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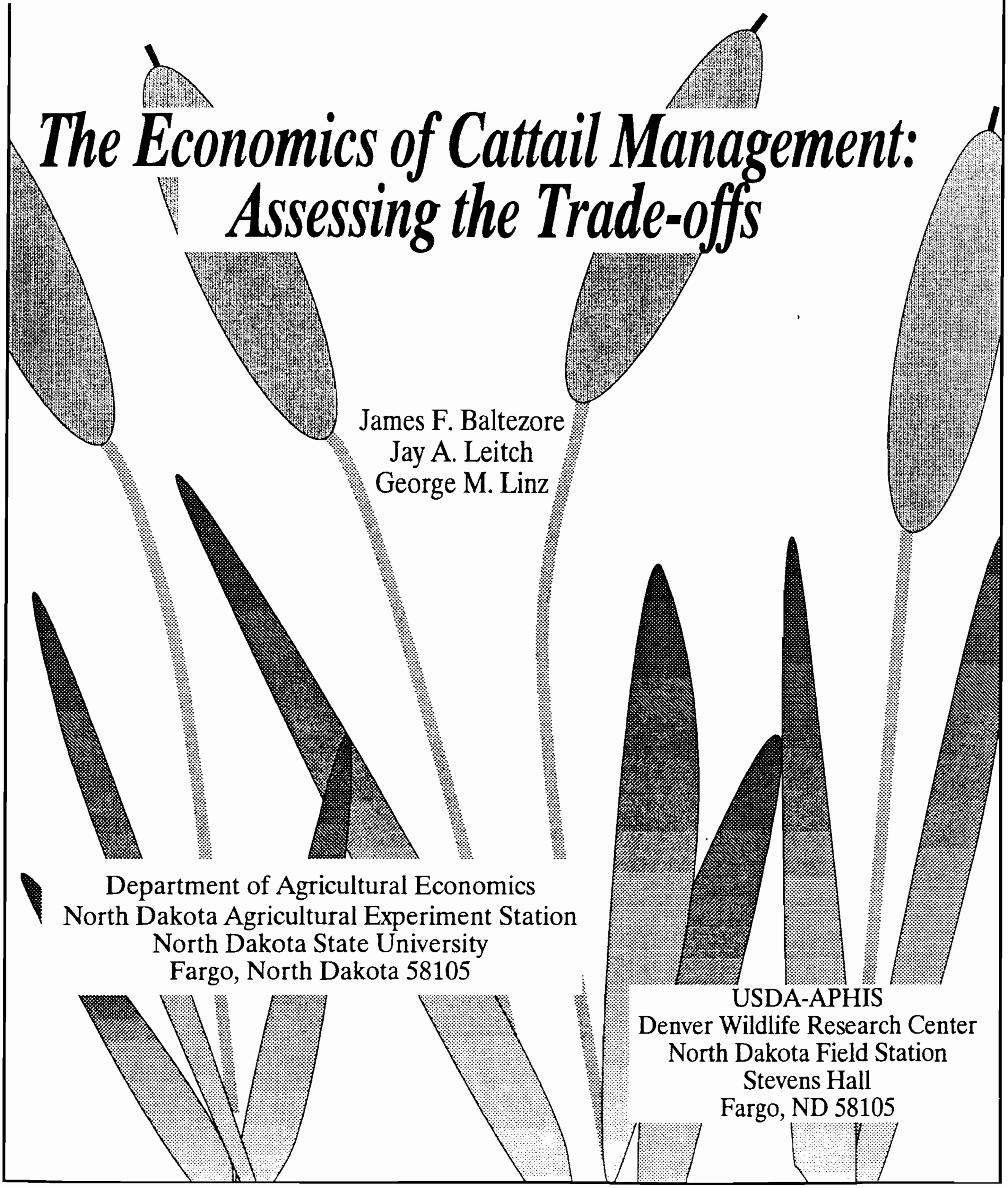

The Economics of Cattail Management: Assessing the Trade-offs

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Table of Contents

Table of Contents (continued)

List of Tables

List of Appendix Tables

List of Figures

Highlights

The purpose of this study was to identify, quantify, and compare the costs and benefits of selected cattail control methods. Objectives were to (1) estimate the extent of bird depredation of sunflowers, (2) assess various techniques of controlling bird depredation, (3) model the biological and economic impacts of controlling cattails to manage blackbird depredation, and (4) conduct a benefit-cost analysis of controlling bird depredation through cattail management.

Several lethal and nonlethal control methods have been or are used to control bird depredation of sunflowers. Lethal control methods include surfactants and DRC-1339 grain baits. Nonlethal control methods include mechanical scare devices, chemical repellents, cultural practices, plant genetics, and habitat alterations. Lethal control methods did not meet the criteria of cost effectiveness, environmental safety, and implementation ease. Several nonlethal methods also did not meet these conditions. Habitat alteration appeared, a priori, to be the best method to meet these conditions.

A benefit-cost analysis of altering a 25-acre wetland 100 percent choked with cattail indicated that net benefits were maximized if 70 percent were treated (approximately 18 acres). Total net producer returns to treatment were $3,059 or $170 for each cattail acre treated.

Society benefits from reducing the amount of cattail in a wetland through additional sunflower production and from improved waterfowl habitat. Society's costs are the opportunity costs of treatment outlays and degraded habitat for several game and nongame species that depend on wetland habitat. Benefit-cost analysis indicated that treating 70 percent (approximately 18 acres) of the cattail in a 25-acre, 100 percent choked wetland maximized net benefits to society. Net returns to treatment were $2,718 or $151 per cattail acre treated.

These results are invariant with respect to increasing sizes of wetland since the modeled relationships are linear. Additional investigations may lead to the use of nonlinear relationships, but data were not available for more robust model specifications.

The appropriate sharing of cattail treatment costs is an issue. Sunflower producers and waterfowl interests are primary direct beneficiaries of cattail control in overgrown wetlands. The producers, however, are compelled by state and federal law to maintain wetlands for the national good. Producers are thus faced with an unusual situation: they must protect wetland for society, but that protection contributes to personal financial losses for the producers. Many producers may not feel obligated to incur additional expense to protect themselves from something they are forced to protect for society. Farm operators should manage depredation-susceptible fields and crops to minimize losses, while other beneficiaries of wetlands and cattail management programs should incur their share of the costs of cattail management. Those representing waterfowl interests should also contribute, but at a lower level. The determination of absolute levels that each should contribute will need to be decided through the political process.

The Economics of Cattail Management: Assessing the Trade-offs

James F. Baltezore, Jay A. Leitch, and George M. Linz*

Introduction

Cattails (*Typha spp.*) are an integral and important part of prairie wetland ecosystems. They help to support many valued wetland outputs for society. For example, society benefits from wildlife supported by cattail habitat and from improved water quality as cattails filter nutrients out of marshes (Stromstad 1992).

Cattails can have detrimental impacts. Cattail infestations reduce oxygenation and microbial activity in wetlands (Messersmith et al. 1992). An overgrowth of cattails can "choke" a wetland to the extent that waterfowl habitat is diminished (Kantrud 1986, McEnroe 1992). Cattails provide excellent habitat for red-winged and yellow-headed blackbirds and common grackles, which damage some crops, especially sunflowers (Lamey et al. 1993, Huffman 1992, Lamey et al. 1992, Linz et al. 1992, Thorsness et al. 1992, Hothem et al. 1988). There may be no other sunflower pest that engenders the kind of producer frustration and emotion than blackbird depredation. Producers can see the birds in their fields from the road, as opposed to weevils or more subtle diseases in early development.

Managers have periodically thinned dense stands of emergent vegetation to increase waterfowl use of wetlands (McEnroe 1992, Solberg and Higgins 1993). Cattail management in prairie wetlands must consider the interests and concerns of wildlife (as expressed by wildlife advocates), farm operators, and society. Cattail management programs should be evaluated to determine if the outcomes are worth the costs. Benefits are often inadequately considered in the development and implementation of control techniques. Politicians may endorse solutions to pest problems for political purposes and not for economic efficiency (Graham 1971, 1978; Wiens 1986). Bureaucrats and managers may be more concerned with physical or biological goals than with economic efficiency. However, simple frameworks or models to compare costs and benefits of wildlife management techniques (Dolbeer 1981) such as cattail control do not exist.

Purpose

This study identifies, quantifies, and compares costs and benefits of selected cattail control measures. Specific objectives are

- to estimate the extent of bird (red-winged blackbirds and common grackles) depredation of sunflowers,
- to discuss various methods of controlling or mitigating depredation,

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- to model the biologic and economic impacts (benefits and costs) of controlling cattails to manage depredation, and

- to develop a benefit-cost analysis of controlling depredation through cattail management.

An initial assessment of the overall bird depredation of sunflowers was conducted to assess the magnitude of the problem. Control methods were evaluated to identify a cost-effective procedure to reduce depredation.

Study Area

The study area comprises the state of North Dakota. Specific areas of concern are North Dakota counties that grow sunflowers within the Prairie Pothole Region (Figure 1). Sunflower production is concentrated in the drift prairie and Missouri Coteau (Figure 2). Bird damage will be heaviest in these regions because they are primary sunflower production areas and have the highest concentration of individual water areas per square mile of any region in the lower 48 states containing up to 140 wetlands per square mile (Stewart 1975).

The primary sunflower-producing counties in North Dakota are in the northwest, north central, northeast, central, east central, and southeast agricultural statistics districts (Figure 3). These districts accounted for 89 percent of the state's sunflower production from 1982 to 1991 (North Dakota Agricultural Statistics Service 1993). North Dakota counties outside of the Prairie Pothole Region (PPR) have only isolated or individual cases of bird damage due to the combination of a lack of preferred bird habitat (i.e., wetlands and cattails) and unsuitable agronomic conditions to produce sunflowers.

Procedures developed within the study can be applied to other states. Results and conclusions may be generally applicable to the portions of South Dakota, Minnesota, and Canada that lie within the PPR (Figure 1).

Cattails in North Dakota Wetlands

Three types of cattails are found in North Dakota--common cattail (*Typha spp.*), narrow-leaved cattail (*Typha angustifolia*), and hybrid cattail (*Typha glauca*) (Kantrud 1992). The hybrid cattail is a cross between the common and the narrow-leaved cattail (Kantrud 1986, 1992; Messersmith et al. 1992).

No narrow-leaved cattails and only a few cattail-dominated wetlands were found in North Dakota at the start of the 20th century (Metcalf 1931). The first discovery of narrow-leaved cattails in North Dakota was in 1942 (Kantrud 1992). During the last 50 years, narrow-leaved cattails have spread rapidly across North Dakota wetlands, initially dominating wetlands in the southeastern corner of the state and spreading to wetlands in central portions of the state.

The distributional history of the hybrid cattail in North Dakota parallels that of narrow-leaved cattail (Kantrud 1992). The plant

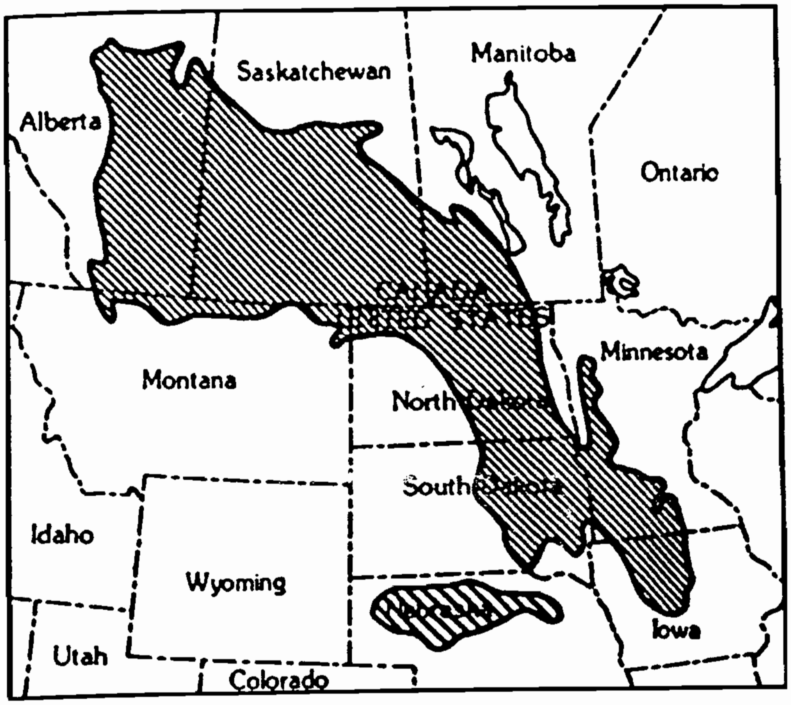

Figure 1. The Prairie Pothole Region

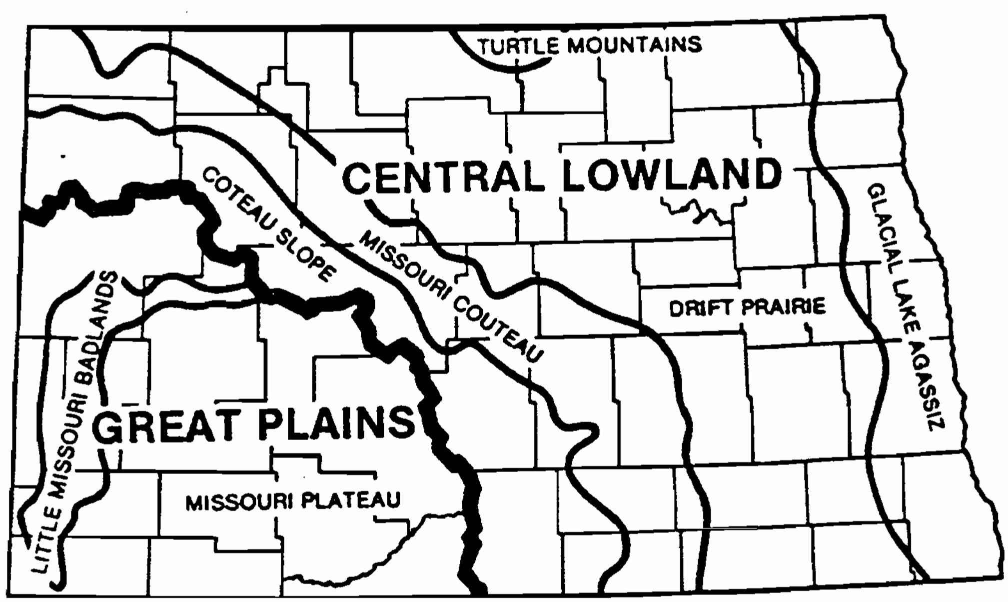

Figure 2. Major Physiographic Subdivisions of North Dakota

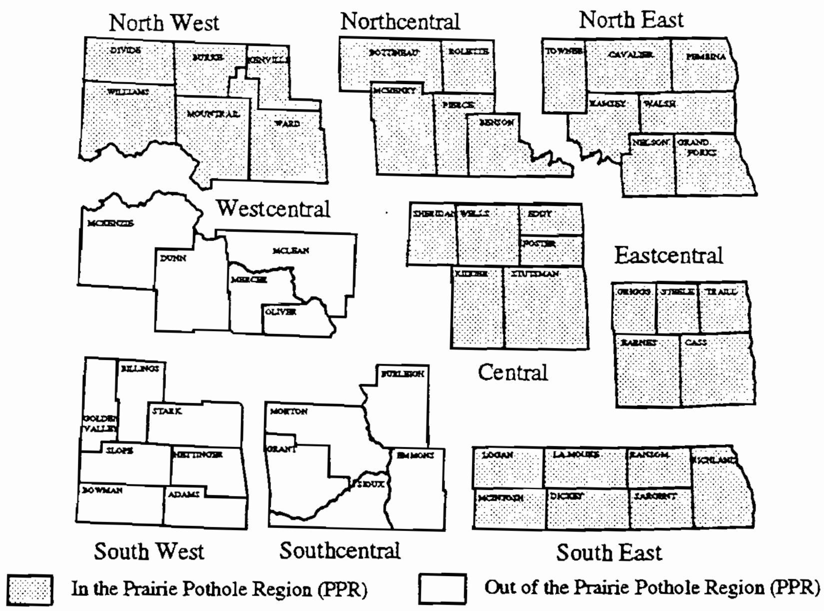

Figure 3. North Dakota Agricultural Statistics Districts

spread rapidly across the PPR of North Dakota during the 1950s and now is the most abundant hydrophyte in the state. North Dakota's PPR wetlands are ideally suited for hybrid cattails because most are of intermediate salinity, are disturbed periodically by tillage and siltation, and are not grazed, allowing cattails to replace native vegetation.

The forces of climate, grazing, and fire were once natural regulators of the abundance and species composition of vegetation in prairie wetland (Kantrud 1986). However, changes to more intensive agriculture production and the near elimination of wild prairie fires have allowed cattail to spread more rapidly among wetlands. Ditches and swales associated with modern highways likely facilitated the spread of narrow-leaved cattails to and across the state.

Control of hybrid cattails is difficult due to a large rhizome system that enables the plant to reestablish rapidly after tip-growth is killed (Linde et al. 1976, Messersmith et al. 1992). Hybrid cattail can tolerate deeper water than other cattail species and can expand as basins fill with sediment and decrease water depth (Swanson 1992). Methods of controlling cattail include mechanical destruction, burning, grazing, water level manipulation, chemical treatments, and various combinations of these methods (Linz et al. 1991, Solberg 1989, Schultz 1987, Murkin and Ward 1980, Murkin 1979, Beule 1979).

Cattail may serve useful functions through filtering nutrients out of marshes, providing winter cover for resident wildlife, enhancing waterfowl and non-game habitat, and supplying other values society may not yet be aware of (Stromstad 1992). However, an overgrowth of cattail can "choke" a wetland, severely diminishing the quality of waterfowl habitat and providing a desirable roosting site for grackles and red-winged blackbirds (Lilleboe 1991). The continued expansion of cattail range across North Dakota wetlands and its increased density within wetlands has prompted wildlife agencies to consider cattail management programs.

Cattail can be controlled or managed to improve marshes for waterfowl and marsh birds with a secondary benefit of blackbird and grackle control (McEnroe 1992). The goal of cattail management is to remove cattail from an infested wetland to improve waterfowl use and to reduce the potential for large concentrations of birds (Huffman 1992). The optimal percentage of cattail to remove is the point where net social benefits of a wetland are maximized. That is, net benefits are maximized when the costs associated with the removal of one more unit of cattail from a wetland are equal to the benefits resulting from the removal of the previous unit of cattail.

Bird Depredation of Sunflowers

North Dakota produced 60 percent of the sunflowers grown in the United States over the past 5 years (North Dakota Agricultural Statistics Service 1993). Several annual or cyclical pests affect sunflower production. Except for controlling bird depredation, inexpensive and functional methods for controlling sunflower damage from other pests are available (Anderson 1992).

Most of the sunflower crop in North Dakota is produced in the area of the state that provides favorable conditions for local blackbirds and corresponds to the late summer migration path of blackbirds. Sunflower production losses occur when red-winged blackbirds (*Agelaius phoeniceus*), yellow-headed blackbirds (*Xanthocephalus xanthocephalus*), and common grackles (*Quiscalus quiscula*) damage ripening sunflower heads (Sedgwick et al. 1986). (**For this study, only damage from red-winged blackbirds and common grackles are considered.** Yellow-headed blackbirds probably are responsible for less than 10 percent of the bird damage to sunflowers annually [Linz 1994]. "Bird damage" refers to sunflower yield losses attributable to red-winged blackbirds and common grackles.)

Bird damage to sunflower crops is not distributed uniformly among fields. The amount of damage a particular field receives is closely related to the proximity and the size of nearby bird roosts, to bird flight lines, and to patches of trees (Guarino and Cummings 1986, Otis and Kilburn 1988).

Damage Estimates

Sunflower production losses due to birds can be considerable, both at the farm and regional levels. Sunflower damage in North Dakota was estimated to be over $10 million from 1986 to 1991, or

$1.67 million annually (Huffman 1992). Nearly 20 percent of North Dakota sunflower producers indicated bird damage was their most serious production problem (Lamey et al. 1992, 1993).

Estimates of sunflower depredation losses from birds are needed to evaluate the cost effectiveness of cattail management. Two methods were used to estimate the long-term dollar losses from bird depredation of sunflowers in North Dakota. The first was based on farm operator estimates of bird damage. The second was based on bird consumption of sunflowers.

Farm Operator Estimates

Several studies have been conducted to estimate the extent of sunflower damage from bird depredation. Lamey et al. (1992) determined that 14 percent of North Dakota's sunflower growers suffered bird damage greater than 10 percent. Hothem et al. (1988) found that 1.2 to 2.7 percent of the sunflower crop is lost to blackbird depredation annually. In site-specific areas, Sterner and Hothem (1982) estimated sunflower damage at 5 percent in 1981, and Linz et al. (1985) estimated sunflower damage at 2 percent in 1984. Linz et al. (1989) found that sunflower damage in two North Dakota counties was 8 percent in 1986 and 4 percent in 1987.

Most of these studies were limited in scope, addressing blackbird damage for a particular year or over several years in selected areas. Estimates of long-term damage from data for only one or two years of damages may be biased because the amount of blackbird damage depends upon several factors, such as sunflower acreage, sunflower prices, weather, and blackbird populations. These factors can and do fluctuate considerably over time.

A comprehensive procedure was developed to estimate farm operators' long-term damage from blackbird depredation of sunflowers. The dollar amount of sunflowers lost due to blackbird depredation in North Dakota was estimated, using the following equation:

$$D = V_{wo} - V_w,$$

where

D = dollar value of damage attributable to blackbird depredation of sunflowers,

V_{wo} = the dollar value of North Dakota sunflower production without blackbird damage, and

V_w = the dollar value of North Dakota sunflower production with blackbird damage.

The value of sunflower production without blackbird damage (V_{wo}) is

$$V_{wo} = (SP_{lta} \times (1 + D_{fl})) \times PS_{ltaj},$$

where

SP_{lta} = the ten-year average sunflower production in pounds within the prairie pothole region (Appendix A),

D_{fl} = the long-term percentage sunflower yield reduction estimate at the farm level (Appendix B), and

PS_{ltaj} = the adjusted ten-year average price of sunflowers per pound (Appendix C).

The value of sunflower production with blackbird damage (V_w) is

$V_w = SP_{1t} \times PS_{1t}$,

where

SP_{1ta} = the ten-year average sunflower production in pounds within the prairie pothole region (Appendix A), and

PS_{1ta} = the ten-year average price of sunflowers per pound.

The ten-year (1982-91) average sunflower production within the prairie pothole region (SP_{1t}) is 1.9 billion pounds (Appendix A). The 1982 to 1991 average price of sunflowers (PS_{1ta}) was 9.55 cents per pound (North Dakota Agricultural Statistics Service 1993). The long-term sunflower damage estimate at the farm level (D_{f1}) is 6.4 percent (Appendix B). The adjusted price of sunflowers per pound (PS_{1taj}) is 9.08 cents (Appendix C).

Substituting these numbers into the respective models yields the following:

$$V_{WO} = 1,910,722,000 \times (1+0.064) \times 0.0908$$
$$= \$184,597,145$$

$$V_W = 1,910,722,000 \times 0.0955$$
$$= \$182,473,951.$$

Subtracting V_W from V_{WO} produces an annual damage estimate of $2,123,194 of foregone sales at the farm level. This amounts to $1.27 per sunflower acre within the Prairie Pothole Region.

Bird Consumption Estimates

An alternative damage estimate was developed to estimate bird depredation of sunflowers based on estimated bird consumption. This method relates the consumption habits and characteristics of birds with the physical properties of the sunflower plant to mitigate bird damage. Bird consumption damage estimates are compared with damages at the farm level to establish "reasonable bounds" on the dollar value of bird sunflower depredation.

The average ripening period for sunflowers is 16 weeks; however, the sunflower is susceptible to bird depredation for approximately 6 weeks or 42 days (Jeng 1988). Sunflowers are most vulnerable for 18 days after anthesis (Sedgwick et al. 1986, Cummings et al. 1989) or when the seeds are in the dough stage (Figure 4). Approximately 75 percent of total bird damage to sunflower heads occurs during this period. Sunflowers become less vulnerable as their achenes develop and harden.

Sunflowers provide an excellent high-energy food source for migrating flocks of birds. Sunflower seeds comprise 67 percent of a male's and 21 percent of a female's diet for red-winged blackbirds during the sunflower-ripening period (Linz et al. 1993). Sunflower seeds comprise 48 percent of both male's and female's diets for common grackles during the sunflower-ripening period (Homan et al. 1994).

Blackbirds begin roosting in dense cattail marshes during July, which corresponds to the sunflower early ripening period (Linz et al.

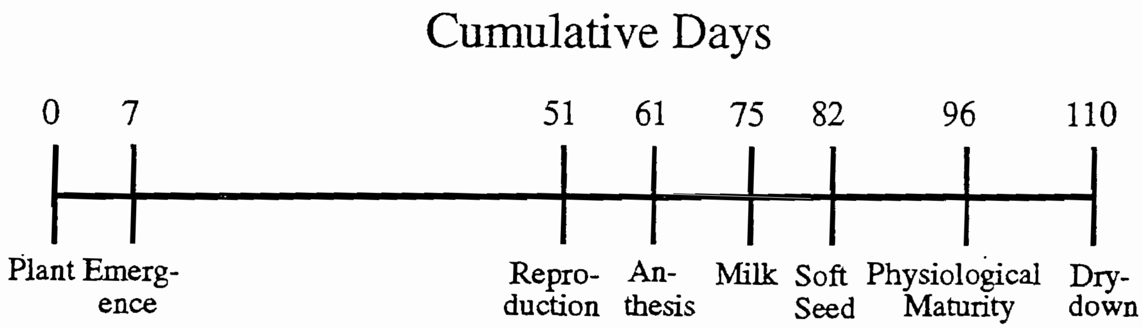

Figure 4. Stages of Sunflower Development

1992). Cattails provide excellent habitat for blackbird roosting in the fall during migration (Linz et al. 1992). Blackbirds roost in dense cattail marshes because (1) cattails are more available than trees in the prairies, (2) temperatures near water levels underneath the cattail canopy are warmer than the air (a desirable condition for birds losing their feathers through molting), and (3) cattail cover provides blackbirds habitat to escape predators. The proximity of marshes containing cattails or other blackbird-attracting habitats is the largest factor influencing blackbird damage levels on sunflower fields (Otis and Kilburn 1988). Blackbirds often roost near sunflower fields and eat substantial amounts of sunflower seeds (Hothem et al. 1988, Otis and Kilburn 1988).

Although birds can damage sunflower heads considerably, the sunflower plant has characteristics that mitigate a portion of the depredation damage. Damage estimates to sunflower heads may not directly correlate to a true yield loss by weight (Sedgwick et al. 1986). For example, a sunflower head damaged 25 percent based on surface area does not experience a full 25 percent reduction in yield by weight.

Typically, bird damage to sunflower heads peaks before the seed fully matures (Cummings and Marsh 1980, Sedgwick et al. 1986, Cummings et al. 1989). Consequently, the sunflower plant can redirect energy to the remaining undamaged seeds, effectively compensating for some or all of the loss in yield. Compensatory growth **only occurs if the seed**

is removed from the head during the first 2 weeks (14 days) after anthesis (Sedgwick et al. 1986, Cummings et al. 1989). The amount of compensation increases as the level of damage increases. Compensatory growth can range from 6 percent to 44 percent. Yield (based on weight) between damaged and undamaged heads does not differ statistically if 15 percent or less of the developed seed area on a sunflower head is removed during the soft-seed stage.

A damage model based on blackbird consumption of sunflowers was developed to incorporate many of these factors. The damage a sunflower head receives is a function of the stage of sunflower development. No blackbird damage occurs between when the sunflower is planted and anthesis (Figure 4). Damages begin following anthesis and peak about 10 days later (Figure 5). Damages decline gradually from that point until harvest as the sunflower seeds become less desirable.

Damage (D) was estimated, using the following equation:

$$D = D_{t1} + D_{t2}$$

where

D = dollar value of damage attributable to bird depredation of sunflowers,

D_{t1} = dollar value of sunflower damage occurring in time period 1, and

D_{t2} = dollar value of sunflower damage occurring in time period 2.

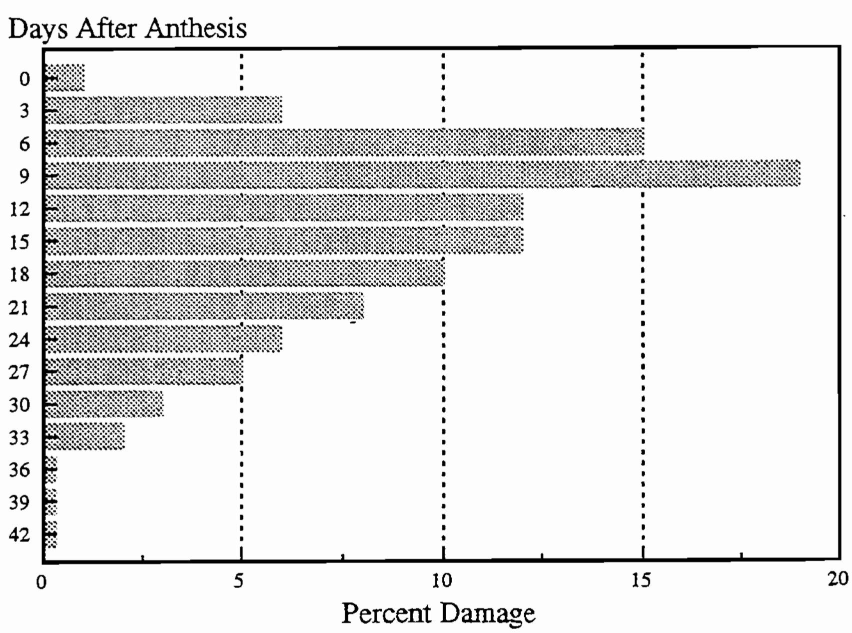

Figure 5. Actual Damage Distribution to Sunflowers From Blackbirds

Damages were divided into two periods to capture the compensatory growth capabilities of the sunflower plant and the changes in bird consumption of sunflower seeds as the plant matures. Damages during time period 1 (D_{t1}) are those associated with the first 14 days after anthesis when damage is highest and compensatory growth occurs. Damages during time period 2 start 15 days after anthesis and continue until the sunflower plant is harvested (28 total days).

Damage for time period 1 was estimated, using the following equation:

$$D_{t1} = C_{b1} \times D_c \times P_b \times PS_{1t} \times D_f$$

where

- D_{t1} = dollar value of damage attributable to blackbird depredation of sunflowers during the first 14 days after anthesis,
- C_{b1} = pounds of sunflower seeds one blackbird consumes per day during this time period,
- D_c = days blackbirds consume sunflower seeds during the time period,
- P_b = long-term average population of blackbirds in the North Dakota prairie pothole region,
- PS_{1t} = ten-year average price of sunflowers per pound, and
- D_f = net damage factor for blackbird depredation of sunflowers.

Damage for time period 2 was estimated, using the following equation:

$$D_{t2} = C_{b2} \times D_c \times P_b \times PS_{1t}$$

where

- D_{t2} = dollar value of damage attributable to blackbird depredation of sunflowers from 15 days after anthesis to harvest,
- C_{b2} = pounds of sunflower seeds one blackbird consumes per day during the time period,
- D_c = number of days blackbirds consume sunflower seeds during the time period,
- P_b = long-term average population of blackbirds in the North Dakota prairie pothole region,
- PS_{1t} = ten-year average price of sunflowers per pound.

Besser (1979) estimated that a blackbird eats 1.4 ounces of seed daily when seeds are half-filled and 0.8 ounce daily when seeds are filled or nearly filled. Daily consumption for each time period equals pounds of seed consumption times the percentage of sunflowers in the bird's diet. The percentage of sunflower in the bird's diet is 46 percent for both time periods, based on a simple average of the diets of male and female red-winged blackbirds and common grackles [(67+21+48+48)/4)]. Blackbird consumption in time period 1 (C_{b1}) was 0.0402 pounds [(1.4 ounces x .45) / 16 ounces per pound]. Blackbird consumption of sunflower seeds decreases in time period 2 because the sunflower plant becomes less desirable. Blackbird consumption in time period 2 (C_{b2}) was 0.023 pounds [(0.8 ounces x .45) / 16 ounces per pound].

Blackbird depredation of sunflowers is highly concentrated, implying that extensive damage occurs in limited areas. For example, only 10 percent of the North Dakota sunflower plants may receive damage, but some of those that are damaged experience more than 50 percent damage. A net damage factor for blackbird depredation of sunflowers was developed to represent the concentration of damage after adjusting for compensatory growth. The net damage factor (D_f) was assumed to be 0.85. This implies that 85 percent of the damage to sunflower heads during period 1 exceeds the compensation ability of the sunflower plant. If the concentration of damage were reduced (i.e., if the damage were spread over more sunflower heads), the factor would be smaller.

Stehn (1989) estimated there were typically 13.2 million blackbirds in the primary sunflower growing areas in September. Nelms (1991) estimated that the population distribution of red-winged blackbirds and common grackles was 63 percent and 37 percent, respectively. This implies that the long-term average population of birds (red-winged blackbirds plus common grackles) damaging sunflowers in the North Dakota prairie pothole region (P_b) is 21.0 million (13.2 / 0.63). The ten-year average price of sunflowers per pound (PS_{1t}) was $0.0955 (North Dakota Agricultural Statistics Service 1993).

Substituting these values into the equations for each time period produces the following:

$$D_{t1} = (0.0402 \times 14 \times 21{,}000{,}000 \times 0.0955 \times 0.85) = \$959{,}391$$
$$D_{t2} = (0.0230 \times 28 \times 21{,}000{,}000 \times 0.0955) = \$1{,}291{,}542.$$

Blackbirds cause $2,250,933 of damage on North Dakota sunflowers, based on annual blackbird consumption of sunflower seeds during both time periods. This represents $1.35 per planted acre of sunflowers within the North Dakota Prairie Pothole Region.

Approximately 40 percent of damage occurred during the first time period, which is somewhat lower than previous estimates (Cummings et al. 1989) However, previous studies were based on the percentage of sunflower heads damaged. This method does not account for compensatory growth of the remaining seeds. Consequently, damage estimates using this method would tend to be higher than actual damage.

The bird consumption estimate is 6 percent higher than the farm level consumption estimate. Several reasons can explain this disparity:

- Farm producers may not realize the amount of blackbird damage actually occurring.
- Biological relationships are imprecise.
- Models are improperly specified.

Farm operators who experience only slight to moderate sunflower yield reductions from bird damage may not be aware of the magnitude of the problem. Consequently, these producers may underestimate the amount of bird damage actually occurring.

Estimates of blackbird consumption of sunflower, the number of feeding days, the blackbird population, net damage factor, and blackbird consumption factor may not be correct. For example, Besser (1979) indicated that blackbird consumption estimates may be conservative. Models used to estimate blackbird damage may not include all the factors relating blackbird damage to sunflower production.

The absolute level of blackbird damage occurring in North Dakota is based on a simple average of the two estimates. The amount of annual damage to ripening sunflowers from blackbird depredation is $2,187,064 or $1.31 per sunflower acre in the PPR.

Damage Distribution

Blackbirds feed according to the principles of optimal foraging theory, which state that blackbirds select the easiest and, at the same time, the most nutritious food to maximize their feeding efficiency (Pyke 1984). Blackbird foraging on sunflowers is a collection of related behaviors, including searching and locating the best field to feed in, choosing the most nutritious sunflower heads available in the field, and applying different strategies in choosing, pecking, and hulling the individual sunflower achenes of a head (Maynard Smith 1978, Krebs 1981). The culmination of these behaviors maximizes nutrient gain and minimizes feeding costs to the bird. Blackbirds chose sunflower fields based on their proximity to their night roost and the risk of attack from predators (Jeng 1988).

Sunflowers provide an excellent food source. Dense cattail stands in prairie pothole wetlands offer water, loafing, and roosting habitat for blackbirds. The combination of sunflower fields and cattail-choked wetlands leads to blackbird congregations and subsequent damage to ripening sunflowers.

The amount of damage birds inflict on a particular sunflower field depends primarily on (Anderson 1992, Besser 1978)

- the size of the field,
- the field's proximity to wetland,
- the number of birds,
- the number of days birds feed in each field,
- the size of the wetland, and
- the percentage of open water within the wetland.

Variations in these factors explain the great disparity of damage that occurs among sunflower fields. For example, less than 5 percent of all sunflower fields in North Dakota received more than 10 percent overall yield loss (Guarino and Cummings 1986). Blackbird damage within one particular sunflower field can range from no yield loss to 91 percent loss (Jeng 1988).

An inverse relationship exists between the size of a sunflower field and the amount of blackbird damage. This is apparent since the damage is effectively spread over more acres as the size of the sunflower field is increased. This assumes that other damage factors are held constant and that blackbirds are not attracted to a particular sunflower field because of its size.

An inverse relationship also exists between damage and the distance separating a field and a wetland. Dolbeer (1981) found yield losses of more than 10 percent in corn fields within 3 miles of a major late-summer roost (Figure 6). Fields more than 6 miles from a roost usually received less than 5 percent losses. Besser et al. (1979) found that 22 percent of blackbird visits were to sunflower fields within 3 miles of their roost, 59 percent to fields 3 to 6 miles away, 16 percent to fields 6 to 12 miles away, and 3 percent to fields more than 12 miles away. Over 80 percent of the sunflower damage blackbirds cause occurs within 6 miles of their roost, assuming a direct and proportional relationship between visits and bird damage. For this study, blackbird damage to sunflower fields was assumed to be zero if the blackbird roost was more than 10 miles away.

The bird-carrying capacity of a wetland increases as the size of the wetland increases. This implies a direct relationship exists between the size of the wetland and the amount of blackbird damage. Wetlands with more surface area had more habitat suitable for birds. The amount of bird damage to adjacent sunflower fields will increase as the size of the cattail-infested wetland increases.

The percentage of open water (i.e., no emergent vegetation) within a wetland also affects the bird-carrying capacity of a wetland. Weber (1978) found an inverse relationship between the number of blackbirds within a wetland and the percentage of the wetland that was open water. Linz et al. (1992) found that the numbers of blackbirds within wetlands decreased as the percentage of open water increased. Few blackbirds will roost in a wetland if the percentage of cattails in the wetland is 30 percent or less (Linz 1993).

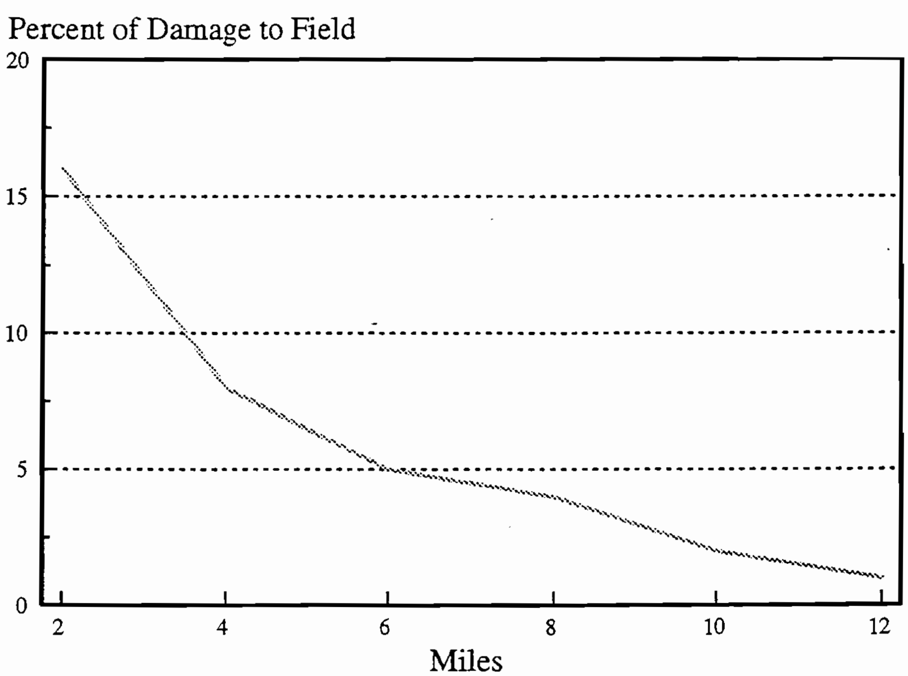

Figure 6. Relationship Between Bird Damage and Distance

The various combinations of field size, wetland proximity, wetland size, and percent open water cause a wide distribution in sunflower damage among fields. The variability of damages suggests that one method for controlling bird depredation of sunflowers may not be economically feasible for all growers. One or a combination of control methods may provide the most economical solution to reducing damages.

Controlling Bird Depredation

Various methods, some lethal and some nonlethal, are used to control bird depredation of sunflowers. Lethal methods reduce bird populations. Nonlethal methods disperse bird populations, spreading the damage among more producers, but at lower levels. Several lethal and nonlethal methods will be described.

Individual producers bear the cost of controlling bird depredation for most on-farm control methods. Public or jointly funded programs are available for some collective efforts. However, the availability of public funds varies, based on budget constraints and the allocation of funds within the political process.

Lethal Control Methods

Lethal control methods destroy birds through poisoning or reducing their natural defense mechanisms against hypothermia. Primary lethal controls are surfactants and DRC-1339 treated grain baits.

Surfactants

PA-14 is a surfactant sprayed on bird roosts to lower the surface tension of water and enhance wetting. Birds treated with this chemical before a rain are likely to die of hypothermia (Stickley et al. 1986).

The effectiveness of surfactants to reduce bird populations is limited. White et al. (1985) found that the population of blackbirds within 25 miles of a roost recovered within 2 weeks, even after killing 1.1 million blackbirds (96 percent of the estimated population). The rapid turnover in blackbird populations limits the effectiveness of surfactants (U.S. Department of the Interior 1976).

Some benefits may be realized if the surfactant is sprayed on bird roosts during anthesis and it rains within hours. Sunflowers are most vulnerable to bird damage the first 2 to 3 weeks after anthesis. Reducing the bird population for a portion of this time may be efficient.

Surfactants have potential drawbacks, such as spillover effects on nontargeted wildlife. Other wildlife living among bird roosts are affected if they come in contact with surfactants. Spillover effects have created considerable disputes between agricultural and wildlife advocates. The Environmental Protection Agency (EPA) has withdrawn registration for this product, making it illegal to use.

DRC-1339

DRC-1339 treated grain bait is a slow-acting chemical toxicant (Glahn and Wilson 1992). Birds are killed when uric acid is deposited in kidney tubules and pericardium (Schafer 1989, Linz et al. 1988). DRC-1339 treatment is 99 percent effective in killing birds within 1 to 3 days (Lefebvre 1987). However, as with surfactants, blackbirds may be able to repopulate the same areas to similar levels within a short period (U.S. Department of Interior 1976, White et al. 1985). Further research is needed to develop optimal management strategies for DRC-1339 to determine the most efficient application or if it is safe.

DRC-1339 may also affect nontargeted wildlife. Birds live in association with other wildlife that are affected. Prolonged use of DRC-1339 may create unintended, as yet unknown, environmental problems. Including the costs associated with killing nontargeted wildlife and unintended environmental costs reduces the benefits of using DRC-1339.

Nonlethal Control Methods

Nonlethal control methods have received more attention given the limited cost effectiveness and spillover effects of lethal control methods. Nonlethal control methods are used to disperse bird populations. Birds are discouraged from congregating and locating in certain areas through various means, such as mechanical scare devices, chemical repellents, cultural practices, plant genetics, and habitat alteration, and aircraft hazing (Linz et al. 1993, Linz and Hansel 1994).

Mechanical Scare Devices

Mechanical scare devices include exploders, pyrotechnics, firearms, and airplanes. Each is used to frighten birds from sunflower fields to reduce bird consumption of sunflower seeds within particular fields and to spread the damage across a broader area (Huffman 1992). Most are labor intensive in the mornings and evenings and sometimes all day, depending upon conditions (i.e., number of birds present, stage of sunflower development).

Sunflower producers can protect their crops if they patrol their sunflower fields and use a rifle to disperse birds. Producers can move blackbirds effectively and economically with a rifle if fired above the birds, causing the feeding flock to flush, and followed with a series of rounds behind them (Besser 1978). The method is not designed to kill birds, but to frighten them into finding other habitat, spreading the damage among more producers, but at lower damage rates.

Over 30 percent of North Dakota sunflower producers rated using firearms effective in controlling blackbird depredation of sunflowers (North Dakota Agricultural Statistics 1990). Sixty percent rated it somewhat effective. Frightening blackbirds with firearms will work for those producers with perseverance and time to continuously monitor fields and take appropriate actions for the 6 weeks when sunflower heads are vulnerable. However, the time required to effectively disperse flocks may be excessive.

Pyrotechnics involves using a shotgun to deliver a firecracker rather than a potentially lethal round. The firecracker explodes above the birds, scaring them to other fields or habitat. Nearly 60 percent of North Dakota sunflower producers use cracker shells from shotguns to protect their fields (North Dakota Agricultural Statistics Service 1990). Sixty percent indicated this method was somewhat (54 percent) or very (6 percent) effective in protecting sunflowers, although 40 percent said it was not effective. The method requires considerable time and effort.

Exploders (propane cannons) produce a louder sound than shotgun pyrotechnics. One exploder can protect up to 10 cropland acres (Besser 1978). To increase their effectiveness, exploders should be moved frequently so that birds do not become acclimated to the noise. Nearly 65 percent of North Dakota sunflower producers use exploders (North Dakota Agricultural Statistics Service 1990). Only 4 percent of producers rated propane cannons as very effective, while 63 percent rated them as somewhat effective. One-third rated exploders as not effective.

Exploders increase production costs because an exploder cannon and propane or gas must be purchased. Additional expenses are incurred repairing and maintaining the unit. Also, considerable time is involved in frequently moving and situating exploders in strategic field areas. Costs and returns associated with exploders may not justify the added expense.

Airplane patrols have been implemented to harass birds. The U.S. Congress provided money, beginning in 1986, for a hazing program to reduce blackbird depredation of sunflowers. Periodic low-level flying over sunflower fields with shooting as reinforcement is used to move blackbirds out of problem areas. A total of 12,912 (2,152 annually) hours have been flown during the 6 years of hazing blackbirds in North Dakota (Huffman 1992) at a cost of $243,000 ($113 per hour).

The effectiveness of airplane hazing to control blackbirds is questionable. Thirty-one percent of North Dakota sunflower producers rated airplane hazing as very effective, and 50 percent rated it somewhat effective (North Dakota Agricultural Statistics Service 1990). Airplane hazing received the highest overall rating among all methods. This is not surprising since the individual producers do not normally bear the costs of hazing. Yet, when producers were asked about allocation of funds for aerial hazing, 41 percent indicated funds should be increased, 33 percent indicated no change, and 26 percent indicated that funds should be redirected to other methods. Other researchers suggested that airplane hazing is ineffective because blackbirds often take refuge from the plane in the crop (Besser 1978) or in nearby cattails.

Chemical Repellents

Some chemicals can frighten blackbirds from fields, thereby protecting crops from depredation (Besser 1978, Besser and De Grazio 1985, Knittle et al. 1988). Chemicals, such as 4-aminopyridine, 4-AP, can elicit distress sounds, erratic flight, and other behaviors that frighten unpoisoned blackbirds. (Although the chemical can and does kill some blackbirds, it is not considered a lethal method because its primary objective is to frighten and disperse blackbirds to other areas.) Entire flocks of blackbirds can be dispersed after less than 1 percent of blackbirds consumed baits (Besser et al. 1984, Besser and Hanson 1985). The chemical is applied in various ways. The most common application method is mixing 4-AP with corn and spreading the mixture in several locations in and near the field.

Chemicals repellents provide some relief from bird depredation. Damage has been reduced by 87 percent in some fields, and benefit cost ratios of 9 to 1 have been reported (Besser and De Grazio 1985). Although chemical control methods are effective in some instances, more than half of North Dakota sunflower producers do not use chemical repellents (North Dakota Agricultural Statistics Service 1990). Over 55 percent of producers who used 4-AP indicated it was not effective in controlling blackbird damage to sunflowers. Chemical repellents have not been used extensively because of limited cost effectiveness (Jeng 1988), inconsistent results (Huffman 1992), killing nontargeted animals (Besser and De Grazio 1985), and potential degradation of the environment (White et al. 1985).

Cultural Practices

Cultural methods can be used to reduce bird populations and sunflower damage. Sunflower fields should not be planted within a quarter mile of wetlands that harbor 5,000 or more roosting or loafing blackbirds (Besser 1978). Sunflowers should not be planted next to shelterbelts or wooded areas blackbirds frequent for loafing cover. At least a 100-yard buffer strip of an unattractive crop (forage, pasture, sugarbeets, potatoes, soybeans, pinto beans, and other legumes) could be planted between the blackbird area and the sunflower field.

Producers could plant at lower rates to produce larger heads if sunflowers are planted in susceptible areas. (Larger heads are produced if fewer seeds are planted per acre because of reduced competition among growing plants for moisture and nutrients.) Producers could coordinate with neighbors to ensure uniform ripening and a sufficient number of sunflower acres so that the damage can be spread over more producers, but at lower rates. Producers could consider the cost effectiveness of harvesting sunflowers earlier and drying the seeds to shorten the time the crop is vulnerable to blackbird damage.

A major portion of cropland near bird roosts should not be tilled until most or all sunflower fields have been harvested. Birds consume weed seeds and some insects from crop stubble, reducing their consumption of other feedstuffs (i.e., sunflowers). Producers could also leave the harvest stubble of sunflowers until all sunflowers are harvested, providing alternate feeding areas.

Over 20 percent of North Dakota farm operators do not use cultural methods to control blackbird damage (North Dakota Agricultural Statistics Service 1990). Cultural methods can be implemented for little or no cost, and producers who do use them rated them the second most effective means of controlling bird damage. Nearly 80 percent of sunflower producers rated cultural methods as very or somewhat effective. North Dakota producers should reexamine their sunflower management practices to ensure that they are incorporating cultural control methods to minimize bird depredation of sunflowers.

Plant Genetics

Blackbirds chose seeds based on the average food gain value, handling time, and the encounter rates of different seeds (Stephens and Charnov 1982). Most variations in blackbird damage among sunflower varieties are related to morphological differences (i.e., the size and shape of bracts, the shape of heads, angle of the flower, and head-to-stem distance), which pose various difficulty levels to feeding blackbirds (Parfitt 1984, Seiler and Rogers 1987). Highly bird-resistant or bird-tolerant sunflowers have been developed with natural morphological and chemical traits to discourage blackbird feeding (Mah et al. 1990). These sunflower hybrids suffered less bird damage (Fox and Linz 1983); but they tended to be of lower yield and lesser quality, and oil concentrations were below standard oilseed hybrids (Parfitt and Fox 1986). However, seed companies have not used bird resistant genetic material due to higher costs of production and potentially low sales volume.

Morphological sunflower factors can be used to discourage bird feeding. These factors can make sunflower seeds a less profitable food source to feeding birds. Birds will substitute alternative feed sources (i.e., insects and weed seeds) and change their feeding locations when the food gain value of sunflower seeds equals the average for the surrounding habitat.

Producers with sunflower fields highly susceptible to bird damage should consider planting sunflower hybrids with high natural defenses. The producer may receive lower returns because of lower quality and oil content, but higher yields from reduced damage could offset lower returns. Producers can receive higher net returns if the income from higher yields, with lower quality and oil content, exceeds the income from lower yields, with higher quality and oil content. Combining bird-resistant sunflower varieties with conventional methods of dispersing birds should increase producers' abilities to protect sunflower fields from bird depredation and increase returns from sunflower production.

Habitat Alterations

A new approach to reducing bird depredation of sunflowers is based on habitat alterations. The landscape mosaic directly affects the size, dispersion, and foraging patterns of wildlife populations in a particular area (Wiens 1986). Changing some aspects of the local habitat may reduce bird damage to sunflowers (Linz et al. 1993) and may offer secondary wildlife benefits.

Various methods have been used to alter habitat conducive to bird roosting and loafing. Most efforts have focused on reducing the area of cattails in cattail-choked wetlands. Lowering the percentage of cattails in wetlands reduces the potential for large bird roosts, which translates into less bird depredation of sunflowers. Methods used to reduce the percentage of cattails in wetlands include burning, shearing/mowing, discing, and applying herbicides.

Burning cattails in wetlands began naturally with virtually uncontrolled prairie fires during pre-settlement times (Kantrud 1992). Prairie fires were partially responsible for restricting the range expansion of cattail during this time and for maintaining a diverse wetland habitat (Blair 1992). Fire suppression began with European settlement, which also coincides with the range expansion of cattail across the Great Plains. Evidence suggests that fires were effective in controlling the spread of cattail.

Some landowners do controlled burns of cattail-choked wetlands. Burning cattail may help to slow their spread within the wetland or to adjacent wetland, but does little to reduce the concentration of existing cattail (Blair 1992). Burning cattail aftermath also reduces habitat for other wildlife that depend on cattail for winter cover. Reducing habitat in some areas of the state can have a detrimental impact on wildlife, since suitable habitat is limited (McEnroe 1992).

Shearing, mowing, and discing have also been used to control cattail. These methods are used on cattail in wetland that seasonally dry out or wetland that is frozen during the winter. The goal is to stop the spread of cattail within the wetland and to other wetland. The costs of shearing or mowing wetlands vary from $50 to $100 per acre (McEnroe 1992). Discing costs vary from $10 to $14 per acre.

The effectiveness of these controls is similar to that of fire. The spread of cattail may be slowed, but results vary from year to year with only limited success reported (Beule 1979). Cattail control is difficult due to the large rhizome system that enables the plant to reestablish rapidly after top growth is removed (Messersmith et al. 1992, Linde et al. 1976). Research is needed to assess the effectiveness of winter and summer season controls. Secondary impacts on wildlife also must be considered.

Herbicides probably provide the most effective method of controlling cattail in shallow prairie wetlands (Messersmith et al. 1992). Fragmenting solid stands of cattail with herbicides reduces blackbird usage, which can lower sunflower damage (Linz et al. 1992). Reducing the concentration of cattails in wetlands reduces their use by fall-migrating and roosting blackbirds.

Roundup® and Rodeo® are the primary herbicides applied to cattail. Roundup® herbicide can be used only on cattail where surface water is not present (not approved for aquatic use.) Applying Roundup® to cattail is less expensive than using Rodeo® because chemical and application expenses are lower. Thus, Roundup® should be the first alternative considered to reduce cattail when water is not present. However, the results of controlling cattails on dry wetlands may be less than on the more preferred wet areas.

Rodeo[R] can be applied to cattails in wetlands with surface water (approved for aquatic use). Herbicide should be applied to cattails during peak growth, which occurs during mid-August to frost. The most effective time coincides with plant maturity. Herbicide should be applied to cattail in standing water at least 12 inches deep to reduce cattail regeneration from seeds. Treated areas will remain free of cattail for several years (Linz et al. 1992). Dead cattail shoots collapse 2 years after treatment and take another 2 years to decompose completely (Mason and Bryant 1975). Burning or over-ice mowing in the fall or spring following treatment accelerates decomposition, creating openings sooner (up to 1 year earlier). Reducing cattail litter in the marsh lessens possible adverse effects on water quality from the decomposition of large amounts of vegetation (Linz et al. 1992, Solberg and Higgins 1993). Flooding the wetland may reduce standing cattail litter (Murkin et al. 1989).

Recommendations for applying Rodeo[R] are (Linz et al. 1992, Linz et al. 1993, Linz and Hanzel 1994, and Berglund 1994)

(1) limiting treatment to cattail marshes containing water and traditionally harboring large numbers of blackbirds,
(2) applying the herbicide at 2 quarts per acre,
(3) treating at least 70 percent of the cattail by alternately spraying 50-foot-wide strips and skipping 20 feet between strips, and
(4) treating cattail from mid-August until the first frost to maximize herbicide efficacy and to decrease the possibility of spray drift damaging small grain crops.

Cattails toward the center of the wetland should be given priority because they will grow back the slowest since they are underwater and birds prefer the middle where there is water (Lilleboe 1993).

The herbicide is applied in a mixture containing a surfactant and a drift retardant. The mixture (Rodeo[R], surfactant, and drift retardant) is practically nontoxic (Henry and Higgins 1992). Rodeo[R] is nontoxic, the surfactant is moderately toxic, and the drift retardant is an insignificant hazard. No evidence of synergistic effects among the three chemicals exists.

The total cost of treating one acre of cattails with Rodeo[R] is $55 (Linz et al. 1993). The cost includes herbicide, surfactant, drift retardant, and application expenses. Assuming a sunflower price of 9½¢ per pound, birds must consume at least 576 pounds of sunflowers during the season to cover treatment costs (based on a $55 per acre cost). This implies that each acre of treated cattail must displace a minimum of 480 feeding birds that consume 0.0287 pounds of sunflower per day for 42 days.

More than 55 percent of North Dakota sunflower producers have not used cattail management strategies to control blackbird damage of sunflowers (North Dakota Agricultural Statistics 1990). Nearly 45 percent of those producers who do use cattail management to control blackbird damage of sunflowers rated the control method very effective. Another 43 percent of producers rated this control method effective.

Sunflower producers who have cattail-choked wetlands harboring considerable numbers of birds will likely receive net benefits from cattail management. Altering cattail concentrations in wetlands with herbicides is effective in controlling bird populations. The herbicide provides relief from bird depredation of sunflowers with virtually no environmental degradation.

Summary

Management techniques for dispersing and reducing bird damage to sunflowers must be (1) cost effective, (2) environmentally safe, and (3) easily implemented (Linz et al. 1993). Applying these criteria to both lethal and nonlethal control methods can assist producers in selecting the most cost-effective means of control. Control methods can be ranked and implemented according to their cost effectiveness.

Lethal control methods may not meet these criteria. It is unknown if DRC-1339 will be effective in controlling blackbird depredation of sunflowers and potential environmental costs are not fully known. Unknown cost effectiveness, expanded public concern for the environment, and increased animal welfare interests may limit the use of lethal control methods.

Several nonlethal control methods also do not satisfy these conditions. Chemical repellents are generally not cost effective and have spillover environmental impacts. Mechanical scare devices are generally not cost effective and are labor intensive. Some environmental alteration methods (i.e., burning, shearing/mowing, and discing) are generally not cost effective, yet are easily implemented and are environmentally benign.

Cultural practices can be implemented for little or no additional cost and may provide positive economic returns. They are environmentally safe and are easily implemented. Sunflower producers could adopt cultural practices initially and reevaluate the extent of bird depredation before considering additional control methods. If economic damage persists, producers could consider selecting sunflower hybrids resistant to bird damage.

If economic damages continue, a more aggressive strategy of environmental alteration could be considered. The most effective environmental alteration method is herbicides. Chemical herbicides can be cost effective in some circumstances, are generally environmentally safe, and are easily implemented.

The remainder of this paper presents an economic analysis of cattail management, using habitat alteration. Specifically, the economic trade-offs of using Rodeo® herbicide are assessed from state and producer perspectives. Both biological and economic impacts are examined.

Biological Impacts of Rodeo[R] Herbicide

Using herbicides to alter the wetland environment can potentially affect wetland biological functions. Herbicides can change wetland vegetation, water chemistry, and wildlife, which directly impacts the biological functioning of the wetland. Biological changes in these areas may have economic impacts on society. These impacts must be considered in developing efficient cattail management strategies.

Vegetation

Herbicides are any chemical substance used to eliminate vegetation or to restrict vegetative growth. Herbicides are sprayed on cattails to increase the amount of open water in a wetland to eliminate bird roosting and nesting. However, other vegetation growing in the wetland may also be affected. Emergent vegetation, primarily cattails and algae, are the primary vegetation in a wetland that are impacted when herbicides are applied.

Cattails

Rodeo[R] applied to cattail stands can reduce the number of live cattail stems 99.7 percent 1 year after treatment (Solberg and Higgins 1993). Residual cattail stems dominated the treated portions of wetland 1 year later. Bladderwort dominated the sprayed portions of treated wetlands 2 years after treatment.

The transition of wetland vegetation from cattails to bladderwort does not financially impact society (unless some individuals think cattails have intrinsic value or bladderwort has financial value). Consequently, no dollar values are directly associated with the decrease in cattails or increase in bladderwort. Cattail and bladderwort uses and their values discovered in the future can be included once they are identified and quantified.

Algae

Algae (*Chlorella*) can tolerate low concentrations of glyphosate (the chemical ingredient in Rodeo[R] herbicide) (Goldsborough and Brown 1988, Maule and Wright 1984, Christy et al. 1981). However, the ability of *Chlorella* to survive glyphosate treatments decreases as the level of glyphosate increases. The ability of *Chlorella* to withstand higher concentrations of glyphosate is enhanced as clay particles are added to the growth medium. Research in progress suggests glyphosate has no effect on algae at the levels necessary to control cattails in wetlands (Linz 1994).

The potential does exist to destroy algae with excessive glyphosate application rates (Solberg and Higgins 1993). Further research is needed to determine specific glyphosate levels that affect algae and secondary impacts resulting from these changes. For example, algae are known to be an important trophic component for some consumer invertebrates (Nelson and Kadlec 1984). A reduction in algae may have detrimental effects on other wetland inhabitants, which may have societal value.

Algae reduction in a wetland does not financially impact society. Consequently, no dollar values can be directly assigned to this change. Algae uses and their values can be included once they are discovered, identified, and quantified.

Water Chemistry

Chemicals associated with Rodeo[R] herbicide and its application can be nontoxic to nontarget wildlife. However, the natural decomposition process of cattails may affect water chemistry. Researchers have suggested that detritus added to the wetland after treatment should be monitored (Solberg and Higgins 1993). Litter decomposition in shallow water may affect water chemistry (Brinson et al. 1981). Decaying cattails could cause anaerobic conditions in wetlands, increasing the potential incidence of avian botulism, which thrives under anaerobic conditions (Stromstad 1992). However, the addition of cattails may have a minimal impact on water chemistry (Linz 1994).

Research assessing the relationship between decomposing cattails and water chemistry is nearly completed. Changes in water chemistry do not inherently lead to a financial impact on society. However, changes could have direct impacts on plant and animal life, which frequent the wetland. Impacts should be identified and quantified so that dollar values can be assigned and included in a benefit-cost analysis of the economics of cattail management.

Wildlife

Some of the most intensively farmed areas of North Dakota are areas where cattails provide a considerable amount of quality wildlife habitat. Cattails provide essential winter cover for many wildlife species (McEnroe 1992, Stromstad 1992). These are also the areas where bird depredation to crops is most common.

Various wildlife species will be affected from habitat alterations. Wildlife garnering the most concern include birds, deer, furbearers, and aquatic life forms. Altering habitat can reduce populations of some wildlife species, while increasing populations of others. The following discussion examines the trade-offs among wildlife species for various wildlife habitats.

The impacts of glyphosate-induced habitat alteration on wildlife are estimated, using changes in species populations for various cattail treatment levels. A common procedure used among studies involves statistical comparisons of species populations between a control wetland and other wetlands in which the concentration of cattails has been reduced. Typically, researchers treated between 50 and 90 percent of the cattails in a wetland and monitored wildlife population levels.

Avian

At least 96 species of birds use North Dakota wetlands (Blixt 1993). Avian species can be broadly classified into 4 groups--sparrows and perching birds, rail and shore birds, upland game, and waterfowl. Population changes for each bird classification are examined to assess the impacts of glyphosate (Rodeo^R)-induced habitat alteration. Several indicator bird species within each group are examined to more fully assess the impacts of habitat alteration.

Sparrow and Perching Birds. The number of sparrows is not affected, even at high (90 percent) treatment levels (Blixt 1993). The number of song sparrows does not differ statistically between treated and control wetlands. Habitat alteration may not affect sparrows because they are active in the low prairie and wet meadow zones of a wetland, which typically are not targeted for herbicide application.

Reducing the amount of cattails does affect the number of marsh wrens in a wetland (Linz et al. 1992, Blixt 1993). Wetlands with high treatment levels (between 70 and 90 percent) have fewer marsh wrens than control wetlands. However, the wren population for wetlands with moderate treatment levels (50 percent) does not differ statistically from control wetlands. The reduction in cattail density may reduce the food base and nesting substrate for marsh wrens (Blixt 1993).

Habitat alteration does statistically affect the number of common yellowthroats for high (90 percent) wetland treatment levels (Blixt 1993, Santillo et al. 1989). However, no statistical difference in the number of common yellowthroats is found at lower treatment levels (50 and 70 percent). The reduction in yellowthroats may be attributed to a reduction in forage from killing live emergent vegetation.

The number of red-winged blackbirds is affected at high (70 and 90 percent) treatment levels (Blixt 1993, Linz et al. 1992, 1993). Red-winged blackbirds are less likely to be affected at moderate-to-low treatment levels. Yellow-headed blackbird populations are not sensitive to habitat alterations in wetlands. However, other environmental factors may have mitigating treatment impacts (i.e., annual water level variations in the wetland).

Rails and Shore Birds. The effects of habitat alteration on the abundance of rails is uncertain. Research has produced mixed results on the impact of habitat alteration and the number of rails (Blixt 1993, Linz et al. 1992). Researchers have hypothesized that management practices used to benefit waterfowl should be compatible with rail habitat requirements (Johnson and Dinsmore 1986, Gibbs et al. 1991). Therefore, changes in waterfowl numbers can be used as proxies to indicate the expected change in the number of rails (see the "Waterfowl" section for details).

Shorebird populations increase significantly for moderate (50 and 70 percent) treatment levels (Blixt 1993). Reducing cattail concentrations increases access to shallow water and mudflat habitats migrating shorebird require (Fredrickson and Taylor 1982).

Upland Game Birds. Pheasants, partridge, and grouse are the primary upland game birds habitat alteration potentially affects. Few empirical studies have been conducted to estimate the impact of habitat alteration on populations of specific upland game species in wetlands. Theoretical evidence suggests that cattail-choked wetlands enhance the survival of wintering upland game populations in winters with average or less snowfall (Kantrud 1992, Stromstad 1992).

Upland game requires dense, tall winter cover near adequate food supplies to survive. Cattails provide essential thermal and escape cover. Cattail-choked wetlands provide vital habitat for upland game in intensively cultivated areas where winter cover is already scarce.

Larger cattail-choked wetlands have the most value to wintering pheasants (Stromstad 1992). These wetlands also have the potential to harbor the largest number of blackbirds. These wetlands are the most likely to be targeted for habitat alteration.

Additional research is needed to establish the relationship between wetland habitat and upland game populations. Ideally, research should examine specific specie populations relative to different cattail treatment levels. A quantitative relationship is needed so that wildlife values can be estimated and included in the economic evaluation of habitat alteration. For this study, treatment was assumed to reduce the population of upland game within a wetland in proportion to the level of treatment.

Waterfowl. The loss and general degradation of habitat has been identified as the major waterfowl management problem in North America (U.S. Fish and Wildlife Service and Canadian Wildlife Service 1986). Considerable research involving habitat/habitat alteration and waterfowl populations has been conducted. Research results show that dense, unbroken stands of cattails can reduce waterfowl use of wetlands (Weller and Spatcher 1965, McEnroe 1976, Murkin et al. 1982, Kantrud 1986, Anderson 1992, Henry and Higgins 1992, Solberg and Higgins 1993). Part of the reason waterfowl use these wetlands less frequently is because of low invertebrate and benthic productivity (Murkin et al. 1982).

Research indicated that waterfowl populations increase when cattail-choked wetlands are fragmented (Keith 1961, Weller and Spatcher 1965, Nelson and Dietz 1966, Patterson 1976, Beule 1979, Kaminski and Prince 1981, Murkin et al. 1982, Hubbard 1984, Solberg and Higgins 1993). Fragmenting cattail stands increases the percentage of open water within the wetland, providing additional preferred breeding habitat for waterfowl. Federal and state wildlife agencies have frequently managed cattail through fragmentation of dense cattail stands to increase waterfowl use (Beule 1979, Murkin and Ward 1980, Kantrud 1986, Schultz 1987, Solberg 1989, Solberg and Higgins 1993).

Treating cattail-choked wetlands may not be effective in increasing waterfowl in wetlands the first year after treatment (Blixt 1993). However, waterfowl numbers do increase in subsequent years as the amount of live emergent vegetation is reduced. Wetlands in the hemi-marsh stage (50 percent open water and 50 percent emergent vegetation) attract more waterfowl than wetlands with other combinations of open water and emergent vegetation (Bishop et al. 1979, Murkin et al. 1982, Henry and Higgins 1992, Kantrud 1992). For example, wetlands with 30 percent open water or 70 percent open water attracted fewer waterfowl than wetlands with 50 percent open water.

Dabbling and diving ducks prefer wetland with openings in the marsh canopy (Kantrud 1986). These waterfowl also avoid wetland with monotypes of live emergents. Reducing the height and density of tall emergents generally increases breeding duck use of the wetland.

Evaluating habitat alteration on individual species indicates that some alterations do not statistically affect the number of mallards or blue-winged teal initially (Bishop et al. 1979, Blixt 1993). Two years are needed for the dead emergents to fall into the wetland and several more years to decompose completely, creating open water within the wetland. Extending the time horizon for 3 or 4 years may provide increases in mallard and teal populations in wetlands.

Breeding pair estimates of waterfowl did not differ statistically between treatment and cattail-dominated wetlands (Solberg and Higgins 1993). However, duck pair densities increased as cattail were removed from choked wetlands (Keith 1961, Solberg and Higgins 1993). Duck nest densities are also higher on treated wetlands than on cattail-choked wetlands. No statistical difference in duck nesting success (i.e., percentage of nests producing a duckling) exists between choked and treated wetlands.

Summary. Additional research is needed for each individual bird species and for different levels of wetland treatment. Priority should be given to those species classified as threatened or endangered if financial resources are a limiting factor. The relationship between populations and wetland treatment levels must be fully developed to accurately represent the economic impact of habitat alteration on avian wildlife.

Deer

Cattail-choked wetlands provide essential habitat for white-tailed deer (Stromstad 1992). Choked wetlands provide thermal and escape cover, enhancing the probability of winter survival (Kantrud 1992). Deer are known to congregate adjacent to large cattail marshes as winter approaches.

Additional research is required to determine quantitative impacts of habitat alteration on deer populations. Research is needed to determine the relationship between the number of deer in a wetland and cattail concentration. The number of deer in a wetland is assumed to decrease as the percentage of open water or open areas in a wetland increases.

Furbearer

Furbearer species that are potential users of wetland include the following:

- mink (*Mustela vison*)
- muskrat (*Ondatra zibethicus*)
- coyote (*Canis latrans*)
- skunk (*Mehpitis mephitis*)
- beaver (*Castor Canadensis*)
- jackrabbit (*Lepus townsendii*)
- otter (*Lutra canadensis*)
- raccoon (*Procyon lotor*)
- red fox (*Vulpes vulpes*)
- weasels (*Mustela frenata*)
- badger (*Taxidea taxus*)
- bobcat (*Lynx rufus*)
- lynx (*Lynx lynx*)

Several furbearers are endangered in North Dakota, including the black-footed ferret, north river otter, and fisher (Leitch et al. 1993). Several other furbearers are on a watch status, including the eastern spotted skunk, virginia opossum, and common gray fox.

Few researchers have examined the relationship between habitat alteration and furbearer populations. Researchers suggest that muskrat populations increase as emergent vegetation in a wetland increases (Bishop et al. 1979). Conversely, eliminating vegetation is found to dramatically reduce the number of muskrats in a wetland.

Additional research is needed to estimate the impact of habitat alteration on furbearer populations in wetlands. This research is especially needed for endangered furbearers or watch status species. Some wetlands may be excluded from habitat alteration if certain furbearers are found to exist. For this study, furbearer populations are assumed to decrease as the percentage of open water in a wetland increases.

Aquatic

Habitat alteration may affect various aquatic wildlife that depend upon wetlands. General classes of aquatic wildlife found in wetlands are fish, amphibians, reptiles, and invertebrates (Niering 1988). Little research is available concerning impacts of glyphosate-induced habitat alteration on fish, amphibians, and reptiles. Additional research is needed to quantify these impacts so that they may be part of the economic analysis of cattail management.

Aquatic invertebrates are important factors in breeding waterfowl habitat selection of northern prairie marshes in the spring (Swanson and Meyer 1973, Joyner 1980, Murkin and Kadlec 1986). Invertebrate numbers may surpass all other measured physical and biological variables as indicators of wetland quality for breeding ducks. Therefore, the effects of habitat alteration on aquatic invertebrates are an important consideration in cattail management.

Invertebrates can be found in different wetland profiles. Those in or upon the water are considered aquatic invertebrates. Invertebrates on the bottom of the wetland or contained within the soil at the bottom of the wetland are benthic invertebrates.

Glyphosate-induced habitat alteration does not appear to have a negative impact on aquatic invertebrates (Folmar et al. 1979). Research results suggest that the number of invertebrates in treated sloughs and marshes is similar to untreated cattail-choked wetlands

(Murkin et al. 1982, Solberg and Higgins 1993, Henry 1992, Henry and Higgins 1992, Lilleboe 1993). Other research findings implied that creating openings in cattail-choked wetlands increases the number of aquatic invertebrates in wetlands (McKnight and Low 1969, Whitman 1974, Berrie 1976, Voigts 1976, Kaminshi and Prince 1981, Murkin et al. 1982).

A positive correlation exists between waterfowl populations and the number of benthic invertebrates in a wetland (Murkin et al. 1982). Benthic invertebrates appear to have the greatest influence on blue-wing teal and mallard use of wetlands. Initial research results suggest that the number of benthic invertebrates increases as cattails are removed from a wetland. However, more information is needed on the relationship between benthic invertebrates and habitat alteration (Solberg and Higgins 1993). Specifically, changes in the number of benthic invertebrates for various levels of wetland treatment are required.

Summary

Hypothesized relationships between species populations observed in a wetland and the percentage of open water are presented in Figures 7 and 8. They represent general relationships for particular species and among species. Relationships were based on information gathered from prior research.

Trade-offs do exist between wildlife populations and open water in a wetland. Some wildlife populations will increase if a portion of cattails are removed from a wetland (rails, shorebirds, waterfowl, and invertebrates). Others wildlife populations decline if habitat is altered (red-winged blackbirds, wrens, upland game, furbearer, and deer). Still other wildlife populations remain mostly unaffected by marginal or moderate alterations (yellow-headed blackbirds and yellowthroats).

Establishing these relationships is important in the valuation process of changes in wetland outputs. A complete economic analysis of cattail management cannot be adequately performed without this information. Additional research is needed to refine and quantify these relationships and to develop relationships for other wildlife species that habitat alteration affects.

Economic Evaluation

Efficient decision making can only be achieved through adherence to economic principles. The purpose of most economic paradigms is to facilitate making decisions (Ferguson and Maurice 1978). Economics can be used to describe or model the various relationships that exist in markets for and among goods and services. Understanding and quantifying these relationships within an analytical framework provide the foundation for identifying optimal solutions with a given set of conditions.

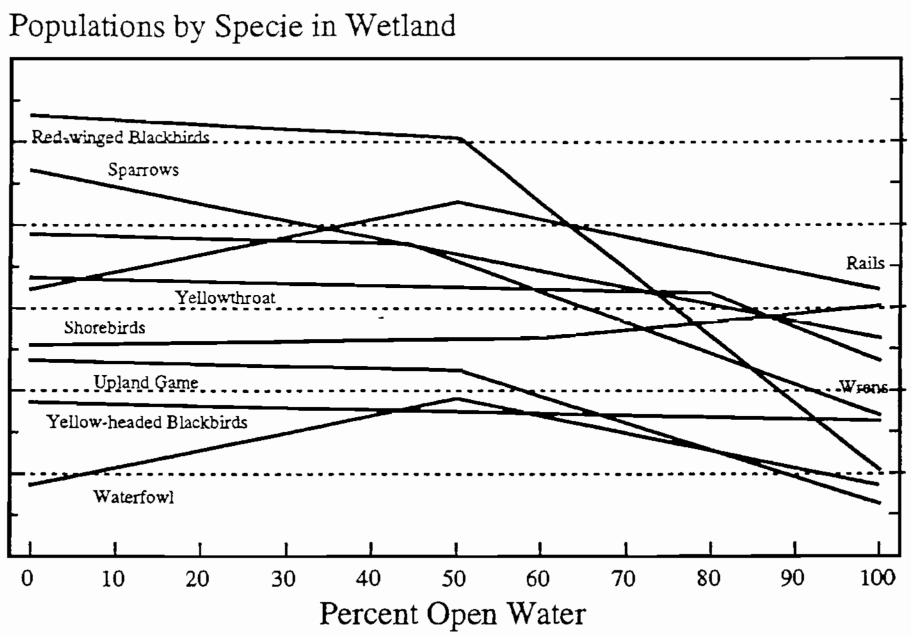

Figure 7. Conceptual Relationship Between Avian Species and Percentage of Open Water in Wetland

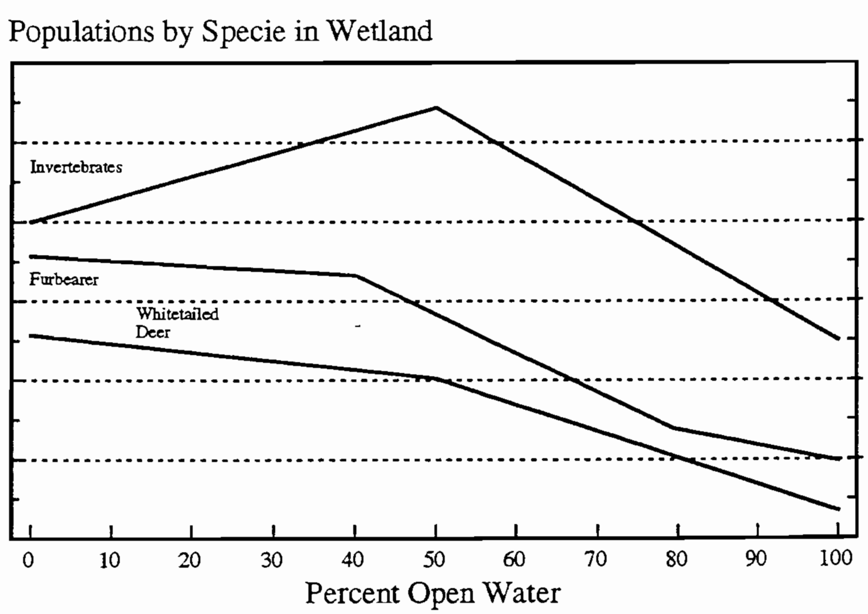

Figure 8. Conceptual Relationship Between Invertebrate, Furbearer, and Deer and the Percentage of Open Water in Wetland

Various economic analyses are available to evaluate the economics of cattail management. They include benefit-cost analysis, cost-effectiveness analysis, and impact analysis (Tietenberg 1992). The appropriate analytical procedure to use depends primarily on the information available to decision makers.

Benefit-cost analysis is the most rigorous technique and requires the greatest amount of information for assessing outcomes and provides the most precise evaluation about the efficiency of various policies (Tietenberg 1992). All the benefits and all the costs associated with a particular policy are considered either quantitatively or qualitatively.

Cost-effectiveness analysis is a systematic method for finding the lowest-cost means of achieving a desired outcome. This procedure is used when benefits cannot be directly identified or measured. The procedure does not produce efficient allocation because no consideration is given to the value of the benefits.

An impact analysis is used when information needed to perform a benefit-cost analysis or a cost-effectiveness analysis is not available. This technique tries to quantify the outcomes associated with various actions, but does not convert all outcomes into one measure, such as dollars. Impact analysis does not provide enough information to identify an optimal solution.

Benefit-cost analysis was selected to assess the economics of cattail management. This technique facilitates identifying all benefits and costs associated with different cattail management strategies. Dollar values can be applied to each if and when they are available. Benefits and/or costs that cannot be quantified with existing data will be qualitatively addressed and will provide the impetus for future research.

Benefit Cost Analysis

Three main decision rules are used with benefit cost analysis--net present-value criterion, benefit-cost ratio, and positive net present-value criterion. Net present-value criterion implies that resources should be used to maximize the present value of net benefits received. The benefit-cost ratio criterion suggests that actions could be taken without loss when the ratio of the present value of benefits to the present value of costs exceeds 1.0. The positive net present-value criterion implies that an activity where the present value of net benefits is greater than zero can be put on a list of activities for continued consideration. Both the benefit-cost ratio and positive net present-value criteria ensure that benefits are equal to or greater than costs. However, neither necessarily identifies the most efficient solution.

The maximum net present-value criterion was selected to assess cattail management strategies. An efficient solution (i.e., maximized net benefit) is achieved at the point where the marginal benefit equals the marginal cost, when Q_1 units are supplied (Figure 9). This point corresponds to where the marginal benefit equals the marginal cost and total benefits exceed total costs by the largest amount.

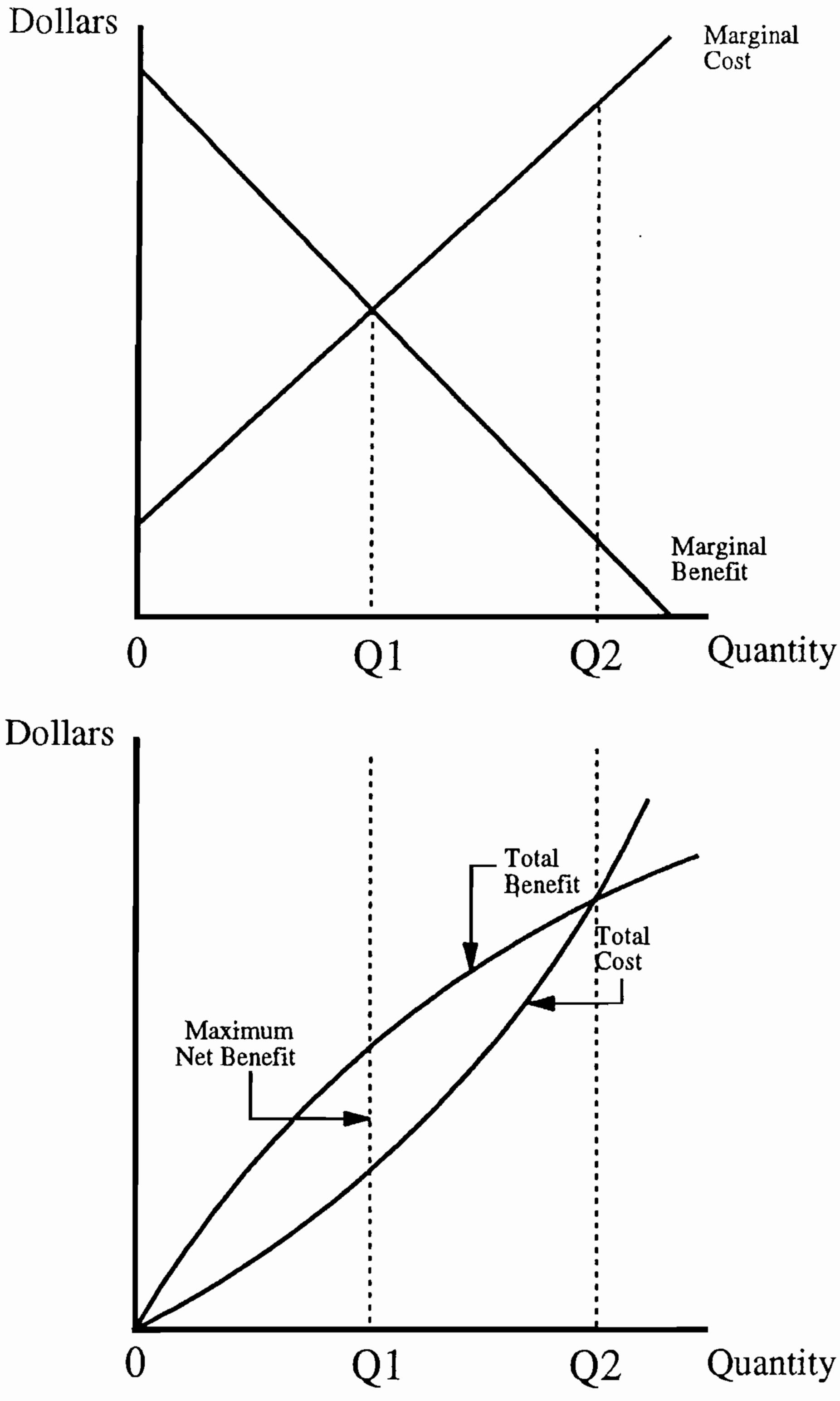

Figure 9. Efficiency Point in Benefit-cost Analysis

Benefits and costs must all be identified to conduct a benefit-cost analysis (Figure 10). Benefits and costs associated with cattail management, using Rodeo^R herbicide to reduce cattail concentrations in wetlands, include treatment costs, changes in blackbird damage to sunflowers, and changes in wetland outputs. Placing dollar values on treatment costs and changes in blackbird damage are relatively easy and straightforward. However, valuing wetland outputs is more challenging, primarily because of information gaps in basic wetland research.

Value of Wetland Outputs

Wetland outputs fall into several classifications, including (Hovde 1993, Mitsch and Gosselink 1993)

- wildlife habitat,
- aquatic habitat,
- groundwater recharge,
- flood control,
- sediment entrapment,
- nutrient assimilation,
- aesthetics, and
- education/research.

These outputs generally describe the consumptive and nonconsumptive uses of wetlands. The economic values of these outputs are equivalent to user expenditures or the dollar value or benefit the user derives from having the output available. Wetlands also have option values, which represent future user values. Option values represent a preference or willingness to pay for preservation so that consumption can occur at a later time. Wetlands may have existence values in addition to present and future use values. Existence values represent the intrinsic value of a resource.

The total economic value of a wetland is the sum of the dollar values of its compatible outputs and uses. The total dollar value equals user values (consumptive, nonconsumptive, and option values) plus existence values (intrinsic values) (Pearce and Turner 1990). Changes in the total economic value of the wetland combined with direct changes in income (reduced blackbird depredation of sunflowers) and expenses (treatment costs associated with the environmental altering technique) are arranged according to benefits and costs and applied to a benefit-cost analysis. Results from the benefit-cost analysis provide information necessary to assess the economics of cattail management (Figure 10).

Not all values are affected as a result of altering the wetland. Option and existence values do not perceptibly change if cattails are partially removed from wetlands. The reduction in cattails is temporary, lasting between 3 and 5 years. Wetland outputs can be reestablished in amounts similar to those that existed prior alteration during this time period.

Nonconsumptive values also do not change perceptively. Time and money spent observing, photographing, and feeding wildlife are assumed to be the same before and after reducing cattail concentrations. Fewer cattails may increase the diversity of wildlife and habitat

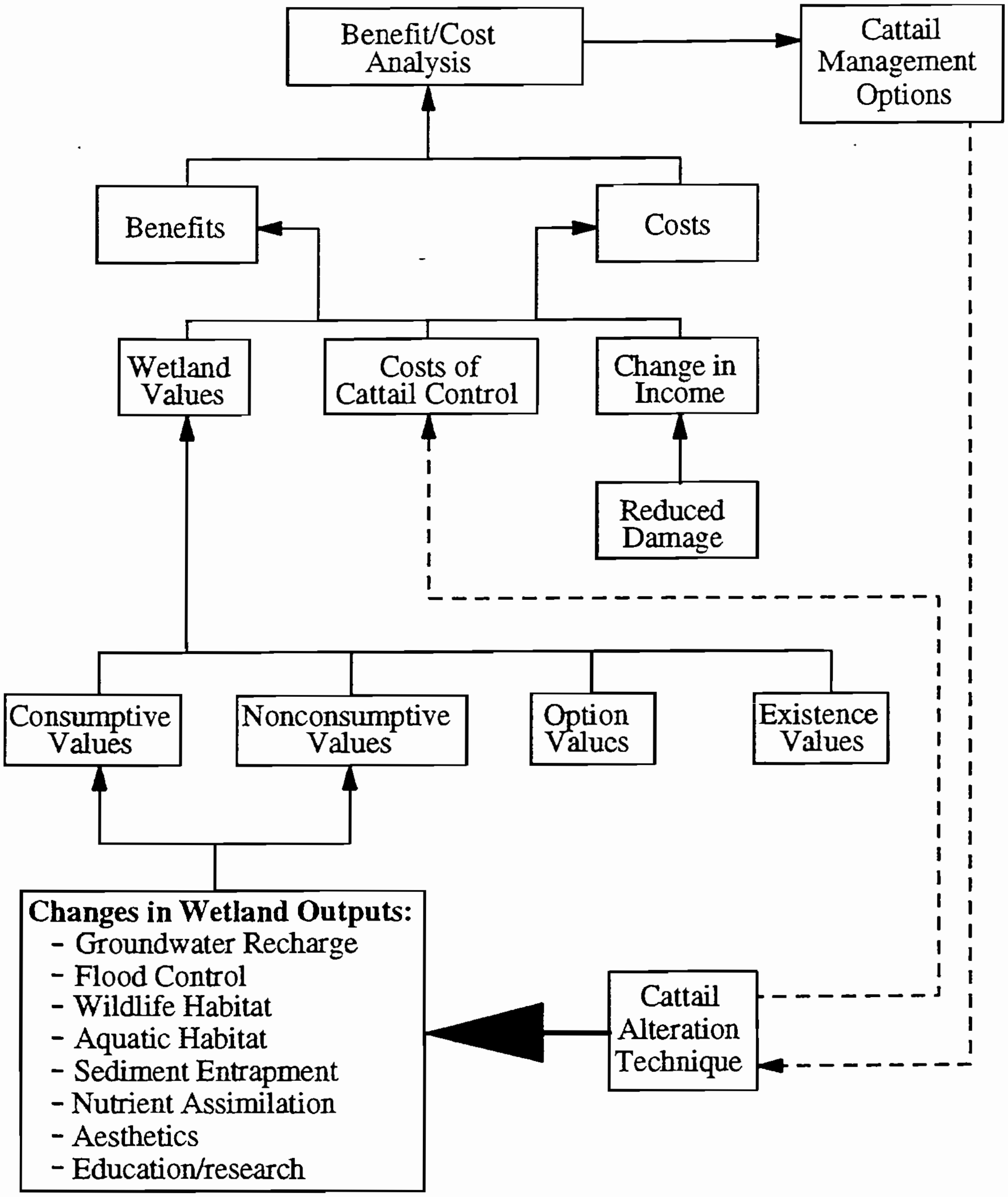

Figure 10. Conceptual Model for Assessing the Economics of Cattail Management

associated with a wetland, thereby increasing nonconsumptive values. However, basic research is not available to quantify these changes.

Some consumptive values are affected; however, the impact may be too small to consider, and/or the basic research needed to estimate the full impact of some changes is not available. Outputs affected, but not quantified and not included in the analysis, are groundwater recharge, flood control, sediment entrapment, and nutrient assimilation.

Reducing cattail concentrations should increase the wetland's capacity for groundwater recharge. Having fewer cattails lowers the amount of water required for cattail growth and may reduce evapotranspiration losses, allowing additional water for recharge. However, the relationship between cattail concentrations and changes in groundwater recharge has not been quantified.

Reducing cattail concentrations may affect the ability of the wetland to impact flood flows. Fewer cattails may increase the water level within a wetland, lowering the wetland's capacity to retain flood-waters. However, the relationship between cattails and flooding has not been estimated.

Sediment entrapment may decrease as cattails are removed. Cattails reduce the flow of water, causing sediments to collect in the wetland. Fewer cattails may lessen the wetland's ability to capture and store sediments. Research is needed to determine the correlation between changes in cattail concentrations and a wetland's sediment entrapment capacity.

The wetland's nutrient assimilation output may also be affected. Fewer cattails and a higher percentage of open water imply less wetland vegetation to absorb nutrients in flow-through wetlands. Fewer nutrients may be retained in the wetland as a result. Research is needed to determine the change in the wetland's nutrient assimilation capacity for different cattail concentration levels.

For this analysis, the aggregate change in wetland benefits and costs among groundwater recharge, flood control, sediment entrapment, and nutrient assimilation outputs is assumed to equal zero. Benefits and costs associated with these wetland outputs can be incorporated once their relationships have been fully identified and quantified. Dollar values can be applied, allowing the change in output to be included in the benefit cost analysis.

Individual Producer Perspective

The economics of cattail management vary, depending upon the level at which decisions are made and the factors various participants consider in the decision-making process. The economic perspective individual producers have concerning cattails/wetlands differs from other perspectives because of the factors included in the decision-making process. It also is the level at which the desire for action originates.

Primary economic factors individual producers consider are the control costs incurred and the expected returns from cattail management. Collectively, producer decisions concerning cattail management are primarily based on profitability. The producer must decide if the habitat-altering technique will provide positive net benefits. Agricultural producers are often motivated by outcomes other than profit, such as removal of a nuisance or the pride of being a "good farmer" (Danielson and Leitch 1986). Producers, however, are compelled by state and federal law to maintain wetlands for the national good. Producers are thus faced with an unusual situation: they must protect wetland for society, but that protection contributes to personal financial losses for the producers. Many producers may not feel obligated to incur additional expense to protect themselves from something they are forced to protect for society.

Generally, producers are unlikely to value changes in the "natural" outputs of wetland and to include them in their decision-making process. Individual producers receive few direct benefits from these types of wetland (assuming the wetland is not enrolled in a state or federal government program) and typically incur ownership costs. The situation is also clouded by the fact that many farmers would prefer to convert wetland to cropland, rather than maintain them and suffer the depredation consequences. Federal and state laws, however, make it nearly impossible to alter wetlands. Thus, farmers are prevented from converting wetlands to increase their well being in order to protect the national interest in wetland values. Consequently, this study does not include wetland value changes in the benefit cost analysis for individual producers. However, the framework is provided, and the procedure is discussed to include wetland values for those individual producers who place a value on wetland outputs.

Many other factors complicate the cattail control issue from the individual's perspective and can only be resolved on a case-by-case basis. These include

- some wetlands have several owners, with different interests;
- some wetlands are owned by absentee landowners;
- some wetlands are owned by the government and managed by the U.S. Fish and Wildlife Service;
- some wetlands are owned by farmers who do not produce sunflower;
- farmers near, but not owning, wetlands can benefit without contributing;
- farmers rotate sunflower on a three- to five-year schedule and may not benefit from cattail control in all years it is effective;
- cattail control on selected wetlands may just shift the problem to other, uncontrolled wetlands;
- it is not certain that blackbirds will be a problem "next year," so control investments made this year may not pay off.

State Perspective

The state perspective differs from the individual producer perspective. The decision process at the individual producer level examines benefits and costs accruing to the producer, while the process at the state level examines benefits and costs accruing to society. The state perspective not includes direct benefits and costs to the producer, but benefits and costs to those who are not directly involved in the decision-making process, but nonetheless impacted as a result individual producer or government actions to control cattails.

The state perspective requires that all impacts (to the producer and to society) be identified and quantified. The aggregate impacts (producer plus society) are incorporated into the benefit-cost analysis so that all interests are represented. Factors used to represent producer impacts from altering wetland habitat have been described previously. Factors representing impacts on society are changes in wetland outputs. Wetland outputs affected must be identified, and the impact must be assessed to determine if it is a societal benefit or cost. Dollar values are assigned to the outcome, facilitating inclusion in the benefit-cost analysis.

Wetland outputs included in the analysis are wildlife consumptive values. The consumptive values of various wildlife species are in the benefit-cost analysis, based on the amount of habitat altered. Incorporating wildlife consumptive values permits changes in the economic value of wetland outputs to determine efficient levels of cattail management.

Wildlife Values

Wildlife values are based on procedures outlined in Hovde (1993). Values for each wildlife group are a function of

- total hunting expenditures in the state for the particular activity,
- the dependency of the wildlife group on wetlands, and
- the total number of wetland acres in the state.

Wildlife groups included are waterfowl, deer, furbearer, and upland game.

Wildlife values are estimated, using the following equation:

$$V_w = (E_w \times D_w) / A,$$

where

V_w = the average annual value per wetland acre for a specific wildlife group,
E_w = the total hunting expenditures in North Dakota for a specific wildlife group,
D_w = the wildlife group's wetland dependency coefficient, and
A = the total number of wetland acres in North Dakota.

Hunting expenditures for each wildlife classification are based on a survey of North Dakota resident hunters during the 1990-91 season (Baltezore and Leitch 1992). The dependency coefficient represents the percentage of the wildlife's life support attributable to wetlands (Leitch 1978). Approximately 2.5 million acres were used as an estimate of wetland habitat in North Dakota (Dahl 1990).

The total economic value of a recreation experience is the participant's direct expenditures plus the value over and above actual expenditures participants are willing to spend (called consumer's surplus by economists) (Anderson et al. 1985). Combining the two values provides a measure of total willingness to pay. However, the value of their recreation experience is only the willingness to pay in excess of direct expenditures. This amount represents the true net worth of the recreation experience.

The average annual wildlife value per wetland acre represents only the expenditure for the hunting experience. Leitch and Kerestes (1982) estimated that licensed sportsmen in North Dakota placed a personal value on their activity 1.4 times greater than their actual expenditure. Thus, the consumer surplus or net worth of outdoor recreation is 40 percent of expenditures.

Total North Dakota hunting expenditures range from a low of $20 million for furbearers to a high of $46 million for deer (Table 1). Waterfowl and furbearers are 40 percent or more dependent upon wetlands, while upland game and deer are less than 15 percent dependent. The estimated average annual wildlife value per wetland acre ranges from a low of $0.66 for deer to a high of $2.39 for waterfowl after adjusting for dependency and consumer's surplus (Table 1). This may still overestimate since it allocates all consumer surplus to wildlife and none to other components of the experience.

TABLE 1. AVERAGE ANNUAL WILDLIFE VALUES PER WETLAND ACRE, WATERFOWL, DEER, FURBEARER, AND UPLAND GAME, NORTH DAKOTA, 1994

Wildlife Classification	Total Hunting Expenditure[a]	Dependency Coefficient[b]	Wetland Acres[c]	Consumer's Surplus[d]	Net Value[f]
	- mil $ -	- % -	- mil -	- % -	- $/ac -
Waterfowl	34	44	2.5	40	2.39
Furbearer	20	40	2.5	40	1.28
Upland Game	41	15	2.5	40	0.98
Deer	46	9	2.5	40	0.66

[a]Source: Baltezore and Leitch 1992.
[b]Source: Leitch 1978.
[c]Source: Dahl 1990.
[d]Source: Anderson et al. 1985.
[e]Total hunting expenditures multiplied by the dependency coefficient, divided by wetland acres, and multiplied by consumer's surplus.

Treatment Costs

The cost of chemically treating cattail in wetland includes expenses for chemicals and for application. Chemical costs include expenses for herbicide (Rodeo[R]), surfactant, and drift retardant. Per acre cost estimates used in this study assume the chemical mixture is applied following the recommendations discussed in the "Habitat Alteration" section.

The cost of treating cattail with Rodeo[R] herbicide is $55 per wetland acre (Linz et al. 1992). Nearly 90 percent of the cost ($49 per acre) is herbicide expense. Application expense varies, but is about $5 per acre. Surfactant and drift retardant expense is $1 per acre.

A treatment cost of $55 per acre in one year eliminates emergent cattail for several years (Linz et al. 1992, Solberg and Higgins 1993) and should be capitalized to account for the number of years treatment is effective. Treatment is assumed to be effective for 3 years. At a capitalization rate of 6 percent (amortization factor 0.3741), the annualized cost is $21 per wetland acre treated. A minimum charge of $125 per treatment means no fewer than 5 wetland acres are treated.

Wetland Bird Population

Several bird species roost in cattail-choked wetlands and may damage sunflowers. Species primarily responsible for damaging sunflower are red-winged blackbirds and common grackles. The number of birds located in and around wetland is the predominant factor determining the amount of sunflower damage.

The number of birds per cattail acre was estimated from a census of red-winged blackbirds in eight cattail-choked wetlands in North Dakota in 1986 (Linz et al. 1991). These wetlands have an average of over 42,800 red-winged blackbirds from August through October (Table 2). North Dakota wetlands, assuming each wetland is 90 percent choked with cattails, have an average of over 67,900 (42,800 / 0.63) red-winged blackbirds and common grackles (Nelms 1991). The average number of birds per cattail acre is 1,310.

Results

Results of the producer and state level benefit-cost analyses follow. The producer level analysis examines only those benefits and costs accruing to individual producers. The state level analysis includes all benefits and costs to society.

Producer Level

A 25-acre wetland 100 percent choked with cattails can contain more than 32,750 birds capable of damaging sunflowers (Table 3). Researchers have found as many as 87,000 birds in a 25-acre wetland (Linz 1994). Bird damage to sunflower fields adjacent to the wetland is $3,770, assuming producers take no action to prevent damage.

TABLE 2. AVERAGE BIRDS PER CATTAIL ACRE, NORTH DAKOTA WETLANDS

Wetland[a]	Wetland Acres[a]	Percentage Choked[b]	Cattail Acres[c]	Blackbirds[a]	Bird Adjustment Factor[d]	Total Birds[e]	Birds per Cattail Acre[f]
Ibsen	1,284	90	1,156	142,100	1.6	225,939	195
Blegens	37	90	33	46,300	1.6	73,617	2,208
Mikes	435	90	391	36,200	1.6	57,558	147
Pelican	741	90	667	26,100	1.6	41,499	62
Command	22	90	20	58,146	1.6	92,452	4,621
Swensons	10	90	9	5,133	1.6	8,161	918
Johns	15	90	13	16,096	1.6	25,593	1,919
Peterburg	54	90	49	12,562	1.6	19,974	408
Average	325	n/a	292	42,830	n/a	68,099	1,310

[a]Information was based on Linz et al. (1991a).
[b]The exact percentage choked was unavailable. However, wetlands selected for study were those between 70 and 100 percent choked.
[c]Cattail acres were wetland acres times the percentage choked.
[d]The number of birds was adjusted to account for common grackles. The average number of blackbirds per wetland is 42,830. The distribution of birds is 63 percent blackbirds and 37 per common grackles (Nelms 1991). This implies that the average total number of blackbirds and common grackles per wetland is 67,900 (42,830 / 0.63). The bird adjustment factor equals the average total number of blackbirds divided by the average total number of all birds (blackbirds and common grackles) or 1.6 (42,830 / 67,900).
[e]The number of blackbirds times the adjustment factor equals total birds.
[f]Total birds divided by cattail acres equals birds per cattail acre.

Treating the first 5 cattail acres within the wetland with Rodeo[R] reduces the number of birds by more than 6,500 to 26,200 (Table 3). The amount of sunflower damage is reduced by $687. Total treatment cost to achieve this damage reduction amount is $125. The net benefit to the producer from treating 5 cattail acres is $562.

Net benefit (total benefit minus total cost) from treatment is maximized when 18 cattail acres (approximately 70 percent) are treated (Table 3 and Figure 11). At this point, the number of birds causing damage equals zero. Total treatment benefit is $3,437, and total treatment cost is $378. The net treatment benefit realized exceeds $3,000.

Net benefit from treatment decreases as more than 18 cattail acres are treated (Table 3 and Figure 11). Treatment costs continue to increase while total treatment benefits do not change, causing net benefits to decrease. Economic theory and common sense suggest treating more than 18 cattail acres in this wetland is not economically feasible.

TABLE 3. SUNFLOWER PRODUCER BENEFIT-COST ANALYSIS OF HABITAT ALTERATION USING RODEO® HERBICIDE, NORTH DAKOTA, 1994

Birds[a]	Treated Cattail	Sunflower Damage-Period One[b]	Sunflower Damage-Period Two[b]	Total Sunflower Damage	Total Treatment Benefit[c]	Total Treatment Cost[d]	Net Treatment Benefit[e]
	- acres -	- $ -	- $ -	- $ -	- $ -	- $ -	- $ -
32,750	**0**	**1,466**	**1,970**	**3,437**	**0**	**0**	**0**
31,440	*1*	*1,408*	*1,892*	*3,299*	*137*	*125*	*12*
30,130	*2*	*1,349*	*1,813*	*3,162*	*275*	*125*	*150*
28,820	*3*	*1,290*	*1,734*	*3,024*	*412*	*125*	*287*
27,510	*4*	*1,232*	*1,655*	*2,887*	*550*	*125*	*425*
26,200	**5**	**1,173**	**1,576**	**2,749**	**687**	**125**	**562**
24,890	**6**	**1,114**	**1,498**	**2,612**	**825**	**126**	**699**
23,580	**7**	**1,056**	**1,419**	**2,475**	**962**	**147**	**815**
22,270	**8**	**997**	**1,340**	**2,337**	**1,100**	**168**	**932**
20,960	**9**	**939**	**1,261**	**2,200**	**1,237**	**189**	**1,048**
19,650	**10**	**880**	**1,182**	**2,062**	**1,375**	**210**	**1,165**
18,340	**11**	**821**	**1,103**	**1,925**	**1,512**	**231**	**1,281**
17,030	**12**	**763**	**1,025**	**1,787**	**1,650**	**252**	**1,398**
15,720	**13**	**704**	**946**	**1,650**	**1,787**	**273**	**1,514**
14,410	**14**	**645**	**867**	**1,512**	**1,925**	**294**	**1,631**
13,100	**15**	**587**	**788**	**1,375**	**2,062**	**315**	**1,747**
11,790	**16**	**528**	**709**	**1,237**	**2,200**	**336**	**1,864**
10,480	**17**	**469**	**631**	**1,100**	**2,337**	**357**	**1,980**
0	**18**	**0**	**0**	**0**	**3,437**	**378**	**3,059**
0	*19*	*0*	*0*	*0*	*3,437*	*399*	*3,038*
0	*20*	*0*	*0*	*0*	*3,437*	*420*	*3,017*
0	*21*	*0*	*0*	*0*	*3,437*	*441*	*2,996*
0	*22*	*0*	*0*	*0*	*3,437*	*462*	*2,975*
0	*23*	*0*	*0*	*0*	*3,437*	*483*	*2,854*
0	*24*	*0*	*0*	*0*	*3,437*	*504*	*2,933*
0	*25*	*0*	*0*	*0*	*3,437*	*525*	*2,912*

[a]Assumes a 25 acre wetland that is 100 percent choked. Bold numbers represent possible outcomes. The italicized numbers between 0 and 5 cattail acres treated are not possible because a minimum of 5 acres must be treated. Italicized numbers for 18 or more cattail acres treated are not rational because the number of birds in a wetland equals zero when 70 percent or more of the wetland is open water.

[b]See "Blackbird Consumption" section for details on damage estimates.

[c]Total sunflower damage if no cattail acres are treated ($3,770) minus total sunflower damage for the specific number of cattail acres treated.

[d]Annualized treatment costs are $21 per cattail acre. A minimum of 5 cattail acres must be treated at a cost of $125.

[e]Total treatment benefit minus total treatment cost.

State Level

The state-level perspective accounts for all economic impacts to the producer and society. Not all economic impacts are part of this analysis because primary data are not available in some cases. This benefit-cost analysis should be redone when these data become available.

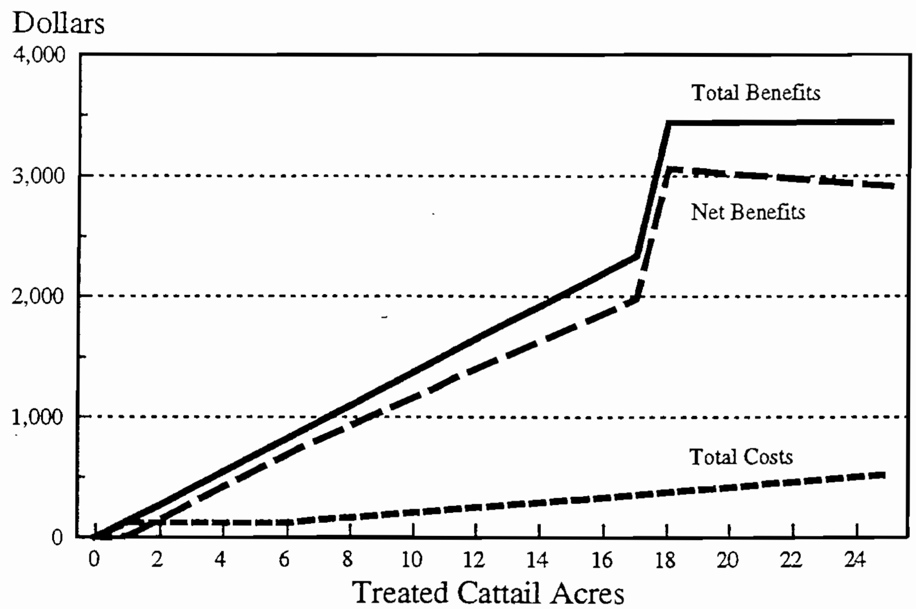

Figure 11. Producer Benefits, Costs, and Net Benefits of Habitat Alteration Using Rodeo[R] Herbicide, North Dakota, 1994

A 25-acre wetland 100 percent choked with cattails provides society with $73 of benefits (Table 4). [**Wetland outputs that are essentially unaffected by cattail treatment (e.g., flood control, sediment entrapment) are not included in these analyses.**] Deer, furbearer, and upland game outputs are responsible for the benefits society receives from the wetland. Sunflower or waterfowl outputs the 100 percent-choked wetland provides to society are zero.

Treating 5 acres of cattail in the wetland increases total societal benefits to $633 (Table 4). Additional sunflower production is responsible for most of the increase in total societal benefits. Increases in sunflower and waterfowl outputs more than offset the decrease in deer, furbearer, and upland outputs. Total treatment costs are $125. The net benefit to society from treatment is $508.

Net societal benefits are maximized when 18 cattail acres in the wetland are treated (Table 4 and Figure 12). Treating these cattail acres provides $2,718 of net benefits. Most of the benefit (99 percent) society receives is from additional sunflower production. Since all production expenses have already been incurred, sunflower damage prevented represents sunflower made available for consumption at no additional cost.

Net societal benefits decrease if more than 18 cattail acres are treated. Total benefits decrease at this point, and total costs continue to increase. Treating more than 18 cattail acres in this wetland is not economically feasible for the society.

Net societal benefits from wildlife outputs are at their highest when no cattail acres are treated (Table 4). The value of deer, furbearer, and upland game outputs in untreated wetlands more than offsets the foregone waterfowl outputs if cattails were controlled.

TABLE 4. SOCIETAL BENEFIT-COST ANALYSIS OF HABITAT ALTERATION USING RODEO[R] HERBICIDE, NORTH DAKOTA, 1994

Birds[a]	Treated Cattail	Societal Benefit-Sunflower[b]	Waterfowl Benefit	Deer Benefit	Furbearer Benefit	Upland Benefit	Societal Benefit-Wildlife[c]	Total Societal Benefit[d]	Total Treatment Cost[e]	Net Benefit[f]
	- acres -	- -	- $ -	- $ -	- $ -	- $ -	- $ -	- $ -	- $ -	- $ -
32,750	0	0	0	16	32	25	73	73	0	73
31,440	1	12	2	16	31	24	73	85	125	-40
30,130	2	150	5	15	30	23	72	222	125	97
28,820	3	287	7	14	28	22	72	359	125	234
27,510	4	425	10	14	27	21	71	496	125	371
26,200	5	562	12	13	26	20	71	633	125	508
24,890	6	699	14	12	24	19	70	769	126	643
23,580	7	815	17	12	23	18	70	885	147	738
22,270	8	932	19	11	22	17	69	1,001	168	833
20,960	9	1,048	22	10	21	16	68	1,116	189	927
19,650	10	1,165	24	10	19	15	68	1,233	210	1,023
18,340	11	1,281	26	9	18	14	67	1,348	231	1,117
17,030	12	1,398	29	9	17	13	67	1,465	252	1,213
15,720	13	1,514	29	8	15	12	64	1,578	273	1,305
14,410	14	1,631	26	7	14	11	59	1,690	294	1,396
13,100	15	1,747	24	7	13	10	53	1,800	315	1,485
11,790	16	1,864	22	6	12	9	48	1,912	336	1,576
10,480	17	1,980	19	5	10	8	43	2,023	357	1,666
0	18	3,059	17	5	9	7	37	3,096	378	2,718
0	19	3,038	14	4	8	6	32	3,070	399	2,671
0	20	3,017	12	3	6	5	27	3,044	420	2,624
0	21	2,996	10	3	5	4	21	3,017	441	2,576
0	22	2,975	7	2	4	3	16	2,991	462	2,529
0	23	2,954	5	1	3	2	11	2,965	483	2,482
0	24	2,933	2	1	1	1	5	2,938	504	2,434
0	25	2,912	0	0	0	0	0	2,912	525	2,387

[a]Assumes a 25-acre wetland that is 100 percent choked.
[b]Benefits are from the "Net Treatment Benefit" column in Table 3.
[c]Total of waterfowl, deer, furbearer, and upland wildlife benefits.
[d]Total of sunflower and wildlife societal benefits.
[e]Annualized treatment costs are $21 per cattail acre.
[f]Total societal benefit minus total treatment cost.

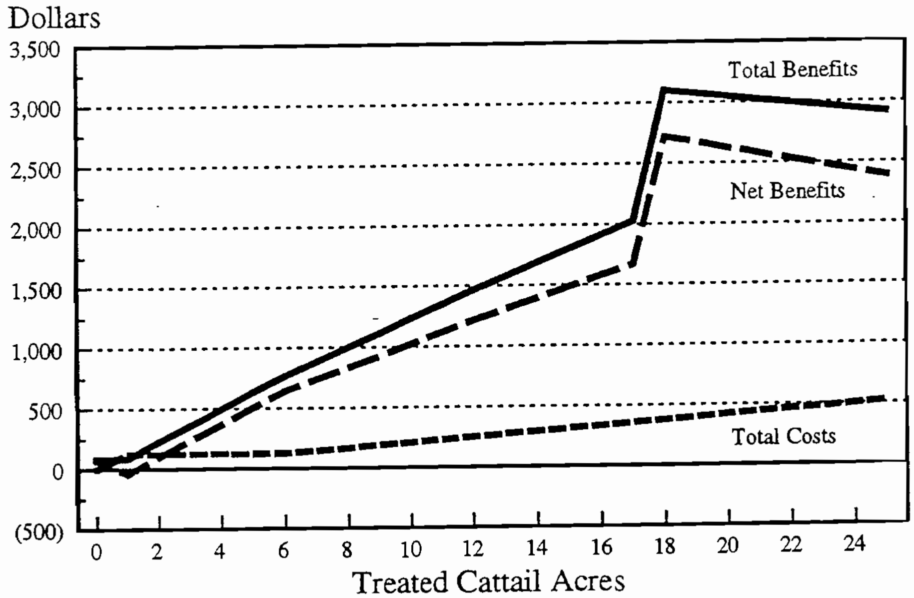

Figure 12. Societal Benefits, Costs, and Net Benefits of Habitat Alteration Using Rodeo R Herbicide, North Dakota, 1994

Treating 18 cattail acres reduces societal wildlife benefits from $73 to $37. This represents a 50 percent ($36) decrease in wildlife outputs. However, society benefits from additional sunflower production as well. The value of sunflower production more than offsets the loss of wildlife outputs up to and including 18 treated acres.

Summary

Sunflower production losses due to birds can be considerable when spatially concentrated. Production losses are from $2.1 to $2.2 million in foregone cropsites annually. Production losses at the producer level lead to a loss of economic activity at the regional level.

Management techniques to reduce bird damage to sunflowers should be cost effective, environmentally safe, and easily implemented. Nearly all lethal control methods and several nonlethal control methods do not satisfy these criteria. Habitat alteration through cattail management is the preferred option to meet these criteria at this time.

Habitat alteration can be used to improve wetland for waterfowl and marsh birds and to control bird depredation of sunflowers. One method of habitat alteration is cattail management. The goal of cattail management is to remove a portion of cattail from overgrown wetland to improve waterfowl use and to reduce the wetland's attractiveness to birds that damage sunflower. The optimal percentage of cattail to remove is the point where social net benefits are maximized.

Reducing cattail concentrations affects many biological functions of wetland. Eliminating cattail alters the vegetation, the water chemistry, and the wildlife composition of a wetland. Changes in wetland functions directly impact wetland outputs. The overall effect on wetland outputs is sensitive to the amount of cattail removed.

Altering a 25-acre wetland 100 percent choked with cattail is economically justified up to 70 percent treatment (18 acres) of the emergent cattails. Treating 18 acres maximizes the net benefits ($3,059) to the producer from removing cattail. Treating more or less than 70 percent of the cattail reduces the producer's net benefits.

The state or society also benefits from reducing the amount of cattail in a wetland. Treating 70 percent of the cattail in a 25-acre, 100 percent-choked wetland also maximizes the net benefits to society.

These results are invariant with respect to increasing sizes of wetland since the modeled relationships are linear. Additional investigations may lead to the use of nonlinear relationships, but data were not available for more robust model specifications.

Conclusions

Beneficiaries from cattail control are producers and society. The producer benefits from higher returns to production. Society benefits from the increased well-being of the producer and from improved waterfowl wildlife habitat.

Some beneficial outputs are lost with cattail control. Benefits from deer, furbearer, and upland game outputs are reduced. Consequently, compensation for the loss of these benefits should be considered.

Financial gains producers and society realize from cattail control should be sufficient to compensate others whose benefits are reduced. Beneficiaries should be willing to pay for cattail control and to compensate for reduced benefits of others. Excluding any beneficiary from these financial responsibilities allows him to become a "free rider" on the system.

The issue becomes the appropriate share each beneficiary should contribute and how losses might be compensated, if al all. The determination of absolute levels each should contribute is the responsibility of policymakers.

Sensitivity Analysis

Numerous assumptions regarding functional relationships among and between biological, management, agronomic, market, and socioeconomic variables were made to reach the results of this study (Table 5). Altering any of these estimates or assumptions or adding variables to the model may change the optimal level of cattail treatment for a particular wetland. Changes in the estimated number of birds per cattail acre, the price of sunflower, and sunflower consumption per bird per day are most likely to affect the optimal level of cattail treatment.

TABLE 5. CATTAIL CONTROL MODEL VARIABLES AND ASSUMED (POINT) ESTIMATES, NORTH DAKOTA, 1994

Model Variable	Assumed or Point Estimate
Number of sunflower damaging birds per cattail acre	1,600
Percentage of cattail at which birds damaging sunflower are fully eliminated	30
Pounds of sunflower consumption per bird per day	
Period 1	0.0402
Period 2	0.0230
Dollar per pound price of sunflowers	0.0955
Number of days birds consume sunflower	
Period 1	14
Period 2	28
Total	42
Net sunflower damage factor	0.85
Per acre dollar cost of herbicide	55
Number of years herbicide is effective	2
Hunting expenditures (million dollars)	
Waterfowl	34
Furbearer	20
Upland Game	41
Deer	46
Wildlife dependency coefficient	
Waterfowl	0.44
Furbearer	0.40
Upland Game	0.15
Deer	0.09
Number of wetland acres in North Dakota (million acres)	2.5
Consumer's surplus percentage of expenditure	.4

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Appendix A

Sunflower Production--
Pounds, acres, and pounds per acres

APPENDIX TABLE 1. SUNFLOWER PRODUCTION, BY REGION, NORTH DAKOTA, 1982-91

Year	Northwest	North Central	Northeast	Central	East Central	Southeast	Total
	thousands of pounds						
1982	249,250	544,326	561,150	805,540	583,750	567,456	3,311,472
1983	197,305	347,760	401,527	557,999	296,190	327,500	2,128,281
1984	210,200	356,280	469,930	596,700	341,000	347,900	2,322,010
1985	109,240	274,090	291,720	506,310	316,410	354,650	1,852,420
1986	114,240	219,760	258,400	475,840	338,480	271,920	1,678,640
1987	158,720	274,130	316,800	469,300	260,620	310,520	1,790,090
1988	98,420	127,040	241,110	302,330	209,310	183,420	1,161,630
1989	61,850	141,990	185,020	317,235	203,700	258,040	1,167,835
1990	69,250	151,630	227,200	395,460	342,460	313,900	1,499,900
1991	111,500	229,410	393,290	493,080	495,910	471,750	2,194,940
Average	**137,998**	**266,642**	**334,615**	**491,979**	**338,783**	**340,706**	**1,910,722**

Source: North Dakota Agricultural Statistics Service

APPENDIX TABLE 2. SUNFLOWER PRODUCTION, BY REGION, NORTH DAKOTA, 1982-91

Year	Northwest	North Central	Northeast	Central	East Central	Southeast	Total
	acres						
1982	250,000	514,000	522,000	694,000	467,000	514,000	2,961,000
1983	191,500	334,000	361,100	531,900	282,000	347,000	2,047,500
1984	270,000	415,000	429,000	603,000	299,000	348,000	2,364,000
1985	136,000	260,500	306,000	471,500	236,000	266,500	1,676,500
1986	93,500	175,500	191,500	360,000	216,000	188,000	1,224,500
1987	106,900	176,500	211,000	328,500	174,000	201,200	1,198,100
1988	124,300	184,500	219,500	352,500	179,000	203,800	1,263,600
1989	88,300	170,500	198,100	337,200	170,800	191,500	1,156,400
1990	78,000	152,000	205,500	334,500	232,500	241,500	1,244,000
1991	104,000	199,500	272,000	410,000	293,000	311,000	1,589,500
Average	**144,250**	**258,200**	**291,570**	**442,310**	**254,930**	**281,250**	**1,672,510**

Source: North Dakota Agricultural Statistics Service

APPENDIX TABLE 3. SUNFLOWER PRODUCTION PER ACRE, BY REGION, NORTH DAKOTA, 1982-91

Year	Northwest	North Central	Northeast	Central	East Central	Southeast	Total
	lbs/acre						
1982	997	1,059	1,075	1,161	1,250	1,104	1,118
1983	1,030	1,041	1,112	1,049	1,050	944	1,039
1984	779	859	1,095	990	1,140	1,000	982
1985	803	1,052	953	1,074	1,341	1,331	1,105
1986	1,222	1,252	1,349	1,322	1,567	1,446	1,371
1987	1,485	1,553	1,501	1,429	1,498	1,543	1,494
1988	792	689	1,098	858	1,169	900	919
1989	700	833	934	941	1,193	1,347	1,010
1990	888	998	1,106	1,182	1,473	1,300	1,206
1991	1,072	1,150	1,446	1,203	1,693	1,517	1,381
Average	**977**	**1,049**	**1,167**	**1,121**	**1,337**	**1,243**	**1,163**

Source: North Dakota Agricultural Statistics Service

Appendix B

Farm Level Sunflower Damage

The level of damage at the farm level is estimated, using two surveys of North Dakota sunflower growers (Lamey et al. 1992, 1993). Damage is based on the simple average percentage of respondents reporting various percentage yield loss levels. Percentage yield losses and percentage of respondents are

Percent Yield Loss	1990 Survey	1991 Survey	Average
	------ percent of respondents -------		
0 - 5	66.3	59.8	63.1
5 - 10	19.3	25.6	22.5
11 - 25	10.2	11.5	10.9
26 - 50	3.5	2.6	3.1
51 - 100	0.2	0.5	0.4

Ideally, damage estimates should be based on a long-term study of blackbird depredation of sunflowers at the farm level. However, such data are not available.

To determine the extent of damage at the farm level, an undamaged yield must be estimated. Adjusting the reported state average sunflower yield (which includes sunflower damage) for each damage level reported and relating that amount of damage to the percent of respondents with that particular damage level is used to calculate the undamaged yield. The percentage of damage, adjusted yield, percent of respondents reporting a particular damage level, and undamaged yield are

(1) Reported Yields[2]	(2) Damage (%)	(3) Adjusted Yield[3] (lbs/ac)	(4) Respondents (%)	Undamaged Yield[4] (lbs/ac)
1,163	2.5	1,192	63.1	752
1,163	8.0	1,256	22.5	283
1,163	18.0	1,372	10.9	150
1,163	38.0	1,605	3.1	50
1,163	75.5	2,041	0.4	8
			Total=	1,243

The damage is the midpoint of the range of damage estimates reported in Lamey et al. 1992, 1993. The adjusted yield is calculated by multiplying the 10-year average yield (1,163 pounds per acre) by 1 plus the percentage of damage (i.e., 1 + 0.025 = 1.025 for 2.5 percent damage). The percentage of respondents weights the various adjusted yields to determine an undamaged yield for the state.

[2]North Dakota Agricultural Statistics Service.

[3]Column 1 multiplied by 1 + (column 2/100).

[4]Column 3 multiplied by column 4.

The percent of sunflower damage at the farm level was estimated, using the following equation:

$$D_{f1} = (1 - (Y_d / Y_{ud}) \times 100,$$

where

D_{f1} = the percentage of sunflower yield reduction,
Y_d = the damaged 10-year average sunflower yield, and
Y_{ud} = is the undamaged sunflower yield.

The percentage yield reduction at the farm level from blackbird depredation of sunflowers in North Dakota is 6.4 percent [(1 - (1,163 / 1,243) x 100)].

Appendix C

Adjusted Sunflower Prices

The 10-year average price of sunflowers was adjusted to reflect the increased sunflower production if blackbird depredation of sunflowers was eliminated. The adjusted price was estimated, using the following equation (Coon and Wilson 1986):

$$PS_{1taj} = PS_{1ta} - \frac{\Delta C}{(E_s - E_d) \times \frac{Q}{PS_{1ta}}}$$

where

PS_{1taj}	=	the adjusted price of North Dakota sunflowers,
PS_{1ta}	=	the report 10-year average price of sunflowers in North Dakota,
C	=	the change in the supply of sunflowers from the elimination of blackbird depredation,
E_s	=	the price elasticity of supply for sunflowers,
E_d	=	the price elasticity of demand for sunflowers, and
Q	=	the reported 10-year average of sunflower production.

The change in supply is equal to the difference between the undamaged sunflower production [1,910,722,000/(1-.064)] and the 10-year average sunflower production (1,910,722,000) or 130,647,658 pounds (2,041,369,658 - 1,910,722,000). The elasticities of sunflower supply and demand are unknown. Consequently, the elasticities of soybeans were used as proxies. The price elasticities of demand and supply were -1.015 and 0.378, respectively (Holt 1992).

The adjusted price is

$$PS_{1taj} = 0.0955 - \frac{130,647,658}{(0.378 + 1.015) \times \frac{1,910,722,000}{0.0955}}$$

$$PS_{1taj} = 0.0908$$

An additional 130,647,658 pounds of sunflower in North Dakota would decrease the price of sunflowers by 0.47 cents per pound from what was received over the ten-year period.