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# Are lakes a public good or exclusive resource? Towards value-based management for aquatic invasive species

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## ABSTRACT

Invasive species are a prominent driver of global environmental change and management of biological invasions is a complex issue that requires attention to social and ecological contexts. Management efforts implemented without consideration of social dimensions have often been delayed or have failed due to community resistance. Despite this, much invasive species research has focused solely on the ecological dynamics of invasions. To advance our understanding of the social dimensions of efforts to confront invasive species, we analyze decision-making among stakeholders impacted by starry stonewort (*Nitellopsis obtusa*), a freshwater alga and key emerging invader in lakes in the upper midwestern US that, to our knowledge, has not been explored in the human dimensions of invasive species literature. Through a content analysis of 46 semi-structured interviews with stakeholders associated with lakes invaded by *N. obtusa* in Indiana, Wisconsin, and Minnesota, we assess stakeholders' management preferences and the factors that shape both preferences and current practices. We examine current management strategies, perceptions of the importance of addressing starry stonewort, and stakeholder goals, as well as motivational and structural factors that shape and potentially limit decision-making. We highlight two "lake ethics" that emerge from our results where stakeholders see lakes as either a public good or an exclusive resource. We present a typology of these two distinct lake ethics and explore their implications for future efforts to manage *N. obtusa*, suggesting that managers should move towards value-based approaches that consider underlying community values tied to natural resources.

## 1. Value-based invasive species management for a changing environment

Invasive species are one of the most prominent drivers of global environmental change, arguably second only to climate change (Bellard et al., 2016). The social-ecological impacts of invasive species are likely to be exacerbated under a changing climate (Beaury et al., 2020). This is partially because many of the traits that contribute to their invasiveness, such as broad environmental tolerances, may also help them succeed under new climate regimes (Mainka and Howard, 2010). Developing social-ecological resilience to invasions—that is, increasing the inter-related capacity of human and natural communities to withstand this disturbance (Folke, 2016)—requires an understanding of both the processes that underlie the spread and ecological effects of a particular invasive species and of the social dynamics that exist where the species might spread. These include the potential benefits or harms the species

may cause, as understood by various stakeholders, and the perceived acceptability of and commitment to various management approaches.

Why be concerned about these social processes? Specific choices about management, and the level of resources to commit can be contentious. These struggles largely arise from a difference within management communities' values or preferences, including risk perception (Sharp et al., 2011; Wald et al., 2019). In the past, management strategies have often been implemented without consideration of the values, perceptions, accepted risks, knowledge, or goals of the people involved with or impacted by an invasive species. These social elements are often in conflict and neglecting to understand them, or even acknowledge their influence on the success of management efforts, has led to numerous failures in invasive species management despite the noted general support for action (Estevez et al., 2015; Kapitzka et al., 2019; Shackleton and Gambiza, 2008).

Even before management efforts are considered, the notion of

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invasiveness itself is a nuanced and controversial one that reflects human societies' complex and often ambivalent relationship with the natural world (Subramaniam, 2001). While the designation of a species as invasive may have a basis in seemingly objective scientific principles from the fields of ecology and conservation, this designation also always represents a value judgment about the ecosystem in question, nature writ large, and the particular species in question. Put another way, nonhuman species become "social problems" when they fail to fill a socially appropriate role (Jerolmack, 2008). A growing body of research has explored the problems inherent in much invasive species discourse, including elements of xenophobia, racism, and species-ism (Dinat et al., 2019; McNeely, 2011). Some scholars have called to stop using the term "invasive species," while others have argued that the field of invasion biology should be eliminated (Guaşu and Tindale, 2018). Many of these critiques acknowledge the anthropocentric framing inherent to the concept of "invasive" species.<sup>1</sup> How processes such as invasions are "socially constructed" is both shaped by factors such as biophysical place and socio-cultural properties of affiliated communities and can shape how or if management responses are undertaken (Houser, 2018; Freudenburg et al., 1995). In other words, if invasive species definitionally impact human communities, and most human communities seek to manage their impacts, then conceptions of invasive species are anthropocentric and cannot be successfully addressed without engaging with the complex human communities that seek to manage them (Sullivan et al., 2017).

In short, social factors need to be considered for effective management of invasive species (Estevez et al., 2015). Developing appropriate policy for invasive species management requires that researchers gain a better understanding of the processes that shape stakeholders' preferences, capacities for adopting given strategies, and goals. However, most research on invasive species, including starry stonewort (e.g., Muthukrishnan et al., 2018a; Sleith and Karol, 2021; Ginn et al., 2021), has focused on ecological processes, both in terms of predicting where invaders may spread (habitat suitability) and what impacts they may have (effects on other parts of the ecosystem). But those efforts, if they don't engage with the social dimensions of management, and specifically diverse stakeholders' values surrounding invasive species and the environment, will have limited utility to support environmental decision-making (Tebboth et al., 2020). As we discuss below, starry stonewort (*Nitellopsis obtusa*) provides an ideal and important opportunity to empirically examine these social factors in invasive species management.

### 1.1. Starry stonewort (*Nitellopsis obtusa*): the human dimensions of an emerging aquatic invasive species

Starry stonewort (*Nitellopsis obtusa*) is a freshwater alga that is a key emerging invader in the upper midwest region of the United States (Larkin et al., 2018). *N. obtusa* can grow in dense mats, displacing native species, reducing local diversity, and creating nuisances for recreational activities (Glisson et al., 2018; Larkin et al., 2018). *N. obtusa* initially established in North America in the St. Lawrence River in Quebec, likely in the early 1970s (Karol and Sleith, 2017). In the past decade, its presence has been rapidly expanding in the midwestern states of Indiana, Michigan, Wisconsin, and Minnesota, where it has become a species of particular concern to state-level management agencies (Larkin et al., 2018). In this region, lakes are an important economic resource and a cultural symbol closely tied to regional identity (e.g., Minnesota's moniker as "The land of 10,000 lakes"; Winkler et al., 2013). *N. obtusa* is primarily spread through human activity at multiple scales. Introduction of *N. obtusa* to North America was likely in ballast water of trans-oceanic

<sup>1</sup> It is worth noting that some scholars have rejected these critiques, such as Ricciardi and Ryan (2018), who argue that they amount to a form of scientific "denialism" similar to climate change denialism.

shipping from Europe (Sleith and Karol, 2021). At the regional scale, dispersal between lakes is mostly driven by movements of recreational boats and boating equipment that contain fragments of *N. obtusa* (Kao et al., 2021; Larkin et al., 2018). Within lakes algal fragments are moved by boats as well, but they may also disperse to different locations naturally, driven by currents or wind. But even in this scenario dispersal is often facilitated by human activity that disturbs *N. obtusa* patches creating fragments that can move more easily.

Once introduced, it is also likely that *N. obtusa* invasion dynamics are influenced by human activity via impacts on lake level water quality (Muthukrishnan et al., 2018a), projected shifts associated with the changing climate of the region (e.g., ice-out date, growing season length, average water temperature) (Romero-Alvarez et al., 2017), and facilitation by introduction of other invasive species. Given the relatively recent establishment of *N. obtusa* in the region, existing regional, state, or local guidance is limited, and best practice management strategies do not exist. Developing effective, value-based management strategies will require a deeper understanding of how diverse sets of stakeholders across the region are conceptualizing *N. obtusa* invasions and their decision-making processes. To the best of our knowledge, there are no peer reviewed qualitative social science studies of how human communities are considering or managing *N. obtusa* invasions.

Effective community engagement around natural resource management approaches depends in part on regionally- and problem-specific tailoring (Reimer et al., 2014), which relies on a specific understanding of local communities' views of these problems and their solutions. In consequence, more research on the *N. obtusa* problem as it manifests in the upper Midwest is likely required to develop effective engagement techniques and realize more value-based management of this species. Further, and more broadly, aquatic invasive species are less studied and understood than their terrestrial counterparts and there are few studies of the human dimensions of freshwater aquatic invasive species generally (Cuthbert et al., 2021).

There are a variety of management strategies that communities often consider when deciding how to manage *N. obtusa* (Table 1). Each method is associated with different goals and drawbacks. How a human community decides on a management approach, including doing nothing, is tied directly to that community's broader set of values and relationship with the environment (Graham et al., 2019).

### 1.2. Research questions

Importantly, the decision and motivation to label a species as invasive and then take actions to manage it represents a broader set of values regarding the affected ecosystem and landscape. Understanding different approaches to invasive species management requires understanding the social and cultural relationships that stakeholder communities have with their environments. For this reason, an important task for developing an understanding of management approaches to *N. obtusa* is developing a typology that describes these different values and how people relate to the broader human-environment lake community. A typology of this sort allows for nuance in evaluating stakeholder values and preferences making it, we argue, a better approach for determining management goals and methods than approaches that model values on a continuum between perceived extremes. In this study, we explore the following research questions to develop such a typology:

- 1) How do stakeholders' values and cultural relationships with their lakes shape preferences and current management approaches?
- 2) How are stakeholders making their current management decisions? What social and biophysical factors are shaping these decisions?
- 3) Are there regional differences or differences across stakeholder types in these management preferences, practices, and decision-making processes?

There are multiple scales of governance involved in *N. obtusa*

**Table 1**  
Potential *N. obtusa* management strategies.

Strategy	Goal	Potential drawbacks	Source
Boat/aquatic vehicle inspections (prior to lake entry and exit)	Preventing introduction and secondary spread; reduction	Inspection costs; time intensive	Sleith et al. (2015)
Chemical applications (algaecides alone, or in combination with herbicides)	Eradication, reduction	Algaecides often ineffective; negatively impact aquatic community	Glisson et al. (2018)
Lake closures to recreational users	Preventing introduction and secondary spread	Loss of use fees; users may ignore closure unless enforced; loss of opportunity to use public resource	Discussion with <i>N. obtusa</i> decision-makers (department of natural resources officials)
Educational campaigns	Preventing introduction and secondary spread	More education alone can have limited effect on personal actions	Discussion with <i>N. obtusa</i> decision-makers (department of natural resources officials)
Mechanical removal (via harvesters, hand pulling, or diver-assisted suction harvesting)	Reduction	Labor intensive; long-term commitment	Glisson et al. (2018)
Physical management (e.g., benthic barriers on lakebeds)	Reduction	Unsure if successful; can be more expensive than alternatives	
Legislation to prevent transport of invasives	Preventing introduction and secondary spread	Time intensive to pass legislation; enforcement costs	Discussion with <i>N. obtusa</i> decision-makers (department of natural resources officials)
“Wait and see”	Additional information about invasion	Invasion may intensify; more difficult to manage later	Discussion with <i>N. obtusa</i> decision-makers (department of natural resources officials)

management, including lake associations, state and regional resource managers, along with many household-level actions related to invasive species control. Perspectives from across these multiple levels of influence are critical to account for in evaluating the factors shaping management decision-making. We contribute a typology of “lake ethics,” which describe value orientations for a diversity of stakeholder types across a spatial gradient (human communities located in Indiana, Wisconsin, and Minnesota). While prior scholarship on stakeholders’ support for environmental management initiatives has examined the problem in terms of their environmental value orientations, often modeled on a continuum between “ecocentrism” and “anthropocentrism,” our analysis and the resulting typology add nuance to such distinctions. We consider how the value stakeholders assign to the biophysical landscape stems from the social relationship with it and cultural meaning it carries for them. This meaning in turn stems from factors like discourses of socioeconomic status that result in value orientations that transcend dichotomous schemes like ecocentrism/anthropocentrism. We expect that this typology will be useful for researchers unpacking the complexities of aquatic invasive species management in diverse locations facing environmental change.

## 2. Methods

Our project involved interviews with stakeholders associated with lake communities across a latitudinal gradient spanning Indiana, Minnesota, and Wisconsin. We interviewed stakeholders associated with three lakes in each state. Interviews were part of a broader social-ecological project, and lakes were selected in part for their biophysical characteristics and suitability for conducting ecological surveys of *N. obtusa*.

### 2.1. Semi-structured interviews

We conducted 46 semi-structured interviews with stakeholders associated with our project lakes from 2019 to 2021. Stakeholders included state department of natural resource officials (who are largely responsible for upholding any state laws related to invasive species management generally), private aquatic invasive species management company representatives, members of nonprofit lake organizations, lake governance association board members, lake-front property owners, and general recreational lake users. The breakdown of the interviewees by stakeholder type and location is in Table 2. For the purposes of this project, we consider stakeholders as those individuals or groups primarily making or influencing management decisions on lakes affected by, or with the potential to be affected by, *N. obtusa*. Interviewees were selected using a combination of purposive and snowball sampling techniques (Cresswell and Plano Clark, 2011). First, we intentionally recruited respondents either involved in *N. obtusa* management (e.g., department of natural resource officials) or associated with our project lakes (e.g., lake association members). Then, during interviews we asked interviewees if their decisions were influenced by additional stakeholders (e.g., members of lake associations, boater associations) and we asked them to recommend additional interviewees. Potential participants were shown a study information sheet and gave their consent to participate. This research was approved by Indiana University’s Institutional Review Board.

All interviews were guided by a semi-structured protocol and performed either in-person or via video calls, with open ended prompts on topics including who the interviewee worked with on *N. obtusa* issues (government officials, members of the public, NGOs, etc.), whether they have encountered *N. obtusa*, current and/or preferred management strategies (if any), whether they perceived *N. obtusa* as an important issue, and goals/ideal management outcomes (see Supplementary Materials for the full interview protocol). We initially conducted all interviews in-person, but transitioned to remote interviews starting in March 2020 during the COVID-19 pandemic. Remote interviews were conducted using Zoom software, using video calls to approximate some of the features of an in-person interview (e.g., body language interpretation). All interviews were audio recorded and recordings were transcribed verbatim and manually (by people). Transcripts were analyzed using content analysis (Bernard, 2011) to identify themes. Because our interviews followed a standardized interview protocol informed by existing literature on the human dimensions of invasive species (e.g., Epanchin-Niell et al., 2009), we employed a structural coding approach (Guest et al., 2012; MacQueen et al., 2008; Namey et al., 2008; Saldana, 2016), wherein top-level codes were developed deductively based on the interview questions themselves. Subcodes were arrived at through iterative, inductive analysis based on “concept coding” (Saldana, 2016). This involved summarizing interviewees responses to relevant interview questions or coding them in vivo (Charmaz, 2014; Corbin and Strauss, 2015) into representative subcodes, and then further refining these subcodes according to emergent themes. For example, subcodes of “Native Species Revival” and “Prevent Ecological Impact” were nested into the subcode “ecological health,” under the top-level code “Main Goals for Management.” Table 3 contains our simplified coding scene, containing our top-level codes and final subcodes.

**Table 2**  
Stakeholder characteristics.

	Lake association governance member	DNR	Other gov. AIS employee	University outreach	Scientist	NGO	Private AIS mgmt	Property owner or public recreationist	Total
Indiana	3	2			1	1	2	1	10
Minnesota	4	4	1	1	1	1		9	21
Wisconsin	3	5			1	1	1	4	15
Total	10	11	1	1	3	3	3	14	46

**Table 3**  
Simplified coding scheme.

Code	Subcode	Brief description
Main Goals for Management	Ecological Health	Management is motivated by concern for the nonhuman ecology of the lake
	Prevention	Management aims to stop the spread of <i>N. obtusa</i> or prevent lakes from being invaded
	Human Use Value	Management aims to prevent <i>N. obtusa</i> from interfering with recreational activities on the lake
Perceived Causes	Natural	Climatic or ecosystem factors are cited as causes of <i>N. obtusa</i> invasion (e.g. temperature, precipitation, or wildlife behavior)
	Recreation	<i>N. obtusa</i> invasion is perceived as being caused by recreational activities like boating and fishing
	Social	Invasion is attributed to social factors like negligence of lake-goers, lack of awareness, or policy failures
Management Methods	Anti/Non-Management	Preference for foregoing management of <i>N. obtusa</i> either temporarily or permanently
	Preventative	Methods aimed at preventing <i>N. obtusa</i> invasion before it happens (e.g. boat cleaning programs, lake closures)
	Financial Capacity	Fundraising efforts to support other management methods
	Building Education	Outreach programs and awareness campaigns
	Physical	Hand pulling and mechanical harvesting of <i>N. obtusa</i>
	Chemical	Chemical treatments, most commonly with copper sulfide
Obstacles for Management	Natural	Physical characteristics of lake or adverse ecological effects of management cited as barriers
	Social	Perceived lack of cooperation or awareness in other stakeholders cited as barriers
	Administrative	Funding shortages and permitting issues cited as barriers

### 3. Results

The main distinctions in attitudes, goals, and management practices that we found through our content analysis of interviews were geographically patterned. Interviewees from Indiana tended to describe their main goals for managing *N. obtusa* as motivated by protecting the human use value of the lake, in the form of opportunities for recreational activities like fishing, boating, swimming, etc. Wisconsin interviewees, meanwhile, tended to cite prevention efforts like stopping the spread of *N. obtusa* to new lakes as their primary goal, while Minnesota interviewees were most likely to explain their goals in terms of protecting the ecological health of the lake (e.g., preventing *N. obtusa* and other

invasive species from outcompeting native species). Interviewees from all three states typically mentioned recreational activities, especially boating, as primary causes of *N. obtusa* invasions. Wisconsin interviewees, though, also mentioned social factors, such as perceived negligence or apathy of lake-goers, and Indiana interviewees posited natural explanations like precipitation patterns. In terms of the main barriers to management, respondents in both Indiana and Minnesota frequently cited administrative barriers like permitting issues for management and the high cost of treatment methods. Wisconsin and Minnesota interviewees also cited social factors like a lack of cooperation in management efforts or awareness regarding *N. obtusa*. Table 4 summarizes these overall trends.

#### 3.1. Comparison across stakeholder types

The most commonly cited main goal of management for interviewees who were employees of the DNR was “prevention,” typically expressed as a desire to keep *N. obtusa* from invading new water bodies. This is placed in context by the fact that the main barrier to management that this group most often mentioned was the lack of a proven method for effectively removing *N. obtusa* from invaded lakes. Property owners and recreationists also mostly cited “prevention” as their main goal, while citing social factors, particularly the perceived lack of cooperation of other stakeholders, as the main barrier to management. Lake association governance members, meanwhile, most often prioritized protecting the human use value of lakes as their main goal, though three interviewees of the nine in this group cited lakes’ ecological health as their main goal.

#### 3.2. An emerging “lake ethic” that shapes aquatic invasive species management

We argue that approaches to *N. obtusa* management are shaped by the prevailing “lake ethic” of a given region. We define a lake ethic as a set of dispositions, values, and socioeconomic characteristics that dictate the cultural meaning of a lake and the source of its value as perceived by stakeholders. In our data, we identify two distinct lake ethics: the “public good” ethic, which emphasizes human use value and recreation, and the “exclusive resource” ethic, which emphasizes a lake’s intrinsic value stemming primarily from the nonhuman ecology it supports. We arrived at this concept using an “abductive” (Timmermans and Tavory, 2014) approach to analysis, which prompts researchers to identify surprising themes based on both emergent patterns in the data and a concurrent reading of existing literature. This typology is far from mutually exclusive, and instead represents two idealized types. Importantly, our typology does not preclude other possible lake ethics not captured in our data, which may interpret lakes as having other sources of value.(Table 5).

In an additional round of coding, we coded each individual interview for which of these lake ethics it aligned most closely with. This gave us a general picture of how these lake ethics break down along lines of geography and stakeholder type. Indiana interviewees slightly leaned towards the Public Good lake ethic, with six out of 10 interviewees coded accordingly. Meanwhile, the vast majority of Minnesota interviewees (17/21) were more aligned with the Exclusive Resource lake ethic. Wisconsin was split nearly evenly, with eight out of 15 interviewees coded as aligned with the Exclusive Resource lake ethic. As for

**Table 4**  
Overview of management goals, perceived causes, and barriers by state.

	Coarse characterization	Exemplary quotation
<b>Indiana</b>		
Main management goals	Human Use Value	“The current goal because there’s not effective controls is managing so that recreation can continue.”
Perceived causes of invasion	Natural, Recreation	“Well, I suspect it would be the amount of nutrients that are in that lake, phosphorus, and the amount of boat traffic that spreads that around.”
Main management barriers	Administrative	“You know, if the DNR doesn’t permit it till a certain date and it’s already past the most effective time to treat it, then that’s a policy issue.”
Current strategies	Chemical, Non-Management	“If you try to mechanically take it out of the lake, it’s just gonna splinter into lots of pieces, and then it’ll just spread. So, ... I don’t think, at this point, [that] is gonna work. I hate to see all these chemicals put in the lake, though.”
<b>Minnesota</b>		
Main management goals	Prevention	“I think number one priority is ... we don’t want it to spread to other lakes.”
Perceived causes of invasion	Recreation	“I am really worried that it’s gonna spread because ... about 30 % of our boaters are going to another waterbody within five days.”
Main management barriers	Administrative, Social	“[The] Main barrier is users don’t understand the risk and haven’t internalized it and made it personal.”
Current strategies	Physical	“We are strictly mechanical at this time. One of our members - ... we helped him purchase a mechanical harvester from the folks up at Ness Lake.”
<b>Wisconsin</b>		
Main management goals	Prevention	“The department’s goal is still primarily to prevent the spread of starry stonewort.”
Perceived causes of invasion	Social, Recreation	“It’s basically the mobility of people and ...more people owning boats, and being unaware of what they’re doing.”
Main management barriers	Social	“I see a lot of outdoorsmen that are kind of like deniers of all this stuff. So, they don’t want to take the time to clean off their boat trailer, clean off their decoys, or scrub their wader boots.”
Current strategies	Preventative, Physical	“Wisconsin has a pretty active prevention program, primarily through our Clean Boats, Clean Waters. It’s a volunteer based program where ... folks ... sit at the boat launch and talk to boaters ...[and] make sure their equipment is clean.”

**Table 5**  
Overview of two distinct lake ethics among stakeholders in the midwestern US.

The Public Good	The Exclusive Resource
Lakes should be accessible and recreation unfettered	Lakes are valuable so long as they remain relatively unchanged by human activity
Lake ecology facilitates enjoyment (fishing, boating, recreation)	Lake ecology has intrinsic value that provides benefits
Invasives are impediments to human enjoyment	Invasives are result of undue human influence on an ecosystem
Chemical treatment and nuisance management	Prevention and physical treatment

stakeholder types, DNR employees were also split evenly, with four each coded as aligning with either lake ethic. All three property owners in our sample (which all came from our Minnesota sample) were aligned with

the Exclusive Resource lake ethic. Six out of nine interviewees who were governance members of a lake association favored the Public Good lake ethic.

**3.2.1. The public good lake ethic**

The Public Good lake ethic treats lakes as a source of recreation and enjoyment whose access should be maximized. The value of a lake according to this lake ethic derives from the enjoyment it facilitates for residents and visitors in the form of boating, fishing, swimming, water sports, and other recreational activities. Environmental management efforts thus seek to maximize these benefits with less emphasis placed on preserving a particular ecosystem status quo (i.e., ecosystem changes, such as invasive species, are acceptable as long as services are maintained). This does not mean that a lake’s value is purely utilitarian or that the lake’s ecology is not an important driver of that value. In this lake ethic, however, the ecology of the lake is a source of value insofar as it facilitates ecosystem services such as recreational activities. For example, protecting an ecosystem capable of supporting a robust fish population is a goal that resonates strongly with the Public Good lake ethic.

This lake ethic’s emphasis on human use-value and recreation informs a conception of environmental problems with particular goals, management strategies, and perceived causes. In terms of causes, the Public Good lake ethic interprets environmental problems like aquatic invasive species in terms of the natural environment itself. This might include explanations like unique weather patterns creating the necessary conditions for invasive species or the levels of certain nutrients in the lake. Where these explanations include social or human drivers of invasive species, these are framed as mediating factors. For instance, while boating is the most commonly cited perceived cause of *N. obtusa* invasion in our data, a Public Good lake ethic phrasing of this causal relationship emphasizes the natural environment itself as well:

“...there’s fishermen that do go out on Lake Michigan fishing and then ... they [say], ‘Hey, the fishing’s no good here. Let’s go try Pike Lake. I heard they’re catching perch or whatever there. Let’s go fishing there.’ ... I’m sure there’s plenty of that. So that’s how it spreads.”

–Stakeholder affiliated with Pike Lake governance.

In this quotation, inter-lake boat travel is posited as a driver for the spread of invasive species, but the natural environment (in this case the attractiveness of a given lake as a fishing destination) is the driver of that boating traffic.

This example points to a certain amount of ambivalence regarding human social relationships to the natural environment that characterizes the Public Good lake ethic. On one hand, the natural environment is a source of enjoyment and community benefit. On the other hand, that benefit is contingent on certain environmental conditions. For this reason, the main goals associated with the Public Good lake ethic are to facilitate human use of the lake and protect the conditions that support it. As one interviewee from Indiana put it:

“The current goal because there’s not effective controls is managing so that recreation can continue.” –Indiana DNR employee

This translates to approaches to manage aquatic invasive species like *N. obtusa* that heavily rely on forms of “nuisance management” like chemical treatments designed to contain the plant to areas of the lake where it will not impede boating, swimming, or other activities. Stakeholders that embody a Public Good lake ethic also might adopt a “non-management” approach, where stakeholders reason that *N. obtusa* does not pose significant enough threats to recreation activities to justify the investment in management procedures.

**3.2.2. The exclusive resource lake ethic**

The Exclusive Resource lake ethic perceives lakes as having intrinsic value derived from the nonhuman ecosystems they support and their



biophysical characteristics. Like the Public Good ethic, people benefit from the value that lakes offer through recreation activities, but there is a greater emphasis placed on the lake itself as an object of “nature,” with nature considered a separate entity from humans. Thus, the biophysical landscape and ecosystem is a more direct source of value, offering residents and lake goers the opportunity to enjoy the aesthetic pleasure of an undeveloped shoreline or of flora and fauna, rather than merely facilitating activities like sport fishing.

Because human enjoyment of the lake is not the main source of its value under this lake ethic, it promotes environmental management that favors protecting the ecosystem over maximizing recreation opportunities. Thus, in terms of management strategies, the Exclusive Resource lake ethic is characterized by a preference for physical methods like mechanical harvesting over chemical treatments that may have potential or unknown future ecological consequences. For instance, when asked what the primary goals ought to be when managing aquatic invasive species, one Minnesota interviewee stated:

“To reduce without harming the local ecosystems ... How can people do that without poisoning a whole lake or draining a whole lake? I think it will be important to see how we can find, like, the one Goldilocks chemical that can take out ... the milfoil without disrupting the ecosystems.” –Fisherman of Minnesota lakes

While management approaches and their potential risks must align with the value this lake ethic places on ecosystem health, the primary goals of management associated with the lake ethic are to prevent the spread of aquatic invasive species to new water bodies and minimize their environmental footprint. This reflects a view of invasive species as primarily a threat to nonhuman ecological well-being, as opposed to a hindrance for human recreation and related ecosystem services.

One particular theme that emerged from our interviews sheds light on the values that inform the Exclusive Resource lake ethic. Several interviewees expressed an opposition to development on lakesides or a nostalgia for times when fewer people lived on or visited their lakes:

“[The lake has] been here for millions of years before us and in a short time we’ve managed to wreck it, or have done some serious damage to it. So we have to take that into account first, because if we don’t, all those other things get rendered useless. There’s no economics. Your spirit is damaged.” –Minnesota lake association member

“I grew up on a lake and ... when I was a kid a lot of the property, a lot of the land around it was undeveloped, and a lot of it was just kind of not real heavily used, seasonal cabins. There [were] a lot less people on the lake, and now there’s a lot more big houses and manicured lawns that people have running all the way to the water’s edge. ... That lakeshore management I think is probably a bigger issue” –Minnesota lake homeowner

These quotations capture a fundamental ambivalence towards humans’ relationship to lakes and lake well-being that characterizes the Exclusive Resource lake ethic. On the one hand, lakes’ natural wonder offers an intrinsic boon to humans who enjoy it, yet this is seen as feasible only on a relatively small scale; too much development or other human impact on the environment threatens to mute a lake’s value. This attitude extends to preferences for managing *N. obtusa*, where stakeholders exhibiting the Exclusive Resource lake ethic contend with a struggle to balance managing the invasive species while minimizing impact to the lake ecosystem.

### 3.3. Socioeconomic distinctions across lake communities

Class status and other socioeconomic distinctions are an implicit (and sometimes explicit) factor in the differences between the Public Good and Exclusive Resource lake ethics. While we do not have quantitative socioeconomic data on the different lakes in our study, class

emerged as an important factor in our interviews during discussions of both the financial cost of aquatic invasive species management and of cultural values surrounding lakes and aquatic invasive species.

Among the most commonly cited obstacles to managing *N. obtusa* throughout our interviews was the financial burden imposed by treatment programs. However, the terms in which the burden of cost was discussed varied in ways that characterize differences between the two lake ethics. For the Public Good lake ethic, when cost was mentioned it was not simply viewed as an obstacle, but often as a barrier significant enough to shape the decision of whether or not to pursue management action in the first place. Interviewees that were aligned with the Public Good lake ethic often reasoned that the monetary price of certain interventions like chemical treatment programs would be worth their potential benefit to recreational activities. Moreover, the Public Good lake ethic is characterized by explicit references to the socioeconomic identity of a lake community. Such references often arose during discussions of the cost of aquatic invasive species management. When asked about the main barriers to aquatic invasive species management, one Indiana interviewee responded:

“Well, first of all, some of the problem is that, socioeconomically, we’re not a rich lake. ... It’s a non-ski lake, a ten-mile-a-hour speed limit. It’s about 160 acres in size, and probably a third to 40 % live there year-round. And they’re not well-to-do people. They’re not poverty [sic], but they’re not \$250,000.00-\$300,000.00 Lake James homes. So we don’t have deep pockets.” –Indiana fishermen

Here cost is not just an administrative hurdle, but a factor deeply connected to the lake community’s identity and ultimately its economic capacity to act. This shapes the goals and strategies of the Public Good lake ethic: aquatic invasive species management aims to reduce the nuisance caused by these species, rather than making large scale interventions.

On the other hand, adherents of the Exclusive Resource lake ethic view *N. obtusa* and other invasive species as existential threats, given the connection between a lake’s ecology and its intrinsic value. One homeowner in Minnesota opined that residents of lake community should contribute to the cost of aquatic invasive species management, for fear that the economic ramifications of failing to act:

“A lot of people ... stand to lose and benefit from this in terms of, you know, economics, not only the residents on the lake, the city of Paynesville, the Paynesville township, Stearns County, Meeker County, the DNR, you know, all that. If it affects our property values and they go south on us ... I don’t know what the value is around the lake, but it’s I’m sure several hundred million dollars. There’s some big properties out here. So when I wrote to the watershed district to be on record, I told them I expect that they need to look into partnering with the rest of these folks.” –Homeowner on Minnesota lake

Stakeholders characterized by the Exclusive Resource lake ethic sometimes discussed cost as an obstacle to management. But, as in the quote above, cost was frequently framed as a necessary hurdle to overcome and not a deciding factor in whether to take action to manage *N. obtusa*.

Besides discussions of cost, the other context in which socioeconomic distinctions between lake communities came up in our interviews was in discussions of lake use and cultural values. As discussed above, the adherents of the Public Good lake ethic are invested in maximizing the opportunities a lake offers for recreational activities like boating, fishing, or water sports. At times, interviewees who aligned with the Exclusive Resource lake ethic made it clear that they felt differently about these same activities, even sometimes viewing them with disdain. Since the Exclusive Resource lake ethic privileges lakes and their ecosystems as objects of nature, these recreational activities may be seen as preventing enjoyment of the lake in these terms rather than facilitating it. Importantly, this was most common for property owners, which inflects this attitude with socioeconomic difference. One homeowner in

Wisconsin said the following when asked about the causes of aquatic invasive species:

“Well, it’s basically the mobility of people... owning boats, and being unaware of what they’re doing. I don’t think people [are] malicious about this whole thing. They’re just uninformed. It’s the same thing with the wake boats, you know, that they’re getting to be a huge problem. And, you know, they’re just out there having fun ... [while] I sit on my deck, you know, a half a mile away, I’m hearing some guy’s music on the back of the boat. And I’m going, you know, come on. I don’t want to hear this. I want to sit here and enjoy some serenity. I’m lucky enough to live on the lake. I don’t want to be listening to your damn music.” –Homeowner on Wisconsin lake

Underpinning this sentiment is the fundamental difference between the two lake ethics in terms of what defines an ideal lake community. Rather than maximizing recreation opportunities, adherents of the Exclusive Resource lake ethic like the interviewee quoted above see value in serenity, natural beauty, and a minimal human footprint. Because this mode of recreation is inherently more exclusive, it inherently reflects a more advantaged class identity, or at least the aspiration for such an identity.

#### 4. Discussion

Our approach of generating a typology of lake ethics treats the question of stakeholder support for invasive species management as one of *how* stakeholders value nature, as opposed to one of *how much* they do. Previous scholarship on various environmental problems has modeled stakeholder “value orientations” on a continuum between “biocentric” and “anthropocentric” poles (Vaske et al., 2001; Sharp et al., 2011; Pradhananga et al., 2015). Elsewhere, survey researchers have used instruments like Dunlap and Van Liere’s influential “New Environmental Paradigm” scale to measure support for environmentalism (Dunlap and Van Liere, 1978; Dunlap, 2008; Bernstein and Szuster 2019). While these approaches have offered critical insight to the environmental social sciences, our analysis offers a nuanced assessment of stakeholder preferences by shifting the analytical focus to the cultural meanings of nature for stakeholders, which transcend traditional value orientation scales.

For instance, both of our lake ethics could be interpreted as either “biocentric” or “anthropocentric” in various ways. The Public Good lake ethic privileges human recreation, which suggests an anthropocentric value orientation. On the other hand, though, the human enjoyment of the lake emphasized in this lake ethic is deeply connected to social engagement with the ecosystem itself, especially in the form of sport fishing. As noted, protecting a robust fish population and the ecosystem that supports it is an important goal for the Public Good lake ethic. Meanwhile, given its emphasis on the intrinsic value of lakes’ ecosystems, the Exclusive Resource lake ethic appears to align with a biocentric value orientation. This interpretation, however, misses the socioeconomic context discussed in section 3.5, which shows that interpretations of this intrinsic value are deeply rooted in human-centered concerns like the aesthetic enjoyment of the landscape or lakeside property values.

Approaching the human dimensions of aquatic invasive species management from the standpoint of lake ethics allows for an interpretation that includes different ways of valuing nature and thus produces different goals for management, different preferred management methods, etc. Moreover, though two distinct lake ethics emerged in our analysis, this does not foreclose the possibility of other lake ethics in different contexts, where lakes have distinct cultural meaning and thus distinct sources of value. For instance, the indigenous Ojibwe of the upper Midwest hold the native wild rice (manoomin, or *Zizania palustris*) that grows in the lakes of the region to be sacred (Matson et al., 2021), and the White Earth Band of Ojibwe adopted a tribal ordinance in 2018 recognizing its intrinsic rights (CDER, 2018). Based on the ongoing work

of the authors, there is some concern among Tribal stakeholders that *N. obtusa* may harm wild rice populations, which would likely pose a set of stakeholder concerns stemming from a distinct lake ethic not captured in our data.

More broadly, these findings reflect a long history of research in the environmental social sciences that reveal the importance of how individuals’ and communities’ values shape perceptions of and ultimately their preferred actions related to natural resource management issues (Dentzman et al., 2016; Freudenburg et al., 1995). Socio-cultural context likely played a role in the presence of these ethics. As noted, some respondents explicitly referenced their community’s socio-economic status as a justification. Beyond this, we expect that the significant cultural affiliation that residents of Minnesota have with lakes—“Land of 10,000 lakes”—in part contributed to our Minnesota interviewees’ greater likelihood of holding the Exclusive Resource ethic. While our data cannot speak specifically to this influence, it is frequently observed that contextual social processes, such as widespread cultural messaging, shape individual’s construction of meaning and concerns related to natural resource issues (Houser et al., 2020; Hendrickson and James, 2005).

#### 4.1. Limitations

Our study was designed to elicit the differences in values, preferences, and actions related to *N. obtusa* management across stakeholder types and states. However, our data collection was disrupted by the COVID-19 pandemic. In March 2020, we transitioned from conducting in-person interviews where participants were able to show us parts of their lake communities and where we were able to recruit potential interviewees on-site at our lakes, to remote interviews that lacked these features. Because of this, we were not able to interview as many members of the general public as we had initially planned (see Table 2) and we recognize that some of our findings may be impacted by this. To address this, we recruited members of recreational fishing communities from online forums (via Reddit online communities for midwestern fishing) but we were still unable to interview members of the public in Indiana.

We also recognize that there are critical dimensions of lake ethics that we are not identifying in this study, notably those of Native American stakeholders, many of whom are actively involved in *N. obtusa* management in and around our study lakes. We intentionally did not include those perspectives in this study because we have ongoing social-ecological work with these communities that is being implemented from a co-production framework. We will actively pursue analyzing the human dimensions of *N. obtusa* management and lake ethics with these communities in the future and we are striving to ensure these groups’ perspectives and knowledge are evaluated and presented in accordance with their community values and preferences.

#### 5. Conclusion: towards value-based aquatic invasive species management

Decisions about how to address *N. obtusa* in lake communities in our study were informed by a complex set of interacting values and preferences that resulted in two distinct lake ethics—the Public Good and the Exclusive Resource ethics. Looking to the future, a logical next question is: how can this knowledge of lake ethics inform practical management efforts on-the-ground? The first step is recognizing that our findings indicate that decisions related to *N. obtusa* are likely going to vary across communities based on their underlying lake ethic. Communities that are represented by the public good lake ethic are more likely to respond to approaches that minimize the nuisance presence of *N. obtusa* and recognize the value of the lake community for recreation and human enjoyment. Communities that are represented by the exclusive resource lake ethic are more likely to respond to approaches that seek to remove and minimize *N. obtusa* in recognition of the value of other non-human

aquatic species and the lake community as a whole. These different perspectives may also influence the types of information stakeholders find most important to inform their decision-making, and thus the information that would be most useful for researchers to provide. For example, individuals with the Exclusive Resource lake ethic would likely find results from studies of the interactions between invaders and native communities or habitat suitability models (e.g., Muthukrishnan et al., 2018a, Muthukrishnan et al., 2018b) most useful, while those with the Public Good ethic may be more interested in the efficacy and cost-benefit analyses of different management strategies (e.g., Glisson et al., 2018). That specific individuals and communities have different conceptions of their resources and how to manage them aligns well with past work (Reimer et al., 2014). It also indicates the need for more place and problem specific social science research to generate this knowledge and thereby enable more tailored and effective public engagement around aquatic invasive species and natural resource issues generally. Acknowledging these differences in fundamental values can help managers, especially higher-level, top-down managers, understand why community preferences and approaches to management may differ and why communities may be resistant or open to specific strategies (Carter et al., 2021).

### CRedit authorship contribution statement

**Andrew McCumber:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Abigail Sullivan:** Conceptualization, Methodology, Investigation, Writing – original draft, Supervision, Funding acquisition, Writing – review & editing. **Matthew Houser:** Conceptualization, Funding acquisition, Writing – review & editing. **Ranjan Muthukrishnan:** Conceptualization, Funding acquisition, Writing – review & editing.

### Declaration of Competing Interest

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

### Data Availability

The data that has been used is confidential.

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### Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at [doi:10.1016/j.envsci.2022.10.022](https://doi.org/10.1016/j.envsci.2022.10.022).

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