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Valuing stakeholder preferences for environmental benefits of stormwater ponds: Evidence from choice experiment

Joan Ureta [a,*], Marzieh Motallebi [b], Michael Vassalos [c], Mustapha Alhassan [a,d], J. Carl Ureta [a]

[a] Department of Forestry and Environmental Conservation, Clemson University, Clemson, SC, USA
[b] Baruch Institute of Coastal Ecology and Forest Science, Clemson University, Georgetown, SC, USA
[c] Department of Agricultural Sciences, Clemson University, Clemson, SC, USA
[d] Water, Environmental, & Ecosystems Division, United States Bureau of Reclamation, Technical Service Center, Denver, CO, USA

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ABSTRACT

With population growth driving urban expansion in many cities in the United States, there is a need for a sustainable way to manage stormwater. Green stormwater infrastructure (GSI) is considered an innovative way to handle stormwater because of its potential to provide multiple ecosystem services (ES) beyond flooding reduction. However, there is limited research regarding the society's perceived value for GSI practices' co-benefits. This study utilized stated-preference data obtained from a choice experiment in an online survey of 1159 South Carolina (SC) residents to estimate a monetary value for the ES provided by wet detention ponds— the most widely adopted stormwater practice in coastal counties of SC. The benefits examined are flooding reduction, water quality, wildlife habitat, recreation, and scenic beauty. The data were analyzed using a Mixed logit formulation. Considering the differences across the state, the model was estimated separately for five counties. Findings indicate that residents are willing to pay $13.8 to $37.8 annually for a 50% improvement in pollutant removal efficiency of ponds in addition to their current stormwater fee. Also, they are willing to pay $12.5 to $42.9 per year for the nearest pond to have buffer vegetation and wildlife. They are also likely to pay $5 to $22.5 for ponds to contribute to their neighborhood's scenic beauty. Furthermore, the results indicate that respondents from three counties are willing to pay $5.4 to $13.2 for a 50% improvement in flooding reduction, while those from two counties are likely to pay $3.9 to $4.9 for ponds to have recreational benefits. The findings of the study could help stormwater managers in designing their stormwater management programs, especially for better evaluation of stormwater utility fees.

1. Introduction

Rapid urbanization is changing how we view and manage stormwater. Moreover, the conversion of natural vegetation into impervious surfaces alters the way water flows in a landscape (Chen et al., 2017; Oudin et al., 2018). Aside from flooding, this poses challenges to water quality and stream health, among others. In the US, untreated urban stormwater runoff is the primary source of water pollution (Pazwash, 2016). In the past, conventional stormwater systems were built to divert runoff from populated areas through a series of gutters and pipes, which drained into large detention basins (National Research Council, 2009). These basins served as centralized stormwater treatment facilities and were strategically located beside receiving water bodies to treat runoff before discharge. Conventional systems were designed to transport water as fast as possible from its source to treatment facilities; however, high-velocity runoff also carries multiple pollutants as it travels across the landscape (Gilroy and McCuen, 2009; Sparkman et al., 2017). For urban areas with combined sewer systems, an increase in runoff could result in an overflow of untreated stormwater and liquid wastes once the system capacity is exceeded (Irwin et al., 2017).

With population growth driving urban expansion in many states in the US (Bounoua et al., 2018), there is a need for a sustainable way to manage stormwater (Qiao et al., 2018). Green stormwater infrastructure (GSI) has become a popular alternative stormwater management strategy because of its potential to provide multiple ecosystem services (ES) such as flooding reduction, water quality improvement, carbon sequestration, and increase in property values (Fletcher et al., 2015; Prudencio and Null, 2018). Some of the most common GSI practices

* Corresponding author. Department of Forestry and Environmental Conservation, Clemson University, Clemson, SC, 29634, USA.
E-mail address: joanu@g.clemson.edu (J. Ureta).

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include rain gardens, bioretention cells, vegetative swales, permeable pavements, and green roofs. Recent studies also classified other stormwater infrastructures with larger service areas (e.g., stormwater ponds, constructed wetlands) as GSI practices under the premise that they provide multiple benefits to the public (Beckingham et al., 2019; Moore and Hunt, 2011; Prudencio and Null, 2018; Venkataramanan et al., 2020). GSI practices maximize the benefits of stormwater control measures by enhancing infiltration and treating runoff as close to its source (US EPA, 2019; Fletcher et al., 2015).

Although used interchangeably with low impact development (LID) or best management practices (BMPs), GSI practices highlight the importance of designing stormwater control measures that have a broader role in delivering ES (Fletcher et al., 2015). Unlike LIDs, GSI practices are not limited to nature-based solutions but also encompass engineered-based solutions that could preserve the natural hydrology of a landscape. Furthermore, GSI practices differ from BMPs because of their decentralized design and capacity to deliver different ecosystem services in addition to flooding reduction (Fletcher et al., 2015, US EPA, 2020). GSI practices typically use a network of green spaces to provide various environmental benefits such as improved water quality, carbon sequestration, climate regulation, wildlife habitat, scenic beauty, recreation, and education (Prudencio and Null, 2018). They could also improve the property values of surrounding residential areas (Mazzotta et al., 2014).

Due to the on-site and decentralized approach of GSI practices, community participation is crucial to upscale their environmental benefits on a landscape level (Baptiste et al., 2015; Jayakaran et al., 2020; Montalto et al., 2013; Zuniga-Teran et al., 2020). However, while efforts were made to engage residents and property owners, recent studies showed that GSI practices received lower interest than expected (Dhakal and Chevalier, 2017; Venkataramanan et al., 2020). Nevertheless, the ES provided by GSI practices are rarely quantified in biophysical units or monetary terms (Moore and Hunt, 2012; Prudencio and Null, 2018; Ward et al., 2008). However, for efficient stormwater management, it is crucial to understand how residents view and value the ES provided by local stormwater strategies.

The most common techniques used for estimating the monetary value of the different benefits of GSI practices are hedonic pricing (Mazzotta et al., 2014) and stated preference techniques such as contingent valuation method (CVM) and discrete choice experiment (DCE). Hedonic pricing is used to investigate the property value effects of different GSI practices such as stormwater ponds (e.g., Irwin et al., 2017; Lee and Li, 2009), urban wetlands (e.g., Lupi et al., 1991; Mahan et al., 2000; Tapsuwan et al., 2007), green streets (e.g., Donovan and Butry, 2010; Netusil et al., 2014, 2010), green roofs (e.g., Ichihara and Cohen, 2011), and combination of different types of GSI practices (e.g., Bowman et al., 2012; Conway et al., 2010; Ward et al., 2008). While the property value effects of GSI practices could be observed using consumer behavior in real estate, willingness-to-pay (WTP) and preferences for their additional benefits are often estimated using hypothetical markets since there is typically no actual market for these benefits (Meng and Hsu, 2019). These techniques rely on administering a carefully designed survey to solicit the WTP of target stakeholders (Tietenberg and Lewis, 2018).

Various studies used CVM to measure residents' WTP on water quality benefits of stormwater practices (e.g., Chui and Ngai, 2016; Clousten, 2003; Croke et al., 1986; Jorgensen et al., 2004; Lindsey, 1994; Lindsey et al., 1995). However, CVM value the stormwater program in general and it does not provide individual estimates for the different types of ES generated by GSI practices. To overcome this limitation, DCE has been applied in recent stormwater-related valuation studies. For instance, a study in Champaign-Urbana, Illinois estimated that the residents' WTP ranges from $34 to $40 per year for the improvement of each type ES (i.e., flooding reduction, improved water quality, and increased infiltration) which can be associated with stormwater structures (Londoño Cadavid and Ando, 2013). Similar results were also observed in other areas such as in Sydney, Australia for a reduction in flash flooding and water restrictions, improvements in stream health, and cooler summer temperatures (Brent et al., 2017); in Chicago (Illinois) and Portland (Oregon) for improvement of aquatic habitat, and water quality from boatable to swimmable (Ando et al., 2020). DCE was also used for studies determining the preference of stormwater agencies on the design and capabilities of green infrastructure (Meng and Hsu, 2019), as well as for exploring the influence of visual presentation on the choice behavior of respondents for stormwater structures (Golshani, 2015; Shr et al., 2019).

Similar to other states in the US, stormwater management is one of the most pressing issues in coastal South Carolina (SC). The rapid rate of urbanization as characterized by an increase in impervious surface area, coupled with increasing population (Drescher et al., 2007; Schroer et al., 2018; Ureta et al., 2020), adds to the complexity of stormwater management (Holleman, 2018). In compliance with the Clean Water Act and the National Pollutant Discharge Elimination System program, most land development projects in coastal SC integrate wet detention ponds in their designs (Dickes et al., 2016). As the most commonly adopted stormwater practice, these ponds have become an important feature of the coastal landscape (Drescher et al., 2007). While mainly built to reduce flooding, Beckingham et al. (2019) classified these ponds as a GSI practice because of the wide range of benefits they provide to the public (e.g., ecological habitat, pollution control, carbon sequestration, cultural services, scenic beauty). Although some studies assessed the efficiency of stormwater ponds specifically for SC (e.g., Schroer et al., 2018; Morsy et al., 2016), very few research endeavors studied residents' preferences for their additional benefits (Burnett and Mothorpe, 2018). Understanding their preferences is important in the planning and design of ponds to ensure that desired benefits are maximized.

This paper seeks to estimate the WTP of SC coastal residents for the improvements of ecosystem services provided by wet detention ponds. Unlike previous stormwater-related DCE studies, which investigated the co-benefits of local stormwater programs in general, this paper focuses on the ES provided by stormwater ponds under the assumption that different stormwater structures deliver varied types and amounts of ES. The study valued five types of ES— flooding reduction, water quality, wildlife habitat, scenic beauty, and recreation. A discrete choice experiment is utilized to quantify these services in monetary terms. The results of this paper could guide stormwater managers and developers in designing residential ponds that are not just efficient but have desirable co-benefits for residents.

2. Methods

2.1. Study area

Flooding is a major problem in coastal South Carolina (Holleman, 2016). To illustrate, in 2013, about one-third of the population in coastal SC were already residing inside floodplain areas (NOAA Office for Coastal Management, 2019). With increasing population and rapid development, stormwater management becomes more challenging, especially for the coastal counties of SC (Ellis et al., 2014). This paper focuses on five out of eight coastal counties of SC— Beaufort, Berkeley, Charleston, Dorchester, and Horry. These counties were selected because they are the most populous and developed coastal counties in SC.

Beginning in 1992, wet detention ponds have become the most widely adopted stormwater practice in coastal SC (Drescher et al., 2007). These ponds have a permanent pool of water throughout the year. Unlike retention ponds which gradually infiltrate collected runoff, wet detention ponds have elevated outlets where excess stormwater drains. In 2013, there were about 21,594 wet detention ponds in eight coastal counties of SC (Smith, 2018). Approximately 81% of these ponds are in the study site (Fig. 1).

Residential ponds account for 25% of all the stormwater ponds in

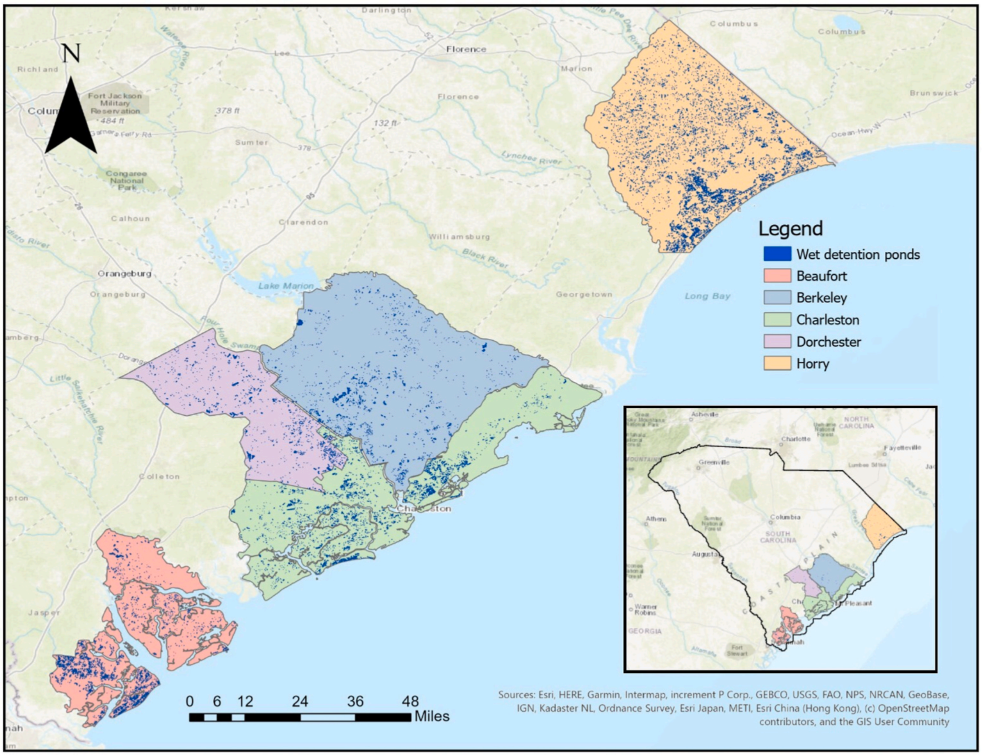


Fig. 1. Location of wet detention ponds in the study site (Smith, 2018).

South Carolina. These ponds could be classified as quasi-public goods because although they benefit the public by reducing floods and improving water quality, homeowners' associations (HOA) largely cover the installation and maintenance costs of these ponds. At the same time, HOA enjoys the direct benefits of these ponds such as scenic beauty, property value effects, and recreational benefits that might be negligible for other residences far from the ponds. Also, each county in SC is implementing its stormwater management programs; hence preferences could vary depending on local needs, as well as the effectiveness of local stormwater initiatives.

2.2. Data collection

The data for this study were obtained from an online survey distributed to residents of the five counties of SC. The survey was administered using Qualtrics (2019) from October to November 2019. The final sample included 1159 respondents. The online survey platform was selected because a majority of SC residents (79%) are connected to the internet (U.S. Census Bureau, 2018). Also, recent DCE studies utilized internet-based surveys for ease of presenting complex sets of options to the respondents (Champ et al., 2017). The survey instrument was comprised of four main sections— perception of local flooding, awareness of GSI practices and their ES, choice model scenarios, and socio-demographic characteristics.

The survey instrument was carefully designed to ensure that the choice sets are clear and relatable to the respondents. Hence, prior to the actual DCE survey, an online perception survey was administered first to SC coastal residents to assess their awareness of GSI practices. This perception survey was pretested with 20 stormwater managers and 50 coastal residents. Qualtrics distributed the survey in January 2019, and the final sample included 1031 respondents from all the eight coastal counties of SC. The results of the perception survey indicated that the

Table 1
Respondent's perception of the prevalence of GSI practices per county.

Type of GSI practices	Mean rate of prevalence*								
	Beaufort (n = 132)	Berkeley (n = 124)	Charleston (n = 273)	Colleton (n = 14)	Dorchester (n = 86)	Georgetown (n = 36)	Horry (n = 346)	Jasper (n = 20)	Total (n = 1031)
Wet ponds	2.87	2.76	2.83	2.86	3.08	3.39	3.38	2.65	3.05
Constructed wetlands	2.58	1.99	2.24	2.43	1.91	2.33	2.34	2.55	2.27
Dry ponds	1.79	1.73	1.76	1.71	1.88	2.00	2.03	2.25	1.88
Rain gardens	1.52	1.55	1.79	2.36	1.71	2.14	1.75	1.75	1.73
Bioretention cells/ Bioswales	1.34	1.18	1.51	0.57	1.20	1.94	1.63	1.85	1.47
Vegetative swales	1.89	1.71	1.80	1.14	1.51	2.19	1.93	1.60	1.82
Infiltration trenches	1.29	1.09	1.42	0.79	1.28	2.03	1.62	1.90	1.44
Green roofs	0.87	0.82	1.05	1.00	0.86	1.64	1.07	1.15	1.01
Rooftop (Downspout) disconnection	2.64	2.55	2.51	3.00	2.53	2.47	2.73	2.35	2.61
Rain barrels or cisterns	1.20	1.19	1.59	1.57	1.48	1.72	1.37	1.00	1.40
Continuous permeable pavement systems	1.55	1.18	1.45	1.57	1.15	1.83	1.45	1.45	1.42

Rate: 1–5 with 1 being the least common and 5 being the most common.

survey participants were most familiar with wet detention ponds (Table 1) and their ES, especially flooding reduction, water quality improvement, and biodiversity benefits (Table 2).

Using the information from the perception survey and previous literature (e.g., Beaufort County, 2020; Berkeley County, 2020; Charleston County, 2020; Dorchester County, 2020; Horry County Government, 2020; Vulava et al., 2019), a second survey was designed and administered to SC coastal residents to estimate their WTP for the ES provided by wet detention ponds. Following the recommendations of Johnston et al. (2017), a content validity assessment was undertaken to assess the appropriateness of the DCE survey design and implementation. Hence, the survey instrument was pretested with 50 stormwater managers and practitioners and adjusted based on their feedback.

Considering that 51% of the respondents of the perception survey were not aware of the existing stormwater utility fee (SUF) rates, a qualifying question was included in the DCE survey to target the residents who are paying the fee on behalf of their household. This was done to ensure that survey participants are aware of the current rate of SUF. Consequently, they would consider their budget constraints when deciding how much they would be willing to pay in addition to their current SUF for the improvement of ES provided by stormwater ponds. The number of samples per county was relative to the five coastal counties' actual population percentage distribution. For instance, most of the respondents reside in Horry (33%) and Charleston (25%) counties, which are also the most populated in coastal SC. Table 3 shows the attributes which were included in the DCE survey instrument.

The attributes of flooding reduction, impact to water quality, and stormwater fee have three different levels (25%, 50%, 75%), similar to Londoño Cadavid and Ando (2013). The status quo for flooding reduction was based on the results of the perception survey (Ureta et al., 2021), while the pollutant removal efficiency was based on the study of Vulava et al. (2019) in SC. For the stormwater fee, different bid amounts were assigned per county depending on their current average SUF. Since stormwater management programs vary per county, they also have different guidelines for collecting a stormwater fee. For instance, Charleston County has the highest SUF for residential properties amounting to $72.00 annually (Charleston County, 2020). In contrast, Dorchester County collects $31.97 per year from single-family homes (Dorchester County, 2020)— the lowest base rate among the five coastal counties. Since the rate is relative to the county of residence, different bid amounts were used per county to not overestimate or underestimate the resident's WTP. Thus, three price levels were used per county, which represented 25%, 50%, and 75% of the county's mean stormwater fee during the time of the study.

Since there were six attributes (5 ES and 1 stormwater fee) with two to three levels each, the statistical software JMP (SAS Institute Inc., 2019) was utilized to automatically randomize the attribute levels for each choice set. With a D-efficiency of 92%, JMP generated 16 choice sets with two options for each set. The status quo was added as the third option. Four choice sets were presented to each respondent. Fig. 2 shows one of the choice sets that was used for the survey in Beaufort County.

Table 2
Level of importance of ecosystem services provided by GSI practices.

Ecosystem service	Mean*	Std.	Rank
Improve water quality	4.48	0.87	1
Reduce flooding	4.47	0.88	2
Restore wildlife habitat	4.257	0.94	3
Provide erosion and sediment control	4.24	0.92	4
Restore vegetation	4.18	0.95	5
Sustain stream base flow/water supply	4.156	0.94	6
Improve air quality	4.155	1.02	7
Provide pollination opportunities	4.07	1.02	8
Improve aesthetic value or scenic beauty	3.88	1.03	9
Reduce ambient air temperatures	3.777	1.12	10
Increase revenue or property values	3.776	1.12	11
Improve recreational value	3.29	1.42	12
Improve cultural benefits	3.18	1.41	13

Rate: 1–5 with 1 being not important and 5 being extremely important.

Table 3
Stormwater ponds management attributes and levels.

Attribute	Description	Status Quo	Management levels
Flooding reduction	Number of floods in your lawns/backyard	73% of the coastal residents experience ankle-deep flooding in their lawns after heavy rainfall.[a]	25%, 50%, or 75% less frequent than current
Impact to water quality	Pollutant removal efficiency	According to the International BMP Database, median pollutant removal rates for wet ponds range from 17 to 96%, depending on the pollutant type.[b]	25%, 50%, or 75% more efficient than current
Home for wildlife	Buffer vegetation, fish, waterfowl, alligators		With or without
Scenic beauty	Scenic beauty		With or without
Recreational value	Canoeing and catch-and-release fishing	Examples in Charleston where some ponds have boat ramps	With or without
Stormwater fee	Additional stormwater fee per month	Mean annual stormwater fee per county: Beaufort $87; Berkeley $36; Charleston $72; Dorchester $32; Horry $44.4	25%, 50%, or 75% of the current average stormwater fee[c]

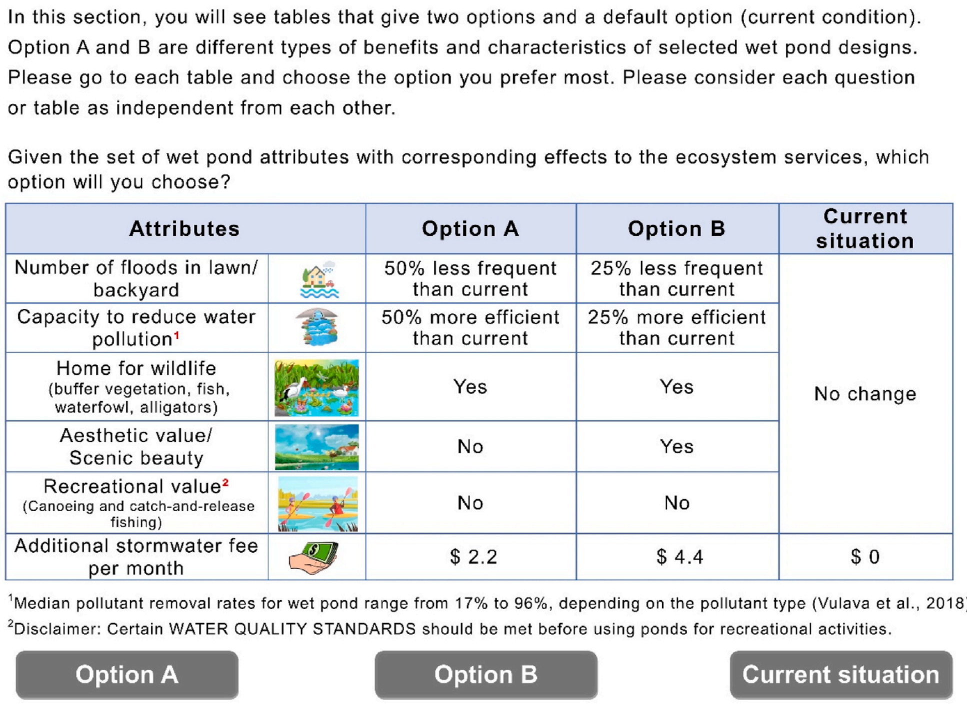
[a] *Based on the results of the perception survey* (Ureta et al., 2021).
[b] Adopted from Vulava et al. (2019)..
[c] These levels were presented in monetary value ($) in the actual survey.

2.3. Econometric model and estimation strategy

Discrete choice experiment (DCE) is a stated preference technique that is based on Lancaster's characteristics of value theory (1966) and random utility model (RUM) (McFadden, 1974; Thurstone, 1927). Following Lancaster's characteristics of value theory (1966), DCEs are designed to capture an individual's preferences among a set of alternatives for a good or policy (Veronesi et al., 2014). Respondents are asked to choose between mutually exclusive alternatives that differ in terms of attributes and levels (OECD, 2018). It follows the random utility model (RUM), which assumes that individuals have a utility-maximizing behavior (McFadden, 1974; Thurstone, 1927). As such, a rational individual will choose the set of options that provides the highest level of utility (Train, 2009). As shown in Equation (1), U_{ij}represents the utility that a respondent i obtains from choosing alternative j.

$$U_{ij} = v_{ij}(x_{ij}, \beta) + \varepsilon_{ij} \quad (1)$$

The respondent's utility has two main elements—deterministic (v_{ij}) and stochastic (ε_{ij}) (Train, 2009). The deterministic element (v_{ij}) refers to the portion of the utility that could be observed by the researcher. It is a function of a vector of attributes (x_{ij}) and a vector of unknown parameters (β). In this study, x_{ij} refers to the vector of different ecosystem services provided by wet detention ponds, while β is the attributes' corresponding coefficients that are being estimated. Alternatively, the stochastic element (ε_{ij}) is the unobservable portion of the utility which is known only to the decision maker but not by the researcher (Train, 2009). Since it cannot be observed and cannot be predicted exactly by the researcher, it is treated as random with a density $f(\varepsilon_n)$ (Train, 2009). Subsequently, alternative j will only be chosen over alternative k if alternative j will yield greater utility than alternative k ($U_j > U_k$).


In this section, you will see tables that give two options and a default option (current condition). Option A and B are different types of benefits and characteristics of selected wet pond designs. Please go to each table and choose the option you prefer most. Please consider each question or table as independent from each other.

Given the set of wet pond attributes with corresponding effects to the ecosystem services, which option will you choose?

Attributes		Option A	Option B	Current situation
Number of floods in lawn/ backyard		50% less frequent than current	25% less frequent than current	No change
Capacity to reduce water pollution[1]		50% more efficient than current	25% more efficient than current	
Home for wildlife (buffer vegetation, fish, waterfowl, alligators)		Yes	Yes	
Aesthetic value/ Scenic beauty		No	Yes	
Recreational value[2] (Canoeing and catch-and-release fishing)		No	No	
Additional stormwater fee per month		$ 2.2	$ 4.4	$ 0

[1]Median pollutant removal rates for wet pond range from 17% to 96%, depending on the pollutant type (Vulava et al., 2018).
[2]Disclaimer: Certain WATER QUALITY STANDARDS should be met before using ponds for recreational activities.

Option A | Option B | Current situation

Fig. 2. Example of choice set in Beaufort County.

Equation (2) shows the probability that respondent *i* will choose alternative *j* over *k* (Train, 2009).

$$\begin{aligned} P_{ij} &= \text{Prob}\left(U_{ij} > U_{ik} \forall k \neq j\right) \\ &= \text{Prob}\left(v_{ij} + \varepsilon_{ij} > v_{ik} + \varepsilon_{ik} \forall k \neq j\right) \\ &= \text{Prob}\left(\varepsilon_{ik} - \varepsilon_{ij} < v_{ij} - v_{ik} \forall k \neq j\right) \end{aligned} \tag{2}$$

Several regression models could be used to analyze the choice sets depending on the specifications of the density of unobserved factors $f(\varepsilon_n)$ (Train, 2009). Initially, both conditional logit (CL) and mixed logit (MXL), also known as random parameters logit (RPL), were utilized for this study. While CL assumes independence of irrelevant alternatives (IIA), MXL relaxes the IIA assumption and accounts for preference heterogeneity (Hole, 2013; OECD, 2018; Penn et al., 2014). The IIA property indicates that adding or removing one alternative does not affect the ratio of probability for any two alternatives (Train, 2009). By assuming that IIA property holds, CL model can be obtained as follows:

$$P_{ij} = \frac{\exp\left(v_{ij}\right)}{\sum_{j=1}^{J} \exp\left(v_{ik}\right)} \tag{3}$$

Unlike conditional logit, MXL allows one or more parameters to be randomly distributed and acknowledges that the coefficients in the model can differ across decision-makers (Hole, 2013). By relaxing IIA assumptions, the choice probability can be modeled as follows (Champ et al., 2017; Train, 2009).

$$P_{ij} = \int \frac{\exp\left(x_{ij}^{'}\beta\right)}{\sum_{j=1}^{J} \exp\left(x_{ik}^{'}\beta\right)} f(\beta|\theta) d\beta \tag{4}$$

The density function of β is represented as $f(\beta|\theta)$. Meanwhile, the marginal willingness-to-pay (MWTP) was derived using the following equation:

$$E\left(WTP^{k}\right) = -\frac{E\left(\beta^{k}\right)}{\beta^{price}} \tag{5}$$

The $E(\beta^k)$ is the attribute coefficient, while β^{price} is the cost coefficient (Batstone et al., 2010; Brent et al., 2017). Using Krinsky-Robb (KR) parametric bootstrapping with 1000 draws, the distribution of the mean MWTP was computed, as well as the upper and lower bounds of the MWTP which represents 95% confidence interval (Brent et al., 2017; Londoño Cadavid and Ando, 2013).

Hausman's specification test showed that the independence of irrelevant alternatives (IIA) assumptions do not hold, which implies that CL model is not recommended for the analysis. For this reason, only the results of MXL model were presented in this paper. Log-likelihood and McFadden's pseudo R-squared were used to assess the goodness of model fit (Hauber et al., 2016; Train, 2009). In addition to the Hausman test, a joint test of significance was estimated to determine the appropriate model specifications for the analysis. The result of this test rejected the null hypothesis that the estimates are equivalent between the county samples. This suggests that the bid amounts per county are statistically different and could not be used for a pooled regression analysis.

3. Results and discussion

3.1. Descriptive statistics

Table 4 shows the socio-demographic profile of the 1159 respondents. The respondents' profile was compared with the census data (U.S. Census Bureau, 2018) to determine if the sample reflected the general socio-demographic characteristics of the population of each county.

The study sample slightly overrepresented females, individuals with higher education, and those who own their primary residence. Since the survey was answered by only those who pay the stormwater fees for their households, the latter is not unexpected because the utility fee is typically reflected in their annual property tax bill. Renters, on the other hand, might not be aware that part of their rent is intended for that purpose. Meanwhile, the other demographic characteristics including age, employment, and income of the respondents are comparable with the 2018 census data.

Aside from the socio-demographic profile that could be compared with census data, Table 4 also shows the structural and locational attributes of the respondents' primary residence. The majority of the

Table 4
Descriptive statistics of selected variables.

Variable	Description	Respondents (Census[a])				
		Beaufort n = 157	Berkeley n = 168	Charleston n = 296	Dorchester n = 138	Horry n = 400
Male	Dummy: 1 if male	0.43 (0.49)	0.35 (0.49)	0.32 (0.48)	0.22 (0.48)	0.41 (0.48)
Age	Age in years (Mean)	53.85 (44.8[b])	46.92 (36[b])	48.09 (37.6[b])	47.80 (36.5[b])	51.90 (45.2[b])
Employed	Dummy: 1 if employed	0.48 (0.49)	0.64 (0.59)	0.65 (0.62)	0.58 (0.60)	0.51 (0.53)
College	Dummy: 1 if college or graduate degree holder	0.75 (0.36)	0.61 (0.22)	0.69 (0.40)	0.58 (0.26)	0.63 (0.22)
Income	Dummy: 1 if annual household income is equal to or more than $50,000	0.79 (0.60)	0.60 (0.60)	0.67 (0.58)	0.62 (0.60)	0.64 (0.48)
House ownership	Dummy: 1 if house owner	0.89 (0.71)	0.80 (0.68)	0.71 (0.60)	0.74 (0.71)	0.85 (0.71)
Household size	Number of people in household (Mean)	2.79	2.87	2.70	2.91	2.79
Length of residency	Number of years at current home (Mean)	15.08	17.74	21.13	14.66	14.33
Impervious cover	Dummy: 1 if residence has 50% or more impervious surface	0.33	0.26	0.34	0.32	0.33
Distance to a water body	Dummy: 1 if residence is less than a mile from nearest water body	0.55	0.42	0.56	0.43	0.51
Familiarity with ponds	Dummy: 1 if the respondent saw an actual wet pond prior to survey	0.86	0.87	0.90	0.89	0.90
Living beside ponds	Dummy: 1 if residence is located beside the pond	0.29	0.17	0.16	0.22	0.23
Pond condition	Dummy: 1 if nearest pond is in good condition	0.69	0.67	0.66	0.65	0.70
Basement/house flooding	Dummy: 1 if house had been flooded at least once	0.34	0.25	0.31	0.21	0.29
Flooding of lawns	Dummy: 1 if backyard/lawn had been flooded at least once	0.66	0.71	0.67	0.69	0.70
Street flooding	Dummy: 1 if street had been flooded at least once	0.57	0.58	0.58	0.58	0.61
Flooding problems	Dummy: 1 if the respondent perceives that flooding is a problem in their county	0.50	0.57	0.80	0.68	0.73

[a] Source: U.S. Census Bureau, 2018 American Community Survey 5-Year Estimates. The average values of each variable were calculated using the census data of 5 coastal counties of SC.
[b] Median age of the entire population.

survey participants were living less than a mile from the nearest water bodies. When asked to rate the condition of the nearest pond, the majority perceived that the ponds nearest to them were in good condition. A small percentage of the houses were also situated beside a pond. When it comes to flooding-related experiences, the majority of the respondents experienced ankle-deep backyard flooding or street flooding at least once. Lastly, the majority of the respondents believe that flooding is indeed a problem in their counties (Table 4).

3.2. Estimation results

The estimation results of the county-specific mixed logit models are reported in Table 5. Three attributes (*Home for wildlife, Scenic beauty, Recreational value*) were modeled as dummy variables in which 1 pertains to the presence of these ES and 0 otherwise. On the other hand, *Number of floods* and *Pollutant removal* were modeled as continuous variables; hence their estimates show the probability of the residents to be willing to pay for a 1% improvement of these ES. While the coefficients on all the ES attributes were specified to have a normal distribution, the stormwater fee was modeled to be distributed lognormally and multiplied by −1 (Ando et al., 2020; Brent et al., 2017; Hole, 2007). Lastly, *Status Quo* was entered in the model as a dummy variable wherein 1 represents the third option (current situation), while 0 pertains to Options A and B. Except for the *Stormwater* fee which was specified to have a fixed coefficient, all the other attributes were modeled to have random coefficients.

Across the five counties, the mean estimates of *Pollutant removal, Home for wildlife,* and *Scenic beauty* are positive and statistically significant. This implies that the improvement of these ES increases the likelihood of the residents paying a premium above their current stormwater fee. On the other hand, *Recreational value* is only significant in Dorchester and Horry. This suggests that for the other counties, developing ponds into recreational areas (e.g., canoeing, catch-and-release fishing) would not affect residents' probability to pay above their current fee. Also, *Number of floods* was found to be significant only in Berkeley, Charleston, and Horry. This implies that the residents'

Table 5
Estimation results of county-specific mixed logit models.

Attributes	Mean coefficients (Standard deviation)				
	Beaufort	Berkeley	Charleston	Dorchester	Horry
Status Quo	−1.056* (2.681***)	−1.207** (−2.239***)	−0.901** (−1.837***)	−1.032** (0.719)	−1.66*** (2.635***)
Number of floods	0.001 (−0.014)	0.007* (−0.011)	0.009*** (−0.021)	0.001 (−0.029)	0.011*** (0.024)
Pollutant removal	0.018*** (0.007)	0.019*** (0.026***)	0.017*** (0.015)	0.021*** (0.02***)	0.017*** (0.011***)
Home for wildlife	1.048*** (1.629***)	1.047*** (1.043***)	1.192*** (1.187***)	1.054*** (1.445***)	0.698*** (0.905***)
Scenic beauty	0.549*** (0.067)	0.375** (0.693*)	0.614*** (−0.342)	0.667*** (−0.185)	0.283*** (0.093)
Recreational value	−0.023 (−0.507**)	0.227 (−0.388)	0.035 (−0.019)	0.303* (0.414)	0.275*** (0.41*)
Stormwater Fee (log)	−1.228***	−0.296	−0.947***	−0.079	−0.398***
Log likelihood	−557.68	−586.502	−1016.483	−464.464	−1379.425
McFadden R^2	0.112	0.111	0.091	0.0713	0.120
AIC	1141.37	1199.00	2058.97	954.93	2784.85
BIC	1199.12	1257.64	2124.96	1011.01	2854.76
Number of observations	1884	2016	3552	1656	4800
Individuals	157	168	296	138	400

Significance levels: ***$p < 1\%$, **$p < 5\%$, *$p < 10\%$.

likelihood to pay increases with the reduction in flooding frequency in these three counties. For the other two counties, a lower proportion of respondents viewed flooding as a problem in their locality. Hence, this could have affected their WTP for flood reduction. The *Status Quo* is statistically significant across all the models and exhibited a negative sign. Thus, moving away from the status quo generates a positive utility for the respondents. This is consistent with the results of Ando et al. (2020) and Brent et al. (2017), which show that residents prefer improvement in local stormwater management projects over the current situation.

The significant sign of the standard deviation reflects heterogeneous preferences among respondents (Penn et al., 2014). From the magnitudes of significant SD relative to the mean coefficients (Champ et al., 2017; Hole, 2007), the associated Z-scores show that a huge proportion of respondents in Berkeley (77%), Dorchester (85%), and Horry (94%) preferred a higher reduction in pollutant removal efficiencies of ponds. On the other hand, more than two-thirds of the samples from each of the five counties favored ponds with biodiversity benefits. Ponds that contribute to the scenic beauty of the neighborhood were favored by all respondents in Horry and 71% of samples in Berkeley. Lastly, 75% of the respondents in Horry preferred ponds to have recreational benefits.

3.3. County-specific marginal willingness to pay

The mean marginal willingness-to-pay (MWTP) for the improvement of ecosystem services provided by wet detention ponds are reported in Fig. 3. Using the Krinsky-Robb (KR) parametric bootstrapping, the lower and upper bounds of MWTP were estimated based on a 95% confidence interval. Since the bid amounts were relative to the current rate of SUF in each county, the MWTP for each attribute varies across the study site. The results of the joint test of significance confirmed that the bid amounts are statistically different and could not be used for a pooled analysis.

On average, respondents from Beaufort county are willing to pay 6.30 cents per month or 75.60 cents annually for a 1% improvement in pollutant removal efficiency of ponds. If the efficiency could be improved by 50%, residents are willing to pay $3.15 per month or $37.80 per year. Also, they are willing to pay $3.58 per month or $42.96 per year for ponds to be more conducive for wildlife (e.g., fish, waterfowls). Residents are also willing to pay $1.88 monthly or $22.56 annually for ponds to have an improved scenic beauty. Overall, each household would be willing to pay $103.32 per year to improve the pollutant removal efficiency by 50%, as well as the biodiversity benefits and scenic beauty of the pond nearest to them. In 2018, about 70,607 households were living in Beaufort (United States Census Bureau, 2018). By multiplying the number of households with the combined mean

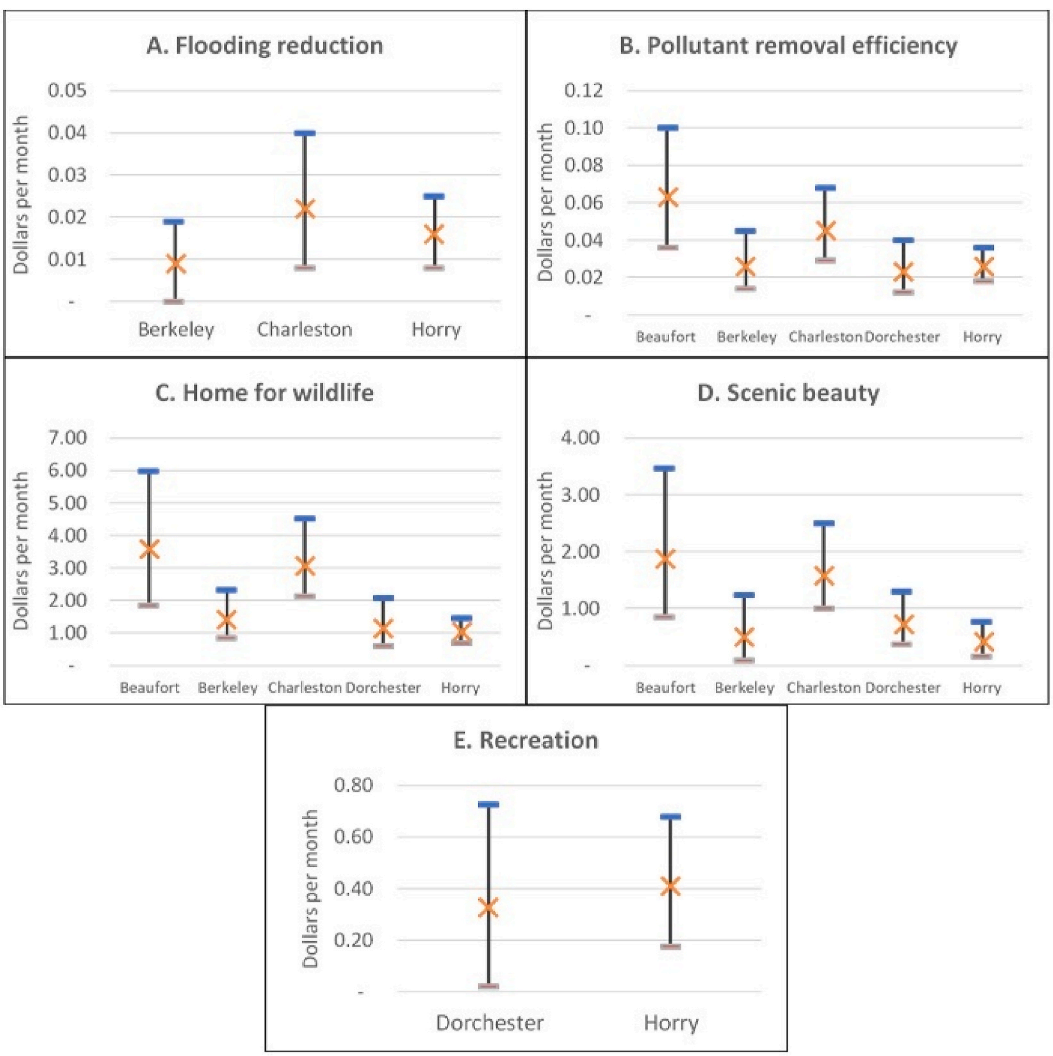


Fig. 3. Marginal willingness-to-pay for changes in ecosystem services: (A) 1% reduction in flooding frequency, (B) 1% reduction in pollutant removal efficiencies of ponds, (C) presence of buffer vegetation and wildlife, (D) contribution to the scenic beauty of the neighborhood, (E) recreational value of ponds.

MWTP, improvement of the three ES would generate a combined community benefit of $7,295,115.24 (Table 6).

Survey participants residing in Berkeley are willing to pay an average amount of $0.009 per month or 10.80 cents annually for a 1% reduction in flooding frequency. If backyard flooding incidence could be reduced by 50%, residents would be willing to pay $5.40 per household annually. When it comes to a 1% increase in pollutant removal efficiency, residents are willing to pay 2.60 cents every month. Hence, each household would be willing to pay $1.30 monthly or $15.60 annually if a 50% improvement in pollutant removal efficiency could be achieved. Alternatively, the mean MWTP for biodiversity is valued at $1.41 per month or $16.92 per year. On average, respondents are also willing to pay 50 cents per month or $6.00 per year to ensure that ponds would contribute to the scenic beauty of their surroundings. Given the 50% improvement in both flooding reduction and pollutant removal efficiencies, as well as the development of ponds to provide biodiversity benefits and scenic beauties, each household in Berkeley would be willing to pay $43.92 annually. This would translate to a total community benefit of $3,290,969.52 (Table 6) given that there were 74,931 households in Berkeley (United States Census Bureau, 2018).

Similar to the results in Berkeley, the residents in Charleston county are willing to pay for the improvement of four ES of wet detention ponds. They are willing to pay $13.20 annually for a 50% reduction in flooding frequency and $27.00 for a 50% improvement in pollutant removal efficiency of the pond nearest to them. Also, they are willing to pay $36.84 and $18.96 for the nearest pond to have biodiversity benefits and scenic beauty, respectively. Overall, each household would be willing to pay $96 annually for these benefits. Given that there were 156,482 households in Charleston (United States Census Bureau, 2018), improvement of the aforementioned benefits will generate an overall community benefit of $15,022,272.00.

In Dorchester, survey participants are willing to pay for the improvement of the pollutant removal efficiency, biodiversity, scenic beauty, and recreational benefits of ponds. Their mean MWTP for 50% improvement in pollutant removal efficiency is valued at $13.80 annually. They are also willing to pay $13.68 per year for the nearest ponds to have vegetation and be a wildlife habitat. Also, they are willing to pay $8.64 and $3.96 annually for the scenic beauty and recreational benefits of ponds. In total, each household would be willing to pay $40.08 on top of their current stormwater fee for these services. Considering that 54,549 households were living in Dorchester (United States Census Bureau, 2018), then improvement of the ponds' features would generate a total community benefit of $2,186,323.92.

Contrary to the other four counties, the residents of Horry County are willing to pay for the improvement of all the ES. On average, they are willing to pay $9.60 and $15.60 annually for 50% improvement in both flooding reduction frequency and pollutant removal efficiency of the pond nearest to them. They are also willing to pay annually for the nearest ponds to have wildlife ($12.48), scenic beauty ($5.04), and recreational benefits ($4.92). Overall, each household would be willing to pay $47.64 for the improvement of these five ES. Given that there were 128,586 households in Horry (United States Census Bureau, 2018), this would translate to a total community benefit of $6,125,837.04.

3.4. Comparison of marginal willingness to pay per each type of ES

Flooding reduction was significant in three counties, wherein the annual MWTP ranges from $0.108 to $0.264 given a 1% reduction in frequency. These estimates were lower than the computed values in Champaign-Urbana, Illinois where residents would be willing to pay $0.7 per year for local stormwater programs that would reduce basement flooding by 1% (Londoño Cadavid and Ando, 2013). Intuitively, this huge disparity in MWTP could be associated with the severity of flooding-related experiences of the residents. In coastal SC, although a huge proportion of the residents experienced backyard flooding, only one-fourth of the samples cited that their houses had been flooded at least once (Table 4). This is contrary to the samples in Champaign-Urbana, Illinois who experienced basement flooding three to four times a year on average (Londoño Cadavid and Ando, 2013). In a separate study, residents in Chicago, Illinois were also found to be willing to pay an annual amount of $0.72 for local stormwater programs that would make flooding 1% less frequent, while those from Portland, Oregon would pay $0.24 for the same outcome (Ando et al., 2020). Similar to the case in Portland, Oregon (Ando et al., 2020), flooding was seasonal in coastal SC and not as frequent and costly compared to Illinois. It should be noted that 6 billion-dollar flooding disaster events affected Illinois between 1980 and 2020 compared to only 2 billion-dollar in SC (NCEI, 2020). Hence, it is not surprising that SC coastal residents have lower MWTP for flooding reduction than the households from Illinois. On the other hand, in a related study in Sydney and Melbourne, Australia, residents were willing to pay approximately $25.00[1] to support stormwater programs that would reduce the incidence of a flash flood by half (Brent et al., 2017). This estimate was higher than the computed MWTP for 50% flooding reduction in the study site, which ranges from $5.4 to $13.2 annually. This difference could also be associated with the varied local needs for flood protection.

For water quality benefits, residents from five counties are willing to pay $0.276 to $0.756 annually for a 1% improvement in pollutant removal efficiencies of ponds. Hence, a 50% improvement in pollutant removal efficiencies of ponds would translate to a benefit of $13.80 to $37.80 per household. Although previous DCE studies also investigated the value of water quality improvement as a result of local stormwater programs (Ando et al., 2020; Brent et al., 2017; Londoño Cadavid and Ando, 2013), these studies focused on water quality which was associated with stream health. There were also other attempts to value the water quality benefits of other stormwater control measures such as urban trees (e.g., McPherson et al., 1999; McPherson and Simpson, 2002; Millward and Sabir, 2011), stormwater and sewage treatment upgrades (Clousten, 2003; Hatton MacDonald et al., 2015), and general improvements in stormwater programs (Jorgensen et al., 2004; Lindsey et al., 1995) using other valuation techniques. The results of these stormwater-related studies were not comparable with the estimates computed in this study since this paper valued the water quality benefits of wet detention ponds, instead.

When it comes to biodiversity enhancement, residents are willing to pay $12.48 to $42.96 annually for ponds to serve as wildlife habitat. These estimates for MWTP are quite comparable with the results of Ando et al. (2020). They estimated that the residents of Chicago and Portland were willing to pay $1.90 per month for the improvement of aquatic habitat from good (with no more than 15 species of fish) to excellent (with 15–20 different types of fish, including rare species). Although the MWTP for biodiversity in Beaufort and Charleston was twice the computations of Ando et al. (2020), it should be noted that this study used a dummy variable of "Yes" or "No" instead of levels from good to excellent. Also, the biodiversity enhancement in this paper is specific to wet detention ponds and does not refer to the condition of nearby streams.

Scenic beauty was found to be significant across the five models. Results showed that residents are willing to pay $5.04 to $22.56 per year for ponds to contribute to the scenic beauty of their neighborhood. Meanwhile, only the samples from Dorchester and Horry counties were willing to pay an annual amount of $3.96 to $4.92 for ponds to provide recreational benefits.

4. Conclusions and policy implications

Although constructed mainly to address flooding problems, green stormwater infrastructure (GSI) offers valuable ecosystem services (ES)

[1] The original value is 34 Australian dollars converted to US dollars using the Internal Revenue Service (IRS) yearly average currency exchange rate (Internal Revenue Service, 2020).

Table 6
Annual community benefits of stormwater ponds in coastal South Carolina.

Annual community benefit	Beaufort	Berkeley	Charleston	Dorchester	Horry
	N = 70,607	N = 74,931	N = 156,482	N = 54,549	N = 128,586
Reduce Flood (50%)	–	404,627.40	2,065,562.40	–	1,234,425.60
Pollutant removal (50%)	2,668,944.60	1,168,923.60	4,225,014.00	752,776.20	2,005,941.60
Home for wildlife	3,033,276.72	1,267,832.52	5,764,796.88	746,230.32	1,604,753.28
Aesthetic	1,592,893.92	449,586.00	2,966,898.72	471,303.36	648,073.44
Recreation	–	–	–	216,014.04	632,643.12
Total	7,295,115.24	3,290,969.52	15,022,272.00	2,186,323.92	6,125,837.04

including water quality improvement, recreation, and scenic beauty. However, there is limited research regarding society's perceived value of these additional ES. This study adds to the literature by estimating a monetary value for the ES provided by wet detention ponds in South Carolina (SC). Moreover, this paper illustrated the capability of choice experiment model in valuing the different ES of a GSI practice.

Contrary to most used valuation techniques in stormwater literature (e.g., hedonic pricing, contingent valuation method), CE allows the valuation of different attributes of a GSI practice or a stormwater program. While there have been few studies that applied CE in valuing the benefits of local stormwater programs, this is one of the first attempts to investigate the different ecosystem services of one type of GSI practice. Furthermore, compared to previous studies that focus mainly in one county or city, we also contributed to the literature by evaluating WTP across five different counties (i.e., Beaufort, Berkeley, Charleston, Dorchester, Horry) considering that each county in SC implements its own stormwater programs and has different stormwater utility fee (SUF) rates. SC is the focus area because of flooding issues, increasing population and rapid development which create further challenges for stormwater management. Wet detention ponds were selected because they are the most common GSI practice in SC, hence residents could easily relate to the choice model scenario and choice questions. The relatability of the topic reduces the bias in WTP estimates.

The findings revealed that the improvements in water quality, scenic beauty, and biodiversity features of ponds are desirable for the residents across the study site. Specifically, depending on county of residence, survey participants are willing to pay an average of 30%–50% premium for a 50% improvement in pollutant removal efficiencies of the nearest ponds. Also, they are likely to pay a premium of 28%–51% for the nearest pond to have buffer vegetation and serve as a home for wildlife. Lastly, residents would be willing to pay 11%–27% premium for the nearest pond to contribute to scenic beauty of their neighborhood. These results suggest that the residents value the ecosystem services that could be observed directly and more often. Since wet detention ponds have a permanent pool of water throughout the year, the water quality of ponds has an evident impact on the surrounding houses. When not properly maintained, this could be a disamenity to homeowners.

For a 50% reduction in flooding frequency, only the residents living in Berkeley, Charleston, and Horry are willing to pay a premium in addition to their current stormwater fee. Also, residents of these counties have higher MWTP for 50% improvement in pollutant removal efficiencies of ponds compared to a 50% improvement in flooding reduction. This suggests that respondents in these localities put more value on the improvement in ponds' water quality benefits than the changes in its flooding reduction feature. On the other hand, only the residents in Dorchester and Horry are willing to pay a premium for the nearest pond to have recreational benefits. These results suggest that the desirability and prioritization of ecosystem services of GSI practices could vary depending on local preferences and conditions. Since flooding incidence is seasonal in SC, respondents from other counties prefer improvements in other ES than the flooding reduction feature of the nearest ponds. For other counties, these ponds might not be seen or desired as recreational facilities.

Findings from this work could help stormwater managers and developers in designing their stormwater management strategies. By designing GSI practices that are desirable for local communities, the benefits that they could receive from these structures would be optimized. While installation and retrofitting of existing ponds entail huge costs to local stakeholders, benefits that would be generated by improving the ecosystem services provided by these ponds could outweigh the cost in the long run. As a pioneering study in South Carolina, our findings could also guide a better evaluation of stormwater utility fees.

This paper also shows the social acceptability of the stormwater utility fee. Historically, stormwater management programs were funded by state and local funds through their general fund budget (Allen, 2020; DeForest, 2020). Without a steady source of funds, the local government relies on other means such as special assessments, development fees, impact fees, permits, and inspection fees (Zhao et al., 2019). However, these funds are not solely intended for managing stormwater and have restricted use for stormwater-related activities (Allen, 2020). Funding for stormwater programs could also be overshadowed by other local government priorities such as the provision of other public services (DeForest, 2020). To generate a dedicated and stable source of long-term revenue, stormwater utility fee has become an alternative fund source (Allen, 2020; DeForest, 2020; Malinowski et al., 2020; Zhao et al., 2019). Unlike the general fund budget, stormwater fee revenue may be used to cover direct costs such as construction, maintenance, and operations (Allen, 2020).

It should be noted that this paper only covered the five coastal counties of South Carolina. Because stormwater management programs typically vary per county, the MWTP that was computed might not apply to the rest of the state, especially upland counties where wet detention ponds are not that common. Furthermore, this research focus only on residential ponds and the computations might not reflect the benefits derived from commercial, golf, and other types of stormwater ponds. While the estimates are not directly transferable to other types of GSI practices, the results could give insights into the residents' preferences for co-benefits that could be provided by GSI practices. Future studies could compare the preferences of residents for stormwater management from upland and coastal counties. Sampling could also be designed between different states to draw national implications.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Appendix 1. Mean willingness to pay for ES of stormwater ponds

Improvement in benefits	Mean (lower bound- upper bound) WTP per month (S)				
	Beaufort	Berkeley	Charleston	Dorchester	Horry
Reduce flood		0.009 (−0.002, 0.019)	0.022 (0.008, 0.04)		0.016 (0.008, 0.025)
Pollutant removal	0.063 (0.036, 0.1)	0.026 (0.014, 0.045)	0.045 (0.029, 0.068)	0.023 (0.012, 0.04)	0.026 (0.018, 0.036)
Home for wildlife	3.58 (1.838, 5.975)	1.41 (0.84, 2.322)	3.07 (2.136, 4.511)	1.14 (0.595, 2.076)	1.04 (0.693, 1.448)
Scenic beauty	1.88 (0.849, 3.472)	0.50 (0.082, 1.233)	1.58 (1.008, 2.5)	0.72 (0.371, 1.296)	0.42 (0.162, 0.771)
Recreation				0.33 (0.021, 0.726)	0.41 (0.175, 0.679)

Author contribution

Joan U. Ureta: Conceptualization, Methodology, Formal analysis, Writing- Original Draft, Writing – review & editing. Marzieh Motallebi: Conceptualization, Methodology, Supervision, Project administration, Funding acquisition. Michael Vassalos: Conceptualization, Methodology, Validation, Writing – review & editing. Mustapha Alhassan: Methodology, Validation, Writing – review & editing. J. Carl Ureta: Formal analysis, Writing – review & editing.

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