Association Between Local Land Use and Herbicide Concentrations in Wetlands of the Platte River Basin, Nebraska

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Abstract

Association between local land use and concentrations of selected herbicides in wetlands was examined at 31 sites in Nebraska. Sites were selected based on water depth, surface area, and the management of sites as wildlife habitat. In May and August 1994, water-column samples were collected at each of the sites and were analyzed for selected herbicides.

The wetlands were categorized into three groups consisting of 8 to 13 sites, each based on a cluster analysis of land use within a 1-kilometer radius. Sites in group 1 contained about 74 percent rangeland; group-2 sites contained about 14 to 30 percent each of rangeland, cropland, and wetland; and group-3 sites contained about 78 percent cropland. Significant differences in herbicide concentrations in the water column between groups were identified using Wilcoxon-Mann-Whitney tests. Atrazine and total herbicide concentrations in the water column were found to be significantly different between groups 1 and 3 and groups 2 and 3 in both May and August. Atrazine and total herbicide concentrations between groups 1 and 2 were not significantly different in May or August samples. These results indicate that herbicide concentrations in the water column in wetlands within the Platte River Basin may be directly related to local land use.

Keywords: Wetlands, Land Use, Atrazine, Herbicides, Platte River

Introduction

Primary land use in Nebraska is agriculture related; however, Dahl (1990) estimated that during the 1980's, about 1.9 million acres of wetlands existed within the State. These wetlands have a variety of functions, including: flood and erosion moderation, sediment trapping, nutrient retention, and potential ground-water recharge. Wetlands in Nebraska also provide critical habitat for wildlife. Wetlands along the Platte River and in other areas are recognized as migrational and breeding habitat for numerous shorebirds and waterfowl (Gersib, 1991).

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As a predominantly agricultural state, Nebraska relies on large quantities of herbicides to sustain crop production. In 1987, approximately 90 percent of the corn, soybean, and grain sorghum acreage in the State was treated with herbicides, which included a total of almost 26 million kilograms of alachlor, atrazine, cyanazine, and metolachlor (Baker et al., 1990). Over the past 15 years, research has unmasked a number of "environmental hormones"—chemicals and pollutants that disrupt biological processes, often by mimicking the effects of naturally produced hormones such as the female hormone estrogen (Raloff, 1984). Exposure to endocrine-disrupting chemicals in the environment has been associated with abnormal thyroid function in birds and fish; decreased fertility in birds, fish, shellfish, and mammals; decreased hatching success in fish, birds, and turtles; demasculinization and feminization of male fish, birds, and mammals; defeminization and masculinization of female fish, gastropods, and birds; and alteration of immune function in birds and mammals (Colborn et al., 1993). The herbicides alachlor and atrazine are among the chemicals with widespread distribution in the environment reported to have reproductive and endocrine-disrupting effects (Colburn et al., 1993). Recent studies have been conducted to document the occurrence of agricultural chemicals in ground water, streams, and reservoirs (Spalding, 1990; Bevans et al., 1993; Goolsby et al., 1993); however, little has been done to determine the effects of agricultural land use on the water quality of adjacent wetlands.

As part of the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program (Hirsch et al., 1988), a multidisciplinary study of water resources of the Platte River Basin, the Central Nebraska Basins NAWQA, was initiated in 1991. The principal objectives of the project are to determine the status and trends of the quality of water resources and to identify natural and human factors affecting these resources. As part of this study, selected wetlands within the basin were sampled to collect baseline chemical, physical, and biological data. The atrazine and total herbicide data from the water-column samples along with existing land-use coverages were used to determine the effects of local land use on the concentrations of herbicides within selected wetlands in the Platte River Basin.

Description of the Study Area

The Central Nebraska Basins NAWQA study area consists of the region drained by the Platte River from North Platte, Nebraska, downstream to the river's confluence with the Missouri River south of Omaha, Nebraska (Fig. 1). The study area consists of about 78,000 square kilometers, and includes the Elkhorn, Cedar, Dismal, and Loup Rivers, as well as smaller tributaries. The climate within the basin ranges from semiarid to subhumid, with mean annual precipitation varying from about 46 centimeters in the northwest to about 76 centimeters in the east. The western part of the basin is characterized by vegetated sand dunes ranging in topographic relief from a few meters to more than 100 meters (Bleed and

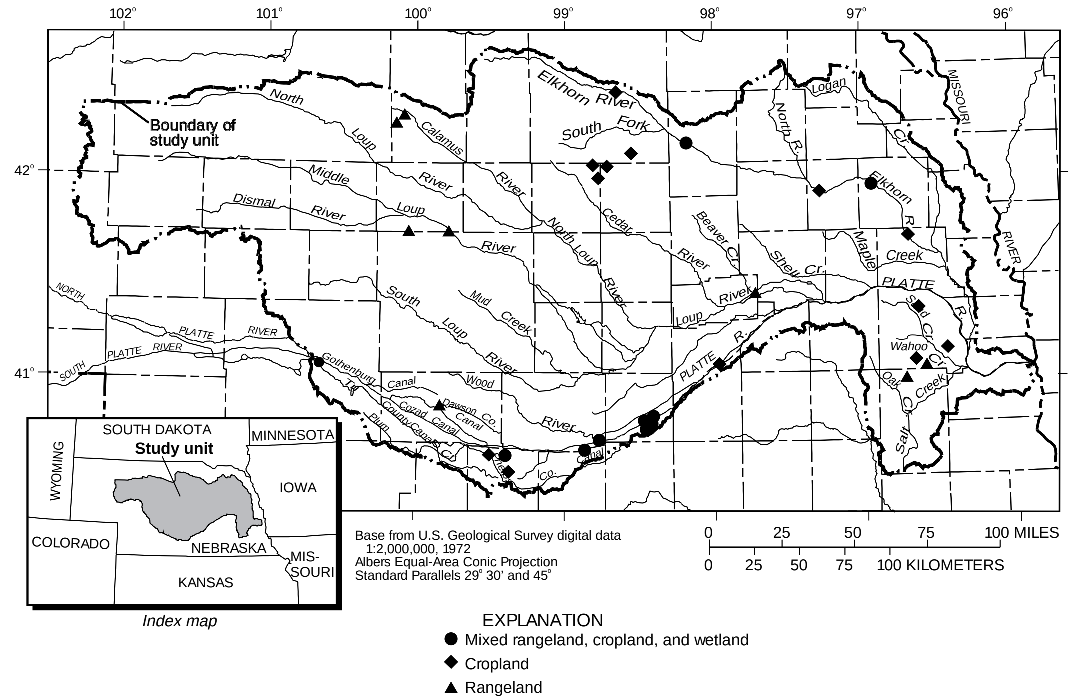

Figure 1. Location of wetlands by land-use group within the Platte River Basin, Nebraska.

Flowerday, 1990), and the dominant land use is rangeland. Land in the remainder of the study area is generally used for crop production, except for small to medium-sized urban areas along the Platte River, and areas of rangeland that occur where local relief and dissections are most pronounced (Zelt and Jordan, 1993).

Methods

Initial site selection was based on wetland management practices. The U.S. Fish and Wildlife Service's National Wetland Inventory (NWI) data (U.S. Fish and Wildlife Service, 1981) was used to identify wetlands that occurred in wildlife management areas within the State. Private organizations and local natural resources agencies also were contacted to identify additional wetlands that were managed as wildlife habitat, as well as privately-owned sites with little or no maintenance. Initially, 84 wetlands were selected, generally characterized as palustrine wetlands, less than 20 acres in size, with a water depth at low water of less than 2 meters, and lacking wave-formed or bedrock shoreline features (Cowardin et al.,1979). Although most of the wetlands were small, isolated water bodies with emergent vegetation, sites also included vegetated areas occurring shoreward of lakes or on river floodplains. Generally, sites selected included only wetlands that were seasonally or semi-permanently flooded, as indicated on the NWI maps. Following reconnaissance to identify wetlands with sufficient surface area and water depth to remain wet during sampling periods in May and August, and with adequate vegetation for aquatic invertebrate habitat, 31 sites were selected (Fig. 1).

Wetland sampling was conducted in May 1994, shortly after initial herbicide and fertilizer application to adjacent cropland, and in August 1994, several months into the growing season. Generally, a transect was established along a gradient of habitats from shoreline to shoreline. Water-column samples were collected with a polytetrafluoroethylene well bailer at either 5 or 10 equidistant points along the transect and then composited. Where average water depth was approximately 2 centimeters or less, water-column samples were collected with a syringe. Approximately 4 liters of water were collected and composited at each site. Two sites sampled in May 1994 were not sampled in August due to extreme water level changes.

Water-column samples analyzed for selected herbicides were pre-processed according to NAWQA procedures (Shelton, 1994), and sent to the U.S. Geological Survey's Organic Research Laboratory in Lawrence, Kansas for analysis using gas chromatography/mass spectrometry (Meyer et al., 1993). Water samples were analyzed for the following herbicides: acetochlor, alachlor, ametryn, atrazine, cyanazine, metolachlor, metribuzin, prometon, prometryn, propazine, simazine, and terbutryn, and for the atrazine metabolites deethylatrazine and deisopropylatrazine. Additional quality-assurance samples were sent to the laboratory to verify that the concentrations of herbicides detected were not influenced by sampling methods, processing techniques, or equipment contamination. These samples included replicate, reference, and blank-water samples. Generally, the detection level for the herbicides and atrazine metabolites was 0.05 micrograms per liter. For deisopropylatrazine, the detection level of 0.20 micrograms per liter for the analysis of samples collected in May was lowered to 0.05 micrograms per liter for the analysis of samples collected in August.

The dominant categories of land use adjacent to the sites were identified using geographical information system (GIS) coverages. The estimation of the percentage of each land-use category within a wetland drainage area would require a detailed knowledge of the hydrology of the site. Lacking this information, a fixed radius of 1 kilometer was used to determine the percentages, and based on these percentages, the sites were organized into groups using a cluster analysis technique. The cluster procedure begins with each site as an individual cluster and progressively combines sites (based on Euclidean distance) until the specified number of groups is obtained.

Wilcoxon-Mann-Whitney tests (Snedecor and Cochran, 1989) then were used to compare atrazine and total herbicide concentrations of groups 1 and 2, 2 and 3, and 1 and 3, to determine if differences between groups are significant. All values for herbicide concentrations less than the detection level were considered to be one-half the detection level for the Wilcoxon-Mann-Whitney tests.

Results and Discussion

Almost 94 percent of the wetlands sampled during the study contained detectable amounts of the selected herbicides or metabolites. Table 1 shows the number of samples and herbicide detections, and the range and median concentrations of the herbicides and metabolites commonly detected.

Atrazine is the most heavily used herbicide in Nebraska (Baker et al., 1990), and was detected in 94 percent of the samples collected in May 1994, and in 64 percent of the samples collected in August 1994. Concentrations ranged from 0.06 to 15 micrograms per liter in May and 0.07 to 3.0 micrograms per liter in August. The herbicides alachlor, cyanazine, and metolachlor, and the atrazine metabolites, deethylatrazine and deisopropylatrazine were also detected at several sites. Few studies have documented the occurrence of herbicides in wetlands in the Midwest; however, a study of reservoirs yielded similar results with these compounds detected in 82 to 92 percent of the samples collected during four sampling periods from April to November 1992 (Goolsby et al., 1993).

Although the selected herbicides generally were detected 33% more often in May than August, median concentrations of the herbicides detected in August were higher (Table 1). A study of Lake Perry, Kansas found that the timing of precipitation and runoff affected the amount of atrazine flushed into the reservoir (Fallon, 1994). Throughout much of the Central Nebraska Basins study area, precipitation for May 1994 was 50 percent or more below the monthly normal values (National Oceanic and Atmospheric Administration, 1994). Higher herbicide concentrations likely would have been detected in the wetlands in May had the amounts of precipitation and the resulting runoff been greater immediately following herbicide application. During the study of Lake Perry, the deethylatrazine-to-atrazine ratio (DAR) was used to determine the relative age of atrazine in the reservoir, and the lowest DARs (<0.10) were found immediately after the runoff events following atrazine application. These DARs in the reservoir gradually increased (up to 0.29) during the growing season as atrazine degraded in the soil, flushed off fields, and moved into the reservoir (Fallon, 1994). The median DARs in the wetlands in May and August were 0.23 and 0.5, respectively. Although the median DAR was lower in May than in August, both values are indicative of atrazine degradation that has taken place en route to the wetland or within the wetland, and are not typical of DARs calculated from areas receiving runoff immediately following herbicide application.

Analysis of GIS coverages identified three dominant land-use categories—rangeland, cropland, and wetland. Additional land-use categories were identified, but did not significantly affect the formation of clusters and were eliminated during the cluster analysis. The sites were organized into the following three groups: group 1 had 8 sites, and surrounding land use consisted of about 74

Table 1. Concentrations of herbicide compounds frequently detected in the Platte River Basin wetlands, May and August 1994 (*, all concentrations are in micrograms per liter).

Herbicide or atrazine metabolite	Number of detections (number of) samples) May-August	Concentrations detected* Range May-August	Median May-August
Alachlor	10(31) 1(29)	0.05-2.8 0.37	0.09 0.37
Atrazine	29(31) 18(29)	0.06-15 0.07-3.0	0.28 0.40
Cyanazine	16(31) 4(29)	0.06-1.6 0.08-3.0	0.17 0.29
Deethylatrazine	16(31) 17(29)	0.05-1.7 0.05-2.2	0.18 0.24
Deisopropylatrazine	3(31) 8(29)	0.09-0.46 0.05-0.44	0.26 0.23
Metolachlor	21(31) 3(29)	0.05-1.8 0.07-0.64	0.10 0.22

Table 2. Atrazine and total herbicides concentrations detected in the Platte River Basin wetland groups, May and August 1994 (*, all atrazine and total herbicide concentrations are in micrograms per liter).

Group Number (dominant land use)	Number of detections (number of) samples) May August	concentrations detected Range May August	Median May August	Number of detections (number of) samples) May August	concentrations detected Range May August	Median May August
Group 1 (rangeland)	6(8) 2(7)	0.09-0.70 0.07-0.40	0.16 0.23	6(8) 2(7)	0.25-1.4 0.07-0.76	0.35 0.41
Group 2 (mixed)	10(10) 5(10)	0.06-0.49 0.07-0.75	0.19 0.10	10(10) 6(10)	0.12-1.1 0.13-1.3	0.44 0.27
Group 3 (cropland)	13(13) 11(12)	0.14-15 0.14-3.0	0.38 0.92	13(13) 11(12)	0.24-22 0.23-6.2	0.86 2.3

percent rangeland; group 2 had 10 sites, with surrounding land use of 14 to 30 percent of each of the three categories; and group 3 had 13 sites of which the dominant land use was cropland (about 78 percent). Although the sites selected are generally managed as wildlife habitat, over one-third of all the sites were surrounded by cropland.

Results are summarized by group in Table 2. The number of total herbicide detections included sites with one or more herbicide or atrazine metabolite detections. Total herbicide concentration is defined here as the sum of the concentrations of all herbicides and atrazine metabolites detected (Table 2). Although herbicides are detected frequently in all groups during May, the number of herbicide detections in areas not dominated by cropland dropped substantially in August. Based on the Wilcoxon-Mann-Whitney tests, the concentrations of atrazine in the water column of each group were found to be significantly different between groups 1 and 3 (p=0.003 and p=0.005, in May and August, respectively) and groups 2 and 3 (p=0.01 and p=0.005 in May and August, respectively). Similarly, median concentrations of total herbicides differed significantly between groups 1 and 3 (p=0.006, in both May and August) and groups 2 and 3 (p=0.007 and p=0.009 in May and August, respectively). Although herbicide concentrations between groups 1 and 2 were not significantly different, atrazine and other herbicides were detected in May and August at 89 and 41 percent of the sites in these groups, respectively.

The results indicate that whereas wetlands surrounded predominantly by cropland have significantly higher concentrations of atrazine and other selected herbicides than other wetlands, agricultural chemicals are present in almost all sites sampled, regardless of surrounding land use. Among the herbicides frequently detected were atrazine and alachlor, two compounds reported to have disruptive effects on the endocrine, reproductive, and immune systems of wildlife due to direct or indirect exposure during critical periods of development (Colburn, 1993).

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