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Environmental Management

ISSN 0364-152X
Volume 64
Number 6

Environmental Management (2019)
64:746-756
DOI 10.1007/s00267-019-01219-x

Springer

Environmental Management (2019) 64:746–756
https://doi.org/10.1007/s00267-019-01219-x

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Received: 10 April 2019 / Accepted: 10 October 2019 / Published online: 9 November 2019

Abstract

Based on a case study carried out on the Lac Saint-Pierre (LSP) World Biosphere Reserve (Québec, Canada), this paper estimates ecosystem service loss, more precisely the loss related to cultural and recreational activities of the LSP due to the fall of its water level under the pressure of climate change. We measure two dimensions of this loss. As a first step, the extrapolation of our representative survey reports \$100 million annual loss in terms of recreation revenue due to the trip reduction to LSP, which is about 60% of current level. Subsequently, the travel-cost data and the contingent behavior data are combined in a revealed and stated behavior panel random-effect estimation, which reports an additional loss measured by consumer surplus that visitors can obtain from their trips up to \$232 million, signifying 42% of reduction in their current value.

Keywords Revealed-Stated preference combination · Ecosystem service related to cultural and recreational activities · Climatic changes · World Biosphere Reserve · Lake Saint-Pierre

Introduction

Man and the Biosphere (MAB) Programme, launched in 1971 by the UNESCO, aims to support and implement interdisciplinary scientific research that addresses the challenges of biodiversity conservation and sustainable development of populations at both local and global scales (Ishwaran 2012). The global network of biosphere reserves is its main tool and provides support sites for the implementation of empirical studies, involving different actors such as scientists, local communities, or managers of natural areas (Schultz et al. 2011). In 2017, 669 biosphere reserves in 120 countries are identified in this global network. Included since 2008 in the Biosphere Reserves Action Plan (UNESCO 2008; UNESCO 2016), ecosystem services (ES) have emerged as a key concept for the management of these biosphere reserves (Bridgewater and Babin 2017).

The concept of ES has been developed to reflect the links of dependence between biodiversity and society. For example, early work focused on the functioning of ecosystems and their role in meeting the needs of human well-being (Ehrlich and Mooney 1983; Costanza et al. 1997). In 2005, the publication of the Millennium Ecosystem Assessment Report (MA 2005) was a milestone in the international recognition, both scientific and political, of the concept of ES. Following the MA, initiatives such as The Economics of Ecosystems and Biodiversity (TEEB 2010), and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (Diaz et al. 2015), have sought to go further by assessing in a more systematic way the economic benefits corresponding to these ES. Consensually, these ES are defined as "the benefits humans derive from ecosystems" and thus constitute the link between biodiversity and human well-being (MA 2005).

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The most common typology of ES is also that of MA (2005) and has four categories of services: provisioning services result from the direct exploitation of ecosystems (e.g., food, timber, energy, and genetic resources); regulatory services come from processes of regulation of the ecological functions that humans benefit from (e.g., regulation of diseases, purification of water, and pollination); cultural services contribute to the cultural, spiritual, and esthetic dimensions of human well being (e.g., ecotourism, values of education, and beauty of landscapes); support services represent the basic processes essential to the existence of all ecosystems (e.g., nutrient cycle and biomass production) and allows the maintenance of the three categories of services mentioned above.

In a context of climate change associated with a biodiversity crisis, ES appear to be a preferred tool for scientists and policy makers for decision support. On the one hand, the scientific literature dealing with ES is constantly increasing since the publication of Costanza et al. 1997 and leads to considered ES as "*a major academic field, drawing in various academic disciplines, perspectives, and research approaches*" (Abson et al. 2014). On the other hand, the Aichi targets (CBD 2010) encourage the implementation of ES assessments in order to raise people's awareness regarding biodiversity values by stakeholders (target 1), integrate biodiversity values into national and local development strategies, planning processes and national accounting (target 2), and restore and safeguard essential ES (target 14). In this context, biosphere reserves are also tasked with assessing the ES they produce and reporting to the MAB program.

Each category of ES cited above implicitly refers to specific types of assessment (EPA (Environmental Protection Agency) 2009). Nevertheless, the methods for determining economic values are all based on monetary valuation principles in the sense that they reflect the monetary expression of people's attachment to the environment. Through these methods, it is a question of studying the preferences of individuals either on the basis of their actual behaviors, or on the basis of their statements during surveys, to determine the utility that they obtain from having these ES.

Based on the case of the Lac Saint-Pierre (LSP) World Biosphere Reserve (Quebec, Canada), this paper seeks to analyze the actual and potential impacts of climate change on ES associated with cultural and recreational activities practiced at the LSP. To do so, we propose to measure two dimensions of this loss. As a first step, we report the losses in terms of revenue associated with reductions in Quebec people's recreational expenditures to visit LSP. Subsequently, the travel-cost data, based on an assessment of actual behavior, and the contingent behavior data, based on expected of future visiting decisions, are combined in a panel random-effect estimation to assess the demand for recreational uses. In this context, this study aims to contribute to the understanding of the effects of climate change on cultural ES by using their potential loss of economic value.

Data

Field Study: LSP

The LSP is a floodplain covering an area of about 500 km^2. It constitutes a unique ecosystem formed by a great diversity of wetlands, representing ~40% of the wetlands found along the St. Lawrence River. These wetlands serve as habitat for a large number of wildlife and plant species, including 72% of the birds listed in Quebec, and 70% of freshwater fish species found in Quebec. Because of its ecological importance internationally, the LSP was designated a Ramsar site in 1998, and was declared a World Biosphere Reserve in 2000 by UNESCO (Fig. 1).

Nearly 75% of the Quebec population lives in the large watershed of the LSP, one-third of whom (1.9 million people) live in the watersheds of direct tributaries (MDDEFP 2013). ES related to fishing, flood prevention, or water purification benefit this population directly. This ecosystem is also the support for recreational and tourism activities, generating employment and income in this sector.

In recent decades, the integrity of the LSP ecosystem has been profoundly affected by human activities in both its watersheds and directly on the floodplain, resulting in habitat loss for fauna and flora (MDDEFP 2013). Although water pollution from contaminants in sediment from the LSP has decreased due to the implementation of several government programs, water quality is still a concern in many areas. For 2 decades, there has been a decline in the population of some species of fish such as the yellow perch, a situation that has become so critical that a moratorium on perch fishing was introduced in 2012.

While much remains to be done to improve the water quality of the LSP, and more generally its ecosystem, climate change risks are making these improvement efforts even more difficult. Ongoing climate change has the potential to result in significant changes to the Lake's hydrological regimen, including, among other things, likely lower or earlier floods and more severe low flows. Episodes of massive fish mortality related to unusually high water temperatures, such as that observed in 2001 (Mingelbier et al. 2001), may also be more frequent. Thus, in addition to their effects on habitats, these climatic conditions will make it potentially increasingly difficult to reconcile the protection of biodiversity with the maintenance or development of certain activities practiced on the LSP, such as fishing.

Fig. 1 Lac Saint-Pierre and its principal tributaries (Environnement Canada, 2013[1])

Construction of the Questionnaire

An interdisciplinary working group of 18 experts, consisting of six biologists, four economists, three environmental scientists (ecology, forestry, etc.), two geographers, two hydrologists, and 1 biostatistician was formed. The purposes of these panels were: (1) to identify a baseline scenario and prospective scenarios related to the quality of LSP in the context of climate change; and (2) select and characterize the attributes of the LSP that can be modified by climate change and influence the well-being of users.

The identification of baseline and prospective scenarios of the LSP was first carried out on the basis of the Huard (2016) hydrological study in which the water levels of the Great Lakes and St. Lawrence River are analyzed on the historical database (1990–2013), and modeled against potential future climate conditions (2015–2065). In addition, the biophysical and economic impacts related to water level changes at the LSP are estimated on the basis of flows replenished at Sorel by Environment Canada (Bouchard and Morin 2000). The typical prospective scenario that was identified corresponds to a hot and dry climate in which the flow of water is greatly reduced, which lead to a fall of water level in LSP of 30–40 cm, equal to 10–14% of its current average water level, about 3 m. Given the predicted reduction of water level, the panel of the experts identified five attributes of the LSP that are most likely to be affected by lower water level and at the same time have more direct impact on the well-being of lake users. They are (1) the ecological quality of fish habitat, (2) the ecological quality of bird habitat, (3) the water quality, (4) riparian conditions, and (5) LSP's global reserve status. To describe the potential impact of the climate change on the ES of LSP, the current status and the expected deteriorations of each of the five attributes were presented in Table 1.

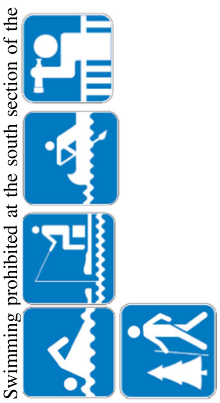
The questionnaire was divided into two parts.[2] The first part aims to collect information about the demand function of trips to LSP in a travel-cost method style. It includes questions concerning the cultural and recreational activities practiced by respondents, their trips to the LSP during the past year, and the expenditures incurred during their last trip. Other questions were also asked about respondents' socioeconomic profiles and their environmental attitude and their general cultural and recreational activities in natural environment. The second part aims at measuring the well-being variation of the LSP users following a deterioration in the quality of the LSP. After being presented with the hypothetical scenario describing the potential changes of LSP under the climate change (Table 1), every respondent was asked about the number of trips that he/she plans to make in the next year to the LSP.

Sampling

After a pretest phase, the questionnaire was administered online. The targeted respondents are general Quebec population aged 18 and over, including both visitors and non-visitors of LSP. The online survey was administered by two online survey companies: Survey Sampling International and Research Now. Respondents were recruited from the large nonrandom samples of Quebec Internet

[1] http://www.ec.gc.ca/stl/default.asp?lang=Fr&n=09C5A944-1

Table 1 Lac Saint-Pierre under climate change: current situation versus the hypothetical future situation

	Current situation	Hypothetical future situation
Habitat quality for fish	In deterioration (1) Eight threatened fish species, equivalent to 10% of the 79 species found there (2) Yellow Perch is subject to a 5-year moratorium on sport and commercial fishing	In accelerated deterioration (1) Increase in the number of fish species with precarious status (2) Restriction of sport and commercial fishing in the coming decades
Habitat quality for birds	Risk of deterioration Twelve species of vulnerable or threatened birds, equivalent to 4% of the 288 species existing on the lake	In deterioration Increase in the number of precarious bird species, change in bird communities and appearance of more typical species in southern regions
Water quality (in term of possible activities)	Average Swimming prohibited at the south section of the lake 	Bad Only non-contact activities with water are allowed 
Waterfront condition (space available for recreational tourism activities)	Current situation	A reduction in available space of around 20% compared with the current situation
Status of UNESCO and Ramsar Site	Maintained	Threatened

respondents that the two compagnies possess to satisfy requirements for representativeness and were compensated for their participation. Members of the survey panel were sent an email invitation to our survey, but were not told in advance of its subject. Upon accepting the invitation, respondents were presented with an informed consent letter, which contains background information of our research project.

Of the 2361 respondents who completed our questionnaire, 451 visited the LSP in the past. Of these, 165 respondents made at least one trip to the LSP during the last 12 months. Since the sociodemographic profile of the sample population is relatively well correlated with the sociodemographic profile of the Quebec population, we can assume that the probability of a Quebecer having visited the LSP during the last 12 months is equal to 7% (=165/2361).

Loss in Recreation Revenue Caused by Climate Change: Revealed Preferences

As a first step, by using the information in our survey concerning the variations in the number of trips auto-reported by the respondents after considering the potential deterioration in ES of LSP, we conduct a simple financial analysis to estimate the potential loss in recreation revenue.

Of the 165 respondents who visited in the last 12 years LSP, 155 provided complete information on expenditures related to their last visit to the LSP, Table 2 shows these expenditures details. Accommodation is the largest expense item with \$8785 spent (27.95% of total expenses). Food (\$8450) and transportation costs (\$7381) represent the second and third largest items, accounting, respectively, for 26.89 and 25.03% of total expenditures.

Using these data, we calculate the average expenditure at \$202.74 per visit, the average group size at 3.13 people (children and adults combined) and the average length of a visit at 2.48 days (Table 3). We can thus calculate the average daily expenditure per person at \$26.11 (=202.74/(3.13 × 2.48)). Combining these unit costs with the total volume of annual visits, which is assumed as 7% of total Quebec general population, we can extrapolate the total recreation revenue that LSP receive from these visitors is about \$176 M/year. This number should be considered as conservative when compared with the past studies such as MDDEFP (2013), Groupe Conseil Genivar Inc. (2005), BCDM Conseil Inc. (2005a), BCDM Conseil Inc. (2005b), and Collard et al. (2010), which report a total tourism revenue for the similar activities up to \$624 M. We can explain such difference by two reasons, the first is that the 165 respondents who visited the LSP in the past 12 months cannot represent the whole situation of the general LSP tourists, since our sampling strategies only allow us to concern about the representativeness of the whole sample with respect to the total population of Quebec. Secondly, it is also possible that the details of the expenditures related to the last visit that reported by the 155 visitors contains errors and imprecisions.

The survey data also report a decrease in the average number of trips to LSP of 2.69 times if the lake undergoes a deterioration as described in Table 1, which signifies a reduction of total trip by 56.87%. The reduction in the total revenue that LSP can receive from its cultural and recreational activities under climate change context is thus estimated at about $100 million/year.[3]

Loss in Consumer Surplus of Visitors to LSP under Climate Change Context

The loss of revenue from cultural and recreational activities on LSP reported in last section consists only of a lower bound estimate for the loss of the value of the ecological services of LSP. Logically, to motivate a visit, the gain in terms of the utility an individual can obtain from his/her trip must be greater than the amount he pays. From the point of view of microeconomics, we distinguish between the payment to obtain a good or service and the total satisfaction that we can obtain by consuming it. The difference between the total satisfaction and the payment is called as "consumer surplus," which measures the monetary gain obtained by consumers because they are able to purchase a product for a price that is less than the highest price that they would be willing to pay (Boulding 1945). To measure the loss in terms of consumer surplus, we combined a revealed preference method, travel cost and a stated preference method, contingent behavior together.

Table 2 Details of expenses incurred during the last LSP visit in the last 12 months ($N = 155$)

Expenditures	Total expenses ($)	%
Direct transport costs	7381	23.49
Food	8450	26.89
Lodging	8785	27.96
Material/Equipment	2265	7.21
Purchase of access right/permit/package	2603	8.28
Other expenses	1941	6.18
Total	31,425	100.00

Method

Whitehead et al. (2008) points out that revealed preference and stated preference approaches are complementary. Revealed preference data are often limited to analyzing behavior in responses to a limited range of markets or environmental changes, and stated preference surveys can be designed to collect data on hypothetical behavior beyond the range of historical experience. Combining revealed preference data with stated preference data can therefore allow an extension of behavioral model beyond limited range of historical experience. On the other hand, the stated preference methods directly ask individuals to disclose their preference, after presenting a hypothetical scenario. These methods are often criticized by the potential hypothetical biases, which can lead to exaggeration of people's

Table 3 Calculation details of the economic benefits of recreational tourism activities

Average expenses (A)	$26.11/day
Average annual number of visits per individual (B)	4.73 trips/year/person
Average number of days per visit (C)	2.48 days/trip
Population of Quebec in 2014 (D)	8,214,672 person
Probability for a Quebecer to have been to the LSP in the last 12 months (E)	0.07
Number of Quebec tourists at the LSP in the last 12 months (F = D × E)	574,087.62 person
Number of visits to the LSP by Quebeckers in the last 12 months (G = B × F)	2,715,434.44 trips
Number of days of visits to LSP by Quebeckers in the last 12 months (H = G × C)	6,734,277.42 days
Total annual revenue from recreational activity in LSP (I = H × A)	**$175,831,983/year**
Average reduction in number of trips per year (J)	−2.69 trips/year/person
% of reduction with respect to current situation (K = J/B × 100%)	−56.87%
Loss in total annual revenue of recreational activities in LSP	**−$99,997,470.20/year**

For better concordance and to facilitate the comparison of the results between methods, the calculations of the economic benefits associated with the LSP visits that we present in the next tables are based on the information given by the 117 people which provided answers to the contingent behavior question about their future trips to LSP under the impacts of climate change. The average number of visits of the 155 respondents is 4.54 times/year preference by a factor of 1.3–3 (List and Gallet 2001, Little and Berrens 2004, Murphy et al. 2005), due to lack of consequentiality in the proposed hypothetical scenario (Carson and Groves 2007). The combination of revealed and stated preferences data has therefore been favored by some authors (e.g., Whitehead et al. 2000; Azevedo et al. 2003; Whitehead et al. 2008; Haefen and Phaneuf 2008) to overcome the hypothetical bias of declared preferences.

In this paper, we therefore propose to combine the travel-cost data (revealed preference) and the contingent behavior data (stated preference) to evaluate the potential recreation benefits loss caused by expected negative climate change impacts on LSP. Such a combination allows us first to use the revealed preference data to calibrate visitors' preference to the current conditions, and then to adopt the stated contingent behavior data to estimate the potential variations in people's preference due to expected deterioration in the quality of LSP under climate change.

Figure 2 illustrates the demand curve of an individual i to visit the LSP in the current situation Q_0, more precisely, $N_{i0} = f(C_i, Q_0, Z_i)$, where the number of trips in last year (N_{i0}) of this individual i depends on the travel-cost C_i, the quality of Lake Q_0, and the socioeconomic characteristics of the individual i, Z_i. As the logic predicts, the demand curve is decreasing, which means that an increase in the travel-cost C_i reduces the number of trips, N_i. For a given individual i, with a travel-cost equal to C_i, we can identify the number of his trips to LSP from his demand curve as N_i and thus deduces the total travel costs of the individual, equal to the area B_i ($=N_{i0} \times C_i$). Since the surface below the demand curve measures the total utility that this individual can obtain from his visits, the triangular surface Ai measures the net benefits, called as consumer surplus that the individual i obtain through his N_i times of visits. Suppose now a deterioration in lake quality from Q_0 to Q_1 discourages this individual's desire to visit LSP, so the demand curve shifts to the left and becomes $N_{i1} = f(C_i, Q_1, Z_i)$. As illustrated in Fig. 2, at constant travel costs at C_i, the number of visits of this individual i reduces to N_{i1}. The surface Ai' represents the new consumer surplus associated with his/her N_{i1} visits. We use the difference between the area A_i and A_i' to

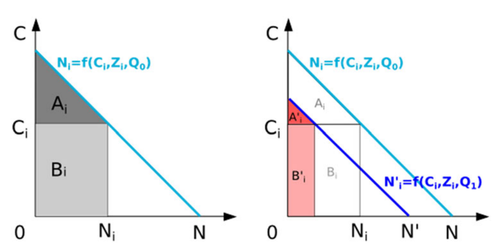


Fig. 2 The estimated visit demand for an individual i with the current quality of the lake (left) and with the deteriorated quality of the lake (right)

measure the loss of visitors' consumer surplus from visiting LSP due to change and the difference between B_i and B_i' to measure the loss of revenue related to the cultural and recreational activities over the LSP.

Based on this logic, we pool the both trip responses given by each individual N_{it} ($t = 0$ or 1) together and estimate a joint recreation demand model. The random-effect negative binomial model is employed to take into account the potential heterogeneity among respondents.

Assume that N_{it}, the number of trip taken by individual i in a scenario t is drawn from a negative binomial distribution with mean μ_{it}.[4] We therefore can have μ_{it} that depends on a series of explanatory variables grouped into C_i, Q_t, and Z_i and individual heterogeneity. More specifically, the expected mean of the annual number of visits of the LSP of an individual i is determined by his travel cost to LSP, C_i, the vector of the sociodemographic variables of this individual Z_i, and the quality of the lake Q_t. Here, two situations t are described: the current or actual situation ($Q_t = 0$) and the future or hypothetical situation in case of lake deterioration ($Q_t = 1$).

$$\mu_{it} = \exp(\beta_0 + \beta_1 C_i + \beta_2 Q_t + \beta_3 Z_i + u_i),$$

where u_i is a random effect for individual i. This term allows capturing trip variation across individuals that cannot be explained by the included explanatory factors. By assuming $\exp(u_i)$ following a gamma distribution, the unconditional number of trips, N_{it}, based on Hausman et al. (1984), follows a negative binomial distribution, which loosens the restrictive assumption of the Poisson distribution that the variation is equal to the mean.

The vector of sociodemographic variables that we include to explain demand (Z_i) includes age, gender, income, annual frequency of cultural and recreational activities (fishing, nature observation, cycling, and hiking in nature), and purchase or not of an annual fishing license from the LSP Wildlife Area Community, whether respondent lives in urban area, whether he or she owns a cottage, his/her health status, etc. Finally, travel costs (C_i) represent the travel costs of individuals for each of their trip to LSP. Considering the potential underestimation of the auto-reported travel expenditures that we observed in the last section, we decided to use the fuel costs and car wear to travel from one's residence to the LSP to measure the travel cost here. Precisely, the travel costs are calculated by using the function $C_i = c \times d_i$. Here d_i is the minimum travel distance from respondent's place of residence to the closest recreation site over the LSP, which is calculated via the application *Google Map*. c is equal to \$0.53/km,

[4] The negative binomial distribution is a generalized Poisson distribution including a gamma noise variable that has a mean of 1 and a scale parameter of v.

corresponding to the travel cost per km that includes fuel, maintenance, tires, insurance, driving license and registration, depreciation, car loan, etc., based on the information collected from Canadian Automobile Association (2013).[5]

Results

We presented the statistical descriptions of the data used in our combined estimation method in Table 4. Explanations on the formation of variables are given in the notes at the bottom of the table.

Table 5 presents the results of the random-effect negative binomial model. As expected, the coefficient associated with the travel cost is negative and significant at 95%, which means that higher is the cost of transport, fewer trips are made in a year: this confirms the decreasing demand curve for trips to LSP. We also confirm statistically that the deterioration of the LSP under the pressure of climate change has a statistically significant negative effect on the frequency of trips to the LSP. The number of trips is also found to be significantly affected by the recreational activity practiced by respondents at LSP. Our result reveals that, all else being equal, respondents come more often to LSP for bird observation are significantly more frequent visitors to LSP. Similarly, the number of trips is statistically higher among individuals who are accustomed to purchase annual fishing licenses from the LSP Wildlife Area Community. Male respondents tend to visit LSP more often than female respondents. Finally, although statistically insignificant, we note that the signs of the coefficients for the other variables such as income, health status, cottage, and urban residents also correspond well to our expectation.

[5] Although some interesting literatures have developed around the credibility of both the auto-reported travel cost and the standardized transport cost proxied by distance (see Randall 1994; Ovaskainen et al. 2012, among others), using the fuel cost and car wear as proxy of travel cost is a common way in the related literature, since very often the transport cost consists of the biggest expenditure of a trip. By using this proxy, we depart from the tourism revenue context since in both the travel cost and the contingent behavior data, we were more interested to measure visitors' preference captured in consumer surplus, equal to the difference between total satisfaction and the actual payment. So here, a more precise measurement of the real cost payed for a trip comes to be very important, we therefore adopted the distance-based measurement in aims of gaining in measurement precision. We acknowledge certainly the potential problem with this standardized measurement of the travel cost, since people may consider the length of the travel in very heterogeneous way. We hope our combined methods based on random-effect estimation model for panel data to capture at least some part of this heterogeneity between people. We did the same estimation with the auto-reported expenditure data, but the results were statistically insignificant and very difficult to interpret. We also believe these unsatisfactory results can be explained by the potential omissions in the auto-reported trip related expenditure data that we observed in the previous section.

Table 4 Descriptive statistics ($N = 117$)

Variable	Mean	Stan. dev.	Min.	Max.
Number of visits in the last 12 months (current situation)	4.73	5.90	0.51	44.44
Number of visits in last 12 months (deteriorated situation)	2.04	2.56	0.23	18.81
Cost of the trip (in $)	64.05	52.15	3.65	378.22
Average income	0.38	0.49	0	1
Gender	0.63	0.48	0	1
Annual fishing frequency	5.08	11.57	0	52
Annual hiking frequency	4.84	10.53	0	52
Bird observation frequency	5.74	10.39	0	52
Annual cycling frequency	5.29	13.08	0	52
Health status	0.15	0.36	0	1
Urban	0.74	0.44	0	1
Cottage	0.13	0.34	0	1
AFC Authorization	0.11	0.32	0	1

Average income = 1 if income is <$50,000, 0 if income is >$50,000; sex = 1 if it is a man, 0 if it is a woman; state health = 1 if the individual has a health problem that prevents him from doing recreational-tourist activities, 0 otherwise; in urban areas = yes = 1, no = 0; cottage = own cottage on LSP = 1, 0 otherwise; AFC clearance = 1 if the respondent has purchased LSP AFC fishing authorizations each year for the last 5 years, 0 otherwise

For a representative respondent of our survey, based on our estimation, the expected number of trips can be written as:

For current situation: $n_{i0} = \mathrm{Exp}(N_{it}| C_i, Q_0, Z_i) = \exp(\beta_0 + \beta_1 C_i + \beta_2 Q_0 + \beta_3 Z_i)$.

Under climate change: $n_{i1} = \mathrm{Exp}(N_{it}| C_i, Q_1, Z_i) = \exp(\beta_0 + \beta_1 C_i + \beta_2 Q_1 + \beta_3 Z_i)$.

For both situations, the consumer surplus can be calculated as following:

$$CS_{it} = \int_{C_i}^{\infty} \exp(\beta_0 + \beta_1 C_i + \beta_2 Q_t + \beta_3 Z_i) dC_i = \frac{\exp(\beta_0 + \beta_1 C_i + \beta_2 Q_t + \beta_3 Z_i)}{\beta_1} = \frac{n_{it}}{\beta_1}.$$

Therefore the variation in consumer surplus under the pressure of climate change will be

$$\Delta CS_{it} = \frac{\exp(\beta_0 + \beta_1 C_i + \beta_2 Q_0 + \beta_3 Z_i)}{\beta_1} - \frac{\exp(\beta_0 + \beta_1 C_i + \beta_2 Q_1 + \beta_3 Z_i)}{\beta_1} = \frac{n_{i0} - n_{i1}}{\beta_1}$$

As the sample mean value of number of trips is 4.73 for current situation, the consumer surplus of the LSP under current situation can be deducted as $999 for a representative respondent of our sample (=−(4.73/

Table 5 Results of the RP–SP combined method (negative binomial model with random effect)

Variables	Nb. annual visits	
Transport costs[a]	−0.00473**	(2.14)
Lake quality (=1 after CC)	−0.843***	(6.43)
Average income	0.035	(0.16)
Gender	0.33*	(1.89)
Annual fishing frequency	−0.0156	(1.47)
Annual hiking frequency	0.0204	(1.49)
Bird observation frequency/year	0.0276*	(1.89)
Annual cycling frequency	0.00122	(0.16)
Health status	−0.233	(0.97)
Urban	−0.0358	(0.19)
Cottage	0.176	(0.60)
AFC authorization	0.743**	(2.18)
Constant	0.830***	(2.71)
Observations	234	
Number of individuals	117	

Student's t value in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, estimation model: binomial negative to the random effect

[a]This distance was calculated using the Google Map application and corresponds to the number of kilometers separating the respondent's city of residence and the center of the north or south bank of the LSP (according to the bank closest to the place of residence). The constant c corresponds to the amount an individual spends on average per km, estimated at $0.53/km based on information collected by the Canadian Automobile Association (CAA 2013) and corresponding to the ratio between all annual expenses related to fuel, maintenance, insurance, driver's license, registration, depreciation, auto loan, and the total number of kilometers driven per year

−0.0047326)), which is equal to $211.20 per trip or $85.16 per day per visitor in average. Based on more than ten past studies using similar methods as ours, Poe et al. (2013) reported in their review study that the net benefits of recreational fishing in the Great Lakes Basin, to which the LSP belongs, vary around US$22–91 per day per visitor. Our number came to be comparable to those reported in their paper (Table I.1, pp. 6–7), but stayed close to the upper bound. We also compared our results with some more recent studies which, employing either travel-cost, contingent behavior, or their combined methods, measured the recreational value of some open-water ES similar to those of LSP. As illustrated in the Table 6. The average consumer surplus per trip of these studies, conducted in comparable socioeconomic context, ranges from 63 to 973 CAD per day. Therefore, our study seemed fall on the lower bound of value range. But we believe the comparison with the review of Poe et al. (2013) to be more relevant, since the sites in the other more recent studies may not be comparable in terms of their geographical location from their potential recreational users. For example, some sites studied in these studies may locate in more isolate places, which implies higher transport costs, which may in their turn to affect the frequency between trips and the length of each trip. These differences may then make direct comparison of consumer surplus between sites somewhat difficult.

The reported total consumer surplus for the average of 4.73 times visits to LSP is obviously higher than total expenditure for these visits, which can be calculated by the auto-reported average expenditure for each visit $26.11 × 4.73 = $123.50 or by the average transport cost calculated from fuel cost and car wear $64.05 × 4.73 = $302.96. Based on the conception of consumer surplus, which is the net satisfaction after deducting the payment, we can infer that the total satisfaction of the ES of LSP for a representative respondent of our sample is $999 + $123.5 = $1122.5 (auto-reported expenditure) or $999 + $302.96 = $1301.96 (transport cost).

Extrapolating this consumer surplus value from our representative sample to the entire Quebec population, we estimate an average consumer surplus for a representative Quebec person to be $49.51 per year, which signifies a total consumer surplus of LSP for the whole Quebec population amount to $407 M/year (more details about the extrapolation are in Tables 7 and 8).

We can also calculate the reduction in consumer surplus due to climate change which is equal to $569 (=(4.73/(−0.0047326)) − (2.04/(−0, 0047326)). According to our calculation, the average value of use of a Quebecer from the LSP will reduce from $49.51/year to $21.31/year, representing a 42% reduction in current value at the Quebec scale, this loss in value is in the order of $232 million for the whole Quebec population.

Discussion

This study estimates the loss of economic value of recreation-related ES of the LSP under the pressure of climate change. Two methods were used in a complementary way: the accounting method that calculates the variations in the annual revenue of cultural and recreational activities and the combination of the travel cost and the contingent behavior data to estimate the loss in visitors' utility measured by consumer surplus.

While both methods report significant negative impacts of this degradation linked to climate change on the value of recreation-related ES of the LSP, the interpretation of these results must nevertheless be made with caution.

First, our results are highly dependent on the quality and reliability of the data obtained through our online survey. One of the key pieces of this study is the expenditures each respondent made during their most recent trip to LSP. Besides having 10 out of 165 (6%) who did not report this information, we also observed some irregularities or

Table 6 Estimated consumer surplus of recreational activities based on ES of open-water system

Authors (year)	Studied sites	Country	Consumer surplus per trip	Consumer surplus per day
Chae et al. (2012)	Marine protection area of Lundy	Great Britain	814–1864 CAD (514–11800£)	–
du Preez and Hosking (2011)	Rhode	South Africa	1823 CAD (14025 ZAR)	372 CAD (2862 ZAR)
Grilli et al. (2018)	The Salmon rivers Moy and Corrib	Ireland	848–1940 CAD (562–1286€)	424–970 CAD (281–643€)
Olaussen (2016)	Salmon rivers	Norway	–	126 CAD (973 KOR)
Pokki et al. (2018)	Salmon rivers (River Teno)	Finland	355–510 CAD (235–338€)	63–91 CAD (41.89–60.25€)

Table 7 Calculation of the consumer surplus of the LSP under current condition

N	2361 persons
A_i minimal (minimum access value of our sample)	\$108.29/year
A_i maximal (maximum access value of our sample)	\$9391.32/year
$\frac{\sum_i A_i}{n}$: average consumer surplus of our sample ($n = 2361$ people)	\$49.51/year/person
Population of Quebec in 2014	8,214,672 persons
Total consumer surplus of the LSP for the Quebec population	\$407 M/year

exaggerations in the information reported by the 155 respondents. Although readjustments (replacing figures clearly exaggerated by the sample mean) were made to avoid bias, we were unable to make further checks on what appeared to be reasonable information. This remains the main reason that led us to use the extrapolation of transportation cost to travel distance between the residence and LSP in the combination model, which reduce the direct comparability between the two parts of analyses. In particular, we suspect that people gave more focus to the past trip that has incurred the highest expenditures. We also observed some very big number in some travel cost inquired in our survey, in particular the materials and equipment, for which some respondents may have tendency to report the entire purchase price instead of their actual depreciation during the last trip. Both observations can contribute to an overestimation of the LSP's annual revenue related to cultural and recreational activities. On contrary, the value of ES of LSP may also be underestimated since we did not include the value of the time or the opportunity cost of the time spending in visiting LSP. In addition, in the demand function for trips to LSP, we choose not to include potentially existing substitute recreational sites into our consideration. Although this intention was motivated by the uniqueness of the LSP as recreational site for Quebec population, excluding the substitute sites of LSP may also lead to an underestimation of the value of LSP.

Come to the method that combines revealed and stated preference data, although the panel data estimation method allows us to control some nonobservable characteristics of each respondents that can affect their recreational decisions with respect to LSP, we cannot exclude the possibility that such approach still suffers from most of the bias related to stated preference methods. The main concern is on the credibility of the expected number of trips reported by the respondents. As Carson and Groves (2007) point out, the respondent's perception that the survey is hypothetical will not necessarily yield hypothetical results, the relevant question is whether the survey is perceived by the participants as consequential. Vossler et al. (2012) also suggest that respondents' preferences may be revealed by hypothetical questions, provided that participants view their decisions as likely to influence reality (e.g., public policies). Although the consequence of the climate change described in our hypothetical scenario can be considered as realistic, we are not certain about to what extend the respondents regard such scenario as credible and to what extend such scenario can motivate their incentive to anticipate rationally their behavior in the future. This may be particularly true since the deterioration described in the hypothetical scenario is one that no one has experienced in the past.

We should also give caution when interpreting the aggregate results provided in this paper. The extrapolation of the sample means to the aggregate value of LSP is based on the assumption of the representativity of our sample with respect to the general population of Quebec. Such representativity actually requires our survey to meet the condition that every person living in Quebec has the same probability to be recruited to our survey, which in its turn can be used to justify the extrapolation from the average probability to visit LSP observed in our database to the whole population. Given that the sample frame of our survey is two large online panels, we cannot exclude the possibility that some characteristics of the people willing to participate in such panels are relevant to their cultural and recreational activities choice.

Table 8 Calculation of the change in the consumer surplus of LSP caused by climate change (CC)

	After CC	Before CC	Variation
A_i or ΔA_i minimum (minimum access value or minimum variation)	\$46.61/year	\$108.29/year	−\$61.68/year
A_i or ΔA_i maximum (maximum access value or maximum variation)	\$4041.60/year	\$9391.32/year	−\$5349.72/year
$\frac{\sum_i A_i}{n}$: average consumer surplus of our sample ($n = 2361$ people)	\$21.31/year/person	\$49.51/year/person	−\$28.20/year/person
Population of Quebec in 2014	8,214,672 persons		
Total consumer surplus of the LSP for the Quebec population (million dollar)	\$175 M/year	\$407 M/year	−\$232 M

Conclusion

ES assessments are carried out around the world at both local and global scales considering the dependencies between society and nature in order to promote the conservation of biodiversity. In this context, UNESCO's MAB program has established local assessments of ES within its network of global biosphere reserves. The evaluation carried out within the LSP's reserve proposes two methods for assessing the potential loss of the value of ES under the pressure of climate change, first of all by a method based on the calculation of the loss of revenue of the recreational and tourism activities supported by these ES, then by the combination of the travel cost and contingent behavior data to measure the loss of consumer surplus of the LSP visitors. These figures are informative but should be considered with the potential biases inherent in their methods and cannot be self-sufficient in the context of an ES assessment. They can be useful economic indicators for the implementation of broader analyzes based on multi-criteria approaches or as part of an accounting approach. In a context of climate change, we believe our study can contribute to the group of analyses interesting in the evolution of the demand for cultural and recreational activities in view of their synergies and/or possible compromises with the demand for other types of ES.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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References

Abson DJ, von Wehrden H, Baumgärtner S, Fischer J, Hanspach J, Härdtle W, Heinrichs H, Klein AM, Lang DJ, Martens P, Walmsley D (2014) Ecosystem services as a boundary object for sustainability. Ecol Econ 103:p29–p37. https://doi.org/10.1016/j.ecolecon.2014.04.012

Azevedo CD, Herriges JA, Kling CL (2003) Combining revealed and stated preferences: consistency tests and their interpretations. Am J Agric Econ 85(3):525–537 https://www.jstor.org/stable/1244980

BCDM Conseil Inc. (2005a) Rapport III: La pêche sportive au lac Saint-Pierre en 2003. Pêche sur la glace: évaluation des retombées économiques. Pour leministère des Ressources naturelles et de la Faune, Direction de la recherche sur la faune, Québec. p 67

BCDM Conseil Inc. (2005b) Rapport IV: La pêche sportive au lac Saint-Pierre en 2003. Pêche en eau libre: évaluation des retombées économiques. Pour leministère des Ressources naturelles et de la Faune, Direction de la recherche sur la faune, Québec. p 89

Bouchard A, Morin J (2000) Reconstitution des débits du fleuve Saint-Laurent entre 1932 et 1998. Environnement Canada, Service météorologique du Canada, Section Hydrologie. Rapport technique RT–101

Boulding KE (1945) The concept of economic surplus. Am Economic Rev 35(5):851–869

Bridgewater P, Babin D (2017) UNESCO–MAB Biosphere Reserves already deal with ecosystem services and sustainable development. Proc Natl Acad Sci USA 114(22):E4318. https://doi.org/10.1073/pnas.1702761114

CAA (2013) Coûts d'utilisation d'une automobile. Au-delà de l'étiquette de prix: comprendre les dépenses liées au véhicule. Édition 2013. Association Canadienne des Automobilistes

Carson RT, Groves T (2007) Incentive and informational properties of preference questions. Environ Resour Econ 37(1):181–210

CBD (2010) Decision UNEP/CBD/COP/DEC/X/2 adopted by the conference of the parties to the Convention on Biological Diversity at its tenth meeting. Convention on Biological Diversity (CBD). https://www.cbd.int/decision/cop/?id=12268

Chae D-R, Wattage P, Pascoe S (2012) Recreational benefits from a marine protected area: a travel cost analysis of Lundy. Tour Manag 33(2012):971–977

Collard A, Villeneuve F, Dombrowski P, Couture R (2010) Portrait faunique du Centre-du-Québec, Rapport préparé par la Fédération québécoise des Chasseurset pêcheurs, Région 17, pour la Commission Régionale sur les Ressources Naturelles et le Territoire du Centre-du-Québec

Costanza R, d'Arge R, de-Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neil R, Paruelo J, Raskin R, Sutton P, van den Belt J (1997) The value of the world's ecosystem services and natural capital. Ecol Econ 25(1):3–15. https://doi.org/10.1016/S0921-8009(98)00020-2

Daily G (1997) Nature's services: societal dependence on natural ecosystems. Island Press, Washington, DC

Díaz S, Demissew S, Carabias J, Joly C, Lonsdale M, Ash N, Larigauderie A, Adhikari JR, Arico S, Báldi A, Bartuska A, Baste IA, Bilgin A, Brondizio E, Chan KMA, Figueroa VE, Duraiappah

A, Fischer M, Hill R, Koetz T, Leadley P, Lyver P, Mace GM, Martin-Lopez B, Okumura M, Pacheco D, Pascual U, Pérez ES, Reyers B, Roth E, Saito O, Scholes RJ, Sharma N, Tallis H, Thaman R, Watson R, Yahara T, Hamid ZA, Akosim C, Al-Hafedh Y, Allahverdiyev R, Amankwah E, Asah ST, Asfaw Z, Bartus G, Brooks LA, Caillaux J, Dalle G, Darnaedi D, Driver A, Erpul G, Escobar-Eyzaguirre P, Failler P, Moustafa A, Fouda M, Fu B, Gundimeda H, Hashimoto S, Homer F, Lavorel S, Lichtenstein G, Mala WA, Mandivenyi W, Matczak P, Mbizvo C, Mehrdadi M, Metzger JP, Mikissa JB, Moller H, Mooney HA, Mumby P, Nagendra H, Nesshover C, Oteng-Yeboah AA, Pataki G, Roué M, Rubis J, Schultz M, Smith P, Sumaila R, Takeuchi K, Thomas S, Verma M, Yeo-Chang Y, Zlatanova D (2015) The IPBES Conceptual Framework-connecting nature and people. Curr Opin Environ Sustain 14:1–16

du Preez M, Hosking SG (2011) The value of the trout fishery at Rhodes, North Eastern Cape, South Africa: a travel cost analysis using count data models. J Environ Plan Manag 54(2):267–282. https://doi.org/10.1080/09640568.2010.505837

Ehrlich P, Mooney H (1983) Extinction, substitution, and ecosystem services. BioScience 33(4):248–254. https://doi.org/10.2307/1309037

EPA (Environmental Protection Agency) (2009) Valuing the protection of ecological systems and services. U.S. Environmental Protection Agency, Office of the Administrator, Science Advisory Board. Washingtin, DC, p 139

Grilli G, Landgraf G, Curtis J, Hynes S (2018) A travel cost evaluation of the benefits of two destination salmon rivers in Ireland. J Outdoor Recreat Tour 3292018:1–7

Groupe Conseil Genivar Inc. (2005) Étude des impacts socio-économiques: La sauvagine en migration dans le Québec méridional, particulièrement la Grande Oie desneiges et la Bernache du Canada. Environnement Canada, Ottawa, Canada. 63 pages and appendix

Huard D (2016) Étude économique régionale des impacts et de l'adaptation liés aux changements climatiques sur le fleuve Saint-Laurent: Description des scénarios climatiques. Rapport présenté à la Division des impacts et de l'adaptation liés aux changements climatiques, Ressources naturelles Canada et au gouvernement du Québec. Montréal: Ouranos

Hausman J, Hall B, Griliches Z (1984) Econometric Models for Count Data with an Application to the Patents-R & D Relationship. Econometrica 52(4):909–938. https://doi.org/10.2307/1911191

Ishwaran N (2012) Science in intergovernmental environmental relations: 40 years of UNESCO's Man and the Biosphere (MAB) Programme and its future. Environ Dev 1:91–101. https://doi.org/10.1016/j.envdev.2011.11.001

List JA, Gallet CA (2001) What experimental protocol influence disparities between actual and hypothetical stated values? Evidence from a meta-analysis. Environ Resour Econ 20(3):241–254

Little J, Berrens R (2004) Explaining disparities between actual and hypothetical stated values: further investigation using meta-analysis. Econ Bull 3(6):1–13

MA (Millenium Ecosystem Assessment) (2005) Ecosystems and Human Well-being. Vol 2: Current states and trends. Island Press, Washington DC, p 917

MDDEFP (2013) Retombées économiques des activités de chasse, de pêche et de piégeage au Québec en 2012 : Synthèse. Ministère du Développement durable, de l'Environnement, de la Faune et des Parcs, p 26. https://www.mffp.gouv.qc.ca/publications/faune/statistiques/retombees-economique-ccp.pdf

Mingelbier M, Trencia G, Dumas R, Dumas B, Mailhot Y, Bouchard C, Manolesco DC, Brodeur P, Hudon C, Ouellette G (2001) Avis scientifique concernant la mortalité massive des carpes dans le Saint-Laurent durant l'été 2001. Société de la faune et des parcs du Québec, Ministère de l'environnement, Biodôme de Montréal, Environnement Canada. p 25

Murphy JJ, Allen PG, Stevens TH, Weatherhead D (2005) A meta-analysis of hypothetical bias in stated preference valuation. Environ Resour Econ 30(3):313–325

Olaussen J (2016) Catch-and-release and angler utility: evidence from an Atlantic salmon recreational fishery. Fish Manag Ecol 23 (3–4):253–263. https://doi.org/10.1111/fme.12167

Ovaskainen V, Neuvonen M, Pouta E (2012) Modeling recreation demand with respondent-reported driving cost and stated cost of travel time. J For Econ 18(4):303–317

Poe GL, Lauber B, Connelly NA, Creamer S, Ready RC, Stedman RC (2013) Net benefits of recreational fishing in the Great Lakes Basin: a review of the literature. Department of Natural Resources, N.Y.S. College of Agricultural and Life Science, Cornell University, Ithaca, NY, p 79. HURU Series no. 13–10. http://dnr.cornell.edu/hdru/pubs/HDRUReport13-10.pdf

Pokki H, Artell J, Mikkola J, Orell P, Ovaskainen V (2018) Valuing recreational salmon fishing at a remote site in Finland: a travel cost analysis. Fish Res 208(2018):145–156

Randall A (1994) A difficulty with the travel cost method. Land Econ 70(1):88–96

Schultz L, Duit A, Folke C (2011) Participation, adaptive co-management, and management performance in the world network of biosphere reserves. World Dev 39(4):662–671. https://doi.org/10.1016/j.worlddev.2010.09.014

TEEB (2010) Kumar P (ed) The economics of ecosystems and biodiversity ecological and economic foundations. Earthscan, London

UNESCO (2008) Madrid action plan for biosphere reserves (2008–2013). UNESCO, Paris

UNESCO (2016) Lima Action Plan for UNESCO's Man and the Biosphere (MAB) Programme and Its World Network of Biosphere Reserves (2016–2025)

von Haefen RH, Phaneuf DJ (2008) Identifying demand parameters in the presence of unobservables: A combined revealed and stated preference approach. J Environ Econ Manage 56(1):19–32

Vossler CA, Doyon M, Rondeau D (2012) Truth in consequentiality: theory and field evidence on discrete choice experiments. Am Economic J 4(4):145–171

Whitehead JC, Haab TC, Huang J (2000) Measuring recreation benefits of quality improvements with revealed and stated behavior data. Resour Energy Econ 22:339–354. https://doi.org/10.1016/S0928-7655(00)00023-3

Whitehead JC, Pattanayak SK, Van Houtven GL, Gelso BR (2008) Combining Revealed and stated preference data to estimate the nonmarket value of ecological services: an assessment of the state of the science. J Economic Surv 22(5):872–908. https://doi.org/10.1111/j.1467-6419.2008.00552.x