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Research article

Understanding the preferences of water users in a context of cyanobacterial blooms in Quebec

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ABSTRACT

Algal blooms, whether they are harmful or more akin to a nuisance, do pose negative impacts on human well-being. In the province of Quebec, excessive phosphorus that contributes to the problem of cyanobacterial blooms comes mainly from non-point sources. Limited regulation on the management of this nutrient leads to its strong accumulation in soils and, combined to climate change effects, contributes to increasing the magnitude of the effects of algal blooms on humans and the environment. The presence of cyanobacteria in water has impacts on its colour, texture and odour, in addition to posing threats to the health of recreationists, as some cyanobacteria are known to release toxins during blooms. This research focuses on studying the impacts of algal bloom events on recreationists and people living close to affected waterbodies. More specifically, we explore the preferences of individuals for different ecosystem services (ES), mainly cultural ES, provided by waterbodies (i.e., recreational activities, aesthetic aspects, and ecological health). We also estimate the average willingness to pay, financed through an increase in municipal taxation, for mechanisms that would allow the resolution of this issue. To achieve these objectives, we use a choice experiment approach, enclosed in a questionnaire that was carried out in person to 252 people. Conditional logit with and without interactions, and a random parameter logit (mixed logit) are alternatively used. Results show that individuals value first their ability to perform recreational activities, followed by the ecological health of waterbodies, and the aesthetic aspects (i.e., odour and visual aspects). Interestingly, the fact that people reported taking part in fishing activities influenced the way they prioritized ES in the choice modelling exercises. Based on the most robust model, we estimate the average willingness to pay at CA$353/household per year to fund a suite of solutions aimed at improving overall water quality.

1. Introduction

Eutrophication is a naturally occurring phenomenon that has increased in magnitude through anthropogenic practices and climate changes (Wolf and Klaiber, 2017). One of the main symptoms of eutrophication is cyanobacterial blooms which are occurring worldwide (Hernández-Prieto et al., 2014). Ecological effects of eutrophication in waterbodies include increased vegetal biomass and oxygen depletion, leading to changes in food web structures, ecological habitats, and in communities of species (Pinay et al., 2017). They can also include the proliferation of cyanobacteria and the release of cyanotoxins. Socio-economic effects involve human diseases caused by the release of cyanotoxins, the restriction of recreational activities, foul smell, changes in water colour and texture, all affecting individual well-being. An anthropologic study (Dubé, 2012) carried out among riparian areas of three water bodies in Quebec outlined the fact that cyanobacterial blooms are a source of disgust or disutility for many individuals. Furthermore, some people who had direct contact with cyanobacteria have been so disgusted that they stopped going into lakes at all (Dubé, 2012). This could be considered to be anecdotal evidence, but it highlights the real issue of the impacts of cyanobacterial blooms on the well-being of recreationists, residents living near waterbodies, and on the

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recreotourism industry. Lake and river ecosystems are largely regulated at the watershed level (Bedient et al., 2013) and, in this somewhat closed ecosystem-management unit, water is a public good. Although access of individuals to waterbodies can be restricted by regulation or privatization of shorelines, water itself moves freely. Thus, contaminants can be brought in waterbodies from different sections of the watershed, following its hydrogeochemical structure (Bedient et al., 2013). Excess phosphorus, an important element causing cyanobacterial blooms in lakes, comes mainly from non-point sources like agricultural practices, municipal waste, and erosion from roads and construction sites (Anderson et al., 2002). Phosphorus also has the property of remaining in soils and sediments for decades, and it is thus bio-available for a long period (Reed-Andersen et al., 2000). In this context, a complete halt to the use of phosphorus in fertilizers, and pesticides will not completely stop blooms right away (Sattari et al., 2012; Sharpley et al., 2013). Despite this situation, a change in practices, through stricter regulations or incentives, will likely be the most effective method to eliminate the issue in the long run (Chouinard and Bérubé, 2015).

The main objective of this research is to assess the willingness to pay (WTP) of recreationists and people living near waterbodies in southern Quebec, Canada, who have experienced episodes of cyanobacterial blooms, for management measures to reduce or eliminate the problem. A second objective was to understand how the cyanobacterial bloom's effects on ecosystem services (i.e., degraded landscape, foul smell, restricted recreational activities and altered ecological health) affect preferences and derived utility. To this end, a choice experiment method is used, as it can take into account the multidimensionality of the evaluated goods and can provide useful outputs for future public policies (Dachary-Bernard and Rambonilaza, 2012).

In this research, we focus on the human-centred concept of ecosystem services (ES), because it highlights the relationship between ecosystems and human well-being. ES are defined in the Millennium Ecosystem Assessment (MEA 2005) as the contribution of ecosystems to human well-being, and are divided into four categories: supporting services, provisioning services, regulating services, and cultural services. Cultural ecosystem services (CES) include intangible services that are sometimes difficult to measure quantitatively, but that are essential to human well-being. Fish et al. (2016) define CES as "the contribution ecosystems make to human well-being in terms of the identities they help frame, the experiences they help enable and the capabilities they help equip (: 212)." This definition of CES includes strictly defined ES and the context within which they are experienced (Pereira et al., 2005; Chan et al., 2012; Kenter et al., 2015; Díaz et al., 2015; Fish et al., 2016). The Common International Classification of Ecosystem Services (CICES) has classified them in five groups: "Physical and experiential interactions with natural abiotic components of the environment"; "Intellectual and representative interactions with abiotic components of the natural environment"; "Spiritual, symbolic and other interactions with the abiotic components of the natural environment"; "Other biotic characteristics that have a non-use value"; "Other characteristics of living systems that have cultural significance". More concrete examples of CES given by CICES in these groups are nature-based recreation, ecotourism, knowledge about the nature and environmental management, local identify, artistic inspiration, mental and moral well-being (CICES V5.1). Among them, "nature-based recreation" is the one used most often to estimate quantitatively CES, but its value doesn't capture the array of values that waterbodies represent for individuals. This is why this research includes different CES, including recreation, as attributes in the choice experiment. The use of these attributes will provide more insight into the relative importance of ES to individual utility when eliciting WTP.

Individual utility is one form of valuation. The concept of values, as described by Kenter et al. (2015), includes transcendental values, associated with ethics and cultural norms, contextual values, associated with attitudes and preferences, and value indicators (: 89). In this research, we want to measure willingness to pay as an indicator of contextual (individual) values. As a complement, the information gathered as part of the survey can hint at what attitudes, preferences and values drive respondent pro-environmental behavior. Stern et al. (1999) distinguish between different types of public support for environmental and social movements, including activist support, and three types of non-activist support. These include low-commitment active citizenship, acceptance of policies that require material sacrifices, and changes in behavior in the personal or private sphere (: 82). The Value-Belief-Norms theory described in Stern et al. (1999), suggests that different values (altruistic, egoistic, traditional and openness to change), combined with an awareness of the consequences of a problem, ascription of responsibility and pro-environmental personal norms lead to different forms of support for environmental movements. Using the work of Stern et al. (1999), de Groot and Steg (2008) describe a value instrument to understand the propensity of individuals to adopt pro-environmental behavior that focuses on egoistic (social power, wealth, authority, influence), altruistic (equality, world peace, social justice, welfare of others) and biospheric values (preventing pollution, respect the earth, unity with nature, protect the environment). The biospheric value was added in de Groot and Steg (2008) list of value orientations as a stand-alone element, even though it was included in Stern et al. (1999) category of altruistic values ("Preventing pollution, conserving natural resources; Unity with nature, fitting into nature: 95"). In any case, understanding what values lead to pro-environmental behavior, either active or passive, in a population could be useful to design and publicize policy instruments efficiently.

Social acceptability of policy measures in a population can be assessed using the input of citizens. The evaluation of proposed policy measures is possible, in part, through the monetary valuation of ES. The use of monetary value for ES in public and private decision-making has been limited in the past (Laurans et al., 2013; Dupras et al., 2015, 2016; Kermagoret and Dupras, 2018), but there is increasing avenues for its use, including for ecosystem-wide planning, as well as for strategic and regional planning (Chichilnisky and Heal, 1998; Compton et al., 2011; Tammi et al., 2017). The literature investigating preferences for water quality improvement in a context of algal bloom assesses direct and indirect impacts to population groups. The measure of impacts is carried out using revealed preference methods and stated preference methods. Revealed preference methods, such as damage cost, hedonic pricing and travel cost, rely on data from real markets to estimate benefits associated to recreation and water quality (Kosenius, 2010). They have been used, for example, to measure the impacts of algal blooms on the fishing industry (Beville et al., 2012; Wolf et al., 2017), on property value (e.g. Wolf and Klaiber, 2017), and on tourism (e.g. Palm-Forster et al., 2016). Stated preference methods, such as contingent valuation and choice experiment, rely on surveys to obtain information on preferences for which market data is not available. Contingent valuation studies have measured WTP in relation to the risk posed by cyanobacteria to human health (Tyler et al., 2009; Hunter et al., 2012) and in relation to nutrient reduction to improve water quality (e.g. Atkins et al., 2007; Nelson et al., 2015). The advantage of the choice experiment over the contingent valuation is its ability to allow for an understanding of preference ordering (Dachary-Bernard and Rambonilaza, 2012; He et al., 2017). Studies using the choice experiment approach are abundant in the literature, but the ones that also consider water quality are more limited. In the literature we found, only one study was performed in the premises of our study area of Lake Champlain (Smyth et al., 2009), but it did not include the computation of WTP and focused on management approaches for Lake Champlain instead of looking at preferences in terms of ES. Some studies concentrated on the preferences of specific groups of recreational users, such as recreational anglers (Beville et al., 2012; Zhang and Sohngen, 2018). Finally, studies have estimated the general public's preferences for water quality attributes, through nutrient reduction policies, usually as part of the Water Framework Directive's implementation in Europe

(Kosenius, 2010; Taylor and Longo, 2010; Ahtiainen et al., 2015). In these studies, all of the attributes selected in the choice experiments were visibility of sea bottom, presence of slime, the number and variety of fish species, the length of algal blooms (in days or weeks), and the congestion at the beach. Considering the limited number of studies on the preferences for water quality improvement through nutrient reduction, especially in Canada, our interest in obtaining WTP values and preferences ordering to inform public policy, and the emphasis of this study on CES, this research is well founded.

In the upcoming sections, we will describe the methodology employed to carry out the choice experiment and perform the analysis of the results (Section 2). Section 3 will include results, and Section 4 will include a discussion of the results in the light of other studies, and present the main advantages and disadvantages of the chosen approach. Finally, Section 5 will conclude.

2. Materials and methods

2.1. Study area

In 1996, cyanobacteria have started to become an emerging preoccupation for the province of Quebec's government and, in 1999, signalling of cyanobacterial blooms have started to be reported to the government (Robert et al., 2004). Drinking water sampling started in 2001 (Robert et al., 2004). In the province of Quebec, cyanobacterial blooms have been occurring below the 53rd parallel (city of Fermont), as shown in Fig. 1. Each dot of Fig. 1 represents a waterbody that has been affected by a bloom since 2004 (MDDELCC, 2018a). The main cause of this symptom of anthropic eutrophication is an over enrichment of nutrients (mostly phosphorus and nitrogen) in water bodies from diverse sources, such as agriculture, inadequate sewage installations, unpaved roads, forestry activities, and activities that contribute to erosion (GRIL, 2007). As of 2015, almost 500 lakes in the province had been affected by a cyanobacterial bloom (MDDELCC, 2018a).

A recent study carried out in the province of Quebec (Chaire de tourisme Transat 2017) shows that 8.8% of Quebec population have practiced canoeing and kayaking activities and that 2.9% have practiced sailing and wind sports at least once in the period of 2016–2017. This study also shows that elements influencing the choice of location to perform these recreational activities are mainly the beauty of the landscape and accessibility. In the case of sailing and wind sports, the preferred sites for conducting these activities included Lake Champlain, the Saint-Lawrence River, the Lake of Two Mountains (lac des Deux Montagnes), Lake St-François and Lake Memphrémagog (Chaire de tourisme Transat 2017). In addition, a 2012 survey indicated that there were 711,610 recreational fishers in the province (Daigle/Saire, 2013). Looking at private residences, properties located near leisure area, with access to water and with views on natural environments were sold mainly in the Laurentides region (40%), in Lanaudière (17%), in Montérégie (13%), in Estrie (11%) and in Outaouais (10%) in 2014 (FCIQ, 2014).

The Missisquoi Bay, a large cross-border incursion of the northern part of Lake Champlain located in part in the State of Vermont (United States), has the longest history of cyanobacterial blooms in the province of Quebec. Agricultural lands in its watershed, mainly large-scale cultures and dairy farming, take up 34% of the land area in the Canadian floodplain, and forested areas take up 58% (Chouinard, 2015). The watershed is mainly rural, with urban areas taking up only 1% of the land area. Each year, cyanobacterial blooms occur in July/August/September, but the exact start of the blooms can vary (Bowling et al., 2015).

Non-point sources of phosphorus are largely responsible for anthropic eutrophication and the resulting cyanobacterial blooms. From a Canadian perspective, the control of these sources of nutrients to improve water quality is limited in the current Quebec legislative framework when it comes to defining norms to reduce concentrations of phosphorus and nitrogen in waterbodies (Tabaichount et al., 2019). Although the control of these nutrients at the source could improve water quality in the long term (Chouinard and Bérubé, 2015), short-term solutions, such as improving detection (to reduce risk to health), applying chemicals in water bodies or mechanically harvesting algae and cyanobacteria, can affect targeted aspects (ES) of the lake experience (EXXEP, 2004; Schindler and Vallentyne, 2008).

2.2. Choice experiment

The choice experiment approach, selected as part of this study, is one of the stated preferences methods, available in the ES valuation toolbox (Dupras and Revéret, 2015). This method, compared to other stated preferences methods, such as contingent valuation, allows for a better understanding of the various elements (i.e., attributes) being valued (Lienhoop and Völker, 2016). In practice, it implies describing ES and the cost as attributes and their specifying levels (Hanley et al., 2002). Then alternatives/scenarios are developed as a function of the attributes and their levels in a random design, so that we can observe the trade-offs that are made by respondents when choosing a scenario. Respondents are then presented with a limited number of scenarios, along with a Status Quo option, they are asked to choose their favourite option. The trade-off is made between the improved level of attributes and the cost, allowing respondents to decide the level of satisfaction they have for each scenario, then the best scenario can be identified.

2.3. Survey development

A questionnaire composed of three sections was developed: in Section we wanted to determine the level of knowledge of respondents on the issue of cyanobacteria. Section two focused on recreational habits of respondents and on the choice experiment. Finally, Section three included socio-economic and attitudinal questions. The attributes for the choice experiment were chosen based on a literature review (Bennett et al., 2008; Smyth et al., 2009; Marsh and Baskaran, 2009; Taylor and Longo, 2010; Dubé, 2012; Marsh, 2012; Ahtiainen et al., 2015; Larue et al., 2017; Kenter, 2016) and on contextual studies on the issue of cyanobacterial blooms in the Missisquoi Bay (EXXEP, 2004; Marsden and Langdon, 2012; Blais, 2015; Chouinard, 2015). The selection of attributes was also informed by a meeting with an expert from the Missisquoi Bay watershed organization (OBV BM) and by two focus groups with experts on the issue of cyanobacterial blooms. The focus groups also contributed to the validation of the survey's content. The questionnaire was pre-tested with groups of individuals from diverse backgrounds, especially to clarify language and evaluate the comprehension of questions and choice cards. The survey took about 15–20 min to complete.

As part of the choice experiment section, each respondent was presented with five choice cards that each included a choice A, a choice B and an option that represented the Status Quo. To limit the hypothetical bias, where respondents could possibly over or under state their WTP due to an incomplete grasp of the situation presented, we explained the overall scenario so that it seemed credible. We also reinforced the notion that there was no good or bad answers so that respondents would feel more at ease. Among each choice set, a status quo option was available. In the choice cards, the Status Quo option represented the deterioration of the waterbodies in absence of measures to control nutrients.

Overall, there were three (3) blocks of scenarios which were divided into five (5) choice sets, each presenting three (3) options including the Status Quo. The scenarios were generated randomly, using SAS software, based on the five attributes and corresponding levels described in Table 1. Initially, the software generated 18 options (6 scenarios per block) with an overall D-efficiency of 1.80 and a D-error of 0.55. However, in each block, there was at least one dominating scenario. Given that we wanted balanced options, one scenario was removed

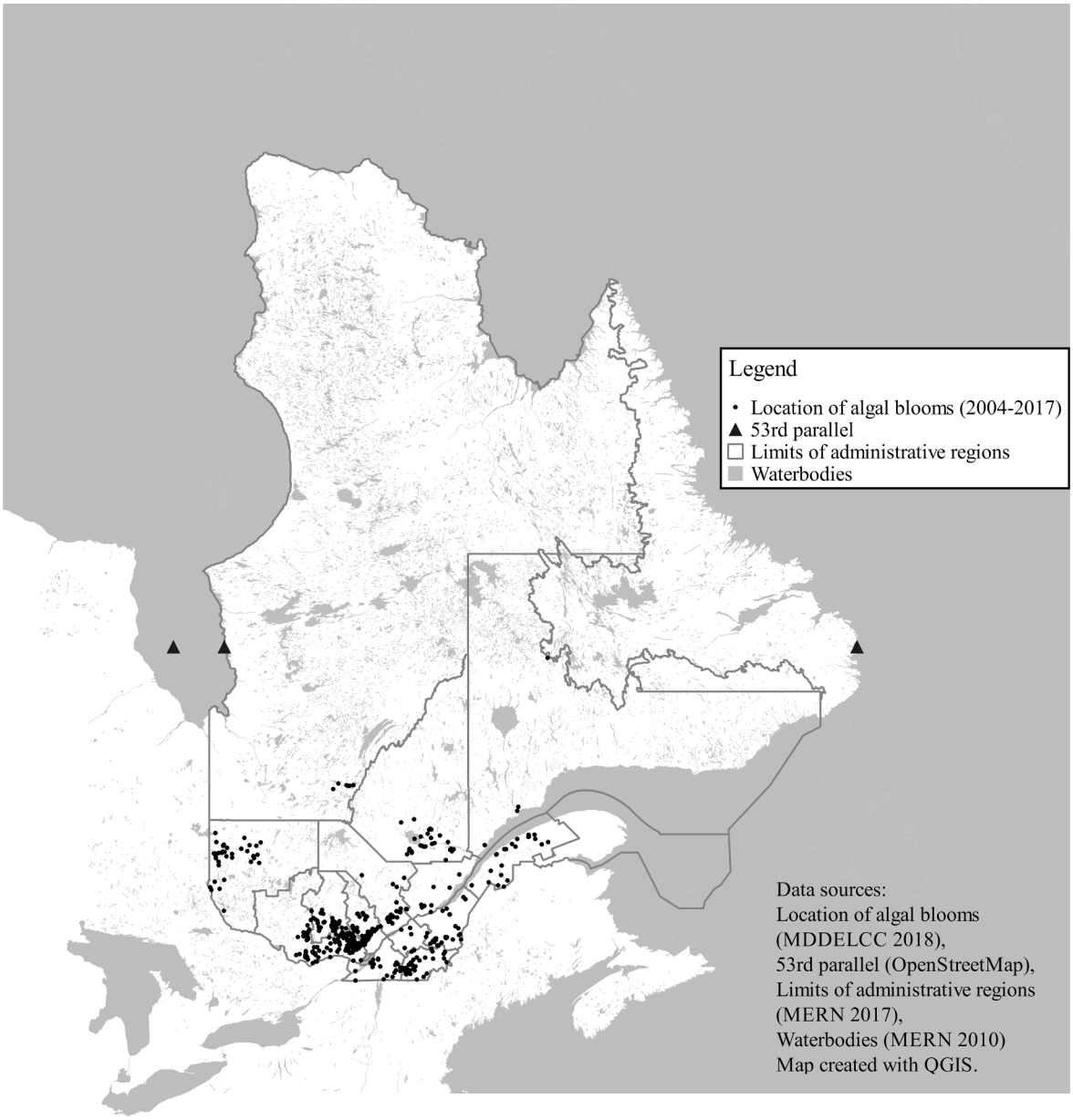


Fig. 1. Occurrences of cyanobacterial blooms in Quebec from 2004 to 2017. Data sources: MDDELCC. Ministère du Développement durable, Environnement et Lutte contre les changements climatiques du Québec, 2018; MERN, Ministère de l'Énergie et Ressources naturelles Québec, n.d., n.d.; OpenStreetMap, 2018.

from each block, that's why we ended up with five alternatives per block (3), with a D-efficiency of 1.46, and a D-error of 0.69. In Table 1, the attribute levels with a star represent the ones that were used to generate the Status Quo option. The $0 option was strictly limited to the Status Quo option.

The question asked to respondents as part of the choice experiment was the following: "blue-green algal blooms occur each year in many lakes in the south of Quebec. Solutions are considered to reduce or eliminate the negative impacts of these blooms, but the implementation of these solutions come at a cost. This cost would be borne by residents of the watershed and gathered through a municipal tax. For tenants, the cost would be added to their monthly rent. The money thus gathered would be spent according to watershed management priorities as set out by watershed organizations, municipalities, regional management units (MRC — *Municipalités régionales de comtés*), and other stakeholders." Fig. 2 showcases an example of a choice card presented to participants as part of the choice experiment. In this study, respondents were asked to choose their preferred option for each choice card.

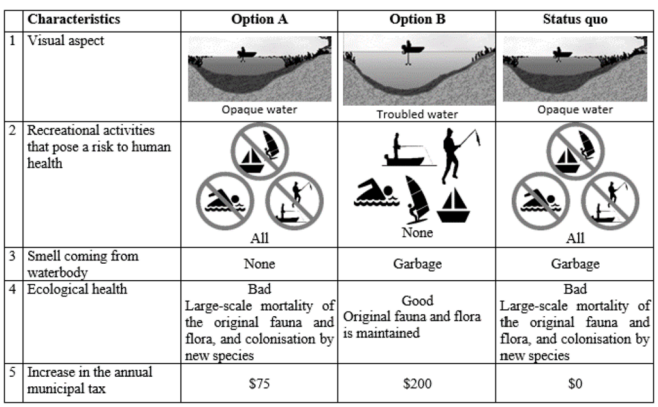
2.4. Data collection

The site selection for the data collection was made based on whether or not the waterbody near the city/beach had been impacted by a cyanobacterial bloom at least once in the last 10 years. We also focused on waterbodies in the Missisquoi bay watershed and on the region where the watershed is located (81%) because of the importance of the phenomenon in this area. Potential respondents were contacted at random using the intercept survey approach and following a non-probabilistic design. More specifically, we approached potential respondents on beaches and recreational areas near water bodies (38%), and we conducted 'door-to-door,' where people were met at home (62%). In the latter approach, the choice of streets to visit to perform the 'door to door' was made using a randomized procedure, whereas the choice of beaches and recreational areas to visit was based on anticipated affluence. This combination of approaches was carried out to maximize responses as the data collection was performed near the end of the summer (mostly in September and October). The surveys collected from

Table 1
Attributes and levels.

Attribute	Description	Attribute levels		
		Level 1: current degradation	Level 2: slight improvement	Level 3: great improvement
Visual aspect	Visual aspect of the water body (water clarity)	Opaque water*	Troubled water	Clear water
Recreational activities	Activities that are not recommended on water bodies because of their risk to health.	All activities*	Swimming	None
Odour	Smell coming from the water body.	Garbage*	Cut grass	None
Ecological health (Eco Health)	Level of mortality of native flora and fauna, including fish species (qualitative levels)	Bad*	Intermediate	Good
Cost	Annual increase in municipal tax (amount collected and spent at the watershed level)	$0** $15 $30 $50 $75 $100 $200		

Note: Attributes with a '*' were used to define the Status Quo option, and the attribute with a '**' was strictly used for the Status Quo option.



	Characteristics	Option A	Option B	Status quo
1	Visual aspect	Opaque water	Troubled water	Opaque water
2	Recreational activities that pose a risk to human health	All	None	All
3	Smell coming from waterbody	None	Garbage	Garbage
4	Ecological health	Bad Large-scale mortality of the original fauna and flora, and colonisation by new species	Good Original fauna and flora is maintained	Bad Large-scale mortality of the original fauna and flora, and colonisation by new species
5	Increase in the annual municipal tax	$75	$200	$0

Fig. 2. Example of a choice set (original choice sets were in French Canadian). Source: 'Visual aspect' drawings—F. Savard, 2005

the two methods were tested to determine if they could be combined by performing student t tests on the key socio-demographic variables, i.e. Age, Education, Income, and Sex. The results showed no significant differences between the samples, with the exception of Age and Education, where individuals met through the 'door-to-door' method are slightly older and less educated. The results of these tests are available in the Appendix, Table 1. The questionnaire was administered in person by the surveyors to increase response rate (Bateman et al., 2002). To make the experience of respondents more efficient and less tiresome, the questionnaire was administered using connected tablets and the Qualtrics survey software, which enabled the use of conditional branching.

2.5. Data analysis

To achieve the objectives of estimating WTP and observing trade-offs between attributes associated with water quality in a recreational context, the use of the Logit analysis developed by McFadden (1974) is the most appropriate. This method is based on the random utility theory (Thurstone, 1927; McFadden, 1974), where the choice of an individual maximizing its utility includes a random component that can come from a number of factors including a lack of information about the choices presented (Dachary-Bernard, 2007). The utility function is written as follows:

$$U_{in} = V_{in} + \varepsilon_{in} \tag{1}$$

Where U_{in} is the utility of individual i for alternative n, V_{in} represents the deterministic element of the utility and ε_{in} is a random term error independent and identically distributed (iid) extreme value distribution.

According to the random utility theory, the utility that can be estimated is V_{in}. In the choice experiment, a Status Quo option is included along with the alternatives proposed in each choice set, to be consistent with the utility and demand maximization theory (Bateman et al., 2002). Thus, the information from the choice experiment can be used to estimate a welfare value (WTP), which can then be used in cost-benefit analysis.

Assuming a linear functional form, the deterministic utility function V_{in} can be expressed as:

$$V_{in} = \beta_{im} X_{in} + \varepsilon_{in} \tag{2}$$

where X_{in} is the vector of determinants of utility and β_{im} corresponds to the vector with associated marginal utility coefficients.

Considering the attributes composing the choice experiment of our study, the indirect utility function associated to individuals' choices can be expressed as follows:

$$V_{in} = ASC_{AB} + \beta_V VISUAL_n + \beta_R RECREATION_n + \beta_O ODOUR_n + \beta_E ECOHEALTH_n + \beta_C COST_n + \varepsilon_{in} \tag{3}$$

Where the coefficients ASC_{AB}, β_V, β_R, β_O, β_E and β_C represent the marginal utility associated to the non-Status Quo alternatives and the ES (i.e., VISUAL, RECREATION, ODOUR, ECOHEALTH) and the monetary attribute (i.e., COST), respectively. The ratio of marginal substitution obtained by dividing the coefficient of the attribute β_x by the coefficient of the monetary attribute β_C approximates the marginal WTP for a level of provision of each x ES attribute:

$$WTP_x = -\beta_X/\beta_C \tag{4}$$

As part of the analysis itself, we started with the conditional logit (CL) analysis (McFadden, 1974), then we did a CL analysis with interactions, by including socio-economic and behavioral characteristics in the model. The CL model analyzes solely the individual choices as a function of attributes. In this model parameters are assumed to be constant across respondents, which is equivalent to an analysis in terms of the average preference of the respondents. Interaction effects between individual socio-economic characteristics and the attributes of the experiment have been tested in order to explore the determinants of preferences in the sample. The CL analysis with interactions allows for a better understanding of how groups of individuals make their choices. The interactions tested were based on prior hypotheses about the preferences of the population. In the analysis, this required the creation of new variables representing interactions between attributes and selected variables taken from the questionnaire. We hypothesized that age, income and education levels had an effect on preferences, based on previous studies (e.g., Bennett et al., 2008; Taylor and Longo, 2010), but also that behavior such as the choice of vacation location, the activities performed, whether or not individuals possess a waterfront property, and the distance they are willing to travel has an impact on

Table 2
Summary of sample demographic characteristics of respondents.

Demographic variables	Beach respondents (n = 85)	Door-to-door respondents (n = 138)	Respondents (n = 223)	Census data[a]—Quebec population
Gender				
Female (%)	52	54	53	50.3
Male (%)	48	46	47	49.7
Age[b]				
18–24 years old (%)	5	1	3	10
25–39 years old (%)	27	19	22	25
40–54 years old (%)	22	18	20	25
55–64 years old (%)	25	34	30	18
65 years and older (%)	21	28	25	23
Education attainment				
Elementary school (%)	2	4	3	20
High school or professional diploma (%)	27	33	31	38
CEGEP (collegial) (%)	34	25	29	21
University (%)	37	38	37	21
Annual household income (n = 195; No responses n = 28)				
Less than $24,999 (%)	16.5	11	13	18
$25,000—$49,999 (%)	23	20	21	30
$50,000—$69,999 (%)	16.5	18	17	19
$70,000—$99,999 (%)	19	23	22	18
More than $100,000 (%)	25	28	27	15
Survey site				
Montérégie and Estrie (%)	41	94	74	–

Data sources.
[a] Statistique Canada, 2017.
[b] Statistique Canada. Tableau 17-10-000501-, 2017

preferences. We also hypothesized that the trust towards governments has an effect on whether or not individual chose the Status Quo alternative, following the results of Morardet et al. (2015). Finally, we hypothesized that having grandchildren would have an effect on preferences, as an indicator of concern for other generations. The variables that have been included in the final model are described in the Appendix, Table 2.

The CL models with and without interactions both require that the sample follow the independence of irrelevant alternatives (IIA) property. This property states that the probability ratio of any two alternatives to be selected are independent of the presence/absence of any other alternatives in the choice set (Kosenius, 2010; Hensher et al., 2005). These models were preferred at first because they are more appropriate for panel data and repeated choices (Cameron and Trivedi, 2005). The Hausman-McFadden test was executed to determine if the IIA property is followed in the sample (see Appendix, Table 3). Finally, to account for the heterogeneity of responses in our sample and to relax the IIA hypothesis (Rigby and Burton, 2003), we performed a random parameter logit (RPL). Then, we computed WTP estimates.

3. Results

A total of 252 people of 18 years old and above completed the questionnaire between August 27, 2017, and November 5, 2017. The response rate was of 43% (252 responses out of 585 people met), which is comparable to other aural survey modes such as telephone (44%) and interactive voice response (28%) (Dillman et al., 2009). The response rate was most likely affected by the length of the survey (15–20 min).

Table 2 provides an overview of the demographic characteristics of respondents, with a comparison to census data of the Quebec population, and including the breakdown by survey method. Notably, we observe that 53% of respondents are women. With regard to age groups, we notice that there is an under-representation of people under 54 years old and an over-representation of people above 55 years old. Based on the location of the survey, we observe that the age distribution is especially skewed with the door-to-door approach. This can be explained by the period where we undertook the survey, which was after classes started again, by the fact that younger people may be at home less often during the day, especially compared to people that are retired, and that older people may be more inclined to answer surveys.

Twenty-eight respondents decided not to reveal their annual household income. As a result, for the subsequent analysis, we supposed that it would be equal to the Quebec median family income of $59,822 (Statistique Canada, 2017). Based on the remaining information, we observed that the median family income of respondents fell into the $70,000 to $99,999 category, which is consistent with the 2015 Canadian median income of $70,336, but higher than the 2015 Quebec median family income of $59,822 (Statistique Canada, 2017). A majority of respondents have a high school or collegial level of education (60%), which is consistent with the Quebec population, but the proportion of people with a university degree (37%) was higher than the Quebec population (21%) (Statistique Canada, 2017).

Among the 252 questionnaires collected, 18 included incomplete answers and were thus removed from the database. In addition, when examining the responses to the choice experiment, it was noted that 11 respondents provided protest responses. Protest responses arise when the Status Quo option is chosen more than three times (out of the five choice cards) and are not a real preference for the Status Quo but are justified as follows: respondents didn't want to pay for the issue, they believed it should be financed by others, or they already pay enough taxes. As a result and following recommendations by Barrio and Loureiro (2013), and Meyerhoff and Liebe (2008) among others, protest responses have been excluded from our database before proceeding with analysis. Of the 223 completed questionnaires that could be used for the analysis (3345 observations), 175 represented responses from active recreationists (2625 observations).

Only 32% of respondents believed that their personal behavior could have an impact on cyanobacterial blooms, and within this group, 61% stated that they had adopted practices to limit their contribution to the problem. The most cited practices include avoiding the use of chemical fertilizers, pesticides, soap and detergent-containing phosphates, and avoid throwing waste into waterbodies. The most cited reason of people who stated they haven't adopted practices, but believed that their behavior could have an impact on the issue, was a lack

Table 3
Results of the econometric analysis.

	Conditional logit			Conditional logit with interactions			Random parameter logit (RPL)		
	Coefficient		SE (p)	Coefficient		SE (p)	Coefficient		SE (p)
ASC	1.087	***	0.22 (0,000)	0.775	***	0.25 (0.002)	0.823	***	0.25 (0.001)
Visual aspect	0.242	***	0.06 (0.000)	0.258	***	0.06 (0.000)	0.284	***	0.08 (0.001)
Recreational activities	0.766	***	0.06 (0.000)	0.336	**	0.13 (0.020)	1.296	***	0.16 (0.000)
Odour	0.190	***	0.06 (0.001)	0.269	***	0.07 (0.000)	0.432	***	0.09 (0.000)
Eco Health	0.571	***	0.06 (0.000)	0.158		0.18 (0.389)	0.910	***	0.11 (0.000)
Cost	−0.0017	***	0.0008 (0.03)	−0.0046	**	0.002 (0.018)	−0.0083	***	0.001 (0.000)
Sd.Visual	–		–	–		–	0.504	***	0.12 (0.000)
Sd.Activities	–		–	–		–	1.335	***	0.16 (0.000)
Sd.Odour	–		–	–		–	−0.439	***	0.15 (0.004)
Sd.EcoHealth	–		–	–		–	0.696	***	0.12 (0.000)
ASC * Age				0.658	**	0.32 (0.040)			
Activities * water				0.269	**	0.13 (0.033)			
Activities*Dist				0.003	*	0.002 (0.067)			
EcoHealth *education				0.168	***	0.06 (0.003)			
EcoHealth*fishing				−0.256	**	0.11 (0.018)			
Odour*water* Impacted				−0.227	**	0.11 (0.046)			
Activities* GrandChildren				0.438	***	0.12 (0.000)			
Cost*Trust				0.004	*	0.002 (0.078)			
Log likelihood	−1279.52			−1253.99			−757.99		
LR chi2	1012.24 (0.000)			1063.30 (0.000)			109.33 (0.000)		
AIC/n	0.769			0.758			0.459		
Pseudo-R2	0.2834			0.2977					
Nb of individuals	223			223			223		
Observations	3345			3345			3345		

(Significance levels: at 1% "***"; at 5% "**"; at 10% "*"; SE = Standard Error; p = probability; sd: Standard deviation; LR: Log-likelihood Ratio; chi2: chi squared; AIC: Akaike Information Criteria; n: nb of observations).

of information on actual problematic behavior.

3.1. Econometric analysis

CL, CL with interactions and RPL were carried out on the whole set of respondents using Stata/SE (version 15) (StataCorp, Texas).

3.1.1. Relative importance of attributes

The results of the CL and RPL analyses provide a first look at the data in terms of the attributes initially selected and in terms of the general enthusiasm of respondents. The RPL analysis extends the CL analysis through the introduction of randomly distributed variables. It provides a way to generalize the CL model to allow the utilities of each alternative to be correlated (Cameron and Trivedi, 2005: 512). The introduction of random parameters has the property of inducing correlation across alternatives (Cameron and Trivedi, 2005: 513). In our analysis, the coefficient "ASC" is a binary variable that represents the "opt-in" options. When looking at the coefficients of the ASC, the fact that the coefficient has a positive value indicates that the "opt-in" options (A or B) are preferred to the Status Quo ("opt out"). This information further indicates that respondents are willing to embrace changes in policy to improve water quality.

When looking at the relative importance of attributes in the CL analysis, Table 2 shows that the attribute "Recreational activities" exhibits the highest increase in utility from level 1 (current degradation) to level 3 (high improvement), followed by "Eco Health", "Visual aspect", "Odour", and "Cost". When looking at the results of the RPL, we can see that the order of preference is inverted for the attributes "Odour" and "Visual aspect", compared to the results obtained from the CL analysis. In both cases, the sign of the attribute "Cost" is negative, which is consistent with the fact that higher levels (i.e. an increasing monetary contribution) represents a constraint. In the RPL analysis, the significance of the standard deviation coefficients at the 5% level of every attribute reveals that accounting for heterogeneity in the sample was appropriate, and that the heterogeneity within these attributes is important.

Furthermore, in the CL and RPL analysis, all of the attributes have a significant effect on utility and the coefficients are all positive, except cost, which indicates that, as the attributes levels increase, they generate a higher utility. This confirms that the choice of attributes was performed adequately, supporting the assumption that a better environmental quality increases utility and that a higher cost to be borne decreases utility. Based on the log likelihood ratios (Log likelihood) and the Akaike Information Criteria (AIC) values (obtained using "estat ic"/n), shown in Table 3, we can state that the RPL model is the most interesting, given its lower values. A complete model comparison using the AIC criteria is available in the Appendix, Table 4.

3.1.2. Attitudes towards attributes

The CL model with interactions includes combinations of the attributes and of socio-economic and attitudinal data that were gathered in the questionnaire. The variables that were included in the model in Table 3 are presented in more detail in Table 2 of the Appendix. The interaction between the ability to perform recreational activities safely and the variable that relate to the importance of water when choosing a destination for vacations (Activities*water) is significant at the 5% level. It shows that people choosing a vacation spot for the presence of water derive more utility from the available activities in waterbodies. Similarly, people who are willing to travel farther to access lakes

Table 4
Marginal WTP for the random parameter logit model ($CA per household per year).

	Random parameter logit	
	Estimate	CI
Visual aspect	34	(14.3; 59.6)
Activities	157	(118.6; 220.5)
Odour	52	(32.5; 80.3)
Eco Health	110	(82.0; 159.3)
Total	353	(247.4; 519.7)

(CI: 95% confidence interval).

without cyanobacteria (Dist) exhibit an increase in utility from an improvement in the recreational activities attribute (Activities*Dist). The results also show that people who choose a vacation location based on the presence of a waterbody and who have been impacted by cyanobacteria in the past (Water*Impacted) do not derive an improvement in utility from an absence of odour coming from the water (Odour*water*Impacted). This result may be caused by the fact that the intermediate level (smell = cut grass) is not marginally better than the best level (smell = no smell).

The variable "trust" was added as an interaction with the attribute "Cost" (Cost*Trust) to determine whether or not trust towards the information provided by the government relative to water quality had an impact on the choice of a scenario when it came to the price attribute. The trust variable was measured as part of the survey to determine the overall attitude of respondents towards the government. The coefficient for this interaction shows that at the 10% level, the variable is significant. This positive value implies that people who have confidence towards the information provided by the government would be willing to pay higher amounts to improve water quality.

Focusing on other significant interactions, we can see that older respondents (Age) (above 55 years old) have a higher preference for the non-Status Quo alternative than younger respondents. Educated people (education) (with a college degree and above) give more value to ecosystem health. Respondents who have grandchildren (GrandChildren) prefer an improvement in the potential to perform recreational activities safely. Finally, the utility of fishers (fishing) decreases when ecological health improves. This result is surprising, but it could be explained by an association between water quality improvement and conservation. Indeed, fishers may frown upon conservation practices, as it could limit their ability to undertake recreational fishing. For example, fishing associations displayed a negative reaction to a ban of live bait for winter fishing introduced in Quebec in 2017, even though this restriction was implemented to prevent the spread of invasive species (Duchaine et al., 2017; Émond, 2018).

The results from the remainder of the questionnaire provide more information on the attitudes and perceptions with regard to the issue of cyanobacterial blooms. Results show that only 31% of people believe that their individual actions have an effect on cyanobacterial blooms. This result is in contrast with the fact that 52% of respondents believe that individuals are among the best suited to resolve the issue of cyanobacterial blooms. Although this percentage is high, 78% of respondents believe that the government is among the best suited to resolve the issue, followed by the private sector (49%), and by non-governmental organizations (43%) (more than one choice was allowed). The questionnaire also asked what solutions respondent think would be the most effective to resolve the issue. Among solutions presented to respondents (more than one choice was allowed), the most commonly selected (above 50%) were solutions targeting the agricultural sector, mainly vegetated buffer strips, and strengthening environmental regulations.

3.2. Willingness to pay

These values, shown in Table 4, represent the amount a person would be willing to pay annually, through their city taxes, to improve water quality, based on maximal improvement with regard to each attribute. The confidence intervals were calculated using the Krinsky-Robb's method and 2500 repetitions. The marginal WTP values are significantly larger for the CL model when compared to the RPL model. This result can be explained by the heterogeneity in the results, as shown in Table 3. Given that the best representation of the data comes from the RPL model, the marginal WTP values obtained from the RPL model are more reliable. Consistent with the ranking of the coefficients, the two most important WTP values were found for the ability to perform recreational activities, with an average value of CA$157/household/year using the RPL method, and the ecological health of the waterbody, with an average value of CA$110/household/year. The WTP values found for the Odour and Visual aspect of the waterbodies were estimated at an average of CA$52/household/year, and at CA$34/household/year, using the RPL model. Using these values and their respective confidence intervals, the total WTP for these four attributes is an average of CA$353/household/year, with a lower bound of CA$247/household/year and an upper bound of CA$519/household/year. We believe these WTP values to be additive, because they estimate the value associated with an appreciation of ES that is related to the experience of these ES and not to their production. As a result, we assume that the WTP values can be added for two reasons. First, because they refer to the experience of individuals with regard to different aspects of CES and to ecological health and second, because the models used as part of the analysis are based on a marginal substitution of each service.

4. Discussion

In this study, we have used the choice experiment method to elicit willingness to finance solutions to limit the impacts of eutrophication and to examine the effect of blooms on respondent utility. The results indicate that age, education, and having grandchildren have an impact on individual preferences, and so does the importance of water for vacation destinations, the distance people are willing to travel and whether or not people perform fishing activities. The influence of age and education is not a surprise, given that these socio-economic indicators have been cited as important elements in preference construction with regard to water quality in other studies (e.g. Bennett et al., 2008 (Australia), Taylor and Longo 2010 (Bulgaria)). However, income and sex were not found to be significant factors in preference determination, which is why we didn't include these variables in the final model. This result is in contrast with the findings of Hunter et al. (2012) study in Scotland, where household income was positively related to WTP and where they found that female had a higher level of concern for environmental issues, which led to higher WTP. However, this study was more interested in the perception of health risks than the recreational and aesthetic properties of Loch Leven. The results of Nelson et al. (2015), show that income had a significant effect on WTP for recreational water users in Utah (United States), but that sex did not have a significant effect on WTP. The lack of significance with regard to income in our results may be caused by the relatively high number of people who declined to answer this question.

The availability of the recreational activities was found to be more important to those choosing their vacation destination due to the presence of water, but this attribute was not found to be more important for those who performed recreational activities in the water (i.e. swimming, nautical activities). This indicates that the respondents value this attribute for the sake of others as well as for themselves, a result further suggested by the preference of people who have grandchildren for the recreational activities attribute. The high importance of the ecological health attribute shows a certain level of biospheric concern (Arias-Arévalo et al., 2017; Stern et al., 1999). On the other hand, the two other attributes, presence of odours and aesthetics, can be described as egoistic values (Kenter et al., 2015), as they are experienced more keenly at the individual level. As a result, we can suppose that when responding to the survey, individuals not only thought of themselves and of their egoistic preferences, but that they have inherent preferences that considers the impact of eutrophication on other beings. This intuition would, however, need to be confirmed using deliberative methods.

The confidence towards governments was found to be a significant factor (at the 10% level) influencing the choice of the cost attribute in this study, but it is not a significant factor in the choice of 'opt-in' alternatives. This result is in line with the work of Morardet et al. (2015) (France) who have showed that confidence in governments and ethics can be limiting factors when choosing a solution to resolve water

quality issues. The relative ranking of preferences, where the availability of recreational activities is the most valued, followed by the ecological health of waterbodies and by aesthetic elements is similar to the finding of Marsh and Baskaran (2009) (New Zealand) where the ranking is as follows: Ecology, Swimming, Water clarity. Our results are also in line with previous stated preference studies performed in Quebec where citizens reported a high WTP for wetland protection for water quality and biodiversity conservation purposes (He et al., 2017), conservation, enhanced recreational activities, and water quality for the Greater Montreal Blue Network (Poder et al., 2016), and for biodiversity protection and aesthetics in agroenvironmental settings (Dupras et al., 2018).

The qualitative results from our survey have shown that respondents largely looked up to the government (78%) as among the best suited to resolve the issue of cyanobacterial blooms, and to the agricultural sector for specific solutions to resolve the issue, including vegetated buffer strips. Our results have also shown that respondents are favourable to the implementation of solutions to improve water quality even at a cost ($353/household/year [CI: $247.4/household/year, $519.7/household/year] for the four attributes). Considering these results, the government has some legitimacy to choose from a suite of tools to force change in practice. As mentioned earlier, the control of phosphorus from non-point sources is limited in the current Quebec legislative framework (Tabaichount et al., 2019), but this could be resolved through the adoption of regulations under the *Loi sur la qualité de l'environnement*, article 46 (Sanchez et al., 2007). Another possibility is for the government to implement a market for the control of nutrients, which would be feasible given the Quebec's institutional and legislative frameworks (Government of Canada, 2006; Sauvé et al., 2006; Sanchez et al., 2007). Such a market would need to take into account the transboundary nature of some watersheds in Quebec, such as the Missisquoi Bay watershed, which is shared with Vermont and New York. The fact that we didn't include the states within transboundary watersheds is a limit of this analysis.

Despite the reliance of respondents on actions from the government and from the agricultural sector to resolve the issue of anthropic eutrophication and its effects, local initiatives have been shown to stand the test of time and to have a greater social acceptability than top-down measures (Dubé, 2012; Gaddis et al., 2010). As such, the reliance on watershed organizations and their role as facilitators among interest groups in water management (Milot, 2008) is another method of including local concerns in governance mechanisms and in solutions to reduce or control pollution that has been integrated in the *Quebec Water Strategy* (MDDELCC, 2018b). This approach has the potential to mobilize different sectors of governance and to lead to effective integrated watershed management (Milot, 2008; MDDELCC, 2018b), but more research needs to be done on this subject in the Quebec context (Comtois and Turgeon, 2008).

The choice experiment method is a pragmatic and useful tool that conveys the value associated with an appreciation of ES. The estimated WTP values can then be used to evaluate the potential of market mechanisms for pollution reduction, to perform cost-benefit analysis, and to estimate social acceptability of management approaches. However, this method is limited by the fact that it aims to measure the appreciation of respondents for a set of ES through WTP. Using this method, hypothetical scenarios proposing independent ES levels and hypothetical public policy must be defined so that each ES level can be met independently. It is more difficult for choice experiment methods to derive values for ES from a policy or a project (Bateman et al., 2002: 274), especially from an ES production (ecological) point of view. In this case, some of the ES levels cannot be considered as independent, therefore their monetization via a choice experiment method could result in the double counting of their potential cost. However, from the point of view of an ES user (which is the starting point of the choice experiment method), we believe such independency between ES may still be imaginable, as they refer to an experience for the individuals.

5. Conclusion

The issue of cyanobacterial blooms, whether toxic or not, is not likely to be resolved in the near future, even if changes in practices are undertaken right away. In this context, it could be important to keep residents of affected areas informed of what is being done to resolve the issue, especially since we found that trust towards the information provided by governments has an effect on the utility of cost. Throughout this research, we have examined the preferences of individuals in a context of decreasing water quality in the south of Quebec. We have focused our attention on selected CES (ability to carry out recreational activities safely, presence of odours, and the visual aspect of the waterbodies), and on a generic measure of water quality. The results from this study show that people place a higher value on the availability of the recreational activities and on the ecological health of water bodies than on visual and olfactory aspects. Furthermore, age, education, choice of vacation destination, distance travelled, having grandchildren, and the practice of fishing all informed respondent's utility. Based on this preference ranking, it may be useful to develop better prediction tools on the concentration of toxins in waterbodies to enable safe recreational activities, all the while implementing practices to prevent eutrophication, and keeping in mind that respondents stated a significant demand for water quality enhancement. The total average WTP is estimated at CA$353/household/year in revenues from taxation, respectively for recreation (CA$157/household/year), water ecosystem integrity (CA$110/household/year), odour control (CA$52/household/year), and visual aspect (CA$34/household/year). Despite these high values, the fact that respondents were presented with four predetermined ES suggests that the computed WTP represents only a portion of total value with regard to water quality improvement. The results from this study can be seen as a starting point for a dialogue on ways to improve water quality at the watershed level. But, for a more extensive picture of preferences and to determine what solutions are applicable to specific localities given local contexts, targeted projects should be undertaken.

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Declaration of interest

None.

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Appendix

Table 1
Student t tests of key demographic variables from the two sampling methods.

Socio-demographic variables	Sample estimates		t value	p-value	CI
	Door-to-door (=1)	Beaches			
Age	0.62	0.46	8.93	< 2.2e-16	0.12 0.19
Education	2.97	3.05	−2.42	0.02	−0.14–0.015
Income	90650	86807	1.58	0.11	−930.15 8616.03
Female (=1)	0.54	0.52	1.45	0.15	−0.009 0.06

Note: CI (95% confidence interval).

Table 2
Description of variables included in the conditional logit model with interactions

Variables name	Description/Question asked to respondents	Coding method
ASC	Refers to the Alternative Specific constant.	Status Quo option (0) Non-Status Quo options (1)
Age	Age category.	18–54 years old (0) 55 years old and more (1)
Education	Highest level of education.	Elementary (1); High school (2); College (3); University (4)
Income	Annual household income.	Less than $24,999 (12500); $25,000 to $49,999 (37500); $50,000 to $69,999 (60000); $70,000 to $99,999(84500); $100,000 to $299,999 (200000); $300,000 and more (300000); No responses (65600)
Sex	Female or male.	Male (0) Female (1)
Dist	How far would you be willing to travel to go to a lake without cyanobacterial blooms?	0 km (0); 1–15 km (8); 16–30 km (23.5); 31–60 km (46); 61–100 km (81); more than 100 km (100)
Fishing	Do you fish?	No (0) Yes (1)
Water	Is the presence of water an important factor in the choice of a vacation destination?	No (0) Yes (1)
Impacted	Have you ever been impacted by the presence of cyanobacterial blooms?	No (0) Yes (1)
GrandChildren	Do you have grandchildren?	No (0) Yes (1)
Trust	Do you trust the information provided by governments with regard to water quality?	No (0) Yes (1)

Table 3
Test of the IIA hypothesis

Population	All responses	
	χ2 value	p-value
Alternative A dropped	29.23	0.0001
Alternative B dropped	55.96	0.0000
Status Quo alternative dropped	0.42	0.9948

(χ2 value: chi-square value).

Table 4
Model comparison using Akaike Information Criteria

Model	K	AIC	AIC/n	Δ(AIC/n)	w_i
RPL	10	1535.98	0.46	0	0.37
CLi	14	2535.98	0.76	0.30	0.32
CL	6	2571.04	0.77	0.31	0.32

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