NYSG Completion Report

REPORT WRITTEN BY: Robert Johnston **DATE:** November 21, 2022

A. PROJECT NUMBER AND TITLE:

R/CHD-13-NYCT, Eliciting and Modeling Residential Lawn and Landscape Practices: Systematic Information to Assess Knowledge, Explicate Behavior and Inform Management across the Long Island Sound Watershed

B. PROJECT PERSONNEL:

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C. PROJECT RESULTS

C1. MEETING THE OBJECTIVES

Objective 1. Adapt the survey, experimental design, and models of residential lawn care currently developed for an ongoing NSF CNH project to the New York and Connecticut portions of the Long Island Sound (LIS) watershed.

The survey and model design adapted methods developed for the prior NSF Coupled Natural and Human Systems (CNH) project led by the PIs (*Multi-scale Coupled Natural Human System Dynamics of Nitrogen in Residential Landscapes*, Award# 1615560). Two variants of the choice experiment survey were developed, focusing on choices and behavior related to (1) lawn fertilization and (2) lawn conversion to rain gardens or conservation landscaping. The survey was designed following contemporary practices for discrete choice experiments (DCEs) on revealed/stated behaviors. Questions elicited information on multiple types of lawn and landscape behaviors under current and potential future conditions. The survey was designed to characterize patterns of behavior, attitudes and knowledge, and elicited information on how homeowners' lawn/landscape practices vary across groups and respond to potential future scenarios (e.g., reflecting environmental conditions, policy changes, information, public programs, etc.). Additional questions tracked selected elements of the Comprehensive Conservation and Management Plan's Public Engagement and Knowledge Ecosystem Target, adding new data points to 2006 Public Perception Survey baseline. Feedback on the survey was obtained from stakeholders and experts involved in the study of LIS water quality, hydrology, lawn care and related topics to ensure that the project was relevant to practical needs. The survey was developed for implementation via mixed-mode, push-to-web sampling, with the online questionnaire hosted on the Qualtrics platform. Additional materials required for survey implementation were also developed, including survey invitation mailings (letters and postcards).

Objective 2. Extend the survey instrument to include components of the 2006 Public Perception Survey.

The final surveys incorporated multiple components of the 2006 Public Perception Survey to provide updated data points. The specific elements to be included were determined in coordination with LIS Study partners and stakeholders (scientists and staff). To as great an extent as possible given survey mode differences (the 2006 survey was implemented via telephone, compared to a more contemporary mixed-mode approach for the current effort), identical question language was used. Updated data points focused on (a) perceptions of LIS water quality, (b) recreational uses of the Sound, (c) perceived "connections" to the Sound, and (d) patterns in lawn care and fertilizer use. These questions were pretested and developed alongside other survey components. Results for these questions are summarized under Objective 6.

Objective 3. Pretest the instrument and models for application to LIS watershed residents.

We conducted both qualitative pre- and pilot testing of the questionnaire as described in the project proposal and EPA QAPP. These pretesting and development activities included survey pretests with individual experts and stakeholders in the LIS watershed, together with pretesting in five focus groups with 27 non-expert respondents. The first two focus groups were held in April/May 2020 with randomly sampled homeowners living in Connecticut coastal counties, with 6 participants per group. The final three focus groups were held with a total of 15 New York residents with homes in the LIS watershed, during July/August 2020. Participants were recruited by a professional focus group firm using random sampling methods for small-N research, targeting adult residents making household lawn care decisions. Focus groups were held remotely via Zoom and moderated by PI Johnston. Prior to each focus group, subjects completed draft versions of the survey instrument, for a total of N=27 individual pretests during focus groups. In addition to pretests conducted during focus groups, an additional N=54 questionnaire field tests were implemented over the course of survey development, with input from both expert and non-expert respondents selected by the study team (for a total of N=81 questionnaire pilot tests). Results were used to make final revisions to survey design and sampling methods to ensure that quality control standards were met. Given the high degree of similarity in the survey instruments and sampling methods, we were also able to leverage prior results from the NSF sister project in the Chesapeake Bay Watershed as a practical pretest of questions and survey implementation methods developed for the LIS application.

Objective 4. Implement the survey over a large, stratified random sample of New York and Connecticut LIS watershed households, using mixed-mode mail/internet design.

The final household survey was programmed online using Qualtrics and implemented using large sample, address-based, push-to-web sampling. The main survey was implemented during January – May 2021. The survey sample frame included single-family homeowners within (a) all municipalities in the four Connecticut coastal counties and (b) all municipalities of Westchester, Nassau, and Suffolk Counties in the state of New York that significantly overlap the LIS Watershed. The resulting study area for survey sampling is shown in Figure 1.

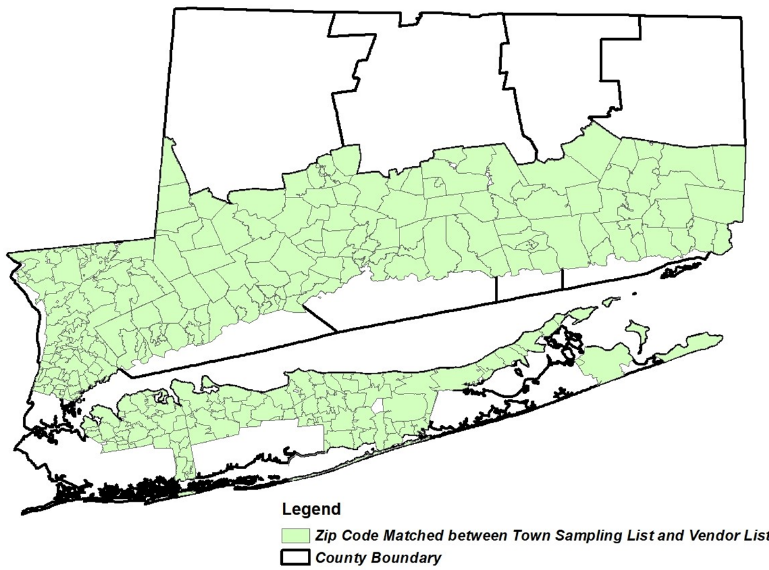


Figure 1. Study Area for Household Survey Sampling

Within this study area, the sample frame was further restricted to single-family homeowners with residential lot sizes from 0.1 to 5.0 acres. Based on this screening criteria, names and addresses for survey invitation mailings were obtained using an address-based residential occupancy list derived from the US Postal Service Delivery Sequence File, obtained from a mailing list vendor. This list was validated prior to survey implementation, including geocoding addresses to verify the geographical coverage of the mailing sample. Survey participation was solicited through a sequence of mailed invitation letters that provided the website to participate in the online survey. Each survey respondent was provided a unique ID and password that allowed the data to be geolocated to the household mailing address for spatial analysis. A total of 2,013 homeowners responded to the main-wave survey, of which 1,996 responses provided sufficient data to enable analysis (6.7% response rate), including 1,203 respondents in Connecticut and 793 respondents in New York (17 surveys do not identify a primary residence). A second and final wave of survey implementation was conducted in 2022, with a final follow-up mailing that offered a $25 gift card for each survey response. This final mailing yielded in an additional 331 responses, for a total of 2,344 completed questionnaires (7.8% response rate). These final-wave responses were used to provide additional sample size for the choice experiment models discussed under Objective 6.

Objective 5. Link survey data to measures of lawn greenness, foliar nitrogen content and other lawn attributes for a sub-sample of surveyed households, along with GIS and other data, to (a) validate survey data and (b) link responses to observable lawn conditions.

Data from the survey responses was geolocated and linked to spatially-explicit parcel and tax-assessor data compiled from PLACES (https://placeslab.org/), Regrid (https://regrid.com/) and other sources, thereby providing additional data to support the analysis of lawn care behavior. From our initial 30,000-household mailing list, we were able to link 29,477 addresses to data on parcel and housing characteristics in PLACES (98% of the sample) and link 27,882 addresses to parcel boundaries (93% of the sample), providing an excellent foundation for subsequent data analysis using these supplementary geospatial data.

The survey included a question that invited survey respondents to indicate their potential interest in having one of the research team visit their property to assess lawn greenness, foliar nitrogen content and other lawn attributes. From responses to this invitation, 88 homeowners were selected for this on-site lawn evaluation, with selected lawns distributed across the target study area. Those respondents were re-contacted to arrange times for the lawn measurements to take place, including a measure of the normalized difference vegetation index (NDVI) used as a standard measure of lawn greenness. These measurements were taken using the Fieldscout® CM1000 NDVI Meter in two 0.25 x 0.25 m quadrats both their front and backyards, yielding a total of four plots for each parcel. Turfgrass and weed species were identified in each plot. Additional data were collected on yard turfgrass quality, using a 10-point scale that considered coverage, color, density, uniformity, texture, and disease or environmental stress. Each parcel was observed twice (spring and summer), with separate measurements on the front and back yard.

Combined analysis of households' reported fertilizer application behavior with observed biophysical measures of lawn greenness and foliar nitrogen content (for a subsample of 88 survey respondents) reveals relationships between these variables—for example households' reported fertilizer use is correlated with foliar nitrogen content and NDVI. These cross-validation results demonstrate that households' self-reported fertilizer use is related to objectively verifiable lawn conditions.

As an illustration of these findings, NDVI measurements were taken as a way to quantitatively assess the greenness of participant yards, possibly to serve as a proxy for assessing soil nitrogen content. Additionally, this methodological approach has the advantage of being rapid and easy to conduct, while also offering an aspect of accessibility over visual ratings or descriptions of color. That said, difficulty obtaining a corresponding measured brightness above 0 would sometimes occur due to time of day or cloud coverage, possibly impacting NDVI data. While respondents reported specific numbers that ranged from 0 to 5 for the frequency of fertilization during the past twelve months, this data shows the most significant differences when contrasting people who reported no fertilization versus people who reported any amount of fertilization, whether low or high in frequency. These results are shown in Figure 2.

As shown by Figure 2, the both fertilizer application (yes versus no) and the number of applications is positively correlated with observable lawn greenness (NDVI), although this correlation is primarily statistically significant during the spring. Similar patterns are found for both front and back yard. At least two conclusions can be drawn from these correlations. First, these findings support the validity of survey responses on fertilizer use, as self-reported fertilizer applications by homeowners are correlated with observable and verifiable lawn conditions. Second, fertilizer applications appear to improve lawn greenness, supporting the commonly held belief that residential fertilizer use improves lawn appearance.

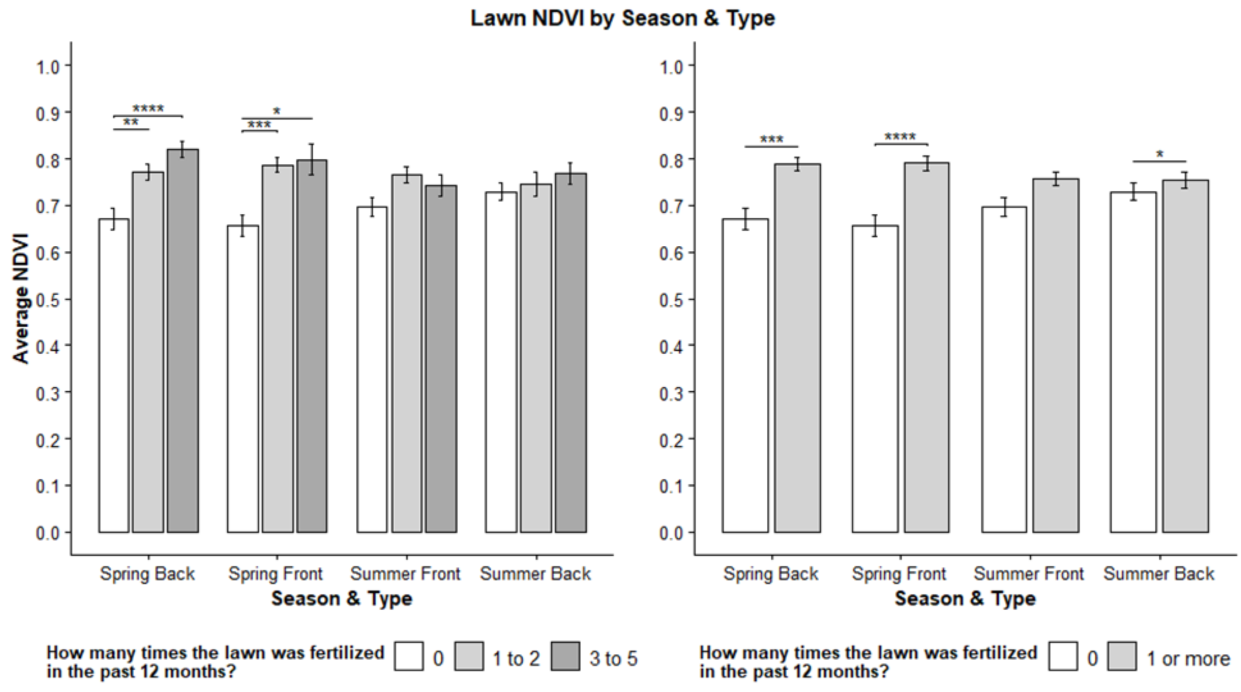


Figure 2. NDVI values were taken from five readings within two randomly placed quadrat for both front and back yards (spring and summer). Normality and homoscedasticity of variance of the data were assessed, and t-tests with Holm-Bonferroni adjustments conducted. Significance values **** $p \leq 0.0001$, *** $p \leq 0.001$, ** $p \leq 0.01$, * and $p \leq 0.05$.

Objective 6. Apply the integrated models in coordination with stakeholders to forecast management outcomes and test behavioral hypotheses related to changes in lawn care behavior, including the effect of program and policy changes on specified lawn care behaviors in different areas of the LIS watershed, among different resident groups.

The survey questionnaire collected an extensive range of household-level data on topics including (a) homeowner lawn fertilizer applications and other lawn management activities, (b) household demographics, (c) housing and yard characteristics (d) perceptions about water quality in LIS, (e) recreational activities related to LIS, (f) whether the household would support alternative types of policies to reduce the negative impacts of fertilizer use on LIS water quality, and (g) whether the household would enroll in possible cost-share programs that incentivize conservation landscaping or rain gardens. Given the extent of the data and modeling it is not possible to present all results within this final report. Hence, we focus this final report on a selected set of main results.

Lawn Fertilization Behavior
Table 1 summarizes the percentage of homeowners by the number of lawn fertilizer applications in 2020. Lawn fertilizing is a two-step decision—whether to fertilize and if yes how often. About 40% of homeowners did not apply fertilizer. On average, fertilizer use in New York is slightly higher than Connecticut. The average number of lawn fertilizer applications in New York was 1.53 times per year, while only 1.26 times per year in Connecticut.

Table 1. Residential Lawn Fertilizer Applications in 2020

Number of lawn fertilizer applications	Connecticut	New York	All
0	45.1%	32.7%	40.1%
1	18.5%	20.6%	19.3%
2	15.4%	20.4%	17.4%
3	7.4%	9.0%	8.0%
4	7.0%	8.4%	7.6%
5	2.6%	2.6%	2.6%
6	1.0%	0.9%	1.0%
>= 7	0.4%	0.6%	0.5%
Average number of fertilizer applications	1.26	1.53	1.37
Total survey respondents	1,203	793	1,996

Predicting the Likelihood and Frequency of Lawn Fertilization

We analyzed the household-level factors that explain variation in two sequential decisions for lawn fertilizer use. The first decision is whether or not to fertilize. To analyze this decision, a discrete choice (binary) probit model was used to estimate the likelihood of fertilizing as a function of household and parcel characteristics (e.g., age, education, income, house size, etc.). For those households who fertilize, the second (conditional) decision is the frequency of application (e.g., 1, 2, 3, etc.). To analyze this second-stage decision, a count data model (zero truncated negative binomial) was used to predict the frequency of lawn fertilizer applications, as a function of the same household and parcel characteristics explaining.

Table 2 shows factors that are positively or negatively associated with the likelihood of lawn fertilization and number of fertilizer applications, together with the statistical significance of each effect. Models were estimated for all respondents from the main survey wave that provided sufficient data for analysis (N=1,996), along with subsamples for Connecticut (N=1,203) and New York (N=793) homeowners. Results show that housing characteristics are strongly associated with the likelihood of fertilizing. Among other findings of the model, homeowners in newer, larger homes are much more likely to apply fertilizer. Newer and/or larger homes are also associated with a greater likelihood of fertilizer use, compared to older and/or smaller homes. Homeowners with larger residential lots (l to 5 acres) are also less likely to fertilize relative to those on small lots (<=1/4 acre). Few demographic characteristics are strongly associated with the likelihood of fertilizing.

Results also provide insight into the factors associated with the frequency (number) of annual fertilizer applications, conditional on the prior decision to apply. Results show that newer homes are associated with a higher frequency of applications relative to older homes (built before 1950). While house size is strongly associated with the likelihood of fertilizing, it does not have a significant relationship to the frequency of applications. Lower income households (<$50,000) have a relatively lower number of fertilizer applications. Homeowners who have lived in their current residence for a longer duration also tend to fertilize more often. Men tend to apply fertilizer more frequently.

Table 2. Factors Affecting the Likelihood of Lawn Fertilization and Number of Fertilizer Applications

Variable	Probability of Lawn Fertilization			Number of Fertilizer Applications		
	CT	NY	All	CT	NY	All
State						
Connecticut (baseline)			+			0
New York						
Lot size (acres)						
<= ¼ (baseline)						
¼ – 1	0	--	0	0	0	0
>= 1	---	--	---	0	0	-
House built year						
Before 1950 (baseline)						
1950 – 1959	0	+	++	0	0	0
1960 – 1979	+	+	++	+	0	++
1980 – 1999	++	+++	+++	+	+	++
2000 – 2020	+++	+	+++	++	+	+++
House size (square feet)						
< 1,500 (baseline)						
1,500 – 2,000	0	++	0	0	0	0
2,001 – 2,500	0	++	++	0	0	0
> 2,500	++	+++	+++	0	0	0
Household income						
< $50,000	--	0	-	--	0	-
$50,000 – $100,000	-	0	0	0	0	-
$100,000 – $200,000	0	+	0	0	0	0
> $200,000 (baseline)						
Years residing in the house	0	++	+	+	0	+
Pets spending time outdoors (yes=1)	0	0	0	0	0	0
Gender (male=1)	+++	0	+++	0	+++	++
Age over 65 years (yes=1)	0	0	0	0	0	0
Have children (yes=1)	0	0	0	0	0	0
Highest degree of education						
No college	0	0	0	0	0	0
College	0	0	0	+	0	++
Advanced degree (baseline)						
If behavior worsens water quality in LIS						
Yes	+	+	++	0	0	0
No (baseline)						
I do not know	0	0	0	0	0	0
Association membership (yes = 1)						
Homeowner's association	0	0	0	0	0	+
Neighborhood association	-	0	0	0	0	0
Neither (baseline)						

+++: positive at 1% level; ++: positive at 5% level; +: positive at 10% level; 0: no significance; ---: negative at 1% level; --: negative at 5% level; -: negative at 10% level

Spatial Prediction of Residential Lawn Fertilizer Use

Grounded in these data and results, we produced a spatial prediction of the probability and average number of fertilizer applications for all single-family households in the LIS study region. This spatial prediction approach is a two-step process. The first step estimates the two statistical models represented in Table 2 for the probability and frequency of applications using our survey data, with explanatory variables limited to those available for all parcels in the study region (house age, house size, lot size and Euclidean distance to the LIS shoreline). The second step is to create model predictions for all single-family households in the study region. Before making the predictions, we screened available tax assessor data to include single-family households with residential lot sizes from 0.1 to 5.0 acres. We then use the statistical model to predict the probability of fertilizer (Figure 2) and the average number of applications (Figure 3) for all of these single-family households. Here, we show illustrative predictions for Connecticut only (489,828 households)—as more complete parcel data was available for this state. Partial results for New York (for those municipalities that provide adequate parcel data to implement the predictions) are available from the researchers upon request, but are omitted here for conciseness.

As shown by Figures 3 and 4, the spatial disparity in households' lawn fertilizing behavior is evident. Generally, households in urban and suburban areas are less likely to fertilize their lawn and have a lower number of fertilizer applications than those in exurban areas. Additionally, households in municipalities closer to New York, especially those with newer larger homes, have the highest probability of lawn fertilization and the highest number of fertilizer applications.

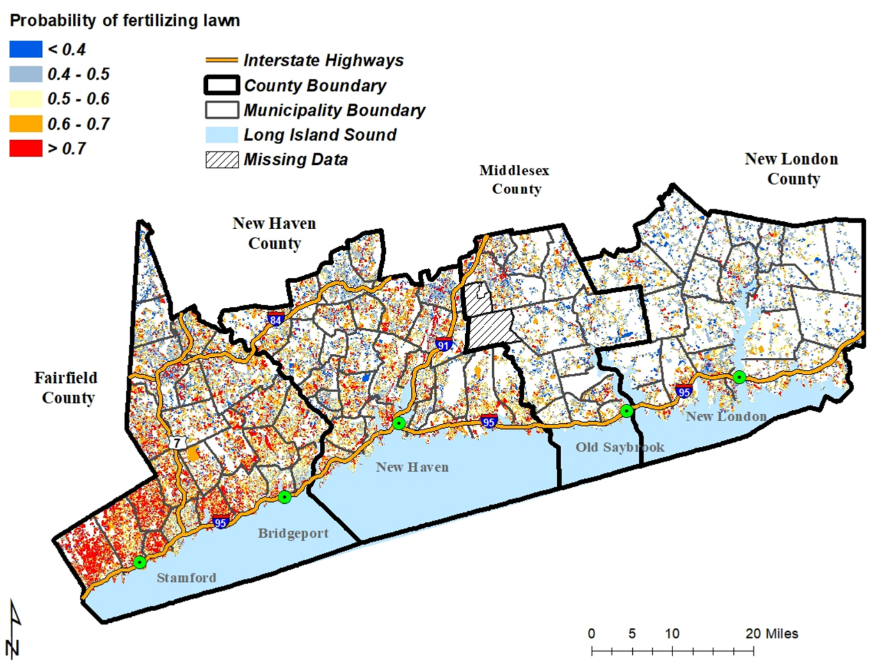


Figure 3. Predicted Probability of Lawn Fertilization in Connecticut Study Area

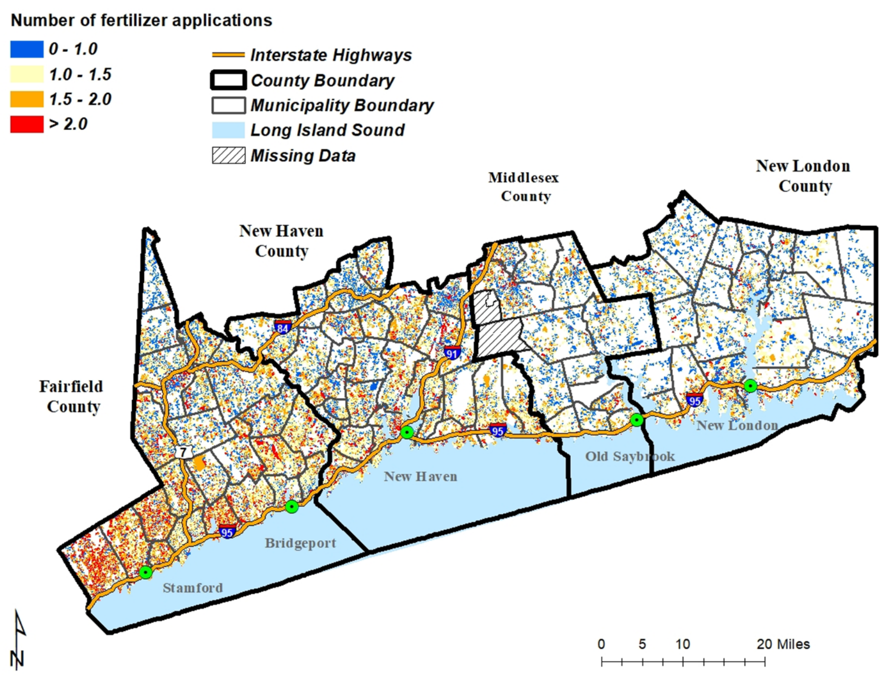


Figure 4. Predicted Number of Lawn Fertilizer Applications in Connecticut Study Area

Tables 3.1 and 3.2 show the predicted average number of fertilizer applications by house year built and house size, respectively in Connecticut and New York. Differences in fertilizer applications are substantial across built-year and house-size categories. For instance, households with larger newer homes have significantly more fertilizer applications than those with smaller older homes in both Connecticut and New York.

Table 3.1 Predicted Average Number of Fertilizer Applications by Year Built and House Size in Connecticut

House size / Year built	<1500	1500-2000	2000-2500	2500-3000	>3000	Total
pre-1940	0.76	0.84	0.90	1.00	1.50	0.99
1940-1959	1.03	1.15	1.25	1.36	1.93	1.16
1960-1979	1.15	1.26	1.38	1.48	2.17	1.36
1980-1999	1.37	1.49	1.60	1.68	2.24	1.70
2000-2021	1.67	1.77	1.86	1.99	2.65	2.21
Total	1.06	1.17	1.31	1.45	2.03	1.32

Table 3.2 Predicted Average Number of Fertilizer Applications by Year Built and House Size in New York

Year built \ House size	<1500	1500-2000	2000-2500	2500-3000	>3000	Total
pre-1940	1.03	1.07	1.09	1.10	1.17	1.09
1940-1959	1.45	1.49	1.51	1.52	1.59	1.49
1960-1979	1.63	1.68	1.71	1.71	1.84	1.71
1980-1999	2.04	2.06	2.05	2.06	2.10	2.08
2000-2021	2.38	2.37	2.42	2.43	2.49	2.46
Total	1.42	1.48	1.58	1.66	1.81	1.56

Predicting Household Responses to Policies and Programs Affecting Lawns and Fertilizer

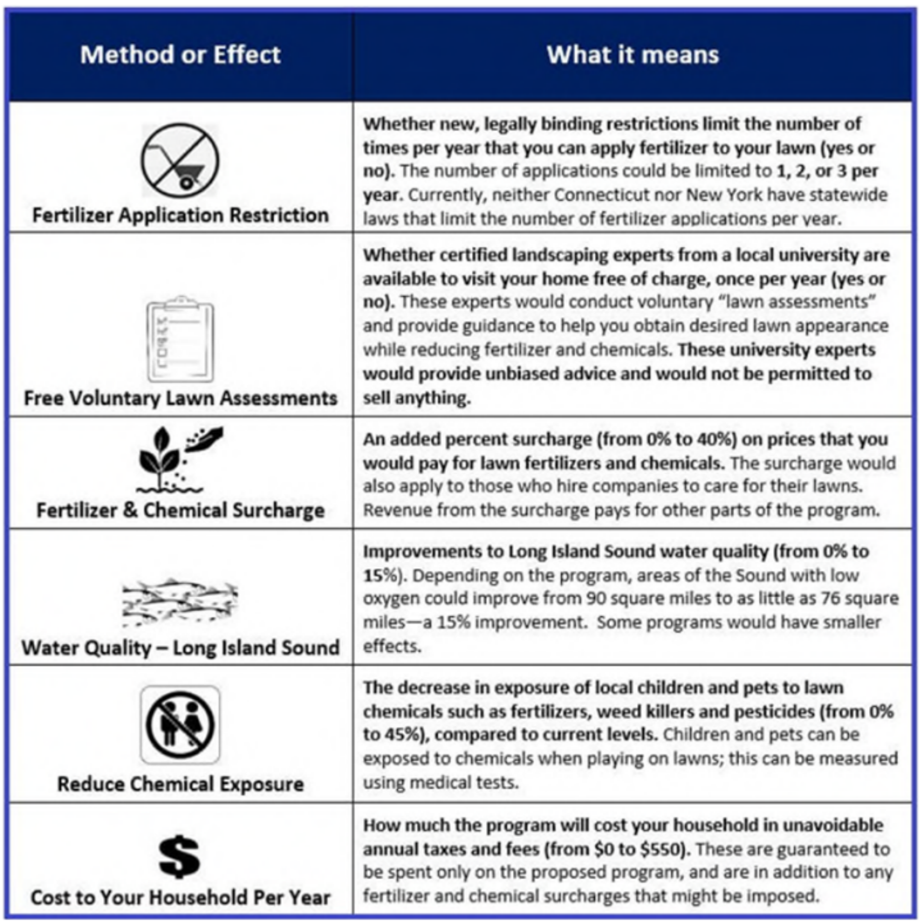
Discrete choice experiments (DCEs) are a class of survey-based preference-estimation techniques that characterize public values and support for policy or program alternatives using data from voting choices. DCE questions were included in the household survey to evaluate the probability that different types of households would support (i.e., vote 'yes' for) alternative, hypothetical future policies that would both reduce lawn fertilizer use (compared to the status quo with no policy changes) and potentially improve LIS water quality. These potential policies included elements such as restrictions on fertilizer applications, tax surcharges on fertilizer products, educational programs for lawn assessments, and other mechanisms.

Table 4 shows the attributes and levels used to define the voting or choice questions. Figure 5 shows the table that defined these variables in the questionnaire. Figure 6 shows an illustrative example of a DCE question from the survey. Each survey respondent was asked to consider 3 out of 48 possible programs to reduce the impact of lawn fertilizers on LIS water quality, and vote 'yes' or 'no' for each program based on their preferences. To produce the 48 possible choice questions that was included in the survey (based on a mix-and-match combination of attribute levels from Table 4), the DCE experimental design was developed using a Bayesian D_b-efficiency criterion for a choice model covariance matrix. The resulting design included 48 profiles blocked into 16 survey versions, each with 3 choice tasks.

Table 4. Attributes and Model Variables in Fertilizer Policy Discrete Choice Experiment

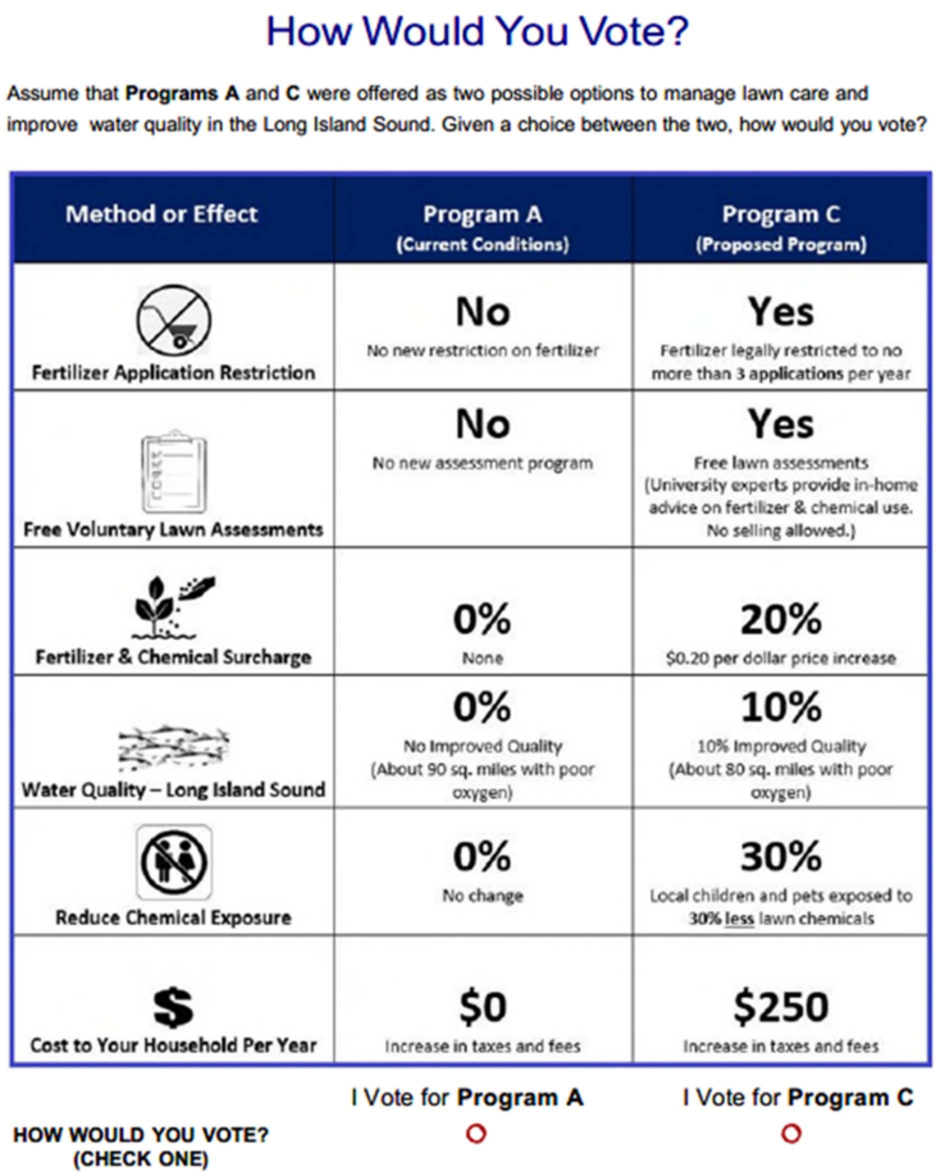
Attribute	Variable Name in Model	Description	Possible Attribute Levels in Discrete Choice Experiment
Fertilizer Application Restriction	*1_Applications_allowed* *2_Applications_allowed* *3_Applications_allowed*	New, binding restriction on the number of lawn fertilizer applications per year. Either "no new restrictions, or restrictions to maximum of 1 to 3 applications per year.	1, 2, 3, (no new restriction is the omitted baseline)
Free Lawn Assessments	*Free_Lawn_Assessment*	Whether landscaping experts from a local university are available to visit homes free of charge, to provide guidance to help obtain desired lawn appearance while reducing fertilizer and chemicals.	No (0), Yes (1)

Fertilizer & Chemical Surcharge	*Fertilizer_Surcharge*	An added percent surcharge (from 0% to 30%) on prices paid for lawn fertilizers and chemicals. The surcharge would also apply to those who hire companies to care for their lawns.	0%, 10%, 20%, 30%
LIS Water Quality (Improvement)	*LISS_Water_Quality*	Improvements to Long Island Sound water quality (from 0% to 15%), measured as average percentage reductions in the area of the Sound (sq. mi.) with moderate or worse dissolved oxygen (<3.0 mg/l) in summer.	0%, 5%, 10%, 15%
Reduce Chemical Exposure	*Reduce_Chemical_ Exposure*	The decrease in exposure of local children and pets to lawn chemicals such as fertilizers, weed killers and pesticides (from 0% to 45%).	0%, 15%, 30%, 45%
Cost to Your Household Per Year	*Cost*	Binding annual household cost to pay for new program (in new taxes and fees).	$0, $25, $50, $100, $150, $250, $350, $550



Method or Effect	What it means
Fertilizer Application Restriction	**Whether new, legally binding restrictions limit the number of times per year that you can apply fertilizer to your lawn (yes or no).** The number of applications could be limited to **1, 2, or 3 per year.** Currently, neither Connecticut nor New York have statewide laws that limit the number of fertilizer applications per year.
Free Voluntary Lawn Assessments	**Whether certified landscaping experts from a local university are available to visit your home free of charge, once per year (yes or no).** These experts would conduct voluntary "lawn assessments" and provide guidance to help you obtain desired lawn appearance while reducing fertilizer and chemicals. **These university experts would provide unbiased advice and would not be permitted to sell anything.**
Fertilizer & Chemical Surcharge	**An added percent surcharge (from 0% to 40%) on prices that you would pay for lawn fertilizers and chemicals.** The surcharge would also apply to those who hire companies to care for their lawns. Revenue from the surcharge pays for other parts of the program.
Water Quality – Long Island Sound	**Improvements to Long Island Sound water quality (from 0% to 15%).** Depending on the program, areas of the Sound with low oxygen could improve from 90 square miles to as little as 76 square miles—a 15% improvement. Some programs would have smaller effects.
Reduce Chemical Exposure	**The decrease in exposure of local children and pets to lawn chemicals such as fertilizers, weed killers and pesticides (from 0% to 45%), compared to current levels.** Children and pets can be exposed to chemicals when playing on lawns; this can be measured using medical tests.
Cost to Your Household Per Year	**How much the program will cost your household in unavoidable annual taxes and fees (from $0 to $550).** These are guaranteed to be spent only on the proposed program, and are in addition to any fertilizer and chemical surcharges that might be imposed.

Figure 5. Explanation of Fertilizer Policy Choice Attributes within the Questionnaire



How Would You Vote?

Assume that **Programs A** and **C** were offered as two possible options to manage lawn care and improve water quality in the Long Island Sound. Given a choice between the two, how would you vote?

Method or Effect	Program A (Current Conditions)	Program C (Proposed Program)
Fertilizer Application Restriction	**No** No new restriction on fertilizer	**Yes** Fertilizer legally restricted to no more than 3 **applications** per year
Free Voluntary Lawn Assessments	**No** No new assessment program	**Yes** Free lawn assessments (University experts provide in-home advice on fertilizer & chemical use. No selling allowed.)
Fertilizer & Chemical Surcharge	**0%** None	**20%** $0.20 per dollar price increase
Water Quality – Long Island Sound	**0%** No Improved Quality (About 90 sq. miles with poor oxygen)	**10%** 10% Improved Quality (About 80 sq. miles with poor oxygen)
Reduce Chemical Exposure	**0%** No change	**30%** Local children and pets exposed to 30% less lawn chemicals
Cost to Your Household Per Year	**$0** Increase in taxes and fees	**$250** Increase in taxes and fees

HOW WOULD YOU VOTE? (CHECK ONE)	I Vote for **Program A** ○	I Vote for **Program C** ○

Figure 6. Sample Choice Question from Fertilizer Policy Discrete Choice Experiment. This represents one out of 48 possible choice questions viewed by respondents. Each possible question was distinguished by attribute levels within the proposed program. Each respondent answered three of these questions, selected from the full set.

Latent class, multinomial logit models were developed to analyze these responses and evaluate both household preferences and the probability that different groups of households would support potential new policies. Latent class models allow preferences to differ systematically over different groups of homeowners (for example those who care more about lawn condition versus those who care more about environmental impacts of lawn care). The dependent variable for the model is binary response indicating whether or not a household would vote for the proposed program (yes = 1, no = 0), compared to a no-program status quo. Results are shown in Table 5.

Table 5. Latent Class Multinomial Logit Results—Fertilizer Policy DCE

	Class 1		**Class 2**	
	Coeff.	Std.Error	Coeff.	Std.Error
Status Quo Constant	-2.86981***	0.28663	1.06054***	0.36254
1_Application	0.14497	0.21194	-0.89916***	0.28764
2_Applications	-0.00862	0.21602	-0.08835	0.26273
3_Applications	0.09084	0.24035	0.19967	0.35428
Free_Lawn_Audits	-0.08877	0.18767	1.19900***	0.33396
Surcharge	-0.01424**	0.00579	-0.01682***	0.00606
LIS_Water_Quality	0.04778**	0.01894	0.11577***	0.03533
Reduce_Chemical_Exposure	-0.00392	0.00571	0.03041***	0.01043
Cost	-0.00504***	0.00038	-0.02253***	0.00414
Class probabilities				
Class Probability	0.60853***	.01856	0.39147***	0.01856
LL	-2005.671			
AIC	4049.5			
BIC	4167.9			
Chi-sq	1253.803			
R-squared	0.2381			
N	3,798			

Summarizing these results, we find that homeowners fall into two groups, or latent classes. Class 1 respondents tend to support restrictions on lawn use (and care about improvements in LIS water quality; $p < 0.05$), but do not support surcharges on lawn fertilizer ($p < 0.05$). We title this group "environmental and cost," because their responses only show concern for environmental and monetary dimensions of the program. In contrast, Class 2 respondents (which we title "lawn people") LIS value water quality improvements ($p < 0.01$), but have *negative* preferences for strict restrictions on fertilizer use (i.e., limited to 1 or fewer applications per year; $p < 0.01$) and for surcharges levied on fertilizer products ($p < 0.01$). This group also has strong positive preferences for the provision of free, lawn-related educational programs ($p < 0.01$). The first group tends to generally support policies to reduce the negative impacts of lawn care on LIS water quality, whereas the second group tends not to support these policies. Overall, a sampled household has a 61% probability of falling into the first group ("environmental and cost") and a 39% probability of falling into the second group ("lawn people"). Neither group showed negative preferences for *moderate* restrictions on fertilizer applications (e.g., limited to 2 or 3 applications per year), suggesting that there is widespread support for *some types* of restrictions on household fertilizer use, in order to achieve LIS water quality objectives. Results such as these can be used to predict the likelihood that households would support (or vote for) alternative types of policies that could be proposed to reduce lawn fertilizer use across the LIS watershed.

A second set of DCE questions enabled predictions of households' willingness to convert lawns to alternative landscaping (e.g., rain gardens, conservation landscaping) in response to proposed incentive (or cost-share) programs for lawn conversion practices, with a focus on quantifying barriers (or "transaction costs") that commonly inhibit program participation. Models were developed using data from DCE questions that elicited information on whether each household would enroll in potential cost-share programs that incentivize lawn conversion. The proposed programs varied over several program attributes, such as the percent cost-share paid and barriers in the enrollment process (e.g., finding a contractor, filing application paperwork, arranging final inspection, paying full installation costs and receiving a rebate later). A mixed logit model was estimated to predict enrollment (and hence lawn conversion) as a function of program attributes, as well as household demographic and property characteristics.

For conciseness, we only summarize key results of the second DCE here. Full details are available from the authors upon request. Results from this DCE suggest that that common programs to incentivize lawn conversions to rain gardens and conservation landscaping may not be optimally designed to encourage these conversions. Mixed logit model results show that the enrollment barriers related to typical cost-share program requirements (e.g., application paperwork for project design ($p < 0.05$); financing projects up-front with rebate later ($p < 0.01$)) are sufficient to negate much of the incentive provided by typical cost-share payments and substantially reduce program participation. Results also suggest that households prefer to locate their own contractor to perform lawn conversion projects rather than having program sponsors assign contractors ($p < 0.05$). Predicted household enrollment in the presented cost-share programs increases substantially when steps are taken to minimize enrollment barriers, compared to the typical case in which all of these barriers are imposed. In cases such as these, program resources typically allocated to provide higher cost-share payments in lawn conversion programs could be more effectively spent on strategies to attenuate these enrollment barriers. These results suggest that systematic changes to policy and incentive program design can have substantial implications for the probability that lawn conversions will occur across the watershed.

Summary of Additional Survey Results (Selected)

A set of additional survey results is summarized below, including responses to questions that updated selected components of the 2006 Public Perception Survey. Results are identified by survey question number. Results are drawn from 1,996 completed responses to the main survey sample obtained in 2021. A detailed summary of all survey results—suppressed here for conciseness—is available from the authors upon request.

Q5a: Does your property have a front yard with lawn?

Front yard with lawn	Frequency			Percent		
	CT	NY	All	CT	NY	All
Yes	1,138	742	1,880	94.6%	93.6%	94.2%
No	50	43	93	4.2%	5.4%	4.7%
Missing	15	8	23	1.2%	1.0%	1.2%
Total	1,203	793	1,996	100%	100%	100%

Q5b: Does your property have a back yard with lawn?

Back yard with lawn	Frequency			Percent		
	CT	NY	All	CT	NY	All
Yes	1,120	724	1,844	93.1%	91.3%	92.4%
No	61	54	115	5.1%	6.8%	5.8%
Missing	22	15	37	1.8%	1.9%	1.9%
Total	1,203	793	1,996	100%	100%	100%

Question 5c. For each of these activities on your lawn (in the past 12 months), did you “do it yourself”, hire a professional, both or neither? “Do it Yourself” includes activities done by you, family, or friends (any non-professional).

All Sample

Activity	DIY	Hire a Pro	Both	Not Done	Missing	Total
Fertilizing	720	465	67	590	154	1,996
Watering	1,293	31	41	454	177	1,996
Mowing	1,239	613	63	16	65	1,996
Insecticides	318	383	51	971	273	1,996
Weed control	577	393	71	750	205	1,996
Maintaining	1,424	165	240	61	106	1,996
Trimming	1,148	365	320	58	105	1,996
Raking	1,188	422	229	68	89	1,996

Activity	DIY	Hire a Pro	Both	Not Done	Missing	Total
Fertilizing	36.1%	23.3%	3.4%	29.6%	7.7%	100%
Watering	64.8%	1.6%	2.1%	22.7%	8.9%	100%
Mowing	62.1%	30.7%	3.2%	0.8%	3.3%	100%
Insecticides	15.9%	19.2%	2.6%	48.6%	13.7%	100%
Weed control	28.9%	19.7%	3.6%	37.6%	10.3%	100%
Maintaining	71.3%	8.3%	12.0%	3.1%	5.3%	100%
Trimming	57.5%	18.3%	16.0%	2.9%	5.3%	100%
Raking	59.5%	21.1%	11.5%	3.4%	4.5%	100%

CT Only

Activity	DIY	Hire a Pro	Both	Not Done	Missing	Total
Fertilizing	452	216	28	403	104	1,203
Watering	702	8	10	360	123	1,203
Mowing	875	251	30	8	39	1,203
Insecticides	198	189	23	617	176	1,203
Weed control	354	182	30	504	133	1,203
Maintaining	941	48	105	42	67	1,203
Trimming	790	127	174	43	69	1,203
Raking	844	163	96	45	55	1,203

Activity	DIY	Hire a Pro	Both	Not Done	Missing	Total
Fertilizing	37.6%	18.0%	2.3%	33.5%	8.6%	100%
Watering	58.4%	0.7%	0.8%	29.9%	10.2%	100%
Mowing	72.7%	20.9%	2.5%	0.7%	3.2%	100%
Insecticides	16.5%	15.7%	1.9%	51.3%	14.6%	100%
Weed control	29.4%	15.1%	2.5%	41.9%	11.1%	100%
Maintaining	78.2%	4.0%	8.7%	3.5%	5.6%	100%
Trimming	65.7%	10.6%	14.5%	3.6%	5.7%	100%
Raking	70.2%	13.5%	8.0%	3.7%	4.6%	100%

NY Only

Activity	DIY	Hire a Pro	Both	Not Done	Missing	Total
Fertilizing	268	249	39	187	50	793
Watering	591	23	31	94	54	793
Mowing	364	362	33	8	26	793
Insecticides	120	194	28	354	97	793
Weed control	223	211	41	246	72	793
Maintaining	483	117	135	19	39	793
Trimming	358	238	146	15	36	793
Raking	344	259	133	23	34	793

Activity	DIY	Hire a Pro	Both	Not Done	Missing	Total
Fertilizing	33.8%	31.4%	4.9%	23.6%	6.3%	100%
Watering	74.5%	2.9%	3.9%	11.9%	6.8%	100%
Mowing	45.9%	45.6%	4.2%	1.0%	3.3%	100%
Insecticides	15.1%	24.5%	3.5%	44.6%	12.2%	100%
Weed control	28.1%	26.6%	5.2%	31.0%	9.1%	100%
Maintaining	60.9%	14.8%	17.0%	2.4%	4.9%	100%
Trimming	45.1%	30.0%	18.4%	1.9%	4.5%	100%
Raking	43.4%	32.7%	16.8%	2.9%	4.3%	100%

Q6a. During the past year (the past 12 months), how many total times did you fertilize your lawn or have it done by a professional?

Fertilize the lawn	Frequency			Percent		
	CT	NY	All	CT	NY	All
0 (never)	542	259	801	45.1%	32.7%	40.1%
1 time	222	163	385	18.5%	20.6%	19.3%
2 times	185	162	347	15.4%	20.4%	17.4%
3 times	89	71	160	7.4%	9.0%	8.0%
4 times	84	67	151	7.0%	8.4%	7.6%
5 times	31	21	52	2.6%	2.6%	2.6%
6 times	12	7	19	1.0%	0.9%	1.0%
>= 7 times	5	5	10	0.4%	0.6%	0.5%
Missing	33	38	71	2.7%	4.8%	3.6%
Total	1,203	793	1,996	100%	100%	100%

Q6b. Have you or a professional applied fertilizer to your current lawn at any time during the past 5 years? (only those who choose 0 in Q6a will answer Q6b)

Past lawn fertilizer	Frequency			Percent		
	CT	NY	All	CT	NY	All
Yes	80	38	118	14.8%	14.7%	14.7%
No	432	207	639	79.7%	79.9%	79.8%
Unsure	30	14	44	5.5%	5.4%	5.5%
Total	542	259	801	100%	100%	100%

Q6c. Compared to five years ago, would you say your fertilizer use on your lawns and gardens has, ...

Fertilizer use	Frequency			Percent		
	CT	NY	All	CT	NY	All
Increased	82	50	132	6.8%	6.3%	6.6%
Decreased	167	108	275	13.9%	13.6%	13.8%
Stayed about the same	510	405	915	42.4%	51.1%	45.8%
I don't know	218	123	341	18.1%	15.5%	17.1%
I don't use fertilizer	202	93	295	16.8%	11.7%	14.8%
Missing	24	14	38	2.0%	1.8%	1.9%
Total	1,203	793	1,996	100%	100%	100%

Q7. Approximately how much do you spend per year, in total, on fertilizer and chemicals for your lawn? (If a professional company applies these for you, please include the fertilizer and lawn chemical portion of your bill).

How much spent	Frequency			Percent		
	CT	NY	All	CT	NY	All
$0	418	201	619	34.7%	25.3%	31.0%
$0-100	256	153	409	21.3%	19.3%	20.5%
$100-200	102	90	192	8.5%	11.3%	9.6%
$200-500	128	75	203	10.6%	9.5%	10.2%
> $500	105	57	162	8.7%	7.2%	8.1%
Missing	194	217	411	16.1%	27.4%	20.6%
Total	1,203	793	1,996	100%	100%	100%

Q8a. Is your property part of one of the following?

Affiliation	Frequency			Percent		
	CT	NY	All	CT	NY	All
Homeowners Association	26	34	60	2.2%	4.3%	3.0%
Neighborhood Association	66	64	130	5.5%	8.1%	6.5%
Both	10	9	19	0.8%	1.1%	1.0%
Neither	1,065	662	1,727	88.5%	83.5%	86.5%
I don't know	8	8	16	0.7%	1.0%	0.8%
Missing	28	16	44	2.3%	2.0%	2.2%
Total	1,203	793	1,996	100%	100%	100%

Q8b. Are you subject to homeowners association or other rules that specifically address the appearance or care of your lawn? (Note: Only those who choose HOA, NA, or both in Q8a will answer Q8b)

Answer	Frequency			Percent		
	CT	NY	All	CT	NY	All
Yes	21	27	48	20.6%	25.2%	23.0%
No	76	72	148	74.5%	67.3%	70.8%
I don't know	5	8	13	4.9%	7.5%	6.2%
Total	102	107	209	100%	100%	100%

Q9. How would you rate the water quality in Long Island Sound?

Water quality	Frequency			Percent		
	CT	NY	All	CT	NY	All
Excellent	32	45	77	2.7%	5.7%	3.9%
Good	379	236	615	31.5%	29.8%	30.8%
Fair	376	200	576	31.3%	25.2%	28.9%
Poor	93	63	156	7.7%	7.9%	7.8%
I don't know	296	235	531	24.6%	29.6%	26.6%
Missing	27	14	41	2.2%	1.8%	2.1%
Total	1,203	793	1,996	100%	100%	100%

Q10a. In your opinion, how safe are the following water-related activities from a health perspective?

All Sample

Activity	Very Unsafe	Somewhat Unsafe	Somewhat Safe	Very Safe	I don't know	Missing
Swimming	37	166	813	582	354	44
Eating fish and shellfish	93	260	783	367	441	52

Activity	Very Unsafe	Somewhat Unsafe	Somewhat Safe	Very Safe	I don't know	Missing
Swimming	1.9%	8.3%	40.7%	29.2%	17.7%	2.2%
Eating fish and shellfish	4.7%	13.0%	39.2%	18.4%	22.1%	2.6%

CT Only

Activity	Very Unsafe	Somewhat Unsafe	Somewhat Safe	Very Safe	I don't know	Missing
Swimming	23	99	520	345	188	28
Eating fish and shellfish	58	158	486	225	243	33

Activity	Very Unsafe	Somewhat Unsafe	Somewhat Safe	Very Safe	I don't know	Missing
Swimming	1.9%	8.2%	43.2%	28.7%	15.6%	2.3%
Eating fish and shellfish	4.8%	13.1%	40.4%	18.7%	20.2%	2.7%

NY Only

Activity	Very Unsafe	Somewhat Unsafe	Somewhat Safe	Very Safe	I don't know	Missing
Swimming	14	67	293	237	166	16
Eating fish and shellfish	35	102	297	142	198	19

Activity	Very Unsafe	Somewhat Unsafe	Somewhat Safe	Very Safe	I don't know	Missing
Swimming	1.8%	8.4%	36.9%	29.9%	20.9%	2.0%
Eating fish and shellfish	4.4%	12.9%	37.5%	17.9%	25.0%	2.4%

Q10b. Do you think there is anything that you do now as part of your everyday behavior that worsens the quality of water in the Long Island Sound?

Answer	Frequency			Percent		
	CT	NY	All	CT	NY	All
Yes	168	145	313	14.0%	18.3%	15.7%
No	736	440	1,176	61.2%	55.5%	58.9%
I don't know	271	192	463	22.5%	24.2%	23.2%
Missing	28	16	44	2.3%	2.0%	2.2%
Total	1,203	793	1,996	100%	100%	100%

Q12.1b Which of the following do you currently have on your property? Please select all that apply.

Answer	Frequency			Percent		
	CT	NY	All	CT	NY	All
Flower garden	404	272	676	71.4%	67.5%	69.8%
Vegetable garden	223	148	371	39.4%	36.7%	38.3%
Area of native or tall grass	157	99	256	27.7%	24.6%	26.4%
Area with bushes or shrubs	452	337	789	79.9%	83.6%	81.4%
Forested or wooded area	322	145	467	56.9%	36.0%	48.2%
Conservation landscaping	85	63	148	15.0%	15.6%	15.3%
Rain garden	37	35	72	6.5%	8.7%	7.4%
Wetland or march	97	27	124	17.1%	6.7%	12.8%
Other	96	72	168	17.0%	17.9%	17.3%
Missing	35	26	61	6.2%	6.5%	6.3%

Note: The sum of frequencies exceeds the number of total observations for all sample (N=969), CT only (N=566), and NY only (N=403) since this is a multiple-choice question. The number of total observations is used as the denominator to calculate the percentage.

Q17a. Last summer (between Memorial Day and Labor Day 2020), did you visit Long Island Sound for recreation on or near the water?

Answer	Frequency			Percent		
	CT	NY	All	CT	NY	All
Yes	385	183	568	60.4%	46.9%	55.3%
No	191	163	354	30.0%	41.8%	34.5%
I am not sure	6	6	12	0.9%	1.5%	1.2%
Missing	55	38	93	8.6%	9.7%	9.1%
Total	637	390	1,027	100%	100%	100%

Q17e. What recreational activity was the most common purpose of your trips to the area you visited most often? (Note: Only those who choose yes in Q17a will answer Q17e)

Recreational activity	Frequency			Percent		
	CT	NY	All	CT	NY	All
Swimming	44	19	63	11.4%	10.4%	11.1%
Visiting the beach	96	52	148	24.9%	28.4%	26.1%
Picnicking	6	2	8	1.6%	1.1%	1.4%
General sightseeing	29	14	43	7.5%	7.7%	7.6%
Boating, sailing, kayaking, canoeing	64	26	90	16.6%	14.2%	15.8%
Hiking or walking	102	50	152	26.5%	27.3%	26.8%
Fishing or shell fishing	19	11	30	4.9%	6.0%	5.3%
Other	17	6	23	4.4%	3.3%	4.0%
Missing	8	3	11	2.1%	1.6%	1.9%
Total	385	183	568	100%	100%	100%

Household Demographics: Due to the purposeful screening of survey respondents to include only single-family homeowners in particular areas, the demographic characteristics of the sample are not expected to match those of the general population in Connecticut or New York. In addition, respondent characteristics are typically influenced by factors such as the survey mode (here, push-to-web), the language in which the survey is administered (here, only English).

Q20a. What is your gender?

Gender	Frequency			Percent		
	CT	NY	All	CT	NY	All
Female	376	236	612	31.3%	29.8%	30.7%
Male	677	454	1,131	56.3%	57.3%	56.7%
Other	7	3	10	0.6%	0.4%	0.5%
Missing (only this variable)	0	3	3	0%	0.4%	0.2%
Missing (all seven demographic variables)	143	97	240	11.9%	12.2%	12.0%
Total	1,203	793	1,996	100%	100%	100%

Q20b. What is your age?

Age	Frequency			Percent		
	CT	NY	All	CT	NY	All
< 40	124	54	178	10.3%	6.8%	8.9%
40 – 60	404	282	686	33.6%	35.6%	34.4%
60 – 80	497	320	817	41.3%	40.4%	40.9%
> 80	25	27	52	2.1%	3.4%	2.6%
Missing (only this variable)	10	13	23	0.8%	1.6%	1.2%
Missing (all seven demographic variables)	143	97	240	11.9%	12.2%	12.0%
Total	1,203	793	1,996	100%	100%	100%

Q20c. How many people live in your home including yourself?

Household size	Frequency			Percent		
	CT	NY	All	CT	NY	All
1	141	56	197	11.7%	7.1%	9.9%
2	489	290	779	40.6%	36.6%	39.0%
3	172	127	299	14.3%	16.0%	15.0%
4	176	136	312	14.6%	17.2%	15.6%
>= 5	76	74	150	6.3%	9.3%	7.5%
Missing (only this variable)	6	13	19	0.5%	1.6%	1.0%
Missing (all seven demographic variables)	143	97	240	11.9%	12.2%	12.0%
Total	1,203	793	1,996	100%	100%	100%

Q20d. How many children under the age of 18 live in your home? Please provide an answer for each age category.

All Sample

Number of children	0-5 years	6-12 years	Above 12 years	0 – 18 years
0	1,357	1,293	1,176	1,148
1	76	127	217	154
2	48	61	132	177
3	6	14	31	53
4	0	1	14	28
>= 5	1	1	8	23
Missing (only this variable)	268	259	178	173
Missing (all seven demographic variables)	240	240	240	240
Total	1,996	1,996	1,996	1,996

Number of children	0-5 years	6-12 years	Above 12 years	0 – 18 years
0	68.0%	64.8%	58.9%	57.5%
1	3.8%	6.4%	10.9%	7.7%
2	2.4%	3.1%	6.6%	8.9%
3	0.3%	0.7%	1.6%	2.7%
4	0.0%	0.1%	0.7%	1.3%
>= 5	0.1%	0.1%	0.4%	1.2%
Missing (only this variable)	13.4%	13.0%	8.9%	8.7%
Missing (all seven demographic variables)	12.0%	12.0%	12.0%	12.0%
Total	100%	100%	100%	100%

CT Only

Number of children	0-5 years	6-12 years	Above 12 years	0 – 18 years
0	834	808	742	719
1	51	74	116	91
2	33	40	69	108
3	4	9	15	28
4	0	1	8	18
>= 5	1	1	4	16
Missing (only this variable)	137	127	106	80
Missing (all seven demographic variables)	143	143	143	143
Total	1,203	1,203	1,203	1,203

Number of children	0-5 years	6-12 years	Above 12 years	0 – 18 years
0	69.3%	67.2%	61.7%	59.8%
1	4.2%	6.2%	9.6%	7.6%
2	2.7%	3.3%	5.7%	9.0%
3	0.3%	0.7%	1.2%	2.3%
4	0.0%	0.1%	0.7%	1.5%
>= 5	0.1%	0.1%	0.3%	1.3%
Missing (only this variable)	11.4%	10.6%	8.8%	6.7%
Missing (all seven demographic variables)	11.9%	11.9%	11.9%	11.9%
Total	100%	100%	100%	100%

NY Only

Number of children	0-5 years	6-12 years	Above 12 years	0 – 18 years
0	523	485	434	429
1	25	53	101	63
2	15	21	63	69
3	2	5	16	25
4	0	0	6	10
>= 5	0	0	4	7
Missing (only this variable)	131	132	72	93
Missing (all seven demographic variables)	97	97	97	97
Total	793	793	793	793

Number of children	0-5 years	6-12 years	Above 12 years	0 – 18 years
0	69.3%	67.2%	61.7%	54.1%
1	4.2%	6.2%	9.6%	7.9%
2	2.7%	3.3%	5.7%	8.7%
3	0.3%	0.7%	1.2%	3.2%
4	0.0%	0.1%	0.7%	1.3%
>= 5	0.1%	0.1%	0.3%	0.9%
Missing (only this variable)	16.5%	16.5%	9.1%	11.7%
Missing (all seven demographic variables)	12.2%	12.2%	12.2%	12.2%
Total	100%	100%	100%	100%

Q20e. In 2019, what was your total gross household income?

Household income	Frequency			Percent		
	CT	NY	All	CT	NY	All
$0 - $9,999	5	6	11	0.4%	0.8%	0.6%
$10,000 - $14,999	3	0	3	0.2%	0%	0.2%
$15,000 - $19,999	8	4	12	0.7%	0.5%	0.6%
$20,000 - $29,999	8	7	15	0.7%	0.9%	0.8%
$30,000 - $39,999	21	5	26	1.7%	0.6%	1.3%
$40,000 - $49,999	27	12	39	2.2%	1.5%	2.0%
$50,000 - $59,999	36	11	47	3.0%	1.4%	2.4%
$60,000 - $79,999	103	38	141	8.6%	4.8%	7.1%
$80,000 - $99,999	87	38	125	7.2%	4.8%	6.3%
$100,000 - $119,999	99	46	145	8.2%	5.8%	7.3%
$120,000 - $139,999	71	40	111	5.9%	5.0%	5.6%
$140,000 - $159,999	77	61	138	6.4%	7.7%	6.9%
$160,000 - $179,999	46	32	78	3.8%	4.0%	3.9%
$180,000 - $199,999	44	22	66	3.7%	2.8%	3.3%
$200,000 - $249,999	73	59	132	6.1%	7.4%	6.6%
$250,000 - $299,999	34	31	65	2.8%	3.9%	3.3%
$300,000 or more	70	82	152	5.8%	10.3%	7.6%
I'd rather not answer (or missing)	12	40	52	1.0%	5.0%	2.6%
Missing (all seven demographic variables)	143	97	240	11.9%	12.2%	12.0%
Total	1,203	793	1,996	100%	100%	100%

Q20f. What is the highest degree or level of school you have completed?

Education	Frequency			Percent		
	CT	NY	All	CT	NY	All
Elementary or high school	6	2	8	0.5%	0.3%	0.4%
High school diploma	48	27	75	4.0%	3.4%	3.8%
GED or other high school completion	5	3	8	0.4%	0.4%	0.4%
Some college	121	45	166	10.1%	5.7%	8.3%
Associate's or other two-year college degree	63	34	97	5.2%	4.3%	4.9%
Bachelor's or other four-year college degree	334	209	543	27.8%	26.4%	27.2%
Master's degree, professional degree, or doctorate degree	466	361	827	38.7%	45.5%	41.4%
Missing (only this variable)	17	15	32	1.4%	1.9%	1.6%
Missing (all seven demographic variables)	143	97	240	11.9%	12.2%	12.0%
Total	1,203	793	1,996	100%	100%	100%

Objective 7. Extend results in tandem with Long Island Sound Study (LISS) Public Involvement and Education and coordinate with stakeholders to explore implications for changes in local and regional lawn care behaviors.

The team engaged in a sequence of meetings, workshops and other events to explore project results in coordination with stakeholders and consider implications for changes in local and regional lawn care behaviors. Many of these events involved LISS Public Involvement and Education, including project partner Judy Preston from the University of Connecticut and Robert Burg, the LIS Study Communications Coordinator, among others. Based on these interactions, subsequent activities are underway (or have been planned) to apply and extend project results beyond the life of the funded grant, in partnership with end-users. Among engagement events that took place during the grant, the team convened LISS stakeholders and partners in June 2020 and September 2021 in virtual workshops to present and discuss interim project results. Results were presented to the LISS Science and Technical Advisory Committee during November 2021. On May 12, 2022, project results (and implications for on-the-ground actions to reduce nitrogen loading) were discussed at a webinar hosted by the Long Island Sound Coastal Watershed Network, entitled *"Local Actions to Tackle Nitrogen Pollution."* Results were also presented to scientists and stakeholders in *"Residential Lawn Fertilizer Use and Nitrogen Loading Intensity Across the Long Island Sound Watershed,"* as part of the 2022 Long Island Sound Research Conference (May 18).

In addition to these large-group meetings and presentations, multiple small-group engagements were held with individual end-user groups. These included a virtual meeting with a group (coordinated by Janet Barclay of the U.S. Geological Survey, New England Water Science Center) developing a model of groundwater flow and nitrogen transport for Long Island, to discuss the potential of coordinating our project's social science modeling (e.g., to predict fertilizer application across the watershed) with efforts to model nitrogen transport. Similar meetings were held with Jamie Vaudrey from the University of Connecticut. Multiple additional hollow-up meetings were held with representatives of the New York Department of Environmental Conservation (Susan Van Patten, Michele Golden) to discuss the application of model predictions to understand nitrogen loading due to lawn fertilizer, along with implications for behavior-change campaigns.

Beyond the meetings and presentation described above, development of project methods relied upon engagement and interactions with Long Island Sound Study staff, agency and other stakeholder representatives. The project plan was developed with input from Long Island Sound Study staff such as Mark Tedesco, EPA Long Island Sound Office Director; James Ammerman, Long Island Sound Science Coordinator; and Robert Burg, Long Island Sound Study Communications Coordinator. Judy Preston was a partner on the project and solicited additional feedback and input from stakeholders and agency staff across the watershed. Additional input during the project was obtained from groups including the Nature Conservancy in Connecticut (via Adam Whelchel, Director of Science, and Holly Drinkuth, Director of Outreach and Watershed Projects). These and other engagements led the team to develop a follow-up proposal that was just submitted to the 2023-2025 Long Island Sound Study Research Program, in coordination with partners from the University of Connecticut (e.g., Jamie Vaudrey, David Dickson), the University of Maryland (Dave Newburn) and the University of Miami (Haoluan Wang). Details are presented below, under section C4.

C2. Scientific Abstract

This project developed social science models to explain and predict lawn and landscape practices among homeowners across selected New York and Connecticut portions of the LIS watershed. Among other objectives, the project developed a statistical model, grounded in large-sample, mixed-mode survey data, to explain variations in lawn care practices across the watershed and inform approaches to improve outcomes such as nitrogen export and stormwater runoff. Survey data was validated using biophysical measures of lawn greenness and foliar nitrogen content. The project also updated selected components of the 2006 Public Perception Survey. Results are drawn from a survey of single-family homeowners within (a) the four Connecticut coastal counties and (b) municipalities of Westchester, Nassau and Suffolk Counties (New York) that overlap the watershed. The questionnaire was developed over a two-year process in coordination with stakeholders and partners of the Long Island Sound Study, with input from focus groups with watershed residents and pilot tests. The push-to-web questionnaire was implemented in 2021, with an initial mailing and follow-up reminders. Of 30,000 mailed invitations, 2,013 total responses were obtained, with 1,996 providing sufficient data for analysis. A second-wave of implementation in 2022 yielded an additional 331 responses, for a total of 2,344 survey returns (7.8% response rate).

Using survey and parcel data, a two-stage regression model was estimated to characterize effects of household and parcel characteristics on fertilizer applications during the prior twelve months. Integration of these results with parcel data allows applications to be predicted across the domain, for single-family residential parcels. Further integration of an estimate of mean nitrogen deposition per application produces estimates of predicted nitrogen (N)-loading intensity due to residential fertilizer use, which are then mapped across sub-embayment watersheds. Large variations in predicted N-loading intensity across sub-watersheds suggests the benefit of targeted interventions that focus on particular areas for residential fertilizer-reduction, rather than broadly focused programs that may cover areas where fertilizer use is already low.

Survey data also enabled the estimation of discrete choice, random utility models that predict the extent to which households would support different types of actions to reduce fertilizer use across the watershed, and how households would react to different types of cost-share programs that incentivize landscape best management practices (such as conservation landscaping and rain gardens). Among other key results, these models show that a majority of watershed households would support programs that impose modest restrictions on household fertilizer in exchange for measurable improvements in LIS water quality. Models of households' predicted enrollment in cost-share programs for conservation landscaping and rain gardens suggest that the greatest barriers to enrollment in these programs include the difficulty of site plans and application paperwork, along with common requirements to make up-front payments before cost-share payments are received. Finally, combined analysis of households' reported fertilizer application behavior with observed biophysical measures of lawn greenness and foliar nitrogen content (for a subsample of survey respondents) reveals significant relationships between these variables—for example households' reported fertilizer use is strongly correlated with foliar nitrogen content. These validation results demonstrate that households' self-reported fertilizer use is related to verifiable lawn conditions.

C3. Problems Encountered

No unanticipated problems were encountered beyond delays and adjustments due to the COVID19 pandemic. For example, due to COVID19 restrictions, no in-person meetings were possible among project team members, requiring a transition to remote meetings held via Zoom. Focus groups also had to occur via Zoom, requiring amended IRB approvals. Household visits to complete the lawn observations were delayed until late spring 2021 due to the pandemic, which restricted the travel of university researchers. Original survey response rates were slightly lower than anticipated after the first three mailings to sampled households, also likely due to the pandemic (e.g., people distracted or under stress and hence less willing to complete surveys). As a result, we sent an additional two reminder letters, which increased response rates as intended. In all cases, the research team was able to adjust methods so that objectives could be met.

C4. New Research Directions

Engagement with stakeholders and partners throughout the project led the team to develop a follow-up proposal that was just submitted to the 2023-2025 Long Island Sound Study Research Program, in coordination the University of Connecticut (e.g., Jamie Vaudrey, David Dickson), the University of Maryland (Dave Newburn) and the University of Miami (Haoluan Wang). This new, proposed project will (if funded) develop an integrated targeting model and tool for Long Island Sound (LIS) to inform/support behavior-change campaigns for residential fertilizer use, by predicting the effects of prospective behavior changes on nitrogen (N) loads to LIS waters. This proposed project was designed at the direct request of end users. Upon seeing fertilizer-use predictions from this project (presented in the meetings and workshops discussed above) these end-user groups asked whether predictions of this type could be linked with updated N-loading models to characterize effects on N loads to LIS. End users also asked if such an integrated tool could be designed to predict the effects of fertilizer-reduction behavior-change campaigns. This follow-up project has been designed to meet these needs, conditional on a positive funding decision by the LISS. If funded, this new research will provide a heretofore unavailable capacity for end users to target behavior-change campaigns in ways that produce the greatest N-load reductions. The project will thus support efforts to promote sustainable behaviors across the watershed. It builds upon relationships and past work through which the project personnel (e.g., Johnston, Vaudrey, Dickson) and their organizations have engaged with end users to provide science that informs management. It will further capitalize on Vaudrey's position as Research Coordinator for the new CT NERR. End users who have already informed (and will be involved with) the proposed work include public agencies (e.g., NYS DEC/Sue Van Patten; CT DEEP/Kelly Streich) and private organizations (e.g., Citizen's Campaign for the Environment/Adrienne Esposito; The Nature Conservancy/Holly Drinkuth; Save the Sound/Peter Linderoth; others). These and other groups have been involved in discussions around this work and strongly encouraged this proposal.

C5. Interactions

Participation, engagement and interactions with extension staff and agency/stakeholder representatives (among other end-users) are described in detail under Objective 7 above.

C6. Presentations and Publications

The following is a list of presentations and publications from the project.

Presentations (presenting author in bold):

Ryan, C.D., and P.M. Groffman, 2022. A Sociobiogeochemical Approach to Assessing Soil

Nitrogen Content within the Long Island Sound Watershed. ASA, CSSA, SSSA International Annual Meeting, Baltimore, MD. November 8.

Johnston, R.J., D.A. Newburn, H. Wang, T. Ndebele and C. Nolte. 2022. Residential Lawn Fertilizer Use and Nitrogen Loading Intensity Across the Long Island Sound Watershed. Long Island Sound Research Conference, Bridgeport, CT. May 18.

Johnston, R.J., D.A. Newburn, H. Wang, T. Ndebele and C. Nolte. 2022. Residential Lawn Fertilizer Use and Nitrogen Loading Intensity Across the Long Island Sound Watershed. Webinar, Long Island Sound Coastal Watershed Network, Local Actions to Tackle Nitrogen Pollution, May 12.

Johnston, R.J., D. Newburn, C. Polsky, P. Groffman, T. Ndebele, H. Wang, C. Ryan and H. Kim. 2021. Residential Lawn Fertilizer Management in the Long Island Sound Watershed. Long Island Sound Study, Scientific Technical Advisory Committee Meeting. Virtual, November 19.

Johnston, R.J., T. Ndebele, D. Newburn, C. Polsky and P. Groffman. 2020. Eliciting and Modeling Residential Lawn and Landscape Practices Across the Long Island Sound Watershed. Long Island Sound Study Principal Investigators Meeting (virtual). June 22.

Johnston, R.J., T. Ndebele and D.A. Newburn. 2020. Revealed / Stated Preference Survey of Lawn and Landscape Behavior in the Greater Baltimore Area. Invited presentation to US EPA Long Island Sound Study, April 20.

Johnston, R.J., T. Ndebele, D. Newburn, C. Polsky and P. Groffman. 2019. Eliciting and Modeling Residential Lawn and Landscape Practices: Systematic Information to Assess Knowledge, Explicate Behavior and Inform Management across the Long Island Sound Watershed. Long Island Sound Study Principal Investigators Meeting. University of Connecticut, Avery Point, February 21.

Unpublished Technical Reports

Newburn, D.A., R.J. Johnston, H. Wang, T. Ndebele, H, Kim and C. Polsky. 2021. Lawn Care and Fertilizer Use Survey of Long Island Sound Watershed Households: Selected Summary Statistics. Unpublished report, George Perkins Marsh Institute, Clark University. September 9.

Student Papers and Posters

Burt, J. 2022. Joint Modeling of Fertilizer Use and Recreational Demand in the Long Island Sound. Graduate Student Research Poster, Department of Economics, Clark University, Worcester, MA.

D. ACCOMPLISHMENTS

D1. IMPACTS & EFFECTS

As described above, the project produced a new tool that enables direct, parcel-level prediction of fertilizer applications across the study area (see prediction maps presented under Objective 7 above). This model shows profound differences in the amount of fertilizer being applied by households across different areas of the watershed. Predictions from this model have been presented to multiple end-user groups, to help inform actions intended to reduce LIS N loading due to residential fertilizer use. These results have direct implications for the potential impact of behavior-change campaigns and other efforts to reduce residential fertilizer applications. Also as described above, this project made major contributions to scientific knowledge surrounding household preferences and behavior related to lawn care, fertilizer use and public programs. These contributions are currently being developed into formal reports and publications for dissemination to scientific and end-user groups. This project also led to the follow-up project proposal summarized under C4. New Research Directions, developed in partnership with end-users.

D2. Scholar(s) & Student(s)

Scholar(s): No NYSG Scholars are working on this project.

Student(s):

- The project supported a post-doctoral research associate (now research scientist) at Clark University, Tom Ndebele. Dr. Ndebele assisted with the project for the entire duration, from 2019-2022.
- A graduate student from the University of Maryland, Department of Agricultural and Resource Economics (Haoluan Wang) worked on the project as an hourly research assistant, and was supported by the subaward to Florida Atlantic University. He was supported on the project from 2020-22, assisting with survey implementation and data analysis. He graduated from the University of Maryland in May 2022, with a PhD in Agricultural and Resource Economics.
- The project supported 40 hours of work by graduate student Nicholas Milligan at Florida Atlantic University, who assisted with GIS analysis to inform survey sampling. This technical assistance was not part if his degree program.
- A graduate student from the University of Maryland, Hyoseul Kim, contributed to the project during the summer of 2021 but was **not** financially supported by Sea Grant funds. She worked under David Newburn at the University of Maryland and contributed to statistical analysis of the survey data.
- A graduate student from CUNY, Christopher Ryan, worked on the project as a research assistant for Peter Groffman on the field study of lawn conditions and greenness during the entire project duration (2019-2022), but was **not** financially supported by Sea Grant funds. He has not yet graduated.
- A PhD student at Clark University, Ghamz E Ali Siyal, assisted with the project during 2019-20 (helping to develop sampling plans) but was **not** financially supported by Sea Grant funds.
- A PhD student at Clark University, Jordan Burt, assisted with the project as part of her initial dissertation research during 2021-2022, analyzing relationships between recreational visits to LIS and household fertilizer use. Her work was **not** financially supported by Sea Grant funds.

D3. Volunteers

As described above (and in addition to students listed in section D2), the project has relied on the volunteer collaborative support of Professor David Newburn from the University of Maryland and Judy Preston from the University of Connecticut. These experts have not been financially supported by the project. Over the life of the project Professor Newburn volunteered approximately three months of full-time effort to the project. Judy Preston volunteered approximately one week of full-time effort.

D4. Patents

No patents were produced by this project.

D5. Leveraged Funding

No leveraged funding has been obtained as of this completion report. As described under Section C4, we have submitted a proposal for funding to develop an integrated targeting model and tool for Long Island Sound (LIS) to inform/support behavior-change campaigns for residential fertilizer use, by predicting the effects of prospective behavior changes on nitrogen (N) loads to LIS waters.

E. Stakeholder Summary

Non-point sources potentially account for the majority of LIS nitrogen load and lawn fertilizer has been among the most difficult of these sources to reduce. Estimates suggest that most nitrogen in some LIS embayments is linked to lawn fertilizers. While other sources of nitrogen are on a path to meet reduction targets, nitrogen from residential fertilizer applications has remained level or increased. Without action, this problem is likely to worsen. In response, policymakers and stakeholders across the LIS watershed have proposed various types of policies, programs and behavior-change campaigns to promote practices that reduce fertilizer use and problems related to stormwater runoff from residential parcels (which can carry fertilizer into waterways and ultimately to LIS). However, the effect of these efforts depends on human behavior—including who is currently fertilizing and where, and the extent to which watershed residents would support policies and programs to attenuate problems related to residential lawn fertilizer use and stormwater runoff. Prior to this project, there was little systematic information on these household behaviors and preferences, and no model had been developed to predict variations in lawn care practices such as fertilizer use across the watershed.

To address this gap in knowledge and understanding, this project developed social science models to explain and predict lawn and landscape practices among homeowners across selected New York and Connecticut portions of the LIS watershed. Among other objectives, the project developed a predictive statistical model, grounded in large-sample survey data, to explain variations in lawn care practices across the watershed and inform approaches to improve outcomes such as nitrogen export and stormwater runoff. The project was overseen by Clark University in collaboration with City University of New York, Florida Atlantic University, and the University of Maryland. The household survey addressed topics related to single-family homeowners' residential lawn fertilizer decisions in the Connecticut and New York portions of the LIS watershed. The first goal of the survey and data analysis was to understand whether and how often homeowners fertilize their lawn. We identified which types of households have a higher or lower number of lawn fertilizer applications according to demographics, perceptions of water quality in LIS, awareness of recommendations on fertilizer use, and other household factors. The second goal was to predict lawn fertilizer applications for all single-family households across Connecticut and New York portions of the LIS watershed using data obtained from our surveyed sample. This information can provide policymakers and other stakeholders with a better understanding of how residential lawn fertilizer applications differs across space (e.g., different municipalities or neighborhoods), and where these applications are greatest (and lowest). It can also help local governments and outreach professionals target specific groups to reduce lawn fertilizer use and the negative impacts of residential fertilizer on environmental conditions in and around LIS.

Survey data also allowed us to predict whether Connecticut and New York households would support different types of policies and programs to reduce fertilizer use across the watershed, and how households would react to different types of cost-share programs that incentivize landscape best management practices (such as conservation landscaping and rain gardens). Among other key results, these models show that a majority of watershed households would support binding programs that impose some level of restrictions on household fertilizer use in exchange for measurable improvements in LIS water quality. Models of households' predicted enrollment in cost-share programs for conservation landscaping and rain gardens further suggest that the greatest barriers to enrollment in these programs include the difficulty of site plans and application paperwork, along with common requirements to make up-front payments before cost-share payments are received. Results of this type can help develop policies and programs that garner strong support of watershed households, and are hence more likely to succeed.

Finally, our combined analysis of households' reported fertilizer application behavior with observed biophysical measures of lawn greenness and foliar nitrogen content (for a subsample of our survey respondents) shows strong relationships between these variables. For example, households' reported fertilizer use is strongly correlated with foliar nitrogen content and lawn conditions. These results help to validate our survey results—showing that the behaviors reported by households in the survey (e.g., how much fertilizer they report using) are strongly correlated to objective lawn conditions that can be observed and verified by researchers.

F. PICTORIAL

Key graphics developed by the project (e.g., fertilizer prediction maps) are presented in the main body of the report above.