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Optimizing the use of decoy plots for blackbird control in commercial sunflower

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ABSTRACT

In 2004, USDA's Wildlife Services began to cost share 8-ha Wildlife Conservation Sunflower Plots (WCSP) with sunflower growers to lure migrating blackbirds away from commercial sunflower fields. During late summer and fall of 2004 and 2005, blackbirds used sunflower more than other crops, especially WCSP placed near blackbird roosts. Blackbird density in WCSP and commercial sunflower was negatively associated with nearby habitat types (<2.4 km) that provided alternative foraging locations, including hectares of sunflower, wheat, and fallow lands. Blackbird density was positively associated with shelterbelts, wetlands, and unused habitats, such as soybean fields. Blackbird damage was lower in commercial sunflower fields closely associated with WCSP (≤2.4 km) than commercial sunflower fields >10 km from WCSP. Across both years, birds removed an average of 435 kg/ha and 49 kg/ha of sunflower seed in WCSP and commercial sunflower fields, respectively. Additionally, in 2005, blackbirds removed 181 kg/ha of seed in commercial sunflower >10 km from WCSP (reference fields). WCSP had a cost-benefit ratio of 3.4:1; however, in reference sunflower fields, birds removed 3.2 times more sunflower seed than in commercial sunflower fields near WCSP. Our data suggest that producers should consider planting cost-shared WCSP as part of an integrated pest management strategy to reduce blackbird damage to commercial sunflower.

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1. Introduction

Blackbirds (Icteridae) are responsible for over $US100 million in damage annually to grain, fruit, and other industries in the United States (Linz et al., 2004). Post-breeding blackbird flocks migrating through the Prairie Pothole Region (PPR) of U.S. northern Great Plains often consist of red-winged blackbirds (*Agelaius phoeniceus*), common grackles (*Quiscalus quiscula*), and yellow-headed blackbirds (*Xanthocephalus xanthocephalus*). These mixed-species foraging flocks, estimated to number 70 million, cause economically important damage to commercial crops, especially sunflower (Peer et al., 2003).

Blackbird depredation has been a major production problem for sunflower producers since it became a commercially viable crop in the 1970s (Linz and Homan, 1998). Intensive field surveys conducted annually across North Dakota show that blackbirds consistently impede sunflower producers (Lamey and Luecke, 1991; Berglund, 2008). Peer et al. (2003), using a bioenergetics model, estimated that sunflower growers (@$US0.26/kg) annually sustain blackbird damage over $US5.0 million. Although, blackbirds remove only 2–3% of commercial sunflower annually, damage may be much higher around cattail-dominated (*Typha* spp.) wetlands that are often used as night roosts (Sawin, 1999; Linz et al., 2004). Some growers are forced to plant less profitable crops around traditional roosts and in areas that commonly receive high damage to avoid blackbird depredation (Kleingartner, 2002).

USDA Wildlife Services, in cooperation with sunflower producers, is seeking environmentally safe, non-lethal damage management methods to alleviate blackbird damage to sunflower. Otis and Kilburn (1988) examined environmental factors around highly damaged sunflower fields and found that presence of nearby wetlands significantly increased damage. They recommended that sunflower producers avoid planting near roosts and loafing areas (i.e., cattail-dominated wetlands and shelterbelts) in order to reduce damage, although this can be difficult in the PPR as cattail-inundated wetlands are abundant. Subsequently, management of emergent vegetation in wetlands with glyphosate herbicide was initiated in 1991 as a blackbird roost dispersal technique (Linz et al., 1995; USDA, 2006). This damage management strategy can disperse blackbird roosts, improve waterfowl habitat, and reduce damage to adjacent sunflower fields (Linz et al., 1995; Leitch et al., 1997). Some smaller wetlands are not eligible for the program,

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however, and some producers and resource managers prefer to leave dense cattail stands in tact for resident wildlife (Stromstad, 1992).

Lure or "decoy" plots have been shown to reduce crop damage by blackbirds, waterfowl, cranes, and cockatoos (Gustad, 1979; Cummings et al., 1987; USDA, 1998; Temby and Marshall, 2003). In the early 1980s, Cummings et al. (1987) demonstrated that decoy plantings of sunflower (Wildlife Conservation Sunflower Plots) reduced bird damage to commercial sunflower fields. They concluded that decoy field placement was critical to success and suggested that the decoy crops be planted on state and federal wildlife management areas, refuges, and idle farmland. A cost-share program was not available in the 1980s; therefore, blackbird decoy plots were not widely implemented.

In 2004 and 2005, USDA/Wildlife Services contracted with cooperative sunflower growers to plant blackbird decoy plots, Wildlife Conservation Sunflower Plots (WCSP). Growers planted 8-ha WCSP of oilseed sunflower in locations with historical blackbird problems and were compensated $US375.00/ha and were provided planting seed in 2005. Growers were instructed not to harass blackbirds, harvest, or till WCSP until the spring following planting. We assessed the efficacy of WCSP for reducing blackbird abundance and damage in commercial sunflower. Our objectives were to (1) compare blackbird use of WCSP to commercial sunflower and other non-sunflower crops, (2) determine the intrinsic and extrinsic characteristics of sunflower fields and WCSP that influence blackbird use, (3) evaluate economics of planting WCSP for blackbird damage management, and (4) formulate guidelines for future placement and management of WCSP in the northern Great Plains.

2. Materials and methods

The PPR of the northern Great Plains is composed of agriculture lands, grasslands, shelterbelts, and abundant small wetlands. Our study area was centered in the Southern Drift Plains of east-central North Dakota, but included areas within the Northern Drift Plains and Missouri Coteau (Stewart, 1975). During the summer and fall, the PPR sustains up to 50% of North American waterfowl and millions of wading, grassland, and other migratory birds which use native grasslands, shelterbelts, wetlands, and agricultural fields for habitat (Baldassarre and Bolen, 2006). Small grain, soybean, hay, corn, and sunflower crops are common in the Drift Plains due to the once abundant tall- and mixed-grass prairie that made this land fertile and desirable for cultivation (Stewart, 1975). Sunflower is an important commodity in this region due to local processing and refining infrastructure, but is considered a minor crop (~400,000 ha planted annually) in North Dakota (NASS, 2007).

In 2004 and 2005, cooperators planted 14 and 21 WCSP, respectively, near cattail-dominated wetlands (roosts) and in blackbird damage-prone areas. We conducted point counts and vegetation measurements from 24 August to 19 October 2004 and from 10 August to 28 October 2005 in the WCSP, one commercial sunflower field, and one small grain field within 2.4 km of each WCSP. We used a plastic template (Dolbeer, 1975) to measure bird damage (percent lost and kg/ha) in the WCSP and all commercial sunflower fields ($n = 74$) found within 2.4 km of the WCSP. In 2005, we randomly selected six commercial sunflower and six commercial non-sunflower fields (reference fields), located 10–30 km from any WCSP (within the same physiographical region), for point counts and damage surveys (sunflower only).

We divided fields into 1-ha units and conducted 50-m circular point counts in 15% of randomly chosen hectares not adjacent to one another (Reynolds et al., 1980; Ralph et al., 1995). Regardless of field size, we conducted at least two counts per field from the center of each randomly selected hectare. We measured crop density (number of rooted plants), row width, percent canopy cover using a spherical densitometer (Ganey and Block, 1994), weed density (number of rooted non-crop plants identified to family), surface seed availability (seeds suctioned from soil and litter surface using a portable vacuum), and tallest plant height in two 1-m^2 subplots inside each hectare selected for a point count after bird censuses. We obtained aerial photographs from the USDA's NRCS Digital Gateway and overlaid all major land uses using ESRI's ArcInfo 9.1 Geographic Information System.

In 2004, we surveyed each plot three times, and in 2005, we reduced survey effort to two rounds due to the increased number of study sites and the addition of reference fields, sunflower and non-sunflower crop fields located 10–30 km away from a WCSP. Reference fields were surveyed for birds only once in 2005 due to logistical and time constraints associated with the large study area, bird surveying protocol, and short-time interval in which blackbirds use sunflower in North Dakota in the fall. Sites were surveyed in the same order within each round of observations.

We conducted damage surveys from 30 September to 7 October 2004 and 30 September to 10 October 2005, in all commercial fields within a 2.4-km radius of each WCSP. Each sunflower field had 24 damage assessment points evenly distributed along transects (Hothem et al., 1988). We assessed bird damage in the six reference sunflower fields from 5 October to 7 October 2005. Each damage assessment point included all sunflower heads in the row contained within a 1.5-m linear locale.

2.1. Statistical analysis

To standardize for differences in field sizes, we converted blackbird abundances into relative densities (birds/0.78 ha; hereafter birds/ha) according to the area encompassed by point counts. We did not employ distance sampling methods to obtain accurate estimates of densities because blackbirds flock irregularly (Beletsky, 1996). Instead, we calculated relative blackbird densities to be used as an index between field types and as the response variable in habitat analysis (Martin, 1980). We examined the response variable and all independent variables (Table 1) for correlations and deviation from normality using Microsoft Excel Pop Tools and JMP (SAS Institute Inc., 2005). Non-normal data were transformed using either $\ln(x+1)$ or $\mathrm{sqrt}(x)$ transformations as appropriate. We also examined residuals for clustering and uniform distribution. We used model selection based on Akaike's second-order Information Criterion (AICc) as the primary statistical analysis for comparing habitat and landscape variables to bird abundance because it is sensitive to smaller sample sizes than AIC (Burnham and Anderson, 2002). Incomplete blocks of data were excluded from model selections and compared to blackbird densities using one-way

Table 1
Independent variables consisting of vegetation characteristics observed from all point-count selected hectares, land use hectares within 2.4 km of WCSP, and non-crop plant abundances within each point-count selected ha used in model building

Independent variables		
Vegetation characteristics	Land use	Non-crop plants
Canopy cover	Alfalfa	Amaranthaceae
Crop density	Beans	Asteraceae
Row width	Canola	Brassicaceae
Surface seed availability	Corn	Chenopodiaceae
Tallest plant height	Developed	Poaceae
Weed density	Grass	Polygonaceae
	Fallow	Solanaceae
	Flax	
	Sunflower	
	Trees	
	Wetlands	

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analysis of variance (ANOVA). Incomplete data included metrics not collected during inclement weather and sampling methods used in only one year of the study. We examined blackbird density in WCSP in relation to habitat variables in and around each site using linear mixed models (Proc MIXED in SAS, SAS Institute Inc., 2005; Riffell et al., 2006). We designated year as a random effect and nested survey round within year.

We formed two sets of models for WCSP and commercial sunflower fields, an *a priori* and a *post-hoc* model set. We constructed *a priori* models based on previously published blackbird–habitat relationships and our knowledge of blackbird ecology (Stone and Danner, 1980; Otis and Kilburn, 1988; Homan et al., 1994; Lamey and Dietrich, 2003; Linz et al., 2003). We used SAS Proc MIXED to analyze each independent variable (Table 1) with each response variable and ranked them in order of lowest AICc value (the best performing independent variables) to the highest (the worst performing independent variable) to construct performance-based models (*post-hoc* models). We used a pool of 24 independent variables, however, each model included only 2–5 variables because of small sample size ($n = 35$). All final models were evaluated using SAS Proc MIXED and maximum likelihood estimation as we varied the fixed effects throughout the final models in each set (Littell et al., 1996; Riffell et al., 2006).

Akaike's second-order Information Criterion for model retention was restricted to 10 AICc units as ΔAICc scores > 10 indicate non-competitive models (Burnham and Anderson, 2002). We used model averaging to assess an averaged coefficient or beta value (β) for individual variable performance. This technique is valuable when several models compete or no one model accounts for 0.90 of the model average weights (β). Additionally, we evaluated variable importance to account for uncertainty within the model selection process (Burnham and Anderson, 2002). We ranked all competing models according to ΔAICc, calculated model weights, relative variable importance, and model averaged parameter estimates from the final set of competing models (Burnham and Anderson, 2002; Riffell et al., 2006). Interpretation of independent variable importance was based on biological plausibility of the model, average variable importance across all models, model averaging, and the frequency of inclusion within best model sets and among both response variable sets.

We compared blackbird densities within each field type separately for 2004 and 2005 using ANOVA. We assigned field types as treatment effects and survey round as the repeated measure in Proc MIXED (SAS Institute Inc., 2005). We used *post-hoc* Tukey multiple comparisons to test for differences between WCSP, commercial sunflower, non-sunflower crop fields, reference non-sunflower crop fields, and reference sunflower fields. Similarly, we compared field types with bird damage estimates (dependent variable) using ANOVA in Proc MIXED with the Tukey multiple comparisons test. Additionally, we used bird damage estimates from each WCSP to compare vegetation characteristics with percent damage in each field type using ANOVA following Otis and Kilburn (1988). We used percent damage as the dependent variable and mean values of each vegetation metric across all survey rounds for each independent variable (% canopy cover, row width, density of crop plants, tallest plant height, non-crop seed abundance, and non-crop plant density). Vegetation characteristics were also incorporated in AICc model selection analysis, but often times could not be included due to missing values resulting from the vagaries of weather. We set alpha equal to 0.10 for all analyses.

We report estimates of production and losses due to blackbirds in WCSP and commercial sunflower according to Jaeger et al. (1983). WCSP production was estimated using the data gathered during damage surveys which included area of developed and undeveloped seeds within each head, number of heads per unit area, row width, and field size. As only percent damage was available from our commercial sunflower fields, we used county-wide production data available from the National Agricultural Statistics Service and average field size from those fields surveyed for blackbird abundance within 2.4 of each WCSP ($n = 31$) to generate commercial sunflower production estimates. We used production estimates from commercial fields and published estimates of mature seed weight per unit area of developed sunflower heads (Jaeger et al., 1983) to generate the mass removed by blackbirds. Using average whole seed prices from 2004 and 2005, we estimated the value of seeds lost to birds in WCSP compared to commercial sunflower and generated a cost-benefit ratio of WCSP (Cummings et al., 1987; NASS, 2007).

3. Results

3.1. Blackbird observations

In 2004, blackbird densities differed across all crop types ($P < 0.01$; Fig. 1). Blackbird density was higher in WCSP ($\bar{x}$ = 251 birds/ha; SE = 70.4) than in non-sunflower crops ($\bar{x}$ = 1.7 birds/ha; SE = 1.5), but was similar between WCSP and commercial sunflower ($\bar{x}$ = 200 birds/ha; SE = 75.9). In 2005, blackbird densities differed across all field types ($P = 0.06$). Blackbird density was higher in WCSP ($\bar{x}$ = 27.3 birds/ha; SE = 9.4)

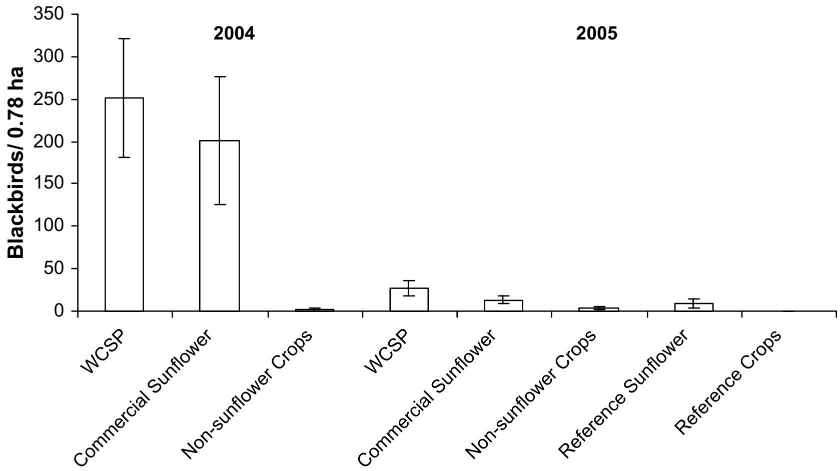

Fig. 1. Relative blackbird density (birds/0.78 ha with SE) in WCSP, commercial sunflower, non-sunflower crops, commercial sunflower not associated with a WCSP (reference sunflower), and non-sunflower crops not associated with a WCSP (reference crop) in 2004 and 2005.

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than in non-sunflower crops ($\bar{x}$ = 3.6 birds/ha; SE = 2.5) and reference non-sunflower crop fields ($\bar{x}$ = 0 birds/ha; SE = 0), but was similar to commercial sunflower ($\bar{x}$ = 13.3 birds/ha; SE = 4.6) and reference sunflower ($\bar{x}$ = 9.3 birds/ha; SE = 4.9).

3.2. Habitat analysis

Blackbird abundance was low in soybean and other non-sunflower crops compared to commercial sunflower and WCSP. Therefore, we omitted soybean and other non-sunflower fields from the habitat analyses. Within WCSP, the top performing model included the variables Poaceae (abundance of plants within this family), wheat (hectares of wheat), and sunflower (hectares of sunflower), and was a performance-based model. Of the 14 variables in the top 4 blackbird models, all those within 1 ΔAICc unit, 12 variables were land uses. In the top 5 model sets for commercial sunflower, models within 1.9 ΔAICc units, 11 of 16 variables were land uses. The top performing model in commercial sunflower included trees (hectares of shelterbelts), corn (hectares of corn), and soybeans (hectares of soybean). Generally, *post-hoc* models had lower ΔAICc scores than *a priori* formulated models due to overwhelming influence of land use variables in all model sets, which was unexpected (Table 2).

Within WCSP, hectares of beans and corn were positively related to blackbird densities (Table 3). Hectares of sunflower, wheat, and fallow lands were negatively related to blackbird densities within WCSP. Poaceae (VI = 0.76), sunflower hectares (VI = 0.68), wheat hectares (VI = 0.67), soybean hectares (VI = 0.48), and fallow hectares (VI = 0.44) had the highest variable importance (VI). In commercial sunflower, blackbird densities were positively related to shelterbelt hectares, Poaceae, soybean hectares, and wetland hectares while negatively related to corn hectares, sunflower hectares, and Chenopodiaceae. The most influential variables on blackbird density in commercial sunflower were trees (VI = 0.80), Poaceae (VI = 0.69), corn (VI = 0.54), soybeans (VI = 0.47), and wetlands (VI = 0.34).

3.3. Blackbird damage

We evaluated bird damage to seed heads just before harvest in each commercial sunflower field ($n = 74$) within 2.4 km of the WCSP, WCSP ($n = 34$), and reference commercial sunflower fields (monitored only in 2005; $n = 6$). In 2004, damage was 4.6% ($n = 25$, SE = 1.4) in commercial fields compared to 38.6% ($n = 13$, SE = 8.9) in WCSP. In 2005, damage was 3.1% ($n = 49$, SE = 0.6) in commercial fields compared to 31.6% ($n = 21$, SE = 6.4) in WCSP and 10.3% ($n = 6$, SE = 3.4) in reference sunflower. Overall, WCSP ($\bar{x}$ = 34.3%, SE = 7.4) received higher damage ($P < 0.01$) than commercial sunflower ($\bar{x}$ = 3.7%, SE = 0.1) or reference sunflower fields ($\bar{x}$ = 10.3%, SE = 5.1) (Fig. 2).

We did not detect an association of vegetation characteristics including row width ($P = 0.85$), abundance of crop plants ($P = 0.11$), percent canopy cover ($P = 0.68$), tallest plant height ($P = 0.54$), total non-crop plant abundance ($P = 0.60$), or non-crop seed weight ($P = 0.72$) with percent bird damage in WCSP.

In 2004, WCSP produced 940 kg/ha ($n = 13$, SE = 171.7) and birds removed 340 kg/ha ($n = 13$, SE = 104.5) or 2720 kg/WCSP. In 2005, WCSP produced 1640 kg/ha ($n = 21$, SE = 74.1) and birds removed 530 kg/ha ($n = 21$, SE = 109.7) or 4240 kg/WCSP. Commercial sunflower seed production for our study area averaged 899 kg/ha in 2004 and 1773 kg/ha in 2005 (NASS, 2007). In 2004, birds removed 41.7 kg/ha ($n = 25$, SE = 8.7) or 1657 kg/commercial field of average size ($\bar{x}$ = 33 ha). In 2005, birds removed 56.3 kg/ha ($n = 49$, SE = 16.1) or 1876 kg/commercial field of average size ($\bar{x}$ = 40 ha). In reference fields in 2005, birds removed 181 kg/ha ($n = 6$, SE = 60.2) or 9560 kg/field of sunflower seed.

In WCSP, birds removed $US88.4/ha or $US707.2/plot in 2004 (@$US0.26/kg) and $US159.0/ha or $US1272.0/plot in 2005 (@$US0.30/kg; NASS, 2007). In commercial sunflower, birds removed $US10.6/ha or $US431.0/commercial field in 2004 and $US16.9/ha or $US563.0/commercial field in 2005. In reference sunflower fields, birds removed $US54.5/ha or $US2,868.0/field, 3.2 times the sunflower seed in WCSP protected commercial sunflower

Table 2
Blackbird candidate models, the formulation technique, and ΔAICc values for WCSP and commercial sunflower

Field type	Formulation	Models	ΔAICc
WCSP	PBM	Poaceae, wheat, sunflower	0
	PBM	Poaceae, fallow, beans, sunflower	0.7
	PBM	Beans, Poaceae, wheat	0.9
	PBM	Beans, fallow, sunflower, wheat	1
	PBM	Poaceae, fallow, beans	2.2
	PBM	Beans, corn, sunflower, wheat	2.4
	PBM	Fallow, Poaceae, wheat, corn	4
	A priori	Poaceae, wetlands, trees, sunflower	5.1
	A priori	Poaceae, wetlands, trees	5.6
	A priori	Chenopodiaceae, Poaceae, trees	6.5
	A priori	Grass, wetlands, trees, Poaceae	7.3
	A priori	Trees, wetlands, sunflower	7.3
	A priori	Chenopodiaceae, Poaceae, wetlands, trees	7.4
	A priori	Asteraceae, wetlands, trees, sunflower	9.4
Commercial Sunflower	PBM	Trees, corn, beans	0
	PBM	Corn, trees, Poaceae	1
	PBM	Corn, beans, Poaceae	1.1
	A priori	Poaceae, wetlands, trees	1.3
	A priori	Chenopodiaceae, Poaceae, wetlands, trees	1.9
	PBM	Beans, Poaceae, corn, trees	2.1
	A priori	Trees, wetlands, sunflower	2.3
	A priori	Chenopodiaceae, Poaceae, trees	2.7
	PBM	Poaceae, Polygonaceae, corn, beans	3.4
	PBM	Poaceae, Polygonaceae, beans	3.4
	A priori	Asteraceae, wetlands, trees, sunflower	3.5
	A priori	Poaceae, wetlands, trees, sunflower	3.7
	A priori	Grass, wetlands, trees, Poaceae	3.7
	PBM	Trees, beans, Poaceae, Polygonaceae	5.1

Performance-based models (PBM) were constructed after data collection. *A priori* models were constructed before completing data collection.

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Table 3
Blackbird model averaging (MA) scores (β) and variable importance (VI) measures for each variable included in the final set of candidate models with 95% confidence intervals (CIs) and the number of models entered

Field Type	Variables	MA – β	β – CI	VI	# Models
WCSP	Asteraceae	−0.00011	0.00000	0.00228	1
	Grass	0.00150	0.00000	0.00653	1
	Chenopodiaceae	0.00108	0.00000	0.01595	2
	Wetlands	0.00217	0.00001	0.05643	6
	Trees	0.00336	0.00002	0.06617	5
	Corn	0.00767	0.00009	0.10963	2
	Fallow	−0.05882	0.00032	0.44690	4
	Beans	0.03013	0.00006	0.48855	4
	Wheat	−0.06210	0.00055	0.67325	5
	Sunflower	−0.04546	0.00033	0.68452	6
	Poaceae	−0.01896	0.00039	0.76321	8
Commercial Sunflower	Grass	−0.00032	0.00000	0.03177	1
	Asteraceae	0.00176	0.00000	0.03511	1
	Polygonaceae	0.00353	0.00002	0.08959	3
	Chenopodiaceae	−0.01487	0.00017	0.13051	2
	Sunflower	−0.00375	0.00004	0.13084	3
	Wetlands	0.01793	0.00004	0.34621	6
	Beans	0.01107	0.00006	0.47888	6
	Corn	−0.07774	0.00038	0.54873	5
	Poaceae	0.05402	0.00007	0.69889	11
	Trees	0.28024	0.00035	0.80962	11

fields. On average, birds removed 435 kg/ha sunflower seed or $US121.8/ha in WCSP, 49.0 kg/ha or $US13.7/ha in commercial sunflower, and 181 kg/ha or $US54.5/ha in reference sunflower fields WCSP (only 2005).

The total value of seeds removed by birds in both years was $US35,905.0 in WCSP. The cost of planting 41 WCSP (~ $US3000.0/WCSP) across both years totaled $US123,100.0 and yielded a direct cost-benefit ratio of 3.4:1. This ratio does not include additional value of wildlife habitat or other benefits provided by the WCSP.

4. Discussion

We found that WCSP placed near roosting areas received higher use and damage than nearby commercial fields and, in 2005, these commercial fields received less damage than randomly selected reference fields not associated with WCSP. Linz et al. (2007) reported similar results finding higher damage in WCSP (60.4%) compared to commercial sunflower fields (17.6%) in 2006. In our study, blackbird use of WCSP was highly variable, with annual damage ranging from 0 to 100%. Thus, blackbirds tend to preferentially select habitats based on some proximate cues. We showed that land use within 2.4 km WCSP influenced blackbirds' use of sunflower, but that blackbird density was not strongly influenced by the abundance of non-crop species, other than grasses, or

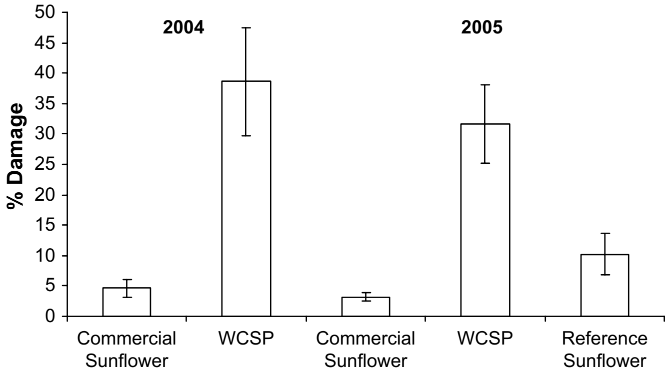

Fig. 2. Percent blackbird damage in commercial sunflower fields and WCSP in 2004 and in commercial sunflower, WCSP, and commercial sunflower not associated with a WCSP (reference sunflower) in 2005 with standard errors.

vegetation characteristics in sunflower fields. Producers should consider juxtaposition of WCSP to sunflower and other blackbird forages such as wheat and fallow lands rather than managing vegetation or manipulating crop characteristics within decoy plots and commercial fields in order to reduce blackbird use.

Blackbirds removed more seed from WCSP and reference sunflower fields than from commercial sunflower associated with WCSP. Similarly, percent damage and dollars lost were higher in WCSP and reference sunflower than protected commercial sunflower, despite commercial fields being 4.6 times larger than WCSP. While the WCSP program is expensive to implement in its current form, there is evidence that WCSP prevented damage to commercial sunflower. In 2005, reference sunflower fields lost $US37.6/ha more than commercial fields associated with a WCSP. The disparity between damage to commercial fields and reference fields may reflect increased energetic costs of blackbirds feeding in commercial fields located considerable distances away from roosts and loafing areas. By planting WCSP in close proximity to roosting habitat, birds conserve flight energy, otherwise used to search for food sources. If we consider the prevented damage from presumed higher energetic costs of foraging in commercial sunflower along with the seed removed in each WCSP, the cost-benefit ratio becomes 2.3:1 and still does not account for guaranteed income (i.e., reduced risk associated with cost-shared WCSP over commercial plantings in the same area), wildlife benefit, and other potential gains associated with WCSP such as over-winter cover.

Given the expense of planting the plots, WCSP are best used to protect high value oil and confectionery sunflower varieties planted near roosts and in flight lines emanating from roosts (Cummings et al., 1987; Otis and Kilburn, 1988). We suggest that the plots (1) be planted near cattail-dominated wetlands that historically have served as night roosts, (2) be placed a short distance from commercial fields but not immediately adjacent to commercial fields, (3) and be planted earlier than commercial fields to habituate birds to sunflower before commercial fields ripen or, alternately, include a mix of varieties that mature at different times to provide ripening sunflower throughout late summer and fall. Additional research is needed on best planting practices, including selection of plot locations, planting times, field size, and variety preferences (Cummings et al., 1987).

Management of blackbird damage to crops is difficult because the birds' foraging patterns are somewhat unpredictable. Further,

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there is a paucity of environmentally safe and effective bird management methods. We recommend that sunflower producers implement an integrated pest management plan that includes cattail management to remove roost habitat, synchronized planting, harassment with pyrotechnics and propane cannons (Linz and Hanzel, 1997), the use of a preharvest dry down product to advance the harvest date and avoid late season bird damage (Johnson and Peterson, 2007), and cost-shared WCSP.

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