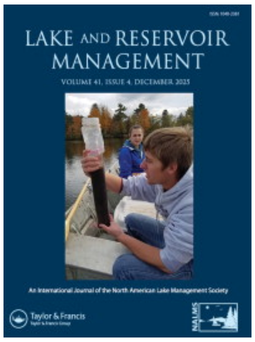

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Public awareness and visual water quality thresholds at a bloom-prone urban lake (Utah Lake, Utah, USA)

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ABSTRACT

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Most recreationists at Utah Lake do not make decisions about when and how to recreate based on chlorophyll *a* (chl-a) concentrations, highlighting the need for more visible and targeted public communication about water quality. This study evaluated the extent to which recreationists and nearby residents were aware of water quality issues at Utah Lake and whether specific aesthetic thresholds—particularly related to chl-*a* and turbidity—influenced perceptions of recreational suitability. Two surveys were conducted in 2022. An intercept survey of 290 active recreationists was administered at various access points around the lake, and a mail survey was distributed to a stratified random sample of 541 households in Utah and Salt Lake Counties. Respondents evaluated images representing different levels of chl-*a* and turbidity and rated the water's suitability for swimming, boating, fishing, fish consumption, and near-water activities. The analysis suggests turbidity, not chl-*a*, may be a more noticeable visual cue shaping perceptions of recreation suitability; however, neither appears to provide a consistent optical proxy for water quality. Additionally, despite recent harmful algal blooms, 35.2% of those in the on-site sample and 48.8% of those in the resident sample reported no awareness of water quality issues at the lake. Together, these findings suggest resource managers should not assume the public understands or recognizes water quality hazards without direct or more targeted communication. Resource managers should consider deploying a broader array of communication tools, including digital alerts, more signage at trailheads and parking areas, and public outreach to support safe, informed recreation and enhance water quality management.

KEYWORDS

chlorophyll *a*; harmful algal blooms; public awareness; recreation management; risk communication; turbidity; water quality perception

Utah Lake, one of the largest freshwater lakes in the western United States, is a critical recreational and ecological resource for communities along the Wasatch Front. It supports a wide range of public uses—from fishing and boating to shoreline picnicking and wildlife viewing. However, persistent water quality challenges, particularly the increasing frequency of harmful algal blooms (HABs), have led to temporary closures and health advisories. These interruptions have not only raised concerns about ecological health and public safety but also potentially altered public perceptions of the lake's suitability for recreation.

Across the United States, growing attention has been paid to how water quality is perceived by the recreating public, especially at lakes susceptible to algal blooms. Numerous studies have shown that people rely heavily on visual cues—such as water clarity, greenness, or scums—when judging whether a waterbody is safe or appealing for recreation (West et al. 2016a, Angradi et al. 2018, Votruba and Corman 2020). These visual perceptions often translate into "perceptual thresholds," where water is deemed unacceptable for recreation once specific visual markers (e.g., turbidity, algal density) surpass an individual's tolerance level (Gibson et al. 2000, West et al. 2016b). Chlorophyll *a* (chl-*a*) is a widely used proxy for algal biomass in nutrient criteria development (Heiskary and Walker 1988), but its value as an indicator of public health risk is limited. Elevated chl-*a* levels may signal algal growth, yet they do not necessarily indicate the presence of harmful cyanobacteria or the toxins they may produce. Serious health effects—including gastrointestinal illness, respiratory distress, and liver damage—have been linked

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to cyanotoxin exposure, not to algal biomass per se (Chorus and Testai 2021). Nevertheless, because visual cues associated with chl-*a* concentrations are often believed to strongly influence public perception of water quality, user perception surveys have played a key role in informing the development of numeric nutrient criteria for recreational waters across the United States.

User perception surveys used to guide the development of numeric nutrient criteria have demonstrated lake users can often identify aesthetic degradation when algal concentrations reach 15–20 μg/L of chl-*a* (Smeltzer and Heiskary 1990, Hoyer et al. 2004). However, perception thresholds can be more difficult to isolate in optically complex lakes like Utah Lake, where visual clarity is influenced by both suspended sediments and algal biomass (Kishbaugh 1994). In such systems—especially those with calcareous or dystrophic characteristics—non-algal turbidity or natural color can obscure algal-related changes in appearance, producing "brownness" or "yellowness" that complicate user judgements. Furthermore, growing evidence suggests public awareness of HAB-related health risks may be incomplete, particularly when signs and advisories are poorly distributed or not clearly visible (Hardy et al. 2016, Jacobi et al. 2024, Jones et al. 2024).

Building on this literature, the current study extends existing methodologies by using a controlled image-based survey design to examine how recreationists perceive the water quality at Utah Lake. While prior research—including the work of Kishbaugh (1994) and Hoyer et al. (2004)—has paired on-site visitor surveys with in situ water quality sampling to assess recreational suitability, this study uses a standardized set of water quality images to elicit respondent evaluations. This approach helped minimize measurement error and controlled for potentially confounding variables such as crowding, shoreline aesthetics, or weather conditions on the day of survey administration. By decoupling perceptual assessments from immediate environmental context, this methodology allowed for more consistent cross-user comparisons and clearer isolation of visual thresholds related to chl-*a* concentrations and turbidity.

This research contributes to a growing body of evidence related to the role visual water quality plays in shaping recreation behavior. By identifying the cues that most influence public perception—and gauging the public's current level of awareness—this study offers practical insights for improving lake managers' risk communication, water quality messaging, and recreation management at urban lakes like Utah Lake.

Materials and methods

Study area

Utah Lake is a large, shallow, and slightly saline (~900 mg/L of dissolved solids) freshwater lake located in central Utah, adjacent to the rapidly growing Provo–Orem metropolitan area (Merritt 2017). Spanning approximately 380 km^2 with a mean depth of less than 3 m, the lake is highly susceptible to wind-driven sediment resuspension and internal nutrient cycling, both of which can significantly alter the visual appearance of the water. These characteristics, along with the lake's naturally high turbidity and seasonal algal blooms, make it an ideal setting to study how optical water quality indicators influence public perceptions of recreational suitability.

Utah Lake's hydrology is shaped by both natural and anthropogenic forces. While the lake's only surface outflow is the Jordan River, which flows north into the Great Salt Lake, more than half of its annual water loss occurs *via* evaporation. This high evaporative loss leads to seasonal increases in salinity and nutrient concentrations, commonly driving water color from the more typical milky grey-brown to a grey-brown-green in the summer (Braegger 2016, Merritt 2017).

Since 2019, the Utah County Health Department, in partnership with the Utah Lake Authority and the Utah Division of Water Quality, has installed permanent educational HAB warning signs at popular access points (Supplemental Material). These durable signs feature images and clear bullet points alerting visitors to indicators of HABs—green "pea soup," surface scums, streaks, or footprints—and direct them to resources like www.habs.utah.gov. When blooms are detected, temporary advisory signs are added or updated to reflect health watches, warnings, or danger levels, with specific instructions to avoid swimming, not boat in scummy areas, keep pets away, and thoroughly clean fish. These onsite postings are complemented by a live Division of Water Quality dashboard and hotline for up-to-date water quality conditions.

Scoping

This study followed the U.S. Environmental Protection Agency's (EPA) recommended 4-step process for developing user perception surveys to inform water quality management: scoping, survey design, data collection, and analysis (Environmental Protection Agency 2021). We conducted a scoping process to identify the types of information that would be most useful to agencies, user groups, and nonprofit organizations involved in managing Utah Lake and communicating water quality risks. Between December 2021 and April 2022, the research team conducted 5 semistructured interviews with a total of 15 members of the Utah Lake Water Quality Study Steering Committee. The objective of the interviews was to identify key questions and themes for inclusion in the user perception survey.

Interviews were guided by a standardized script (Supplemental Material) and conducted with the assistance of a professional facilitator. Notes were taken by both the facilitator and the research team and synthesized into a "key themes" document, which was reviewed and revised collaboratively. We shared the finalized document with the Steering Committee for verification and clarification. All scoping protocols were approved by the Utah State University Institutional Review Board (IRB #12630).

Survey design

Survey questions were informed by prior literature on public perceptions of water quality (Canter et al. 1992, Brody et al. 2004, Hu and Morton 2011, Flint et al. 2017, Barnett et al. 2018) and refined through interviews with members of the Utah Lake Water Quality Study Steering Committee. The final survey instrument (Supplemental Material), reviewed by the Utah Division of Water Quality, included 5 sections: (1) trip characteristics (trip frequency, Utah Lake use history, activities participated in); (2) desirability of water conditions using paired images; (3) perceptions of long-term water quality trends; (4) experience with water quality issues; and (5) sociodemographic characteristics. Additional items captured concerns over specific contaminants, adaptive behaviors, and perceived changes in water quality over time; responses to these items are reported in the Supplemental Material.

Visual assessment of water quality

To assess thresholds in perceived desirability, the survey showed respondents photographs of Utah Lake taken by the Utah Division of Water Quality between June and September 2021 (Fig. 1). Photographs were paired with in situ water quality data, including chl-*a*, turbidity, and other parameters not used in the present analysis. Qualitative feedback received during pilot testing indicated images of sampled water in beakers reduced perceived desirability, even at low chl-*a* levels, likely due to unrealistic comparisons to drinking-water clarity. Therefore, the final image set included only open-water and shoreline landscape photos, with and without a white object in the foreground for reference. The use of the pure white object allowed us to standardize lighting and color conditions across images (using Adobe Lightroom) in an effort to provide a common visual anchor for comparative judgements of water color and clarity (see Palmer and Hoffman 2001).

We selected 5 photos each for shoreline and open water settings, corresponding to low (<10 µg/L) to very high (>250 µg/L) chl-*a* concentrations. Respondents were randomly shown 3 paired images (7.25″ × 2.75″ each). Chl-*a* values were not disclosed to respondents during the survey. For each photo set, respondents rated how desirable the water appeared for 5 activities: swimming, boating, fishing, fish consumption, and near-water activities. Near-water activities were defined as "e.g., hiking, biking, camping, or picnicking near the lake" in the survey instrument. Ratings ranged from "very undesirable" (−3) to "very desirable" (+3), with a neutral midpoint.

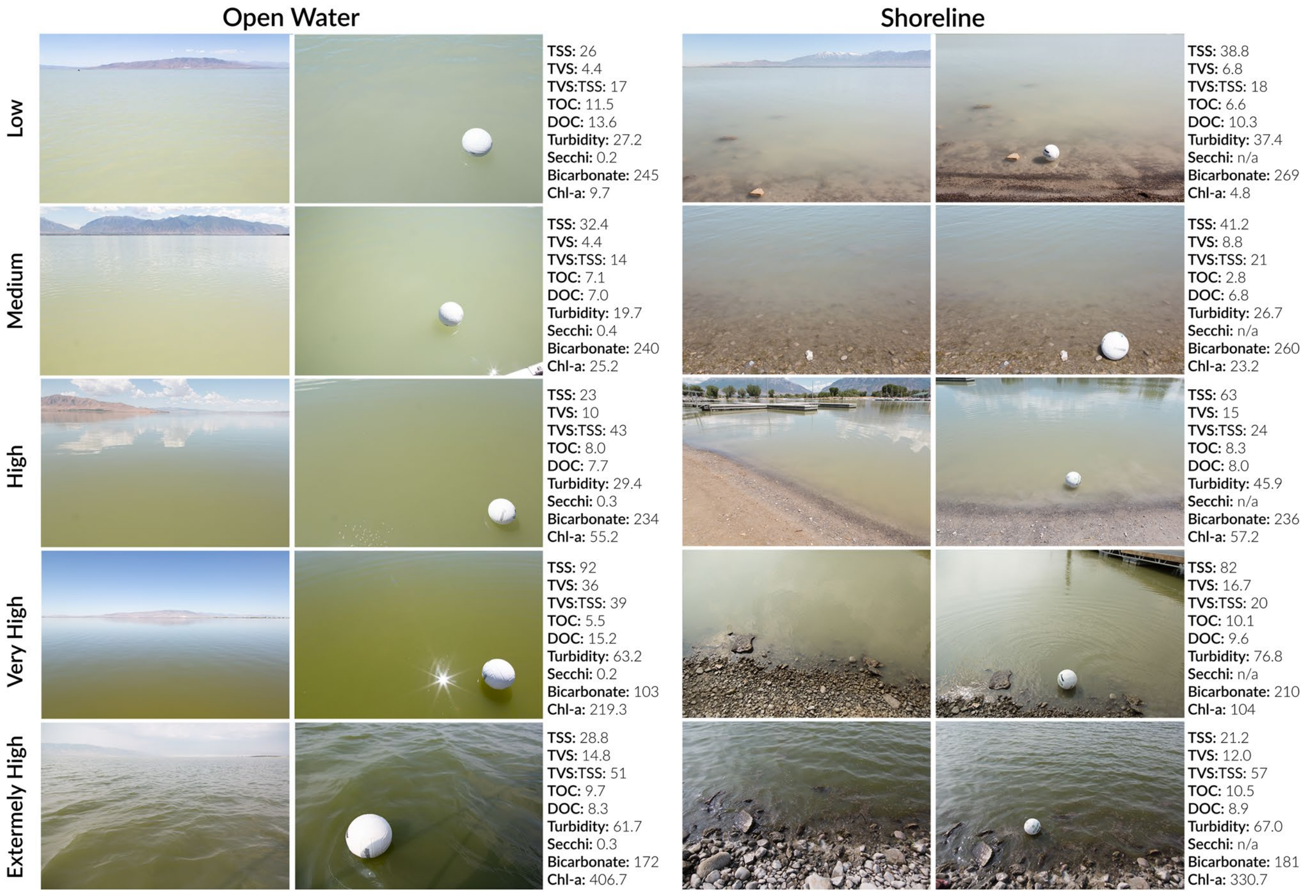

Figure 1. Final image set, with each image's associated water quality/clarity data.

Experience with water quality issues

As already noted, the survey instrument included several questions about respondents' experiences with water quality issues at Utah Lake. Prior experiences may influence visual assessments and consequently should be included as a covariate in the inferential model predicting desirability. To ascertain respondents' prior experience with water quality issues at the lake, the survey simply asked, "have you heard, read about, or experienced any issues related to water quality at Utah Lake?" If a respondent answered yes, then the survey asked "how [they] heard, read about, or experienced issues related to water quality." Response options—provided in a multiple-response format—included from a friend or family member; from a local news report; from a podcast; online; in a local print magazine or newspaper; [because] I tried to visit the lake, but could not, because the access point was closed; [because] I visited the lake, but was dissatisfied with the water quality during my visit; and [because] I saw signs around the lake.

The survey subsequently asked about respondents' perceptions of changes in water quality over time, since they first started visiting the lake. Response options to this question ranged from "It has improved a lot" to "It has gotten a lot worse," with a neutral "The water quality is the same" response option. The survey also solicited information about respondents' level of concern—ranging from "not at all concerned" to "extremely concerned"—regarding HABs, bacteria, and water clarity at the lake. Data from both of these questions were not included as covariates in the inferential model but are reported subsequently to provide context and depth to the findings from the inferential model.

Data collection

We administered 2 parallel surveys during summer 2022. The first was an on-site intercept survey conducted at 6 Utah Lake access sites identified in consultation with the Utah Lake Water Quality Study Steering Committee.

Sampling occurred on weekends (Friday–Sunday) between 12:00 and 20:00. Technicians approached recreationists and asked the individual in the group with the most recent birthday to complete the survey using a tablet and the Qualtrics application.

The second survey was mailed to 1500 randomly selected households in Salt Lake and Utah counties, with the option to respond online. Household addresses were drawn from county parcel datasets (May 2022).

Data analysis

We used descriptive statistics to summarize survey responses (Vaske 2019). Pearson's correlation coefficients were used as an exploratory first step to assess the relationship between chl-*a* and perceived desirability. To assess inference between chl-*a* concentrations (and other covariates) on perceived desirability of the presented water conditions, a random-effects ordinal probit panel data model using the xtoprobit command in Stata 16 (StataCorp LLC 2019) was estimated. Independent variables included (1) chl-*a* concentration; (2) turbidity (NTU); (3) frequency (number of trips taken to the lake in the past 12 months) and duration of lake visitation (length of time in years spent visiting the lake); (4) participation in an activity involving contact with the water—swimming, fishing, boating (motorized and nonmotorized)—on the trip during which the survey was taken (on-site sample) or on the most recent trip to the lake (resident sample); (5) prior experience with lake closures; and (6) standard demographic characteristics (age, income, education, and gender). This approach follows similar methods used in previous nutrient criteria assessments for Utah waters (Jakus et al. 2017).

Survey responses

Between 26 May and 2 August 2022, the research team conducted 27 site-days of on-site data collection at 6 designated locations around Utah Lake. In total, 384 visitors were approached. Of these, 49 individuals (12.8%) declined to participate, 22 (5.7%) were unable to complete the survey due to language barriers, and 45 (11.7%) opted to complete the survey later via email. In total, 290 recreationists completed the survey (268 on-site, 22 via email), yielding a 75.5% response rate (Table 1).

For the resident survey, the research team mailed 1500 surveys to a stratified random sample of households in Salt Lake and Utah counties. After accounting for 54 undeliverable surveys, the effective sample size was 1446. Of these, 237 surveys were completed via mail and 304 online, resulting in 541 total responses and a 37.4% response rate (Table 1).

The resident survey included a screening question to determine recent lake use. Respondents who had visited Utah Lake within the past

Table 1. Survey effort, responses, and response rate.

On-site intercept survey						
Method	Site days	Contacts	Refusals (%)	Prefer email (%)	Language barrier (%)	Completed surveys (%)
On-site survey	27	384	49 *(12.8)*	45 *(11.7)*	22 *(5.7)*	268 *(69.8)*
On-site contact followed by email		45				22 *(48.9)*
Total						290 *(75.5)*

Resident mail-back/online survey				
Method	Contacts	Undeliverable (%)	Effective sample size (%)	Completed surveys (%)
Mail-back survey	1500	54 *(3.6)*	1446	237 *(16.4)*
Online option included in mail-back survey				304 *(21.0)*
Total				541 *(37.4)*

12 months were asked the same trip-related questions as the on-site sample. Respondents who had not visited in the past year skipped these sections automatically (online) or via printed instructions (mail).

Results

Perceptions of water desirability

The core component of the survey involved assessing respondents' perceptions of water suitability for recreation using 3 randomly selected photo-pairs of Utah Lake captured under varying chl-*a* concentrations (Fig. 1).

Across both samples, no statistically significant relationships were found between chl-*a* concentrations and desirability ratings for swimming or consuming fish ($|r| \leq 0.07$; $P \geq 0.055$; Figs. 2 and 3). Significant correlations were observed for boating ($r = 0.07$; $P = 0.040$) and fishing ($r = 0.08$; $P = 0.018$) when shoreline images were shown to the on-site sample. A significant correlation was also observed for near-water activities ($r = -0.22$; $P = 0.007$) when shoreline images were shown to the on-site sample. These findings suggest that chl-*a* concentrations, as represented visually, did not have a consistently significant influence on recreationists' perceptions.

Despite the weak statistical relationship, respondents tended to rate contact activities such as swimming and consuming fish as more sensitive to perceived water quality. For example, 36% of residents rated images as "very undesirable" for these activities, compared to just 15% for non-contact activities. On-site respondents showed a similar trend, though with lower concern overall (20% vs. 5–10%).

Modeling predictors of desirability

A random effects ordered probit panel data model was used to examine additional predictors of desirability ratings among on-site respondents (Table 2). Even after controlling for other factors (trip frequency, lake use history, prior experience with water quality issues at Utah Lake, participation in an activity involving water contact, age, income, education, gender, and photograph location), neither chl-*a* concentrations ($P \geq 0.240$) nor turbidity ($P \geq 0.253$) was significantly associated with desirability ratings for the on-site sample. However, several individual characteristics influenced responses. Trip frequency was positively associated with more desirable ratings of water—regardless of color or clarity—for fishing, consuming fish, and near-water activities. Additionally, those who had been visiting the lake for longer were more likely to rate the water shown to them as desirable for boating ($P = 0.012$); this finding did not hold for the other activity types. Those engaged in contact activities rated the water more desirable for near-water activities ($P = 0.002$); this finding also did not hold across the other activity types. The older respondents were, the more likely they were to rate water as more desirable for fish consumption ($P = 0.006$), while income was negatively associated with the desirability of consuming fish from the water shown ($P = 0.031$). Shoreline images were rated more favorably for near-water activities (hiking, biking, camping, picnicking, etc.) than for open-water images ($P = 0.029$).

In the resident model (Table 3), chl-*a* was again not significantly associated with desirability ($P \geq 0.343$), but turbidity was negatively associated with desirability for swimming and fish consumption ($P = 0.044$ and 0.019, respectively). The frequency of recreation participation at the lake was significantly and positively related to the desirability of water for all activities ($P \leq 0.010$). Those who had been visiting the lake for longer were also more likely to rate the water shown to them in the survey as desirable for boating ($P = 0.006$) and fishing ($P = 0.006$). Individuals engaged in contact activities were more likely to rate water as desirable for all activity types asked about ($P \leq 0.022$). Respondent's age was negatively associated with the extent to which they rated the water shown to them as desirable for boating ($P = 0.020$), fishing ($P = 0.001$), and consuming fish ($P = 0.046$). Income was negatively associated with desirability ratings for swimming ($P = 0.031$) and consuming fish ($P = 0.035$). Education level, however, was positively associated with desirability ratings for swimming ($P < 0.001$), boating ($P = 0.038$), and consuming fish ($P = 0.04$). Women consistently rated the water as less desirable than men across all activities ($P \leq 0.001$) except near-water activities (for which the P value was 0.077).

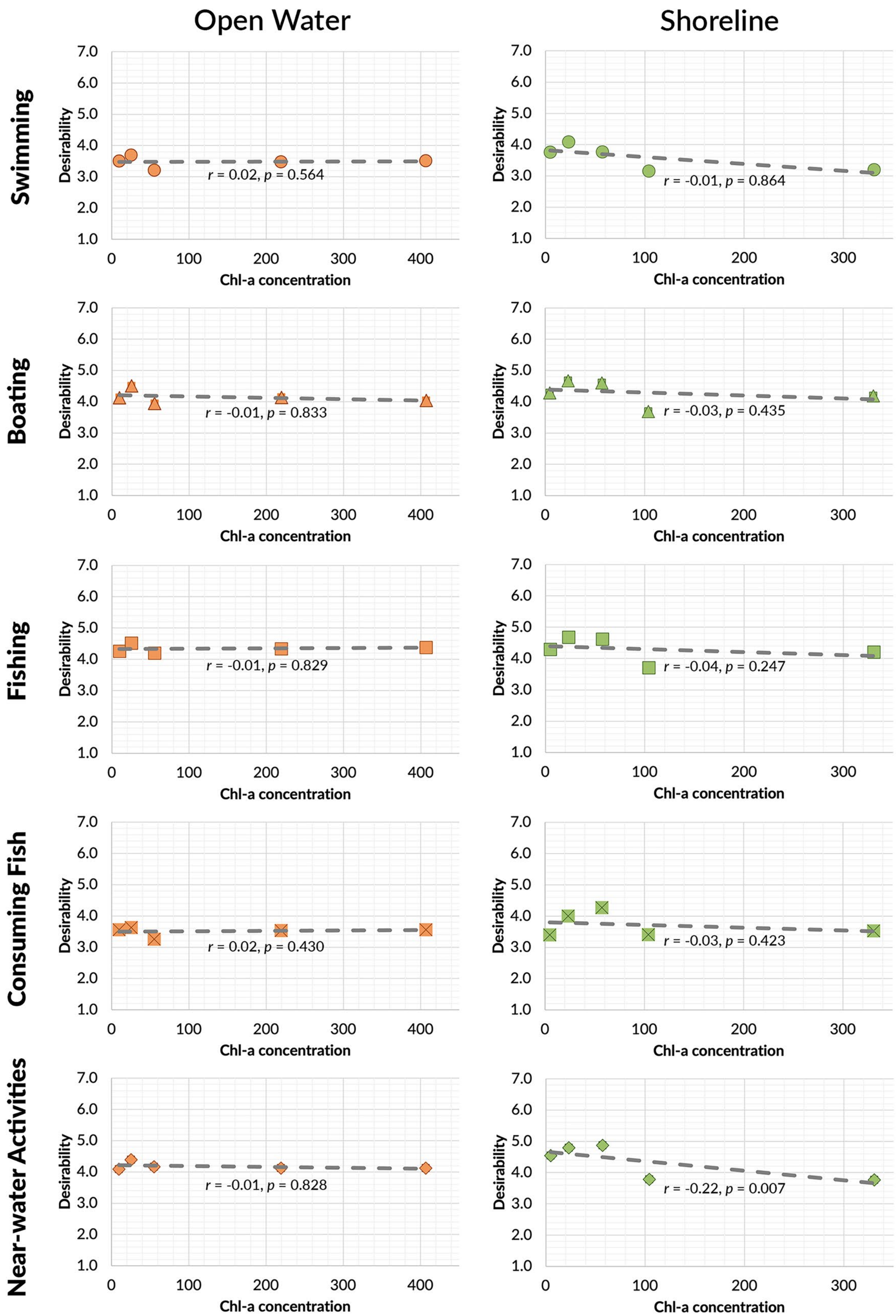

Figure 2. Mean desirability scores for participating in different activities with different chl-*a* concentrations (μg/L) (on-site sample).

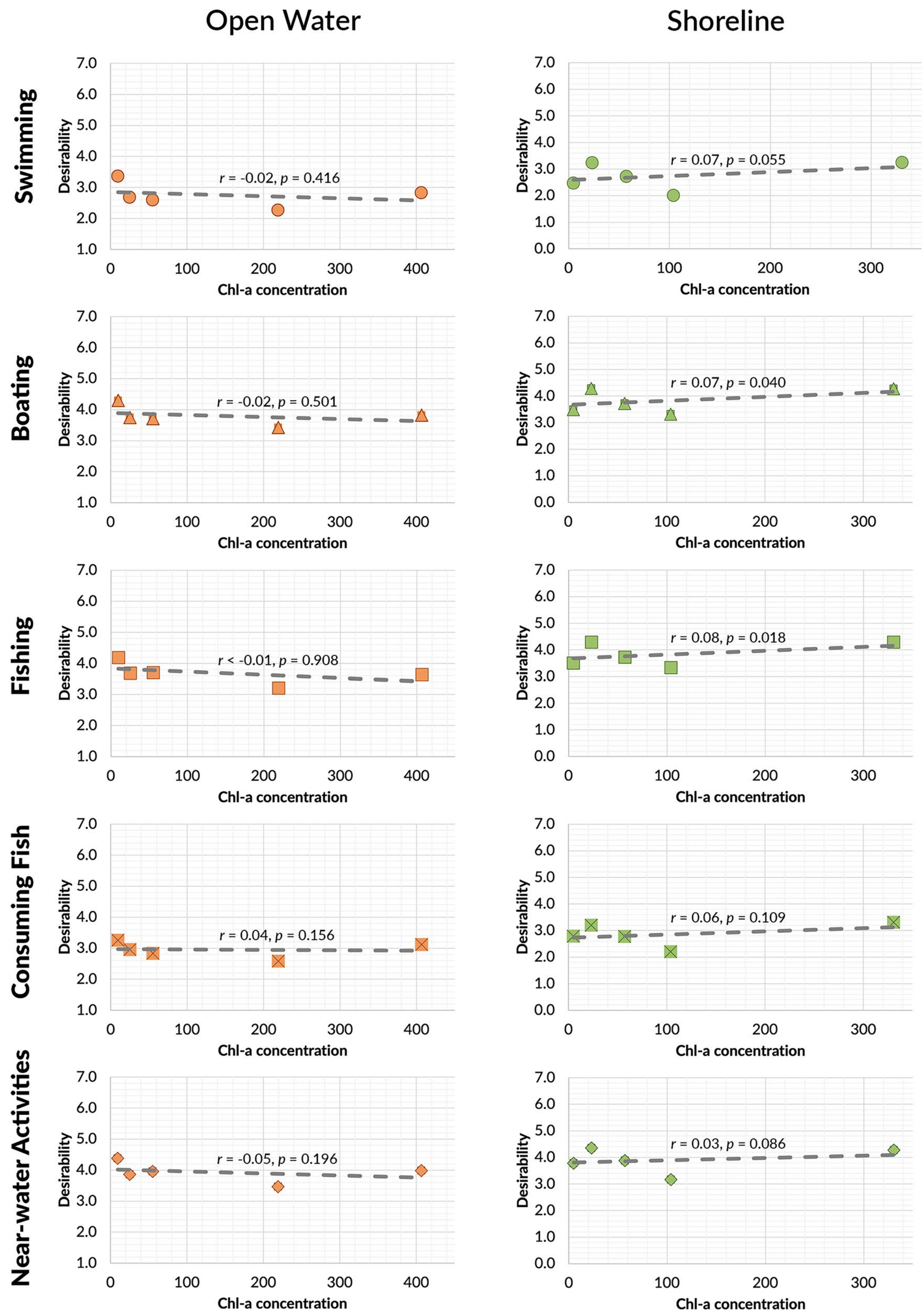

Figure 3. Mean desirability scores for participating in different activities with different chl-*a* concentrations (μg/L) (resident sample).

Together, these results suggested chl-*a* may not be a salient visual cue for the many diverse types of recreationists who use Utah Lake for recreation. The results also suggest that for some recreationists—namely, those whose opinions were captured via the resident survey—turbidity,

Table 2. Estimated coefficients from the random effects ordered probit panel data model predicting desirability for participating in different activities with different chl-*a* concentrations (on-site sample).

Independent variable	Swimming	Boating	Fishing	Consuming fish	Near-water activities
Water quality indicator					
Chl-*a* (μg/L)	−0.032	0.042	−0.035	−0.048	0.030
Turbidity (NTU)	0.001	$-2.22e^{-04}$	0.003	0.004	−0.005
Respondent characteristics					
Trip frequency	0.001	0.001	0.002*	0.001*	0.002*
Use history	$-3.36e^{-04}$	0.005*	0.003	−0.001	0.002
Prior experience with water quality issues at Utah Lake	−0.026	0.035	0.049	0.120	−0.080
Contact activities[a]	−0.009	0.089	0.109	0.078	−0.275*
Age[b]	−0.003	−0.003	0.001	0.006*	−0.002
Income	0.014	0.020	−0.029	−0.027*	$-7.94e^{-05}$
Education	−0.029	0.008	$-1.96e^{-04}$	−0.013	0.021
Gender	−0.002	−0.054	−0.324*	−0.212*	−0.090*
Photograph location					
Photograph location[c]	0.123	0.154	0.067	0.025	0.223*

[a]Contact activities include boating (motorized and nonmotorized), fishing, swimming, and water-skiing. Values coded as 0 = *noncontact activities*, 1 = *contact activities*.
[b]Gender coded as 0 = *male*, 1 = *female*.
[c]Photograph location coded as 0 = *open water*, 1 = *shoreline*.
*Significant at the .05 level. Multicollinearity checked via variance inflation factor (VIF) scores calculated after fitting the models with a standard OLS regression; all VIF scores were acceptable (<3.73).

Table 3. Estimated coefficients from the random effects ordered probit panel data model predicting desirability for participating in different activities with different chl-*a* concentrations (resident sample).

Independent variable	Swimming	Boating	Fishing	Consuming fish	Near-water activities
Water quality indicator					
Chl-*a* (μg/L)	0.076	0.002	0.036	0.081	−0.005
Turbidity (NTU)	−0.016*	−0.007	−0.009	−0.015*	−0.004
Respondent characteristics					
Trip frequency	0.020*	0.011*	0.010*	0.016*	0.002*
Use history	−0.003	0.010*	0.011*	0.003	0.002
Prior experience with water quality issues at Utah Lake	−0.069	−0.015	0.037	−0.027	−0.055
Contact activities[a]	0.564*	0.383*	0.466*	0.544*	0.207*
Age[b]	−0.005	−0.011*	−0.012*	−0.009*	−0.005
Income	−0.053*	−0.033	0.022	−0.038*	0.007
Education	0.075*	0.034*	0.011	0.056*	0.025*
Gender	−0.471*	−0.464*	−0.344*	−0.518*	−0.113
Photograph location					
Photograph location[c]	0.039	0.065	0.015	0.039	0.176*

[a]Contact activities include boating (motorized and nonmotorized), fishing, swimming, and water-skiing. Values coded as 0 = *noncontact activities*, 1 = *contact activities*.
[b]Gender coded as 0 = *male*, 1 = *female*.
[c]Photograph location coded as 0 = *open water*, 1 = *shoreline*.
*Significant at the .05 level. Multicollinearity checked via variance inflation factor scores calculated after fitting the models with a standard OLS regression; all VIF scores were acceptable (<3.46).

not chl-*a*, may be a more noticeable visual cue shaping perceptions of recreation suitability.

Perceived changes in water quality over time

Respondents who recreated at Utah Lake for more than 5 yr were asked whether water quality had changed during their period of visitation. Among on-site respondents with 5–10 yr of experience visiting the lake, 52.9% believed water quality was "about the same" (Fig. 4). Among those with 10–20 yr of experience, 44.0% believed water quality had declined. This declined slightly to 40.7% for those with 20–30 yr of experience. Long-time recreationists (30+ yr) held more polarized views: 24.4% believed water quality had "gotten a lot worse," while 15.6% believed it had "gotten a lot better." Only 2.2% of this group were unsure about change, suggesting stronger convictions among those with long-term lake familiarity.

Responses from the resident sample followed a similar trend. Among those who had recreated at the lake for 5–10 yr, 44.1% believed water quality had worsened. For those with more than 10 yr of use, this increased to approximately 60%.

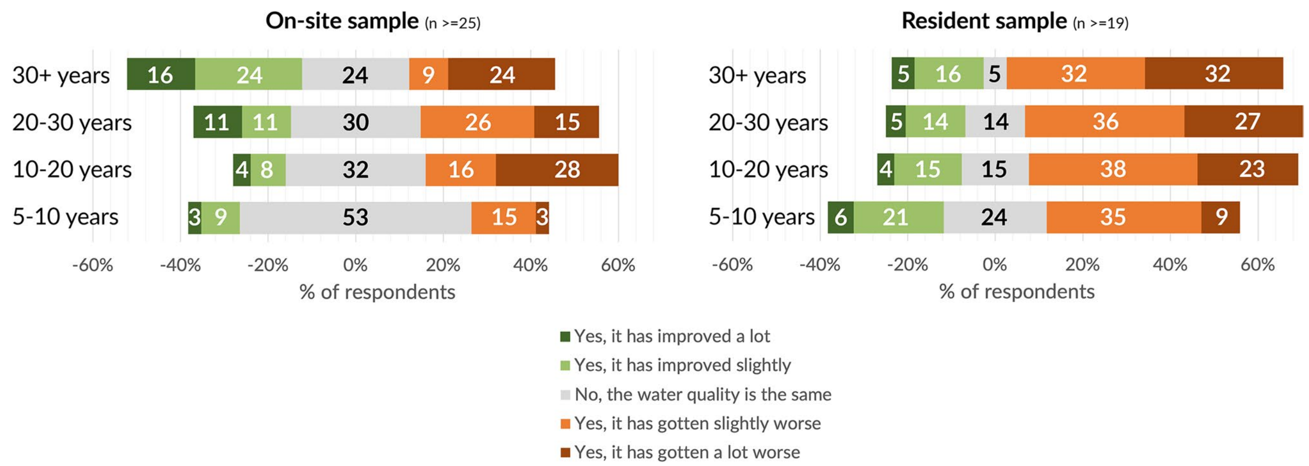

Figure 4. Recreationists' perceptions of changes in water quality over time.

Table 4. Recreationists' experience with water quality issues at Utah Lake.

	Recreationists surveyed at the lake ($n = 384$)		Resident of Salt Lake and Utah counties ($n = 265$)	
Type of experience	%	Rank	%	Rank
Heard about them from a local news report	57.9	1	60.8	1
Read about them online	53.2	2	48.5	3
Heard about them from a friend or family member	50.9	3	53.6	2
Saw signs around the lake	34.5	4	11.8	6
Visited, and was dissatisfied with the water quality	18.1	5	17.3	4
Read about them in a local print magazine or newspaper	9.4	6	13.9	5
Tried to visit, but could not because access point was closed	8.8	7	7.2	8
Heard about them in a podcast	4.7	8	9.3	7

One-third of residents with 30+ yr of experience believed water quality had "gotten a lot worse."

Awareness and concern about water quality issues

Among on-site respondents, 64.8% reported having "heard, read about, or experienced" water quality issues at Utah Lake. Most learned about issues through local news (57.9%), online sources (53.2%), or friends and family (50.9%) (Table 4). Only 34.5% reported seeing signage around the lake.

Among the resident sample, only 51.2% reported awareness of water quality issues. While their sources mirrored those of on-site respondents, only 11.8% reported seeing signs—likely because only half had visited the lake in the prior year.

When asked about specific issues, HABs were the most commonly reported concern among both samples (84.8% of the on-site sample; 70.9% of the resident sample). Poor water clarity was reported by about 60% of each sample. Bacteria-related issues were reported by 33.9% of on-site respondents and 43.0% of the resident sample.

Concern levels varied by issue (Fig. 5). For HABs, 53.9% of on-site respondents and 70.2% of residents expressed moderate or extreme concern. Concern about bacteria-related issues was reported by 49.1% of on-site respondents and 74.3% of residents. For poor water clarity, concern was slightly lower—45.5% for on-site respondents and 60.0% for those in the resident sample.

Discussion

Lack of chlorophyll a thresholds for recreational desirability

Contrary to expectations, there was no consistent evidence that increasing chl-*a* concentrations negatively influenced perceptions of recreational suitability. Recreationists surveyed via both an on-site survey and a resident survey showed little differentiation in their ratings of water shown in

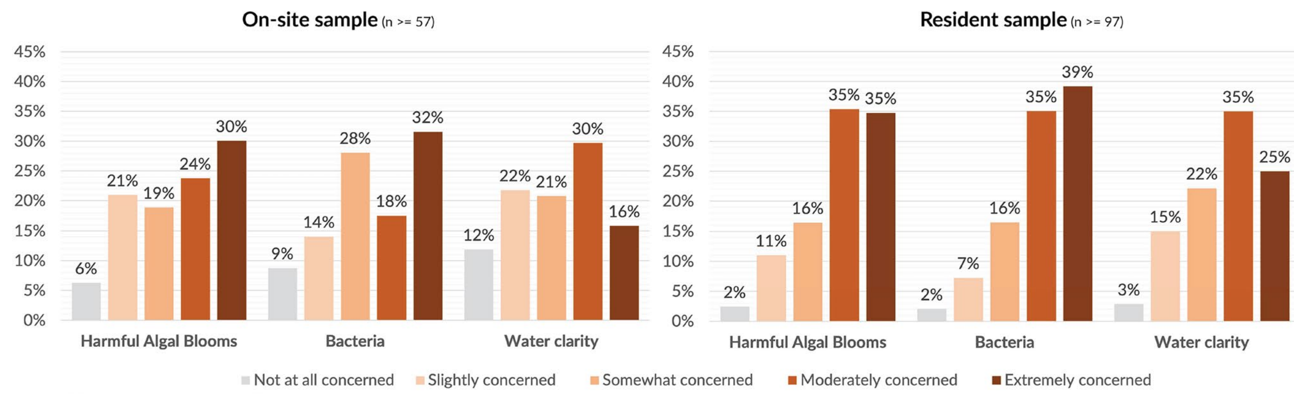

Figure 5. Percentage of respondents indicating concern about harmful algal blooms, bacteria, and water clarity at Utah Lake.

images with chl-*a* concentrations ranging from <10 to >250 µg/L. Even at extreme levels, mean desirability ratings hovered near the midpoint of the scale or higher, indicating neutral perceptions.

This finding contrasts with earlier studies where user perception surveys were used to establish thresholds for aesthetic impairment from benthic algae, often around 15–20 µg/L (Heiskary and Walker 1988, Smeltzer and Heiskary 1990, Hoyer et al. 2004, Smith et al. 2015). One possible explanation is that Utah Lake's water quality is shaped by both algal concentrations and suspended sediments from wind-driven mixing. Despite efforts to isolate the effect of chl-*a* concentrations, turbidity appears to play an important and confounding role in influencing recreationists' perceptions. The co-occurrence of clarity indicators may have obscured respondents' ability to judge chl-*a*-specific visual differences.

Prior research has cautioned against the use of perception surveys in calcareous or dystrophic lakes, where visual complexity—brownness, yellowness, or other cues—complicates interpretation (Kishbaugh 1994). These findings suggest that in optically complex lakes like Utah Lake, perceived water quality may not track with chl-*a* concentrations in a linear or intuitive way.

Turbidity as a more salient visual cue

Although chl-*a* was not a significant predictor of desirability, turbidity was significantly and negatively associated with desirability ratings for swimming and fish consumption among recreationists surveyed via the resident sample. This suggests that, for at least some users, water clarity (as measured by turbidity) may be a more meaningful indicator than water greenness (i.e., chl-*a*). These findings align with those of Do et al. (2021), who used social media sentiment analysis to examine public perceptions of water quality across Utah Lake. Their study found that while both turbidity and chl-*a* influenced sentiment, turbidity exhibited a more consistently negative and linear relationship with user sentiment. Chl-*a*, in contrast, showed a less pronounced and nonlinear relationship, suggesting that it may not serve as a salient visual cue for many types of recreators.

It is important to note that the relationship between turbidity and recreational suitability was not observed among on-site recreationists. This divergence suggests the influence of turbidity may not generalize across user populations or lake contexts. Caution is warranted when attempting to extrapolate this finding to other lakes or recreation settings, particularly those with different visitor demographics or water quality baselines.

One plausible explanation for why the responses of those sampled on site were unaffected by turbidity is that they may represent a more frequent habitual lake user with higher risk tolerances. These users may be less likely to link turbidity to ecological processes or public health risks, and may instead perceive it as a normal feature of a large, shallow lake. Additionally, those in the resident sample, especially those who have grown up near the lake or follow regional news and advisory systems, may have learned to associate murky or brownish water with environmental degradation or health risks. These individuals may interpret turbidity as a proxy for other concerns—such as legacy pollution, sediment resuspension, or the ecological impacts of carp (a notorious invasive species within the system).

Taken together, these findings underscore the importance of user segmentation in understanding how water quality is perceived and communicated. They also highlight the need for further research across multiple lake types and user groups to determine whether—and under what circumstances—turbidity (and possibly chl-*a*) serves as a salient visual cue influencing recreation decisions.

Awareness and concern about water quality issues

We found moderate levels of awareness and concern regarding water quality at Utah Lake. Only about two-thirds (64.8%) of on-site recreationists reported having heard, read about, or experienced water quality issues. This figure dropped to 57.2% among those in the resident sample who had recreated at the lake, and to 44.6% for those who had not. These findings suggest a sizable portion of the public may be unaware of ongoing environmental concerns despite frequent recreation at the lake.

Even among those aware of HABs, excessive bacteria, or poor water clarity, concern varied. For example, 53.9% of on-site respondents and 70.2% of those in the resident sample expressed moderate or high concern about HABs. Concern levels were similarly high for bacteria but somewhat lower for water clarity. These results highlight a persistent gap between awareness and concern.

Implications for recreation management and risk communication

The apparent disconnect between observable water quality conditions and recreationist perceptions presents an ongoing challenge for resource managers. While variation in turbidity influenced desirability ratings among the resident sample, visitors did not associate increases in chl-*a* concentrations with recreation suitability, suggesting water greenness may not serve as a salient or reliable visual cue for judging water quality risks across all lake users. This misalignment reinforces the need for communication strategies that do not rely on users' intuitive assessments of visual water quality alone. Instead, managers must prioritize highly visible, unambiguous advisories that clearly explain when and why water conditions pose a potential health threat.

Survey results further highlight the limitations of current communication infrastructure. Most respondents who were aware of water quality issues reported learning about them through unofficial sources such as news outlets, social media, or word of mouth. Only about one-third of on-site visitors recalled seeing formal water quality signage, pointing to the limited reach of posted advisories. This is particularly concerning given that many recreationists—especially walkers, picnickers, and wildlife observers—may never pass directly by shoreline access points where signage is typically installed. To address this gap, resource managers should consider deploying a broader array of communication tools, including digital alerts, signage at upland trailheads and parking areas, and outreach via local municipalities and recreation-oriented organizations.

The role of aesthetic perceptions in recreation behavior

An underlying assumption of this research is that perceived water quality plays an important role in shaping recreationists' judgments about the suitability of lakes, rivers, and coastal areas for activities such as swimming, fishing, and boating. This assumption is supported by previous research showing that visible cues—such as water clarity, greenness, surface scums, or odor—can significantly influence whether individuals deem a site aesthetically acceptable or physically safe (de França Doria 2010, Keeler et al. 2015, Smith et al. 2015). These insights support the use of perception surveys to inform the development of numeric nutrient criteria and risk communication strategies. However, while perceptions offer a useful lens for evaluating public awareness and preferences, they only partially explain recreation behavior. A large body of research highlights that decisions to engage in water-based recreation are shaped by a more complex interplay of social, environmental, and economic factors.

For example, studies in the outdoor recreation literature emphasize the role of social norms, group dynamics, and recreational habits in guiding behavior (e.g., Heywood 2002, Kyle et al. 2004). People often recreate in familiar places, return to sites out of tradition, or follow group decisions—sometimes irrespective of changing environmental conditions. Moreover, accessibility and amenities—such as proximity to home, availability of parking, restrooms, or shaded areas—often weigh more heavily in site choice than water quality itself (e.g., Siderelis and Moore 1998, Hunt 2005). These practical considerations can override aesthetic or health-related concerns, especially for low-risk users such as walkers or picnickers who may not directly engage with the water.

Risk perception and tolerance also vary widely across user groups and individuals. Some visitors may avoid contact with water at the first sign of murkiness, while others may continue to recreate even during health advisories, especially if they have limited access to alternative recreation options or believe the risks are exaggerated (Hoyer et al. 2004). Notably, recent work has shown many recreationists remain unaware of HABs or underestimate their health risks, particularly when advisories are inconsistently posted or perceived as lacking credibility (Hardy et al. 2016, Jacobi et al. 2024). This work illustrates the visual quality of water does not always—and directly—correlate with accurate risk assessments of risk, and appropriate behavioral responses.

These dynamics have important implications for both research and management. While perception surveys and image-based experiments are valuable tools for identifying aesthetic thresholds and informing nutrient criteria, they are not sufficient on their own to predict or influence behavior. Researchers must take care not to overstate the explanatory power of perceptual data and should seek to integrate other methodologies—including behavioral observation, choice modeling, and longitudinal studies of recreation patterns—to gain a fuller picture of how and why people use waterbodies.

Conclusion

Our findings suggest that while water quality is an important consideration for many users of Utah Lake, most are not able to distinguish or are indifferent to variation in chl-*a* concentrations. Turbidity appears to be a more intuitive visual cue affecting perceptions of suitability, particularly among those surveyed via the sample of nearby residents. These findings reinforce the need for targeted risk communication and education strategies that go beyond reactive advisories.

Given the relatively low levels of public awareness and high variability in aesthetic preferences, managers should adopt proactive, multimodal communication efforts to support safe and enjoyable recreation experiences. These efforts should focus on clarifying the types of water quality issues that exist at Utah Lake, the health risks they pose, and the visual cues that may or may not be reliable indicators of safety. Doing so will enhance both public understanding and confidence in lake management and may ultimately lead to more informed and responsive recreation behavior.

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