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Education and Changes in Residential Nonpoint Source Pollution

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ABSTRACT / Urban areas contribute pollutants such as excess nitrogen and bacteria to receiving water bodies. The objective of this project was to determine if stormwater quality could be improved by educating homeowners and implementing best management practices (BMPs) in a suburban neighborhood. The paired watershed design was used, where a control and treatment watershed are monitored during a calibration and treatment period. Treatment consisted of the education of homeowners and structural changes designed to minimize nonpoint pollution. Some changes in measured behavior were reported. According to the treatment period survey, 11% of respondents in the treatment watershed began fertilizing their lawn based on the results of a soil test, whereas none had done so previously. In addition, 82% of respondents in the treatment watershed stated that they left clippings on the lawn compared to 62% from the initial survey. Twelve of 34 lots (35%) adopted some BMPs following education efforts, indicating a significant (P = 0.001) increase in BMP use overall. However, a χ^2 analysis of survey data indicated no significant changes in measured behavior with regard to specific questions. Analysis of covariance (ANCOVA) results indicated that a 75% reduction in nitrite + nitrate - N (change in intercept, P = 0.001) and a 127% reduction in fecal coliform bacteria (change in slope, P = 0.05) concentrations occurred. However, the treatment period regression was nonsignificant for bacteria. Total nitrogen, total phosphorus, and ammonia-N concentrations did not change significantly. Intensive education efforts produced BMP implementation and measurable water quality improvements.

Urban areas have been recognized as major contributors to nonpoint source pollution (USEPA 2002). Structural best management practices (BMPs) have been the primary method to treat stormwater runoff at the "end of the pipe," but their effectiveness varies and they can be expensive to install (Urbonas 1994). More recently, pollution prevention has been advocated as an alternative to structural solutions. For example, BMPs might be distributed throughout watersheds to minimize discharge and encourage infiltration and treatment (Prince George's County 1999). Furthermore, urban watersheds have been found to contain "hot spots" of nonpoint source pollution. For instance, residential driveways and lawns have been identified as primary sources of fecal coliform bacteria in stormwater runoff (Bannerman and others 1993). Improperly managed lawns might also contribute to excess nitrogen in stormwater runoff (Morton and others 1988). Such hot spots might serve as priority areas for pollution prevention. Although alternatives to the traditional high-input lawn such as the "Freedom Lawn" (Bormann and others 2001) are gaining popularity, most homeowners are unaware of the negative impacts of their lawn care practices on water quality. Education has frequently been suggested as a means to foster adoption of BMPs and to reduce nonpoint source pollution (USEPA 1993). Education might be especially useful in residential areas where pollution prevention is voluntary and depends on the actions of individual homeowners. Education is also emphasized in Phase II of the stormwater regulations (USEPA 2000). Therefore, knowledge of the success of education would be useful to these programs.

Several watershed-based efforts at education have been described (Brenner and others 1998; Hottenroth and others 1999; Swann 2000; USEPA, 1992). Swann (2000), in a literature review, compiled results

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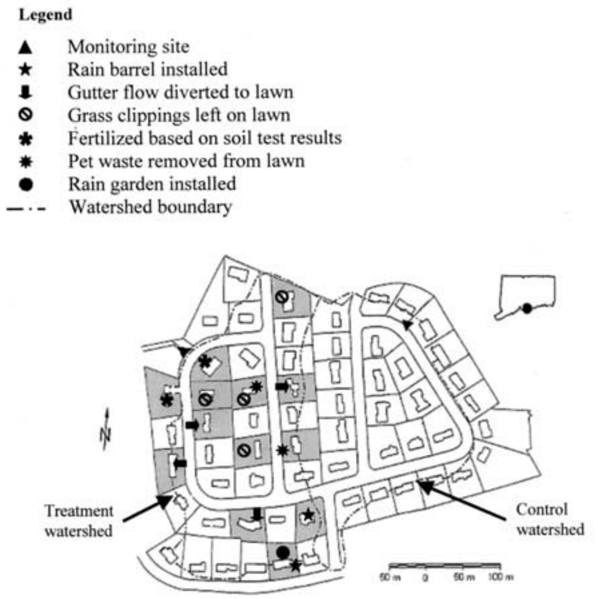

Figure 1. Study of residential neighborhoods in Branford, Connecticut. Shaded lots represent homes that made changes during treatment period; other symbol represent actual changes made.

from several projects that used differing educational methods directed toward changing homeowner practices related to nonpoint source pollution. The most effective methods for producing change appeared to be media campaigns and intensive training sessions. Media campaigns included a mixture of radio, TV, direct mail, and signs. Intensive training included media workshops, consultations, and guidebooks. Up to a 50% increase in the use of BMPs was reported (Swann 2000). Other commonly used techniques, such as newsletters, demonstration projects, and use of the Internet, were not as effective. These studies do not report if education efforts resulted in water quality improvements.

The purpose of this project was to determine whether educating homeowners about residential BMPs could improve the quality of stormwater runoff from a residential neighborhood. This project was intended to go one step beyond the adoption of BMPs and include an improvement in water quality.

Study Area

The project was located in a residential neighborhood near Long Island Sound in the town of Branford, Connecticut. Two adjacent watersheds were studied (Figure 1), following the design of the paired watershed approach (Clausen and Spooner 1993). These watersheds were chosen because they were located in a community with an active volunteer group; they were of manageable size, adjacent to each other, and easily monitored. One was a 5.4-ha control watershed containing 22 homes. The average lot size was 0.25 ha. The other was a 6.1-ha treatment watershed containing 34 homes, with an average lot size of 0.21 ha. The total impervious area was calculated from area measurements on maps to be 23% in both watersheds. Eight lots had property split between both watersheds, but because the driveways and the majority of the lawn area was in the treatment watershed, the residents in these homes received the same education as those withhomes in the treatment watershed. Two new homes were constructed in the control watershed during the study.

All soils in the study area were classified as coarse-loamy, mixed, mesic (Reynolds 1979). Soils in the control watershed were mapped as Wilbraham (Aquic Fragiochrepts) and Menlo (Aeric Fragioquepts) extremely stony silt loam, Wethersfield (Typic Fragiochrepts) loam, and Ludlow (Typic Fragiochrept) silt loam (Reynolds 1979). Treatment watershed soils were mapped as Wethersfield loam, Ludlow silt loam, and Ludlow very stony silt loam (Reynolds 1979). Measured slopes on both watersheds ranged from 2% to 8%.

South central Connecticut receives an average of 1058 mm of precipitation per year and has an annual average temperature of 10.9°C (NOAA 2001). Snow is common during the winter months, and hurricanes occasionally enter the region.

Methods

A paired watershed approach (Clausen and Spooner 1993), using one control and one treatment watershed, was used in this study. The control watershed accounts for year-to-year differences such as climate, and received no treatment. During the 25-month calibration period, no education was performed and no BMPs were implemented on either watershed. 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. A 22-month treatment period began with the education of residents in July 2000.

Education

The treatment applied in this study was providing education to the residents of the treatment watershed. Beginning in 1998, a team from the University of Connecticut provided a series of four sem-

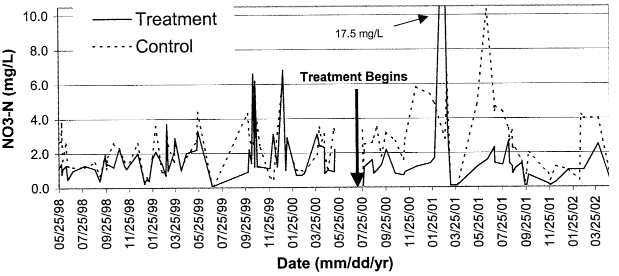

Figure 2. NO_3-N stormflow concentrations from the control and treatment watersheds in Branford, Connecticut.

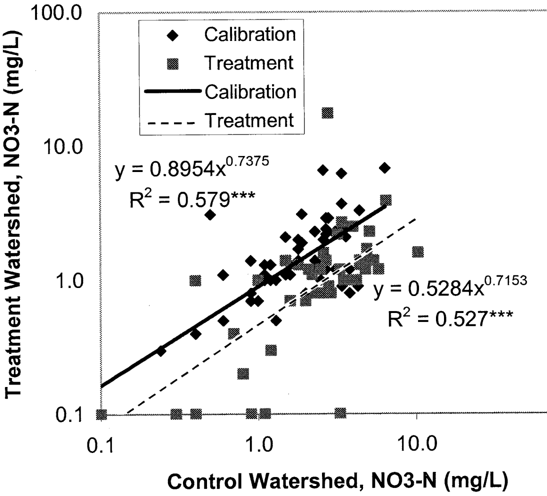

Figure 3. Calibration and treatment period regressions between stormflow concentration of NO_3-N from the control and treatment watersheds in Branford, Connecticut (***$P = 0.001$).

inars open to the public, each on a specific topic. The seminars were attended by anywhere from 15 to 33 participants. Four additional seminars were held for volunteers who would be educating residents directly in the treatment watershed. These four seminars were attended by a minimum of 12 participants. The purpose of the seminars was to educate project volunteers on basic nonpoint source pollution, home site evaluation, lawn care, soil sampling, and educational methods for homeowners. Volunteers were taught how to assess structural features of lots and how to address homeowner practices that contribute to nonpoint source pollution. The final session was a Saturday site assessment demonstration at a volunteer's home.

Trained volunteers performed a site assessment similar to that described by McCann (1997) on the 34 lots in the treatment watershed. The purpose of the residential site assessment was to assess stormwater management, yard and garden care, and pet waste management. A nutrient soil test was also performed on each lawn. Volunteers then recommended changes in practices to homeowners based on information collected and reviewed by extension personnel. Ten specific preventions for the home were recommended, with a focus on three major areas: stormwater runoff management, nitrogen management, and bacteria management.

Survey

A survey was mailed to residents of both watersheds in March 1998, during the calibration period. The survey was designed to collect data on homeowner management (Kulokowich, personal communication, 1999). The survey contained questions regarding lawn care practices such as watering and fertilization, car washing, leaf disposal, and pet waste management. Specific information such as the type of grass in the lawn, the type of fertilizer used, and application rates was not surveyed. The survey was repeated in 2001 with residents of the treatment watershed. This follow-up survey represented the behaviors following education. The results from the follow-up survey were compared to the results from the initial survey using contingency analysis and the chi-square (χ^2) statistic to determine if surveyed behavior changed significantly ($P = 0.05$) as a result of education.

Water Monitoring

A passive stage-height sampler (USDA 1979) was used to obtain stormwater samples as the water level rose. Samples were collected in preacidified 500-mL Nalgene© bottles and were gathered by volunteers.

Samples were analyzed for nitrite + nitrate-N (NO_3-N), ammonia-N (NH_3-N), total Kjeldahl-N (TKN), and total phosphorus (TP) on a Lachat colorimetric flow injection system (USEPA 1983). Total nitrogen (TN) concentrations were calculated by adding TKN and NO_3-N concentrations. Grab samples were also obtained for 30 runoff events and were analyzed at an independent laboratory for fecal coliform bacteria using the membrane filtration technique (APHA 1998).

Statistical analyses were performed using SAS Version 8.2 software (SAS 2001). Because most of the water quality data were found to be log-normally distributed, log-transformed data were used for statistical analysis. Regressions were performed on paired flow and concentration values for calibration and treatment periods. The slopes and intercepts of the two regressions were compared using analysis of covariance (ANCOVA). Calibration regressions were used to pre-

Table 1. Summary of means and percent change for bacteria and nutrient concentrations for the control and treatment watersheds during the calibration and treatment periods in Branford, Connecticut

	Calibration period (n = 60)[a]		Treatment period (n = 44)[b]			
	Control	Treatment	Control	Observed	Predicted	% Change
	(FCU/100mL)					
Fecal coliform bacteria	1382	12341	898	731	1600	−127*
	(mg/L)					
NO_3-N	1.6	1.3	1.9	0.8	1.4	−75***
NH_3-N	0.09	0.18	0.21	0.35	0.23	34
TKN	0.6	1.1	1.3	2	1.9	5
TN	2.7	3.1	3.9	3.3	4	−21
TP	0.073	0.117	0.124	0.226	0.164	27

[a]Number of nutrient samples. Numbers of samples for stormflow and bacteria were 32 and 13, respectively.
[b]Number of nutrient samples. Numbers of samples for stormflow and bacteria were 27 and 13, respectively.
*p-value = 0.05
***p-value = 0.001

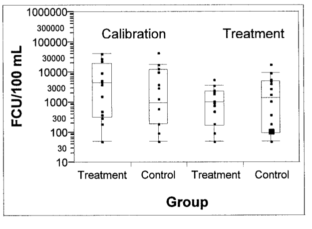

Figure 4. Fecal coliform bacteria concentrations for treatment and control watersheds during the calibration and treatment periods.

dict treatment concentration values, based on control observations during the treatment period. Treatment watershed predicted values were then compared to observed data and a percent change was calculated as the treatment effect.

Results and Discussion

University personnel assisted in several structural modifications in the treatment watershed, following recommendations. In November 2000, four gutter downspouts were redirected so that roof runoff drained to the lawn and not on the driveway. A rain barrel and a rain garden were installed at one house in April 2001, and in May 2001, a rain barrel was installed at another house (Figure 1). The purpose of structural changes was to reduce the volume of water entering the stormwater system. The ultimate goal of low-impact development (LID) is to retain as much runoff on the site as possible (Prince George's County 1999), thus reducing downstream impacts.

Precipitation

Precipitation at Ansonia, Connecticut, located 26 km from the study area, was 1.5%, 15.4%, and 10.8% above normal for the years 1998, 1999, and 2000, respectively. For the years 2001 and 2002, the departure from normal was −4.3% and −2.9%, respectively (NOAA 1998–2002). Greater stormwater pollutant concentrations and exports would be expected during periods of above-normal precipitation. However, the advantage of the paired watershed design is that yearly climate variations are factored out as comparisons are made with a control watershed and not just across different time periods.

Nitrogen and Phosphorus

The concentration of NO_3-N in stormwater runoff significantly ($P = 0.001$) decreased by 75% in the treatment watershed during the 22 months following education (Table 2). The difference in the response of the two watersheds is shown temporally in Figure 2. Before treatment, NO_3-N concentrations in both watersheds were similar; afterward, concentrations in the treatment watershed were generally lower than those in the control watershed. This change was observed as a decrease in the treatment regression intercept for the paired NO_3-N values (Figure 3). Concentrations of NH_3-N, TKN, TN, and TP in stormwater runoff did not significantly change due to the treatment (Table 1). Although NO_3-N is a component of total nitrogen, TN concentrations did not change. NO_3-N concentrations averaged only 24% of TN during the treatment period, and the change in NO_3-N was not large enough to affect TN concentrations.

Table 2. Comparison of survey response rates (percent of respondents in parentheses) between calibration and treatment periods for the treatment watershed, Branford, Connecticut

	Treatment watershed			
	Calibration	Treatment	Chi-square	*P*-Value
Fertilize lawn	22 (76%)	19 (86%)	0.875	0.350
<4 applications/year	14 (64%)	12 (63%)	0.001	0.975
>4 applications/year	8 (36%)	7 (37%)	0.001	0.975
Use professional service	12 (55%)	6 (32%)	2.184	0.140
Use bag instructions	10 (45%)	11 (58%)	2.430	0.119
Use soil test results	0	2 (11%)	2.434	0.119
Remove pet waste from lawn	13 (76%)	7 (88%)	0.414	0.520
Leave clippings on lawn	18 (62%)	18 (82%)	2.350	0.125
Water lawn	24 (80%)	16 (73%)	0.378	0.539
Adopt BMPs	0	12 (35%)	14.57	0.0001

Concentrations of NO_3-N in the control watershed decreased from the calibration to the treatment period (Table 1). Although it is not certain why this occurred, it is possible that below-normal precipitation during the treatment period impacted NO_3-N concentrations. The benefit of the paired watershed design is that changes such as this are statistically factored in when analyzing for a treatment effect.

Although it is not certain why TP and NH_3-N concentrations did not change following education, the unchanged contributions by streets and driveways could be responsible. For example, although high concentrations of total phosphorus (2.67 mg/L) have been reported in runoff from lawns, they were not found to be primary sources for TP (Bannerman and others 1993). In contrast, feeder and collector streets had lower geometric mean concentrations of TP (1.31 and 1.07 mg/L, respectively), but were primary sources of TP due to the large volume of runoff from these surfaces (Bannerman and others 1993).

Pooled event mean concentrations for urban runoff of the Nationwide Urban Runoff Program (NURP), USGS, and NPDES monitoring programs (Smullen and others 1999) were 0.658 mg/L for NO_3-N and 1.73 mg/L for TKN. The mean stormwater concentrations for both the control and treatment watersheds during the calibration and treatment periods were slightly higher than the pooled mean for NO_3-N and slightly lower than the pooled mean for TKN. TP means for this study were lower than the pooled mean of 0.315 mg/L (Table 1).

Bacteria

During the calibration period, bacteria concentrations in both watersheds were similar. After treatment, bacteria concentrations in both watersheds were lower (Figure 4). This change might be due to the fact that there was above-normal precipitation during the calibration period and below-normal precipitation during the treatment period. Such time trends are statistically adjusted using the paired watershed approach. ANCOVA analysis revealed a significant ($P = 0.05$) change in regression slopes. This change represented a 127% reduction in mean bacteria concentrations in stormwater runoff (Table 1). The reduction occurred mostly for higher concentrations. Although the regression between the control and treatment watersheds for the calibration period was significant ($P = 0.001$), the treatment period regression was not. The low number of samples ($n = 14$) might have contributed to this result. Mean fecal coliform bacteria concentrations observed in both the control and treatment watersheds (Table 1) were much lower than those observed by Bannerman and others (1993). They reported concentrations of 92,061 and 56,554 colony-forming units/100 mL for feeder streets and collector streets, respectively.

Survey

The initial survey was given to 61 property owners in both the control and treatment watersheds. For the treatment watershed, response rates of 76% and 65% were obtained for the initial and follow-up surveys, respectively. Chi-square analysis of the responses from the initial and follow-up surveys indicated that no significant changes in surveyed behavior occurred in the treatment watershed following education (Table 2). However, a significant ($P = 0.001$) increase in BMP adoption occurred following education. BMP implementation occurred on 12 of 34 lots (35%). There was no change in whether they fertilized their lawn, the frequency of fertilization, who fertilized their lawn, or amount of fertilizer applied. Management of pet wastes, lawn clippings, and lawn watering also did not change. It is possible that residents made subtle changes that were not reported on the survey. For example, part of the education included general housekeeping practices such as avoiding spreading fertilizer on impervious areas. However, we did not think to ask about this practice in the original survey.

Conclusions

NO_3-N and bacteria concentrations in stormwater runoff decreased significantly due to education, but, surprisingly, TN concentrations did not change. NH_3-N and TP concentrations also did not change from the calibration to the treatment period.

Intensive education efforts, in the form of workshops and one-on-one consulting, resulted in a significant adoption of BMPs; the quality of stormwater runoff also improved. However, our measured behaviors did not change significantly. It is possible that our survey of behaviors did not accurately assess homeowner actions that impact nonpoint pollution. Survey techniques could be improved by asking questions regarding type of fertilizer used, amount of fertilizer applied, and type of grass in the lawn. Such information could provide more insight into the causes of water quality changes. This study suggests that local, state, and federal education efforts aimed at pollution prevention might be successful if intensive education efforts are used.

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Appendix: Residential Survey

Branford River Stewardship Program Residential Survey

1) When your lawn gets cut, what happens to the clippings?

________ They are left on the lawn
________ They are put in a pile on my property
________ They are used as mulch in the garden
________ They are mulched with a mower
________ They are added to a compost pile
________ They are bagged and put in the trash

2) What lawn watering method do you use?
________ I let nature take its course
________ I water by hand with a hose
________ I use a manual sprinkler which I turn on/off and move myself
________ I have an installed sprinkler system set on__________manual or _________automatic
________ Other (please specify)

3) Do you fertilize your own lawn?________ YES________ NO (Go to question five)

3a) How many times each season do you fertilize your lawn?
Spring (March–May)________ times
Summer (June–August)________ times
Fall (September–October)________ times
Winter (November–February)________ times
3b) How do you decide how much fertilizer use?
________ Professional service takes care of fertilizing
________ I base amount on a soil test. (Date soil last tested)________________
________ I use a calibrated spreader set at_______________________________
________ I know how much to use from past experience

4) How do you handle disposal of pet waste?

_______ Waste is handled inside________ Waste is left to decompose outside
_______ Waste is composted________ Waste is picked up and thrown out

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