, p <0.001; RMSEA = 0.062 (90% CI: 0.048-0.075); CFI = 0.980; TLI=0.970; SRMR = 0.039).

After defining the measurement model, we estimated a structural model to test our hypotheses (Figure 3.1). Specifically, we tested twelve hypothesized paths between values and risk perceptions (H1-H6) and risk perceptions and reported behavior (H7-H12). The model was identified given 7 constructs and 15 hypothesized paths and correlations; however, due to the sample size of subgroups in relation to model complexity, parceling was conducted (Matsunaga, 2008). A manifest model including the mean value scores for each construct was then run in RStudio 1.4.1717 (R Core Team, 2020), using lavaan and semTools packages. The full information maximum likelihood (FIML) method was used to account for missing data[1] (von Hippel, 2016). Model fit was assessed using a chi-square test of significance, root mean square error approximation (RMSEA), comparative fit index (CFI), the Tucker-Lewis index (TLI), and standardized root mean square residual (SRMR) (Kline, 2011). Our models were estimated, and fit was assessed separately for the pooled sample and each of the three fishing site subgroups. Non-significant paths were dropped from the final analysis. To compare subgroup models with the pooled sample model, we used an invariance constraints procedure and analyzed differences using a chi-square difference test (Bollen, 1989).

3.4. Results

Our sample was primarily White (88.0%) and male (85.6%), with an average age of 56 years (Table 3.2), which is consistent with past AIS survey research conducted in the Great Lakes region (Connelly et al., 2014). On average, survey participants had fished 29 days in the past year and had 41 years of fishing experience. Representation of anglers from the three

[1] The full information maximum likelihood (FIML) method "repeatedly auditions different combinations of population parameter values" to identify the best model fit (Enders 2010, Applied Missing Data Analysis – p. 61). This method estimates parameters based on all available data, whether or not each case is completed. This method is thus considered more efficient and less biased than deleting incomplete cases or imputation.

sampled states was roughly even (Illinois = 34.5%, Michigan=28.7%, New York = 36.9%). Fishing effort was split across types of species, including salmonids (22.3%), warm water game species such as bass species and walleye (51.1%), and panfish and other species (26.6%).

Table 3.2. Characteristics of recreational anglers in the Great Lakes regions of Illinois, Michigan and New York in the pooled sample and three fishing site subgroups

		All anglers	**Great Lakes and Tributaries anglers**	**Inland waterways anglers**	**Mixed-site anglers**
		Valid %	Valid %	Valid %	Valid %
Gender	Male	88.0	88.2	84.9	89.5
	Female	12.0	11.8	15.1	10.5
	Other	0.0	0.0	0.0	0.0
Race[a]	White	85.6	85.5	89.7	83.5
State	Illinois	34.5	18.0	54.2	31.4
	Michigan	28.7	36.0	22.2	45.0
	New York	36.9	45.9	23.6	23.6
Target Species	Salmonids	22.3	38.3	8.2	22.5
	Warm/coolwater game	51.1	48.1	55.5	50.1
	Panfish and Other	26.6	13.6	36.3	27.4
Fishing method	Shore	36.1	40.6	39.6	32.3
	Boat	44.2	46.5	46.0	42.3
	Boat and Shore	19.7	12.9	14.4	25.5
Age	Ages (M, SD)	56.31 (15.68)	56.67 (14.76)	55.78 (16.43)	56.43 (15.70)
Days fished	Days (M, SD)	29.15 (38.81)	28.17 (35.18)	21.29 (22.22)	33.76 (46.01)
Years fished	Years (M, SD)	40.82 (17.99)	40.28 (17.56)	38.39 (19.62)	42.31 (17.19)
Self-reported fishing skill[b]	Skill (M, SD)	3.72 (1.44)	3.63 (1.48)	3.54 (1.55)	3.85 (1.36)

[a]Less than 10% of respondents selected American Indian, Asian, Black, or Pacific Islander.

[b]Self-reported fishing skill was measured on a 5 point scale ranging from 1=Much lower than average to 5=much higher than average.

Our analysis revealed partial support for the hypothesized relationships in the manifest path model (Figure 3.2). The chi-square test was significant (χ^2=33.511, *df*=9, *P*<.001), thus other fit statistics were referenced, each of which fell within acceptable ranges and demonstrated a good fit of the model to the sample data (*CFI*=0.981; *TLI*=0.956; *RMSEA*=0.060; *SRMR*=0.044). In the pooled sample, biospheric values positively predicted social (β=.326; H3) and personal risk perceptions (β=.271; H4). Personal risk perceptions also increased egoistic values (β=.091), contrary to our hypothesis (H6). Finally, higher personal risk perceptions led to both private (β=.323; H10) and public behaviors (β=.251; H11).

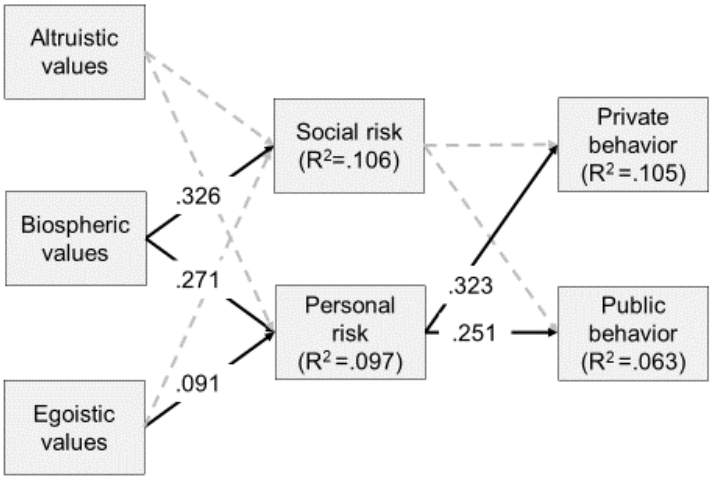

Figure 3.2. Drivers of behavior reported by anglers residing in Illinois, Michigan, and New York counties bordering Lake Michigan or Lake Ontario (N=757). Fit statistics: $\chi 2$=33.511, *df*=9, P<.001; *CFI*=0.981; *TLI*=0.956; *RMSEA*=0.060; *SRMR*=0.044. Hypothesized paths that were non-significant are shown in grey dotted lines.

We compared models between three fishing site subgroups, including Great Lakes and Tributaries (n=172), inland waterways (n=203), and mixed-site (n=382) anglers (Figure 3.3). First, we compared factor means across the three subgroups; anglers who frequented both Great

Lakes and tributaries and inland waterways tended to have higher levels of AIS-relevant reported behavior and perceived greater risk than those who exclusively fished either Great Lakes and tributaries or inland waterways (Table 3.3). Second, we compared regression coefficients among the three groups ($\Delta\chi 2$=31.029, Δdf=22, P=0.096; Table 3.4). A strong positive relationship between biospheric values and both social risk and personal risk perceptions was observed for all three groups. Relationships between risk perceptions and reported behavior varied among the groups. For the inland waterways subgroup, only the relationship between personal risk perceptions and private behavior was significant (β =.243). For mixed-site anglers, personal risk strongly predicted both public (β =.298) and private (β =.360) behaviors. For Great Lakes and Tributaries anglers, personal risk perceptions predicted public behaviors (β =.252) and social risk perceptions predicted private behaviors (β = .318).

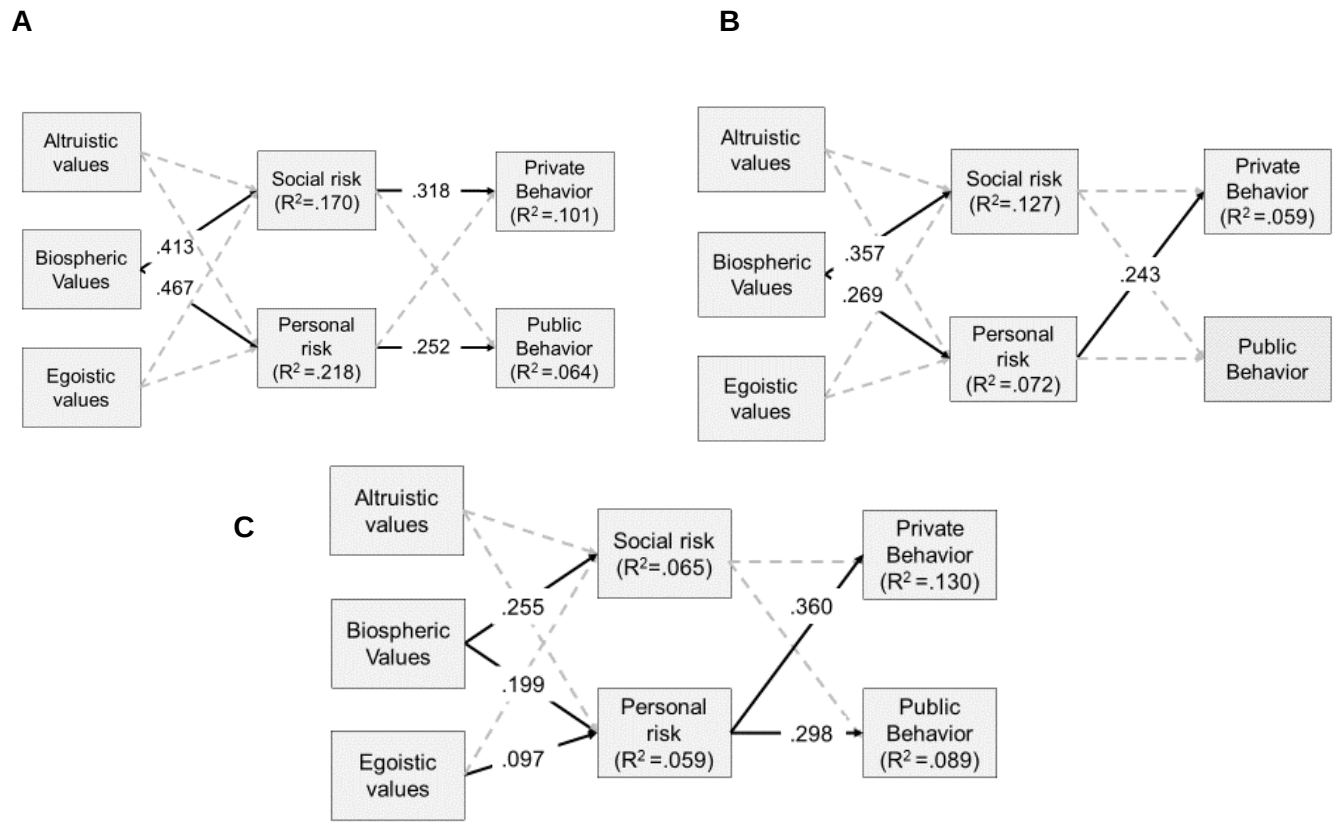

Figure 3.3. Drivers of angler behavior of anglers fishing in the following environments: **A) Great Lakes and tributaries** (Model fit: $\chi 2$=17.447, *df*=12, *P*=0.134; *CFI*=0.983; *TLI*=0.971; *RMSEA*=0.052; *SRMR*=0.051; **B) Inland waterways** (Model fit: $\chi 2$=11.588, *df*=7, *P*=0.115; *CFI*=0.984; *TLI*=0.967; *RMSEA*=0.057; *SRMR*=0.058); and **C) mixed-sites** (Model fit: $\chi 2$=23.680, *df*=9, *P*=0.005; *CFI*=0.976; *TLI*=0.945; *RMSEA*=0.066; *SRMR*=0.043). Hypothesized paths that were non-significant are shown in grey dotted lines.

Table 3.3. Means and ANOVA results for each construct. Within each row, means with different lowercase letters are significantly different at $p < .05$, based on Tukey's honestly significant difference comparison. Eta squared (η^2) provides a measure of effect size (i.e. the ratio of variance explained by the independent variable) and ranges from 0 to 1.

	All anglers	**Great Lakes and Tributaries anglers**	**Inland waterways anglers**	**Mixed-site anglers**			
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	F-value	P-value	η^2
Behavior							
Private	2.51 (1.04)	2.49 (1.04) z	2.21 (0.96) y	2.68 (1.04) z	14.012	0.000	0.037
Public	1.46 (0.71)	1.47 (0.73) zy	1.36 (0.67) y	1.52 (0.72) z	3.298	0.038	0.009
Risk							
Personal	3.39 (1.02)	3.44 (1.04) z	3.21 (1.07) y	3.47 (0.97) z	4.663	0.010	0.013
Social	4.24 (0.95)	4.18 (1.00) zy	4.10 (1.04) y	4.34 (0.86) z	4.527	0.011	0.012
Values							
Biospheric	7.24 (1.61)	7.12 (1.75)	7.13 (1.70)	7.35 (1.49)	1.767	0.171	0.005
Altruistic	7.04 (1.84)	6.85 (1.96)	7.04 (1.90)	7.14 (1.75)	1.413	0.244	0.004
Egoistic	4.90 (1.74)	4.93 (1.86)	4.85 (1.78)	4.91 (1.67)	0.111	0.895	0.000

Table 3.4. Results from a manifest variable path model of the predictors of private and public behavior among recreational anglers. Variables that were non-significant and thus not retained in the final model are noted as "ns".

Dependent variable	Predictor variable	**All anglers**		**Great Lakes and Tributaries anglers**		**Inland waterways anglers**		**Mixed-site anglers**	
		β	R^2	β	R^2	β	R^2	β	R^2
Private behavior	Personal Risk (H_{10})	0.323	0.105	ns	0.101	0.243	0.059	0.360	0.130
	Social Risk (H_7)	ns		0.318		ns		ns	
Public behavior	Personal Risk (H_{11})	0.251	0.063	0.252	0.064	ns	ns	0.298	0.089
Social Risk	Biospheric (H_3)	0.326	0.106	0.413	0.170	0.357	0.127	0.255	0.065
Personal Risk	Biospheric (H_4)	0.271	0.097	0.467	0.218	0.269	0.072	0.199	0.059
	Egoistic (H_6)	0.091		ns		ns		0.097	

3.5. Discussion

We investigated multiple drivers of angler behavior with the goal of informing management strategies that reduce angler transport of AIS in the Great Lakes region. Results revealed that values for environmental protection as a guiding principle in life were fundamentally important for explaining why individuals perceived risks, and in turn, reported engaging in behaviors related to the spread of AIS. A comparison between Great Lakes and tributaries, inland waterways, and mixed-site anglers revealed consistency in values, as expected, but variation in risk perceptions and behavior. These findings provide insight on individual, small-scale behaviors that can have large-scale impacts on environmental sustainability by curbing the effects of unintentionally transported invasive species.

Public behaviors (e.g., talking to others about AIS or engaging in local politics) were not as frequent as private behaviors (e.g., draining a boat after fishing) among all subgroups of recreational angler engaged in this research. While private behaviors were reported "rarely" to "sometimes," public behaviors were reported "never" to "rarely." Although there is room for improvement with both types of behavior, there is a particular need to highlight public sphere behaviors, which are largely absent from current outreach initiative that focus on private behaviors such as boat washing (Seekamp, McCreary, et al., 2016). Angler interest in public sphere behaviors can be initiated through in-depth discussions with anglers that recognize and embrace their values regarding AIS (Barclay et al., 2017; Kemp et al., 2017) and encourage further group action to prevent AIS spread. Thus, campaigns to promote public behaviors, such as encouraging anglers to contact a political representative about an AIS issue or to bring a friend to an upcoming AIS event, may be helpful in generating wider-reaching effects.

Personal risk perceptions were shown to be more influential than social risk perceptions in encouraging behaviors that curb the spread of AIS. Specifically, there was a significant, positive relationship between personal risk perceptions and AIS-prevention behavior for all angler subgroups in this study, whereas the relationship between social risk perceptions and reported behavior was not significant. Thus, for most anglers, regardless of their perceptions of general risks of AIS, they are unlikely to take preventative action until they believe that those risks will impact their own lives. These findings extend past work on the importance of risk perceptions in behavior change (O'Connor et al., 1999; Kothe et al., 2019) by highlighting the particular importance of personal risk perceptions. Past work assessing multiple dimensions of risk has argued that social risk perceptions are higher than personal risk perceptions (van der Linden, 2015; van Riper et al., 2016); we both corroborate this finding and extend it by noting that while personal risk perceptions may be lower, they may also be more influential in predicting behavior. Thus, the current study offers a new perspective on how risk perceptions can aid in encouraging AIS prevention and understanding angler behavior more broadly.

Reported behavior and risk perceptions varied among Great Lakes anglers, inland waterways anglers, and those who frequented both types of fishing environments. Inland waterway anglers had lower personal risk perceptions, as well as lower engagement in private-sphere behaviors than both Great Lakes and mixed-site anglers. Additionally, the relationship between social risk perceptions and behavior related to deterring the spread of AIS was significant only for Great Lakes anglers. It could be that educational campaigns targeted at Great Lakes anglers have successfully communicated the severity of impacts from invasive species on the Great Lakes fishery and the region's economy, whereas inland waterways anglers have had more limited exposure to outreach messages. In support of this argument, AIS messages are

rarely presented at inland sites as compared to Great Lakes access points (e.g., Be A Hero's boat wash stations are only found in Northern Illinois near Lake Michigan, see transportzero.org), and there are large difference in outreach investment across the state (Cole et al., 2016). Given that exposure to AIS messages increases awareness (Seekamp, Mayer, et al., 2016), groups outside of the Great Lakes region should be targeted by future outreach initiatives. These findings highlight the importance of considering distinguishable segments of recreational anglers defined by fishing location (Witzling et al., 2016; Dabrowska et al., 2017). Together, results from the current study clearly show that angler risk perceptions vary across locations and need to be considered when designing strategies to control the spread of aquatic invasive species.

Biospheric values were stronger predictors of AIS risk perceptions than egoistic or altruistic values. Across all subgroups tested, biospheric values significantly predicted both personal and social risk perceptions whereas egoistic values only weakly predicted personal risk perceptions, and the relationship between altruistic values and risk perceptions was not significant. These results suggest that value systems driven by self-worth and achievement result in concerns about personal impacts from AIS, rather than impacts on the environment or community outside of an individual's experience. This finding lies in contrast to past work suggesting egoistic values should be negatively correlated with environmental beliefs (de Groot & Steg, 2008). Additionally, we suggest that anglers who strongly value the environment will be more concerned with the impacts on AIS both to their local fishing site and to the environment more broadly given that biospheric values were far stronger predictors of risk perceptions. As guiding principles in life (Rokeach, 1973), values are one of the most fundamental influences on environmental behavior that remain unchanged throughout the lifespan and could be

incorporated in future fisheries research to complement the large body of work focused on angler satisfaction (Birdsong et al. 2021).

Several message design guidelines can be derived from this study to help close the "knowledge-action gap" (Kollmuss & Agyeman, 2002) and encourage anglers to reduce the spread of AIS. To activate personal risk perceptions, managers can encourage anglers to consider how AIS affect their everyday lives. Angler-relevant topics at risk of being impacted by AIS could include angler's appreciation of the beauty of the landscape, access to favorite waterbodies, ability to catch desired fish species, and damage to personal fishing equipment. To share information about the personal relevance of biological invasions, managers may recruit anglers to serve as spokespersons to share personal narratives about AIS. The spokespersons could be highlighted within brochures or other printed material, by including an image of the spokesperson alongside a quotation of that angler's personal reasons for their concern about AIS and decision to take action. Personal anecdotes about how AIS have changed a favorite fishing site may resonate with anglers who can identify with the spokesperson; past work in other contexts has found a strong relationship between identification with the speaker and intentions to engage in recommended behaviors (Brown et al., 2003; Kosenko et al., 2015). Related research has shown that print newspapers and other anglers are the most common sources of information regarding AIS in this region (van Riper et al., 2020); thus, these sources present opportunities to convey risk information through personal narratives, thus enabling anglers to think about how they will be personally impacted by AIS. Finally, although messaging on social risks (e.g., threats to the economy or fishery more broadly) is unlikely to encourage behavior change for inland waterways anglers, social risk perceptions significantly predicted behavior for anglers

fishing on the Great Lakes and thus we recommend continuing messaging on broad impacts specifically at Great Lakes outreach sites.

For both Great Lakes and inland anglers, the strong influence of biospheric values on risk perceptions presents an opportunity to frame risk messages in line with these values. Past work on invasive species communication has highlighted the importance of engaging "deep frames" such as values that may result in long-term behavior change (Hine et al., 2014). The Be a Hero and Stop Aquatic Hitchhikers campaigns generally draw on the biospheric theme of protecting natural environments, such as through Stop Aquatic Hitchhiker's "protect your waterways" slogan. Our results provide support for this messaging choice, but also suggest the broader definition of biospheric values should be considered. Messages that emphasize the concepts of unity with nature and appreciating the beauty of natural areas, in addition to protecting the environment, would more completely reflect biospheric values, and therefore be more likely to influence risk perceptions. Given the non-significance of altruistic values detected in this study, emphasizing benefits to the community of preventing AIS-spread is unlikely to encourage anglers participation in prevention behaviors. Thus, complementing existing campaigns with messages that highlight personal relevance of AIS and adding additional themes related to biospheric values beyond generally protecting the environment may result in higher risk perceptions and ultimately higher participation in AIS-prevention among recreational anglers.

3.5.1. Limitations

Results from our study should be interpreted knowing there were limitations that emerged throughout the research process. As documented in a growing body of previous research (Coon et al., 2019; Stedman et al., 2019), our low response rate was of concern. It could be that

important differences between our sample and the target population may have influenced responses. We were not able to assess nonresponse bias because we had mailing addresses without an alternative method for contacting non-respondents. That is, we could not confirm whether there were any trends among anglers who did or did not complete our survey. However, we did compare our data with past research (Ready et al., 2012; Connelly et al., 2014) on Great Lakes anglers and observed similarities in demographics and specialization. Future research should continue to consider how differences in characteristics such as levels of specialization may influence non-response bias. This could occur through assessments of license type (Hunt et al. (2021).

3.5.2. Conclusion

Recreational anglers can help prevent the spread of AIS by taking steps such as cleaning their equipment before leaving a waterway; however, despite the prevalence of outreach campaigns to raise awareness of AIS prevention techniques, the risk of AIS transport via anglers remains high. Our study identified relationships among values, risk perceptions, and reported angler behavior in the context of preventing the spread of AIS by anglers in the Great Lakes region. Personal risk perceptions (i.e., believing that one's own fishing experience or the specific environment where one prefers to fish may be harmed by AIS) were strong predictors of both public and private dimensions of AIS prevention behaviors. Two deeper drivers of behavior, particularly biospheric and egoistic values, influenced personal risk perceptions. Future research should further explore the relationship between egoistic values and risk perceptions to understand whether it is rooted in self-interest or a desire for leadership. The messaging implications generated through this research provide a basis for future experiments on how

people with different value profiles respond to messages aimed at increasing risk perceptions and ultimately behavior. In practice, managers should consider complementing language about large-scale environmental impacts of AIS with language that explains how anglers may be personally affected should AIS populations grow or spread. Likewise, outreach campaigns can be supplemented with news articles highlighting personal anecdotes from anglers who have experienced harm caused by AIS. Ultimately, educational outreach campaigns in the context of AIS and beyond can be enhanced by understanding drivers of behavior and aligning message design with the psychological processes that shape angler decision-making.

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CHAPTER 4: ENHANCING AQUATIC INVASIVE SPECIES OUTREACH THROUGH VALUES-FRAMED MESSAGES

4.1. Abstract

Aquatic invasive species (AIS) pose negative threats to ecosystems and society on a global scale by spreading disease, damaging infrastructure, outcompeting native species, and destroying habitat. Humans are responsible for unintentionally transporting AIS on watercraft and equipment moved from one body of water to another and have consequently prompted outreach campaigns that encourage recreational water users to stop the spread of AIS. Many water users now engage in a range of preventative behaviors; however, due to interconnectivity of waterbodies among other factors, there remains a high risk of AIS transport by recreationists. Innovation in environmental communication is urgently needed to more effectively reach water users who are not yet engaging in preventative behaviors. Therefore, we relied on an experimental design to test the persuasive capacity of values-framed outreach messages among recreational water users throughout the U.S. state of Illinois. Results indicated that messages framed in line with self-transcendent values (i.e., focused on other people and the environment) were most likely to resonate with recreational water users. Specifically, participants with strong self-transcendent values were more likely to review the message closely when it was aligned with their values, resulting in stronger beliefs about one's own ability to take action and influence biological invasions. Ultimately, adopting the new messaging strategies developed in this study will support the goal of increasing participation in AIS-prevention behaviors and lowering the risk of AIS spread.

4.2. Introduction

Aquatic invasive species (AIS) are organisms that have established an expanding population outside of their native range and are causing negative human or environmental impacts (Blackburn et al., 2011), such as altering habitat, out-competing native species for food, and interfering with human outdoor activity (Gallardo et al., 2016). Removal of AIS after they have established is near impossible, thus early detection (Larson et al., 2020) and prevention (Leung et al., 2002; Vander Zanden & Olden, 2008) are key. Recreational water users are at risk of spreading AIS when small organisms, such as plants, mussels, and zooplankton, attach to boats or equipment, or are carried along in water within the boat (e.g., ballast water, live wells), allowing these AIS to later be deposited in a new location (Rothlisberger et al., 2010). Thus, informing aquatic recreationists of the ways they can prevent unintentional transport of AIS, and have become priorities for resource management agencies that steward aquatic ecosystems (Pradhananga et al., 2015; Seekamp et al., 2016; Vander Zanden & Olden, 2008; Johnson et al., 2001).

Numerous public outreach campaigns have been developed to raise awareness of the risks posed by AIS and encourage recreationists to partake in risk-prevention behaviors (https://www.invasivespeciesinfo.gov/subject/outreach-and-awareness). Recommended risk-prevention behaviors include removing plants and animals from boats and equipment, draining water from the boat, and drying all equipment thoroughly before leaving the waterbody (Pradhananga et al., 2015). Past work has evaluated the "Be a Hero" campaign, as well as other campaigns including "Stop Aquatic Hitchhikers!" and "Habitattitude" (Kemp et al., 2017; Seekamp et al., 2016), finding that they have successfully raised awareness about AIS (Eiswerth et al., 2011; Cole et al., 2016). However, although awareness is high, and

participation in prevention behaviors has increased modestly, necessary levels for reducing the risk of AIS transport have not been met (Cole et al., 2019). In other words, many people have become aware of the issue, but have not yet taken action. This phenomenon, referred to as the "knowledge-action gap" (Kollmuss & Agyeman, 2002), has sparked calls for research investigating the drivers of behavior relating to AIS and the development of campaigns that move beyond knowledge and awareness to stimulate deeper psychological processes.

4.2.1. Message Framing

Message framing encompasses a broad area of study related to the way information is communicated and understood (Lakoff, 2010). Framing has been defined as "the process by which people develop a particular conceptualization of an issue" (Chong & Druckman, 2007, p. 104), to "reduce the complexity of the world and thereby render it comprehensible and meaningful" (Geise & Baden, 2015, p. 46). For instance, invasive species professionals often use "militaristic" frames, which convey the problem of invasive species in terms of a war or battle between humans and the invader (Clarke et al., 2020; Janovsky & Larson, 2019). This frame has been adopted to help people understand the ecological dynamics of invasive species by explaining these processes with more familiar language. In contrast to "militaristic" frames, researchers have classified "passenger" frames as those which describe invasive species as passive entities that are influenced by a variety of environmental changes (Hart & Larson, 2014). Though at times more scientifically accurate, this frame has low potential to evoke risk perceptions, compared to frames that portray invasive species more menacingly (Hart & Larson, 2014). In conversation and popular press, frames are inevitably evoked, but at times ignorant to unintentional consequences like boomerang effects, in which people interpret the

message incorrectly or reject its contents (Byrne & Hart, 2009), and diverting attention away from more pressing issues (Mando & Stack, 2019).

Outreach campaigns deliberately select message frames by drawing on multiple techniques, like normative framing (e.g., Niemiec et al., 2021) and the use of metaphors (e.g., Raymond et al., 2013). Normative framing highlights how desired behavior, such as cleaning boats to prevent the spread of AIS, is performed by the majority of one's peers, or is expected to be performed by trusted sources (Cialdini, 2003). Although there is robust evidence that normative framing is effective for environmental issues like littering (Cialdini et al., 1990) and water conservation (Lede & Meleady, 2019), there are mixed results on its persuasiveness in the context of invasive species (Wallen & Kyle, 2018; Niemiec et al., 2021). An additional communication strategy is the use of metaphors, defined as a type of frame in which a less familiar object (e.g., invasive species) is compared to a more familiar object (e.g., hitchhikers) to convey meaning and emotion in the explanation (Shaw et al., 2021; Raymond et al., 2013). Metaphorical frames have been shown to heighten risk perceptions of environmental issues (Flusberg et al., 2017) and bolster support for invasive species policy (Kohl et al., 2020). However, there have been ethical concerns raised over militaristic and nativist frames been given their potential to evoke xenophobia (Larson, 2005; Verbrugge et al., 2016; Mando & Stack, 2019). To move past these limitations and energize longer-lasting behavior change, deeper psychological processes such as values should be considered (Nisbet & Mooney, 2007), activated (Raymond & Raymond, 2019) and made accessible as a pathway for dissolving barriers to effective environmental communication (van Riper et al., 2018).

4.2.2. Values

Efforts to engage anglers and stimulate behavior change can be improved by incorporating stable psychological processes such as values – defined as broad goals that serve as guiding principles in life (Rokeach, 1973) – into resource management decisions (Golebie et al., 2021a). Values have been conceptualized and understood through numerous theoretical frameworks (Kenter et al., 2019; Stern et al., 1999; Dietz et al., 2005; Schwartz, 2012), and have been shown to motivate environmental actions such as invasive species prevention (e.g., van Riper & Kyle, 2014) when the behavior is relevant to the underlying value (Sagiv & Schwartz, 2022). In particular, biospheric values (i.e., environmental protection that aids in finding unity with nature) lead individuals to take actions such as conserving water and electricity (Liobikiene & Juknys, 2016) or cleaning boats to prevent the spread of AIS (Golebie et al., 2021a). Altruistic values (i.e., equality, justice, and peace) and egoistic values (i.e., power and influence) also impact behavior, though egoistic values tend to be negatively correlated with environmental behavior (de Groot & Steg, 2008). Despite robust evidence that values are both direct and indirect predictors of behavior (Karp, 1996; Schultz et al., 2005; van Riper et al., 2019; Shin et al., 2022), there has been minimal research on the necessary parameters for activating values that encourage people to participate in environmentally beneficial behaviors.

To infuse communication strategies with value-based content, messaging should align information with an individual's core belief system in appealing ways (Kahan, 2012). Previous research has showed that environmental outreach campaigns are enhanced by content that aligns with the values of a target audience (Lagomarsino et al., 2020); relevant values can be identified by consulting with the target audience (McDermott et al., 2003), conducting surveys

(Golebie et al., 2021), or drawing on known characteristics such as political affiliation (Corner et al., 2014) or gender (Dietz et al., 2002). If a constituency holds strong altruistic values, messages could align with those values by highlighting how the protection of fish habitat would benefit future generations. Conversely, messages that appeal to individual achievement and prestige over the good of a group would run counter to altruistic and biosphere values and thus may not resonate or even be disregarded (Lakoff, 2004). This body of work has indicated that value appeals are effective but partly a function of social pressures (Peloza & White, 2009). Moreover, biospheric messaging can be more influential for an environmental campaign as compared with altruistic and egoistic messages (Hansla, 2011). Further complicating interpretation of message efficacy is the relative influence of alignment with an individual's own values versus the message content itself. Although there is evidence that value alignment may affect one's ability to discern argument strength (von Borgstede et al., 2014) and attitudes (Arp, 2018), its impact on beliefs like risk perceptions and efficacy, and the resulting relevance for AIS-related environmental outreach programs, have yet to be studied.

4.2.3. Reactance

Reactance is integral to how people respond to messages. We define reactance as "the motivational state that is hypothesized to occur when a freedom is eliminated or threatened with elimination" (Brehm & Brehm, 1981, p. 37). If a message is too forceful, readers may perceive it to be a threat to their own choices and resist the message (Quick et al., 2013). For instance, if a boater believes a "remove-drain-dry" sign is aggressive and intrudes on their post-boating routine, they may respond by refusing to remove-drain-dry in an attempt to assert their own autonomy. People are also likely to experience reactance and reject a message when they do not

believe they have the ability to respond (Maddux & Rogers, 1983). Therefore, reactance can be averted by imbuing messages with statements that activate self-efficacy and empower individuals to take responsibility for their actions (Chang, 2021). However, previous research has also indicated that people are more likely to experience reactance in response to an identity threat (Hansen et al., 2010; Murtagh et al., 2012; Ma & Hmielowski, 2021). Therefore, there is a strong need to consider whether reactance is elicited among people who read a message imbued with values that do not align with their own.

4.2.4. Elaboration

The elaboration likelihood model positions message processing along a continuum ranging from low to high elaboration (Petty & Cacioppo, 1986). When engaging in high elaboration, people think systematically about information relevant to the message topic, which is in contrast to low elaboration whereby people use mental shortcuts and heuristics to form their opinions about the message. High elaboration is sought after in communication campaigns because it tends to create stronger attitudes, and longer-lasting effects (O'Keefe, 2013). For example, anglers who carefully read and reflects on AIS brochures are more likely to believe that AIS are a problem, as compared to anglers who skim content or only look at images.

Elaboration depends on issue-involvement, defined as personal relevance of an issue to one's life (Petty & Cacioppo, 1979). When someone has high issue-involvement, they recognize the relevance of the message and are thus motivated to read it closely and think deeply about its contents (Petty et al., 1983). For example, anglers who are concerned about the impacts of AIS are more likely to closely examine informational materials about the same

topic. There is also evidence that messages tailored to individual characteristics increase elaboration (Kroeze et al., 2006). Thus, values may have a similar effect; relevance to one's guiding principles in life may increase perceived issue-involvement, as well as directly increase motivation to engage with a message more closely (von Borgstede et al., 2014; Arp, 2018).

Protection Motivation Theory posits that risk perceptions and efficacy are two key responses to a risk-based message that will predict engagement in prevention behaviors (Rogers, 1975). Risk perceptions that reflect beliefs about the severity of threats are relevant to pro-environmental behavior across a variety of contexts (O'Connor et al., 2999; Kothe et al., 2019). Efficacy includes both self-efficacy, defined as beliefs about one's ability to effectively complete an activity (Bandura, 1977), and response-efficacy, defined as beliefs that the activity itself will have a positive impact (Lewis et al., 2010). A substantial body of previous research has been guided by Protection Motivation Theory and underscored the importance of both efficacy and risk in informing behavior (Floyd et al., 2000). However, no research to date has determined how these variables are impacted by elaboration that is induced by values-framed messages. Assuming a trustworthy message is employed, it is likely that when elaboration is high, risk and efficacy beliefs would also increase (Petty et al., 2009). Therefore, examining the explanatory relationships among elaboration, risk and efficacy will provide insights into the utility of values-framed messaging campaigns.

4.2.5. Study Purpose

Given that values are fundamental drivers of behavior (van Riper et al., 2019) and shown to predict recreationist intentions to prevent AIS spread (Golebie et al., 2021; Shin et al., 2022),

framing outreach messages in line with values may encourage more recreationists to take action. However, values-framing, and more specifically alignment between the values portrayed within a message and the values of the message recipient have yet to be empirically tested. Therefore, this study assessed the effectiveness of AIS outreach messaging framed according to self-transcendent (i.e., biospheric and altruistic) and self-enhancement (i.e., egoistic) values. The following three research questions were addressed: 1) What responses do values-framed messages evoke among recreational water users?; 2) How are relationships among values, involvement, elaboration, and beliefs influenced by messages framed in line with different values?; and 3) How does reading a message aligned with one's values affect their processing of that message?. In response to these objectives, we tested 12 hypotheses using a latent variable path model (Figure 4.1).

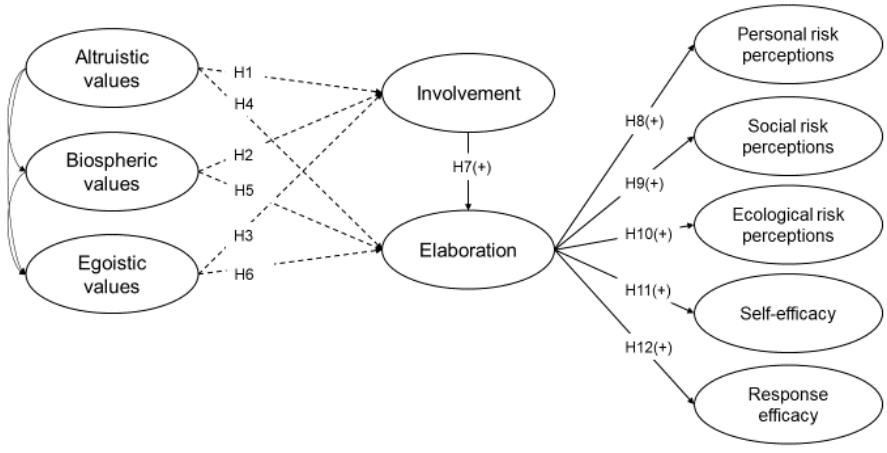

Figure 4.1. Hypothesized model of relationships among values, involvement, elaboration, and beliefs relevant to aquatic invasive species. Twelve hypothesized paths were tested between values and involvement (H1-H3), values and elaboration (H4-H6), involvement and elaboration (H7), and elaboration and beliefs (H8-H12). Plus signs (+) indicate positive hypothesized relationships. Dotted lines indicate hypothesized relationships dependent on message treatment. Values were hypothesized to positively correlate with elaboration if there was message alignment (i.e., biospheric values were hypothesized to positively correlate with elaboration when presented with the self-transcendent message; egoistic values were hypothesized to positively correlate with elaboration when presented with the self-enhancement message).

4.3. Methods

4.3.1. Study Context

This research was conducted across the US state of Illinois (IL) where AIS are of great concern due to the interconnectedness of waterbodies (Cole et al., 2019). We evaluated an outreach campaign that was developed by the IL Department of Natural Resources known as "Be A Hero"; its tagline "Be a Hero, Transport Zero" encourages recreational water users to minimize their risks of transporting AIS (https://www.transportzero.org/). Research has shown that approximately 25% of boaters recognize the Be a Hero campaign (Cole et al., 2016). As resource managers continue publicizing the campaign to new audiences, evaluating the campaign (e.g., Seekamp et al., 2016) and considering modifications will help to further increase its efficacy.

4.3.2. Sampling Methods

This message experiment was implemented through a survey administered to IL residents from May-June 2021. Participants were recruited from a Qualtrics panel of IL residents. Panel members were deemed eligible if they were at least 18 years old and had gone fishing or participated in a recreational water activity (e.g., sailing, kayaking, canoeing, boating, jetskiing) on at least one occasion since 2018. All participants were compensated by Qualtrics for their participation.

Our protocol (#20679) was approved by the University of Illinois at Urbana Champaign Office for the Protection of Research Subjects (OPRS). Participants provided informed consent appropriate for an online survey, as approved by the OPRS. Specifically, upon entering the survey, information about the study and its benefits to the participants were provided, and

participants could indicate their consent by entering the survey. Participants had the ability to withdraw after reading the consent information, and to exit the survey at any time.

Responses were recorded only when the entire survey was completed and when two "attention check" questions were answered correctly (Kung et al., 2018). Invalid responses were discarded when patterns indicated extreme inattention or possible use of bots. The final sample size was 507.

4.3.3. Experimental Design

During the survey, each participant was presented with one experimental outreach message. In consultation with Illinois-Indiana Sea Grant, three treatments were developed to test the effects of values-framed messaging (Table 4.1), modifying a brochure currently in use by the Be a Hero campaign.

Table 4.1. Message content for three treatments that reflected self-transcendent values, self-enhancement values, and a baseline message.

Treatment	Message content
Self-transcendent	PROTECT THE ENVIRONMENT Aquatic invaders can dramatically change the ecosystem and harm native fish species. By completing remove-drain-dry, you can… • Protect the quality of habitats and natural environments • Preserve recreational opportunities for future generations • Build a sense of community among anglers and water users • Ensure the economic benefits provided by the resource will continue to benefit the region

Table 4.1. (cont.)

Treatment	Message content
Self-enhancement	YOUR WATERWAYS ARE BEING IMPACTED Aquatic invaders can block access to waterbodies and prevent you from enjoying your favorite activities. By completing remove-drain-dry, you can… • Protect the waterbodies that you value the most • Ensure you'll be able to enjoy the resource for years to come • Know you have done the right thing to be a responsible angler or boater • Influence other recreationists to take responsibility for the ecosystem
Baseline	Don't dump bait

First, self-transcendent messages incorporated the ideas of altruism and environmentalism as guiding principles in life. Second, self-enhancement message incorporated the ideas of self-interest and goal attainment as guiding principles in life. Finally, a third group received the original message contained in the current version of the brochure, which simply reads: "Don't dump bait." Each participant was randomly assigned one of these three messages to evaluate.

4.3.4. Survey Measures

Three scales were used to measure how participants evaluated messages focused on AIS spread in IL: message effectiveness, reactance, and elaboration. Each scale was drawn from past work and confirmatory factor analysis was performed to evaluate the psychometric

properties for all scales. Reliability was tested using Cronbach's alpha (α) and McDonald's omega (Ω) and considered acceptable when coefficients were greater than 0.60 (Cortina, 1993; Bagozzi & Yi, 1988). Convergent validity was considered acceptable with average variance extracted (AVE) values that exceeded .50 (Hair et al., 2011). We used a six-item message effectiveness scale developed in past work (Davis et al., 2013), and found it to be reliable and valid (α = .908; Ω = .910; AVE=.629). We used a seven-item reactance scale drawn from past work, which defined reactance as "an oppositional response to perceived pressure for change" (Nisbet et al., 2015, pp 42). Due to low reliability in the original reactance scale, all reverse coded items were dropped, resulting in a three-item scale that was deemed acceptable (α = .697; Ω = .700; AVE=.442). To measure elaboration, we selected six items from an established scale (Reynolds, 1997); three items were dropped given standardized factor loading scores below 0.40 (Hair et al., 2011), which resulted in a three-item scale (α = .714; Ω = .727; AVE=.479).

In line with Protection Motivation Theory (Rogers, 1975), risk perceptions and efficacy were measured after exposure to the message. Risk perceptions were assessed by asking participants to report the perceived severity of environmental, social, and personal impacts. Building on previous research that has measured both social and personal dimensions of risk (Brody et al., 2008; Kellstedt et al., 2008; van Riper et al., 2016), we added an environmental dimension to capture the direct threats faced by aquatic ecosystems that may be processed differently than threats that impact humans more directly. To measure self-efficacy, three items were drawn from past work (Bandura, 1977), and adapted to the context of AIS management. Three items measuring response-efficacy were developed during earlier qualitative phases of this project (Golebie et al., 2021a) and were refined in response to past research (Landon et al.,

2018). All risk perception and efficacy scales were reliable (Table 4.2).

Drawing on the Value Belief Norm Theory of Environmentalism (Stern et al., 1993), values were measured using survey items associated with three primary dimensions: biospheric, altruistic, and egoistic. Additionally, a six-item issue scale was adapted from past work (Quick & Stephenson, 2007) to measure issue involvement related to AIS. Two items from the involvement scale were dropped due to low factor loadings, such that the resultant four-item scale was reliable ($\alpha = .832$; $\Omega = .777$; AVE=.522).

Table 4.2. Factor loading scores, means and standard deviation for survey items evaluated by recreational water users in the pooled sample. Measures of internal consistency for each construct include Cronbach's alpha (α) McDonald's omega (Ω), and average variance explained (AVE).

	Factor loading	M (SD)
Biospheric values[1] (α = .798; Ω = .800; AVE=.572)		***4.27 (0.67)***
Protecting the environment: preserving nature	.741	4.37 (0.75)
Unity with nature: fitting into nature	.760	4.12 (0.86)
A world of beauty: beauty of nature and the arts	.766	4.33 (0.78)
Altruistic values[1] (α = .816; Ω = .831; AVE=.627)		***4.25 (0.78)***
Equality: equal opportunity for all	.802	4.28 (0.86)
Social justice: correcting injustice, care for others	.843	4.08 (1.04)
A world at peace: free of war and conflict	.693	4.38 (0.83)
Egoistic values[1] (Spearman-Brown Coefficient =0.768)*		***3.38 (1.02)***
Authority: the right to lead or command	.754	3.35 (1.17)
Influential: having an impact on people and events	.773	3.41 (1.11)
Self-efficacy[2] (α = .865; Ω = .865; AVE=.682)		***4.12 (0.75)***
I understand what I need to do in order to remove AIS from my boat or equipment	.840	4.11 (0.85)
I am capable of performing the tasks required to remove possible AIS from my boat and equipment	.826	4.18 (0.84)
I feel confident in performing procedures necessary to prevent AIS from spreading	.810	4.08 (0.83)
Response-efficacy[2] (α = .846; Ω = .846; AVE=.647)		***4.35 (0.66)***
Cleaning my boat and equipment helps to prevent AIS from spreading	.838	4.36 (0.73)
My own actions to remove, drain, dry will protect fishing waters from AIS	.818	4.30 (0.77)
If everyone remembered to "remove, drain, dry", we could significantly lower the risk of spreading AIS	.759	4.38 (0.77)
Environmental risk perceptions[3] (α = .823; Ω = .823; AVE=.609)		***3.56 (0.79)***
Quality of habitat and natural environments	.809	3.52 (0.88)
Environmental processes (e.g., water cycle)	.807	3.46 (0.95)
Survival of plants and animals	.723	3.69 (0.92)
Personal risk perceptions[3] (α = .815; Ω = .816; AVE=.598)		***3.32 (0.94)***
Your appreciation of the beauty of the landscape	.736	3.33 (1.10)
Your own enjoyment of recreational activities	.774	3.40 (1.05)
Your own access to the waterbody	.805	3.22 (1.14)
Social risk perceptions[3] (α = .843; Ω = .860; AVE=.677)		***3.32 (0.94)***
The local economy	.851	3.14 (1.12)
The community in the region	.895	3.16 (1.11)
Recreational opportunities for future generations	.687	3.66 (1.02)
Involvement[2] (α = .832; Ω = .777; AVE=.523)		**3.04 (0.89)**
The spread of aquatic invasive species is a personally relevant topic for me	.702	3.41 (0.95)
I think about aquatic invasive species a great deal	.772	2.85 (1.11)
I find myself bringing up aquatic invasive species in casual conversation	.680	2.54 (1.18)
When aquatic invasive species come up in conversation I "tune in"	.732	3.35 (1.11)
Elaboration[2] (α = .714; Ω = .727; AVE=.479)		***3.73 (0.73)***
Deep in thought about the message	.854	3.71 (0.90)
Extending a good deal of cognitive effort	.636	3.64 (0.98)
Reflecting on the implications of the arguments	.553	3.83 (0.88)

Table 4.2. (cont.)

Note: measurement model indicated good model fit ($\chi 2 = 769.600$, df = 359, $p < .001$; CFI = .948; RMSEA = .047; SRMR = .046).
[1]Measured on a 5-point scale from 'unimportant' (1) to 'very important' (5)
[2]Measured on a 5-point scale from 'strongly disagree' (1) to 'strongly agree' (5)
[3]Measured on a 5-point scale from 'no impacts' (1) to 'very severe impacts' (5)
*One item was dropped due to poor model fit

4.3.5. Analysis

A sequence of analyses were conducted in response to the objectives. First, mean values of participant message evaluations (i.e., perceived effectiveness, elaboration, and reactance) were estimated and compared against the control message using an ANOVA. Second, to assess relationships among values, elaboration, and beliefs, we used structural equation modeling (Kline, 2011). The modeling process began by assessing the measurement properties for each scale using confirmatory factor analysis and a maximum likelihood estimation procedure. The measurement model demonstrated good fit to the sample data ($\chi^2 = 622.125$, df = 329, $p < .001$; CFI = .961; RMSEA = .042; SRMR = .042).

Next, a structural regression model was estimated to test the 12 study hypotheses. We tested relationships between values and involvement (H1-H3), values and elaboration (H4-H6), Involvement and elaboration (H7), and elaboration and beliefs (H8-H12). Values were hypothesized to be positively correlated with elaboration if there was message alignment. For example, biospheric values were hypothesized to be positively correlated with elaboration when participants were presented with the self-transcendent message whereas egoistic values were hypothesized to be positively correlated with elaboration when participants were presented with the self-enhancement message. The full information maximum likelihood method was used to account for missing data (von Hippel, 2016). Model fit was considered acceptable given Root Mean Square Error Approximation (RMSEA) ≤ 0.07 (Steiger, 2007), Comparative Fit Index

(CFI) ≥ 0.90 (Bentler, 1990), and Standardized Root Mean Square residual (SRMR) ≤ 0.10 (Kline, 2011). Three separate models were estimated for the three groups of participants that received distinctly framed messages. After establishing measurement invariance between the models, differences in path coefficients were assessed. Specifically, we used the chi-square difference test to compare a model that was allowed to vary across the three groups (i.e., configural fit) against a model that constrained all betas to be equal.

4.4. Results

Participants responded favorably to the experimental messages, reporting high effectiveness (*M* = 4.12, *SD* = 0.67), moderately high elaboration (*M* = 3.73, *SD* = 0.73), and low reactance (*M* = 2.63, *SD* = 0.87) across all three messages. There were no significant differences in these values between the messages (Table 4.3). Likewise, there were no significant differences in post-message beliefs (i.e., efficacy and risk perceptions) across the three messages. Rather, all participants reported moderate risk perceptions (Personal: *M* = 3.32, *SD* = 0.94; Social: *M* = 3.32; *SD* = 0.94; Environmental: *M* = 3.56; *SD* = 0.79) and moderately high efficacy (Self: *M* = 4.12, *SD* = 0.75; Response: *M* = 4.35, *SD* = 0.66) after reading the message.

Table 4.3. Mean values and standard deviations for message evaluation and post-message beliefs across the three treatment groups. No significant differences were detected at $p < 0.05$.

	Self-transcendent framing	Self-enhancement framing	Baseline	F	P
Message evaluation					
Elaboration	3.75 (0.72)	3.68 (0.77)	3.75 (0.71)	.511	.600
Perceived effectiveness	4.11 (0.69)	4.10 (0.68)	4.14 (0.64)	.220	.803
Reactance	2.61 (0.90)	2.63 (0.87)	2.64 (0.84)	.019	.981
Post-message beliefs					
Risk perceptions					
Personal	3.27 (0.96)	3.36 (0.90)	3.31 (0.96)	.443	.642
Social	3.28 (0.95)	3.30 (0.96)	3.38 (0.92)	.519	.595
Environmental	3.48 (0.78)	3.60 (0.76)	3.58 (0.82)	1.179	.308

Table 4.3. (cont.)

	Self-transcendent framing	Self-enhancement framing	Baseline	F	P
Self-efficacy	4.09 (0.81)	4.09 (0.76)	4.19 (0.67)	1.195	.304
Response efficacy	4.35 (0.67)	4.30 (0.71)	4.40 (0.60)	1.000	.369

Structural equation models to explain the relationships among values, involvement, elaboration, and beliefs demonstrated acceptable model fit across all three treatment groups, indicating meaningful relationships among these constructs (χ^2 = 634.801, df= 375, p<.001, CFI=.904, RMSEA=.065, SRMR=.089; self-enhancement: χ^2 = 585.789, df= 375, p<.001, CFI=.924, RMSEA=.057, SRMR=.071; baseline: χ^2 = 647.867, df= 375, p<.001, CFI=.902, RMSEA=.065, SRMR=.090). Significant positive relationships between elaboration and all dimensions of risk perceptions and efficacy were detected in all three models (Figure 4.2). The group who received the baseline message displayed particularly strong relationships between elaboration and environmental risk perceptions (β = .688, p <.001). Participants who examined the self-enhancement message likewise had a strong relationship between elaboration and environmental risk perception (β = .618, p <.001) as well as between elaboration and both social (β = .500, p <.001) and personal (β = .528, p <.001) risk perceptions. Participants who viewed the self-transcendent message had notably strong relationships between elaboration and both self-efficacy (β = .688, p <.001) and response- efficacy (β = .599, p<.001).

Table 4.4. Summary of measurement invariance testing between groups by values treatment

	χ^2	df	$\Delta\chi^2$	Δ df
1. Configural fit	1868.5	1125	-	-
2. Constrained factor loadings	1908.1	1165	39.605[1]	40
3. Constrained intercepts	1939.6	1205	31.516[2]	40
4. Constrained residuals	2006.7	1265	67.155[3]	60

[1]Not significant (p = .488)
[2]Not significant (p = .829)
[3]Not significant (p = .245)

Having established measurement invariance (Table 4.4), we statistically compared the models to identify differences in relationships between values and elaboration. Specifically, we compared a model that allowed regression coefficients to vary across the three groups (χ^2 = 2006.7, df = 1265) against a model that constrained all betas to be equal (χ^2 = 2061.8, df = 1289). The constrained model resulted in a significantly worse fit ($\Delta \chi^2$ = 55.077, Δ df = 24, $p < .001$), indicating significant differences in regression coefficients across the three message treatments. In particular, the relationship between biospheric values and elaboration was positive and significant for participants who received the self-transcendent message (β = .980*;* p = .024), but non-significant for the two other experimental groups (Baseline: β = .003*;* p = .985; Self-enhancement: β = .173*;* p = .254). In contrast to our hypotheses, the relationship between egoistic values and elaboration was non-significant for all groups, including the self-enhancement group (β = -.009*;* p = .934).

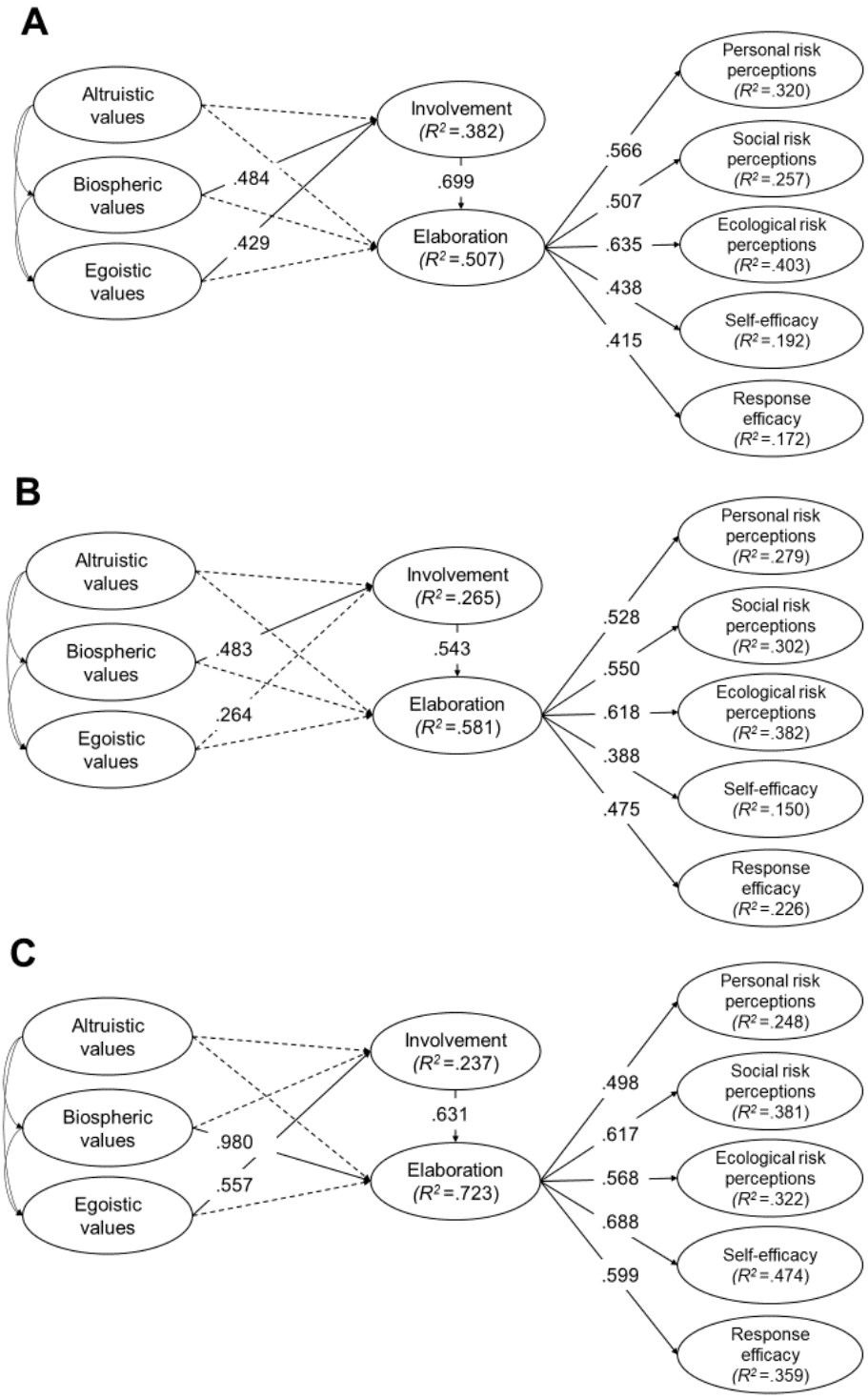

Figure 4.2. Structural equation models analyzing relationships among values, elaboration, and beliefs for three subgroups defined by three treatment groups: A) Baseline, Model fit: χ^2 = 647.867, df= 375, p<.001, CFI=.902, RMSEA=.065, SRMR=.090; B) Self-enhancement message, Model fit: χ^2 = 585.789, df= 375, p<.001, CFI=.924, RMSEA=.057, SRMR=.071; C) Self-transcendent message, Model fit: χ^2 = 634.801, df= 375, p<.001, CFI=.904, RMSEA=.065, SRMR=.089. Dashed lines indicate non-significant relationships.

4.5. Discussion

Through a message experiment involving recreational water users across Illinois, we quantified how value-framing affected elaboration, and, ultimately, beliefs about AIS. Among participants who received a message that embodied self-transcendence, there was a strong relationship between biospheric values and elaboration, in contrast to the baseline message in which values were unrelated to elaboration. Further, given that high elaboration leads to favorable responses to a message when the message is strong (Petty & Briñol, 2011), the strong effects of elaboration on both risk perceptions and efficacy underscored the effectiveness of AIS outreach. That is, the more deeply people think about a message they receive, the more likely they internalize content about the risks of AIS and the steps they can take as individuals. Thus, adopting messages with self-transcendent framing is likely to stimulate in-depth thinking, leading to stronger beliefs, and ultimately, greater participation in pro-environmental behavior.

The relationship between values and elaboration was significant only for the self-transcendence message, whereas no values were related to elaboration in the baseline or self-enhancement treatment. We did not expect the baseline message to evoke a relationship between values and elaboration, given that the baseline message contained a single phrase ("Don't dump bait") and could be described as a regulation frame (Myers et al., 2017) rather than a value frame. We did, however, expect the self-enhancement message to evoke a positive relationship between egoistic values and elaboration. It could be that the self-transcendent message had a more profound impact because of the predominant role of biospheric values in characterizing our sample of recreational water users. Alternatively, it may be the case that biospheric framing is better suited to environmental issues than other types of values, resulting in a more credible message than egoistic framing (Hansla, 2011). Ultimately, values-aligned message campaigns

would be most successful when informed by survey or focus group data on the target audience (e.g., Lauber, 2017) to ensure that the values adopted within the campaign are most relevant to stakeholders.

Without considering the effect of values, the three treatments did not evoke different responses. Specifically, there were no significant differences between the three treatments in message response (i.e., effectiveness, elaboration, and reactance) or post-message beliefs (i.e., risk perceptions and efficacy). This result indicates it was the not message alone that mattered, but alignment between values highlighted in the message and held by the individual. More broadly, the messages in this experiment were well-received; given the consistent mean values in message effectiveness and reactance across message, no message stood out as problematic or untrustworthy. Thus, there was minimal risk of unintended consequences when adding values-framing to a message. This finding may appear to contrast previous research that has evaluated the consequences of messages that align with worldviews, such as Kahan (2012)'s cultural cognition (i.e., worldviews about how society should be structured). Work on cultural cognition shows that people will reject a message that conveys an opposing worldview but accept a similar argument framed in line with a worldview with which they identify (Kahan et al., 2010). One important distinction between cultural cognition and values (Schwartz, 2012) is that different values are not at odds with each other; each person holds a variety of individual values, each to a different degree (Shin et al., 2022). Additionally, values are not necessarily linked with political or social group identities as is the case with cultural cognition (Kahan, 2010). Therefore, values held by a constituency can be prominently highlighted by resource management agencies without concern that people who do not share these values will be alienated.

Elaboration is integral to how messages affect beliefs about issues like AIS. In line with previous research that demonstrated a connection between high elaboration and beliefs (Brown et al., 2010; Ham et al., 2008), we observed a significant positive relationship between elaboration and risk, as well as between elaboration and efficacy across all three message treatments. Regardless of which messages were evaluated by participants, the more closely they read and reflected on the message, the stronger their risk perceptions and efficacy beliefs. Although persuasion can occur at any end of the elaboration spectrum (Petty & Cacioppo, 1986), our results reinforce the argument that high elaboration is more likely to have long-lasting impacts, in part due to the depth of reflection on the message (O'Keefe, 2013). We also contend that for complex topics like the multi-step process of biological invasions (Lange & Marshall, 2016), high elaboration may be a particular asset to help the reader absorb the many facets of a detailed message. Finally, although we tested involvement as an explanatory variable for elaboration, it may be the case the elaboration could explain reported involvement, particularly in light of research that has encouraged the consideration of reverse-causal relationships (Sussman & Gifford, 2019). Causality among values, elaboration, involvement, and beliefs is thus an important question for future study. In summary, high elaboration can be achieved through values-framing, and should be a key goal of environmental communication that seeks to motivate and explain how people can prevent the spread of AIS.

4.5.1. Implications and Areas of Future Research

From our results and analyes, we provide several research implications with the intentions of enhancing messaging campaigns that are designed to communicate about AIS. First, the Be a Hero campaign messages we tested resulted in high perceived message

effectiveness and low reactance regardless of the treatment. Previous research has suggested participants are critical of the logo associated with the *Be a Hero* campaign because it is overly simplified (Kemp et al., 2017). In contrast, our findings indicated a very positive response to *Be a Hero*. However we were evaluating a brochure which contained more detailed information and a broader context than the simple logo evaluated by participants in the Kemp et al. (2017) study. Thus, efforts to communicate using signage or brochures that have the logos embedded in more detailed materials to aid interpretation will likely be well-received.

Although the Be a Hero campaign is well known among water users (Seekamp et al., 2016) and awareness of AIS is high among IL anglers (Cole et al., 2016), concerns about biological invasions in the Great Lakes region are still high (Escobar et al., 2018). Inconsistent actions among anglers (Cole et al., 2019), coupled with inconsistent policies across the Great Lakes region (Peters & Lodge, 2009) leave multiple opportunities for AIS to spread. Reducing the number of AIS Thus, understanding and closing the "knowledge-action gap" (Kollmuss & Agyeman, 2002) continue to be laudable goals, because of the potential to significantly reduce propagule pressure (Simberloff, 2009) by reducing the number of recreationists spreading AIS (Drake & Mandrak, 2014). To encourage more recreationists to take action, research on how message framing affects elaboration and beliefs will be particularly useful because these concepts mediate the relationship between knowledge and action.

Outreach professionals should take steps to build messages that foster elaboration, because it increases the effectiveness of messages both about how AIS are threatening ecosystems and that recreational water users have the ability to make a difference. In particular, educational outreach campaigns imbued with biospheric values should be prioritized in future research focused on recreational water users and biological invasions because of the

prominence of the value orientation (Golebie et al., 2022; Shin et al., 2022; van Riper et al., 2019). This messaging approach would respond to what has been learned about the powerful role of biospheric values in motivating behavior, while acknowledging that value pluralism should be maintained to respect differences among diverse user groups (van Riper et al., 2017; Kenter et al., 2020; Hakkarainen et al., 2020).

The findings in this study should be considered in light of several limitations. First, this research was conducted using a Qualtrics panel. An online panel was selected for several reasons, though primarily because of declining response rates to mailback surveys (Stedman et al. 2019, Coon et al., 2020). Additionally, online panels are increasingly used to understand environmental topics (e.g., Landon et al., 2020, van der Linden et al., 2019). Our use of an online panel resulted in few key differences between our study and those that used mailback surveys (e.g., Cole et al., 2016, Pradhananga et al., 2015; van Riper et al., 2020). Notably, recreationists with lower levels of experiences were recruited (Golebie et al., 2021b). Given the study focus on message testing, rather than quantifying recreational activity or constituent preferences across the state of IL, the more diverse population represented in this study may be considered an asset. Second, our methods were adopted with guidance from a funding agency interested in testing specific messages that would enhance their environmental communication strategies. We worked closely with the resource management agency to design our message manipulations and test candidate messages that could be used in the future. Although these results provided valuable information, the evidence we generated was highly site specific. To generalize results beyond the tailored messages used for this study, future work should aim to represent values with a more complete array of messages. Additionally, our study integrated biospheric and altruistic values within a single message; future work should seek to untangle the effects of these two distinct

value types by testing message that include only one value dimension. Finally, future work should examine how other factors influence the response to values-framed messages. For example, the use of social norms (e.g., Niemiec et al., 2021) shows great promise and may work in concert with values-framing to elicit a more pronounced responses from stakeholders (Peloza & White, 2009). This research approach would be well suited to improve outreach focused on minimizing biological invasions and other natural resource management challenges.

4.6. Conclusion

Recreational water users can unintentionally spread AIS as they travel between waterbodies and therefore threaten the health of aquatic ecosystems. However, many of these users remain unable or unwilling to take preventative measures. Thus, resource management agencies seek ways to improve outreach campaigns that heighten awareness of risks posed by AIS and improve individuals' confidence in taking preventative measures. We confronted this problem by testing the ability of values-framing to convey information in appealing and effective way to recreational water users. We found that self-transcendent messages encouraged participants to think more deeply and increased their perceived ability to take action against the spread of AIS. Thus, AIS outreach campaigns should first identify the value orientations in a constituency and then align messaging with those values to captivate attention and successfully communication about AIS risks and prevention behaviors.

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CHAPTER 5: GENERAL CONCLUSION AND SUMMARY

Through my dissertation, I explored relationships among communication about AIS and drivers of preventive behaviors to minimize AIS spread. Previous research has evaluated drivers of behavior among recreational water users, focusing on awareness of AIS (Eiswerth et al., 2011; Cole et al., 2016) and responses to outreach campaigns (e.g., Seekamp et al., 2016); however, the risks of AIS spread remain high (Cole et al., 2019). Thus, there is a need to consider the role of deeper drivers of behavior, such as individual values (Schwartz, 1992), which have received limited attention in research on recreational water users and AIS (van Riper et al., 2020). To understand the role of values in AIS behavior, the study of environmental behaviors (Stern, 2000) and message framing (Chong & Druckman, 2007) can be extended with theories drawn from the discipline of communication, including Protection Motivation Theory (Rogers, 1975) and the Elaboration Likelihood Model (Petty & Cacioppo, 1986). I integrated these theories to build knowledge of how drivers of behavior among recreational water users could provide insight on messaging strategies that aim to close the knowledge-action gap (Kollmuss & Agyeman, 2002) and encourage water users to engage in conservation activities.

In the three studies comprising this dissertation, I explored communication, values, and risk relevant to aquatic invasive species. In my first study, I found that language used to communicate about invasive species in the peer-reviewed literature was predominantly negative, and featured species-centered and human-centered message frames in relatively equal proportions. I also found that the use of terminology (e.g., ‘invasive’ vs. ‘introduced’) aligned with the stage of invasion, study objectives, and the biodiversity context of the study site. In my second study, I found that biospheric values positively predicted personal and social risk perceptions. Further, while personal risk perceptions were lower than social risk perceptions,

they had a stronger relationship with AIS prevention behavior, in that high personal risk perceptions were associated with more frequent participation in prevention behavior. In my third study, I found that AIS outreach messages framed to reflect self-transcendent values were processed more deeply (i.e., resulted in high elaboration) by recreational water users. Additionally, elaboration predicted risk perceptions and efficacy. Together, the results of these three studies build theoretical knowledge of factors driving AIS-prevention behavior and inform communication strategies for promoting conservation initiatives that minimize the spread of AIS.

5.1. Theoretical Implications

My dissertation research resulted in several theoretical implications. One theoretical implication pertains to the study of risk perceptions as they relate to angler behavior. Protection Motivation Theory has been widely used to understand responses to risk information in health campaigns (Mongeau, 2013) and several environmental issues (see Koeth et al., 2019 for a review) but has rarely been applied to issues pertaining to aquatic recreation. In addition to applying this theory in a novel context, I extend it by examining multiple dimensions of risk perceptions. Study two reveals that personal risk perceptions were more influential than social risk perceptions in encouraging behaviors that curb the spread of AIS. While the importance of risk perceptions in behavior change is well studied (O'Connor et al., 1999), past work has focused on comparing personal and social risk perceptions, showing that social risk perceptions tend to be higher (van der Linden, 2015; van Riper et al., 2016). My work both corroborates this finding and extends it by showing that lower, personal risk perceptions are more influential in predicting behavior. My first and second studies also provide insight on how risk perceptions vary by social and ecological conditions across spatial scales. My first study indicates that

language use among researchers is related to spatial differences in biodiversity across the United States. My second study shows that anglers at inland sites had lower personal risk perceptions than both Great Lakes and mixed-site anglers, likely due to the fact that AIS messages are more common at Great Lakes access points (e.g., Be A Hero's boat wash stations are only found in Northern Illinois near Lake Michigan, see transportzero.org), and there are large difference in outreach investment across the state (Cole et al., 2016). Thus, future work regarding risk perceptions should complement information on the psychological drivers of risk with information on the socio-ecological context that may play a strong role in the formation of risk perceptions. Together, these findings provide new information on how risk perceptions can aid in understanding angler behavior more broadly.

The second theoretical implication from my dissertation research pertains to the study of values in relation to angler behavior. Although values are well-studied across conservation psychology (e.g., Dietsch et al., 2016; Kenter et al., 2019, van Riper et al., 2018), they have seldom been investigated in the context of recreational fisheries (van Riper et al., 2020). My second study revealed that biospheric values strongly predicted risk perceptions, whereas egoistic values weakly predicted personal risk perceptions and there was no significant relationship between altruistic values and risk perceptions. The finding that egoistic values predicted perceived risk of AIS, albeit weakly, contrasts with past work suggesting egoistic values should be negatively correlated with environmental beliefs (de Groot & Steg, 2008). This relationship between egoistic values and personal risk perceptions reveals that pathways for developing environmental beliefs can be drawn from value systems beyond biospheric values. Further, it is notable that egoistic values predicted personal risk perceptions, but not social; this result highlights the need to explore multiple dimensions of environmental beliefs that may

better represent values. My third study provided support for values-aligned messages as a communication strategy. Past work has tested values-framing (Peloza & White, 2009; Hansla, 2011), but framing messages not only in line with values but in line with the known values structure of a target audience is a novel approach. I provided evidence that value-aligned messages result in higher elaboration, revealing a potential mechanism for the efficacy of this framing approach. In summary, my dissertation contributes a new understanding of the role of egoistic values, as well as suggesting that value-alignment in message framing may enhance message responses by activating high elaboration.

5.2. Applied Outcomes

My research has the applied outcome of providing suggestions for enhancing messaging campaigns that seek to encourage recreational water users to take action to prevent the spread of AIS. Many such campaigns have been ongoing (e.g., Seekamp et al., 2016) and have raised awareness of AIS (Eiswerth et al., 2011), however the risks of AIS spread by recreational water users remains high (Cole et al., 2019). Thus, novel message strategies are needed to bolster participation in AIS prevention. Results from my second study reveal the importance of personal risk perceptions in predicting behavior, indicating that outreach messaging should speak to personal implications of biological invasions. Language about large-scale environmental impacts should be complemented with information about the effect on individual anglers. For instance, news articles could highlight personal anecdotes from anglers who have experienced impeded growth of their target species due to food web shifts induced by zebra mussel invasions (Hansen et al., 2020) or lakeshore property owners who saw a decline in value due to overabundance of watermilfoil (Zhang & Boyle, 2010). Emphasizing these personal impacts is likely to have a

stronger influence than emphasizing the broader social and ecological consequences of species invasions, especially when such broader impacts are already widely publicized.

Agencies should also shift their attention to thinking about the role of values in explaining how people process and respond to environmental threats and degradation from AIS. Studies 2 suggests that biospheric values underscore risk perceptions and ultimately behavior among recreational anglers, and study three provides further evidence that self-transcendent (i.e., biospheric and altruistic) messages encourage recreational water users to think more deeply about a message and ultimately feel more confident about their perceived ability to take action against the spread of AIS. Outreach campaigns tend to speak to the idea of protecting the environment, which is only one facet of biospheric values. Complementing these messages with the concepts of unity with nature and appreciating the beauty of natural areas would provide a more complete reflection of biospheric values and therefore be more likely to capture the attention of recreational water users. Ultimately, adopting the new messaging strategies developed in this study will support the goal of increasing participation in AIS-prevention behaviors and lowering the risk of AIS spread. Finally, the effects of values-alignment revealed by my third study suggest that biospheric values may be relevant because recreational water users hold high biospheric values. A different population that held higher egoistic values, for instance, may not relate as well to a biospheric message. Thus, AIS outreach campaigns should first identify the value orientations in a constituency and then align messaging with those values to captivate attention and successfully communication about AIS risks and prevention behaviors.

Finally, standardized language is needed to aid in communication. Assessing language use in the literature following calls for a more standardized approach (Blackburn et al., 2011; Colautti & MacIsaac, 2004), my first study showed that researchers are indeed using terminology

that aligns with the ecological context (i.e., stage of invasion and proportion of non-native species at the study site). Further, researchers used relatively equal proportions of message frames characterized as species-centered and human-centered. Species-centered frames raise concern and public engagement regarding AIS (Hart & Larson, 2014), whereas human-centered frames may be useful for raising self-efficacy, an important predictor of behavior in response to a risk like AIS. Given that science communication within the peer-reviewed literature affects public understanding of research outcomes, these findings provide an important point of reflection for researchers.

5.3. Concluding Remarks

Aquatic invasive species pose social-ecological risks on scales ranging from the state of Illinois to the Great Lakes region to the United States and beyond. To minimize these risks, it is essential to understand drivers of preventative action on an individual level, the effects of outreach messaging, and the social-ecological context in which messaging occurs. Previous work addressing recreational water user behavior has focused on knowledge and awareness, resulting in little evidence on the role of values in AIS prevention. Integrating frameworks drawn from conservation psychology and communication, my dissertation revealed that biospheric values are particularly strong among recreational water users and closely related to perceived risk of AIS, and that these values can be activated in messages to further encourage AIS prevention. Theoretical and conceptual contributions of this work include identification of social-ecological factors that influence communication in the AIS literature, distinctions between personal and social dimensions of risk, and alignment between individual values of a target audience and message framing as a communication strategy. The efficacy of values-framing in AIS outreach

messaging, as well as the importance of highlighting personal risk perceptions, can be applied to communication initiatives with recreational water users in the Great Lakes region and beyond, to promote engagement in conservation behavior and ultimately minimize the risk of inadvertent AIS transport.

5.4. References

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APPENDIX A: LIST OF STUDIES ANALYZED IN CHAPTER 2

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APPENDIX B: CODING PROCEDURES USED FOR CHAPTER 2

1. Bibliographic information

1.1 Publication ID (PDF filename)
1.1 Paper title
1.2 Publication Year
1.3a. Lead author name
1.3b. Lead author institution, as indicated in the author list
- *If agency (e.g. USGS) AND university, include both.*

1.4 Journal

2. Basic information

2.1 Location of study (Please include city/region/state. If city, state please use comma e.g. Champaign, IL)
- If country is outside of the US, it may need to be excluded. Please post in slack!
- List location as described in the study. If there are 2-3 study sites, list all. If more than 3 sites, identify a broader geographical scope. (e.g, if they list a number of lakes that are all in Illinois, the study site might be "Illinois", or if they list a number of lakes but also talk about the "lower Great Lakes", the study site might be "lower Great lakes."

2.2 Primary species of study (if applicable, list the one, or several, species that the study is targeting)

3. Language

3.1 Message frame: Read the *introduction* of the paper and classify the frame used to discuss non-native species
- 3.1.1 Species-centered: does not discuss human influences on species introductions but focuses on the species themselves as the drivers, at times anthropomorphizing the species
- 3.1.2 Human-centered: focus on the human drivers or causes of species introductions or center human responsibility for taking action

3.2 Valence: Read the *introduction* of the paper and classify the frame used to discuss non-native species
- 3.2.1 Positive: While introducing the species in the introduction, the paper assumes positive impacts and emphasizes benefits caused by non-native species
- 3.2.2 Negative: While introducing the species in the introduction, the paper assumes negative impacts and emphasizes harm caused by non-native species
- 3.2.3 Neutral: Effects of non-native species are uncertain, moderate, or both positive and negative

3.3 Terminology

3.3.1 For each of the following words, count the number of occurrences throughout the manuscript (excluding the reference list): alien, exotic, introduced, invasive, non-indigenous, nuisance, non-native

4. Explanatory Variables

4.1 Stage of invasion - *based on description (whether explicit or implicit) within the manuscript, which stage of invasion is the study population, or which stage of invasion is the research addressing? Select all that apply.*

4.1.1 Transportation: species moves to a new location

4.1.2 Introduction: species arrives at a new location and is released into the ecosystem

4.1.3 Establishment: species survives at the new location and reproduces

4.1.4 Spread: species spreads beyond the initial point of introduction

4.2 Transportation vector – *vectors explained in the introduction or explored in the methods, if any. Select all that apply.*

4.2.1 Natural: invasive species transported by dispersal patterns not directly mediated by humans

4.2.2 Human-intentional: Invasive species were transported deliberately by humans (e.g., stocking, biocontrol, aquaculture, agriculture, pet trade, horticulture)

4.2.3 Human-unintentional: invasive species were transported accidentally by humans (e.g., ballast water, recreational equipment)

4.3 Study focus – *based on the stated objective of the study, categorize it as addressing one of the four study focuses stated below*

4.3.1 Prevention: assess the risk of non-native species introduction; evaluate prevention methods

4.3.2 Monitoring: determine whether the species is present; assess population changes

4.3.3 Understand: assess the biological characteristics of a species; quantify the impacts of a non-native species

4.3.4 Control: develop or evaluate a management plan or control method

4.4 Study Discipline – *interpreting the reported methods used in the study, categorize it as one of the below broad groupings of disciplines*

4.4.1 Biological Sciences: the study uses biological or ecological methods to collect data on ecosystems and/or species

4.4.2 Social Sciences: the study uses social science methods such as interviews, surveys, and focus groups to collect data on human behaviors, beliefs, or other characteristics related to non-native species

4.4.3 Interdisciplinary: the study uses methods drawn from both the natural and social sciences

5. Comments

5.0. Add additional information or comments the coder would like to record

APPENDIX C: SURVEY QUESTIONNAIRE USED FOR CHAPTER 3

Aquatic Invasive Species in the Great Lakes Region

Understanding your angling experiences and preferences for invasive species management

Image: Great Lakes Hydrography Dataset

The University of Illinois at Urbana-Champaign and Cornell University are conducting research to learn more about the opinions of recreational anglers in the US and Canada and the spread of aquatic invasive species, which are organisms that move into areas beyond their natural, historic range. You are one of a small number of people chosen for this study, because you have previously purchased a fishing license. Your response is important to us. All information will be kept confidential and your response is voluntary. Results from this research will be shared with managers across the Great Lakes states. Please answer each question carefully and save any additional comments for the final page. This survey will take about 20 minutes to complete.

www.AISresearch.org

Section 1 of 5: Background Information

In this section, we ask you to provide information about your fishing experiences in 2018.

1. **About how many days did you go fishing?** _____Days

2. **About how many years, including this one, have you been fishing?** _____Years

3. **Where do you spend most of your time fishing?** (Please ✓ all that apply)

- ❑ Lake Ontario
- ❑ Lake Michigan
- ❑ Lake Superior
- ❑ Lake Erie
- ❑ Lake Huron
- ❑ Other inland lakes
- ❑ Rivers and/or streams connected to the Great Lakes
- ❑ Rivers and/or streams not connected to the Great Lakes

4. **About what percent of your fishing time is from a boat and from shore?**

Boat: _____% **Shore:** _____%

4b. If you fish from a boat, please ✓ the description of the boat you use most often.

- ❑ A boat that is trailered between fishing sites
- ❑ A boat that is docked at one location for a season
- ❑ Not sure
- ❑ Other: _____

5. **Which species do you frequently fish for?** (Please ✓all that apply)

- ❑ Atlantic salmon
- ❑ Bluegill
- ❑ Brook trout
- ❑ Brown trout
- ❑ Carp
- ❑ Catfish
- ❑ Chinook / king salmon
- ❑ Coho salmon
- ❑ Crappie
- ❑ Drum / sheepshead
- ❑ Lake trout
- ❑ Largemouth bass
- ❑ Muskie
- ❑ Northern pike
- ❑ Rainbow trout / steelhead
- ❑ Smallmouth bass
- ❑ Walleye
- ❑ White bass
- ❑ Whitefish
- ❑ Yellow perch
- ❑ Other: _____

5b. Of these species, which ONE do you target most often? _____

6. **How familiar are you with "certified" bait (free of exotic species or diseases)?**

❑	❑	❑	❑	❑
Not at all familiar	Slightly familiar	Somewhat familiar	Very familiar	Extremely familiar

7. How often do you use live baitfish while fishing?

❑ Never ❑ Rarely ❑ Sometimes ❑ Often ❑ Very Often

8. How often do you do each of the following with extra baitfish when you are done fishing?

	Never	Sometimes	Very Often	N/A
a. Dispose of them in the water where you fish	○ ○	○ ○	○ ○	○
b. Dispose of them on the ground or in trash cans	○ ○	○ ○	○ ○	○
c. Keep them to use later	○ ○	○ ○	○ ○	○

9. How would you rate your fishing skills in comparison to other anglers?

❑ Much lower than average ❑ Lower than average ❑ Average ❑ Higher than average ❑ Much higher than average

10. About how many non-native species (including fish, plants, and other organisms) are currently present in the Great Lakes?

❑ None ❑ Around 20 species ❑ Don't know

❑ Around 200 species ❑ Around 2000 species

11. The agency primarily responsible for managing the Great Lakes fishery is the Fish Authority. ❑ True ❑ False ❑ Don't know

12. Sea lamprey are considered "invasive," meaning they are <u>both</u> unintentionally introduced and causing harm. ❑ True ❑ False ❑ Don't know

13. Aquatic invasive species can be spread through dumping of bait buckets by recreational anglers. ❑ True ❑ False ❑ Don't know

14. Where have you heard about aquatic invasive species? (Please ✓all that apply)

❑ Print newspapers ❑ Online angling forums ❑ Online newspapers
❑ Government officials ❑ Government websites ❑ Webinars
❑ Social media (e.g., Facebook) ❑ Scholarly articles ❑ Public meetings
❑ Professional societies ❑ Public agencies ❑ Charter captains
❑ Friends and family ❑ Environmental groups ❑ Other anglers

Section 2 of 5: Environmental Behavior and Values

In this section, we ask you to think about your personal values and behavior related to fishing, aquatic invasive species, and the environment. This information will help decision makers understand what you care about most.

15. There are many ways that people can minimize the impacts of invasive species on the environment. How frequently have you engaged in the following activities over the <u>past 12 months?</u>

	Never		Sometimes		Very Often	N/A
a. Looked up information about aquatic invasive species	○	○	○	○	○	○
b. Avoided purchasing products that contribute to the spread of aquatic invasive species	○	○	○	○	○	○
c. Took measures (e.g., washed boat or equipment) to personally reduce the spread of aquatic invasive species	○	○	○	○	○	○
d. Participated in a policy process (e.g., voting) related to aquatic invasive species	○	○	○	○	○	○
e. Donated money with the intention of reducing impacts from aquatic invasive species	○	○	○	○	○	○
f. Wrote a letter, sent an email, or signed a petition about aquatic invasive species	○	○	○	○	○	○
g. Encouraged other people to attend an event related to aquatic invasive species	○	○	○	○	○	○
h. Talked to other people in my community about aquatic invasive species	○	○	○	○	○	○
i. Worked with others to minimize impacts from aquatic invasive species	○	○	○	○	○	○

16. We would like to understand your beliefs about environmental impacts from invasive species. How strongly do you agree or disagree with these statements?

	Strongly Disagree		Neutral		Strongly Agree
a. I feel guilty if I spread aquatic invasive species	○	○	○	○	○
b. I am morally obligated to minimize the spread of aquatic invasive species when fishing	○	○	○	○	○
c. People like me should feel personally obligated to limit the spread of aquatic invasive species	○	○	○	○	○
d. My own actions while fishing influence the spread of aquatic invasive species	○	○	○	○	○
e. I have the ability to limit the spread of aquatic invasive species	○	○	○	○	○
f. There are many ways I can help stop the spread of aquatic invasive species	○	○	○	○	○

17. People have different beliefs about aquatic invasive species and the risks they present. How serious of a threat do you think invasive species are to:

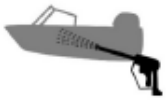
	Low threat	Moderate Threat	High Threat
a. Your fishing experience	○	○ ○ ○	○
b. Your financial well-being	○	○ ○ ○	○
c. The environment where you fish	○	○ ○ ○	○
d. The Great Lakes fishery	○	○ ○ ○	○
e. The economy in the Great Lakes region	○	○ ○ ○	○
f. The environment in the Great Lakes region	○	○ ○ ○	○

18. These questions are about the things you value most. Please rate the extent to which you consider these general ideas to be guiding principles in your life.

	Opposed to my Values				Important				Of Supreme Importance
	1	2	3	4	5	6	7	8	9
a. **Protecting the environment**: preserving nature	○	○	○	○	○	○	○	○	○
b. **Unity with nature**: fitting into nature	○	○	○	○	○	○	○	○	○
c. **A world of beauty**: beauty of nature and the arts	○	○	○	○	○	○	○	○	○
d. **Equality**: equal opportunity for all	○	○	○	○	○	○	○	○	○
e. **Social justice**: correcting injustice, care for others	○	○	○	○	○	○	○	○	○
f. **A world at peace**: free of war and conflict	○	○	○	○	○	○	○	○	○
g. **Authority**: the right to lead or command	○	○	○	○	○	○	○	○	○
h. **Social power**: control over others, dominance	○	○	○	○	○	○	○	○	○
i. **Influential**: having an impact on people and events	○	○	○	○	○	○	○	○	○
j. **Fulfilment of desire**: food, fun, pleasure	○	○	○	○	○	○	○	○	○
k. **Enjoying life**: pursuing hobbies, leisure, socializing	○	○	○	○	○	○	○	○	○
l. **Reducing worries**: seeking comfort and relaxation	○	○	○	○	○	○	○	○	○
m. **Personal growth**: development of new skills, learning, or gaining insight into something	○	○	○	○	○	○	○	○	○
n. **Pursuit of excellence**: attaining a personal ideal in life	○	○	○	○	○	○	○	○	○
o. **Autonomy**: deciding your own future and doing what you believe in	○	○	○	○	○	○	○	○	○
p. **Satisfaction with life:** finding meaning, value, and relevance to a broader context	○	○	○	○	○	○	○	○	○

Section 3 of 5: Future Fishing Scenarios

On the next few pages, we ask you six questions related to possible changes in the conditions of fishing sites in the Great Lakes region. In each of these questions, you need to choose between two hypothetical future scenarios and current conditions. Each future scenario includes multiple features representing environmental characteristics that can only be partially controlled by management. The features are described below. *Please read this material carefully.*

Wash Stations 	Wash stations can be used to disinfect and pressure-wash boats to stop invasive species from spreading. At some US boat launch sites that border the Great Lakes, people are required to drain boats and remove visible plant and animal material before leaving to prevent species from spreading to other waterbodies. Wash station availability is set at three levels: 1. **No wash stations** 2. **Voluntary wash stations** 3. **Mandatory wash stations** (monitored by an official)
Added Cost per Fishing Trip 	Invasive species control and prevention efforts in the Great Lakes are mostly federally funded, and could be enhanced by voluntary contributions. "Added cost per fishing trip" is the extra amount you would be willing to pay each time you go fishing for better invasive species management. 1. Added cost per fishing trip ranges from **$0 to $20 (USD)**
Amount of Native Fish 	Native fish include lake trout, yellow perch and walleye. In recent years, these species have been fairly stable in the Great Lakes, but population levels are lower than they have been historically. 1. Amount of native fish ranges from a **20% decrease** to a **20% increase** from current levels
Impact from Invasive Species 	Invasive species are organisms outside of their historic range that harm the environment. Species such as zebra mussels and sea lamprey have dramatically changed nutrients, water clarity, and habitat in the Great Lakes. Impact from invasive species is set at three levels: 1. **Minimal impacts** 2. **Moderate impacts** 3. **Severe impacts**
Fish Habitat 	Fish habitat refers to the quality of the environment that supports fish. These habitats are critical for successful reproduction and growth of sportfish communities such as salmon and yellow perch, and for prey fish such as smelt and alewife. The quality of fish habitat ranges from: 1. **Poor** 2. **Good** 3. **Excellent**

Each scenario below includes three options. Please select the option with the combination of features that you would prefer to find in the area where you fish.

Fishing Scenario 1

Suppose Option A and Option B were the *only* options available. Which would you choose? Please consider all the features and *check the box that represents your choice*.

Attribute	Wash stations 	Added cost per fishing trip $	Amount of fish 	Impact from invasive species 	Fish habitat 	I would choose
Option A	Mandatory	$0	10% decrease	Severe	Excellent	❒ A
Option B	No wash stations	$10	10% increase	Minimal	Poor	❒ B
Option C	Same as today					❒ C

Fishing Scenario 2

Suppose Option A and Option B were the *only* options available. Which would you choose? Please consider all the features and *check the box that represents your choice*.

Attribute	Wash stations 	Added cost per fishing trip $	Amount of fish 	Impact from invasive species 	Fish habitat 	I would choose
Option A	No wash stations	$10	No change	Minimal	Good	❒ A
Option B	Voluntary	$0	20% increase	Moderate	Excellent	❒ B
Option C	Same as today					❒ C

Fishing Scenario 3

Suppose Option A and Option B were the *only* options available. Which would you choose? Please consider all the features and *check the box that represents your choice*.

Attribute	Wash stations 	Added cost per fishing trip $	Amount of fish 	Impact from invasive species 	Fish habitat 	I would choose
Option A	Mandatory	$15	10% decrease	Minimal	Poor	❒ A
Option B	Mandatory	$5	20% decrease	Minimal	Excellent	❒ B
Option C	Same as today					❒ C

Fishing Scenario 4

Suppose Option A and Option B were the *only* options available. Which would you choose? Please consider all the features and *check the box that represents your choice*.

Attribute	Wash stations 	Added cost per fishing trip $	Amount of fish 	Impact from invasive species 	Fish habitat 	I would choose
Option A	Mandatory	$10	20% increase	Severe	Good	❒ A
Option B	Voluntary	$20	10% increase	Minimal	Excellent	❒ B
Option C	Same as today					❒ C

Fishing Scenario 5

Suppose Option A and Option B were the *only* options available. Which would you choose? Please consider all the features and *check the box that represents your choice*.

Attribute	Wash stations 	Added cost per fishing trip $	Amount of fish 	Impact from invasive species 	Fish habitat 	I would choose
Option A	Voluntary	$15	20% decrease	Moderate	Good	❒ A
Option B	No wash stations	$5	No change	Severe	Poor	❒ B
Option C	Same as today					❒ C

Fishing Scenario 6

Suppose Option A and Option B were the *only* options available. Which would you choose? Please consider all the features and *check the box that represents your choice*.

Attribute	Wash stations 	Added cost per fishing trip $	Amount of fish 	Impact from invasive species 	Fish habitat 	I would choose
Option A	No wash stations	$0	No change	Moderate	Poor	❒ A
Option B	Voluntary	$10	20% decrease	Severe	Good	❒ B
Option C	Same as today					❒ C

19. Did you ignore any of the features while reviewing the fishing scenarios listed above? ❒Yes ❒ No

Section 4 of 5: Cultural Values and Beliefs

In this section, we ask you to reflect on your values as they relate to society as a whole. These kinds of values will help us understand why you make decisions and engage in behaviors that relate to aquatic invasive species.

20. There are many different perspectives on how society should be organized. How strongly do you agree or disagree with these statements?

	Strongly Disagree		Neutral		Strongly Agree
a. We have gone too far in pushing equal rights in this country	○	○	○	○	○
b. Our society would be better off if the distribution of wealth was more equal	○	○	○	○	○
c. We need to dramatically reduce inequalities between the rich and poor, whites and people of color, and men and women	○	○	○	○	○
d. Discrimination against minorities is still a very serious problem in our society	○	○	○	○	○
e. It seems like blacks, women, homosexuals, and other groups don't want equal rights, they want special rights just for them	○	○	○	○	○
f. Society as a whole has become too soft and feminine	○	○	○	○	○

21. There are many different perspectives on the role of government. How strongly do you agree or disagree with these statements?

	Strongly Disagree		Neutral		Strongly Agree
a. The government interferes far too much in our everyday lives	○	○	○	○	○
b. Sometimes government needs to make laws that keep people from hurting themselves	○	○	○	○	○
c. It's not the government's business to try to protect people from themselves	○	○	○	○	○
d. The government should stop telling people how to live their lives	○	○	○	○	○
e. The government should do more to advance society's goals, even if that means limiting the freedom and choices of individuals	○	○	○	○	○
f. Government should put limits on the choices individuals can make so they don't get in the way of what's good for society	○	○	○	○	○

22. We next ask about your views on management of the Great Lakes fishery in your state. Please rate your level of agreement with the statements below.

	Strongly Disagree		Neutral		Strongly Agree
a. My state government has the necessary expertise to manage my state's Great Lakes fishery effectively	○	○	○	○	○
b. In managing my state's Great Lakes fishery, decision-makers consider all relevant points of view	○	○	○	○	○
c. My state government is open to new ideas and alternative points of view on Great Lakes fisheries	○	○	○	○	○
d. My state government's information about Great Lakes management tends to be biased and one-sided	○	○	○	○	○
e. My state government is too influenced by private industries in my state's Great Lakes fishery	○	○	○	○	○
f. My state government makes credible decisions about my state's Great Lakes fishery	○	○	○	○	○

Section 5 of 5: About You

23. What is your gender? ❑ Male ❑ Female ❑ Other

24. In what year were you born? _____

25. What is your annual household income (in USD) before taxes? (Please ✓one)

❑ Less than $20,000
❑ $20,000 - $39,999
❑ $40,000 - $59,999
❑ $60,000-$79,999
❑ $80,000 - $99,999
❑ $100,000 - $124,999
❑ $125,000 - $149,999
❑ $150,000 or more
❑ Prefer not to answer

26. What is the highest level of education you have completed? (Please ✓one)

❑ Some high school
❑ High school graduate or GED
❑ Two-year degree
❑ Bachelor's degree
❑ Professional certificate
❑ Graduate degree

27. With which racial group(s) do you identify? (Please ✓all that apply)

❑ White
❑ Asian
❑ Black or African American
❑ American Indian
❑ Native Hawaiian or other Pacific Islander
❑ Other: _____

Please check the box below if you read the introductory letter (enclosed with this survey)

❑ Yes, I read the introductory letter.

Thanks for your help!

If you have any additional thoughts about this study that were not reflected in the questions above, please share them here.

If you have any questions or would like to see the results please let us know.

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APPENDIX D: SURVEY QUESTIONNAIRE USED FOR CHAPTER 4

A survey about aquatic Invasive Species in Illinois

The University of Illinois at Urbana-Champaign and Illinois-Indiana Sea Grant are conducting research to learn more about the opinions of recreational water users in Illinois and the spread of aquatic invasive species, which are organisms that move into areas beyond their natural, historic range causing ecological and economic problems.

To help decision makers understand the opinions of recreational water users and develop helpful materials for sharing information about aquatic invasive species, we are asking you to participate in this survey. Responding to survey questions about your experiences and preferences as an angler or boater will take approximately 15 minutes.

Those of us at the University of Illinois who may see your information will maintain confidentiality to the extent of laws and university policies. Personal identifiers will not be published or presented. If you have questions or concerns about your rights as a participant please contact the University of Illinois at Urbana-Champaign Office for the Protection of Research Subjects at 217-333-2670 or via email at irb@illinois.edu. If you have any questions about the study, please contact the project leader, Carena van Riper at cvanripe@illinois.edu.

Your participation in this research is voluntary. If you decide to participate, you are free to withdraw at any time. If for any reason you prefer not to participate in this study, you may exit now. If you would like to be removed from our email list, please let us know by responding to our email.

We appreciate your careful consideration of each question. Please save any comments you might have for the end of the survey.

Screening questions

A. Have you gone fishing at least once since 2018?
B. Have you participated in a recreational water activity (sailing, kayaking, canoeing, boating, jetskiing, etc.) at least once since 2018?
C. What is your zip code?
D. In what year were you born?

Section 1 of 6: Background Information

Anglers only (responded "yes" to screening question A).

In this section, we ask you to provide information about your fishing experiences.

1. About how many days did you go fishing in 2020? _____Days

2. About how many years, including this one, have you been fishing? _____Years

3. Where have you spent most of your time fishing?

- ○ Fishing from the shoreline
- ○ Fishing from a boat
- ○ Wading in shallow water (e.g., fly fishing)
- ○ I spend about an equal amount of time fishing from two or more of the above options

3b. Please select the statement that generally describes your experience.
(shown only to those who selected the 4th option above)

- ○ I spend equal amounts of time fishing from a **boat** and the **shoreline**
- ○ I spend equal amounts of time fishing from a **boat** and **wading**
- ○ I spend equal amounts of time fishing from the **shoreline** and **wading**
- ○ I spend equal amounts of time fishing from a **boat**, the **shoreline**, and **wading**

4. Which species do you frequently fish for? (Please select all that apply)

❑ Atlantic salmon	❑ Bluegill	❑ Brook trout
❑ Brown trout	❑ Carp	❑ Catfish
❑ Chinook / king salmon	❑ Coho salmon	❑ Crappie
❑ Drum / sheepshead	❑ Gar	❑ Lake trout
❑ Largemouth bass	❑ Muskie	❑ Northern pike
❑ Rainbow trout / steelhead	❑ Smallmouth bass	❑ Walleye
❑ White bass	❑ Whitefish	❑ Yellow perch
❑ Other: _____		

5. How would you rate your fishing skills compared to other anglers?

❑	❑	❑	❑	❑
Much lower than average	Lower than average	Average	Higher than average	Much higher than average

6. Have you purchased a fishing license between 2018 and 2020? ❑ Yes ❑ No

Boaters only (responded "yes" to screening question B)

In this section, we ask you to provide information about your recreational water experiences.

1. Which recreational activities have you participated in since 2018?
(select all that apply)

- ❑ Sailing
- ❑ Kayaking
- ❑ Canoeing
- ❑ Boating
- ❑ Jetskiing
- ❑ Other: _____

1b. Which activity do you participate in most frequently?

- ❑ Sailing
- ❑ Kayaking
- ❑ Canoeing
- ❑ Boating
- ❑ Jetskiing
- Other: _____
- ❑ More than one of these activities (explain): _____

2. In 2020, about how many days did you participate in the activity you selected in the previous question? _____Days

3. About how many years, including this one, have you been participating in this activity? _____Years

4. How would you rate your level of expertise in this activity compared to other recreationists?

❑	❑	❑	❑	❑
Much lower than average	Lower than average	Average	Higher than average	Much higher than average

All Respondents --

7a. Which of the following do you own? *(select all that apply)*

- ❑ Fishing boat
- ❑ Sailboat
- ❑ Powerboat
- ❑ Pontoon boat
- ❑ Jetski
- ❑ Canoe
- ❑ Kayak
- ❑ Other: _____
- ❑ I do not own any type of boat or watercraft

7b. Please select the description of the boat you use most often.
(shown only to those screened in as a boater, or reported fishing from a boat (Q3))

- ○ A boat that is trailered between fishing sites
- ○ A boat that is docked or moored at one location for a season
- ○ Other: _____

8. We would like to understand your familiarity with aquatic invasive species. How familiar are you with the following types of information?	Not at all familiar	Slightly familiar	Somewhat familiar	Moderately familiar	Extremely familiar
a. The biological characteristics that make a species "invasive"	○	○	○	○	○
b. Names of species that are considered invasive	○	○	○	○	○
c. Ways that invasive species affect the environment	○	○	○	○	○
d. How boaters and anglers can spread invasive species	○	○	○	○	○
e. Types of actions you can take to prevent invasive species from spreading	○	○	○	○	○
f. How to complete recommended preventative actions	○	○	○	○	○
g. Agencies that are responsible for managing invasive species	○	○	○	○	○
h. Management actions that reduce invasive species impacts	○	○	○	○	○
i. The current state of invasive species management at your most frequented waterbody	○	○	○	○	○

9. We would like to gauge your understanding of the species listed below. Which of the following species are considered invasive in Illinois?	Invasive	Not invasive	Not sure
a. Rusty crayfish	○	○	○
b. Channel catfish	○	○	○
c. Asian carps	○	○	○
d. Hydrilla	○	○	○
e. Spiny waterflea	○	○	○
f. Gizzard shad	○	○	○

10. We would like to understand how important the issue of aquatic invasive species is to you. To what extent do you agree or disagree with the following statements?	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. The spread of aquatic invasive species is a personally relevant topic for me	○	○	○	○	○
b. I think about aquatic invasive species a great deal	○	○	○	○	○
c. I find myself bringing up aquatic invasive species in casual conversation	○	○	○	○	○
d. When aquatic invasive species come up in conversation I "tune in"	○	○	○	○	○
e. I don't care about aquatic invasive species	○	○	○	○	○
f. Aquatic invasive species are never at the top of my mind	○	○	○	○	○

Section 2 of 6: Aquatic Invasive Species Outreach Messages

We are testing outreach messages that can be used to inform anglers and boaters about how to minimize the spread of aquatic invasive species. We would like your feedback on one of these messages.

Respondents were selected at random to receive one of six experimental messages. An example of these messages is shown below.

11. We are interested in everything that went through your mind while examining the infographic shown above. Please use the space below to list all thoughts, whether they were about yourself, the information, or others, as well as whether they were positive, negative, or neutral. There are no right or wrong answers.

12. We would like to understand your reactions to the message. While reading the message, were you....	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. Deep in thought about the message	○	○	○	○	○
b. Extending a good deal of cognitive effort	○	○	○	○	○
c. Not really exerting your mind	○	○	○	○	○
d. Doing your best to think about what was written	○	○	○	○	○
e. Reflecting on the implications of the arguments	○	○	○	○	○
f. Taking it easy	○	○	○	○	○

13. We would like to know the effectiveness of the message you just evaluated. Please rate your level of agreement or disagreement with the following statements.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. The message was worth remembering	○	○	○	○	○
b. The message grabbed my attention	○	○	○	○	○
c. The message was powerful	○	○	○	○	○
d. The message was meaningful to me	○	○	○	○	○
e. The message was informative	○	○	○	○	○
f. The message was convincing	○	○	○	○	○

14. We would like to understand your perceptions of the message you just evaluated. Please rate your level of agreement or disagreement with the following statements.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. The message was very objective	○	○	○	○	○
b. The message tried to pressure me to think a certain way	○	○	○	○	○
c. The message did not try to force its opinions on me	○	○	○	○	○
d. The message was very believable	○	○	○	○	○
e. The message was not very credible	○	○	○	○	○
f. The message tried to manipulate me	○	○	○	○	○
g. I felt like the message was trying to persuade me	○	○	○	○	○

15. What information would be helpful for you to know about aquatic invasive species? What do you think should be included in a brochure like the one you reviewed?

_____

16. We would like your input on the best ways of disseminating information such as what you read in the brochure. How useful would the following resources be for you to learn about aquatic invasive species?

	Not at all useful	Slightly useful	Moderately useful	Very useful	Extremely useful
Workshops on aquatic invasive species prevention	○	○	○	○	○
Educational exhibits or displays	○	○	○	○	○
Booths at a sports or fishing show	○	○	○	○	○
Outreach activities at boat launches	○	○	○	○	○
Newspaper, magazine, or newsletter articles	○	○	○	○	○
Television news or programs	○	○	○	○	○
Television public service announcements	○	○	○	○	○
Radio news or programs	○	○	○	○	○
Radio public service announcements	○	○	○	○	○
Brochures and fact sheets	○	○	○	○	○
Species identification cards	○	○	○	○	○
Internet websites	○	○	○	○	○
YouTube videos	○	○	○	○	○
Social media posts (Facebook, Twitter, etc.)	○	○	○	○	○
Scholarly articles	○	○	○	○	○
Public meetings regarding natural resources	○	○	○	○	○

17. We are also interested in the sources of information that you rely on the most. How reliable are the following sources for information about invasive species?

	Not at all trustworthy	Slightly trustworhty	Moderately trustworthy	Very trustworthy	Extremely trustworthy
Family members, friends, or neighbors	○	○	○	○	○
Government employees	○	○	○	○	○
Volunteers	○	○	○	○	○
Bait shop vendors	○	○	○	○	○
Members in boating or angling clubs	○	○	○	○	○
Sales associates at boating or fishing stores	○	○	○	○	○
Charter captains	○	○	○	○	○

Environmental groups	○	○	○	○	○
Other anglers	○	○	○	○	○

Section 3 of 6: Risks of aquatic invasive species

In the following questions, we would like to understand your perceptions of the risks associated with the spread of aquatic invasive species.

18. This question is about the likelihood that invasive species will spread to the waterway that you visit most often. In your opinion, what are the chances…

	0 10 20 30 40 50 60 70 80 90 100%
that invasive species will spread to your waterbody within the next year	
that invasive species will spread to your waterbody within the next ten years	
that humans will be able to prevent invasive species from spreading to your waterbody	

19. If invasive species spread to your most frequented waterbody, how intense would you expect the impacts to be? Please indicate the intensity of potential harm to…	No impacts	Mild impacts	Moderate impacts	Severe impacts	Very severe impacts
a. Quality of habitat and natural environments	○	○	○	○	○
b. Environmental processes (e.g., water cycle)	○	○	○	○	○
c. Survival of plants and animals	○	○	○	○	○
d. Your appreciation of the beauty of the landscape	○	○	○	○	○
e. Your own enjoyment of recreational activities	○	○	○	○	○
f. Your own access to the waterbody	○	○	○	○	○
g. The local economy	○	○	○	○	○
h. The community in the region	○	○	○	○	○
i. Recreational opportunities for future generations	○	○	○	○	○

Section 4 of 6: Preventing the spread of aquatic invasive species

In this section, we ask you to reflect on the actions you could take to prevent aquatic invasive species from spreading.

There are two behavior questions, one reflecting transport on the boat, and one on the fishing equipment. Respondents who reported boating but not fishing receive 20a, respondents who reported fishing from the shoreline online receive 20b, respondents who boat and fish (or fish from boats) receive both batteries of questions.

20a. There are several ways to prevent accidentally transporting invasive species on your boat. Think about your boating trips over the next 12 months. How frequently do you plan to engage in the following activities?	Never	Occasionally	About half the time	Most of the time	Every time I go boating
a. Drain all standing water from the boat	○	○	○	○	○
b. Conduct visual inspections of boats for invasive species	○	○	○	○	○
c. Remove plants, animals, and mud from the boat	○	○	○	○	○
d. Rinse boat and trailer	○	○	○	○	○
e. Wipe down hull with a towel	○	○	○	○	○
f. Allow boat to dry before entering a different body of water	○	○	○	○	○

20b. There are several ways to prevent accidentally transporting invasive species on your fishing equipment. Think about your fishing trips over the next 12 months. How frequently do you plan to engage in the following activities?	Never	Occasionally	About half the time	Most of the time	Every time I go fishing
a. Remove any non-bait fish, plants, and other "hitchhikers" from bait bucket	○	○	○	○	○
b. Dispose of unused live bait in the trash	○	○	○	○	○
c. Drain water from bait bucket before moving to another waterbody	○	○	○	○	○
d. Conduct visual inspections of fishing equipment for invasive species	○	○	○	○	○
e. Remove plants, animals, and mud from fishing equipment	○	○	○	○	○
f. Rinse fishing equipment	○	○	○	○	○
g. Wipe down fishing equipment with a towel	○	○	○	○	○
h. Allow fishing equipment to dry before fishing in a different body of water	○	○	○	○	○

All respondents receive the rest of the survey; no further skip patterns or display logic.

21. We would like to understand how you view your ability to mitigate the impacts from aquatic invasive species. How strongly do you agree or disagree with the following statements?	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. I understand what I need to do in order to remove invasive species from my boat or equipment.	○	○	○	○	○
b. I am capable of performing the tasks required to remove possible invasive species from my boat and equipment	○	○	○	○	○
c. I feel confident in performing procedures necessary to prevent aquatic invasive species from spreading	○	○	○	○	○
d. Cleaning my boat and equipment helps to prevent invasive species from spreading	○	○	○	○	○
e. My own actions to *remove, drain, and dry* will protect fishing waters from invasive species	○	○	○	○	○
f. If everyone remembered to "remove, drain, dry", we could significantly lower the risk of spreading invasive species	○	○	○	○	○

22. There are many reasons it may be beneficial to complete the recommended aquatic invasive species prevention tasks. Please rate your level of agreement or disagreement regarding the following reasons. ***Completing "remove, drain, dry" results in...***	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. Increasing my own knowledge and understanding of the ecosystem	○	○	○	○	○
b. Improved maintenance of my boat or equipment	○	○	○	○	○
c. Knowing that I have done the right thing to be a responsible water user	○	○	○	○	○
d. A sense of community among water-based recreationists	○	○	○	○	○
e. Teaching younger generations about the impact of our behaviors on the environment	○	○	○	○	○
f. Preserving aquatic resources for my community	○	○	○	○	○
g. A healthier ecosystem	○	○	○	○	○
h. More sustainable populations of plants and animals	○	○	○	○	○
i. Better water quality	○	○	○	○	○

23. There are many reasons it may be difficult to complete the recommended aquatic invasive species prevention tasks. Please rate your level of agreement or disagreement regarding the following reasons.	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. I do not have enough time to complete the recommended cleaning tasks that minimize the spread of invasive species	○	○	○	○	○
b. I feel pressure from other recreationists to leave the site without cleaning my boat or equipment	○	○	○	○	○

c. I lack the necessary equipment to effectively clean my boat or equipment	○	○	○	○	○
d. Poor weather conditions often interfere with my ability to complete the recommended cleaning tasks	○	○	○	○	○
e. My health or physical abilities prevent me from effectively cleaning my boating or fishing equipment	○	○	○	○	○

Section 5 of 6: Environmental Values and Trust

In this section, we ask you to think about your personal values. This information will help decision makers understand what you care about most.

24. These questions are about the things you value most. Please rate the extent to which you consider these general ideas to be guiding principles in your life.	Unimportant	Of Little Importance	Moderately Important	Important	Very Important
a. **Protecting the environment**: preserving nature	○	○	○	○	○
b. **Unity with nature**: fitting into nature	○	○	○	○	○
c. **A world of beauty**: beauty of nature and the arts	○	○	○	○	○
d. **Equality**: equal opportunity for all	○	○	○	○	○
e. **Social justice**: correcting injustice, care for others	○	○	○	○	○
f. **A world at peace**: free of war and conflict	○	○	○	○	○
g. **Authority**: the right to lead or command	○	○	○	○	○
h. **Social power**: control over others, dominance	○	○	○	○	○
i. **Influential**: having an impact on people and events	○	○	○	○	○
j. **Fulfilment of desire**: food, fun, pleasure	○	○	○	○	○
k. **Enjoying life**: pursuing hobbies, leisure, socializing	○	○	○	○	○
l. **Reducing worries**: seeking comfort and relaxation	○	○	○	○	○
m. **Personal growth**: development of new skills, learning, or gaining insight into something	○	○	○	○	○
n. **Pursuit of excellence**: attaining a personal ideal in life	○	○	○	○	○
o. **Autonomy**: deciding your own future and doing what you believe in	○	○	○	○	○
p. **Satisfaction with life:** finding meaning, value, and relevance to a broader context	○	○	○	○	○

25. Scientists provide information about fisheries in lakes and rivers throughout the state of Illinois. We would like to know how much you trust the scientific community. To what extent do you agree or disagree with the following statements?	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. I have very little confidence in the scientific community.	○	○	○	○	○
b. Information from the scientific community is trustworthy.	○	○	○	○	○
c. I trust the scientific community to do what's right.	○	○	○	○	○
d. The scientific community often does not tell the public the truth.	○	○	○	○	○
e. I am suspicious of the scientific community.	○	○	○	○	○
26. Fisheries and other recreational activities in Illinois are primarily managed by the Department of Natural Resources (DNR). We would like to know how much you trust this agency. To what extent do you agree or disagree. with the following statements?	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
f. I have very little confidence in the Illinois Department of Natural Resources.	○	○	○	○	○
g. Information from the Illinois Department of Natural Resources is trustworthy.	○	○	○	○	○
h. I trust the Illinois Department of Natural Resources to do what's right.	○	○	○	○	○
i. The Illinois Department of Natural Resources often does not tell the public the truth.	○	○	○	○	○
j. I am suspicious of the Illinois Department of Natural Resources.	○	○	○	○	○

Section 6 of 6: About You

26. What is your gender? ○Male ○Female ○Other

27. In what year were you born? _____

28. What is your annual household income (in USD) before taxes? (Please ✓one)

○Less than $24,999 ○$25,000-$49,999 ○$50,000-$74,999
○$75,000-$99,999 ○$100,000-$124,999 ○$125,000-$149,999
○$150,000-$174,999 ○$175,000-$199,999 ○$200,000 and over
○ Prefer not to answer

29. What is the highest level of education you have completed? (Please ✓one)

○Some high school ○High school graduate or GED ○Two-year degree
○Bachelor's degree ○Professional certificate ○Graduate degree

30. With which racial group(s) do you identify? (Please ✓all that apply)

○White ○Black or African American

○Asian ○Native Hawaiian or other Pacific Islander
○American Indian ○Other:_____

31. With which ethnicity do you identify?

○Hispanic ○Non-Hispanic

32. Which language are you most comfortable reading? _____

33. What is your zip code? _____

Thanks for your help!

If you have any additional thoughts about this study that were not reflected in the questions above, please share them here.

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APPENDIX E: MESSAGE EXPERIMENT USED FOR CHAPTER 4

Figure E.1. Experimental message framed according to *self-transcendent* values. This message was evaluated by 82 participants (16.2%)

Figure E.2. Version two of an experimental message framed according to *self-transcendent* values. This version was also imbued with efficacy messaging; the analysis of which is outside the scope of this dissertation. This message was evaluated by 81 participants (16.0%).

Figure E.3. Experimental message framed according to *self-enhancement* values. This message was evaluated by 79 participants (15.6%).

Figure E.4. Experimental message framed according to *self-enhancement* values. This version was also imbued with efficacy messaging; the analysis of which is outside the scope of this dissertation. This message was evaluated by 93 participants (18.3%).

Figure E.5. Experimental message used as the *baseline*, reflecting the current version of materials used by the *Be a Hero* program. This message was evaluated by 82 participants (16.2%).

Figure E.6. Experimental message used as the *baseline*, reflecting the current version of materials used by the *Be a Hero* program. Though serving as a baseline for the values treatment, this version was also imbued with efficacy messaging; the analysis of which is outside the scope of this dissertation. This message was evaluated by 90 participants (17.8%).