LAWN-WATERING PERCEPTIONS AND BEHAVIORS OF RESIDENTIAL HOMEOWNERS IN THREE KANSAS (USA) CITIES: IMPLICATIONS FOR WATER QUANTITY AND QUALITY

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ABSTRACT

Urbanization is increasing the land area covered with turfgrasses, which may have implications for water quantity and quality. The largest sector of turfgrass is residential lawns. Our objectives were to survey residential homeowners in three Kansas cities about their perceptions, knowledge, and behaviors when irrigating their lawns; each city has distinctive water quantity and quality issues. Surveys were mailed to 15,500 homeowners in Wichita, 10,000 in Olathe, and 5,000 in Salina; the return rate was 11-13%. Wichita residents watered more frequently than Olathe and Salina, possibly because of greater evaporative demand than Olathe, and cheaper water and less concern about water shortages than Salina; Salina and Wichita have similar evaporative demands but Salina had a recent water crisis. Salina homeowners were most concerned about keeping their water bill from getting too high, probably because of higher water costs than the other cities. Overall, 45-60% indicated it was moderately to very important their lawns looked green all the time, while 65-77% ranked water conservation at the same level of importance. Significantly, 61-63% did not know how much water their lawns required and 71-77% did not know how much water they applied to their lawns when they irrigated. About 7-9% swept or blew clippings or lawn-care products directly into streets or storm drains, which run directly into local streams or reservoirs; 9% in Wichita is ~9,000 homeowners. The homeowner's lawn irrigation knowledge and habits must be improved to help conserve water and protect water quality.

INTRODUCTION

With urbanization, significant tracts of natural ecosystem and agricultural land are being replaced with turfgrass (U.S. Geological Survey, 1999; Alig et al., 2004). In the United States, turfgrasses are estimated to cover 16 to 20 million ha of urbanized land, or up to 18% of the land area in some regions (Morris, 2003; National Agricultural Statistics Service, 2004, 2006); this represents an area three times larger than any irrigated crop (Milesi et al., 2005). Furthermore, urbanization in the USA and elsewhere is projected to continue to increase rapidly (Alig et al., 2004), indicating a continued expansion of land area covered with turfgrasses.

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Keywords: green lawns, irrigation, landscape, lawn appearance, turfgrass, water conservation, water quality

The rapid increase of turfgrass in the landscape may have significant implications for water quality and quantity. A number of studies have linked urbanization with declining water quality in surface and ground water reservoirs due to increased concentrations of nutrients and pesticides, some of which are used in lawns (King and Balogh, 2001; U.S. Geological Survey, 2001; Hamilton et al., 2004; Petrovic and Easton, 2005). Irrigation of turfgrass is typical in many urban areas, which increases demand for water resources. Water scarcity is most critical in arid or semi-arid regions experiencing rapid urban growth (Reisner, 1993).

Water quality in urban areas may be affected by runoff or leaching of fertilizer nutrients and pesticides from lawns, but runoff from impervious surfaces is the greatest concern. Runoff from lawns or impervious surfaces may happen during intense rainstorms, when turfgrass is over irrigated, or when irrigation systems are improperly adjusted (Morton et al., 1988; Petrovic, 1990; Brezonik and Stadelmann, 2002). The extent of excessively irrigated turfgrass is not known, but apparently over irrigation has altered the hydrologic system of the Las Vegas Valley such that historically ephemeral washes have become perennial streams in urbanized areas (Mizell and French, 1995). This indicates a critical need to change the behavior of urbanites to reduce their irrigation inputs and thus, conserve water and improve water quality.

The greatest opportunity for conserving water and minimizing runoff and leaching in urban areas may be in residential lawns. From 50% to as much as 80% of all land area covered with turfgrass in the US is composed of residential lawns (Grounds Maintenance, 1996; National Agricultural Statistics Service, 2004, 2006), and up to 75% of residential water use may be for outdoor purposes (Vickers et al., 2001).

Improper perceptions about water requirements for turfgrass or embellished expectations about lawn appearance (e.g., maintaining perfectly green lawns even during drought) may result in over-irrigation. Data are lacking, however, to quantify the prevalence of such perceptions, including how they affect lawn-watering practices. Presumably, the perceptions and practices of homeowners about lawn watering may be influenced by a number of factors including demographics, local climate, water costs, water shortages, etc. Consequently, a first step towards improving water quality and conservation in urban watersheds is to carefully evaluate fundamental perceptions and practices of homeowners in watering their lawns.

Our objectives were to understand the perceptions, knowledge, and behaviors of residential homeowners about the irrigation of their lawns during summer months. In this study, we surveyed residential homeowners in three separate urban areas of Kansas, USA, each with distinct combinations of climate, demographics, and water issues.

MATERIALS AND METHODS

Study locations. Surveys were mailed to residents in Wichita, Olathe, and Salina, Kansas. Each city has related, but also distinctive concerns about water quantity and quality. The first is Olathe, which is located in the Lower Kansas River Watershed and is a suburb of the larger Kansas City metropolitan area that straddles the Kansas and Missouri state borders. Kansas City ranked 29th in the U.S. in 2010 for the amount of land area covered by urban landscapes (U.S. Census Bureau). Olathe grew by 35% from 2000 to 2010, was ranked 24th in the list of fastest growing cities in the nation in 2008, and is also an affluent suburb whose residents typically maintain high-input lawns; median annual household income from 2006 – 2010 was $75,228. In Olathe, water is generally plentiful except during peak water usage in summer months. A review of water use in Olathe and neighboring suburbs in the Kansas City, KS area, however, indicated that many residents were over-watering their lawns and that significant reductions in water use were possible by targeting lawn irrigation by homeowners (N. G. Scott, personal communication).

The second city is Wichita, which is 258 km to the west-southwest of Olathe and located in the Middle Arkansas-Slate Watershed. Wichita is the 49th largest city in the US and grew by 11% from 2000 to 2010 (U.S. Census Bureau). The median annual household income from 2006 – 2010 was $44,360, which was 41% lower than in Olathe. Wichita receives nearly 250 mm less precipitation and averages 1°C higher annually (mean high) than Olathe, resulting in greater irrigation demands for lawns in Wichita (i.e., greater potential evapotranspiration and less rainfall). Unfortunately, Wichita's water sources, which include nearby Cheney Reservoir and the Equus Beds aquifer, are not expected to meet projected needs into the 21st century (Kay Drennen, Wichita Water Center, personal communication). Therefore, in 1995, Wichita implemented an innovative plan to recharge the Equus Beds aquifer with overflow from the Little Arkansas River after rain, when the river had risen to a predetermined level (U.S. Geological Survey, 2012). In this way, the city hopes to store water for later recovery of the groundwater by the city although water conservation by residents will be crucial to ensure the adequacy of this water supply.

The third city is Salina, which lies in the Lower Saline Watershed. Salina is 243 km west of Olathe and 128 km north of Wichita and its climate is more similar to Wichita's than Olathe's. The median annual household income from 2006 – 2010 was $42,027 in Salina, which was also similar to Wichita and substantially less (i.e., by 44%) than Olathe (U.S. Census Bureau). Salina declared its first water emergency in 2006 because its main source of water, the Smoky Hill River, nearly ran dry for the first time in recorded history despite only slightly less than normal precipitation in recent years. Although the growth of Salina between 2000 and 2010 (4.4%) was not as rapid as Wichita or Olathe, concern over water conservation and quality is critical. In particular, water quality is a concern because Salina's increased reliance on ground water supplies has increased the rate of flow of an underground pollution plume (trichloroethylene) from a nearby former Air Force base towards city wells. Therefore, reductions in water use by Salina residents are crucial.

Survey development. A survey was developed to determine how residential homeowners make decisions about watering their lawns, including the frequency of and amount of water applied during irrigation in the summer months of June, July, and August. Homeowners were asked if they knew how much water their lawn required per week and if so, to specify how much. Inquiries were made as to how important it was to keep their lawns green and their neighborhoods looking nice, prevent their water bill from getting too high, keep their lawns alive during hot and dry periods, conserve water, and follow lawn-care guidelines. Surveyees were asked whether they swept or blew their driveways after mowing or applying lawn care products and if they did, whether they swept or blew them back into their lawns or into the street or storm drains.

The survey consisted of five-point Likert-scaled items (Likert, 1932) and multiple choice questions. The Likert-scaled items were ranked from one to five with one = not important and five = very important. For multiple choice questions, participants were asked to select one answer out of two to six options to represent their response to a given question. Where only two options were offered, the question called for either a yes or no response.

Because the targeted population was residential homeowners, all respondents were asked whether they actually owned their homes. In addition, they were asked whether they watered and maintained their lawn themselves. If any respondent did not own their own home or water and maintain their own lawn, their surveys were discarded from the final analysis. As an incentive to participate in the survey, all respondents were entered into a drawing for a $100 gift card from Lowe's® (Corporate Headquarters, Mooresville, NC), which is a home-improvement department store; separate drawings were held for each city, with one $100 gift card per city.

Population and sample. Surveys were mailed to more than 30,000 residential homeowners in three cities in Kansas - Wichita, Olathe, and Salina. Lists of residential homeowner addresses were obtained from the municipal utility in each city. The total population of residential homeowners was 98,708 in Wichita, 26,333 in Olathe, and 14,971 in Salina. To ensure that sampling was uniform geographically across each city, a stratified design was employed. This involved dividing each city arbitrarily into sections. Addresses were then selected randomly from within each section, based on its population proportionate to the total population of the city. Accordingly, Wichita was divided by zip codes into 23 sections, Olathe was divided into 13 sections, and Salina was divided into 54 sections based on route numbers assigned by the municipality.

Each address selected received a one-page, tri-fold survey mailer. Homeowners were asked to complete the survey and return it postage paid. The total number of surveys mailed to residential homeowners included 4,992 in Salina on 28 April; 9,992 in Olathe on 27 May; and 15,534 in Wichita on 2 July; all in 2009. In total, the number of surveys returned by residents included 1,772 from Wichita, 1,110 from Olathe, and 652 from Salina. Thus, the total return rate was 11.4% for Wichita, 13.1% for Olathe, and 11.1% for Salina, or an overall return rate of 11.6%.

Like many mail surveys, this survey had a low response rate (Dillman, 1991). However, a survey with a low response rate can provide meaningful conclusions about the population. For this to be true, we assumed that the homeowners that responded to the survey were a random subgroup of the homeowners who were mailed surveys. In other words, respondents and non-respondents would have provided similar answers to the survey questions. In this case, this assumption seems plausible. Furthermore, when no information is available regarding characteristics of the non-respondents, we cannot quantify the amount of potential non-response bias present. In this case, since no follow-up surveys were attempted, we do not have information on non-respondents (Dey, 1997).

Data analysis. Data were analyzed using the statistical program R (version 2.13, R-Core Development Team, 2011). For each urban area, proportions (and standard errors) of respondents in each category for each survey question were computed using the stratified sampling design of the survey. Additional adjustments were made for sampling from finite populations (Scheaffer et al., 1979). Because the sampling design for each city was independent of the other cities, data for each city were analyzed independently. Within a city, proportions were estimated for each of the geographic sections (23 for Wichita, 13 for Olathe, and 54 for Salina). The proportions for each section were then weighted according to the population of each section and combined to give an overall estimate of the proportion for the city. Some questions on the survey were only intended to be answered by respondents who watered their lawns during the summer. To estimate proportions and standard errors for these subpopulations, we used ratio estimation methods for stratified sampling (Lohr, 2010, see p. 144 for details).

RESULTS AND DISCUSSION

Lawn-watering behaviors. Responses to the question “How often do you water your lawn during dry periods of the summer?” indicated that Salina residents generally watered less frequently than Wichita residents, while Olathe residents were intermediate (Fig. 1). Most Salina and Olathe residents watered once per week or less (44 and 37%, respectively), with “2-3 times per week” the next most-frequent response for each city (27 and 31%, respectively). A higher percentage of Salina homeowners indicated they never watered their lawns (24%) compared to Olathe and Wichita (18 and 15%, respectively). By contrast, most Wichita residents watered 2-3 times per week (31%), and a higher percentage of Wichita homeowners watered 3-4 times per week or more (26%), compared to Salina (3%) and Olathe (15%).

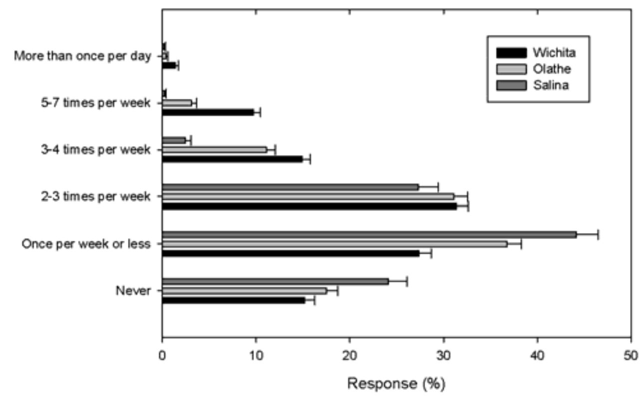

Figure 1. Responses of residential homeowners in three Kansas cities to the survey question “How often do you water your lawn during dry periods of the summer?” Error bars denote the standard error.

The generally lower frequency with which Salina residents water their lawns may be related to a heightened perception of water shortages related to the water shortage of 2006 when the Smoky Hill River nearly ran dry. In support of this, residential homeowners in the U.S. desert southwest ranked water shortages as the main factor that would cause them to reduce irrigation of their landscapes; water shortages were even more important to them than high water bills (Spinti et al., 2004; St. Hilaire et al., 2010). An analysis of water costs for landscape irrigation (assuming water for landscape irrigation was charged at “second-tier” rates, which is water used beyond a certain base amount [e.g., average water use during winter months]) in the three cities also revealed that Salina was roughly 40% more expensive than Wichita, and 55% more expensive than Olathe (personal communication with water municipalities in each city). Thus, higher water costs may also have contributed to less water use in Salina among cities.

By contrast, the higher frequency with which Wichita homeowners watered their lawns could be due to the warmer summers, leading to higher evaporative demand in that city. For example, the evaporative demand among cities as estimated by Penman potential evapotranspiration during June, July, and August is 710 mm in Wichita, 705 mm in Salina, and 614 mm in Olathe (Sophocleous, 1998). Comparatively, precipitation during June, July, and August is 311 mm in Wichita, 314 mm in Salina, and 362 mm in Olathe. Although the evaporative demand is only slightly greater in Wichita than in Salina, Wichita residents may have less concern or awareness about water shortages than Salina residents.

In response to the question “How do you decide when it is time to water your lawn?” most homeowners in Salina and Olathe indicated that they water when the lawn looks dry (41 and 49%, respectively) (Fig. 2). In Wichita, an equivalent number of homeowners watered based on a routine schedule, as when the lawn looks dry (36 and 38%, respectively). The higher number of homeowners watering on a routine schedule in Wichita may be caused, in part, by more than 46% of them having in-ground irrigation sprinklers compared with only 24-28% of homeowners in Olathe and Salina with in-ground systems (data not shown). Bremer et al.

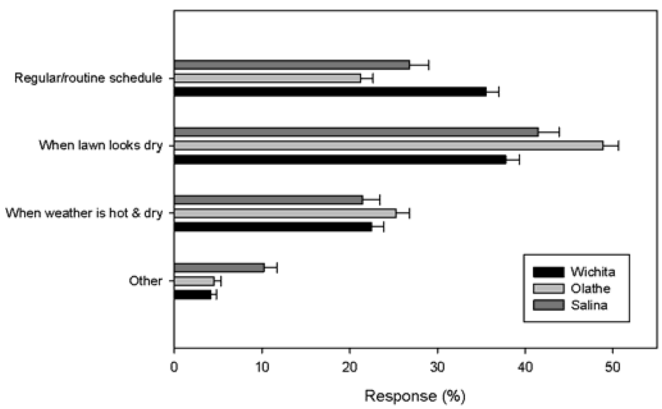

Figure 2. Responses of residential homeowners in three Kansas cities to the survey question "How do you decide when it is time to water your lawn?" Error bars denote the standard error.

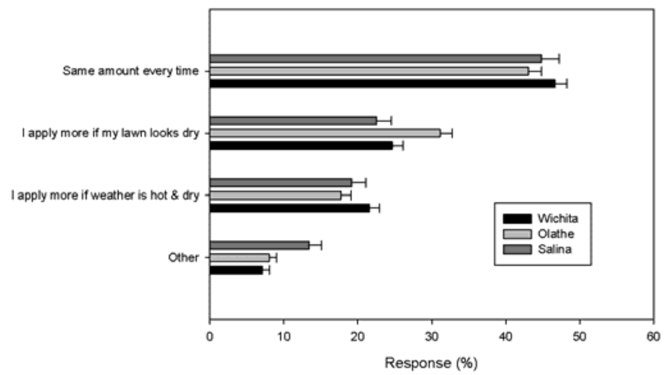

Figure 3. Responses of residential homeowners in three Kansas cities to the survey question "How do you decide how much to water your lawn?" Error bars denote the standard error.

(2012) reported that homeowners with in-ground systems generally water more routinely than those without. More routine watering in Wichita may also be related to the higher evaporative demand in Wichita, which may give homeowners the feeling that their lawn will dry out too fast if they do not water routinely. Although the evaporative demand in Salina is only slightly less than in Wichita, the water shortage in 2006 as well as higher water costs may have reduced the number of residents in Salina that watered on a routine schedule as opposed to waiting until the lawn looks dry.

While a greater percentage of Wichita homeowners watered on a routine schedule compared with Salina and Olathe, there were still substantial numbers watering on a routine schedule in those cities (27 and 21%, respectively). It seems likely that significant water savings could be achieved in all cities if homeowners were better educated about "plant-based" irrigation. There was also a substantial group in each city who watered "when weather is hot and dry" (21-25%); but there were no differences among cities in this category.

In response to the question "How do you decide how much to water your lawn?" most homeowners in each city said they watered "the same amount every time" (43-47%) (Fig. 3). This may not be undesirable if homeowners were adjusting frequency based on their lawns needs, but if many of these homeowners were also watering on a routine schedule, then their lawns will usually be under- or overwatered. Twenty-three to thirty-one percent indicated they applied more water if the lawn looked dry, which is the most desirable strategy for lawn health and water conservation. Olathe had a higher number of homeowners in this category (31%) than Wichita (25%) and Salina (23%). In all three cities a substantial number (18-22%) also said they applied more if weather was hot and dry. Interestingly, Salina had a higher percentage responding "other" (13 vs. 7-8% in Wichita and Olathe). It is unknown how these homeowners were making irrigation quantity decisions.

Knowledge about lawns. Most homeowners (71-77%) in the three cities did not know how much water they were applying when they watered their lawns. Furthermore, 61-63% of homeowners in each city said they did not know how much water their lawn required per week. Of those who indicated they did know, when asked to specify the amount of water their lawns needed, 13-22% reported 5 cm wk^{-1} or more, which is substantially greater than the recommended 2.5 cm wk^{-1} (3.8 cm wk^{-1} during dry summer conditions) (Fagerness, 2001). Clearly, there is much room for improvement in homeowners' general knowledge about lawn irrigation, which could translate to more efficient use of landscape irrigation water.

Perceptions about lawns. The vast majority of homeowners (78-85%) in all cities said it was at least "somewhat important" (i.e., rating of 3 or higher) that their lawn looked green all the time (Fig. 4). This is similar to results from a Nebraska survey, which revealed that 90% of homeowners took pride in the appearance of their lawns and 85% felt a well-kept lawn increased property values (Sewell et al., 2010). More Wichita homeowners considered a green lawn "very important" (29%) than homeowners in Olathe or Salina (23 and 20%, respectively). This may reflect the greater challenge of maintaining a green lawn during the summer in Wichita, as well as less concern about water shortages than in Salina.

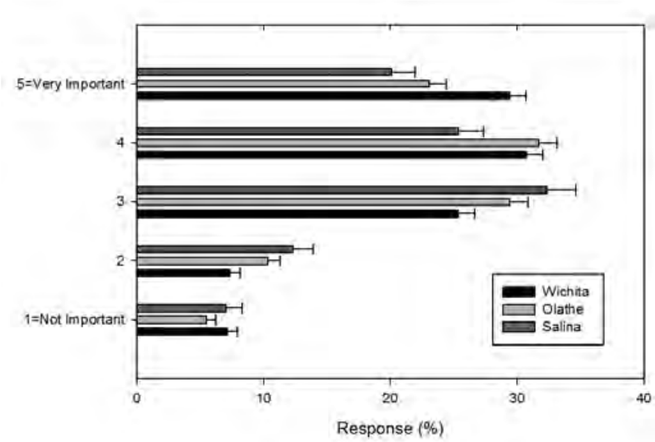

Figure 4. Responses of residential homeowners in three Kansas cities to the statement "I like my lawn to look green all the time." Error bars denote standard errors.

When making lawn decisions, most homeowners in all cities said it was "very important" that they keep their water bill from getting too high, but Salina had more homeowners in this category (58%) than Wichita and Olathe

(42% each) (Fig. 5). Salina's higher water costs are probably at least partially responsible for this difference. Only 9-15% of homeowners across cities said their water bill was of little to no importance (i.e., a rating of 1 or 2).

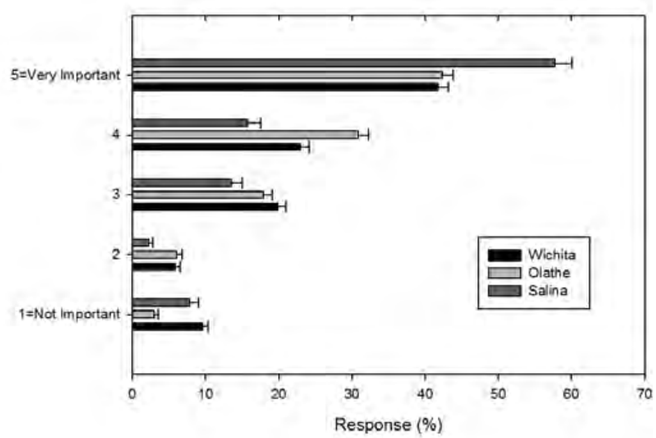

Figure 5. Responses of residential homeowners in three Kansas cities to the statement "I try to keep my water bill from getting too high." Error bars denote standard errors.

Most homeowners in all cities said it was "very important" to keep their lawn alive during hot/dry weather, but it was more important to Wichita homeowners (52%, compared to 40-41% in the other cities) (Fig. 6). This may be, in part, because of the higher evaporative demand in Wichita, which would cause a lawn to die sooner in the absence of water. Although the evaporative demand in Salina is similar to Wichita, recent memories of the 2006 water shortages as well as higher water costs in Salina may have discouraged some homeowners from being as concerned about their lawns. Only 10-13% of homeowners across cities, however, indicated keeping their lawns alive was of little or no importance (i.e., a rating of 1 or 2).

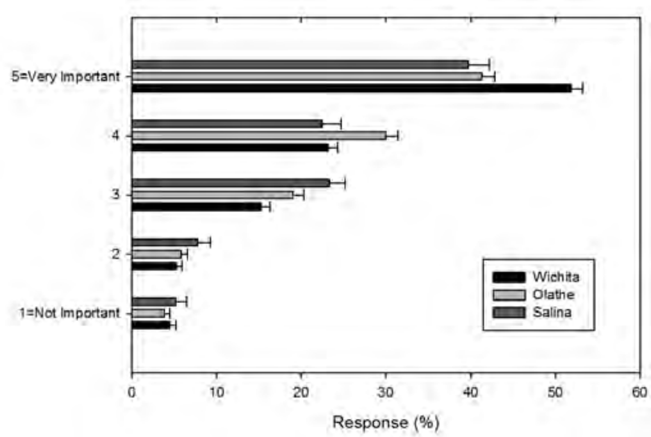

Figure 6. Responses of residential homeowners in three Kansas cities to the statement "I want to make sure that I keep my lawn alive during hot/dry weather." Error bars denote standard errors.

Water conservation was considered moderately or very important (i.e., rankings of 4 or 5) by 64-77% of homeowners in all cities, but Salina residents were more likely to consider it very important (55%), followed by Wichita homeowners (41%) (Fig. 7). This result is easy to understand, given the water emergency experienced by Salina residents in 2006 when their primary water source, the Smoky Hill River, nearly ran dry during the summer. Fewer Olathe homeowners considered water conservation very important (31%), and they were just as likely to say it was moderately important (33%). In contrast to Salina and Wichita, water is more abundant in Olathe, and prices for landscape irrigation are lower.

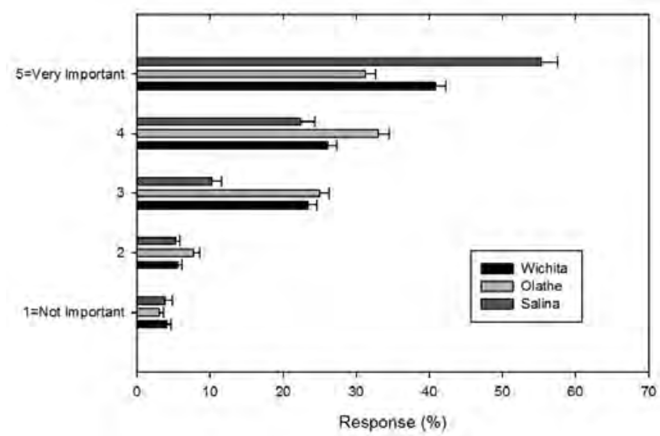

Figure 7. Responses of residential homeowners in three urban areas in Kansas to the statement "I am concerned about water conservation." Error bars denote standard errors.

Eighty-four to eighty-nine percent of homeowners in the three cities said concerns about their neighborhood's appearance were at least somewhat important (i.e., rating of 3 or above) when making lawn decisions (Fig. 8). Compared to the other cities, Wichita homeowners were more likely to say such concerns were "very important" while Olathe homeowners were more likely to say they were moderately important, and Salina homeowners were more likely to say they were only somewhat important.

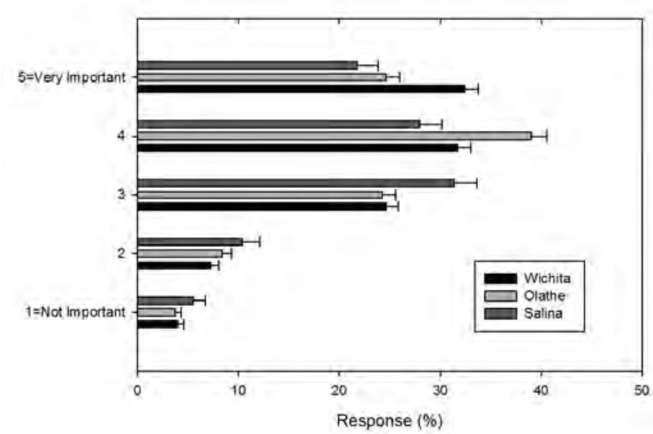

Figure 8. Responses of residential homeowners in three urban areas in Kansas to the statement "It is important that my neighborhood stays looking nice." Error bars denote standard errors.

Questions relating to water quality. Overall, 78-85% of homeowners said following current lawn care guidelines and recommendations was at least somewhat important (i.e., rating of 3 or higher) (Fig. 9). Salina homeowners were most likely to say following current lawn care guidelines and recommendations was "very important" (34%), followed by Wichita (27%) and then Olathe (22%). Again, the acute water shortage experienced by Salina residents, and the relative abundance of water in Olathe may be responsible for these differences.

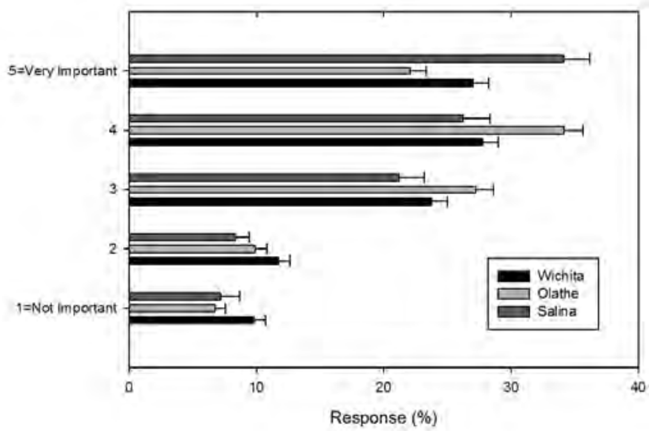

Figure 9. Responses of residential homeowners in three Kansas cities to the statement "I try to follow current lawn care guidelines and recommendations." Error bars denote standard errors.

When asked the question "Do you sweep or blow your driveway after mowing?" 71% of homeowners in each city said yes; however, the majority of homeowners said they did not blow after applying lawn care products. Salina had slightly more homeowners in this category than Wichita and Olathe (62 compared with 56 and 53%, respectively). Given that Salina residents placed greater importance on following lawn-care guidelines among cities (Fig. 9), it is interesting that fewer of them sweep or blow after applying lawn-care products. It is desirable to sweep or blow lawn-care products back onto lawns because these products are otherwise carried by runoff from impervious surfaces (e.g., driveways and streets) directly into local streams or reservoirs (Petrovic and Easton, 2005). Other researchers reported that 92% of all homeowners fertilized their lawns, suggesting the total number of homeowners in our study who didn't sweep or blow after fertilizing was significant (Deitz and Abraham, 2011).

Of the homeowners who sweep or blow, the vast majority (87-93%) in all cities did so back into the lawn (as they should), while 7-9% said they did so directly into the street or storm drains. While the latter numbers seem low at first glance, 9% of homeowners in Wichita, Olathe, and Salina equates to a substantial number in each city (e.g., about 9000 residential homeowners in Wichita) sweeping directly into streets/storm drains, which could have a negative impact on water quality.

CONCLUSION

Watering frequency was greatest in Wichita and least in Salina. Wichita homeowners were more likely to place importance on "having a green lawn all the time," and to be more concerned with keeping their lawn alive during hot weather. Although the evaporative demand is similar between Wichita and Salina, it is likely that Salina residents watered less and were less concerned about their lawns appearance because of higher water costs and their memory of acute water shortages less than three years prior to this survey. Homeowners in Olathe, with its slightly cooler summers and more abundant, relatively less-expensive water supplies, were intermediate between Salina and Wichita in most responses about lawn-watering behavior.

Homeowners in Salina were more concerned than homeowners in Wichita or Olathe about keeping their water bill from getting too high. From this and other attitudes about lawn irrigation reflected in the survey, it appears that higher water costs influence homeowners toward less frequent watering and/or conserving water in general.

There appears to be a significant need to increase homeowners' knowledge about lawn irrigation. A majority of homeowners in all cities did not know how much water they were applying when they watered their lawns, nor did they know how much water their lawn required per week. Furthermore, a small but significant number of homeowners swept lawn care products directly into streets/drains.

Although this survey was conducted in Kansas, USA, the results probably represent a cross section of lawn-watering behaviors, knowledge, and perceptions of residential homeowners elsewhere. Finding effective ways to change lawn-watering perceptions and behaviors, as well as to fill knowledge gaps, should help conserve water and protect water quality in urban watersheds. Examples include, but are not limited to applying lawn-irrigation amounts to match the actual needs of the turfgrass (e.g., through the use of SMART controllers on automatic irrigation sprinkler systems, auditing sprinkler systems, educating homeowners about turfgrass water requirements, waiting to irrigate until lawn shows signs of dryness), encouraging homeowners to follow proper lawn-care guidelines (e.g., sweeping or blowing lawn-care products back into the lawn), encouraging homeowners to allow for some dormancy of turfgrasses during extended drought or hot weather, and adapting to turfgrasses with lower water requirements.

ACKNOWLEDGEMENTS

This research was funded by the USDA National Integrated Water Quality Program (NIWQP) and the Kansas Turfgrass Foundation. Funding of survey printing and mailing was provided by the Wichita Dept. of Environmental Services, Olathe Municipal Services, and Salina Utilities Dept., and gift cards were supplied by Lowe's®. The assistance of Laura Moley and Cathie Lavis in development of the survey was greatly appreciated, as was the assistance of Cody Domenghini and Kenton Peterson in compiling data.

REFERENCES

Alig, R.J., J.D. Kline, and M. Lichtenstein. 2004. Urbanization on the US landscape: Looking ahead in the 21st century. Landscape Urban Planning 69:219-234.

Bremer, D.J., S.J. Keeley, A. Jager, J.D. Fry, and C. Lavis. 2012. In-ground irrigation systems affect lawn-watering

behaviors of residential homeowners. HortTechnology 22:651-658.
Brezonik, P.L. and T.H. Stadelmann. 2002. Analysis and predictive models of stormwater runoff volumes, loads, and pollutant concentrations from watersheds in the Twin Cities metropolitan area, Minnesota, USA. Water Res. 36:1743-1757.
Dey, E.L. 1997. Working with low survey response rates: The efficacy of weighting adjustments. Res. High. Educ. 38:215-227.
Dietz, M.E., and J. Abraham. 2011. Stormwater monitoring and resident behavior in a semi-arid region. J. Ext. 49(2). http://www.joe.org/joe/2011april/a8.php. (Accessed 3 Aug. 2012).
Dillman, D. A. 1991. The Design and Administration of Mail Surveys. Ann. Rev. Sociol. 17:225-249.
Fagerness, M.J. 2001. Watering your lawn. MF-2059. Kansas State University Agricultural Experiment Station and Cooperative Extension Service, Manhattan, KS. January.
Grounds Maintenance. 1996. Turf acreage. Grounds Maintenance 31:10.
Hamilton, P.A., T.L. Miller, and D.N. Myers. 2004. Water quality in the nation's streams and aquifers-overview of selected findings, 1991-2001. U.S. Geological Survey Cir. 1265, p 1-19. U.S. Geological Survey, Washington, DC.
King, K.W., and J.C. Balogh. 2001. Water quality impacts associated with converting farmland and forests to turfgrass. Trans. Amer. Soc. Agr. Eng. 44:569-576.
Likert, Rensis (1932). A technique for the measurement of attitudes. Arch. Psychol. 140:1–55.
Lohr, S.L. 2010. Sampling: Design and Analysis, 2nd Ed. Brooks/Cole, Cengage Learning. Boston, Massachusetts.
Milesi, C, S.W. Running, C.D. Elvidge, J.B. Dietz, B.T. Tuttle, and R.R. Nemani. 2005. Mapping and modeling the biogeochemical cycling of turf grasses in the United States. Environ. Mgt. 36:426-438.
Mizell, S.A., and R.H. French. 1995. Beneficial use potential of dry weather flow in the Las Vegas Valley, Nevada. Water Resources Bull. 31:447-461.
Morris, K. 2003. The national turfgrass research initiative. National Turfgrass Federation, Inc. and National Turfgrass Evaluation Program. Beltsville, MD.
Morton, T.G., A.J. Gold, and W.M. Sullivan. 1988. Influence of overwatering and fertilization on nitrogen losses from home lawns. J. Environ. Qual. 17:124-130.
National Agricultural Statistics Service. 2004. New York Turfgrass Survey. Washington, DC. http://www.nysta.org/news/nystapr/2004/Turfbook04.pdf (Accessed 13 Apr. 2012).
National Agricultural Statistics Service. 2006. Maryland Turfgrass Survey. Washington, DC. http://www.nass.usda.gov/Statistics_by_State/Maryland/Publications/Miscellaneous/turfgrass2006.pdf (Accessed 13 Apr. 2012).
Petrovic, A.M. 1990. The fate of nitrogenous fertilizers applied to turfgrass. J. Environ. Qual. 19:1-14.
Petrovic, A.M., and Z.M. Easton. 2005. The role of turfgrass management in the water quality of urban environments. Int. Turfgrass Soc. Res. J. 10:55-69.
R Development Core Team. 2011. R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.
Reisner, M. 1993. Cadillac desert: The American West and its disappearing water. Penguin Books, New York.
Scheaffer, R.L., W. Mendenhall, and L. Ott. 1979. Elementary Survey Sampling, 2nd Ed. Duxbury Press. North Scituate, Massachusetts.