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Analysis

An Integrative Methodological Framework for Setting Environmental Criteria: Evaluation of Public Preferences

Maryam Ramin[a], Vincent Y.S. Cheng[a], Dong-Kyun Kim[a], Felicity J. Ni[a], Aisha Javed[a], Noreen E. Kelly[a], Cindy Yang[a], Sarah Midlane-Jones[b], Shan Mugalingam[b], George B. Arhonditsis[a,*]

[a] *Ecological Modelling Laboratory, Department of Physical & Environmental Sciences, University of Toronto, Toronto, Ontario M1C1A4, Canada*
[b] *Lower Trent Conservation, Trenton, Ontario K8V 5P4, Canada*

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ABSTRACT

The main objective of the present study is to introduce public preferences into the development of water-quality criteria that effectively balance environmental concerns and socioeconomic values. A novel feature of our research is the analysis of subjective public judgments with Bayesian inference techniques, which are ultimately connected with environmental conditions through mathematical modeling. Our case study is the Bay of Quinte, Ontario, Canada; an embayment at the northeastern end of Lake Ontario with a long history of eutrophication, characterized by frequent and spatially extensive algal blooms and predominance of toxic cyanobacteria. In this study, we present a major survey to determine public opinions on water quality in the area. Our survey was conducted among a random sample of 1527 local residents and tourists during the summers of 2013 and 2014. The key findings of the survey were: (*i*) fishing (29%) and beauty of the area (20%) were the main reasons for public use of the Bay of Quinte; (*ii*) among different water-quality problems, the public chose the algal scums (26%) and the integrity of fish populations (22%) as the main issues; (*iii*) only 30% of the returning visitors noticed that the clarity of water is better now relative to the prevailing conditions five years ago; (*iv*) there is a dramatic change in public sentiment between the beginning and end of the summer season; and (*v*) a substantial portion of local residents were willing to contribute financially towards the restoration of the bay. Our modeling analysis suggests that the likelihood of public satisfaction increases significantly when the total phosphorus concentrations fall below the critical levels of 20–25 $\mu g\,L^{-1}$, which however is a difficult target to achieve even under significantly reduced nutrient-loading conditions. Other biological variables such as chlorophyll *a* concentrations, harmful algal blooms, and toxin levels in locations frequently used by the public appear to more closely influence their satisfaction level.

1. Introduction

In 1987, the International Joint Commission (IJC) amended the Great Lakes Water Quality Agreement (GLWQA), a binational treaty between the United States and Canada, to effectively address the ongoing pollution issues threatening the physical, chemical, and biological integrity of the Great Lakes (Krantzberg, 2012a). The growing appreciation of the complex policy decisions required to restore and maintain the ecological integrity against the cumulative effects of a multitude of tightly intertwined stressors has also brought about a shift towards an holistic ecosystem management (Zhang and Arhonditsis, 2008; Krantzberg, 2012a). The GLWQA provided the framework to guide the management of 43 severely degraded waterbodies, referred to as Areas of Concern (AOCs), and restore beneficial uses that have been impaired, known collectively as Beneficial Use Impairments, or BUIs (Sproule-Jones, 1999; George and Boyd, 2007). Generally, BUIs reflect poor ecological status, in terms of water and sediment quality, habitat degradation, and/or impairments that might adversely affect human health (George and Boyd, 2007).

Remedial Action Plans (RAPs) have been developed and implemented to streamline the ecosystem management process as follows: initial designation of a site as an AOC and identification of BUIs; establishment of desirable (or "delisting") environmental goals, objectives and actions towards ecosystem restoration; final assessment of the progress until all metrics have been met, and the system is ready to be delisted as an AOC (George and Boyd, 2007). RAPs have been based on

* Corresponding author.
E-mail address: georgea@utsc.utoronto.ca (G.B. Arhonditsis).

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a variety of stakeholders from a range of sectors, including but not limited to governmental organizations, academia, industry, agriculture, and conservation agencies (Krantzberg, 2012b), with several AOCs encouraging active participation from local community members. To date, seven out of 43 AOCs have been delisted through this process (White Lake, Deer Lake, Presque Isle Bay, Oswego River, Collingwood Harbor, Severn Sound, Wheatley Harbor), while two other AOCs are "in recovery" status (Jackfish Bay, Spanish Harbor); the latter classification implies that all RAP actions to restore water quality and ecosystem health have been completed, but more time is needed for the environment to recover and for environmental quality objectives to be achieved. The GLWQA marks a novel approach in environmental governance through the incorporation of citizen participation into transboundary environmental protection between Canada and the United States (Krantzberg, 2012a). Community participation provides valuable experiential knowledge, deeper understanding of facts, recognition of natural variability and uncertainty, and incorporation of human values and beliefs (Perkins, 2011; Dietz, 2013). Including citizens in the decision making process also helps legitimize decisions and promotes funding (Krantzberg, 2003). A characteristic example of public consultation was the Ashtabula River and Harbor (Ohio, US), where local citizens not only accepted taxation to support the clean-up of the local AOC, but also formed a successful partnership with governmental bodies that facilitated the local remediation efforts (Lichtkoppler and Blaine, 1999).

Integrating stakeholder and public values with scientific evidence and cost–benefit analyses can be a challenging task, since decision making in environmental restoration projects involves inherent trade-offs among sociopolitical, environmental, ecological, and economic factors (Cangelosi, 2001; Nelson et al., 2009; De Groot et al., 2010; Wegner and Pascual, 2011). Stakeholder and public values can easily become intractable during the decision making process, as they cannot be translated easily into monetary values or quantitative terms (Kiker et al., 2005). Conversely, stakeholders and public have played a key role in encouraging governmental bodies to take more responsibility, as well as in minimizing the risk of future polarization (Krantzberg, 2012b). Public involvement may be as simple as having water users give feedback on the esthetic and water-quality changes of a waterbody (e.g., Carroll and Strang, 2014). Public participation is not unique to the Canadian or American AOCs in the Great Lakes area (e.g., Warriner et al., 1996; Irvin and Stansbury, 2004). For example, Papillion Creek (Nebraska, US), a heavily degraded watershed with flooding issues, is a case where public participation was unsuccessful, in part due to their limited power to forcefully guide the decision making process (Irvin and Stansbury, 2004). The Grand River watershed (Ontario, Canada) has elicited public consultation regarding issues of resource management, groundwater contamination, and urban development (Warriner et al., 1996). Comparative analysis of all of these issues provided a contextually rich account of the circumstances under which public consultation in watershed management can be beneficial for the local restoration efforts (Warriner et al., 1996). Along the same line of thinking, Warriner et al. (1996) highlighted the importance of giving community members an active role in the decision making process, arguing in favor of the notion that ecologically minded societies should embrace direct rather than representative democracy. The motivation for increased citizen participation is founded on the assumption that if citizens become active participants in the policy-making process, governance will become more democratic and effective. One more reason for citizen participation is that ecosystem services embody characteristics of public goods, so we need to employ methodologies that capture their collective character. As a result, policies will be developed with impartial consideration of citizen preferences, and the public will become more understanding of the challenges underlying the decisions made by government administrators (Irvin and Stansbury, 2004).

The objective of this paper is to present a Bayesian methodological framework that engages the perspective of the public on the criteria-setting process through the development of predictive linkages among measurable water-quality variables, such as total phosphorus (TP) and chlorophyll *a* (Chl*a*) levels, and the anticipated public response. The Bay of Quinte (Ontario, Canada) is used as a case study to understand the decision making process and the type of information contributed through citizen participation practices. Based on surveys of visitors and local residents of the Bay of Quinte, we attempt to elucidate the level of public satisfaction with the prevailing conditions in the system. Our framework addresses the urgent need for novel policy analysis tools that bring a shift towards a more democratic and effective governance through (*i*) the introduction of the preferences of primary users/consumers of ecosystem services, which has been a major oversight of the contemporary environmental management practices; and (*ii*) the ability to iteratively update our beliefs by accounting for the significant variability in space and time as well as the uncertainty with our knowledge of the ecosystem functioning.

2. Methods

2.1. Module 1: Public Survey

The first module of our framework involves the public survey to address questions pertinent to the Beneficial Uses of the Bay of Quinte AOC. We prepared a questionnaire to assess the perceptions of both local residents and tourists. The questionnaire comprised twenty-two (22) questions, surveying their preferential uses, their perceptions/concerns about the bay, and their demographic information (Please refer to our Supporting Information). All the representatives from the RAP technical team and the University of Toronto Research Ethics Committee reviewed the questionnaire (RIS Prod ID 00028997). Some modifications were also implemented based on public feedback. We visited the Bay of Quinte and conducted random surveys of local residents and tourists from May to September in 2013 and in 2014 (a total of 25 visits). Average survey length was approximately three minutes per person. A total of 721 individuals were surveyed in 2013 and 806 individuals in 2014 (N = 1527). The main sites were four towns in the upper (Trenton, Belleville, and Deseronto) and middle bay (Picton), where we could access high population numbers to facilitate our survey (Fig. 1).

2.2. Module 2: Bayesian Modeling of Public Perception

The second module aims to assess public perception of the prevailing water-quality conditions according to the socio-economic status (e.g., age, gender, education level and income) of the respondents at different locations and periods of the year. Public perception analysis focused on two important questions: (*i*) What is the level of public satisfaction with the current state of the Bay of Quinte? (*ii*) How does the socio-economic status of respondents relate to their satisfaction? To assess public satisfaction, we developed a multinomial model that quantifies the likelihood of a certain public sentiment/attitude in time and space. The governing equations are as follows:

$$Y_{ijk} \sim \text{Multinomial}(p_{ijk}, N_{ij})$$

$$p_{ijk} = \phi_{ijk} / \sum \phi_{ijk}$$

$$ln(\phi_{ijk}) = \alpha_{ik} + \beta_{jk}$$

$$\sum \alpha_{ik}, \sum \beta_{jk} = 0$$

$$\alpha_{ik}, \beta_{jk} \sim N(0, 10000)$$

where Y_{ijk} is the number (counts) of public response for five satisfaction levels k; in group category j (age, amount willing to donate, education level, and gender) in different months (May to August) or locations i with a given sample size N_{ij}; p_{ijk} refers to the probability of the public

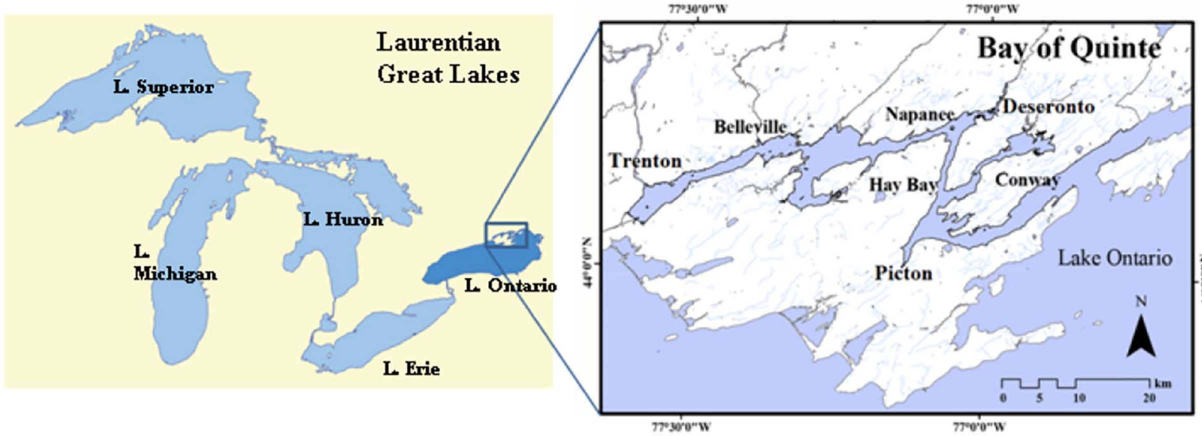


Fig. 1. Map of the Bay of Quinte and main locations surrounding the Bay.

response as determined by the latent variable φ_{ijk}; the two coefficients α_{ik} and β_{jk} are drawn from the uninformative (flat) distributions and are used to delineate the relative importance of time or space *i* and demographic category *j*, respectively, in shaping the level of public satisfaction.

2.3. Module 3: Linkages Between Ecological Conditions and Public Satisfaction

The third module links the level of public satisfaction with the trophic status of the Bay of Quinte. Specifically, we connected the public satisfaction responses with the prevailing water-quality conditions a few days prior to or after the date of the survey (i.e., Chl*a* and TP concentrations). The Bayesian configuration of the third module is structurally similar to the modeling exercise in the second module. The only difference is that the latent variable φ_{ijk} is determined by the prevailing water-quality conditions, C_i, such as Chl*a* or TP concentrations:

$$ln(\phi_{ijk}) = \beta_{0jk} + \beta_{1jk} \cdot ln(C_i)$$

where the regression intercept β_{0jk} and slope β_{1jk} are drawn from non-informative prior distributions.

2.4. Module 4: Linkage Between Management Strategies and Public Satisfaction

We used the process-based eutrophication model developed by Kim et al. (2013) to predict the prevailing water-quality conditions in the Bay of Quinte in response to nutrient loading reduction strategies. Specifically, Kim et al. (2013) advanced the mechanistic foundation of a TP mass-balance model, originally developed by Minns et al. (2004) and more recently modified by Zhang et al. (2013). The model explicitly simulates macrophyte dynamics; the role of dreissenids; and the fate and transport processes of phosphorus in the sediments of the Bay of Quinte, such as particulate sedimentation dependent upon the standing algal biomass, sediment resuspension, sorption/desorption in the sediment particles, and organic-matter decomposition. The spatial variability of various external and internal TP flux in the different segments of the Bay of Quinte are provided in our Supporting Information section (Fig. SI 1; see also Kim et al., 2013). The projected system responses to nutrient loading management strategies were subsequently associated with the public satisfaction levels through the Bayesian modeling network presented in the third module (Fig. 2).

2.5. Bayesian Implementation

Bayesian inference was used as a means for estimating model parameters in the second and third modules, whereby our prior beliefs regarding the question at hand are quantitatively updated by taking into account existing water-quality measurements. Bayesian inference treats each parameter θ as a random variable and uses the likelihood function to express the relative plausibility of obtaining different values of this parameter given the available data from the system (Gelman et al., 2004):

$$P(\theta \mid data) = \frac{P(\theta) \cdot P(data \mid \theta)}{\int_{\theta} P(\theta) \cdot P(data \mid \theta) d\theta}$$

where $P(\theta)$ represents the prior distribution of the model parameter θ, $P(data|\theta)$ indicates the likelihood of data observation given the different θ values, and $P(\theta|data)$ is the posterior probability representing our updated beliefs on the θ values, contingent upon the empirical knowledge from the system. The denominator is often referred to as the marginal distribution of the available data (Gelman et al., 2004) and acts as a scaling constant that normalizes the integral of the area under the posterior probability distribution. To obtain sequences of realizations from the posterior distribution, we used Markov-chain Monte Carlo (MCMC) sampling available in the WinBUGS software (Lunn et al., 2000). For each of the models examined, we used three chains with 50,000 iterations, by keeping every 10th iteration to minimize serial correlation. The first 5000 samples were discarded to eliminate the effect of the initial parameter values assigned (*burn-in*), and convergence was assessed qualitatively by visually inspecting (*i*) plots of the Markov chains for mixing and stationarity and (*ii*) the corresponding density plots of the pooled posterior Markov chains for unimodality. We also assessed convergence quantitatively using the modified Gelman–Rubin convergence statistic (Brooks and Gelman, 1998). The accuracy of the posterior parameter values was examined by ensuring that the Monte Carlo error for all parameters was $< 5\%$ of the sample standard deviation.

3. Results

3.1. Module 1: Public Survey

The public primarily used the Bay of Quinte for fishing (29%), beauty of the system (20%), and other activities (18%), e.g., farmer's market, leisurely walk, and picnicking (Fig. 3a). The qualities of greatest importance to the public were absence of algal scums (26%), sport-fish abundance (22%), followed by less dirt in the water and no odor (16%) (Fig. 3b). The majority of the public was dissatisfied with the water-quality conditions of the bay, including the water clarity (Fig. 4a,b). Their responses to aquatic plants as a major disturbance were mixed; whereas half of the respondents (50.1%) did not see aquatic plants as being a major disturbance, 30.4% and 19.5% saw aquatic plants as a major and somewhat major disturbance, respectively

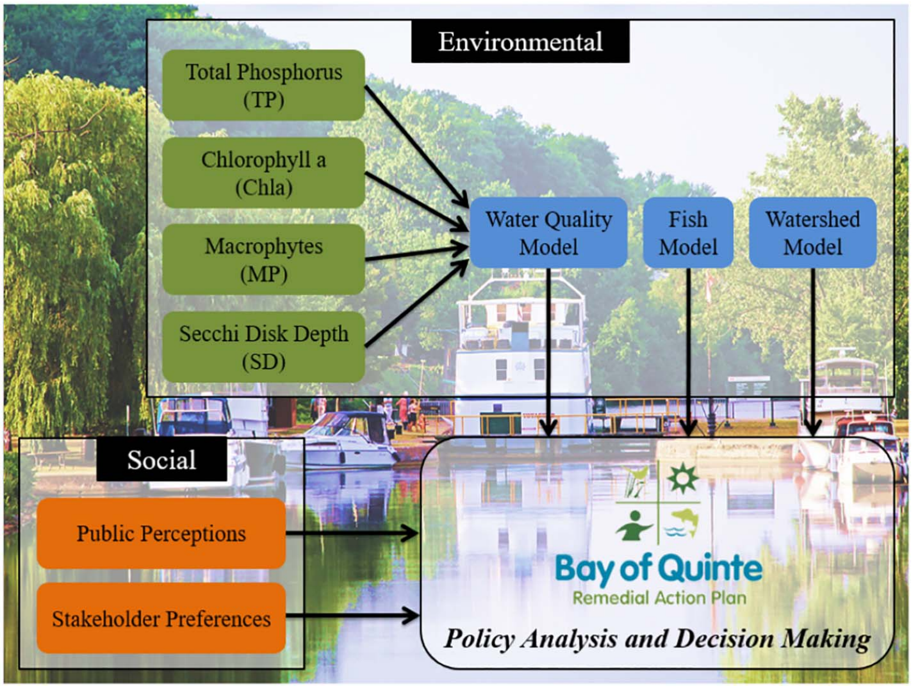


Fig. 2. Engagement and perspective of local people, stakeholders and policy makers on the criteria-setting process and the identification of the optimal water-quality criteria that effectively balance between environmental concerns and socioeconomic values. Our framework aims to establish the missing causal link between model predictions and stakeholder/public perceptions.

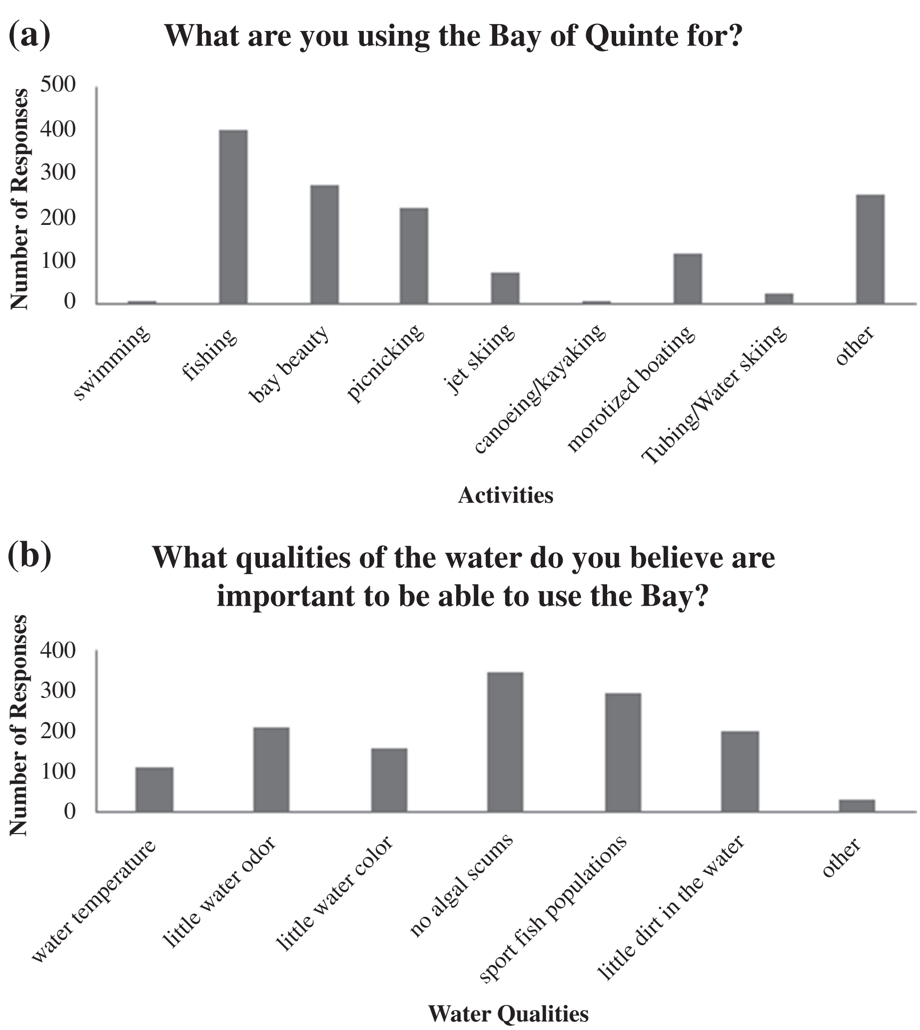


Fig. 3. Bar graphs depicting (a) the public usage of the Bay of Quinte, and (b) the qualities of water the public respondents believe to be important.

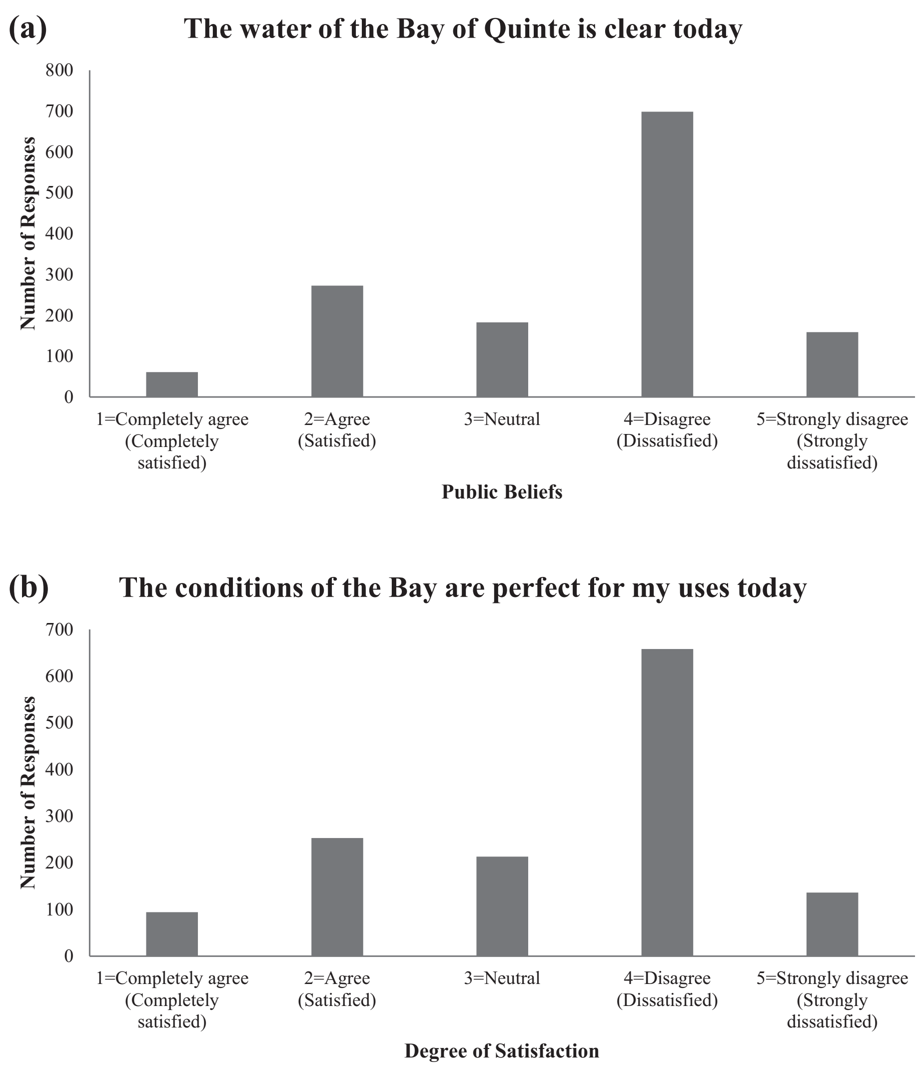


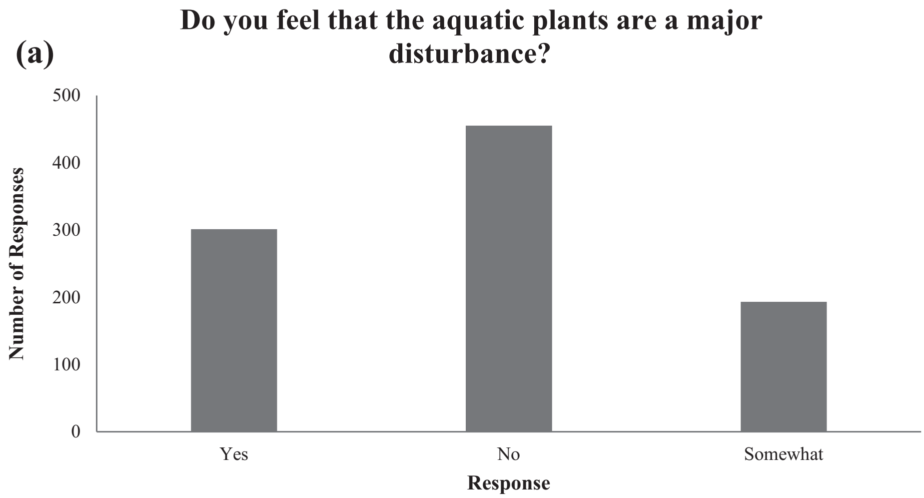
Fig. 4. Bar graphs depicting (a) the public opinion on the clarity of the Bay, and (b) the public opinion on the conditions of the Bay being perfect for their use.

(Fig. 5a). After revealing to the interviewees that aquatic plants represent an important habitat that may play an important role in conserving fish populations, only 4.3% felt the same way regarding their earlier skepticism about their presence in the system, but 34.03% of the respondents were still not completely convinced that aquatic plants may help conserving fish populations (Fig. 5b).

More than two-thirds (68%) of the public surveyed used the bay at least once per month (Fig. SI-2). Of the respondents who had visited the bay more than once, 47% were in the area within the past year, and about a quarter (26% and 27%) had visited within the past five years or more than five years ago, respectively (Fig. 6a). The most noticeable change by the public was water clarity, followed by the odor of water, fish catch, weed, and algae (Fig. 6b). Although there were both positive and negative public perceptions related to the changes in each of the above attributes, we witnessed more positive than negative feedback and the public was generally willing to come back to the Bay of Quinte.

Public satisfaction was examined in time and space by categorizing the summer period into four months, May to August, and the study area into four locations, from upper to lower Bay of Quinte, Trenton, Belleville, Deseronto, and Picton. Public satisfaction declined dramatically from the beginning to the end of the summer season (Fig. 7a,b). The highest percentage of respondents felt that water clarity and smell had improved during our survey in May. This percentage gradually decreased in June and July. In August, more than half of the respondents reported that water clarity and smell had worsened (Fig. 7a). A similar pattern was found with the level of satisfaction regarding the water-quality conditions of the bay, except that the negative perception manifested itself earlier, i.e., in July rather than in August (Fig. 7b). Public satisfaction also varied dramatically by region. While more than a quarter of the responses indicated satisfaction with the conditions in Trenton, less satisfied was the public in Deseronto and Picton, with Belleville being the worst (Fig. 7c).

We examined public satisfaction according to different demographic characteristics; namely, age, gender, education, and proximity of residence to the bay. Each demographic, except gender, was partitioned into five categories. All demographic groups - according to age, education, and location of residence in proximity to the bay - were generally dissatisfied with the state of the bay (Figs SI 3–5). We did not find any significant differences with respect to the satisfaction level among the various age demographics. In relative terms, the younger (< 18 and 18–25) and 50–65 age groups were more dissatisfied than other age groups (Fig. SI 3; see also following multinomial modeling results). Participants with high-school education displayed the lowest satisfaction, whereas individuals with university-level education were relatively neutral in their perception (Fig. SI 4). The most distinct shift in the satisfaction level was displayed with the location of residence relative to the bay (Fig. SI 5). The public who identified their residency as being close to the shoreline was generally more dissatisfied. Lastly, in response to the question whether the public realizes that the Bay of Quinte is listed as an AOC, 55% replied “yes”, which means that just above half of the public was aware that the bay is still considered an impaired area still subject to remedial measures. When asked as to



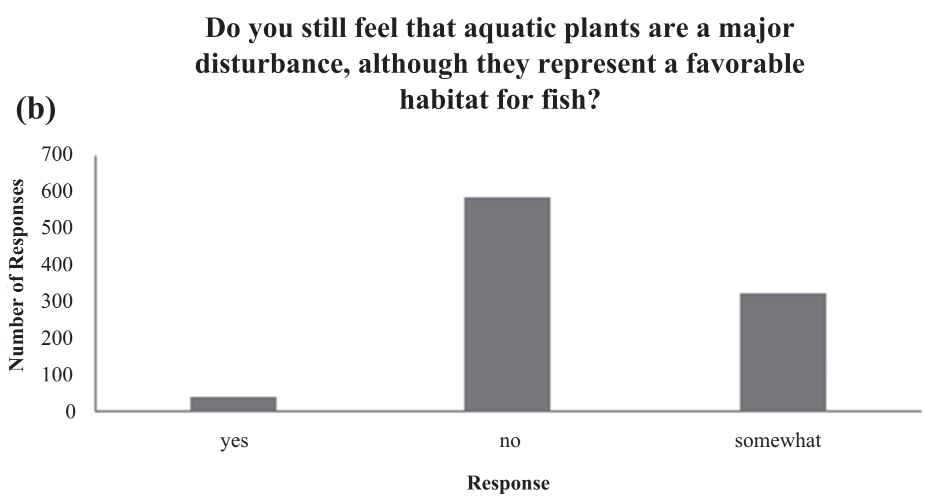


Fig. 5. Bar graphs depicting (a) the public opinion on whether or not aquatic plants are a major disturbance, and (b) whether or not the respondents feel the same, knowing that aquatic plants are favorable habitats for fish.

whether they feel the system was close to being delisted as an AOC, a similar percentage (53%) of the public did not believe that the Bay of Quinte will be restored in the near future.

3.2. Module 2: Bayesian Modeling of Public Perception

What is the level of public satisfaction in relation to their demographic group? The Bayesian multinomial model described in the second module predicted the level of satisfaction in space and time and across different characteristics of the survey participants; such as locals or tourists, age, gender, and education. All age groups of local residents were predicted to hold negative opinions, with the 50–65 age group predicted to be the most dissatisfied (Table 1). Regarding the local/tourist classification, the likelihood of public satisfaction with the current state of the Bay of Quinte was low among local residents, who were generally more dissatisfied than tourists (Tables 1 to 4). For local residents, the satisfaction levels were fairly similar among the different age groups compared to the tourists, with the degree of dissatisfaction ranging from 55%–65%, as opposed to dissatisfaction levels between 44%–68% across the tourist age groups (Table 1). A more detailed prediction by month (Table SI 1) reinforces our earlier results that public perception became exceedingly negative as the summer season progressed. In a similar manner, our predictions by location instead of month showed that the < 18 and 50–65 age groups in Quinte West were mostly dissatisfied (Table SI 2). Interestingly, there were practically no differences in regard to the public satisfaction between genders (Table 2), while a more detailed breakdown by month and locations provided very similar results as stated above (Tables SI 3 and SI 4). In predicting public satisfaction by education and local/tourist classification, there was a slight increase in the likelihood of being satisfied with higher education levels for both locals and tourists, with the only exception being the lowest-education (some high school) group, which was the most satisfied group for both tourists and local residents. The tourists with the lowest education levels were by far the most satisfied. The dissatisfaction level of different education groups among the local residents studied showed much less divergence (50%–63%) than the dissatisfaction levels of the tourists (29%–62%) (Table 3). Dissecting the perceptions by month and location showed very similar results to those stated above (Tables SI 5 and SI 6). Lastly, our modeling results reinforce our earlier finding that the public perception shifted from mainly positive in May to overwhelmingly negative in August for both locals and tourists (Table 4).

How does the socio-economic status of the respondents relate to their satisfaction and their willingness to donate? Our Bayesian multinomial modeling exercise also identified a presumably causal association between donation levels to support the local restoration efforts and their level of satisfaction with the prevailing water-quality conditions. A substantial proportion of local residents, across all age groups, were predicted to be willing to contribute financially towards the restoration of the Bay of Quinte (Tables 5 and SI 7–SI 11). Senior tourists were also

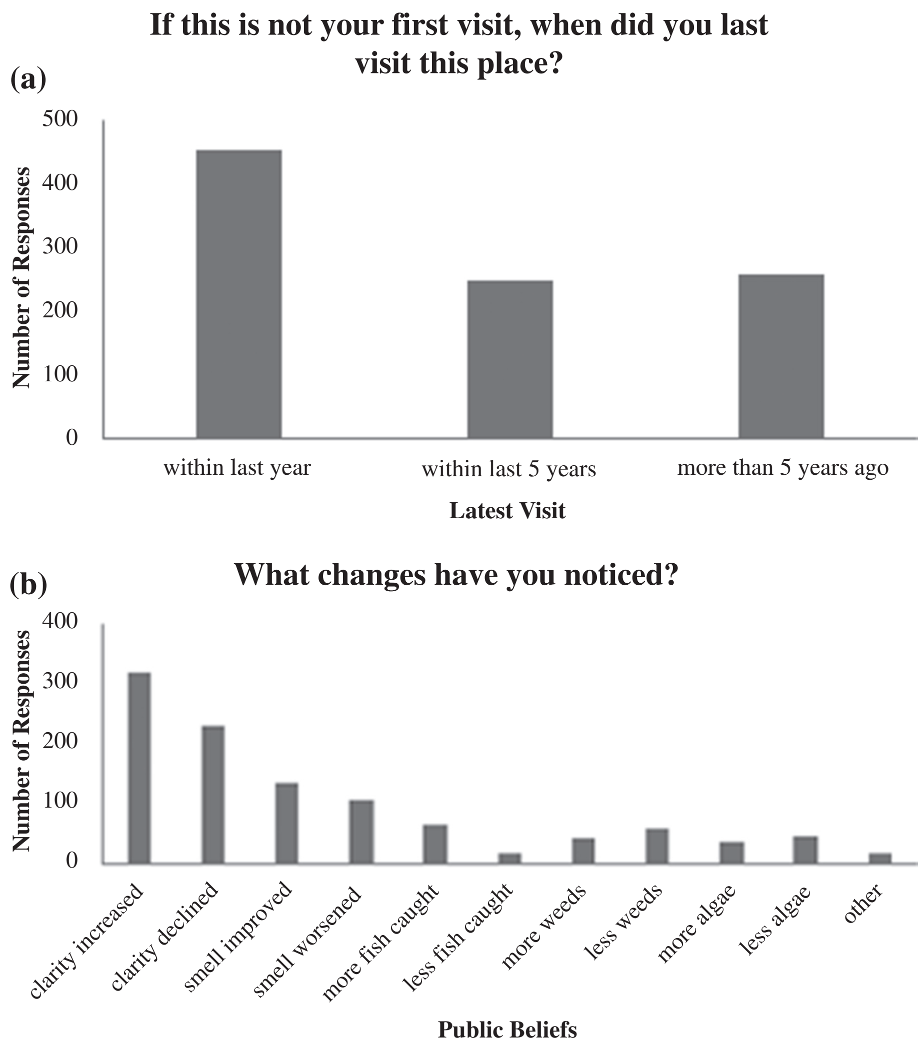


Fig. 6. Bar graphs depicting (a) the public use of the Bay of Quinte, and (b) qualitative changes noticed.

predicted to be willing to donate higher amounts (Table 5), while separating the tourists by gender showed that female tourists are motivated to donate more than male tourists (Table SI 7). The amount that local residents are willing to donate increases with education level from high school to university level, while the opposite was true for tourists (Table SI 8). Counter to the response of the tourists, local residents were also willing to donate more during May and June than July or August (Table SI 9). Overall, the locals were marginally more motivated to donate than the tourists (Table SI 10). Interestingly, the more satisfied locals were willing to donate more than their dissatisfied counterparts, whereas the most dissatisfied tourists expressed greater willingness to contribute (Table SI 11). A more detailed analysis of the willingness of the local/tourist groups to donate in relation to public satisfaction by month revealed similar results as above; that is, the tendency for tourists to donate more in July and August while the local residents seem more supportive in May and June (Table SI 12). A similar analysis on the willingness to donate in relation to public satisfaction by location showed that tourists in Quinte West were by far the most generous groups, especially the ones that were dissatisfied. In contrast, donation amount within the local residents did not vary much by location (Table SI 13).

3.3. Module 3: Linkages Between Ecological Conditions and Public Satisfaction

In the third module, our Bayesian multinomial modeling predicted public perception of water-quality as a function of Chl*a* (Fig. 8) and TP concentrations (Fig. SI 6). Public satisfaction was predicted to decrease significantly from 80% to < 5% as phytoplankton biomass increased from < 3 μg Chl*a* L^{-1} to ~50 μg Chl*a* L^{-1}. The most significant drop in percentage of public satisfaction occurred within the 0–10 μg Chl*a* L^{-1} range, from 80% to nearly 20%, and it gradually declined to < 5% as phytoplankton biomass increased from 10 to 50 μg Chl*a* L^{-1} (Fig. 8 top left). The exact opposite pattern was predicted when our modeling exercise focused on the public dissatisfaction level (Fig. 8 bottom left). Percentage of dissatisfaction increased dramatically from 5 to > 60% as phytoplankton abundance increased from 0 to 10 μg Chl*a* L^{-1}, and it plateaued to > 85% as Chl*a* concentration increased to 50 μg Chl*a* L^{-1}. The variability of neutral perception was comparatively much lower, from 9% to 17% across the 1–50 μg Chl*a* L^{-1} range, with the peak of 17% occurring when the Chl*a* concentration was 5 μg L^{-1} (Fig. 8, top right). Lastly, we calculated a weighted average of the three-perception categorical scheme (specified numerically as satisfied = 1, neutral = 3, and dissatisfied = 5) to predict the total perception as a function of Chl*a* concentration (Fig. 8, bottom right). The latter exercise reinforced the pattern of negative perception that increases linearly from 1 to 10 μg Chl*a* L^{-1}, and remains strongly negative for higher phytoplankton biomass levels. We found similar results when public perception was modeled as a function of TP (Fig. SI 6); namely, public satisfaction fell below 20% once the 30 μg TP L^{-1} was exceeded (Fig. SI 6 top left), and public dissatisfaction correspondingly increased

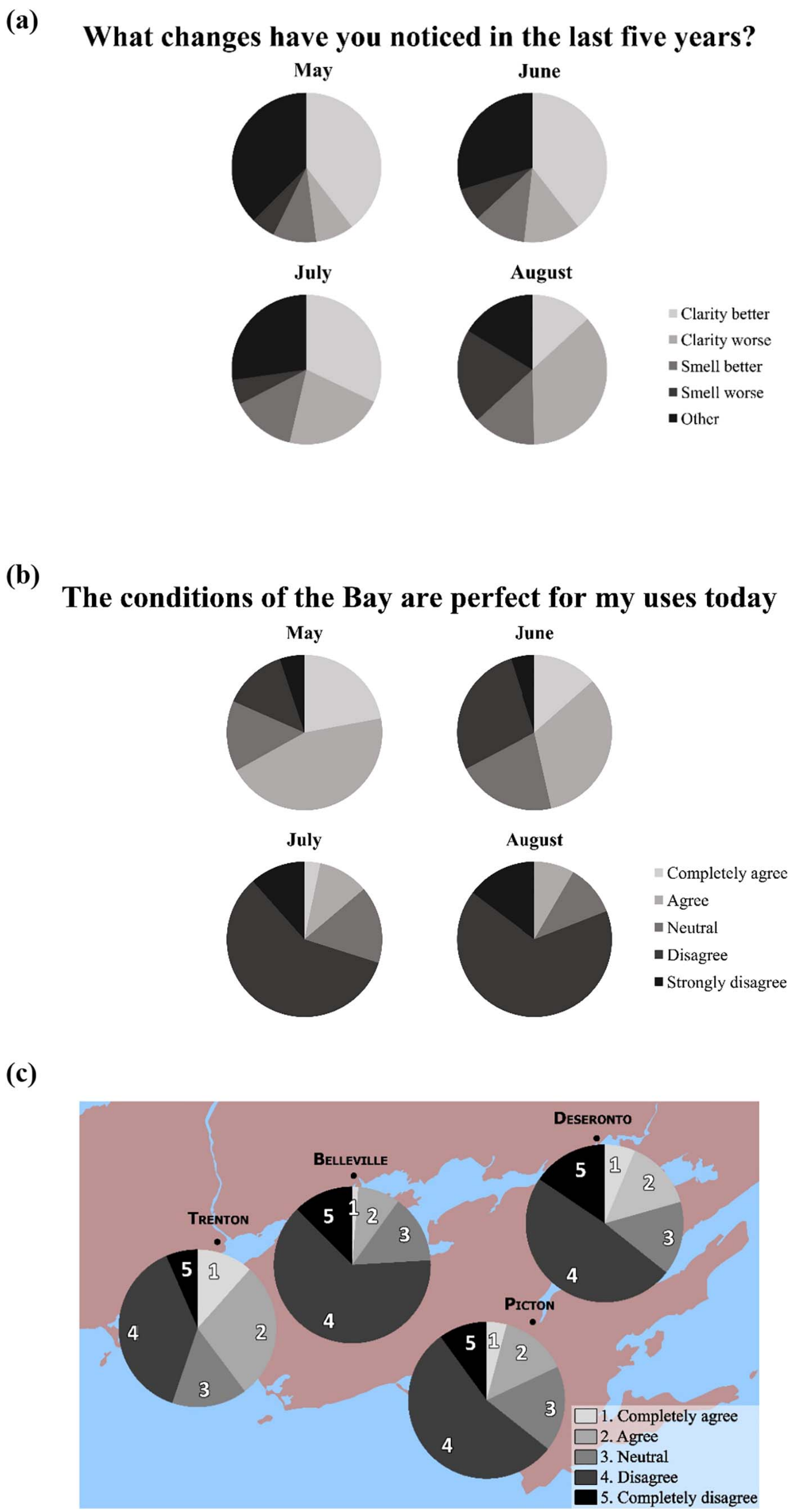


Fig. 7. Pie graphs depicting (a) month-to-month variability of the observed changes over the previous five years, (b) month-to-month variability of the level of satisfaction with the Bay of Quinte, and (c) variability of the level of satisfaction with the Bay of Quinte across different locations in the area.

Table 1
Likelihood (%) of Public Satisfaction level (Satisfied, Neutral, Dissatisfied) by age.

Age	Public Satisfaction (Local)			Public Satisfaction (Tourist)		
	Satisfied	Neutral	Dissatisfied	Satisfied	Neutral	Dissatisfied
< 18	26%	10%	64%	27%	18%	55%
18-25	23%	18%	59%	29%	18%	53%
26-35	33%	12%	55%	29%	28%	44%
36-49	20%	23%	57%	34%	17%	49%
50-65	25%	11%	65%	21%	11%	68%
> 65	23%	17%	60%	35%	9%	56%

Table 2
Likelihood (%) of Public Satisfaction level (Satisfied, Neutral, Dissatisfied) by gender.

Gender	Satisfaction (Local)			Satisfaction (Tourist)		
	Satisfied	Neutral	Dissatisfied	Satisfied	Neutral	Dissatisfied
Male	26%	15%	59%	28%	17%	54%
Female	23%	16%	61%	32%	19%	50%

Table 3
Likelihood (%) of Public Satisfaction level (Satisfied, Neutral, Dissatisfied) by education.

Education	Satisfaction (Local)			Satisfaction (Tourist)		
	Satisfied	Neutral	Dissatisfied	Satisfied	Neutral	Dissatisfied
Some High School	36%	10%	54%	57%	14%	29%
High School	23%	14%	63%	21%	17%	62%
College	24%	17%	59%	36%	13%	51%
University	22%	28%	50%	34%	27%	39%
Post-grad	33%	8%	59%	40%	25%	35%

above 60–70% with ambient TP levels above 25–30 μg TP L^{-1} (Fig. SI 6 bottom left).

3.4. Module 4: Linkage Between Management Strategies and Public Satisfaction

After linking public sentiment with the trophic state of the Bay of Quinte, we used a process-based eutrophication model to assess how nutrient loading management reductions can change nutrient concentrations and subsequently public perception (Kim et al., 2013). We also used the empirical TP-Chl*a* relationship, developed by Zhang et al. (2013), to assess the public perception in response to a potential decline in phytoplankton biomass. Predictions of public satisfaction with water quality are shown at two locations (U_2, U_3) in the upper bay in 2005 (Fig. 9 top row) and 2008 (Fig. 9 bottom row), based on tributary inflow TP concentrations ($TP_{non\text{-}point}$) and flushing rate, ρ ($year^{-1}$), or the number of times the system flushes in one year. These two locations often experience high TP (> 50 μg L^{-1}) and Chl*a* (> 40 μg L^{-1}) concentrations and represent the core area of the Bay of Quinte AOC (see also Kim et al., 2013; Zhang et al., 2013; Arhonditsis et al., 2016). Recent empirical evidence suggests that frequent cyanobacterial blooms, associated with toxic species of the genus *Microcystis,* were observed in these locations, despite a great deal of effort to reduce TP loading over the past three decades (Shimoda et al., 2016). Moreover, a significant amount of ambient phosphorus stemmed from internal nutrient recycling derived from macrophytes and dreissenids (Arhonditsis et al., 2016). When simulating the 2005 conditions, our exercise indicated that public perception in location U2 (a segment from the mouth of Moira River, comprising the Big Bay, Muscote Bay, and North Point Bay) would have been consistently negative regardless of the

Table 4
Likelihood (%) of Public Satisfaction level (Satisfied, Neutral, Dissatisfied) by month.

Month	Satisfaction (Local)			Satisfaction (Tourist)		
	Satisfied	Neutral	Dissatisfied	Satisfied	Neutral	Dissatisfied
May	59%	14%	27%	53%	10%	37%
June	47%	21%	32%	48%	21%	31%
July	15%	16%	69%	14%	20%	66%
August	8%	10%	82%	12%	12%	76%

Table 5
Willingness to donate among groups (local/tourist) by age.

Age	Donation (Local) ($)				Donation (Tourist) ($)			
	< 5	5-50	50-100	>100	< 5	5-50	50-100	>100
< 18	61%	27%	10%	2%	54%	36%	9%	0%
18-25	47%	28%	16%	8%	53%	37%	10%	0%
26-35	47%	44%	7%	2%	54%	32%	12%	2%
36-49	40%	36%	7%	17%	51%	42%	3%	5%
50-65	40%	43%	9%	8%	48%	21%	14%	17%
> 65	52%	30%	5%	12%	35%	29%	18%	18%

$TP_{non\text{-}point}$ and flushing rate considered (Fig. 9 top left panel). When simulating the 2008 conditions, however, not only did perception move closer to neutral from dissatisfied, but also the variability of the flushing rate and $TP_{non\text{-}point}$ induced changes that distinctly affected public perception (Fig. 9 bottom left panel). In location U3 (an area influenced by the inflows of Napanee River, extending to the outlet of Hay Bay), during the 2005 simulations, public perception was more negative than that projected in U2 and quite sensitive to the variability of the hydrodynamic regime and external loading (Fig. 9 top right). Similar to the U2 segment, however, the predicted public perception at U3 improved in the 2008 simulations, and the sensitivity to both flushing rates and tributary TP inflow concentrations also increased (Fig. 9 bottom right panel). An alternative assessment of public satisfaction with water quality, based on predictions of ambient TP concentrations at two locations (U2, U3) in the upper Bay of Quinte in the 2005 and 2008 simulations, is also shown in Fig. SI 7. Overall, our modeling exercise, using the integrated eutrophication-public perception model, showed that public satisfaction appears to be more responsive to phytoplankton biomass rather than ambient TP variability.

4. Discussion

We have presented a novel methodological protocol that strives to integrate public perspective into the criteria-setting process and to identify the optimal water-quality targets that balance effectively between environmental concerns and socioeconomic values. We first focused on addressing two major questions: (*i*) What is the level of public satisfaction with the current state of the Bay of Quinte? (*ii*) How does the socio-economic status of respondents relate to their satisfaction? We answered these questions through our public survey data by estimating the likelihood of a certain public sentiment/ attitude for a given period of the year, location, and demographic group. We then linked typically measured water-quality variables, such as TP and Chl*a* concentrations, to public responses in order to predict the anticipated sentiment of end-users relative to projected changes in the trophic state of the bay. Furthermore, we showcased the ability of the framework to connect the predicted public satisfaction level with a mathematical model that simulates the interplay among phosphorus, phytoplankton, macrophytes, and dreissenids. The presented methodological framework thus aims to serve as a policy analysis tool for setting environmental targets in the Bay of Quinte area, while explicitly considering the public preferences

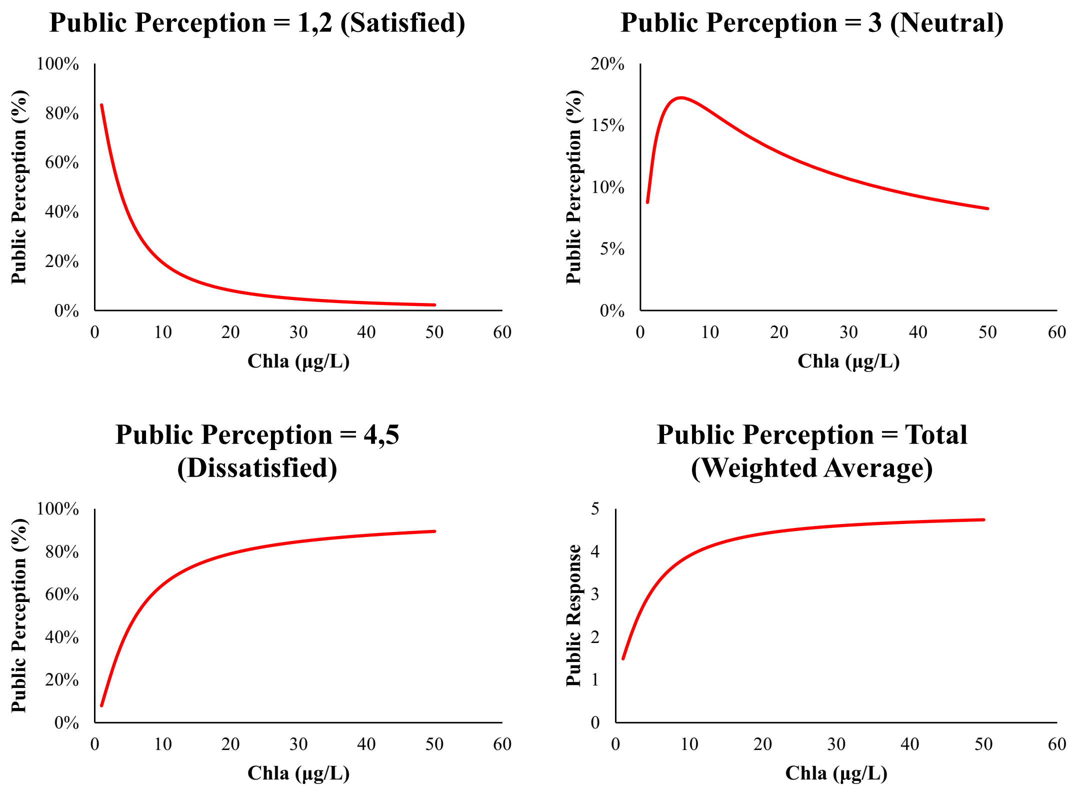


Fig. 8. Public perception of water quality as a function of the total chlorophyll *a* (Chl*a*) concentrations in the Bay of Quinte. The first three panels depict the likelihood of the public to be Satisfied (Public Perception = 1,2), Neutral (Public Perception = 3), and Dissatisfied (Public Perception = 4,5), while the fourth one indicates the change in the sentiment (1 = Completely satisfied, 5 = Strongly dissatisfied) as a function of the ambient Chl*a* concentrations.

and likelihood of satisfaction.

Our public survey primarily showed that both local residents and tourists value the Bay of Quinte as a recreational venue. However, the public is dissatisfied with the current conditions of the bay. The public appeared to be concerned as to whether the fish community is sustainable but are nevertheless ambivalent about the proliferation of macrophytes in the littoral zone, even though they create a favorable fish habitat. Despite the negative sentiment of the survey respondents, our results also suggest that the majority of respondents plan to return to the bay, which in turn may potentially reflect their appreciation that the clarity and odor of the water have improved, fish are being caught, weeds and algae have been reduced, and the bay is closer to being delisted as an AOC. However, their willingness to return may also stem from the fact that the Bay of Quinte is one of the few viable destinations for recreation in the vicinity of the ever-growing Greater Toronto Area. Thus, users recreate in a substandard environment and may be experiencing a psychological discomfort, which could lead either to lower their standards for environmental quality or even to subconsciously raise their perception of the quality of the actual conditions; a process also known as cognitive dissonance (Festinger and Carlsmith, 1959). Simply put, in order to alleviate their emotional discomfort with one of the few recreational destinations in the area, the public may be subconsciously driven to change its perception of what constitutes acceptable water-quality and esthetic conditions (Dickerson et al., 1992; Thøgersen, 2004; Osbaldiston and Schott, 2012; Ferguson, 2016). In either case, the lessening of their degree of dissatisfaction with the prevailing water-quality conditions of the bay could end up having a negative effect on the public support for further investment of funds and other resources to promote ecosystem restoration.

Our findings can be used to draw parallels with other studies that gauged public sentiment towards environmental rehabilitation in other waterbodies, including AOCs. For example, Johnsen et al. (1992) examined public perception and attitudes regarding the restoration efforts in the Lower Green Bay and Fox River AOC, and their survey revealed that the public widely supported the mandate of the local RAP although they were poorly informed about their activities. In a similar manner, assessing public perception across the entire Great Lakes basin, Maack et al. (2014) found that most residents were supportive of policies that have a direct connection to pollution prevention, such as the regulations that reduce the release of pharmaceuticals and other contaminants entering the Great Lakes, even if the cost of drugs increases as a result of the companies' compliance with these regulations. In another study, Marks and Bergelin (2006) surveyed residents' opinions on their views of Saratoga Lake as a water resource, whereby they attempted to shed light on how recreational activities, household economic levels, and degree of proximity to Saratoga Lake influence public perception. The same study challenged the notion that individuals who reside close to a waterbody are the ones that are more engaged with restoration actions. By contrast, our results rendered support to this notion in that residents in proximity to the Bay of Quinte appear to be more motivated and better informed about the local water-quality issues (see our Fig. SI 5). Marks and Bergelin (2006) also found that use of the system for recreational purposes by an individual along with its income were the two primary factors influencing the perception of Saratoga Lake as a new source of drinking water. In particular, the residents believed that using a small lake as a water source would accentuate the water level fluctuations, thus affecting its long-term sustainability for recreation. The same study also suggested that the lack of public understanding of the water quality and contamination issues greatly affects how opinions are formed and proposed that by increasing the level of communication and education within the community, stakeholders might be able to provide better solutions that are beneficial to local residents (Marks and Bergelin, 2006). In our examination of public appreciation with individuals with varying education levels, we found a weakly positive relationship between public satisfaction and education. This could imply that a more educated individual may be more informed of the on-

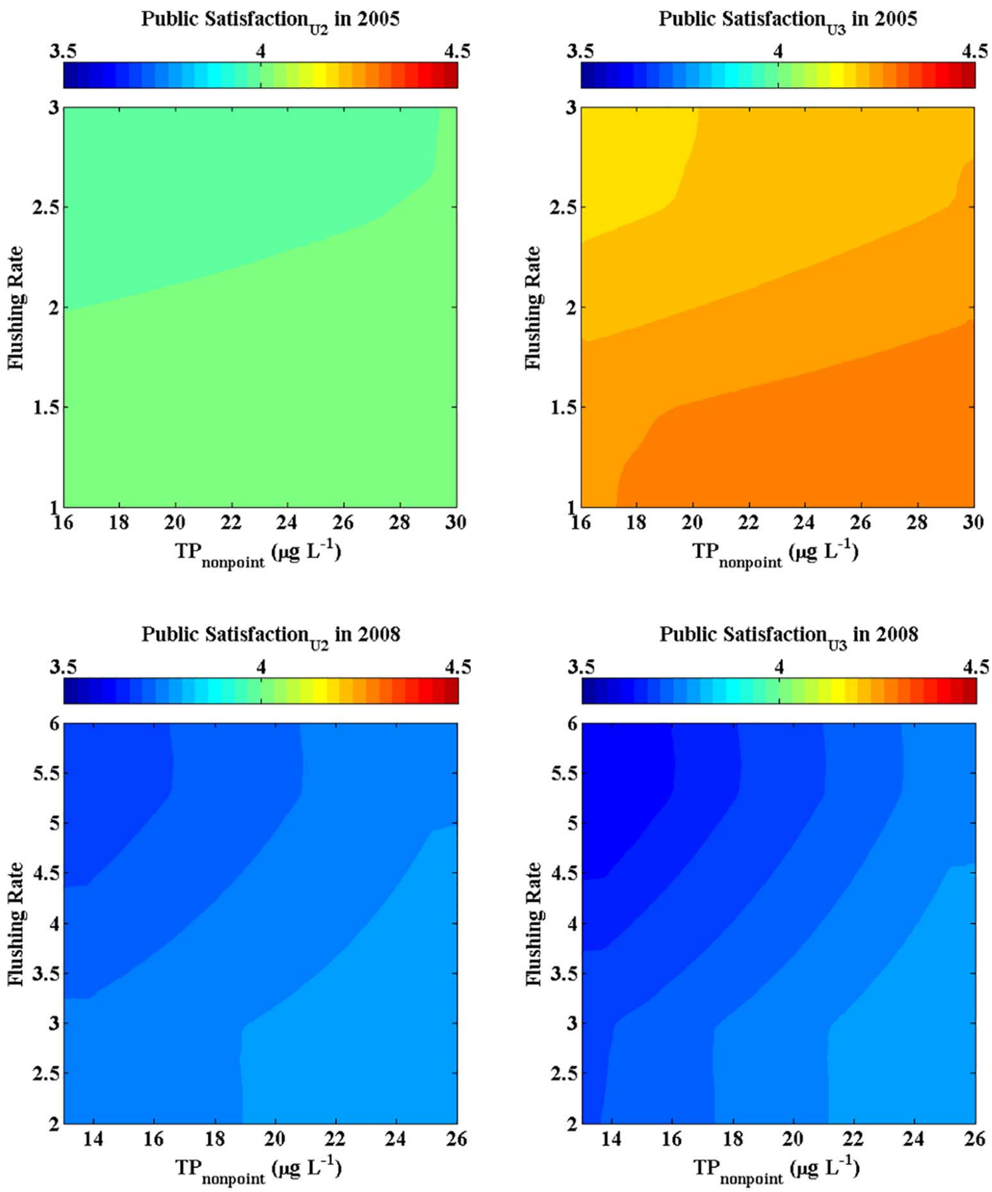


Fig. 9. Prediction of Public Satisfaction (1 = Completely Satisfied, 5 = Strongly Dissatisfied) for water quality at two locations (U2, U3) in the upper Bay of Quinte in 2005 (above) and 2008 (below), based on tributary inflow TP concentrations and Flushing Rate, ρ (year^{-1}) or the number of times the system flushes in one year).

going restoration efforts, as well as more cognizant of the ecosystem complexity and the associated uncertainty.

Our survey identified fishing as one of the main attractions drawing the public to the Bay of Quinte. Recreational fishing provides important economic benefits to the bay, through tourism and other business operations, such as equipment rentals, supplies, and accommodations for anglers (Ewaschuk, 2005). Earlier estimates of angler expenditures showed that $4 million CAD (non-adjusted for inflation) were spent just on rental accommodations between May and October of 1984 and up to $6 million (non-adjusted) in direct expenditures by open-water anglers (Trushinski, 1986). Ice-fishing anglers contributed an additional $1 million (non-adjusted) in direct expenditures during the 1984–85 season (Trushinski, 1986). In 1994, during the peak of the walleye recreational fishery, total expenditure (direct and invested) attributed to walleye angling was estimated to be $11.9 million for the bay (non-adjusted for inflation). However, due to the decline in walleye population beginning in the mid-1990s, total walleye angler expenditures had decreased to $4.9 million in 2000 (Ewaschuk, 2005). Total direct angler expenditure had also decreased from over $6 million during 1996–1997 to $2 million (Ewaschuk, 2005). Nonetheless, angling opportunities for numerous other species, such as largemouth bass and sunfish, have increased, due to the proliferation of aquatic macrophytes, which provide a favorable habitat for these species. Despite the active fishing industry in the bay, the Beneficial Use "Restrictions on Fish Consumption" is still considered impaired due to the high contamination levels recorded. Based on approximately 40 years of contaminant data from different locations in Lake Ontario, Visha et al. (2016) showed that despite the declining trends in PCBs for both lake trout and walleye, the corresponding maximum threshold exposure levels of sensitive demographic groups are frequently exceeded (> 80%). Moreover, new chemicals have started to accumulate; most notably, PBDEs (polybrominated diphenyl ethers), used in fire retardants in plastic consumer products, and PFOS (perfluorooctanesulfonic acid), used in fire-extinguishing foam, stain repellents, and food packaging. Government and industry have taken measures to eliminate these contaminants and reduce their effects, but the Great Lakes will need time to recover and a great deal of remediation effort is still required.

Tourism is one of the top industries to the economy of the Bay of Quinte area, based on the number of related local businesses. In 2012, 3.2 million people visited the bay for tourism purposes (on average, > 3 million per year during 2008–2012), with fishing as the primary attraction for 400,000 of the visitors (McParland, 2016). In monetary terms, tourism represents a $120-million industry, valued at more than $75 million in Belleville alone; money spent in the region from visitors outside a 45 km radius (Williams, 2016a). The sports and event tourism industry alone is worth more than $14 million per year in the region, and it is projected to increase to $40 million (Williams, 2016b). Our survey showed that locals tend to be more dissatisfied than tourists in all demographic categories with the current state of the bay, probably because they live locally and may have higher standards and expectations than visitors. While there is no difference in perception between genders for both local residents and tourists, our survey showed that the age demographic groups are characterized by some variability. Middle-aged and senior citizens (50–65 and > 65) appear to be the most dissatisfied with the prevailing conditions, and this response is somewhat surprising given that these age groups have experienced the historically worst water quality in the Bay of Quinte during the 1970s. We surmise that senior citizens tend to spend more time near the water, and so they have higher standards for the bay. The younger demographic groups (< 18 and 18–25) also tend to be more dissatisfied; a sentiment that may have its roots in the water activities that this group is typically involved, e.g., fishing, canoeing, kayaking, windsurfing, wakeboarding, and beach activities. As mentioned earlier, the education level has little bearing on public perception, since individuals with education levels at two ends of the spectrum did not have distinctly different views. This finding contradicts the popular notion (e.g., Van Liere and Dunlap, 1980; Jones and Dunlap, 1992; Scott and Willits, 1994) that education is moderately (but consistently) associated with greater concern for environment problems (Brody et al., 2005). From the perspective of donation level, there was also no clear evidence that the education level shapes one's perception of environmental hazard risks (Mileti, 1975; Burton et al., 1978; Kunreuther, 1978; Sorensen, 1983; Pilisuk et al., 1987; Saarinen, 1982; Steele et al., 1990).

Efforts to reduce phosphorus in detergents, along with upgrades at local waste water treatment plants, resulted in substantial decline of point-source loadings since the 1970s, prompting a significant decrease in nutrient concentration and phytoplankton biomass levels in the Bay of Quinte (Minns et al., 2011). However, the establishment of invasive zebra and quagga mussels in the mid-1990s complicated the system's restoration. TP concentrations in the post-dreissenid period have since shown significant within-year variability, characterized by relatively low spring and fall levels, 10–15 μg TP L^{-1}, and high summer concentrations, > 50 μg TP L^{-1} (Munawar et al., 2011). This recurring pattern matches closely with the dramatic change in public sentiment, from positive to negative between the beginning and the end of the summer season. The end-of-summer nutrient peaks may stem from the complex interplay among macrophytes, dreissenids, and sediment diagenesis, which appears to modulate nutrient recycling in the Bay of Quinte (Kim et al., 2013). The post-dreissenid period has also been characterized by an increase of the cyanophyte *Microcystis spp*. Although the actual mechanisms that trigger these blooms are not clear yet, the formation of “scums” on the water surface (Jacoby et al., 2000) as well as the fact that some strains of *Microcystis spp*. are toxin producers (Brittain et al., 2000) have profound implications for the esthetics and other beneficial uses in the bay. For example, one of the most common species of this cyanobacterium, *M. aeruginosa*, produces the hepatotoxin microcystin-LR (Repavich et al., 1990; Watson et al., 2008). Interestingly, counter to BUI #9 (Restrictions on Drinking Water Consumption or Taste and Odor Problems) and BUI #10 (Beach Closings), the delisting criteria for BUI #8: “Eutrophication or Undesirable Algae” do not explicitly consider the frequency of violations of total microcystin or microcystin-LR threshold levels.

The delisting objective for Bay of Quinte has been to reduce TP concentration by 25% in the upper Bay of Quinte, such that the seasonal (May–September) average TP concentration is reduced from 40 to 30 $\mu g\,L^{-1}$ and Chl*a* achieves a concentration of 12 $\mu g\,L^{-1}$ in the absence of zebra mussels (with zebra mussels, a further 2–3 $\mu g\,L^{-1}$ Chl*a* reduction should be anticipated) in the upper Bay of Quinte. Based on samples collected from the upper bay (Belleville) during the 2000s, these objectives are relatively frequently achieved (Munawar et al., 2011). More importantly, even if the targeted criteria are met, our model predicts the likelihood of public satisfaction to be < 20%. The likelihood of public satisfaction increases significantly when TP concentrations fall below the critical levels of 20–25 $\mu g\,L^{-1}$, respectively, but this target is extremely difficult to be achieved even under the most optimistic nutrient-loading scenarios (Kim et al., 2013). Given that the predicted level of satisfaction does not change dramatically within the range of TP concentrations attainable in the system, currently or in the near future, it is important to keep in mind that TP is simply a “means to an end” for water quality, and not “the end” itself. Other biological variables such as Chl*a* concentrations, harmful algal blooms, and toxin levels in critical areas for public use may be more sensible (or more “relatable”) for tracking the public satisfaction vis-à-vis the progress of the system during the delisting process. On a positive note, our survey showed that the majority of the public is satisfied when Chl*a* concentrations remain below the 10 $\mu g\,L^{-1}$ threshold and the appreciation level increases dramatically for every incremental decrease of the phytoplankton abundance levels.

We found that a substantial portion of local residents are willing to contribute financially towards the restoration of the Bay of Quinte, and so do tourists who are dissatisfied and have higher expectations for water quality. In the same context, Johnsen et al. (1992) documented that users are not necessarily more supportive of environmental improvements than non-users of a system, especially if support is defined in monetary terms. Instead, both groups argued that financial support should come from industries through pollution fees. Users were also less inclined relative to non-users to support fishing and hunting fees (Johnsen et al., 1992). Davey and Vertrees (1999) also found that the time spent for recreation in a particular system is not always a factor to foster a pro-environmental stance nor are other demographic characteristics. Likewise, we did not find any distinctly different trends between each of the demographic groups examined and their willingness to donate in support of remediation efforts. To promote more active engagement in restoration, Pereira et al. (2005) emphasized the importance of educating the public (through, for example, informal environmental education programs, temporary exhibitions, informative board signs) about ecosystem features and their carrying capacity, the impacts of human activities on ecosystem integrity and beauty, the complexity of management decisions, and the expected time lag between implementation of management strategies and observable outcomes. These activities of social learning may also demonstrate other possible benefits that conservation can bring to local communities (Pinkerton, 1994; Webler et al., 1995; Schusler et al., 2003; Zhang et al., 2016). Previous studies have demonstrated the importance of active local participation in environmental programs to improve landscape perception and appreciation (Múgica and De Lucio, 1996). Gobster (1995) showed that people interacting directly with the landscape usually develop a sense of ecological esthetics and an enhanced understanding and appreciation of ecosystem management activities. Education and outreach are critically important to engaging residents in environmentally sustainable behaviors and provide opportunities for everyone to learn about the importance of environmental protection and stewardship of the Bay of Quinte watershed.

5. Conclusions

Our public survey showed that (*i*) fishing (29%) and beauty of the system (20%) were the main reasons for public to use the Bay of Quinte; (*ii*) among different water-quality problems, the public chose the algal scums (26%) and the integrity of fish populations (22%) as the main issues; (*iii*) the majority of the public (62%) believed that the water is not clear; (*iv*) only 30% of the public, who visited the Bay previously, noticed that the clarity of the water is better now relative to the conditions 5 years ago; (*v*) there was a dramatic change in the sentiment of the public between the beginning and the end of the summer season; and (*vi*) there was a substantial portion of the local residents that were willing to financially contribute towards the restoration of the Bay of Quinte; particularly individuals who had higher expectations about the water quality. Through our modeling exercise, we found that the likelihood of public satisfaction with the bay's status increases significantly only when TP concentrations fall below the critical levels of 20–25 $\mu g\,L^{-1}$, respectively. Nonetheless, this target is difficult to be achieved even under significantly reduced nutrient-loading conditions. Other biological variables such as Chl*a* concentrations, harmful algal blooms, and toxin levels in locations frequently used by the public appeared to more closely influence their satisfaction level. Although the latter finding offers a suite of variables to focus on during the delisting process, it should be noted that the current gap in our understanding of the mechanisms that trigger toxic blooms hampers the ability to draw credible forecasts and thus inevitably adds another layer of uncertainty to the delisting processes.

The Bay of Quinte has a long history of eutrophication, characterized by frequent and spatially extensive algal blooms and predominance of toxic cyanobacteria, and as such is a characteristic example of delisting decisions that have to be made in the face of uncertainty. Given the inevitable risk of unexpected ecosystem responses to the on-going restoration efforts, we believe that the effective integration of the multitude of factors (scientific understanding, public knowledge, and stakeholder perspectives) involved in the environmental policy-making process is the only defensible strategy to impartially determine whether (and when) the system can be delisted as an Area of Concern. Our framework responds to the urgent need for policy analysis tools that extract subjective judgments from public sentiment and directly connect them with the prevailing environmental conditions. Sound public knowledge of the multidimensional properties of ecosystem services are one of the pillars of our approach, which can only be achieved through systematic knowledge building. Our data provide evidence on which groups of the population we need to invest more resources to do so and the characteristics of the population that are more amenable to embrace environmental remedial efforts.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolecon.2018.01.009.

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AN INTEGRATIVE METHODOLOGICAL FRAMEWORK FOR SETTING ENVIRONMENTAL CRITERIA: EVALUATION OF PUBLIC PREFERENCES

[SUPPORTING INFORMATION]

Maryam Ramin[1], Vincent Y.S. Cheng[1], Dong-Kyun Kim[1], Felicity Ni[1], Aisha Javed[1], Noreen Kelly[1], Cindy Yang[1], Sarah Midlane-Jones[2], Shan Mugalingam[2], George B. Arhonditsis[1*]

[1]Ecological Modelling Laboratory,
Department of Physical & Environmental Sciences, University of Toronto,
Toronto, Ontario, Canada, M1C1A4

[2]Lower Trent Conservation,
Trenton, Ontario, Canada, K8V 5P4

* Corresponding author
E-mail: georgea@utsc.utoronto.ca, Tel.: +1 416 208 4858; Fax: +1 416 287 7279.

Section A – Figures and Tables

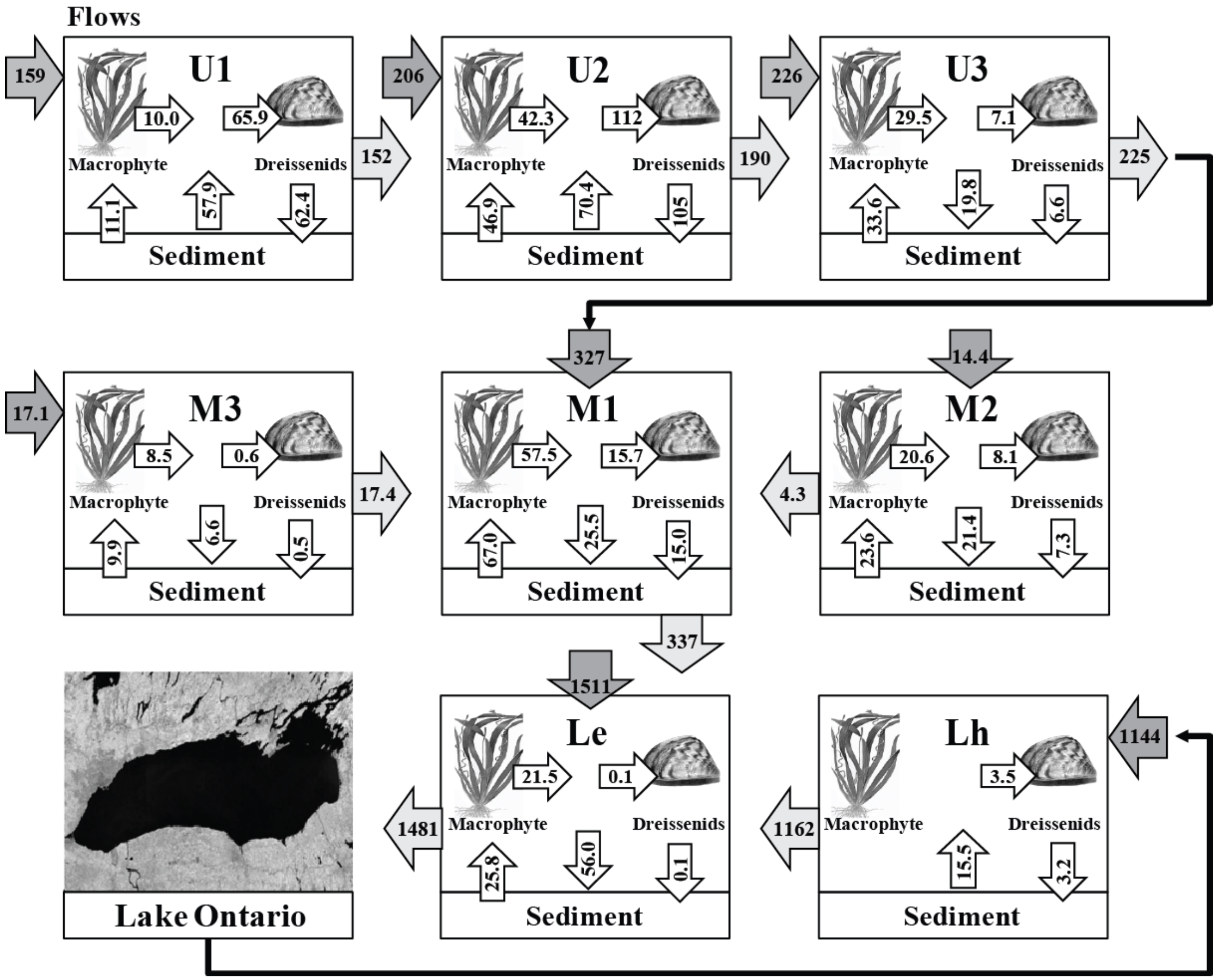

Figure SI-1: Spatial variability of the various external and internal Total Phosphorus (TP) flux rates in the Bay of Quinte. Arrow directions indicate the net contributions (sources or sinks) of the various compartments (Water column, Sediment, Macrophytes, Dreissenid mussels). Darker grey arrows show the TP inflows in a spatial segment, while the lighter grey ones depict the corresponding outflows.

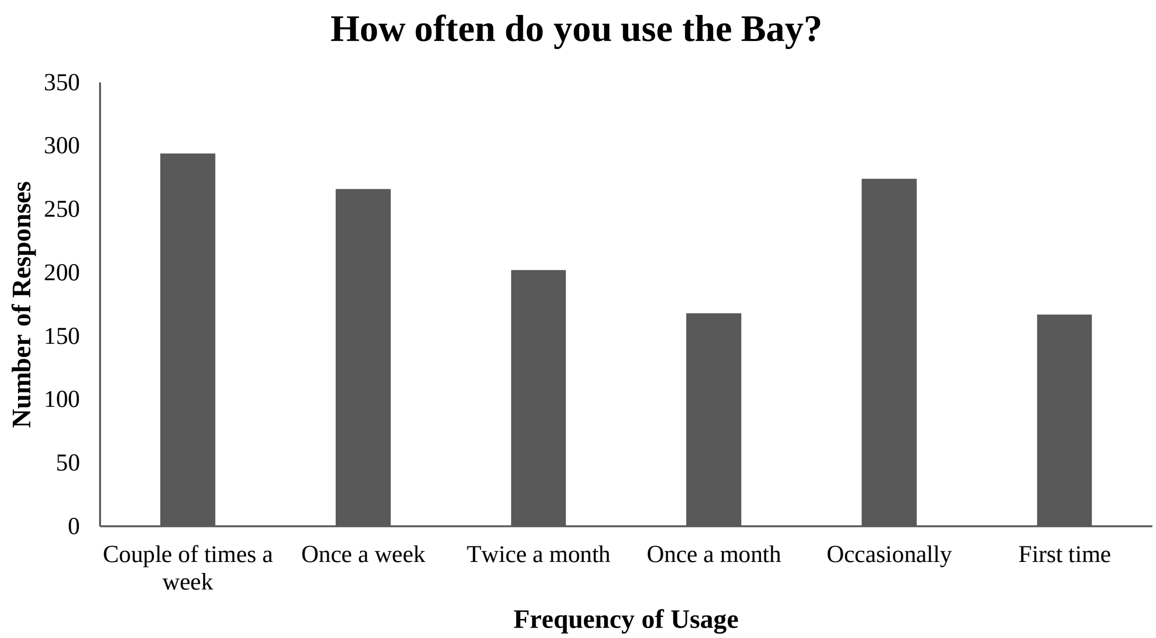

Figure SI-2: Frequency of Bay usage, as reported at the time of survey (summers of 2013-2014).

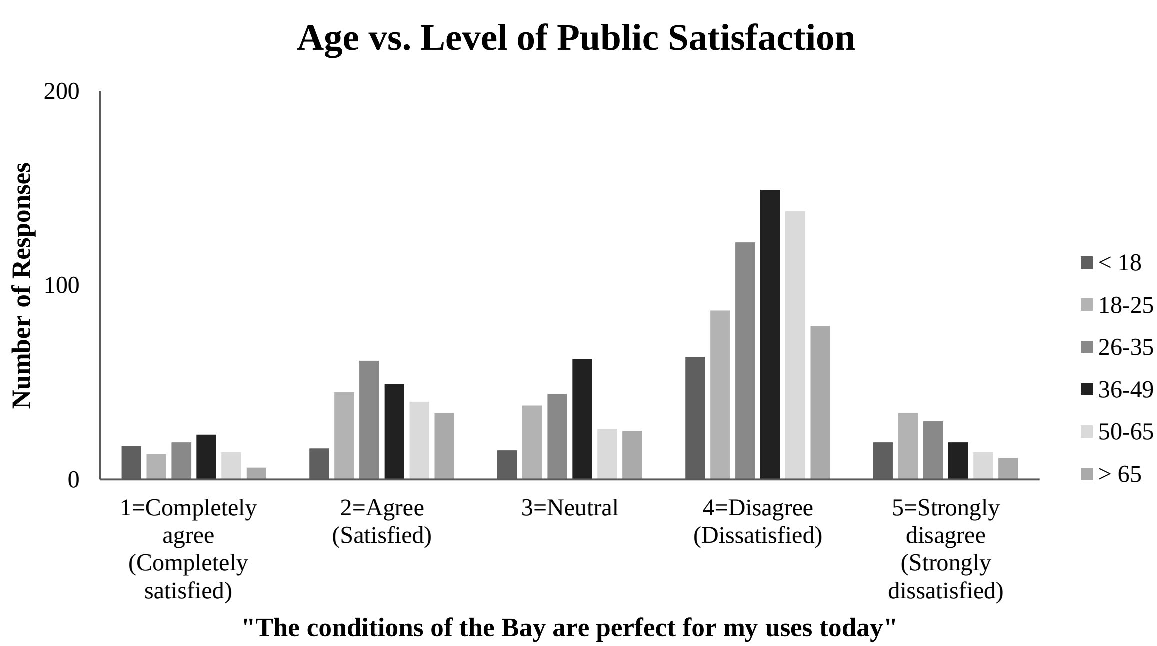

Figure SI-3: Levels of public satisfaction with the Bay across different age groups, as reported at the time of survey (summers of 2013-2014).

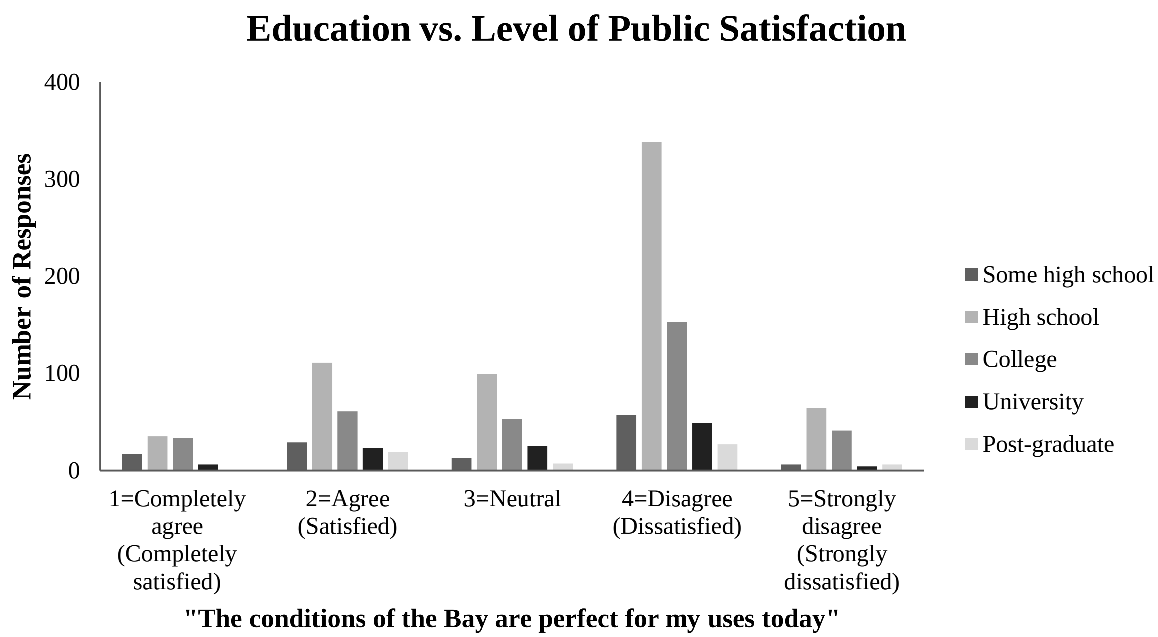

Figure SI-4: Levels of public satisfaction with the Bay across different education levels, as reported at the time of survey (summers of 2013-2014).

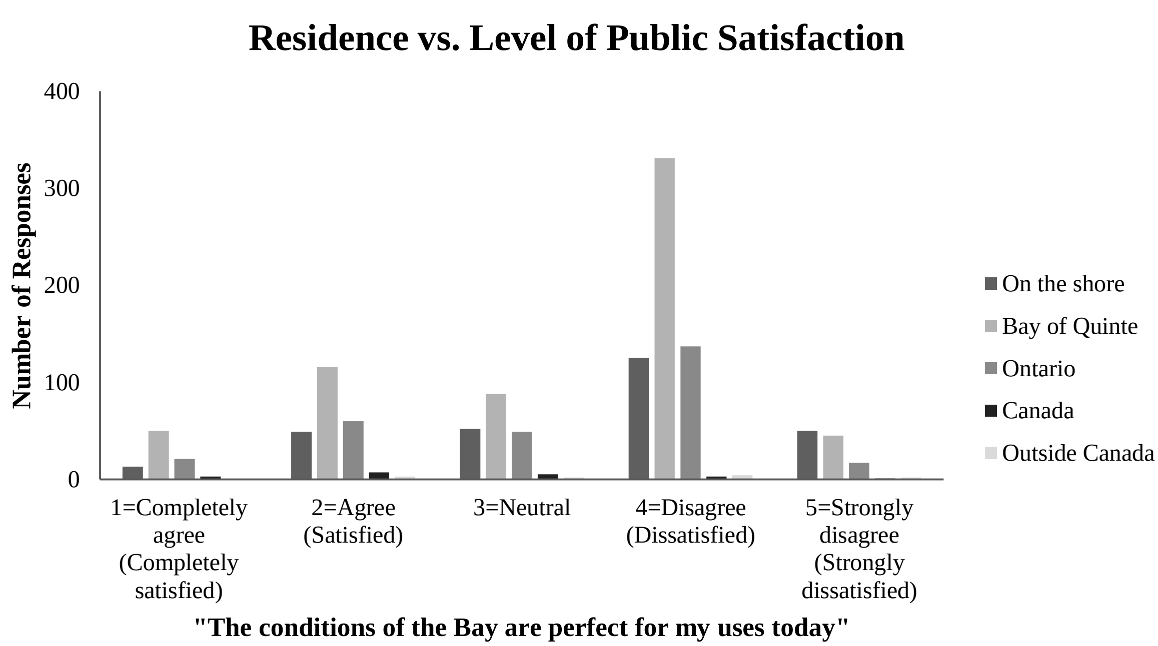

Figure SI-5: Levels of public satisfaction across different areas of residence, as reported at the time of survey (summers of 2013-2014).

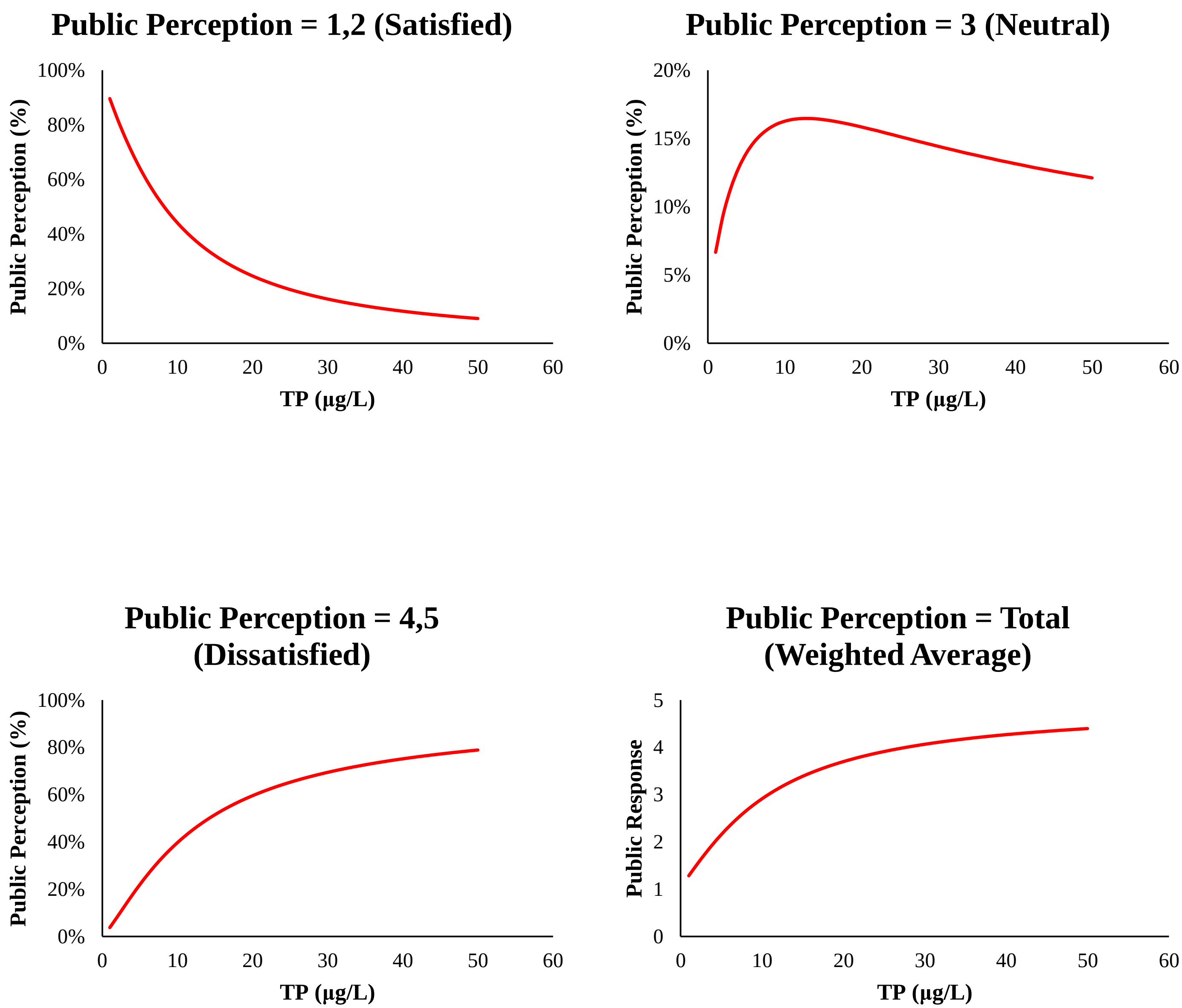

Figure SI-6: Public perception of water quality as a function of Total Phosphorus (TP) concentrations in the Bay of Quinte. The first three panels depict the likelihood of the public to be Satisfied (Public Perception=1,2), Neutral (Public Perception=3), and Dissatisfied (Public Perception=4,5), while the fourth one indicates the change in the sentiment (1=Completely satisfied, 2=Satisfied, 3=Neutral, 4=Dissatisfied, and 5=Strongly dissatisfied) as a function of the corresponding TP concentrations.

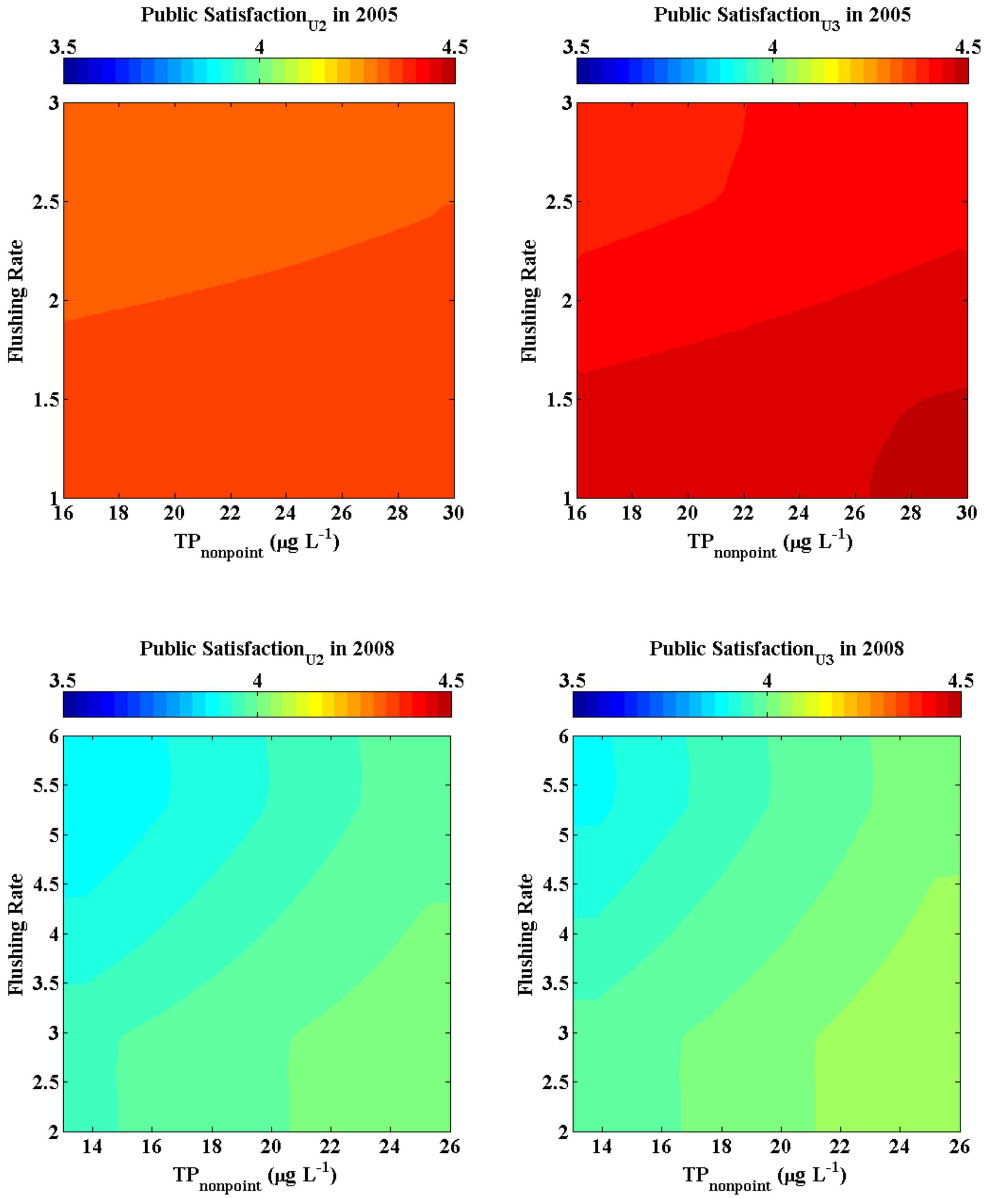

Figure SI-7: Prediction of Public Satisfaction (1=Completely satisfied, 2=Satisfied, 3=Neutral, 4=Dissatisfied, and 5=Strongly dissatisfied) for water quality at two locations (U2,U3) in the upper Bay of Quinte in 2005 (above) and 2008 (below), based on predicted Total Phosphorus (TP) concentrations and Flushing Rate, ρ (*year*$^{-1}$): the number of times a lake flushes in one year, or the reciprocal of Hydraulic Retention Time (HRT)).

Table SI-1: Likelihood (%) of Public Satisfaction (1=Completely Satisfied, 2=Satisfied, 3=Neutral, 4=Dissatisfied, and 5=Strongly Dissatisfied) by month and age.

	Age: < 18					*Age: 18-25*					*Age: 26-35*					*Age: 36-49*					*Age: 50-65*					*Age: > 65*				
	Public Satisfaction					**Public Satisfaction**					**Public Satisfaction**					**Public Satisfaction**					**Public Satisfaction**					**Public Satisfaction**				
Tourist	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
May	11%	15%	19%	55%	0%	8%	43%	13%	33%	3%	19%	24%	17%	33%	7%	20%	33%	11%	34%	2%	23%	16%	9%	48%	4%	9%	52%	7%	31%	1%
June	7%	17%	33%	43%	0%	5%	48%	21%	24%	2%	11%	28%	29%	26%	6%	12%	40%	20%	27%	2%	16%	21%	17%	42%	3%	5%	59%	11%	23%	1%
July	2%	4%	21%	72%	0%	2%	13%	18%	55%	13%	4%	6%	19%	46%	25%	5%	10%	16%	60%	8%	5%	4%	10%	67%	13%	3%	19%	12%	60%	6%
August	0%	5%	17%	78%	0%	0%	18%	15%	60%	7%	0%	10%	18%	58%	15%	0%	15%	14%	68%	4%	0%	6%	9%	78%	7%	0%	25%	9%	63%	3%
Local																														
May	41%	26%	8%	18%	6%	21%	35%	17%	18%	9%	17%	54%	9%	17%	3%	25%	30%	21%	21%	3%	17%	48%	10%	23%	2%	10%	40%	17%	28%	4%
June	33%	22%	13%	25%	7%	15%	27%	25%	23%	10%	13%	46%	14%	24%	3%	18%	23%	30%	26%	3%	13%	39%	15%	31%	2%	7%	30%	23%	35%	4%
July	7%	8%	11%	55%	20%	3%	9%	19%	46%	24%	3%	18%	13%	58%	9%	3%	8%	24%	57%	8%	3%	13%	12%	67%	6%	1%	9%	16%	64%	10%
August	0%	6%	7%	64%	23%	0%	6%	12%	52%	29%	0%	13%	9%	67%	11%	0%	6%	16%	68%	10%	0%	10%	8%	76%	7%	0%	6%	10%	72%	12%

Table SI-2: Likelihood (%) of Public Satisfaction (1=Completely Satisfied, 2=Satisfied, 3=Neutral, 4=Dissatisfied, and 5=Strongly Dissatisfied) by location and age.

	Age: < 18					*Age: 18-25*					*Age: 26-35*					*Age: 36-49*					*Age: 50-65*					*Age: > 65*				
	Public Satisfaction					**Public Satisfaction**					**Public Satisfaction**					**Public Satisfaction**					**Public Satisfaction**					**Public Satisfaction**				
Tourist	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Belleville	2%	5%	27%	66%	0%	2%	19%	20%	51%	8%	4%	8%	25%	45%	19%	4%	13%	19%	57%	5%	5%	6%	14%	67%	9%	3%	29%	12%	52%	4%
Mohawk Bay	1%	3%	32%	63%	0%	1%	14%	25%	51%	9%	2%	5%	30%	44%	18%	3%	10%	24%	58%	5%	3%	4%	17%	67%	9%	2%	22%	16%	55%	4%
Picton	3%	5%	24%	68%	0%	3%	17%	17%	52%	11%	4%	7%	21%	44%	24%	6%	12%	17%	58%	7%	6%	5%	12%	66%	11%	4%	26%	11%	53%	5%
Quinte West	0%	8%	11%	80%	0%	0%	27%	7%	58%	7%	0%	14%	10%	59%	17%	0%	20%	7%	67%	5%	0%	9%	5%	78%	7%	0%	38%	4%	55%	3%
Trenton	8%	17%	24%	50%	0%	7%	49%	13%	27%	4%	13%	25%	20%	30%	11%	14%	37%	13%	33%	3%	18%	19%	12%	46%	6%	7%	61%	7%	23%	2%
Local																														
Belleville	9%	11%	11%	54%	15%	5%	14%	20%	43%	18%	3%	20%	13%	56%	7%	5%	10%	25%	53%	7%	3%	16%	12%	63%	5%	2%	14%	19%	57%	7%
Mohawk Bay	2%	6%	8%	63%	21%	1%	8%	15%	51%	25%	1%	12%	10%	67%	10%	1%	6%	18%	65%	10%	1%	10%	9%	74%	7%	1%	8%	14%	67%	10%
Picton	13%	12%	8%	45%	22%	7%	15%	15%	36%	27%	5%	23%	11%	50%	12%	7%	12%	21%	49%	11%	5%	20%	10%	57%	9%	3%	17%	16%	52%	12%
Quinte West	0%	12%	11%	73%	4%	0%	16%	20%	59%	5%	0%	20%	11%	67%	2%	0%	11%	22%	66%	2%	0%	16%	10%	73%	1%	0%	15%	16%	68%	2%
Trenton	30%	19%	11%	30%	10%	16%	26%	20%	25%	13%	11%	38%	13%	32%	5%	17%	20%	26%	32%	5%	12%	33%	13%	38%	4%	8%	30%	21%	35%	6%

Table SI-3: Likelihood (%) of Public Satisfaction (1=Completely Satisfied, 2=Satisfied, 3=Neutral, 4=Dissatisfied, and 5=Strongly Dissatisfied) by month and gender.

	Male					*Female*				
	Public Satisfaction					**Public Satisfaction**				
Tourist	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
May	17%	28%	12%	35%	9%	16%	32%	15%	32%	5%
June	11%	33%	19%	30%	6%	10%	37%	24%	26%	4%
July	4%	8%	14%	56%	18%	4%	10%	19%	55%	12%
August	0%	11%	10%	72%	8%	0%	13%	13%	69%	5%
Local										
May	20%	43%	13%	17%	7%	27%	34%	14%	21%	5%
June	14%	35%	20%	24%	6%	18%	27%	21%	29%	4%
July	3%	13%	16%	55%	12%	3%	10%	16%	63%	8%
August	0%	9%	10%	63%	18%	0%	6%	10%	72%	11%

Table SI-4: Likelihood (%) of Public Satisfaction (1=Completely Satisfied, 2=Satisfied, 3=Neutral, 4=Dissatisfied, and 5=Strongly Dissatisfied) by location and gender.

	Male					*Female*				
	Public Satisfaction					**Public Satisfaction**				
Tourist	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Belleville	3%	13%	16%	53%	14%	4%	15%	21%	51%	9%
Mohawk Bay	2%	8%	19%	58%	12%	2%	10%	25%	56%	7%
Picton	6%	9%	16%	53%	16%	6%	11%	21%	52%	11%
Quinte West	0%	17%	5%	70%	9%	0%	19%	7%	69%	5%
Trenton	13%	30%	13%	34%	9%	12%	34%	17%	32%	5%
Local										
Belleville	4%	16%	17%	51%	12%	5%	12%	17%	59%	7%
Mohawk Bay	1%	9%	12%	62%	15%	1%	6%	12%	71%	9%
Picton	6%	18%	13%	44%	19%	8%	13%	14%	53%	12%
Quinte West	0%	18%	15%	63%	4%	0%	12%	15%	71%	3%
Trenton	13%	33%	16%	29%	8%	17%	25%	18%	36%	5%

Table SI-5: Likelihood (%) of Public Satisfaction (1=Completely Satisfied, 2=Satisfied, 3=Neutral, 4=Dissatisfied, and 5=Strongly Dissatisfied) by month and education.

	Some High School					*High School*					*College*					*University*					*Post-graduate*				
	Public Satisfaction					**Public Satisfaction**					**Public Satisfaction**					**Public Satisfaction**					**Public Satisfaction**				
Tourist	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
May	23%	31%	11%	25%	10%	16%	29%	17%	31%	6%	27%	25%	9%	31%	7%	12%	42%	15%	29%	1%	0%	48%	13%	32%	7%
June	14%	38%	19%	22%	8%	9%	34%	27%	26%	5%	16%	33%	17%	28%	6%	6%	47%	23%	23%	1%	0%	52%	19%	24%	4%
July	6%	9%	14%	49%	23%	3%	7%	18%	58%	13%	6%	7%	11%	60%	16%	3%	13%	20%	63%	2%	0%	13%	15%	59%	14%
August	0%	13%	11%	64%	12%	0%	10%	13%	71%	6%	0%	9%	8%	75%	8%	0%	16%	13%	70%	1%	0%	16%	10%	67%	6%
Local																									
May	29%	37%	7%	25%	2%	24%	44%	11%	18%	3%	21%	34%	15%	24%	6%	17%	30%	24%	25%	4%	0%	68%	6%	21%	5%
June	21%	33%	12%	32%	2%	17%	38%	19%	22%	3%	14%	28%	24%	28%	6%	10%	23%	36%	27%	3%	0%	60%	9%	26%	5%
July	4%	10%	9%	71%	5%	4%	13%	17%	58%	9%	2%	8%	16%	59%	15%	2%	7%	26%	57%	8%	0%	20%	7%	59%	13%
August	0%	6%	6%	79%	8%	0%	8%	11%	65%	15%	0%	5%	10%	62%	24%	0%	4%	17%	64%	14%	0%	12%	5%	62%	21%

Table SI-6: Likelihood (%) of Public Satisfaction (1=Completely Satisfied, 2=Satisfied, 3=Neutral, 4=Dissatisfied, and 5=Strongly Dissatisfied) by location and education.

	Some High School					*High School*					*College*					*University*					*Post-graduate*				
	Public Satisfaction					**Public Satisfaction**					**Public Satisfaction**					**Public Satisfaction**					**Public Satisfaction**				
Tourist	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Belleville	7%	20%	18%	41%	13%	3%	11%	21%	55%	10%	6%	12%	15%	54%	13%	2%	15%	23%	59%	2%	0%	17%	17%	54%	11%
Mohawk Bay	5%	15%	22%	44%	13%	2%	8%	24%	57%	9%	4%	10%	18%	56%	12%	1%	11%	26%	59%	2%	0%	13%	20%	56%	11%
Picton	11%	19%	14%	42%	14%	4%	11%	17%	58%	10%	9%	12%	12%	54%	13%	3%	15%	18%	62%	2%	0%	17%	14%	57%	12%
Quinte West	0%	23%	7%	59%	10%	0%	13%	7%	74%	6%	0%	14%	5%	72%	8%	0%	16%	7%	75%	1%	0%	18%	6%	69%	7%
Trenton	21%	39%	13%	20%	7%	11%	30%	18%	34%	7%	21%	30%	12%	30%	8%	7%	38%	19%	35%	1%	0%	44%	15%	33%	8%
Local																									
Belleville	9%	18%	11%	58%	4%	4%	15%	17%	54%	10%	4%	11%	19%	53%	13%	3%	9%	30%	51%	7%	0%	24%	8%	56%	12%
Mohawk Bay	2%	11%	8%	73%	6%	1%	8%	12%	65%	13%	1%	6%	13%	63%	18%	1%	5%	22%	62%	10%	0%	13%	6%	65%	16%
Picton	14%	21%	8%	50%	6%	7%	17%	13%	48%	15%	6%	13%	14%	47%	20%	5%	12%	24%	48%	11%	0%	27%	6%	49%	18%
Quinte West	0%	18%	10%	71%	1%	0%	15%	14%	67%	3%	0%	11%	16%	68%	4%	0%	9%	25%	63%	2%	0%	23%	7%	66%	4%
Trenton	25%	34%	9%	29%	2%	14%	33%	16%	32%	6%	14%	26%	19%	33%	8%	11%	22%	30%	33%	4%	0%	52%	8%	33%	7%

Table SI-7: Willingness to donate among groups (local/tourist) by gender.

Gender	**Donation (Local)** *($)*				**Donation (Tourist)** *($)*			
	< 5	*5-50*	*50-100*	*>100*	*< 5*	*5-50*	*50-100*	*>100*
Male	52%	31%	7%	10%	60%	30%	8%	2%
Female	40%	41%	12%	7%	43%	39%	10%	8%

Table SI-8: Willingness to donate among groups (local/tourist) by education.

Education	**Donation (Local)** *($)*				**Donation (Tourist)** *($)*			
	< 5	*5-50*	*50-100*	*>100*	*< 5*	*5-50*	*50-100*	*>100*
Some High School	73%	13%	11%	2%	57%	29%	14%	0%
High School	45%	36%	9%	9%	56%	25%	11%	8%
College	38%	45%	6%	10%	47%	42%	6%	5%
University	39%	42%	5%	15%	54%	36%	7%	3%
Post-graduate	67%	24%	5%	5%	30%	55%	15%	0%

Table SI-9: Willingness to donate among groups (local/tourist) by month.

Month	**Donation (Local)** *($)*				**Donation (Tourist)** *($)*			
	< 5	*5-50*	*50-100*	*>100*	*< 5*	*5-50*	*50-100*	*>100*
May	45%	36%	8%	11%	57%	33%	9%	0%
June	46%	31%	11%	12%	52%	38%	6%	3%
July	47%	39%	8%	6%	49%	33%	13%	5%
August	47%	37%	8%	8%	47%	33%	4%	15%

Table SI-10: Willingness to donate by group (local/tourist).

Group	**Donation (Total)** *($)*			
	< 5	*5-50*	*50-100*	*>100*
Local	47%	36%	9%	9%
Tourist	51%	35%	9%	5%

Table SI-11: Willingness to donate among groups (local/tourist) by level of Public Satisfaction (1,2=Satisfied, 3=Neutral, 4,5=Dissatisfied).

	Donation (Local) *($)*				**Donation (Tourist)** *($)*			
Public Satisfaction	*< 5*	*5-50*	*50-100*	*>100*	*< 5*	*5-50*	*50-100*	*>100*
1,2=Satisfied	44%	34%	11%	10%	43%	52%	4%	1%
3=Neutral	44%	39%	10%	7%	53%	30%	13%	4%
4,5=Dissatisfied	48%	36%	8%	8%	54%	27%	10%	8%

Table SI-12: Willingness to donate by month and level of Public Satisfaction (1=Completely satisfied, 2=Satisfied, 3=Neutral, 4=Dissatisfied, and 5=Strongly dissatisfied).

	1= Completely satisfied				*2= Satisfied*				*3= Neutral*				*4= Dissatisfied*				*5= Strongly dissatisfied*			
	Public Donation ($)				**Public Donation ($)**				**Public Donation ($)**				**Public Donation ($)**				**Public Donation ($)**			
Tourist	**< 5**	**5-50**	**50-100**	**>100**	**< 5**	**5-50**	**50-100**	**>100**	**< 5**	**5-50**	**50-100**	**>100**	**< 5**	**5-50**	**50-100**	**>100**	**< 5**	**5-50**	**50-100**	**>100**
May	57%	35%	4%	3%	48%	44%	7%	1%	53%	25%	20%	2%	59%	21%	17%	3%	55%	31%	13%	2%
June	53%	37%	3%	7%	46%	47%	5%	2%	54%	28%	14%	4%	58%	24%	11%	7%	54%	34%	9%	4%
July	41%	43%	4%	13%	35%	55%	7%	4%	41%	33%	19%	7%	45%	28%	16%	12%	42%	40%	12%	6%
August	39%	42%	1%	18%	36%	57%	1%	7%	46%	38%	3%	13%	48%	30%	2%	19%	45%	43%	2%	10%
Local																				
May	54%	29%	7%	10%	40%	39%	10%	11%	43%	40%	9%	9%	50%	35%	7%	9%	34%	35%	8%	23%
June	55%	24%	10%	12%	41%	34%	13%	13%	45%	34%	11%	10%	51%	30%	9%	10%	35%	29%	10%	26%
July	55%	31%	8%	6%	41%	42%	11%	7%	44%	42%	9%	5%	51%	37%	7%	5%	37%	39%	9%	15%
August	55%	29%	9%	7%	41%	40%	12%	7%	45%	40%	10%	5%	52%	36%	7%	5%	38%	38%	9%	15%

Table SI-13: Willingness to donate by location and level of Public Satisfaction (1=Completely satisfied, 2=Satisfied, 3=Neutral, 4=Dissatisfied, and 5=Strongly dissatisfied).

	1= Completely satisfied				*2= Satisfied*				*3= Neutral*				*4= Dissatisfied*				*5= Strongly dissatisfied*			
	Public Donation ($)				**Public Donation ($)**				**Public Donation ($)**				**Public Donation ($)**				**Public Donation ($)**			
Tourist	**< 5**	**5-50**	**50-100**	**>100**	**< 5**	**5-50**	**50-100**	**>100**	**< 5**	**5-50**	**50-100**	**>100**	**< 5**	**5-50**	**50-100**	**>100**	**< 5**	**5-50**	**50-100**	**>100**
Belleville	59%	36%	3%	2%	48%	46%	5%	1%	54%	30%	14%	2%	57%	28%	12%	2%	51%	38%	10%	1%
Mohawk Bay	50%	34%	6%	10%	42%	45%	10%	3%	42%	27%	24%	8%	43%	24%	21%	13%	41%	34%	17%	7%
Picton	51%	32%	3%	14%	45%	45%	6%	5%	46%	27%	15%	12%	46%	24%	12%	18%	45%	35%	11%	10%
Quinte West	42%	25%	0%	33%	45%	40%	0%	15%	42%	24%	1%	34%	37%	18%	0%	45%	42%	30%	0%	28%
Trenton	51%	39%	3%	7%	41%	51%	6%	2%	46%	33%	15%	6%	48%	30%	13%	9%	44%	41%	10%	5%
Local																				
Belleville	53%	26%	11%	10%	39%	37%	14%	9%	43%	39%	11%	7%	50%	37%	8%	6%	36%	38%	9%	17%
Mohawk Bay	55%	22%	12%	11%	42%	32%	16%	10%	46%	34%	13%	7%	53%	32%	9%	6%	38%	33%	11%	18%
Picton	54%	27%	11%	9%	40%	38%	13%	8%	44%	40%	11%	6%	50%	37%	7%	5%	37%	39%	9%	15%
Quinte West	47%	24%	15%	14%	35%	33%	18%	14%	39%	36%	15%	10%	46%	34%	11%	9%	31%	33%	13%	23%
Trenton	55%	26%	7%	11%	42%	38%	9%	11%	45%	40%	7%	8%	52%	37%	5%	7%	37%	38%	6%	19%

Section B - Questionnaire of the Public Survey

Please respond to the following questions for the conditions and your uses today. ***Date:________________***

1. What are you using the Bay of Quinte (BofQ) usually for (check all that apply)?

____Swimming

____Fishing

____Bay Beauty/Tanning

____Picnicking

____Jet skiing

____Canoeing/Kayaking

____Motorized boating

____Tubing/Water skiing

____Other (specify)____________________________

2. How often do you use the Bay?

____Couple times a week

____Once a week

____Twice a month

____Once a month

____Occasionally

____First time

3. What qualities of the water do you believe are important to be able to use the Bay (check all that apply)?

____Water temperature

____Little water odour

____Little water colour

____No algal scums

____Sport fish populations

____Little dirt in the water

____Other (specify)_____________________________

4. The water of the Bay is clear today.

____Completely agree

____Agree

____Neutral

____Disagree

____Strongly disagree

5. What is the colour of the water?

____Blue

____Green

____Brown

____Brownish / Green

____Other (specify)______________________________

6. The conditions of the Bay is satisfactory for my use(s) today.

____Completely agree

____Agree

____Neutral

____Disagree

____Strongly disagree

7. Do you find the aquatic plants to be a major disturbance of the quality of water?

____Yes

____No

____Somewhat

8. Do you still feel the same way, if we tell you that those aquatic plants are favourable habitats for fish?

____Yes

____No

____Somewhat

9. If you went fishing, how many fish have you caught today?

____0

____1

____2

____3-4

____5-6

____more than 6

____N/A

10. If you went fishing, what type and how many of each fish have you caught today (if applicable)?

____Walleye

____Large mouth

____Smallmouth

____Pike

____Panfish

____N/A

____Other (specify)____________

11. Is this your first visit?

____Yes

____No

11a. If No, how often have you visited this place?

____Within last year

____Within last 5 years

____More than 5 years

11b. What changes have you noticed?

____Clarity better

____Clarity worst

____Smell better

____Smell worst

____More fish catch

____Less fish catch

____More weeds

____Less weeds

____More algae

____Less algae

____Other (Specify) ____________

12. Do you know that the BofQ is categorized as an Area of Concern (AOC) (i.e. a system with serious environmental problems)?

____Yes

____No

13. Do you think that the BofQ is close to being delisted as an Area of Concern?

____Yes

____No

14. Will you come back to this place?

____Yes

____No

Optional Demographic Information

A. What is your age?

____Under 18

____18-25

____26-35

____36-49

____50-65

____65 or older

B. What is your gender?

____Male

____Female

C. What is your race or ethnicity?

____Caucasian/White

____Asian

____African

____Indian (First Nation)

____Other (specify)________________________

D. What is the highest level of education you have completed?

____Some High School

____High School degree

____College degree

____University degree

____Post-graduate university degree

E. Where do you live?

____On the shore

____Bay of Quinte region

____Ontario

____Canada

____Outside Canada

F. How much is your total annual household income?

____Less than $30,000

____$30,000$ to $65,000

____$65,000-$90,000

____>$90,000

G. How would you characterize your political point of view?

____Liberal

____Conservative

____Other (specify)________________________

H. If the local communities or NGO's ask for some help to protect the Bay, to what extend are you willing to participate?

I am a tourist	**I am local**
I am willing to contribute lower than $5	I am willing to contribute lower than $5
I am willing to contribute $5 to $50	I am willing to contribute $5 to $50
I am willing to contribute $50 to $100	I am willing to contribute $50 to $100
I am willing to contribute more than $100	I am willing to contribute more than $100