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Review

Use of glyphosate for managing invasive cattail (*Typha* spp.) to disperse blackbird (Icteridae) roosts

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ABSTRACT

Hybrid cattail (*Typha* × *glauca* Godr.) has become the dominant emergent vegetation in many wetlands of central North America's Prairie Pothole Region (PPR). Hybrid cattail, an invasive species, can outcompete native emergents and form a dense canopy that alters the original physiognomy and ecological processes of the wetland. Blackbirds (Icteridae), which number in the millions in late summer in the PPR, use cattails for reproduction, loafing and roosting. Ripening crops, especially sunflower, planted near wetland roost sites can sustain considerable economic damage from blackbirds. Producers of sunflower in North Dakota and South Dakota can obtain assistance from the U.S. Department of Agriculture's Wildlife Services unit to prevent blackbird damage. Beginning in 1991, Wildlife Services began aerially spraying cattails with glyphosate herbicide to reduce roosting substrate and lessen the severity of localized sunflower damage. As the program enters its 20th year, we review published research aimed at assessing the ecological effects and efficacy of glyphosate use in wetlands. Additionally, we incorporate unpublished data gathered to enhance the program's environmental safety and efficacy.

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1. Introduction

1.1. Sunflower and blackbirds

Sunflower is an important commodity to rural economies of North Dakota and South Dakota (Bangsund and Leistritz, 1995). In 2009, these 2 states produced 76% (1.1×10^6 metric tons) of the U.S. crop (NASS, 2010a). Sunflower became a viable rotational crop in the region in the early 1970s; and from the start, blackbirds (Icteridae) targeted it as a major source of food (Guarino and Cummings, 1985; Hothem et al., 1988; Linz et al., 2002). Blackbirds gorge on the calorie-rich sunflower achenes throughout late summer and early fall preparing for the physical and energetic stresses of migration (Linz et al., 1983b, 1984; Homan et al., 1994). The 3 species causing damage, in order of importance, are the red-winged blackbird (*Agelaius phoeniceus* L.), common grackle (*Quiscalus quiscula* L.) and yellow-headed blackbird (*Xanthocephalus xanthocephalus* Bonaparte). In aggregate, about 75 million blackbirds stage in North Dakota and South Dakota over the duration of pre-migratory and migratory periods beginning in late August and ending in October (Peer et al., 2003).

Annually, U.S. Department of Agriculture's Wildlife Services (USDA-WS) receives hundreds of requests for assistance to protect agricultural crops from damage caused by blackbirds. A majority of requests are for protection of sunflower fields planted near cattail-dominated wetlands, where damage can be economically unsustainable, forcing some growers to remove sunflower from planting rotations (Linz and Homan, 1998; Kleingartner, 2002). In fact, Otis and Kilburn (1988) found that the main predictor of severity levels of blackbird damage is presence–absence of nearby wetlands, with fields located near wetlands receiving 2–4× more damage. A cattail-dominated wetland can harbor >70,000 blackbirds, with wetlands containing >20,000 birds being common in North Dakota (Linz et al., 2003). Blackbirds emanating from cattail roosts employ a foraging strategy that limits their activity radii. For example, >80% of sunflower fields visited by radio-tagged red-winged blackbirds occurred ≤10 km from roost sites (Besser et al., 1981). Choosing the closest available high quality food source provides the bird with an optimal energy gain per unit of energy expended and allows for more rapid storage of migratory energy reserves (Pyke, 1984). Additionally, blackbirds are molting in late summer, which hampers flight efficiency and tends to restrict flight distances (Linz et al., 1983a).

Peer et al. (2003) used bioenergetics and population models to determine that annual direct economic cost from blackbird predation was US$5.0 to $10.0 million. This estimate was

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comparable to the US$4.0 to $11.0 million loss calculated from field surveys of damage conducted statewide in North Dakota, South Dakota and Minnesota in 1979 and 1980 (Hothem et al., 1988). During these years, average field loss was 1–2%, with 2% of surveyed fields showing losses >10%. This amount of damage should not cause serious conflicts between blackbirds and sunflower producers; however, the extent and pattern of damage are inadequately portrayed for the growers that plant in areas with high wetland densities. In the 1990s, 345 randomly selected fields in 4 important sunflower producing counties located in the Prairie Pothole Region (PPR) of North Dakota and South Dakota were surveyed for bird damage; of these, 36 (10%) had damage ≥5% and 22 (6%) ≥10% damage (Linz et al., 2002). Damage >5% is considered an economically important threshold. The high incidence of damage found in this survey probably resulted from a direct relationship between blackbird abundance and distribution of cattail-dominated wetlands (Otis and Kilburn, 1988; Forcey et al. 2008).

In 1991, USDA-WS initiated a cattail management program in North Dakota and South Dakota with a goal to disrupt the critical habitat link between blackbird damage to sunflower and nearby cattail-dominated wetlands (USDA, 2006). Through 2009, USDA-WS has annually sprayed about 1500 ha of cattail, using aerial applications of the herbicide, glyphosate. The techniques used by USDA-WS were developed by scientists over 20 years of experimental research that included studies on spray pattern (strips), percent coverage, glyphosate concentrations and volumes and environmental impacts. In this paper, we review the literature used to support scientific needs of the management program. Moreover, we incorporate findings from unpublished research that enhanced environmental safety and efficacy of the program as it developed and progressed.

2. Cattails in the Prairie Pothole Region

Narrow-leaved cattail (*Typha angustifolia* L.), an Old World species, was well established in eastern North America by the late 1800s (Hotchkiss and Dozier, 1949; Stuckey and Salamon, 1987; Kantrud, 1992). Narrow-leaved cattail hybridized with the indigenous common cattail (*Typha latifolia* L.) and produced a viable cross that is now considered a separate North American species, hybrid cattail (*T.* × *glauca* Godr.). Wind-borne seeds quickly established new stands. By the 1950s, both narrow-leaved and hybrid cattail were commonly found in the PPR (Stevens, 1963; Kantrud, 1992). Hybrid cattail is a generalist and can be found in shallow-water areas (<30 cm) and mudflats of wetlands, margins of ponds and lakes, roadside ditches, irrigation canals and backwater areas of rivers and streams. Once established at a site, it spreads rapidly through robust rhizomatous growth (Merendino and Smith, 1991; van der Valk and Davis, 1978).

Hybrid cattail is a successful invader and competitor with native emergents because it is tolerant of shade, moderate salinities, high concentrations of ammonium and water depths up to 72 cm (Waters and Shay, 1992). These characteristics give hybrid cattail a competitive edge that can result in exclusion of native emergent species (Weller, 1975; Davis and van der Valk, 1978; Farrer and Goldberg, 2009). By the 1970s, hybrid cattail was the most abundant large hydrophyte in wetlands of the PPR (Kantrud, 1992; Galatowitsch and van der Valk, 1994). Wetlands, formerly consisting of mosaics of open water and sparse stands of hardstem bulrush (*Schoenoplectus acutus*, syn *Scirpus*; Buhl ex Bigelow A. Löve and D. Löve), were closed by dense canopies of hybrid cattail (Kantrud, 1992).

The loss of spatial heterogeneity caused by invasive cattail has resulted in declines in diversity and abundance of numerous wetland species and has provided a refuge for migrating blackbirds (Kantrud, 1986; Solberg and Higgins, 1993; Linz et al., 2003). These concerns led Ralston et al. (2007) to estimate the areal coverage of cattail in North Dakota's PPR (97,042 km^2) using 120 3.2 × 3.2 km sample plots. They identified 15,986 wetlands (= 1.1 ha), with 4494 (28%) wetlands (= 2.4 ha) containing cattails. Coverage of cattail averaged 37% of wetland basin areas. Semipermanent wetlands contained over 50% of the total cattail observed in the sample. Semipermanent wetlands harbor the largest numbers of migrating blackbirds (Linz et al., 2003). In Stutsman County, North Dakota, which is a high sunflower production area, an average of 20,500 blackbirds used wetlands averaging 94 ha (Linz et al., 2003).

3. Glyphosate herbicide

3.1. Glyphosate properties

Mechanical methods for managing cattail (e.g., burning, mowing and disking) are labor-intensive, expensive and often ineffective because the stands quickly reestablish themselves through vigorous growth of rhizomes (Beule, 1979). Moreover, semipermanent wetlands typically contain sufficient standing water to prevent use of mechanical equipment. It is possible to manage cattails by flooding, but wetlands in the PPR seldom have water controls to facilitate this action. To overcome these impediments, state and federal government agencies have opted to use aerially applied glyphosate herbicide for controlling cattails (Sojda and Solberg, 1993; Solberg and Higgins, 1993; Linz et al., 2004). Aerial application is the best method for managing cattail in semipermanent wetlands because basin areas are usually too large for ground-based sprayers (Linz et al., 2003).

Glyphosate ([N-(phosphonomethyl) glycine], Chemical Abstract Number 1071-83-6), is a systemic, broad-spectrum, post-emergence herbicide registered by the U.S. Environmental Protection Agency (USEPA) in 1974 and reregistered in 1993 (USEPA Reg. No. 524-343). The Monsanto Company (St. Louis, Missouri, USA) held the patent on the glyphosate molecule until the year 2000; thereafter, a number of companies began formulating and selling glyphosate under a myriad of trade names. In this paper, we refer only to the aquatic formulations of glyphosate and provide mass in acid equivalents. We caution that glyphosate formulated for terrestrial uses may contain non-herbicidal components and surfactants [e.g., POEA (polyoxyethylene-alkylamine)] that have been found harmful to aquatic life *in vitro* (Folmar et al., 1979; Henry et al., 1994; Mann and Bidwell, 1999; Howe et al., 2004; Relyea, 2005).

Glyphosate is most effective in late summer when cattails are actively metabolizing and transporting carbohydrates to their rhizomes. Glyphosate inhibits protein synthesis by blocking the shikimic acid pathway, a metabolic pathway not present in vertebrates and invertebrates (Cole, 1985; Franz et al., 1997; Alibhai and Stallings, 2001). Plants treated with glyphosate show stunted growth, yellowing, leaf wrinkling and wilting, with tissue death occurring 4–20 days following application (Franz et al., 1997). When treating emergents, the potential exists for glyphosate to reach surface waters. On contact with surface water, glyphosate's herbicidal activity decreases rapidly by 1) adsorption to suspended soil particles and sediment, 2) microbial degradation and 3) photolysis (Bronstad and Friestad, 1985). The major pathway for the compound's destruction is microbial degradation. The half-life of glyphosate in soils and water is 3–140 and 12–70 days, respectively. Linz et al. (1999) monitored glyphosate-treated and reference wetlands for 2 years and found no significant post-treatment effects for abiotic variables, including water temperature, pH, PO_4, NO_3-N, dissolved O_2 and total conductivity.