Descriptive and experimental studies on the biotic and abiotic determinants of selected pesticide concentrations in prairie wetland water columns

by

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A Thesis
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Abstract

The determinants of high use agricultural pesticide concentrations in the water columns of Prairie Pothole Region (PPR) wetlands were examined to evaluate if these ecosystems had characteristics of pesticide sinks. For an ecosystem to function as a pesticide sink it needs to receive, retain, and reduce pesticides.

A survey of sixty PPR wetlands (distance between two farthest sites 1,700 km) was conducted to determine the extent to which they received high use pesticides (atrazine and lindane). Sixty-two percent of the wetlands were contaminated with either atrazine or lindane. Pesticide presence was directly related to wetland proximity to pesticide use and precipitation prior to sampling. In June-July lindane presence was positively correlated with phytoplankton concentration; however, in August lindane presence was negatively correlated with phytoplankton concentration.

Laboratory and *in situ* (Delta Marsh, MB) experiments showed that phytoplankton can determine pesticide water column concentrations. For instance, phytoplankton can sorb lindane and remove it from the water column through sedimentation. The extent of pesticide sorption to phytoplankton (*Selenastrum capricornutum*) was directly related to the pesticides' octanol-water partition coefficient. Sorption to phytoplankton decreased volatilization of the pesticide trifluralin. The presence of wetland water column conditions (such as phytoplankton and other particulate matter) increased degradation of atrazine, lindane, and, glyphosate. *In situ* experiments did not detect any atrazine or lindane photolysis. The limited amount of ultraviolet penetration, due to attenuation by aquatic macrophytes, suspended particulates, and dissolved organic carbon, prevented photolysis from being a significant pesticide reduction mechanism in the studied wetlands.

PPR wetlands do posses characteristics of pesticide sinks in that they can receive, retain, and reduce pesticide concentrations. This understanding of wetlands as pesticide sinks will be useful in managing natural and constructed wetlands. Wetland managers should be aware of the high percentage of wetlands that are at risk of receiving pesticides as these may alter ecosystem dynamics. Furthermore, knowledge of the role of algae in determining pesticide concentrations could be used to manage constructed wetlands so as to maximize pesticide retention and reduction.

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The research presented in this thesis truly represents a journey. Thanks to the above mentioned people and organizations I not only completed the journey but I enjoyed the ride.

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Chapter 1: Introduction

Agriculture of the North American Prairie Pothole Region (PPR) has always implemented measures to protect crops from pest damage. Early pest control strategies included primarily physical control measures such as burning and tilling fields (National Research Council 1996). Shortly after the conclusion of World War II, pesticide application became the primary means of pest control (Cunningham 1997). The term pesticide is a general term referring to chemicals which kill or control pest organisms such as insects, weeds, and fungi (Ware 1999). The majority of agricultural pesticides used in the PPR are xenobiotic meaning that they are of anthropogenic origin (Manitoba Agriculture and Food 2001).

Pesticides applied to agricultural fields have the potential to be transported into surrounding environments. Wetlands could potentially be the PPR environment most at risk of agricultural pesticide contamination. A reason for this is due to the abundant number of PPR wetlands (1.04 million hectares of wetlands in North and South Dakota alone, Kantrud *et al.* 1989a), these wetlands are often in close proximity to agricultural fields (Figure 1).

Once in a wetland the impact of a pesticide will be a function of its environmental fate. If a pesticide is rapidly degraded its effect on the environment would be expected to be minimal. Conversely, if a pesticide is persistent and readily bioavailable, it may have a great impact on the wetland ecosystem. Pesticide fate in aquatic ecosystems such as lakes, rivers, and groundwater has been extensively studied (e.g., Gould 1972, Meyer and Thurman 1996). However, relatively few studies have examined pesticide fate in wetland ecosystems (Goldsborough and Crumpton 1998, Davis and Froend 1999). Environmental conditions in prairie wetlands differ from other aquatic environments in which pesticide fate has been studied. Wetlands are typically shallower, warmer and more productive than other aquatic ecosystems (Mitsch and Gosselink 2000). Thus, extrapolation of pesticide

Figure 1. Photograph showing close spatial relationship between wetland and agriculture within the PPR.

persistence data from other aquatic environments to wetlands may be incorrect. An understanding of the determinants of pesticide concentrations in wetlands is needed in order to reduce the risk of wetland contamination and to evaluate the value of wetlands as pesticide sinks.

1.1. Prairie Pothole Region

The Prairie Pothole Region covers an area of 715,000 km^2 (Euliss *et al.* 1999) and extends across three Canadian provinces and five American states (Figure 2). The PPR corresponds to the extent of glacier movement during the Pleistocene Epoch (Mitsch and Gosselink 2000). The overall landscape of the PPR can be described as flat to gently rolling (Sheehan *et al.* 1987). The general geology of the PPR consists of a thin layer of glacial drift which covers stratified sedimentary Mesozoic and Cenozoic rock (Winter 1989). The main soil zones found in the PPR are the Black, Brown, and Dark Brown Soil Zones (Figure C2; Sheehan *et al.* 1987). The climate of the PPR is continental (Winter 1989), characterized by extreme temperatures ranging from 40°C in the summer to -40°C in the winter (Winter 1989). The PPR climate can also be described as being semi- arid and wetlands have a negative water balance with respect to the atmosphere (Winter 1989). Within the PPR there is a north to south gradient of decreasing precipitation as well as a west to east gradient of decreasing precipitation (Euliss *et al.* 1999). The PPR climate is also characterized by wet-dry cycles in which years of drought can be followed by years of abundant rainfall (Winter 1989). Tall grass, short grass, and mixed grass prairie can be found in the PPR (Ducks Unlimited 2001). In addition, the northern portion of the PPR contains aspen parkland, which is characterized by deciduous forests of poplar (*Populus balsamifera*) and quaking aspen (*P. tremuloides*) (Greenwood *et al.* 1995).

1.1.1 Wetlands

Wetland types

There are a number of ways to classify wetlands (Cowardin *et al.* 1979, Weller 1994, Environmental Protection Agency (EPA) 1995, Warner and Rubec 1997, Mitsch and

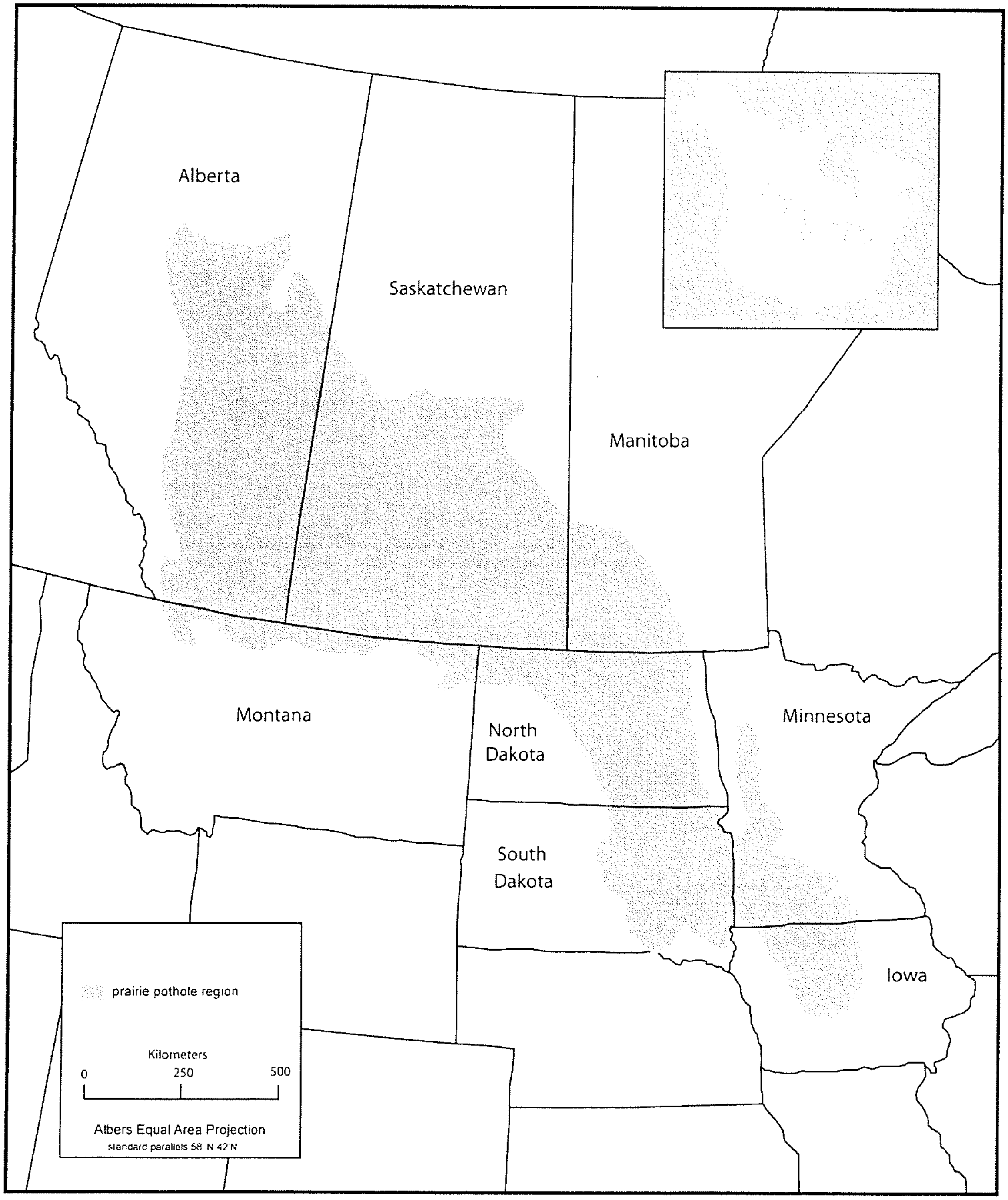

Figure 2. Map of the Prairie Pothole Region of North America.

Gosselink 2000). As the majority of the PPR lies within Canada (Figure 2) I will be using the Canadian Wetland Classification Scheme in my discussion. This classification scheme recognizes five wetland classes based on the "overall genetic origin of the wetland ecosystem and the nature of the wetland environment" (Warner and Rubec 1997) (Table 1). The most abundant wetland class found in the PPR is the marsh (Warner and Rubec 1997).

Most of wetlands in the PPR prairies are of glacial origin (Sheehan *et al.* 1987). During the Pleistocene Epoch when the glacier receded numerous topographical depressions were left behind (Winter 1989, Mitsch and Gosselink 2000). Later many of these depressions filled with water to form wetlands. They are often called potholes because they tend not to have permanent surface inflow or outflow channels (Winter and Woo 1990). Instead they receive water primarily from precipitation, surface runoff and groundwater inflow and lose water primarily through evaporation, transpiration and groundwater outflow (Winter 1989, Winter and Rosenberry 1995). Depending on the amount of precipitation, there can be great seasonal and annual variability in the number of pothole depressions that contain water (Kantrud *et al.* 1989a, Larson 1993, LaBaugh *et al.* 1996). Pothole wetlands are usually classified based on their water permanency (Stewart and Kantrud 1971, Sheehan *et al.* 1987, Warner and Rubec 1997) (Table 2).

Wetland societal values

PPR wetland functions can have corresponding societal values associated with them (Preston and Bedford 1988, Bond *et al.* 1992, Woodward and Wui 2001). For the purpose of the current discussion I will be addressing wetland functions and societal values by looking at the following general categories: wildlife habitat, hydrologic functions, and biogeochemical functions.

Wetlands are able to support a wide array of wildlife due to their unique position as environmental transition zones (Mitsch and Gosselink 2000). Waterfowl are one important group of wildlife that uses the wetland habitat and it has been estimated that the

Table 1 Description of the Canadian Wetland Classification system (Warner and Rubec 1997).

Wetland Class	Characteristics
Bog	Surface raised or level with surrounding terrain; water table at or slightly below the surface and raised above the surrounding terrain; surface waters acidic; moderately decomposed *Sphagnum* peat with woody remains of shrubs; most frequently dominated by *Sphagnum* mosses with tree, shrub or treeless vegetation cover; thickness of peat exceeds 40 cm
Fen	Surface is level with the water table, with water flow on the surface and through the subsurface; fluctuating water table which may be at, or a few centimeters above or below the surface; decomposed sedge or brown moss peat; graminoids and shrubs characterize the vegetation cover; thickness of peat exceeds 40 cm
Swamp	Peatland and mineral wetland; water table at or below the surface; highly decomposed weedy peat and organic material; coniferous or deciduous tress or tall shrub vegetation cover
Marsh	Mineral wetlands; shallow surface water which fluctuates dramatically; little accumulation of organic material and peat of aquatic plants; emergent aquatic macrophytes largely rushes, reeds, grasses, and sedges and some floating aquatic macrophytes
Shallow open water	Transitional between those wetlands that are saturated or seasonally wet (i.e., bog, fen, marsh, or swamp) and permanent, deep water bodies (i.e., lakes) that have a developed profundal zone