Measuring the Direct and Indirect Effect of Scientific Information On Valuing Stormwater Management Programs:A Hybrid Choice Model

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Abstract

Following best practice in stated preference guidelines we use scientific information to develop a realistic hypothetical scenario for stormwater management and water quality improvements in a stated preference valuation survey. We then provide different treatment levels of the scientific information to survey respondents. Using a hybrid choice model, we find that scientific information has no direct influence on referendum votes in favor of a stormwater management program. However, different levels of scientific information have an indirect influence by changing concern about stormwater runoff or by changing perceived understanding of the stormwater management plan. Both of these effects have implications for valuing a stormwater management plan. We suggest that researchers should be aware of how their choice on the information provided may influence responses to a stated preference survey.

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Abstract: Following best practice in stated preference guidelines we use scientific information to develop a realistic hypothetical scenario for stormwater management and water quality improvements in a stated preference valuation survey. We then provide different treatment levels of the scientific information to survey respondents. Using a hybrid choice model, we find that scientific information has no direct influence on referendum votes in favor of a stormwater management program. However, different levels of scientific information have an indirect influence by changing concern about stormwater runoff or by changing perceived understanding of the stormwater management plan. Both of these effects have implications for valuing a stormwater management plan. We suggest that researchers should be aware of how their choice on the information provided may influence responses to a stated preference survey.

Key Words: stormwater management, stream water quality, science communication, stated preferences, hybrid choice models, generalized structural equation method

Introduction

Data from a long-term monitoring project on Boone Creek in Watauga County, North Carolina revealed two primary water quality concerns: (1) elevated stream temperatures with many storm-induced temperature surges each year and (2) salinity values that are not typical of freshwater high-gradient mountain streams (Cockerill and Anderson 2014). Stormwater runoff is the primary culprit for both of these phenomena, with temperature surges occurring on warm days due to runoff from heated pavement and buildings and salinity spikes occurring on cold snowy days when road salt has been applied to area infrastructure. We used these data to develop both text and graphics to include in a survey to assess public attitudes about a stormwater runoff management plan in the Appalachian region. The survey provided information about various methods to reduce stormwater runoff including containment systems and permeable pavement.

To assess the impact of scientific information on individual preference for stormwater runoff abatement, we randomly assigned four levels of scientific information to survey respondents. The first treatment provided no detailed scientific information. This treatment serves as our control. The second treatment provided only a short text (four sentences) of scientific information, while the third provided a long text (eight sentences) of the scientific information. The fourth and fifth treatments added a graphical representation of the scientific information to the short and long text.

We hypothesize that science-based information might directly influence the likelihood of voting yes or no on a stormwater abatement program. We also hypothesize that scientific-based information might influence concern about stormwater runoff and respondents' perceived understanding of the proposed management plan. Using a hybrid choice model, we measure both the direct and indirect effects of the influence of scientific information on the likelihood of voting for or against a stormwater abatement program. Using latent variables that focus on a respondents' concern and understanding we measure the indirect influence that science information has on the likelihood of voting for a stormwater abatement program.

Our results demonstrate that scientific textual information increases individuals' concern for stream water quality. We find, however, that respondents who received both the science text information as well as the graphical representation are no different than those who received no scientific information on their reported level of concern. In addition we find that self-reported understanding of the information provided about the proposed management plan only increased with the short science text with no graphical representation. Our results suggest that the scientific information had no direct effect on preferences for water quality improvements but both long and short versions of scientific information increased respondent concern for stormwater runoff which indirectly increases the likelihood to vote in favor of a stormwater abatement programs. Lastly, we find that the short science text indirectly affects preferences for stormwater management programs through an increase in the perceived understanding of the information provided.

Literature Review

Stormwater management continues to challenge communities throughout the United States as "stormwater pollution, flooding and other impacts impose serious impacts on water quality, public health and local economies" (USEPA 2016). Like all water-related concerns, managing stormwater runoff is complex and requires understanding not only the physical phenomena but social phenomena as well. While public attitudes about runoff specifically related to agriculture have been fairly well assessed, there remains a dearth of information about attitudes in more urban settings. Further, the data that do exist about public knowledge and behavior relevant to stormwater are highly variable. Some studies find that people do not consider runoff to be a concern for their community (Bartlett 2005, Keeley et al. 2013, Turner et al. 2016) while others find a high level of concern (Baptiste et al. 2015). Studies find that there are not consistent or predictable connections between individuals' knowledge about stormwater runoff and their actions to alleviate the negative consequences of runoff (Prokopy et al 2008, Baumgart-Getz et al 2012, Persaud 2013). More specific to our work, temperature and salinity are two negative impacts from runoff, but these have not been well-assessed from a social perspective.

The literature has well established that individual attitudes tend to be quite persistent and that any single message or informational intervention has limited influence on changing attitudes (Albarracin and Shavitt 2018). Relevant to our study, there is strong evidence that people struggle with reading graphs and that pre-existing knowledge or views influence how people interpret graphs and draw subsequent conclusions (Glazer 2011). At the same time, Tal and Wansink (2016) find that presenting graphs, to imply scientific credibility, even when the graphic content is not relevant, can increase the persuasive power of marketing materials. Additionally, Groothuis and Miller (1997) find that information from university sources is among the most trusted of all sources, and individuals use the information provided in the survey to update their knowledge of the problem. We suggest that because respondents may not have well-established attitudes about stormwater runoff and its management we can analyze if and how various combinations of text and graphics influence respondent views. Our work offers insights into using science-derived information about the physical effects of stormwater runoff to improve efforts to evaluate public attitudes about managing stormwater, and more specifically, to better assess attitudes about paying for such management.

In previous research using valuation methods, Whitehead and Groothuis (1992) found that respondents in North Carolina were willing to pay for management to reduce stormwater runoff from agricultural lands. More recently, Londono, Cadavid and Ando (2013) found that respondents value reduced basement flooding more than reduced yard or street flooding. In addition, they found that citizens value improved water quality as well as improved hydrologic function and aquatic habitat from reducing runoff. Bin and Polasky (2004) analyzed how hurricane stormwaters influence property values and found that homes located within a floodplain were of lower market value than those located outside the floodplain. Brent et al. (2017) found that Australian respondents were willing to pay for reduced flash flooding, improved local stream health and decreased peak urban temperatures.

Lund (2015) discusses the importance of integrating physical and social sciences to manage water resources. Van Houtven et al. (2007), based on a meta-analysis of 18 willingness to pay studies for water quality improvements, concluded the following:

> Greater detail and consistency in the type of information reported in published water quality valuation studies would enhance the social utility of the empirical literature. In particular, more detailed characterizations of the studied water resources and affected populations would be beneficial. Ideally, these descriptions would include pre-change and post-change water quality, and information on the spatial and temporal variation in water quality, physical characteristics and typical uses (including designated uses) of the water resources.

Following these suggestions, one goal when designing our survey was to randomly assign respondents different levels of detail about the impacts of stormwater runoff. In our survey, we randomly assigned five levels of scientific information to survey respondents. The first treatment provided no detailed scientific information as our control. The second treatment provided only a short text of scientific information, while the third provided a longer text of the scientific information. The fourth and fifth treatments added a graphical representation of the scientific information to both the short and long text. We used the science-based scenarios to describe temporal variations in both water quality and aquatic health as stormwater runoff alters the temperature and salinity of streams.

To inform our science-based scenarios, we used data from a long-term monitoring project on an urbanized stream in Boone, North Carolina, showing that key stream quality concerns are thermal pollution and salinity from salts used to melt ice on roads and sidewalks. In short, stormwater runoff drives hot, salty water into the stream with concomitant negative consequences (Cockerill and Anderson 2014; Cockerill et al. 2017). We used the information generated from these data to lend realism and scientific credibility to a hypothetical management scenario describing the negative consequences of runoff on stream water quality and showing how stormwater management measures can improve stream water quality.

In the following sections, we summarize the stream monitoring study that provides the scientific background to the hypothetical management scenario, describe the survey deployed, and provide the empirical results. We conclude with a discussion of the role scientific information may play in social science research and how both social and physical science provide insights into managing stormwater.

Scientific Background

Researchers have monitored stream temperatures and salinity levels along Boone Creek for more than a decade (Anderson et al. 2011, Cockerill et al. 2017). The monitoring network now includes five stream gauges, seven electrical conductivity sensors to measure salinity and more than 30 stream temperature sensors along the length of the 1.8 km study reach and adjacent small tributaries.

The data show two primary water quality concerns in Boone Creek: (1) elevated stream temperatures with many storm-induced temperature surges each year of greater than 1^{o} C within 15 minutes, and (2) salinity values that are not typical of freshwater high-gradient mountain streams. Stormwater runoff is the primary culprit for both phenomena, with temperature surges occurring on warm days due to runoff from heated pavement and buildings and salinity spikes occurring on cold snowy days when road salt has been applied to area infrastructure.

Thermal pollution in headwater streams is pervasive in urban areas (Nelson and Palmer 2007). Anderson et al. (2011) first described temperature surges in Boone Creek showing over four summers of monitoring, that the 72 temperature surge events displayed a mean rise of 2.63^{o} C and durations of 30.4 minutes. Cockerill et al. (2017) further noted an increase in the number of surge events over a ten-year monitoring period. Cockerill et al. (2017) showed, for example, 111 temperature surge events occurred in 2015 with 60% of them rising above 20^{o} C, which is a critical temperature for cold-water habitat fauna (Wang and Kanehl 2003; Wang et al. 2003).

Saline contamination of Boone Creek is a more complex problem because, unlike heat, salt does not leave the groundwater/stream system. Instead, runoff from storm events, even during summer months, acts to keep the salinity derived from snowmelt runoff in the riparian aquifers lining the stream. This is a growing issue in many cold-regions. Godwin et al. (2003) show that chloride levels in the Mohawk River, New York, rose 243% between 1942 and 1998. Novotny et al. (2008) discuss similar trends in the lakes within the Twin Cities Metropolitan Area in Minnesota, where urban lakes show 10 and 25 times the sodium and chloride levels, respectively, of non-urban lakes, and levels have been rising since 1960. Road salt runoff negatively affects water quality, aquatic species, concrete infrastructure, and human health (Corsi et al., 2010; Wang et al., 2006). Cockerill et al. (2017) demonstrated with numerical experiments that the dynamics of urban mountain streams like Boone Creek, which show frequent flashy conditions (i.e. streamflow rises rapidly in response to rainfall events, but also recovers quickly following an event), can increase the residence time of salt in the hydrologic system. This occurs because rapid changes in stream stage during storm events raise stream levels above the adjacent water table, leading to reversed gradients and temporary losing stream conditions (i.e. stream water flows into the groundwater system). Thus, under salt or heat contamination, these reversed gradients transport the solutes and/or heat to the groundwater system, where it has to return to the stream as baseflow under much lower energy (gradient) conditions. In summer months, freshwater events create a damming effect, spreading the salt resident in the riparian aquifer and increasing the residence time of the solutes. In this way, stream dynamics play an important role in the residence time of contaminants. Cockerill et al. (2017) also demonstrated that employing stormwater management to reduce stream stage fluctuations by 50% can be nearly as effective at reducing salinity levels as cutting road salt usage in half. Again, this is due to the dynamics of the stream/groundwater interactions, which are reduced under lower flow conditions.

Survey Methods

We developed a survey instrument to assess public attitudes about stormwater management. Our target population included residents of the Appalachian region from North Carolina in the south to New York in the north. This region features mountainous terrain and receives snow. These physical traits allow us to generalize the Boone Creek data for the broader region. We used the Survey Sampling International (SSI) online respondent panel and the SurveyMonkey platform to field the survey. These “opt-in” panels are becoming popular in social science research due to their relatively low cost and ability to quickly collect a large amount of data. Opt-in samples are useful for exploratory research, such as here, but use of these estimates for policy analysis should be done with caution (Baker et al. 2010, Yeager et al. 2011, Lindhjem, Henrik, and Navrud 2011). We conducted a large pilot study and revised the survey based on those results (Groothuis et al. 2017). In addition, we pre-tested the revised survey with 78 SSI panelists and asked a convenience sample of people with diverse backgrounds to take the draft survey and provide feedback. We made some minor changes based on these results.

To assess how detailed, science-based information would influence responses we conducted an experiment. Early in the survey question sequence, we provided one-third of our respondents with the following detailed text based on data from the Boone Creek monitoring program:

> University researchers have been monitoring water quality in the Appalachian Region and find that many streams suffer from "thermal pollution." This means that water temperatures are frequently higher than normal. Additionally, salt content often exceeds recommended levels for a healthy stream system. The salt is from de-icing streets and sidewalks in the winter. Researchers have concluded that the source of the warm and/or salty water is runoff from roads and buildings when it rains or snows. This is called stormwater runoff. This research suggests that there is a connection between stormwater runoff, long term salt levels in rivers and streams and "compromised aquatic health." Compromised aquatic health means that fish and the insects they eat or the plants they need for shelter struggle to live in that water. Because there are complex relationships between stream flow and groundwater, salt remains in the stream's system all year. When it rains, water pushes the salt from the stream into the groundwater system. Following storm events, groundwater returns to the stream (this is called baseflow) carrying the salt with it. Over time this is increasing the total amount of salt in the system and this contributes to compromised aquatic health.

We then randomly provided another third a shorter less detailed version of the text:

> University researchers have been monitoring water quality. In the Appalachian Region, warm, salty water is entering streams as "stormwater runoff" from roads and buildings when it rains or snows. Water temperatures in many streams are frequently higher than normal and salt content is often too high for a healthy stream. Research suggests a connection between stormwater runoff and "compromised aquatic health." Compromised aquatic health means that fish and the insects they eat or the plants they need for shelter struggle to live in that water.

We used the Boone Creek data to populate a model showing rising salinity levels over time (Cockerill and Anderson 2014). As already noted, this finding is in line with research in other regions (Godwin et al. 2003, Novotny et al. 2008, Kaushal et al., 2005). This modeling output was used to create a non-site-specific diagram that accompanied both the short and long version of the text above (Figure 1). The diagram shows increasing salinity levels and highlights that these levels do compromise aquatic health. The diagram also shows both summer and winter salinity peaks from stormwater runoff. The diagram was presented to half of the respondents who received the short science text and to half of those who received the long science text. These combinations created five treatments (Table 1). The first treatment is the control group that received no science information. This treatment consisted of about one third of the total survey respondents (n=273). The second treatment, *Short Science no image,* received only the short science text (n=112). The third treatment, *Long Science no image*, received only the long science text (n=111). The fourth treatment, *Short Science with image*, received both the short science text and the stormwater image of water quality over time (n=122). The fifth treatment, *Long Science with image*, received both the long science text and the stormwater image of water quality over time (n=119).

Geographic location presents a challenge in linking what we understand about a physical system with social attitudes and perceptions about that system. Ideally, we would have robust monitoring data and modeled results for each watershed and would then target people in each watershed with a survey that featured the data from their watershed. The reality, however, is that getting such detailed data for even a single watershed is expensive and time intensive. It is also difficult to identify potential survey respondents based on watershed rather than on a more common political boundary, such as state or zip code. Therefore, given our understanding of cold, mountainous regions generally, we applied actual stream data to generate a scenario that is applicable to a broad population. Further, the survey did consistently refer to the respondent's county by name to focus their attention on thinking about the data presented as being relevant to them.

The survey provided all respondents with a hypothetical scenario explaining how stormwater can be managed:

> Slowing down the water flow is important to reduce water temperatures and salt from stormwater runoff so that by the time the water reaches a stream the temperature is lower. There are numerous stormwater management practices that can slow water flow. These include installing permeable pavement in parking lots and sidewalks, installing rain gardens, cisterns, and other water collection systems.

Three photographs of stormwater management practices showing how rain gardens, rain barrels, and permeable pavement can be used in a local landscape accompanied the text (Figure 2).

Following the Van Houtven et al. (2007) recommendation that stated preference descriptions "include pre-change and post-change water quality, and information on the spatial and temporal variation in water quality" we provided a realistic scenario based upon the scientific information. To provide a status quo baseline to our study, at the midpoint of the survey, all respondents viewed Figure 3 (a simplified version of Figure 1) and the following text:

> The graph illustrates the scientific evidence suggesting that if nothing is done to address stormwater runoff and long-term salt levels, rivers and streams in {respondent's county} will suffer from compromised aquatic health within the next few years. Compromised aquatic health means that fish and the insects they eat or the plants they need for shelter struggle to live in that water.

Figure 3 illustrated that the baseline of stream quality is just below the threshold of compromised aquatic quality and that this line will be crossed in the near future if no stormwater management is implemented. The horizontal axis showed the time horizon and how salt levels have risen over time.

The survey then stated:

> Completely eliminating salt use is usually not a realistic option in {respondent's county}. Another option is to install permeable pavement and water collection systems. These can slow down stormwater so that it enters a stream more gradually. This allows the salt level to become more dilute before it enters the stream.

To provide context for a test of the effect of the scope of the management plan on referendum votes, the survey included a modified version of Figure 3 to illustrate how stormwater management practices can reduce salinity levels by ten percent, twenty-five percent, or fifty percent. Figure 4 shows all three levels of scope; both a twenty-five and fifty percent reduction were below the dashed line representing compromised aquatic health. For the ten percent level the trend line was above showing that even with the stormwater management programs there is compromised aquatic health. Larger values of reduction should increase the probability of a vote in favor of the management program (Whitehead 2016).

The survey included three randomly ordered referendum questions using all three levels of the scope of the management plan coupled with a randomly assigned one-time tax payment vehicle. Leading up to the referendum voting questions, the survey stated:

> The stormwater management plan would require additional funding. Counties in the Appalachian Region raise revenue from different combinations of sales, income and property taxes. Additional revenue from these sources could be used to subsidize the increase in stormwater management practices in {respondent's county}.
>
> Imagine that you have the opportunity to vote on the proposed stormwater management plan in a countywide referendum. If more than one-half (50%) of the voters in {respondent's county} vote for the plan then it would be put into practice and your county tax bill would increase. Now we would like to know how you would vote in a {respondent's county} referendum.

One referendum question was then presented for each level of the scope of the management plan. The survey question stated:

> In this scenario, suppose that an increase in stormwater management practices in {respondent's county} would decrease long-term salt levels by (10%, 25%, or 50%)
>
> In this scenario there is a one-time increase of about $A per household in county sales, income or property taxes to fund a Stormwater Management Plan in {respondent's county}. So, for example, if your combined county sales, income or property tax bill was $1000 last year it would be $1000+A this year and back to $1000 each year after that.

Each respondent saw one randomly chosen value for the one-time tax increase ($A) for each level of scope (Table 2). We randomly assigned higher payment levels for greater amounts of water quality improvement. We added or subtracted a small random number so that the tax amounts would be different in each scenario. The one-time tax amounts were estimated based on the potential range of stormwater management plan costs developed from engineering studies and pretested in Groothuis et al. (2017). At the end of the hypothetical scenarios question we provide the following statement: “Results from this study will be shared with policy makers in {respondent’s county}”. The last statement is designed to enhance consequentiality (Carson and Groves 2007) and, in this context, may suggest to respondents that taxes may rise if the referendum passes.

We then asked: “If you could vote today in a {respondent’s county} referendum, would you vote for or against the stormwater management plan?” Respondents could select from the following options:

> “I would vote for the stormwater management plan”
>
> “I would vote against the stormwater management plan”
>
> “I am undecided”
>
> “I would not vote.”

In our analysis, we coded all undecided voters as no votes as suggested by Groothuis and Whitehead (2002) and Caudill and Groothuis (2005). Respondents who said they would not vote were excluded (n = 59).

Empirical Model

To measure both the direct and indirect influence of scientific information on people's preferences for the stormwater management proposal we use a hybrid choice model (HCM) in a random utility model (RUM) framework. This technique allows researchers to incorporate perceptions and cognitive processes into a respondent’s choice framework using latent variables. We use Stata’s generalized structural equation model (GSEM) to estimate our hybrid choice model. The GSEM method accommodates nonlinear, discrete choice models. The model assumes the variables have a conditional normal distribution. Using this assumption the GSEM simultaneously estimates latent variable models and a discrete choice model and allows us to incorporate the latent attitudinal variables as explanatory variables into the discrete choice utility model.

Hybrid Choice Models were first popular in the transportation literature (e.g., Walker and Ben-Akiva, 2002; Kim et al., 2012) and then recently applied to the stated choice literature (e.g., Czajkowski et al., 2017; Zawojska et al., 2019). The estimation procedure mitigates the problem of measurement error in survey responses to attitudinal questions. Kim et al. (2014) provides an overview of and rationale for HCM, and our discussion of the model follows their description.

In Figures 5, we illustrate the hybrid choice model we estimate showing the effect of science information directly on voting intentions and indirectly through the latent variables of concern for stormwater runoff and perceived understanding of the information provided. The model illustrates three paths through which science can influence respondent vote intentions.

First the direct path is shown by an arrow from the science variables to the vote intention rectangle. The two indirect paths are shown by arrows from the science variables to each of the latent variable ovals. The two latent variables then are linked to the voting intentions models to complete the indirect paths.

The influence of income, the randomly assigned tax amount and the level of scope are illustrated by arrows from these variables to the voting intention rectangle. In structural equation models ovals are used to indicate latent variables and rectangles to indicate exogenous variable. Economic theory predicts that the taxes will be negatively related to voting for the proposal, the scope of the management plan positively related, and income positively related if storm water management is a normal good.

The latent variable (LV) models are composed of a measurement component and a structural component. The measurement component consists of the survey (indicator) question measuring the underlying latent variable that is illustrated by an arrow from the latent variable to the measurement variable. The latent variables are labeled as *Latent Concern* and *Latent Understand.* We measure each using Likert scale questions. The concern measurement question is “How concerned are you about stormwater runoff in (your) County?” The understand measurement question focuses on agreement to the statement “I understand all the information presented to me on the proposed stormwater management plan” that we asked at the end of the survey. The error components of the latent variables are illustrated by ε_n

Each measurement model has the form:

$$I_n = \theta LV_n + \varepsilon_n$$

where I_n is the response of individual *n* on the relevant indicator question, LV_n is the latent variable being measured, θ is a parameter to be estimated and ε_n is a random disturbance term.

The structural component of the LV model contains exogenous variables related to the information the respondent received in the survey. These variables were described earlier: *Short Science no image*, *Long Science no image*, *Short Science with image*, and *Long Science with image*.

For each latent variable the structural equation has the form:

$$LV_n = \Gamma \boldsymbol{X}_n + \xi_n$$

where $\boldsymbol{X}_n$ is a set of exogenous variables with parameters Γ, and ξ is a random disturbance term. The measurement and structural components of the LV model together are also referred to as a MIMIC model (multiple indicators multiple causes).

The discrete choice logit model has the form:

$$y_n = \beta_z X_n^z + \beta_{LV} X_n^{LV} + \varepsilon_n$$

where subscript and superscript z refer to exogenous variables and LV refers to latent variables. The error term ε_n has a conditionally normal distribution. We estimate the likelihood a respondent votes for the stormwater management plan as a function of observed variables: tax increase, the scope of the plan, income, and scientific information and unobserved latent variables: concern and understand. Estimation of the GSEM model is by maximum likelihood. Since the scale of indicators variables is arbitrary, the LV models require normalization constraints to ensure identification. We constrain the variance of the error terms in the measurement models to be one.

Survey Results

We fielded the survey in March and April of 2019 and received 857 responses. We excluded individuals who stated they would not vote, those who did not answer each of the three referendum voting questions, as well as respondents who did not answer other key questions for a final sample of 737 respondents. In response to the question about concern about stormwater runoff, 21 percent of respondents answered “very concerned”, 49 percent “somewhat concerned” 18 percent “somewhat not concerned” and 2 percent “not concerned.” In response to the question about understanding information presented about the proposed stormwater management plan, 21percent of respondents answered “strongly agree,” 48 percent “agree,” 23 percent “neither agree nor disagree,” 6 percent “disagree” and 2 percent “strongly disagree.”

We report the referendum vote responses in Table 2. For each level of stormwater management we find that the percentage of yes votes declines with the tax amount ($p < 0.01$). In Table 3 column one, we report the results of the voting intention model. We find that none of the science treatments have a direct effect on the likelihood of voting for the stormwater management plan. We find that the tax variable is negatively related to voting for the plan and scope of the management plan is positively related to voting for the plan each consistent with theory. We also find that income does not influence the likelihood of voting for the plan.

Focusing on the latent variables we find that coefficients *Latent Concern* and *Latent Understand* are positively related to voting in favor of the stormwater management plan. These results indicate that increases in concern for stormwater runoff and perceived understanding of the information provided on the stormwater management plan increase the likelihood of voting for the stormwater management proposal. We suggest that the concern variable measures the strength of preferences for the benefits that a stormwater management program might provide. Our results show that when the strength of preferences for stormwater improvement increases respondents are more likely to vote in favor of the management proposal. We suggest that the understanding variable captures some of the cognitive uncertainties of a survey question that arise in a hypothetical scenario. Cognitive uncertainties my lead to some respondents to default to the status quo even if they may have a willingness to pay that is greater than the tax amount. This uncertainty may lead to scenario rejects and protest no responses. (Johnston et al 2017)

In column 2 we report the results of the latent variable *Latent Concern*, we find that respondents who received either the long or short version of the scientific information without the image were more likely to report higher levels of concern for stormwater runoff relative to those who received no scientific information. These results suggest that scientific information has an indirect effect on voting in favor of a stormwater management plan through the latent variable of *Latent Concern.* Here we find that respondents who received either the short science text or the long science text used the information to update their concern for stormwater runoff that then increases their likelihood of voting for the stormwater management plan.

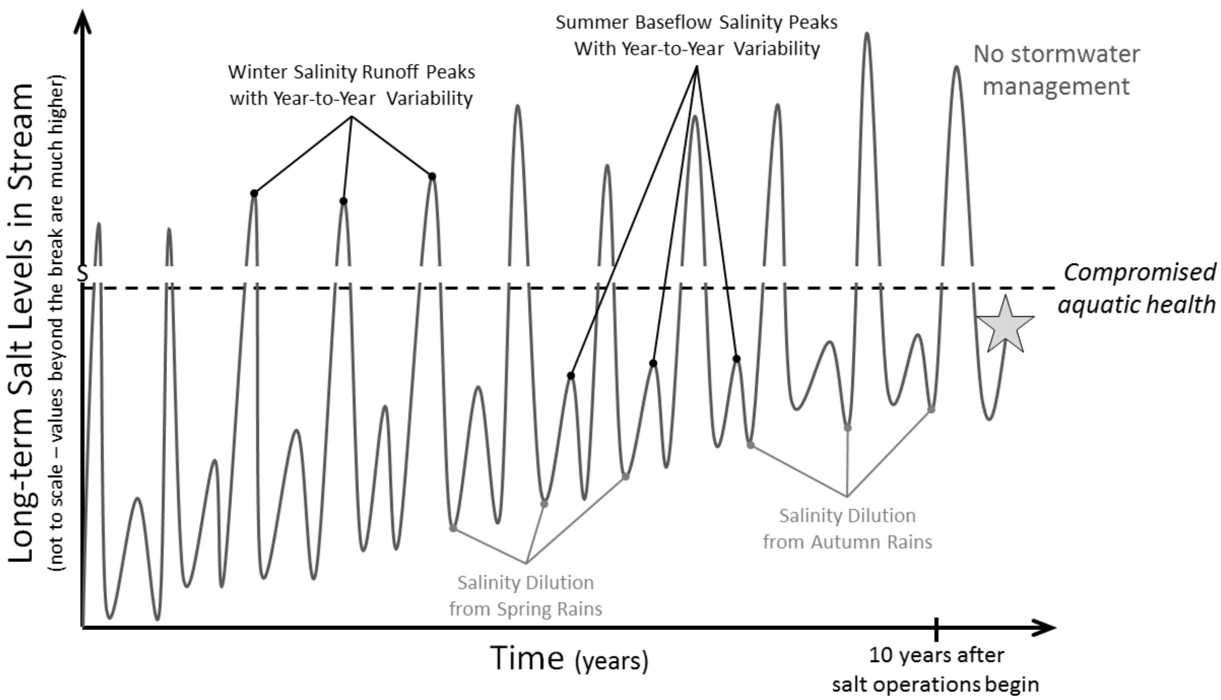
In column 3, we report the structural regression model on the latent variable *Latent Understand* and find that the respondents who received the short scientific information without a pictorial description were more likely to say they understood the information relative to those who saw no scientific information or image. Other methods of expressing the scientific information did not affect understanding. This result suggests that there is an indirect path of science information on the votes in favor of the stormwater management plan. Respondents who receive the short science text without the image have an increased understanding of the scenario and that, in turn, increases their likelihood of voting yes on the stormwater management proposal.

Conclusions

Our results find that there is no direct effect of science on the likelihood of voting for a stormwater management program. Our results do, however, find that there are indirect effects of science information on voting through influencing respondents concern for water quality and perceived understanding of information provided about the stormwater management program. We demonstrate that scientific textual information increases individuals' concern for stream water quality. We find that respondents who received either the short science or long science textual information without the graphical image expressed an increased level of concern that in turn increases their likelihood of voting yes on the storm water management plan. We find that when the graphical representation is included either with the short science or long science text there is no difference relative to those who received no scientific information on their reported level of concern. In addition we also find that self-reported understanding of the information provided about the proposed management plan only increased with the short science text with no graphical representation.

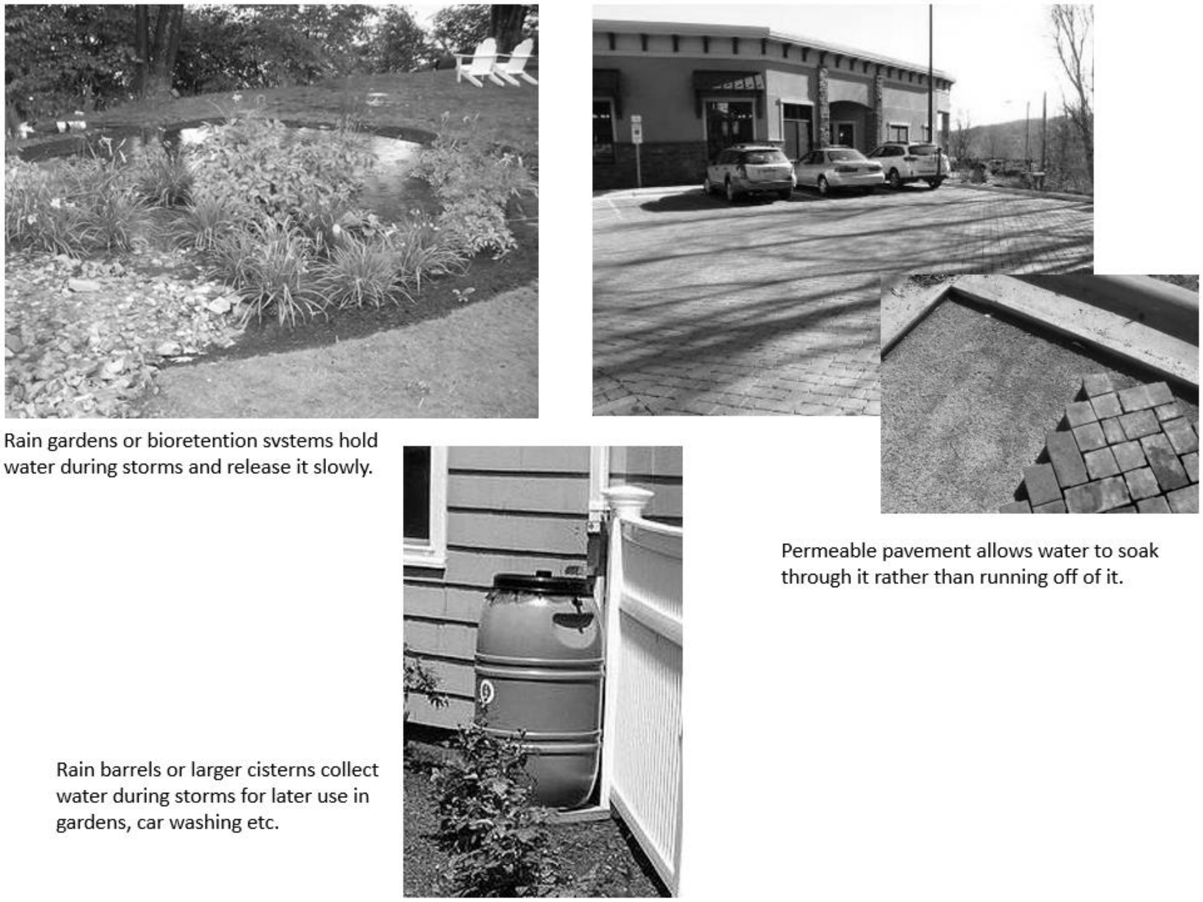
The results of our hybrid choice model suggest that focusing on latent variables that incorporate measures of respondent's perceptions and cognitive processes into a respondent's choice provides an unexplored pathway that the direct effect of science information on vote may not capture. Indeed, in our hybrid choice model, we find that the scientific information has no direct influence on a respondent's likelihood of voting for the stormwater management proposal. However, those who claimed more understanding of the stormwater management plan and those who expressed more concern about stormwater runoff were more likely to vote in favor of the plan and these latent variables and these latent variables were influenced by the level of science provided a survey respondent. Our hybrid choice model captures the indirect influence of science on respondent's choice. We suggest that researchers need to be aware of how the information provided in a survey may influence responses to a stated preference question.

Figure 1



Long-term Salt Levels in Stream
(not to scale – values beyond the break are much higher)
Winter Salinity Runoff Peaks
with Year-to-Year Variability
Summer Baseflow Salinity Peaks
With Year-to-Year Variability
No stormwater
management
Compromised
aquatic health
Salinity Dilution
from Autumn Rains
Salinity Dilution
from Spring Rains
Time (years)
10 years after
salt operations begin

Figure 2.

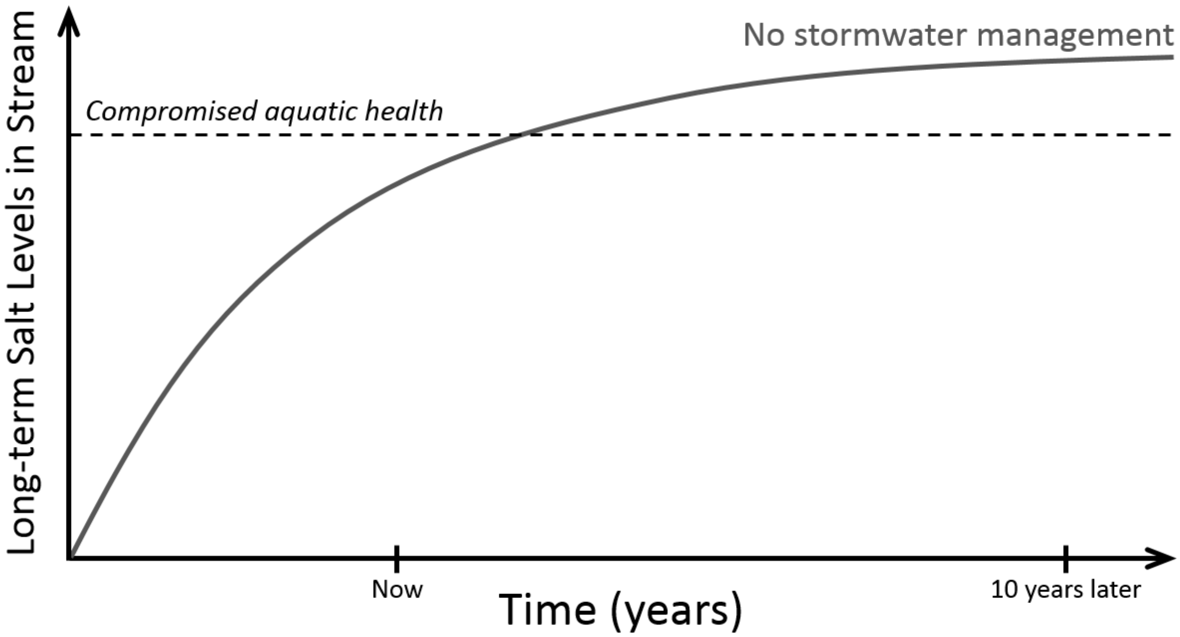


Rain gardens or bioretention systems hold water during storms and release it slowly.

Permeable pavement allows water to soak through it rather than running off of it.

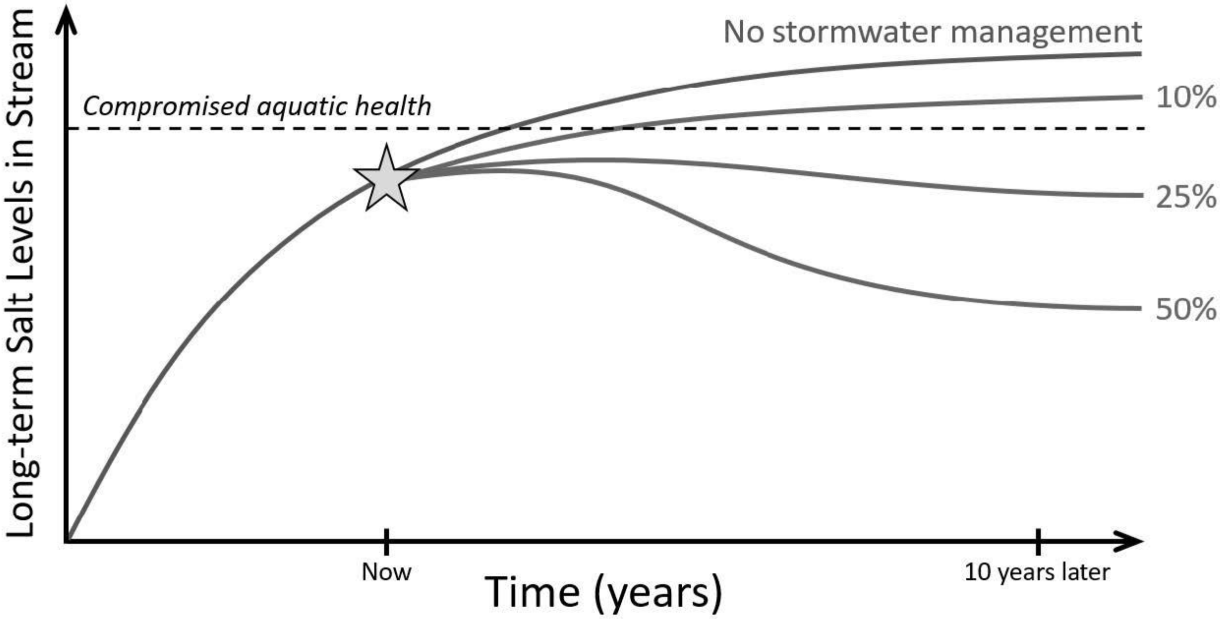
Rain barrels or larger cisterns collect water during storms for later use in gardens, car washing etc.

Figure 3



No stormwater management
Compromised aquatic health
Long-term Salt Levels in Stream
Now
10 years later
Time (years)

Figure 4



Long-term Salt Levels in Stream
Compromised aquatic health
No stormwater management
10%
25%
50%
Now
10 years later
Time (years)

Figure 5

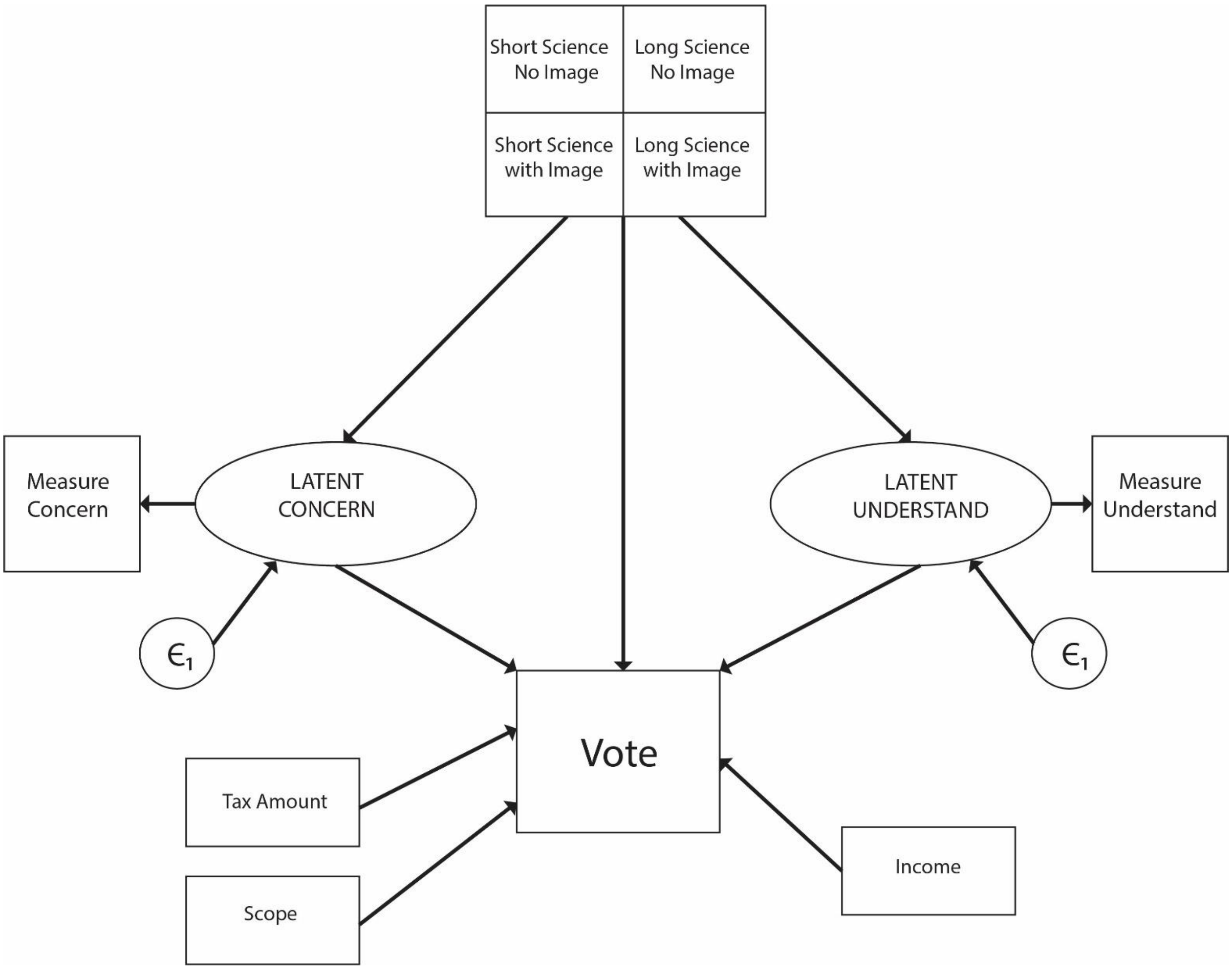

Short Science
No Image
Long Science
No Image
Short Science
with Image
Long Science
with Image
Measure
Concern
LATENT
CONCERN
LATENT
UNDERSTAND
Measure
Understand
ϵ1
ϵ1
Vote
Tax Amount
Scope
Income

Table 1: Scientific Information Treatment Groups

	Information	Number of respondents
Treatment 0	Control with no scientific text or image	273
Treatment 1	Short scientific text without image	112
Treatment 2	Long scientific text without image	111
Treatment 3	Short scientific text with image	122
Treatment 4	Long scientific text with image	119

Table 2. Referendum Vote Responses

Scope = 10			Scope = 25			Scope = 50		
Tax	%For	Sample	Tax	%For	Sample	Tax	%For	Sample
28	60.00	155						
83	45.39	141	79	54.35	138			
129	38.85	157	120	47.79	136	122	45.51	156
162	34.85	132	171	33.99	153	179	40.69	145
226	22.37	152	224	30.30	165	231	33.80	142
			286	26.21	145	280	27.56	127
						329	25.75	167

Table 3. Hybrid Choice Model Results

Variable	Vote	Concern	Understand
Short Science No Image	-.038 (.232)	.416* (.213)	.686** (.240)
Long Science No Image	-.036 (.207)	.599** (.225)	-.023 (.238)
Short Science With Image	.022 (.210)	-.023 (.239)	.309 (.225)
Long Science With Image	.019 (.216)	.103 (.225)	-.018 (.244)
Tax Amount	-.007** .0007		
Scope	.011** (.002)		
Income	.002 (.002)		
Concern	.370** (.061)		
Understand	.368** (.054)		
Constant	.146 (.181)		
Cut 1		-2.096** (.168)	-3.953** (.274)
Cut 2		-.864** (.143)	-2.736 (.188)
Cut 3		1.709 (.154)	-.855** (.140)
Cut 4			1.709** (.154)
Variance		2.89 (.249)	2.70 (.211)

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