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Impacts of Extension Education on Improving Residential Stormwater Quality: Monitoring Results

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Impacts of Extension Education on Improving Residential Stormwater Quality: Monitoring Results

Abstract
The project reported in this article evaluated whether stormwater quality could be improved by educating homeowners and implementing best management practices in a suburban neighborhood. Nitrogen, phosphorus, and bacteria levels from two watersheds were compared using the paired watershed approach. Resident surveys, property site assessments, soil tests, and water quality and quantity monitoring were conducted. A X^2-analysis of survey data indicated no significant changes in measured behavior. Significant (p=0.01) reductions in NO_3-N and fecal coliform bacteria concentrations occurred; however, total nitrogen concentrations did not change significantly.

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Introduction

Nonpoint sources contribute nutrients, bacteria, and other contaminants to receiving water bodies (Chesters & Schierow, 1985). In Connecticut, both the Branford River and Branford Harbor in Long Island Sound are impaired due to low dissolved oxygen and eutrophication caused by excess nitrogen from stormflow (CT DEP, 1998). In addition, high bacteria levels have caused beach and shellfish bed closures on the Branford River and Branford Harbor.

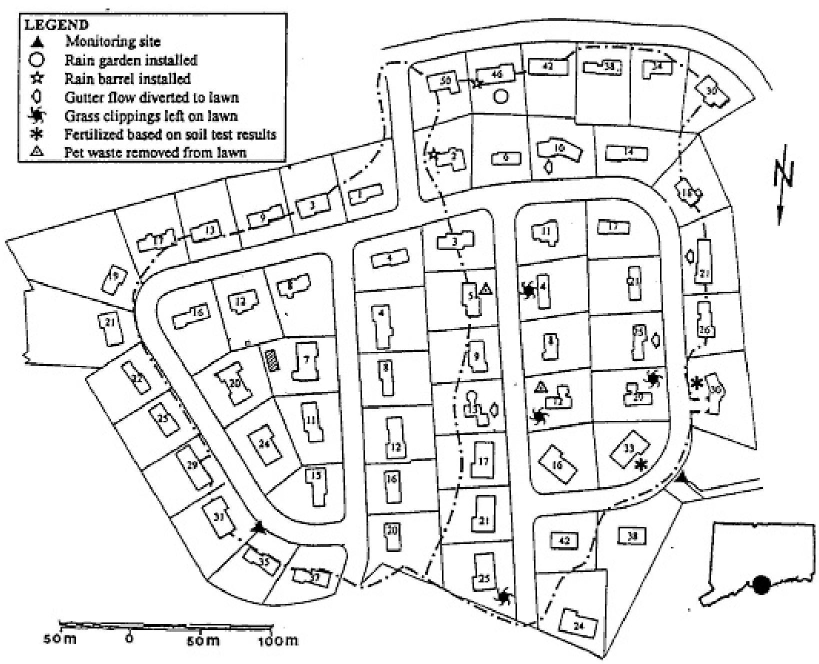
Education is one tool available to foster adoption of best management practices (BMPs) in residential neighborhoods. The role of education in changing the actions of homeowners with respect to nonpoint source pollution has been researched in one study. Swann (2000) found that media campaigns and intensive training seemed to be the most effective method of producing change, with up to a 50% change in the use of BMPs. Other methods such as community newsletters, demonstration projects, and use of the Internet were not as effective as media campaigns and intensive education. However, the ultimate evaluation of nonpoint source education is an improvement in water quality, and education programs typically stop short of measuring a water quality response.

The objective of the project reported here was to determine if the quality of runoff from a suburban neighborhood would improve as a result of educating homeowners about residential BMPs. This project involved a collaboration of Extension educators and university researchers. Pollutants considered for this study were nitrate+nitrite-N (NO_3-N), ammonia-N (NH_3-N), total Kjeldahl-N (TKN), total nitrogen (TN), total phosphorus (TP), and fecal coliform bacteria.

Study Area

The project area was a residential neighborhood located near Long Island Sound in the town of Branford, CT. Two adjacent watersheds were studied (Figure 1). The control watershed was 5.4 ha in area and contained 22 homes, with an average lot size of 0.25 ha. The treatment watershed was 6.1 ha in size, and contained 34 homes, with an average lot size of 0.21 ha. Impervious area was 23% for both watersheds. Eight lots had property in both watersheds. These homes received the same treatment as the homes in the treatment watershed. Two new homes (numbers 20 and 37) were constructed in the control watershed during the study.

Figure 1.
Study of Residential Neighborhoods in Branford, CT. Dashed lines represent watershed boundaries. Numbers represent street numbers. Triangles represent monitoring stations. Other symbols represent changes made after treatment.



Methods

The study design used was the paired watershed approach (Clausen & Spooner, 1993), using one control and one treatment watershed. The control watershed accounts for year-to-year differences such as climate. During the calibration period, no education was performed, and no BMPs were implemented. The purpose of the calibration period was to develop significant regressions between paired observations from both watersheds for the constituents measured. Water quality monitoring began in May 1998, and water quantity monitoring was added in November 1999. The treatment period began with the education of residents in July 2000. The calibration period was 25 months, and the treatment period was 13 months.

Education

A "train the trainer" approach was used to educate volunteers who instructed homeowners. Beginning in 1998, members of the University of Connecticut Departments of Cooperative Extension, Plant Science, and Natural Resource Management and Engineering provided a series of eight evening seminars.

The goal of the seminars was to educate project volunteers and other members of the community on how to properly evaluate home sites, care for lawns, collect soil samples, and educate homeowners. Volunteers learned how to identify structural features of lots and management practices of homeowners that contribute to nonpoint source pollution.

Trained volunteers then performed site assessments similar to Andrews, et al. (1997) on 24 lots in the treatment watershed. A soil test was also performed on each lawn in the treatment watershed. Volunteers recommended changes in homeowner practices based on information collected and reviewed by extension personnel. The recommendations focused on the following:

1. Redirecting runoff from impervious areas to pervious surfaces,
2. Applying fertilizer based on soil test results,
3. Leaving grass clippings on the lawn to reduce nitrogen input, and

4. Disposing pet waste to reduce sources of bacteria.

Several structural modifications were made in the treatment watershed. In November 2000, gutter downspouts were diverted on four houses so that roof runoff drained to the lawn and not on the driveway. In April 2001, a rain barrel and a rain garden were installed at one house. In May 2001, a rain barrel was installed at another house.

Survey

A resident survey was designed to collect data on homeowner management practices during the calibration and treatment periods (Jonna Kulokowich, personal communication, 1999). The survey consisted of questions regarding lawn care practices such as watering and fertilization, car washing, leaf disposal, and pet waste management. Residents of the treatment watershed received the survey by mail in March 1998.

A follow-up survey was given to residents of the treatment watershed in 2001. The results from the follow-up survey were compared to the results from the initial survey using contingency analysis and the X^2 statistic to determine if there was a significant change in surveyed behavior as a result of education.

Water Monitoring

Water monitoring sites were located where concrete stormwater pipes from each watershed discharged into small brooks. Stage data was recorded at each site by a solar/battery powered CR-10 datalogger and pressure transducer. Samples were analyzed for nitrate+nitrite-N (NO_3-N), ammonia-N (NH_3-N), total Kjeldahl-N (TKN), and total phosphorus (TP) on a Lachat colorimetric flow injection system using EPA approved methods (USEPA, 1983). Total nitrogen (TN) concentrations were calculated by adding TKN and NO_3-N concentrations. Grab samples were also obtained for 29 runoff events and were analyzed at an independent laboratory for fecal coliform bacteria.

All statistical analyses were performed using SAS Version 8.2 software (SAS Institute, Inc., 2001). Because most of the water quality data were found to be log-normally distributed, log-transformed data were used for statistical analysis. Mass export was calculated on an event basis by multiplying flow by concentration from the sample that represented that event. Regressions were performed on paired nutrient and bacteria concentration data, nutrient export data, and flow data for the calibration and treatment periods. The slopes and intercepts of the two regressions were compared using ANCOVA. Calibration regressions were used to predict treatment observations based on control observations during the treatment period. Treatment watershed predicted values were then compared to observed data and a percent change was calculated.

Results and Discussion

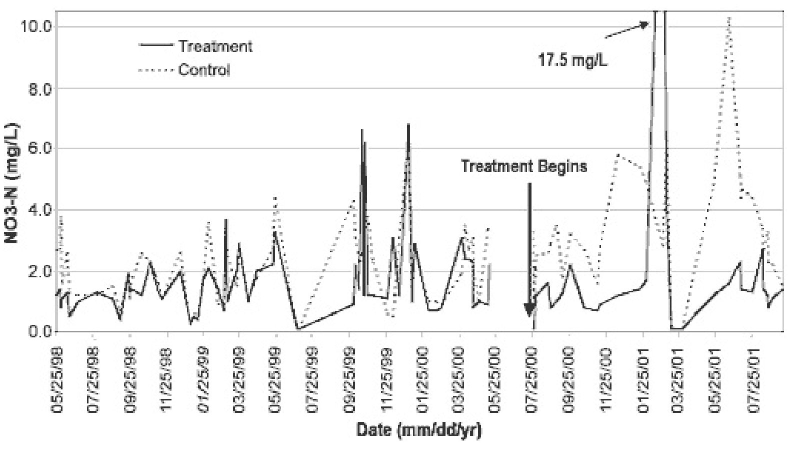
Stormflow

No significant change in event stormflow was found between calibration and treatment periods.

Nitrogen and Phosphorus

The concentration of NO_3-N in stormwater runoff significantly ($p=0.001$) decreased by 60% in the treatment watershed following education (Figure 2). This was observed as a change in intercepts for the calibration and treatment regressions for the paired NO_3-N samples (Figure 3). The percent change was based on the difference between predicted values using the calibration regression equations and observed values for the treatment watershed (Table 1). Concentrations of NH_3-N, TKN, TN, and TP in runoff were not significantly different due to the treatment.

Figure 2.
Stormflow Concentrations of NO_3-N from the Control and Treatment Watersheds in Branford, CT



Results from the Nationwide Urban Runoff Program (NURP) indicated that event mean concentrations in runoff from residential areas were 0.736 mg/L for NO_3-N, 1.9 mg/L for TKN, and 0.383 mg/L for TP (EPA, 1983b). The mean stormwater concentrations for both the control and treatment watersheds during the calibration and treatment periods were slightly higher than the NURP mean for NO_3-N, and slightly lower than the NURP mean for TKN. TP means for this study were lower than the NURP mean of 0.383 mg/L (Table 1).

Figure 3.
Calibration and Treatment Period Regressions Between Stormflow Concentrations of NO_3-N from the Control and Treatment Watersheds in Branford, CT (*** =significant to p=0.001)

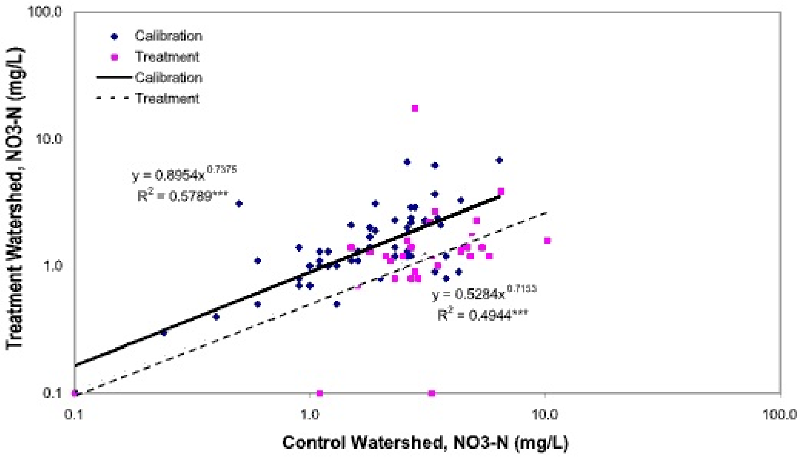


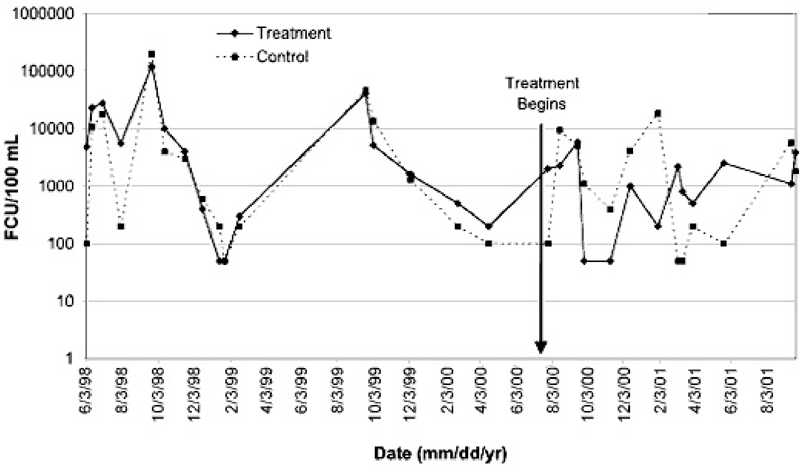
Table 1.
Summary of Means and Percent Change for Flow, Bacteria and Nutrient Concentrations for the Control and Treatment Watersheds During the Calibration and Treatment Periods in Branford, CT

	Calibration Period		Treatment Period			
				Treatment		
	Control	Treatment	Control	Observed	Predicted	% Change
	-------------- (m^3/week) ---------------					
Stormflow	1234.4	512.5	1437.8	363.2	480.7	-32
n	32		12			
	-------------- (FCU/100 mL) --------------					
Fecal Coliform Bacteria	1285	1868	875	1079	1356	-26**
n	17		10			
	------------------- (mg/L) -----------------					
NO_3-N	1.6	1.3	2.3	1.0	1.6	-60***
NH_3-N	0.09	0.18	0.19	0.38	0.22	42
TKN	0.6	1.1	1.3	2	1.9	5
TN	2.7	3.1	4.2	3.4	4.2	-24
TP	0.073	0.117	0.106	0.201	0.148	36
n	63		32			
** P value=0.01 *** P value=0.001						

Bacteria

During the calibration period, bacteria concentrations in both watersheds were similar. However, after treatment, bacteria concentrations in stormwater from the treatment watershed decreased (Figure 4). Using ANCOVA, a significant (F=20.06, p=0.01) change in regression slopes was detected. This change represented a 26% reduction in bacteria levels in stormwater runoff (Table 1). The reduction occurred mostly for high concentrations.

Figure 4.
Stormflow Concentrations of Fecal Coliform Bacteria from the Control and Treatment Watersheds in Branford, CT



Export

None of the regressions for nutrient export were found to be significant. For the treatment regressions, this may have been due to the fact that only eight-paired export values existed. More samples are needed to evaluate nutrient export during the treatment period.

Survey Results

The initial survey was distributed to a total of 61 property owners in both the control and treatment watersheds. Of the 61 receiving the initial survey, 72% completed and returned it. Responses are analyzed based on a nominal scale, according to the classification in Davis (1971). Responses for the survey question regarding fertilization were grouped according to those who fertilized less than four times per year and those who fertilized four or more times per year. The survey question asked how many times per year they fertilized their lawn. This grouping was done to minimize low observed cell frequencies and to simplify presentation of results. Responses to the survey can be seen in Table 2.

Table 2.
Numbers and Percent of Homeowners Responding to Surveys, Calibration, and Treatment Periods, by Question

	Control and Treatment Watersheds	Treatment Watersheds			
	Calibration	**Calibration**	**Treatment**	X^2	**P value**
Fertilize lawn	35 (74%)	22 (76%)	19 (86%)	0.875	0.350
Fertilize less than 4 times per year	26 (74%)	14 (64%)	12 (63%)	0.001	0.975
Fertilize 4 or more times per year	9 (26%)	8 (36%)	7 (37%)		
Use a professional service for fertilization	16 (47%)	12 (55%)	6 (32%)	3.849	0.146
Fertilize based on bag instructions	17 (50%)	10 (45%)	11 (58%)		
Fertilize based on soil test results	1 (3%)	0	2 (11%)		
Remove pet waste from lawn	13 (76%)	13 (76%)	7 (88%)	0.414	0.520
Leave clippings on lawn	30 (65%)	18 (62%)	18 (82%)	2.350	0.125
Water lawn	33 (69%)	24 (80%)	16 (73%)	0.378	0.539

Bracketed groupings represent responses to individual questions and the corresponding calculated X^2 statistic. A p-value of 0.05 or less would indicate that the response rate was significantly different for that question from the initial survey to the follow-up survey, for treatment watershed residents. Analysis of the survey results indicated that no significant changes in measured behavior occurred (Table 2).

The four residents who made changes in their lawn care fertilization practices all live close to the monitoring station in the watershed (Figure 1). It is possible that the impact of their change was greater due to the proximity of their property to the station, even though no significant behavior differences were detected by X^2-analysis watershed-wide. It is also possible that other residents made subtle changes that were not reported on the survey. Part of the education included general housekeeping practices such as the impacts of over-spreading fertilizer on impervious areas.

Conclusions

Intensive education efforts appeared to produce a relatively small change in measured behavior in the first 13 months following treatment. However, bacteria counts in the treatment watershed decreased. Although there was a significant reduction in NO_3-N concentrations, TN concentrations did not significantly change due to treatment. Continued monitoring of water quality and quantity may show changes in nutrient concentrations or in runoff exports; however, at this time the only significant changes due to treatment was a reduction in bacteria counts and NO_3-N concentrations.

Future research might include more detailed survey questions, such as type of fertilizer used (organic vs. inorganic), amount of lime applied to lawns, and whether fertilizer was overspread on impervious areas. Also, the effectiveness of other innovative education methods could be researched. For example, an educational seminar or picnic could be held for residents, and BMPs such as a mulching lawn mower or rain barrels could be raffled off to those in attendance.

Acknowledgements

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