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Recreational users' perceptions of coastal water quality in Rhode Island (USA): Implications for policy development and management

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ABSTRACT

Stakeholders' understanding of water quality influences how they approach water policy problems and their support for potential solutions. This study explores how resource policy in the United States accounts for different water quality meanings held by recreational users. In-person surveys were conducted along the shoreline in Rhode Island (USA) to examine how recreational users make sense of coastal water quality. Findings indicate that recreational users' understanding of water quality is constructed from an array of environmental conditions (e.g., chl *a*, phosphates) and attitudinal factors (e.g., perceived problems associated with sewage, algae, or trash), and the meanings ascribed to water quality extend beyond the biophysical indicators typically employed by water resource managers. Potential management strategies based on these findings include expanding current definitions of water quality and monitoring a broader suite of factors, conducting research that captures nuanced meanings of water quality held by different users, and developing outreach programs that clarify the potential impacts of water quality components on human health and well-being.

1. Introduction

Understanding and acknowledging different views is a critical first step in developing effective policy (Birkland, 2001; Dye, 2005); however, environmental policy processes rarely account for differences in knowledge, beliefs, and understanding across stakeholders, leading to increased conflict and ineffective policy (Adams et al., 2003; Bardsley and Edwards-Jones, 2007). The water quality policy process is no exception. As recent studies suggest, stakeholders, like rural landholders, scientists, foresters, managers, and fishers, ascribe different meanings to water quality and water allocation (e.g., Paolisso and Chambers, 2001; Lukasiewicz et al., 2013; Brisson et al., 2017). Stakeholders' knowledge, understanding, and relationships with water influence how they approach water policy problems and their support for potential solutions. In this study, we explore water quality policy in the United States and how it accounts for different meanings held by various stakeholders. We investigate the water quality policies in place for Rhode Island waters in context of the perceptions of marine recreationalists using an intercept survey at coastal public access sites.

1.1. U.S. water quality policy

In the United States, the Federal Water Pollution Control Act, amended in 1972 as the Clean Water Act (CWA), is designed to protect U.S. coastal and inland waters from deleterious anthropogenic influences. The stated objective of the CWA is to restore and maintain "the chemical, physical, and biological integrity of the Nation's waters" (§ 101a), a clause that has come to be abbreviated as *ecological integrity*. To achieve these objectives, the CWA mandates the elimination of pollutant discharge to protect wildlife and recreation (§ 101a2), often referred to as the "fishable/swimmable" goal. Water quality is characterized in the CWA by the relative abundance of pollutants, which are defined, with certain exceptions, as "dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal, and agricultural waste discharged into water" (§ 502).

Although the U.S. Congress has charged the Environmental Protection Agency (EPA) with administering the CWA, the law gives broad authority to interpret and enforce its provisions to state governments. Of particular import is the state's responsibility to designate official uses of

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navigable waters that in turn determine the water quality standards for a given water body (§ 303). In making these designations, states must assess to what extent a water body has met the fishable/swimmable goal that was to have been met by July 1, 1983. Though that date has long since passed, states must periodically submit a list of waters that are impaired for assigned use designations to the EPA for review, with the aim of meeting this goal at some future time.

In addition to achieving the fishable/swimmable goal, the CWA also mandates the development of water quality criteria (WQC) that serve to protect “the public health and welfare” (§ 303c2a) and support research in pursuit of these goals. The CWA requires that the EPA develop WQC based on the latest scientific knowledge of sources and distributions of pollutants and pollutant byproducts, and of their effects on the health and welfare of the public and on aquatic and marine organisms and ecosystems (§ 304a1). These WQC, consisting of various standards and methods intended to assist states in managing water resources, are not directives but recommendations that state governments may employ or use as guidance in crafting their own criteria. For readily quantifiable pollutants, like chemical or biological stressors, the EPA offers an array of explicit methodologies and standards for allowable concentrations or thresholds. This focus on easily quantifiable water quality attributes necessarily excludes many of the criteria that are of interest to stakeholders other than natural scientists. For pollutants not so readily measurable or to supplement numerical criteria, the EPA offers limited guidance, leaving states to develop “narrative criteria,” which are qualitative statements that describe desired water quality goals according to designated uses. Selecting which criteria to measure or describe is a policy choice.

Water quality policy in the United States has been criticized for failing to account for different perspectives (e.g., Freitag, 2014; Buchwalter et al., 2017; Votruba and Corman, 2020). Critics have recently claimed that the national policy for water quality management focuses too heavily on chemical criteria and would benefit from increased attention to other features (Burton, 2017). This debate on WQC highlights the constructed nature of water quality; that is, that water quality is defined in different ways by different groups like managers, scientists, and the general public.

Scientific studies informing water quality policy have tended to define water quality through a lens of natural science (Boehm et al., 2009; Bierman et al., 2011; Karydis and Kitsiou, 2013), for example, measured chemical and biological properties of water; however, there have been some studies over the years that have focused on public perceptions and understanding of water quality and its management.

1.2. Public understanding of water quality

The majority of studies on water quality perceptions suggest that public understanding is based on sensory input and belief (David, 1971; West, 1989; Paolisso, 2002). Commonly cited influences on public perceptions of water quality include optical water properties, relative abundances of algae and debris, odor, and proximity to sewage or sewage treatment; these are often correlated or conflated phenomena and not necessarily discrete problems (Flotemersch and Aho, 2021). Optical water quality, a combination of color and clarity, results from biogeochemical factors that influence the appearance of water; for example, color saturation may affect water clarity, while suspended particulate composition may affect color (West et al., 2016a). Perceptions of optical properties vary with season, local conditions, depth, and familiarity with a given water body (Smith et al., 1991; House, 1996). Algal abundance, which influences water color and clarity (West et al., 2016a), is also often considered an indicator of poor water quality (Kooyoomjian and Clesceri, 1974), or as constituting poor water quality in its own right (Suplee et al., 2009; West et al., 2016b). Floating debris is likewise seen as either an indicator or as poor water quality itself (Dinius, 1981; Moser, 1984). Los Angeles County residents believed that marine “trash” could make one sick and was a more important source of pollution than sewage or stormwater (Pendleton et al., 2001). Debris apparently originating from sewage (e.g., sanitary items, contraceptives) was found to correlate with low water quality evaluations whether beached (Morgan, 1996) or floating (House, 1996). Proximity to sewage treatment facilities (Morgan et al., 1993; Paolisso, 2002) or the existence of sewage in general are seen as compromising water quality whether or not there are any sensorial manifestations of sewage (David, 1971; Paolisso and Maloney, 2000; Pendleton et al., 2001). Finally, unpleasant odors are frequently cited as indicators of poor water quality; however, studies rarely indicate which odors are considered offensive, and this issue is made more difficult with differing personal tastes and problems inherent in detecting potentially offensive odors (Ditton and Goodale, 1974; Moser, 1984; Tudor and Williams, 2003).

People also understand water quality in terms of its risks to public health. Sensory water quality indicators inform people not just whether recreational water quality meets their recreational expectations, but also whether the water seems safe to be in, on, or nearby. However, people’s ability to make informed risk self-assessments based on perception alone are limited. Debris may be perceived as a risk due to its form or to apparent associations with sewage (Pendleton et al., 2001; Tudor and Williams, 2003), and while odor and optics may serve as indicators of health risk to the public (Strang, 2005, Breen et al., 2018), there is little literature on what associations these sensory phenomena have to risk assessment in the context of perceived water quality. The bulk of recreational water quality studies concerned with risk perception is oriented at pathogens and harmful algal blooms (Codd, 2000; Boehm et al., 2009), potential health threats that are not necessarily apparent to recreationists without the aid of timely communication from resource managers. However, communications from authorities about water quality risks are not always timely, and because water use designations mandate only certain types of testing for a given use, water quality risks may not be assessed, let alone communicated, for a given water body. People often take it for granted that absence of prohibition of an activity (e.g., fishing) is a government endorsement of water quality (Sharp, 2012), unaware that states prioritize water quality standards for specific uses, and regulations may be tailored for those uses only, not for general purpose. For example, when fishing prohibitions exist to protect users from toxic hazards, they may not be communicated effectively or understood by users (Pflugh et al., 1999), and when they are understood, restrictions may be disregarded due to food insecurity or to distrust of government (May and Burger, 1996; Marjadi et al., 2021).

The general public also attributes economic value to water quality. Coastal recreational water quality value can be estimated through a number of different methods that often divide people into user and non-user categories. Several studies have demonstrated that various biophysical water quality characteristics such as low nutrient, chlorophyll, or bacterial concentrations have value to water resource users (e.g., Egan et al., 2009; Eggert and Olsson, 2009; Keeler et al., 2012). Other studies investigate the values associated with indirect uses of water, like aesthetic value (e.g., Corrigan et al., 2009), or with non-use values such as existence value where individuals derive some benefit from knowing a good or service exists (Dumas et al., 2005). Sufficient evidence exists to demonstrate that indirect values and non-use values are important to society, although the mechanisms for the relationship between water quality characteristics and how they contribute to value are not always clear (Johnston et al., 2003; Liu et al., 2017).

Studies on public understandings of recreational water quality reveal that they are formed by a combination of several factors including sensory perception, beliefs, risk assessment, and value. While there is some overlap between public and policymaker conceptions of water quality, particularly with regard to public health risks, other public concerns go largely unconsidered. Although a number of studies have examined public perceptions of water quality, most focus on inland freshwater rather than coastal or marine waters, offer respondents preselected elements of water quality to evaluate rather than soliciting narrative descriptions, and fail to consider factors external to water itself that might affect water quality evaluation. We begin to address these gaps by focusing on one particular user group of Narragansett Bay, Rhode Island (USA): coastal recreational users. In particular, this study examines how this group defines water quality and how current management practices align with this understanding.

2. Methods

2.1. Study region

As a tidally-mixed drowned river estuary in the northeast United States spanning parts of Rhode Island and Massachusetts, with a surface area of 147 miles^2 (Raposa, 2009). The Bay's 1700 mile^2 watershed contains nearly 2 million residents in over 100 towns and cities (NBEP, 2017). Narragansett Bay's 560 miles of coastline hosts a variety of recreational activities (e.g., shellfish harvesting, boating, swimming, socializing) (NBEP, 2017). It is surrounded by 22 municipalities with varying levels of urban development, and supports a number of commercial activities (e.g., fishing, shipping).

The highly urbanized upper Bay is dominated by the Providence, Rhode Island, metropolitan area, while sites further south are more often suburban or rural. Characteristics like water clarity, chlorophyll, nutrients, and industrial chemical contaminants differ throughout the Bay (NBEP, 2017). Hypoxia is common and often prolonged in the warmer months, and markedly more acute in the north than the south, with occasional anoxic events that have resulted in faunal mortality, notably in 2003, when a massive fish-kill occurred in a northwestern corner of the Bay (Raposa, 2009; NBEP, 2017). With varying environmental conditions, recreational activities, and levels of residential and urban development, the Narragansett Bay provides an opportunity to explore how people make sense of coastal water quality.

2.2. Data collection

In-person surveys (Supplementary 1) were conducted with recreational users in English and Spanish at 19 public access sites around the Bay (Fig. 1). Convenience sampling was used where every user at the site was invited to participate. Convenience sampling is a useful approach when there is no population list from which to draw a sample (Bernard, 2002). At sites with many people, every 2nd or 3rd person encountered while walking throughout the site was invited to participate. Surveys took place on 24 non-consecutive days in the summer of 2018, and seven non-consecutive days at one additional site (Sabin Point) in the summer of 2019. Days of the week and times of the day were varied to capture a variety of users at each site. Specifically, stratified random sampling was used to select days of the week. Days were stratified by level of use based on prior research in Narragansett Bay (e.g., Dalton et al., 2010), with fewer recreational users expected on mid-week days (Tuesday-Thursday) than weekend and shoulder days (Friday-Monday). In 2018, the team visited four sites per day, so that each site was visited at least once in the morning and once in the afternoon during the summer. In 2019, one site was visited either in the morning or afternoon on midweek and weekend/shoulder days during the summer.

Over the two summers, eight members of the team conducted surveys. Groups of 2-3 team members were present at each site visit. All team members were trained prior to the field work and met regularly with the team throughout the summer. In addition, survey questions were pilot tested with coastal users in Rhode Island to improve the clarity and understanding of the questionnaire.

All survey participants were read the consent form in either Spanish or English and given the opportunity to provide verbal consent. No identifying participant details were collected. Surveys took about 5 to 10 min to complete. This research was approved by the URI Human Subjects Board (IRB #HU1617-187).

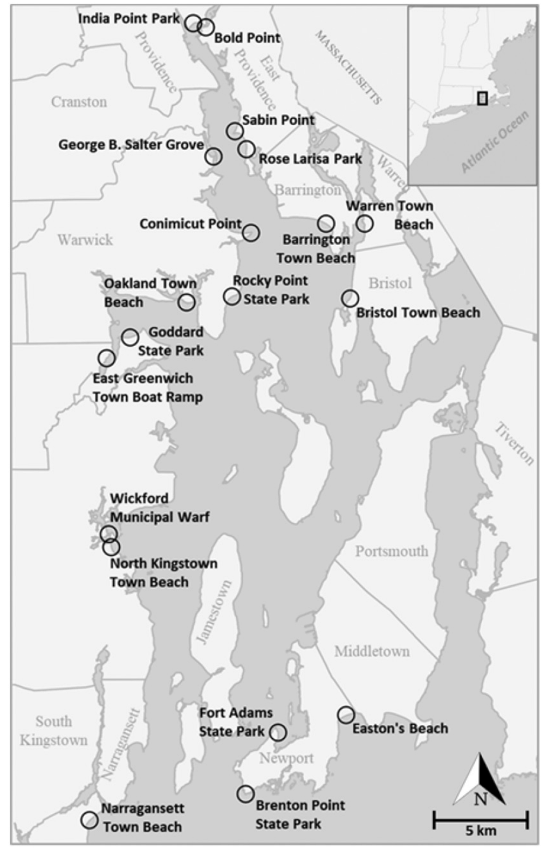

Fig. 1. Narragansett Bay survey sites located in Rhode Island, in northeastern USA (inset). Lighter grey represents land, darker grey represents water. Rhode Island town names are in grey, while open circles with black text represent sites.

2.3. Survey questions

In the survey, respondents were shown a visual water quality scale (Supplementary 1) and asked to rate their assessment of water quality on a scale of 1 = *worst possible quality* to 10 = *best possible quality*. For responses lower than 10, respondents were asked "What would you say are the problems with water quality at this location?" An open-ended format was used to ensure that the potentially wide range of problems people perceive was captured. Responses to this open-ended problem question were recorded verbatim during each interview and coded and categorized by an individual coder using inductive content analysis (Stemler, 2000). This analysis was performed by categorizing words or phrases by similar meaning, connotation, or valence using "emergent coding", i.e., categories were established after initial examination of the responses. Only problems that were mentioned by at least 5% of survey respondents were selected for categorization.

As site conditions have been shown to influence people's perceptions of coastal areas (e.g., Stedman and Hammer, 2006, Vaz et al., 2009), respondents were asked to rate the acceptability of eight different conditions at the site on a scale of 1 = *totally unacceptable* to 10 = *perfectly acceptable*. They rated access to the site, parking availability, site amenities, availability of fish or shellfish for harvesting, crowding, noise, prevalence of litter, and scenery. An index of "site acceptability" was constructed by calculating the unweighted mean of the mean response for each condition. Cronbach's α for this index was 0.642, which falls in an acceptable range (Vaske et al., 2017; Taber, 2018) and captures the broad array of conditions that are applicable to all sites in this study.

To examine linkages between perceptions of water quality and place meanings and attachments (e.g., Stedman, 2003; Andrew et al., 2019), another index, “place attachment,” was constructed by calculating the unweighted mean of responses to three statements: “I am very attached to this place,” “this is a special place for me and my family,” and “no other place can compare to this place,” each rated on a scale of 1 = *strongly disagree* to 5 = *strongly agree*. Cronbach’s α for this index was 0.820.

Respondents were also asked questions about their self-identified relationship to the marine environment (e.g., Davis et al., 2009); self-identification as an environmentalist; and individual demographic characteristics like age, gender, and household income (Table 1).

2.4. Site characteristic data

Characteristics about each site were collected from secondary sources. Median household incomes (MHHI) for a 2-mile radius around each site were calculated from U.S. Census Bureau data (USCB, 2017). Five-year summer (June-Sept) averages for the years 2011-2015 were calculated for the following environmental variables: mean water temperatures for survey dates were obtained from NOAA’s National Data Buoy Center (https://www.ndbc.noaa.gov/); *Enterococcus* values, collected at shoreline and nearshore stations near this study’s sites, were obtained from RIDOH (Sherry Poucher, personal communication) and the Narragansett Bay Commission (NBC, 2020). Chlorophyll *a* (Chl *a*), ammonia (NH_3), and phosphate (PO_4) were collected at nearshore sampling stations within 2 miles of this study’s sites, including stations maintained by the NBC (NBC, 2020), RIDEM’s Narragansett Bay Fixed-Site Monitoring Network (NBFSMN, 2011, 2012, 2013, 2014, 2015), and the University of Rhode Island’s Marine Ecosystem Research Laboratory (Reed and Oviatt, 1976-2019). These environmental variables, *Enterococcus*, Chl *a*, PO_4, and NH_3 are routinely measured water quality attributes that are important for managing public health and ecological integrity and are included in the EPA’s WQC.

Table 1
Individual survey response and site characteristic statistics. Water quality problem responses were coded into absent/present (a/p) categories and ranged from 22.7% to 6.1%. Although gender options were multiple, responses were all binary. Survey response sample sizes varied according to survey completion, while site characteristic sample sizes varied depending on data source availability.

Survey response	Variable type	n	min	max	mean	SE
Water quality	Ordinal scale	638	1	10	6.572	0.076
Macroalgae	Problem (a/p)	634	0	1	0.227	0.017
Pollution	Problem (a/p)	634	0	1	0.175	0.013
Optical WQ	Problem (a/p)	634	0	1	0.162	0.015
Trash/debris	Problem (a/p)	634	0	1	0.115	0.013
No swimming	Problem (a/p)	634	0	1	0.088	0.011
Bacteria/sewage	Problem (a/p)	634	0	1	0.083	0.011
Place beliefs	Problem (a/p)	634	0	1	0.085	0.010
Odor	Problem (a/p)	634	0	1	0.073	0.010
Age	Years	619	18	88	49.409	0.687
HHI	Ordinal scale	531	1	8	5.094	0.093
Gender	Binary (m/f)	628	0	1	0.599	0.020
Place attachment	Index	631	1	5	3.564	0.043
Connectedness	Ordinal scale	628	1	7	5.271	0.065
Environmentalist	Binary (n/y)	626	0	1	0.709	0.018
Site acceptability	Index	634	2.8	10	8.288	0.049

Site characteristic	Unit of measure	n	Min	Max	Mean	SD
Water temp	°C	19	18.5	25.3	22.8	2.3
Enterococcus	(cfu/ 100 ml)	15	34.552	1189.204	258.132	342.773
chl *a*	(μg/L)	16	7.615	27.965	13.979	5.860
NH_3	(μM)	13	0.571	4.745	2.007	1.388
PO_4	(μM)	13	0.404	2.7	0.820	0.402
MHHI	(US $)	19	$57,666	$143,424	$79,714	$20,197

2.5. Data analysis

To better understand how coastal recreational users make sense of water quality along the shoreline of Narragansett Bay, we analyzed how different attitudinal factors, demographic characteristics, and site features influenced perceived water quality ratings. Calculation of descriptive statistics, Spearman’s correlation coefficients, and backward stepwise regression with the water quality rating as the dependent variable, were performed using SPSS 25 (IBM) (Tabachnick et al., 2007). Pairwise deletion was employed to compensate for data gaps in environmental data. Significance for all statistical tests was determined at the commonly accepted 5% level.

To examine how attitudes, demographic characteristics, and site features vary across the sites in the study region, data were averaged for each coastal access site and spatially represented using QGIS 3.10.2.

3. Results

In total, 641 coastal recreational users were surveyed, including 576 in 2018 and 65 more in 2019. Sample sizes at sites ranged from 3 to 88 respondents (Supplementary 2: Table S1). The average age of participants was 49.4 years (SE ± 0.7), with a majority female (381 female, 275 male). Respondents travelled an average of 18.4 miles (SE ± 2.09) to get to survey sites, visiting sites an average of 35.4 (SE ± 3.1) times per year. 43.8% of respondents engaged in activities that involved swimming or wading in survey site waters, with the remainder abstaining from purposive water contact.

Seven of these respondents declined to rate water quality, and so were excluded from analysis. Of the remainder, 46 respondents (7.3%) rated the water quality as 10 (best possible quality), and 80 (12.6%) declined to explain or claimed to have no rationale for their ratings below 10. A further 85 (13.4%) offered rationale that either were not common enough to meet the 5% response threshold for problem categorization or that indicated a lack of understanding of the question. In total, 423 (66.7%) respondents offered rationale that were coded into one or more of 8 categories that emerged from the content analysis of the water quality problems responses (Table 1).

Problem categories that emerged from content analysis included optical water quality, odor, presence of macroalgae/seaweed, sewage/bacteria, trash/debris, pollution (broadly defined), and no swimming, that is, whether a place appeared undesirable or closed for swimming. The final problem category that emerged was place beliefs, a variable that reflects respondents’ beliefs about site-specific conditions that affect water quality. For example, many respondents expressed beliefs that the area had a history or reputation of pollution, that infrastructure like nearby ports or factories reduced water quality, or that hydrodynamic forces in the immediate area were not sufficient to keep the water “clean.”

Table 2
The final model resulting from backward stepwise regression. Predictors are listed in descending order of beta weight.

Predictor	Standardized β coefficient	*t*	p
chl *a*	−0.252	−5.214	<0.001
Macroalgae problems	−0.222	−5.827	<0.001
Optics problems	−0.200	−5.301	<0.001
MHHI	0.184	4.210	<0.001
No swimming problems	−0.169	−4.503	<0.001
Pollution problems	−0.141	−3.739	<0.001
Site acceptability	0.135	3.580	0.001
Bacteria/sewage problems	−0.121	−3.412	0.001
Place belief problems	−0.120	−3.161	0.002
PO_4	−0.112	−2.750	0.007
Odor problems	−0.109	−2.962	0.003
Trash/debris problems	−0.104	−2.864	0.006
Environmentalism	0.074	1.999	0.042

$R = 0.66$, $R^2 = 0.44$, adj. $R^2 = 0.42$, $F = 25.738$ (13, 447), $p < 0.001$

Backward stepwise regression results (Table 2) indicated that 13 of the 22 variables tested were significant contributors to the model, all of which influenced the model only weakly as indicated by their standardized beta coefficients. All of the perceived water quality problems coded from the open-ended responses were statistically significant at the $p < 0.05$ level, as were the biophysical parameters Chl *a* and PO_4, site acceptability, and environmentalist identity.

During the analysis, a high degree of multicollinearity was found between Chl *a*, NH_3, and *Enterococcus* levels. Examination of Spearman correlations (Supplementary 2: Table S2) indicated that very strong relationships ($\rho > 0.94$) between these variables were responsible for this observed collinearity. A site's water quality for one attribute was likely to be of similar quality for the other water quality attributes. *Enterococcus*, a fecal indicator bacterium, was excluded manually from the analysis as a matter of practical significance (Tabachnick et al., 2007; Graham, 2003). Presence/absence of Chl *a*, often used as a proxy for microalgal abundance, is likely more evident sensorially than that of fecal indicator bacteria in marine waters. Additionally, NH_3 was excluded from the model by the software, but neither *Enterococcus* nor NH_3 should be discarded as significant influences. When each of these three dependent variables were included in regression analyses without the other two (all other inputs being equal), statistical significance for each measurement was significant, but when all three were included, diagnostics indicated multicollinearity which resulted in inflated beta coefficients and illogical sign changes. As a result of these considerations, only Chl *a* is reported as an explanatory variable.

When data were examined by site, a spatial gradient in coastal users' perceptions of water quality emerged, with water quality ratings generally lower in the north and higher in the south (Fig. 2). A similar spatial gradient was also observed in mean Chl *a*, NH_3, and *Enterococcus* levels (Fig. 3a), reflecting the differences in the less-developed, seaward southern part of the bay relative to the enclosed, urbanized northern part of the bay. Conversely, MHHI generally increased from north to south, with the notable exception of Barrington Town Beach, which is located in the town with the state's highest MHHI (Fig. 3c). Mean PO_4 distribution was less obviously latitudinal, but still contributed significantly to the model (Fig. 3b).

Perceived water quality problems were more pronounced in upper Narragansett Bay (Fig. 4). A notable exception to this was macroalgae, which was seen as a problem both near the northern end of the Bay, and also on south-facing coasts (Fig. 4a).

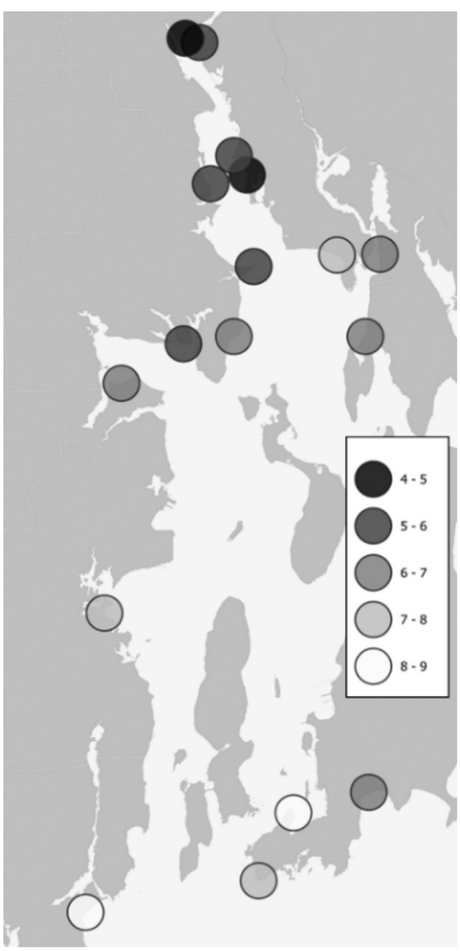

Fig. 2. Perceived water quality ratings on a scale of 1 = worst possible to 10 = best possible. Darker shading indicates lower ratings. Only sites with ≥10 respondents are depicted.

4. Discussion

4.1. Multi-dimensional nature of water quality in Narragansett Bay

Findings from this study of coastal recreational users show that public understanding of water quality in Narragansett Bay is constructed from an array of environmental conditions and attitudinal factors, and the meanings ascribed to water quality extend beyond the biophysical indicators employed by water resource managers. Water quality is a complex construct originating from various social and environmental influences, yet little of this complexity is reflected in the prevailing emphasis in the federal statute and the implementing regulations on biophysical water characteristics.

Our results indicate that, while the water characteristics focused on by policy makers and natural resource managers in Rhode Island capture some meanings ascribed to water quality by recreationists, they do not account for personal observations and beliefs, cultural values, and quality of life concerns, many of which contribute to public understanding of water quality problems (Paolisso, 2002; Cox et al., 2006). In our study, the composite nature of the water quality construct is demonstrated by the influence of multiple factors, each of which individually explain little variance in water quality ratings, but explain a substantial amount of variance when combined.

Chl *a*, typically used as a proxy for microalgal abundance, had the greatest influence on coastal users' perceptions of water quality, though only marginally. Chl *a*, *Enterococcus*, and NH_3, biophysical characteristics that are commonly associated with effluent (Bouvy et al., 2008; Wurtsbaugh et al., 2019), were strongly correlated (Supplementary 2: Table S2). This suggests that the influence of chlorophyll in the model may have more to do with factors associated with wastewater than with microalgae per se. Sensory manifestations of algal blooms may include optical or odor cues, but neither of these perceived water quality problems were significantly correlated with chlorophyll *a*verages. It is not clear why effluent would be an influence on perceived water quality, as problems associated even tangentially with effluent such as "no swimming" or "bacteria/sewage" were at best only weakly correlated with effluent-related biophysical parameters. Local knowledge of biophysical water quality conditions was not assessed.

Macroalgae were considered the most influential of all perceived water quality problems, suggesting that coastal recreational users believe that the presence of macroalgae along their coastal waterways is a problem. However, according to the criteria established under the CWA, macroalgae may or may not indicate a water quality problem related to water pollution. For instance, high nutrient levels in the upper Narragansett Bay often result in ulvoid blooms (Thornber et al., 2017), but in the lower Bay where nutrient concentrations are relatively low, excessive drift macrophyte and beach wrack consists mainly of rhodophytes that appear to originate on nearshore reefs that are unlikely to be the result of anthropogenic eutrophication (Carol Thornber, personal communication). Under the CWA, algae blooms in the upper Bay would be related to water quality problems, while in the lower Bay,

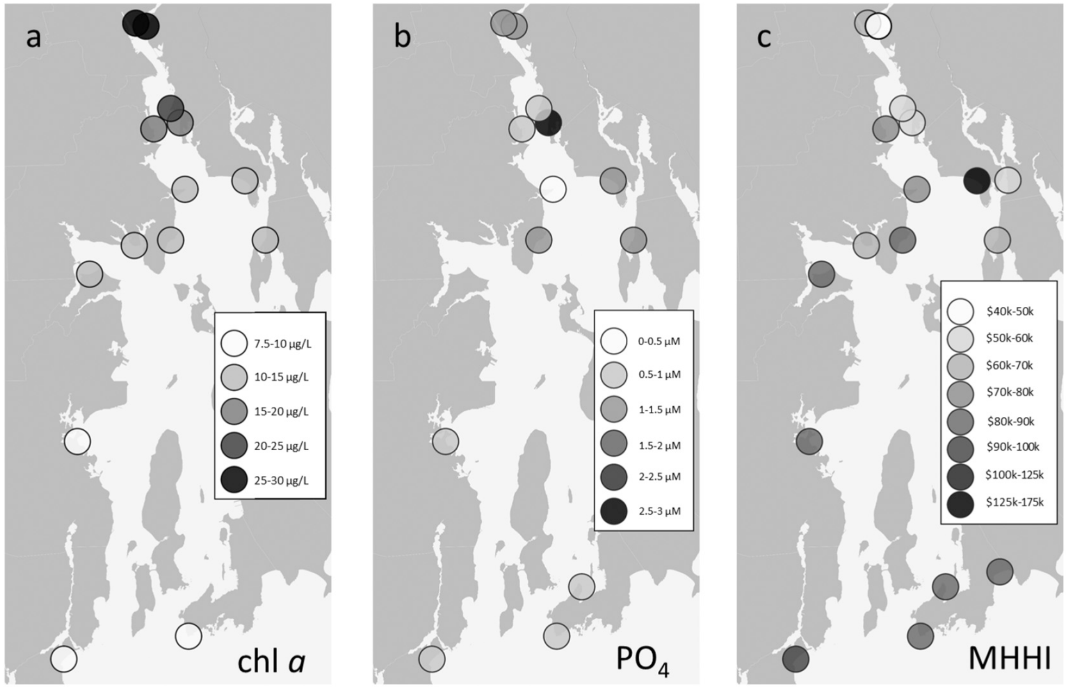

Fig. 3. Site characteristics that significantly contribute to the model at $p < 0.05$. Only sites with sample sizes ≥10 are depicted.

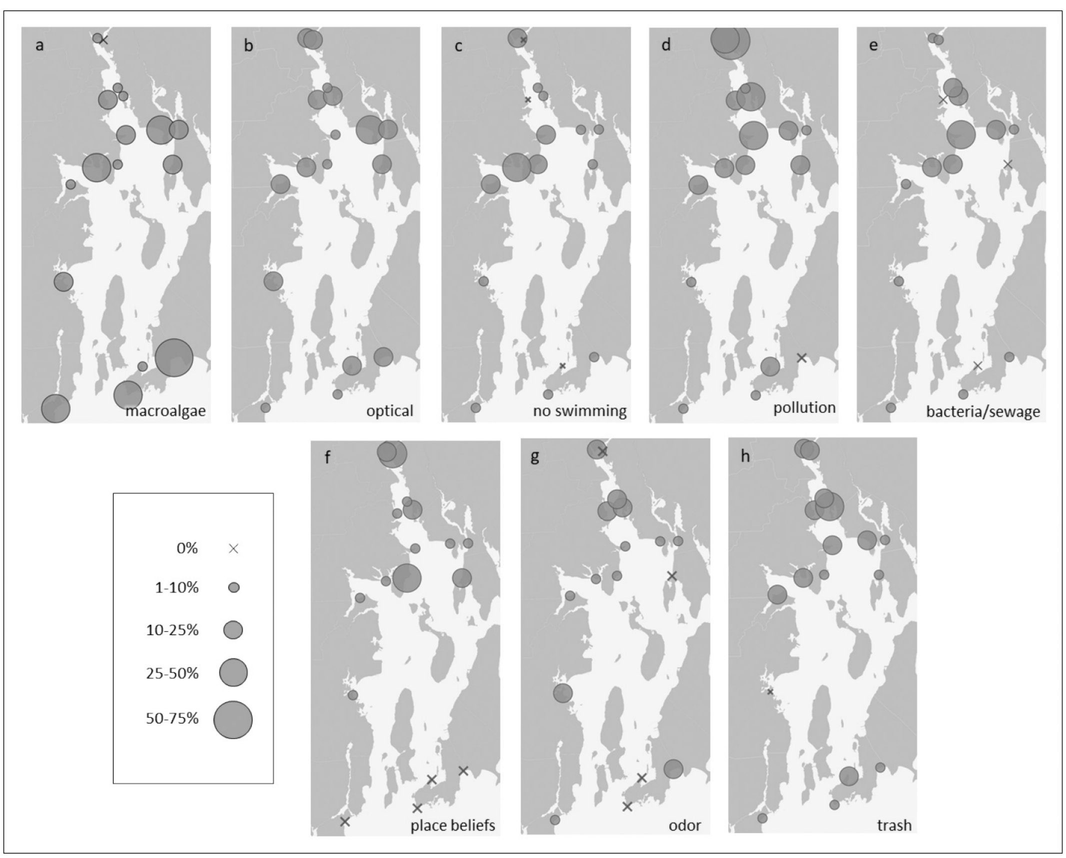

Fig. 4. Water quality problems. Circle size indicates the percentage of respondents reporting the given problem at each site. All have response rates of >5% and all significantly contribute to the model at $p < 0.05$. Only sites with ≥10 respondents are depicted.

macrophyte proliferations would not necessarily be considered a water quality problem. Yet, many coastal recreational users would feel that water quality problems exist in both places. Although macrophyte accumulations do not necessarily indicate that biophysical water quality is problematic from public health or ecological perspectives, it can be a problem for resource users, potentially affecting their experience at a site and leading to shifts in behavior associated with that site (Aretano et al., 2017). If a management goal is to address water quality problems in the public interest, it would be important to consider algae and its social and ecological impacts when addressing water quality problems. If algae are not indicative of pollution, this could be an important opportunity for educational awareness about its role in the ecosystem.

Optical water quality was also an influential predictor of perceived water quality. Like algal abundance, alterations in water clarity or color are not necessarily indicative of public health or ecological concerns, as they may result from naturally occurring sedimentation, seasonal changes in biochemistry or algal abundance, or decomposing wrack. Regardless of actual biophysical impacts, a large body of literature, in addition to the findings of this study, indicate that people commonly associate water optics with pollution and public and environmental health risks (Gooch and Rigano, 2010; West et al., 2016a; Jones et al., 2018).

The MHHI, site acceptability, and self-identification as an environmentalist were the only positive predictors of water quality rating, though the latter was only marginally significant and not correlated with any other significant predictors (Supplementary 2: Table S2). The MHHI and site acceptability were weakly correlated, which may be indicative of the fact that southerly sites, which are for the most part located in more affluent communities than those in the northern Bay, afford visitors more desirable amenities and maintenance, or it may reflect perceptions by site visitors that more affluent neighborhoods are associated with cleaner water. A case in point of the latter possibility is Barrington Town Beach, located in the state's community with the highest median income (USCB, 2017), and though the Town Beach's biophysical water quality indicator levels are comparable or worse than other upper Bay sites, perceived water quality is higher than others in the area.

Both place belief and "pollution" perceptions were mainly confined to the northern end of the Bay where both historic and present-day shipping and port infrastructure are more concentrated and evident than in the south. The biophysical measurements of water also indicate the northern end of the bay is more degraded. Place belief responses often referred to beliefs that the northern reaches of the Bay were "too upper Bay," as one Warren Town Beach respondent put it. The Providence River, the primary river forming the head of the bay, has a long history of industrialization and high population density that have resulted in high levels of chemical and biological pollutant concentrations (NBEP, 2017). While pollutant discharge has largely been mitigated due to wastewater infrastructure improvements, several problems remain, and water treatment challenges have received a lot of media attention over the years that likely influence public perceptions of the River's water quality (NBEP, 2017). Most respondents who used words like "pollution," "dirty," or "contaminated" did not specify what they thought the pollutant was or where it came from. Other studies have found that stakeholders often believe water quality is compromised without being able to identify a source (Paolisso, 2002; Freitag, 2014). Some of the factors related to water quality are at least partially being addressed by state and local management. For example, in Narragansett Bay, nutrient reduction efforts implemented by Rhode Island's Department of Environmental Management (RIDEM) have led to marked improvements in optical water quality resulting in decreased ambient chlorophyll concentrations and hypoxic conditions. (Oviatt et al., 2017). On the other hand, despite longstanding efforts by state management authorities to mitigate fecal indicator bacteria inputs, which likely influence perceived swimmability and bacteria/sewage, concentrations remain high in the upper reaches of the Bay (RIDEM, 2021). Other perceived problems, like odor and trash, do not appear to be addressed by current management efforts.

4.2. Managing multiple dimensions of water quality

As with all policy problems, stakeholders view water quality policy problems in different ways. In general, water resource managers have worked toward supporting the existing paradigm put forth in the CWA that water quality is defined by anthropogenic pollutants, largely failing to consider how it is perceived by the public that water quality policy is designed to serve. Our findings suggest that other factors not anticipated by the CWA are also important to how people think about water quality. These factors are important because they influence how citizens think about water quality policy problems and their solutions and how water quality policies influence human behavior and trust in governance. Additionally, perceptions of water quality likely influence site choice and behaviors at a site (Kooyoomjian and Clesceri, 1974; Ravenscroft and Church, 2011). Managers need to appreciate the socially constructed nature of water quality, which demonstrably goes beyond biophysical factors or even sensory perceptions. Assessment of water quality by the public is yet more complicated, and includes geospatial (Moser, 1984), cultural (Paolisso, 2002), and demographic (Eggert and Olsson, 2009) characteristics of the people that determine what water quality means to them.

The CWA explicitly addresses the need for protection and enhancement of not only environmental water quality, but also "the public health and welfare." There is clear emphasis on public health, particularly for recreationists, but other aspects of human welfare are poorly considered, not just in the CWA but in state implementation of the CWA. Coastal water quality influences human wellbeing not just to people who get in or on the water, but also to those who experience it sensorially even when indirectly (Larson and Stone-Jovicich, 2011). Public perception should be a priority for coastal managers with the aim of improving wellbeing and to more fully address CWA objectives.

Although human and environmental health are clearly important to people, data collection and management efforts are limited by budgets, legislation, and institutional biases. Effort should be expended to monitor and address water quality issues that people are actually concerned about, in addition to those that are traditionally monitored (Karydis and Kitsiou, 2013). Integrating stakeholder water quality meanings, and importantly, communicating that understanding, could lead to more effective policy, for example, by helping policymakers address public water resource concerns or by helping the public understand management foci.

4.3. Incorporating multiple dimensions of water quality into coastal management in Rhode Island

There are a number of ways in which policy could better incorporate public meanings of water quality into coastal management. In addition to restoring and maintaining ecological integrity, the CWA charges states with protection of "the public health and welfare", leaving state governments to determine what that means. In Rhode Island, RIDEM has been tasked with designating uses for navigable water bodies, instituting water quality standards, and monitoring conditions, except for pathogenic conditions which are monitored by the state's Department of Health (RIDOH) (RIDEM, 2018). Rhode Island's Water Quality Regulations (RIWQR, 2019) are oriented specifically at pathogenic human health concerns but lack substantive guidance on other elements of public health and welfare. Many of the listed impairments for Rhode Island waters cover uses for swimming or navigation and may not cover the impacts to recreational users who do not swim, wade, boat, or fish, despite their large number of coastal visits and related economic contributions (Kosaka and Steinback, 2018). As our findings suggest, however, water quality features that do not directly affect public health (e.g., algae, trash) might influence how the public conceives of water quality management problems, which can affect how they interact with coastal waters and their eventual support for (or opposition to) water quality policy measures.

One way that RIDEM has attempted to address this oversight is by developing a set of narrative criteria to supplement biophysical measures and maintain "minimum water quality general criteria and aesthetics" (RIDEM, 2018). These qualitative descriptions or statements are recorded during biennial assessments (RIDEM, 2014) pursuant to the RIWQR requirement that water be free of pollutants that result in disagreeable environmental conditions or accumulations (RIWQR § 1.10.2). Currently, no procedures are prescribed for measuring these disagreeable conditions, but narrative criteria provide an opportunity to account for a diverse set of water quality conditions that are important to stakeholders, like coastal recreational users.

Narrative criteria are a place in the existing legislation that could be more deliberately designed, where social meanings and water quality concerns like those revealed by this study could be more expressly addressed. Some water quality attributes, like the RIWQR requirement that coastal waters have "good aesthetic value," are better suited for assessment through a narrative criteria approach. The content analysis revealed several problem categories that could be integrated into these criteria, such as odor and presence of trash/debris.

Another way to integrate multiple dimensions of water quality into management is through the CWA requirement that states establish total maximum daily loads (TMDL) for pollutants (§303 d1C). Typically, TMDLs are established only for biological and chemical pollutants, presumably because their measurement is relatively straightforward. However, this approach may be applicable to other dimensions of water quality problems as well. RIWQR states that biophysical pollutants, including solid refuse, are not allowable in "such amounts that would impair any usages." It is not clear that any state actions are taken to monitor or remove floating or beach cast debris; these mitigation activities are often relegated to volunteer groups or private landowners. California and Maryland are among the few states with policies governing marine trash pollution using TMDLs rather than subjective and often opaque narrative evaluations (State of California Water Board, 2021; Maryland Department of the Environment, 2021).

An additional way of capturing the complex nature of water quality in monitoring and management is through water quality indices (WQI). Many nations and several U.S. states have developed their own WQI that are designed to reduce various constituent elements of water quality into a single value or set of values that communicate environmental pollution levels to the public, similar to the EPA's Air Quality Index (AQI). Unlike the AQI, the US EPA has not adopted a definitive index for water quality, and states have taken very different approaches to constructing WQI (Lumb et al., 2011; McCarty, 2018). While there has been little agreement on best practices for calculating these indices, the overwhelming majority of both enacted and proposed WQI consider only biophysical measurements (Lumb et al., 2011), despite longstanding criticisms of defining and managing water quality using only this approach (David, 1971; West, 1989; Lee and Lee, 2015). To increase the effectiveness of WQIs, managers could integrate biophysical measures, like levels of pollutants prioritized by the EPA (40 CFR Part 423, Appendix A), with local knowledge, perceptions, and expectations, which could happen locally through narrative criteria, establishment of other social metrics of perceptions, or through citizen science efforts (e.g., Dosemagen and Parker, 2019). Finally, environmental education efforts could supplement management actions. Perceived or actual water quality problems that are ecological rather than anthropogenic in nature have been termed "ecosystem disservices" (Zeide, 1998). These disservices may influence attitudes and behavior as much or more than the concept of ecosystem services, (i.e., perceived or actual ecosystem benefits), but have not been accorded the management attention their influence warrants (Blanco et al., 2019). Much of the algae, both micro and macro, that respondents remonstrated against in this study are not necessarily categorized as pollutants. Outreach, education, and continued research into algal perceptions could be conducted to help people understand that while they might not like algae, they are not necessarily harmful or a sign of pollution. This is particularly true of unprotected coastal areas where storm cast wrack, upwelling or naturally occurring nutrient cycling result in sensorially evident algal accumulations.

Results from this study are useful for explaining public understandings of water quality, but it is worthwhile to note a few limitations of the approach. Since surveys were conducted in person at the access sites, only those who accessed and used a site were included in the sample. Recreational users who choose not to go to a site because they do not find conditions, like parking, access, and water quality, acceptable were likely not included in the sample, potentially leading to bias in the ratings of conditions. Surveying coastal residents away from coastal sites may provide more comprehensive insights into what factors most influence water quality perceptions. Also, water quality perceptions are based on a scale and (typically) short follow-up responses. Encouraging more comprehensive narrative responses would have provided additional insights into how users conceive of different dimensions of water quality.

5. Conclusion

Findings from this study of coastal recreational users in Narragansett Bay highlight the complex nature of water quality. Water quality has multiple meanings, and these meanings affect how people think about and interact with water resources. Policy makers and managers should consider what water quality means to the public when making management decisions to increase safety for recreationists, identify stakeholder engagement needs, and increase management options. The findings from this study highlight some of the meanings held by recreational users. For instance, the responses in this survey provide evidence that macroalgal accumulations may be a social nuisance, though perhaps not an ecological one. Management strategies could entail expanding current definitions of water quality and conducting monitoring on a broader suite of factors, conducting qualitative research to elicit more in-depth insights into coastal residents' perceptions of water quality, and developing outreach programs that clarify the potential impacts of water quality components like algae, chlorophyll *a*, or nutrients on human health and well-being.

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CRediT authorship contribution statement

Ken Hamel: Methodology, Formal analysis, Data curation, Writing – original draft, Visualization. **Katherine Lacasse:** Conceptualization, Methodology, Investigation, Writing – review & editing. **Tracey Dalton:** Conceptualization, Methodology, Investigation, Writing – review & editing, Supervision, Project administration.

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.

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