Response of Black Terns (*Chlidonias niger*) to Glyphosate-Induced Habitat Alterations on Wetlands

GEORGE M. LINZ[1], DAVID L. BERGMAN[1], DAGE C. BLIXT[2], WILLIAM J. BLEIER[2]

[1]U.S. Department of Agriculture, Denver Wildlife Research Center, North Dakota Field Station, North Dakota State University, Fargo, North Dakota, 58105-5517 USA

[2]Department of Zoology, Stevens Hall, North Dakota State University, Fargo, North Dakota 58105-5517 USA

Abstract.—The Black Tern (*Chlidonias niger*) is considered an endangered species in some states and is a category two species for listing as a federally threatened or endangered species. In the northern Great Plains, cattails (*Typha* spp.) have over-grown many wetlands, contributing to the decline in numbers of Black Terns. We aerially sprayed wetlands with glyphosate herbicide to assess the influence of habitat changes on Black Terns. In 1990 and 1991, two separate experiments were initiated in northeastern North Dakota whereby wetlands were randomly assigned one of three spray coverages with glyphosate. In one experiment, Black Terns used treated wetlands more than untreated wetlands ($P < 0.1$). In the other experiment, densities of Black Terns were similar between untreated and treated wetlands ($P > 0.1$). A stepwise multiple regression indicated a significant positive relationship between the number of Black Terns and hectares of water and dead emergent vegetation in the wetland ($r^2 = 0.51$). Black Terns use of a wetland may be positively influenced by floating mats of dead cattails, live emergent vegetation, and open water. *Received 21 February 1994, revised 16 June 1994, accepted 10 September 1994.*

Key words.—Black Tern, cattails, *Chlidonias niger*, glyphosate, habitat, North Dakota, *Typha*, wetlands.

Colonial Waterbirds, 17(2): 160-167, 1994

The Black Tern (*Chlidonias niger*) is considered an endangered species or a species of special concern in Iowa, Pennsylvania, Ohio, Indiana, Illinois, New York, North Dakota, and Wisconsin and is a category two candidate for listing as a federally threatened or endangered species due to the loss and degradation of habitat (Carroll 1988, Hands *et al.* 1989, Knutson 1991, U.S. Fish and Wildlife Service 1992). In the northern Great Plains, Black Terns nest in seasonal (Type III) and semipermanent (Type IV) wetlands (Stewart and Kantrud 1974, Kantrud and Stewart 1984) that contain a good interspersion of open water and emergent vegetation (Weller and Spatcher 1965, Dunn 1979, Mosher 1987). In the last 70 years, cattails (*Typha* spp.) have dispersed across the northern Great Plains and have degraded many wetlands by forming dense monotypic stands (Kantrud 1986).

Generally, birds benefit from increased habitat heterogeneity; whereas, relatively few birds use wetlands dominated by dense stands of cattails (Weller and Spatcher 1965, Weller and Fredrickson 1973, Kantrud 1986, Blixt 1993). Recognizing that cattails are a major problem in the northern Great Plains, wildlife agencies are attempting, with various degrees of success, to manage cattails by burning, cutting, grazing, herbicides, mechanical destruction, water level manipulation, and combinations of these techniques (Baltezore *et al.* 1994). Quantitative data documenting the effects of these cattail management techniques on wildlife, particularly Black Terns, are limited (Kantrud 1986).

In this paper, we examine the impact of managing emergent vegetation (i.e., largely cattails) with glyphosate herbicide on Black Terns in northeastern North Dakota. Our objectives were to (1) compare the numbers of Black Terns using wetlands treated with glyphosate herbicide to untreated (control) wetlands and (2) describe the relationship between Black Tern numbers (dependent variable) and various wetland parameters (independent variables).

STUDY AREA AND METHODS

The study area is located in the Northeastern Drift Plain of North Dakota, which is characterized by the presence of many shallow-basin wetlands that are subject to large annual variations in water coverage (Stewart and Kantrud 1974). The primary land use is growing of small grains, sunflower, hay, and corn. North Dakota receives 77% of its annual precipitation between April and September (North Dakota Agricultural Statistics Service 1993). Long-term average monthly precipitation and temperature during these months in Devils Lake, a city 48 km west of the study area, are 5.4 cm and 14.6° C, respectively (North Dakota Agricultural Statistics Service 1993).

In 1990 (Experiment #1), we randomly designated 12 privately owned cattail wetlands ($\overline{X}$ = 7.4 ha, SE = 1.7 ha) as either untreated (n = 4) or treated at 70% (n = 4) or 90% (n = 4) spray coverage with aerially-applied glyphosate herbicide (RODEO® formulation, Monsanto Company, St. Louis, Missouri). However, one control wetland was deleted from the analysis because of cattle grazing. In 1991 (Experiment #2), we randomly designated another 12 cattail wetlands ($\overline{X}$= 15.5 ha, SE = 3.7 ha) as either untreated (n = 4) or treated at 50% (n = 4) or 70% (n = 4) spray coverage with glyphosate. Ten of these wetlands were federally owned U.S. Fish and Wildlife Service Waterfowl Production Areas. The wetlands were treated in mid- to late-July at a rate of 5.8 l/ha of glyphosate in 46.7 l/ha solution containing 0.2 l/ha surfactant and up to 0.6 l/ha drift retardant.

The herbicide was applied with a fixed-wing agricultural spray plane in strips that were 15 m wide and ran along the long axis of the wetlands. To achieve the 50%, 70%, and 90% treatment levels, the pilot was instructed to skip approximately 15-m, 6.4-m, or 1.7-m strips of vegetation, respectively. For example, for wetlands receiving the 70% treatment, one 15-m strip was sprayed along the edge of the wetland, approximately 6.4-m was skipped, and the next 15-m strip treated, etc., until the entire wetland was traversed. Pilot error was reduced by stationing a person or placing large orange flags at the end of each strip.

Black Terns were counted in all test wetlands in early June and mid-July, 1990-1992. In 1993, birds using the Experiment #2 wetlands were only counted in early June. Wetlands were visited in random order between local sunrise and 5 hr post-sunrise by one or two observers in 1990, and two of three experienced observers in 1991-1993. Counts were made by the same pool of three observers throughout the study.

In 1990, the observer(s) slowly walked around the perimeter of the wetlands and recorded all Black Terns seen in the marsh. In 1991, we established eight count points at uniform intervals around the perimeter of each wetland (Hutto *et al.* 1986, Blixt 1993). The same count points were used from 1991 through 1993. The observers walked to each count point, waited for 1 min, and recorded all Black Terns seen during the next 5 min. Censuses were not conducted in a steady rain or if the wind exceeded 24 km/hr.

Wetland size and percent coverages of open water and emergent vegetation were determined from aerial photographs using a geographic information system (Map and Image Processing System Software, MicroImages, Inc., Lincoln, Nebraska) software (Homan *et al.* 1992). In 1990, Ektachrome photographs obtained from the U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service were used for the habitat analysis of Experiment #1 wetlands. Live and dead emergent vegetation could not be distinguished on these slides. In August 1991-1993, color infrared photographs were taken of all 23 test wetlands. In 1991, live and dead emergent vegetation could not be distinguished in the Experiment #2 wetlands because the vegetation had begun to show the effects of the herbicide treatment.

Data from the two experiments were analyzed separately because (1) the average size of the 1991 test wetlands (Experiment #2) was > 2 times larger than the 1990 test wetlands (Experiment #1) and (2) in 1991, a 50% spray coverage level was substituted for the 90% spray coverage used in Experiment #1. This substitution was suggested by wetland managers concerned about inadequate cover for wildlife in wetlands treated at the 90% level (Stromstad 1992).

We used an arcsine transformation for the habitat data before conducting analyses of variance (ANOVA). A one-factor ANOVA was used to compare percent coverages of water, emergent vegetation, and unflooded ground among wetlands designated for various treatments for each pretreatment year (Cody and Smith 1991). Two-factor repeated measure ANOVA's were used to test the null hypotheses that there were no differences in percent coverages of water, and live and dead emergent vegetation among treatments one and two years posttreatment within Experiment #1 and Experiment #2 wetlands (Cody and Smith 1991).

Kruskal-Wallis tests were used to examine the null hypotheses that average numbers of Black Terns counted within each test year of both experiments were similar among treatments (Conover 1980, SAS 1988). Data for treated wetlands were then pooled and compared to the untreated wetlands with the Wilcoxon test (Conover 1980, SAS 1988). The overall numbers of birds using the test wetlands were compared among years with the Kruskal-Wallis test.

An overall stepwise multiple regression model (regardless of spray coverage and year of treatment) was used to examine the relationships between the number of Black Terns (dependent variable) and wetland size (ha), open water (ha), live emergent vegetation (ha), and dead emergent vegetation (ha) (Cody and Smith 1991). For logistical reasons, wetland managers manipulate emergent vegetation on a percent coverage basis (Huffman 1992). Thus, we investigated the relationships between the number of terns and percentages of open water, dead emergent vegetation, and live emergent vegetation (years 1 and 2 posttreatment combined) using a stepwise multiple regression.

We set the significance level at 0.1 (*a priori*) because (1) resources were not sufficient to increase sample sizes and (2) the consequences of accepting false null hypotheses (Type II error) on populations of Black Terns using wetlands are much greater than if Type I errors (rejecting a true null hypothesis) are made (Tacha *et al.* 1982).

RESULTS

Habitat Characteristics (Experiment #1)

Prior to the application of glyphosate in 1990, there was no significant difference in percent coverages of open water ($\overline{X}$ = 22%, SE = 6%) and emergent vegetation ($\overline{X}$ = 78%, SE = 6%) among treatments (One Factor ANOVA, $F_{2,8}$ = 0.90, P = 0.442; Fig. 1). The percentages of open water did not differ among treatments within 1991 and 1992 (Repeated Measures Two Factor ANOVA, $F_{2,8}$ = 0.87, P = 0.456). In these years, the amount

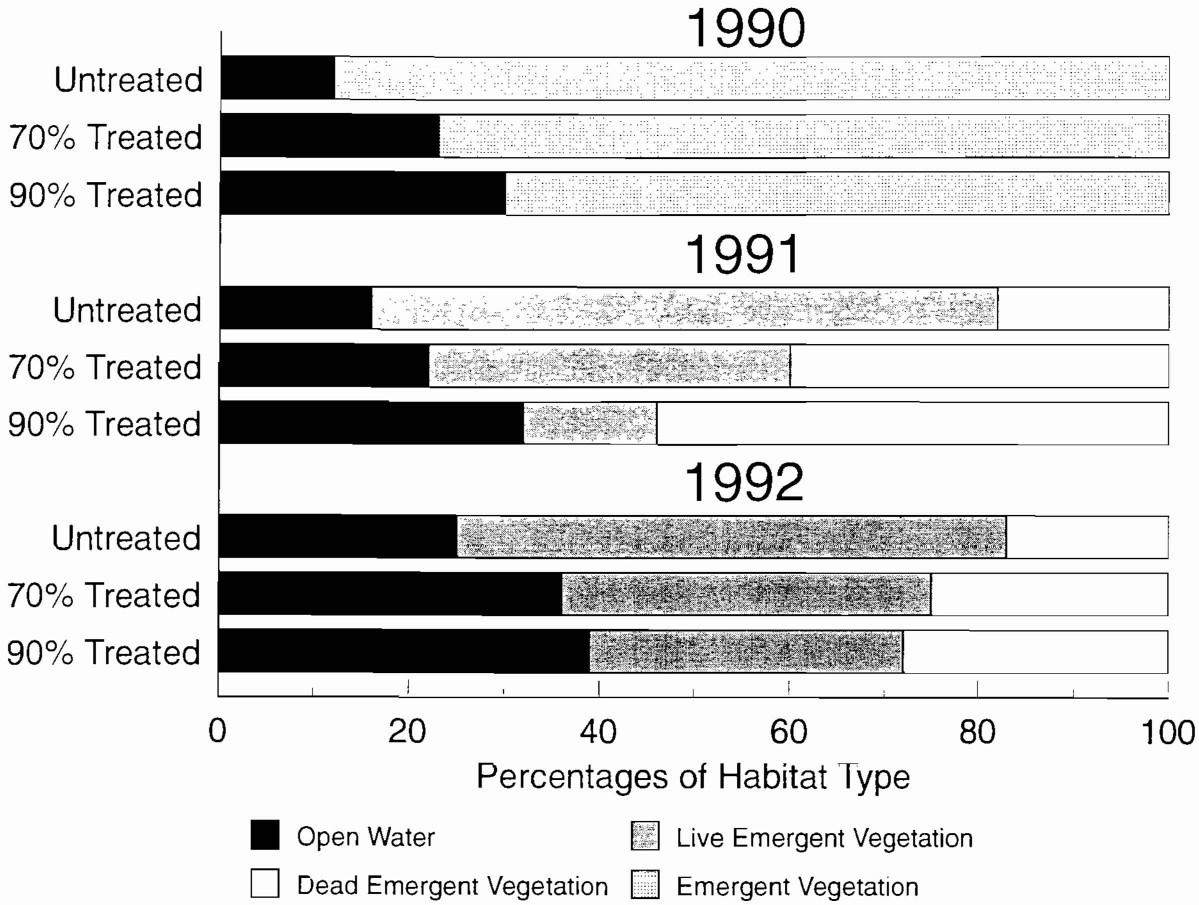

Figure 1. Habitat characteristics of 11 wetlands randomly designated as either untreated (n = 3) or treated at 70% (n = 4) or 90% (n = 4) spray coverages with glyphosate herbicide during July 1990 in northeastern North Dakota. Live and dead emergent vegetation were not distinguished in 1990.

of live emergent vegetation was higher in the controls ($\overline{X}$ = 62%, SE = 6%) than in either the 70% or 90% treatments ($\overline{X}$ = 31%, SE = 4%; Repeated Measures Two Factor ANOVA, $F_{2,8}$ = 7.41, P = 0.015). The live emergent vegetation showed an interaction between treatments and years (Repeated Measures Two Factor ANOVA, $F_{1,8}$ = 6.59, P = 0.020), due to the regrowth of cattail in the 90% treated wetlands in 1992. The percent coverage of dead emergent vegetation was higher in the 90% treated wetlands ($\overline{X}$ = 41%, SE = 6%) than in the 70% treated and control wetlands ($\overline{X}$ = 26%, SE = 4%; Repeated Measures Two Factor ANOVA, $F_{2,8}$ = 3.63, P = 0.075).

Response of Black Terns (Experiment #1)

The number of Black Terns using the 1990 experimental wetlands remained the same among years ($\overline{X}$ = 0.38/ha, SE = 0.13; Kruskal-Wallis test, χ^2 = 2.12, df = 2, P = 0.472). Within each study year, the number of Black Terns surveyed in these wetlands did not differ among the three treatment levels or between treated and untreated wetlands (Table 1). However, during the posttreatment years (1991 and 1992 combined), significantly more terns were found in treated wetlands ($\overline{X}$ = 0.64/ha, SE = 0.24) than in the untreated wetlands ($\overline{X}$ = 0.07/ha, SE = 0.04; Wilcoxon test, Z = -2.19, df = 1, P = 0.029).

Habitat Characteristics (Experiment #2)

Prior to the application of glyphosate to the test wetlands in 1991, the percent coverage of open water ($\overline{X}$ = 10%, SE = 3%) and emergent vegetation ($\overline{X}$ = 90%, SE = 3%) did not differ among the designated treatment levels (One Factor ANOVA, $F_{2,9}$ = 2.60, P = 0.129; Fig. 2). The percentages of open water did not differ among treatments within

Table 1. Comparison of Black Terns densities[1] using wetlands in northeastern North Dakota during June and July (averaged), 1990-92 (Experiment #1).

	Glyphosate Coverages[2]							Glyphosate Coverages[3]				
	Untreated[4]		70%[5]		90%[5]			Untreated[4]		Treated[6]		
Year	Mean	(SE)	Mean	(SE)	Mean	(SE)	χ^2	Mean	(SE)	Mean	(SE)	Z[3]
1990[7]	0.02	(0.02)	0.30	(0.13)	0.16	(0.04)	0.31	0.02	(0.02)	0.23	(0.07)	0.61
1991	0.13	(0.07)	0.24	(0.20)	1.10	(1.00)	0.49	0.13	(0.07)	0.67	(0.48)	0.92
1992	0.02	(0.02)	0.73	(0.23)	0.51	(0.18)	0.56	0.02	(0.02)	0.62	(0.14)	0.36

[1]Number of terns per hectare
[2]Kruskal-Wallis test
[3]Wilcoxon test
[4]n = 3
[5]n = 4
[6]n = 8 (70% and 90% coverages pooled)
[7]Pretreatment

1992 and 1993 (Repeated Measures Two Factor ANOVA, $F_{2,9}$ = 0.52, P = 0.614). In these years, the amount of live emergent vegetation was higher in the controls ($\bar{X}$ = 67%, SE = 6%) than in either the 50% or 70% treatments ($\bar{X}$ = 31%, SE = 4%; Repeated Measures Two Factor ANOVA, $F_{1,9}$ = 6.22, P = 0.020). There was less dead emergent vegeta-

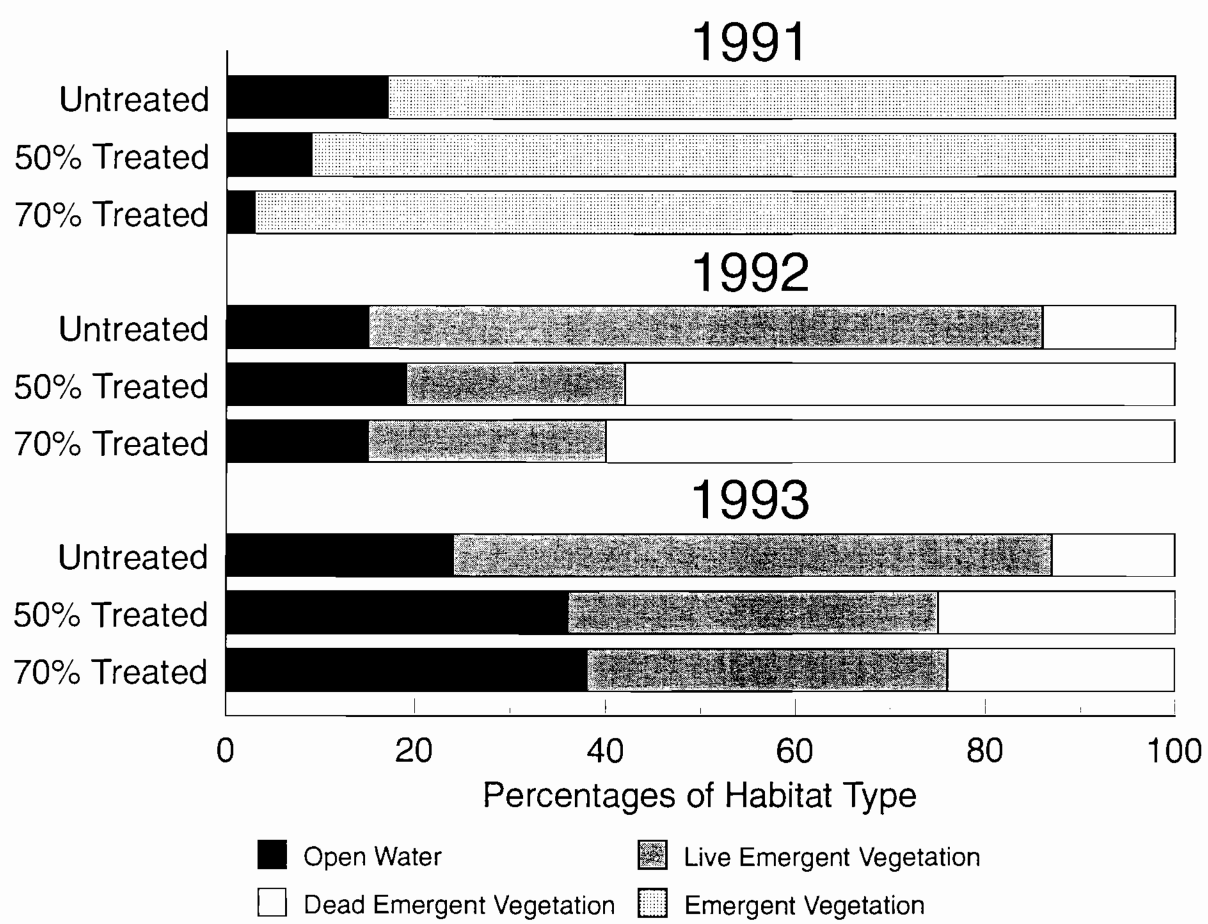

Figure 2. Habitat characteristics of 12 wetlands randomly designated as either untreated (n = 4) or treated at 50% (n = 4) or 70% (n = 4) spray coverages with glyphosate herbicide during July 1991 in northeastern North Dakota. Live and dead emergent vegetation were not distinguished in 1991.

tion in the controls ($\overline{X}$ = 13%, SE = 4%) than in the 50% and 70% treated wetlands ($\overline{X}$ = 42%, SE = 5%; Repeated Measures Two Factor ANOVA, $F_{2,9}$ = 20.69, P = 0.0004).

Response of Black Terns (Experiment #2)

The number of Black Terns using the Experiment #2 wetlands differed among years (Kruskal-Wallis test, χ^2 = 11.66, df = 2, P = 0.003), with more birds detected in 1992 and 1993 ($\overline{X}$ = 0.74/ha, SE = 0.18) than in 1991 ($\overline{X}$ = 0.09/ha, SE = 0.06). Within each of the study years, the number of Black Terns using the Experiment #2 wetlands did not differ among the three treatment levels or between treated and untreated wetlands (Table 2). Moreover, during the posttreatment years (1992 and 1993 combined), similar numbers of terns were found in the treated and untreated wetlands ($\overline{X}$ = 0.74/ha, SE = 0.18; Wilcoxon test, Z = -0.28, df = 1, P = 0.783).

Black Tern-Habitat Relationship

The overall stepwise multiple regression yielded a 2-variable model that contained hectares of water ($F_{2,43}$ = 30.10, P = 0.001) and dead emergent vegetation ($F_{2,43}$ = 8.03, P = 0.007), but not wetland size or live emergent vegetation. The combined years model (n = 46, r^2 = 0.51) was Black Tern numbers = 2.4 + 1.4 (water/ha) + 0.77 (dead emergents/ha). A second multiple regression indicated that there was a significant relationship between the number of Black Terns and percentage of live emergent vegetation (Black Terns = 17.3 - 0.26 (percent live emergents); $F_{1,44}$ = 8.43, P = 0.006, n = 46, r^2 = 0.16), but not among percentages of open water and dead emergent vegetation.

DISCUSSION

Glyphosate Treatments

Overall, treated wetlands had significantly fewer live cattails than the untreated wetlands two years posttreatment. Cattails began to reestablish two years posttreatment in shallow-water and mud-flat areas of the wetlands. Apparently, maintaining water depth > 30 cm after applying the herbicide is critical for reducing the rate of cattail regeneration in treated wetlands (Weller 1975, Merendino and Smith 1991). The cost of aerially applying RODEO® at 5.3 l/ha was about $136.00/ha (Baltezore *et al.* 1994). Thus, it is important to maximize cost-effectiveness by treating areas of the wetland likely to maintain water coverage throughout the growing season.

The percent coverage of dead emergents in the treated wetlands was greater one year posttreatment than two years posttreatment, but remained higher in the treated wetlands than in the untreated wetlands during both posttreatment years. In general, cattail stems

Table 2. Comparison of Black Tern densities[1] using wetlands in northeastern North Dakota during June and July (averaged), 1991-93 (Experiment #2).

	Glyphosate Coverages[2]							Glyphosate Coverages[3]				
	Untreated[1]		50%[4]		70%[4]			Untreated[4]		Treated[5]		
Year	Mean[5]	(SE)	Mean	(SE)	Mean	(SE)	χ^2	Mean	(SE)	Mean	(SE)	Z
1991[6]	0.20	(0.18)	0.01	(0.01)	0.05	(0.05)	0.81	0.20	(0.18)	0.03	(0.02)	0.61
1992	0.38	(0.25)	0.71	(0.47)	1.26	(0.80)	0.15	0.38	(0.25)	0.98	(0.44)	0.20
1993	0.80	(0.45)	0.62	(0.39)	0.68	(0.24)	0.41	0.80	(0.45)	0.65	(0.21)	0.27

[1]Number of terns per hectare
[2]Kruskal-Wallis test
[3]Wilcoxon test
[4]n = 4
[5]n = 8 (50% and 70% coverage pooled)
[6]Pretreatment

are visible two or more years after death, but the rate of decomposition is influenced by physical, chemical, and biological processes that are highly variable among wetlands (Mason and Bryant 1975, Davis and van der Valk 1978, Murkin *et al.* 1989).

Response of Black Terns to Habitat Alteration

Overall, the number of Black Terns observed using the 23 test wetlands increased during the study (1990-1993), probably in response to increasing water coverage throughout the study area. Additionally, the deposition of detritus and the opening of the canopy in the treated wetlands may have enhanced the production of aquatic invertebrates required by wetland-dwelling birds such as Black Terns (Kaminski and Prince 1981, Mosher 1987, Solberg and Higgins 1993). Based on the number of insectivorous birds seen using the treated wetlands (Blixt 1993), glyphosate probably had little direct effect on aquatic insects (Henry 1992).

Black Terns in Experiment #1 were positively influenced by the herbicide treatment. This may have been in response to the treated wetlands having more open water and dead vegetation and less live emergent vegetation than the untreated wetlands. Although the number of Black Terns tended to increase in Experiment #2 during 1992 and 1993, high variability within the treatment groups precluded detection of statistically significant differences. The lack of consistent statistical differences in density of terns (terns/ha) between treated and untreated wetlands suggests the proportion of open water, live emergent vegetation, and dead emergent vegetation is one of many factors influencing the abundance of Black Terns. For example, Brown and Dinsmore (1986) concluded that Black Terns prefer large wetlands (area dependent) but will use smaller wetlands when these wetlands were located within wetland complexes. Indeed, our regression analysis indicates that there is a positive relationship between the number of Black Terns and the area of open water and dead emergent vegetation. This relationship is not surprising because terns seldom use wetlands without surface water and the birds need floating platforms, such as floating mats of dead vegetation, as nest substrate (Cuthbert 1954, Dunn 1979).

Apparently, Black Terns are able to find and rapidly colonize new nesting habitat (McNicholl 1975, Delehanty and Svedarsky 1993). Thus, wetlands with newly formed mats of dead emergent vegetation and open water may be quickly exploited by nesting Black Terns. Although we found a negative relationship between tern density and the percentage of live emergent vegetation, we speculate that some live emergents may be necessary for nest protection and concealment for chicks (Dunn 1979, Hands *et al.* 1989, Knutson 1991). Mosher (1987) determined that Black Terns preferred to nest in areas with 33% open water, 42% matted vegetation, and 25% standing vegetation. However, Black Terns will use wetlands with over 75% emergent vegetation (Weller and Spatcher 1965, Knutson 1991), indicating some behavioral plasticity when selecting breeding habitat. The ideal ratio of open water, live emergent vegetation, and dead emergent vegetation for Black Terns is difficult to determine and may be compounded by numerous other habitat factors on both local and regional scales (Knutson 1991). Even so, the absence of one of these three habitat characteristics will undoubtedly negatively influence the breeding population of these birds.

We conclude that to maximize Black Tern use of wetlands, managers should strive to achieve a good interspersion of open water, live emergent vegetation, and floating mats of dead vegetation in wetlands. In the absence of muskrats (*Ondatra zibethicus*), fire, large herbivores, and water control structures to manipulate water and vegetation coverages in wetlands (Kantrud 1986), aquatic herbicides may be a useful tool for wetland managers to maintain habitat for nesting Black Terns. Staggering herbicide treatments on large wetland complexes may help maintain bird populations by providing wetlands with different stages of cattail decomposition and subsequent regeneration.

Research on the optimal size and configuration of live and dead emergent vegetation patches and water coverage is needed to maximize the number of breeding and migrating birds using wetlands. Finally, increased use of managed wetlands by Black Terns does not necessarily mean that nesting success has been enhanced. Therefore, research on the nesting success of Black Terns and other birds using managed wetlands is needed.

ACKNOWLEDGMENTS

J. Bart, B. Brua, C. Doetkott, G. Fraser, R. Kreil, S. Maxson, M. McEnroe, A. Powell, R. Reynolds and an anonymous referee criticized earlier drafts of the manuscript. The Monsanto Company and North Dakota Game and Fish Department provided much of the herbicide. R. Marquart applied the herbicide. We thank the landowners of northeastern North Dakota and the U.S. Fish and Wildlife Service for granting permission to conduct research on private and federally owned wetlands, respectively. This study was funded by the U.S. Department of Agriculture, Denver Wildlife Research Center, Denver, Colorado and the Department of Zoology, North Dakota State University, Fargo. Reference to a commercial product in this paper does not imply endorsement by these sponsors. This study was conducted under the auspices of Denver Wildlife Research Center study protocols QA-144, QA-180, and QA-242.

REFERENCES CITED

Baltezore, J. F., J. A. Leitch, and G. M. Linz. 1994. The economics of cattail management: Assessing the trade-offs. Agricultural Economics Report No. 320. North Dakota State University, Fargo.

Bergman, R. D., P. Swain, and M. W. Weller. 1970. A comparative study of nesting Forster's and Black Terns. Wilson Bulletin 82: 435-444.

Blixt, D. C. 1993. Effects of glyphosate-induced habitat alteration on birds using wetlands. Unpublished M.S. Thesis, North Dakota State University, Fargo.

Brown, M. and J. J. Dinsmore. 1986. Implications of marsh size and isolation for marsh bird management. Journal of Wildlife Management 50: 392-397.

Carroll, J. R. 1988. Status and breeding ecology of the Black Tern. Kingbird 38: 159-172.

Cody, R. P. and J. K. Smith. 1991. Applied Statistics and the SAS Programming Language (Third edition). Englewood Cliffs, New Jersey, USA: Prentice Hall.

Conover, W. J. 1980. Practical Nonparametric Statistics (Second edition). New York, New York, USA: John Wiley & Sons.

Cuthbert, N. L. 1954. A nesting study of the Black Tern in Michigan. Auk 71: 36-63.

Davis, C. B. and A. G. van der Valk. 1978. The decomposition of standing and fallen litter of *Typha glauca* and *Scirpus fluviatilis*. Canadian Journal of Botany 56: 662-675.

Delehanty, D. J. and W. D. Svedarsky. 1993. Black Tern colonization of a restored prairie wetland in northwestern Minnesota. Prairie Naturalist 25: 213-218.

Dunn, E. H. 1979. Nesting biology and development of young in Ontario Black Terns. Canadian Field-Naturalist 93: 276-281.

Hands, H. M., R. D. Drobney, and M. R. Ryan. 1989. Status of the Black Tern in the northcentral United States. Unpublished Report, Missouri Cooperative Fish and Wildlife Research Unit, Columbia, Missouri.

Henry, C. J. 1992. Effects of Rodeo herbicide on aquatic invertebrates and fathead minnows. Unpublished M.S. Thesis, South Dakota State University, Brookings.

Homan, H. J., W. J. Bleier, D. L. Bergman, and G. M. Linz. 1992. Using GIS to analyze wetland basins in northcentral North Dakota. Pp. 32-34. *In*: Proceedings of a Cattail Management Symposium (G. M. Linz, Ed.). U.S. Department of Agriculture, Denver Wildlife Research Center and U.S. Fish and Wildlife Service, Fargo, North Dakota.

Huffman, L. E. 1992. Magnitude and potential solutions of blackbird-sunflower problem. Pp. 7-8. *In*: Proceedings of a Cattail Management Symposium (G. M. Linz, Ed.). U.S. Department of Agriculture, Denver Wildlife Research Center and U.S. Fish and Wildlife Service, Fargo, North Dakota.

Hutto, R. L., S. M. Pletschet, and P. Hendricks. 1986. A fixed-radius point count method for nonbreeding and breeding season use. Auk 103: 593-602.

Kaminski, R. M. and H. H. Prince. 1981. Dabbling duck and aquatic macroinvertebrate responses to manipulated wetland habitat. Journal of Wildlife Management 45: 1-15.

Kantrud, H. A. 1986. Effects of vegetation manipulation on breeding waterfowl in prairie wetlands–a literature review. Technical Report No. 3. U.S. Fish and Wildlife Service, Washington, D.C.

Kantrud, H. A. and R. E. Stewart. 1984. Ecological distribution and crude density of breeding birds on prairie wetlands. Journal of Wildlife Management 48: 426-437.

Knutson, M. G. 1991. Characteristics of Black Tern (*Chlidonias niger*) nesting habitat at Lakeview Wildlife Management Area, New York. Kingbird 41: 228-236.

Mason, C. F. and R. J. Bryant. 1975. Production, nutrient content and decomposition of *Phragmites communis* Trin. and *Typha angustifolia* L. Journal of Ecology 63: 71-95.

McNicholl, M. K. 1975. Larid site tenacity and group adherence in relation to habitat. Auk 92: 98-104.

Merendino, M. T. and L. M. Smith. 1991. Influence of drawdown date and reflood depth on wetland vegetation establishment. Wildlife Society Bulletin 19: 143-150.

Mosher, B. C. 1987. Factors influencing reproductive success and nesting strategies in Black Terns. Unpublished Ph.D. Dissertation, Simon Fraser University, Burnaby 2, British Columbia, Canada.

Murkin, H. R., A. G. van der Valk, and C. B. Davis. 1989. Decomposition of four dominant macrophytes in the Delta Marsh, Manitoba. Wildlife Society Bulletin 17: 215-221.

North Dakota Agricultural Statistics Service. 1993. North Dakota agricultural statistics 1993. Agricultu al Statistics No. 62. North Dakota State University. Fargo, North Dakota.

SAS Institute, Inc. 1988. SAS/STAT User's Guide, Release 6.03. Cary, North Carolina, USA: SAS Institute, Inc.

Solberg, K. L. and K. F. Higgins. 1993. Effects of glyphosate herbicide on cattails, invertebrates, and waterfowl in South Dakota wetlands. Wildlife Society Bulletin 21: 299-307.

Stewart, R. E. and H. A. Kantrud. 1974. Breeding waterfowl populations in the prairie pothole region of North Dakota. Condor 76: 70-79.

Stromstad, R. 1992. Cattail management: The North Dakota Game and Fish Department perspective. Pp. 38-41. *In*: Proceedings of a Cattail Management Symposium (G. M. Linz, Ed.). U.S. Department of Agriculture. Denver Wildlife Research Center and U.S. Fish and Wildlife Service, Fargo, North Dakota.

Tacha, T. C., W. D. Warde, and K. P. Burnham. 1982. Use and interpretation of statistics in wildlife journals. Wildlife Society Bulletin 10: 355-362.

U.S. Fish and Wildlife Service. 1992. North Dakota's endangered, threatened, and candidate species. Bismarck, North Dakota.

Weller, M. W. 1975. Studies of cattail in relation to management for marsh wildlife. Iowa State Journal of Research 49: 383-412.

Weller, M. W. and C. E. Spatcher. 1965. Role of habitat in the distribution and abundance of marsh birds. Special Report 43, Iowa Agriculture and Home Economic Experiment Station, Ames, Iowa.

Weller, M. W. and L. H. Fredrickson. 1973. Avian ecology of a managed glacial marsh. Living Bird 12: 269-291.