WISCONSIN DEPARTMENT OF NATURAL RESOURCES

RESEARCH REPORT 151

October 1990

INITIAL EVALUATION OF ELECTRIC FENCING AS A PREDATOR DETERRENT IN ESTABLISHED DENSE NESTING COVER

By LeRoy R. Petersen
Bureau of Research, Madison

ABSTRACT

Electric fences were constructed around two 20-acre test plots within an 80-acre stand of established switchgrass on the Haupt Waterfowl Production Area in south central Wisconsin. Waterfowl nest success was measured inside and outside the fences to determine whether the fences were able to deter nest predators and increase nest success. Two fencing designs were examined: a smooth wire fence of 7 high tensile, galvanized wires with a 12-inch panel of 1-inch poultry wire attached near the bottom of the fence, and a polythene wire netting called Flexinet. Fences were operated for approximately 13 weeks from mid-April to mid-July. Nest success was higher ($P < 0.05$) inside the fenced plots than on the adjacent control plots in 1 of the 3 years tested. In the other 2 years, nest success inside the fenced areas was lower than that outside because predators were able to penetrate the fences and because an individual skunk was inadvertently confined within one of the fences for 45 days before it could be live-trapped and removed. Nest density increased on the entire study area from 0.3 to 1.4 nests/acre during the 3-year study. No difference in nest success was observed between fence designs. Cost per additional duckling produced during years of high density and success was \$5.67. Additional work is needed before electric fences become operational waterfowl management tools.

CONTENTS

INTRODUCTION, 3

STUDY AREA, 3

METHODS, 5
- Fence Construction and Maintenance, 5
- Predator Track Counts and Trapping, 6
- Waterfowl Counts and Measures of Reproductive Success, 7
- Vegetation Measurements, 7

RESULTS AND DISCUSSION, 7
- Nest Density, 7
- Nest Success, 9
- Predator Abundance, 10
- Cost Analysis, 10

CONCLUSIONS AND MANAGEMENT IMPLICATIONS, 11

LITERATURE CITED, 12

INTRODUCTION

Predators have been identified as a major factor in the declining nest success of dabbling ducks in the prairie pothole region (Hammond and Forward 1956, Keith 1961, Miller 1971, Smith 1971, Stoudt 1971, Nelson and Duebbert 1974, Duebbert and Lokemoen 1976). Conversely, studies have demonstrated a dramatic increase in duck nest success with temporary reductions in predators (Balser et al. 1968, Duebbert and Kantrud 1974, Duebbert and Lokemoen 1980). Parallel declines in duck nest success associated with predators have been observed in Wisconsin (Livezey 1981, Petersen et al. 1982, Wheeler et al. 1984). Poor breeding success is a major problem that occurs on waterfowl habitat purchased and managed for duck production. Between 1938 and 1981, Wisconsin purchased 266,985 acres of waterfowl habitat (U.S. Fish and Wildl. Serv. 1984). Acquisition costs for upland suitable for nest cover development exceed $1,000/acre, with additional development costs estimated at $250/acre. Upland cover development in Wisconsin has generally followed the dense nesting cover (DNC) recommendations originating from research conducted in the prairie pothole region of the Dakotas, where the density and success of duck nests were positively related to height and density of residual vegetation (Duebbert 1969, Kirsch et al. 1978, Duebbert et al. 1981).

Habitat management has received greater attention than direct predator control in an effort to overcome nest predation. Predator reduction has inherent biological, social, and economic ramifications that result when one resource is managed at the direct expense of a second resource (Connolly 1978).

Cowardin and Johnson (1979) suggested that techniques excluding predators from nesting cover should be investigated because they could achieve waterfowl recruitment without the potential adverse effects associated with direct predator control.

Duck nest density and success on seeded DNC cover provided with additional protective measures, such as electric fencing, could approach that on cover with effective predator reduction. An estimated 20 miles^2 of DNC with predator reduction could have the recruitment potential equal to 430 miles^2 of DNC without predator reduction (Cowardin and Johnson 1979). Lokemoen et al. (1982) evaluated electric fences as predator barriers to seeded nesting cover on Waterfowl Production Areas (WPA's) in North Dakota and western Minnesota during 1978-81. Fences increased nest success and production of dabbling ducks, while costing $0.65-$0.87 for each additional duckling produced within fenced plots.

Differences in predator densities, waterfowl breeding densities, and land-use patterns necessitated the need for geographic replication in Wisconsin with the work of Lokemoen et al. (1982). In addition, Flexinet[1] fencing had not been previously tested. A pilot study of electric fencing was therefore conducted between 1980 and 1983. The research objective was to test the ecological and economic effectiveness of using electric fences to increase duck reproductive success in established DNC. The management problem was to evaluate cost-effective and socially acceptable techniques for controlling predators in managed waterfowl nest cover. Electric fencing is only one of several alternative or non-lethal methods of predator control, and is the only technique evaluated in this report. This study was a preliminary effort because electric fencing used as a predator deterrent was virtually untested in the Great Lakes region, indicating a cautious approach.

STUDY AREA

The preliminary nature of this study resulted in the use of only a single study area: the Haupt Waterfowl Production Area (HWPA), a 100-acre tract near Poynette in Columbia County, Wisconsin (Fig. 1). Purchased in 1974 by the U.S. Fish and Wildlife Service (USFWS) and managed by the Wisconsin Department of Natural Resources (DNR), the HWPA is adjacent to Schoeneberg's Marsh. A 135-acre semi-permanent (Type IV of Steward and Kantrud 1971) hemi-marsh (Weller and Spatcher 1965), the HWPA is within 0.5 mile of 3 other Type IV-V wetlands varying in size from 9 to 15 acres. Monotypic switchgrass (*Panicum virgatum*) DNC was seeded in 1977-78 on 80 acres of suitable uplands.

Both the treatment and control plots were located within this switchgrass stand (Fig. 1). Plots were rectangular in shape, with the marsh on the south edge of the property, followed to the north by the first control plot, the 2 adjacent treatment plots, and finally the second control. Plot location was designed to reduce possible bias associated with distance to water.

Surrounding land use was primarily cash crop farming, with a few farms still active in dairy operations. Over 65% of the land within 1 mile of the HWPA is cropped, predominantly corn (72%), hay fields (23%), oats (3%), and winter wheat (1%). The remaining land use was 26% wetlands, 6% woodlots, and 3% miscellaneous habitat.

---

[1] Reference to trade names does not imply government endorsement of commercial products.

The HWPA is composed of the St. Charles-Ossion-Dodge soil association, a complex characterized by a repeating pattern of silt-capped glaciated uplands, mainly drumlins, and wet valleys (Mitchell 1978). Soils are loamy throughout with moderate permeability, slow to dry in the spring and after long rainy spells. The growing season is 160 days, with a mean annual precipitation of 31 inches. The climate is continental and has a 48 F average annual temperature (Burley 1964).

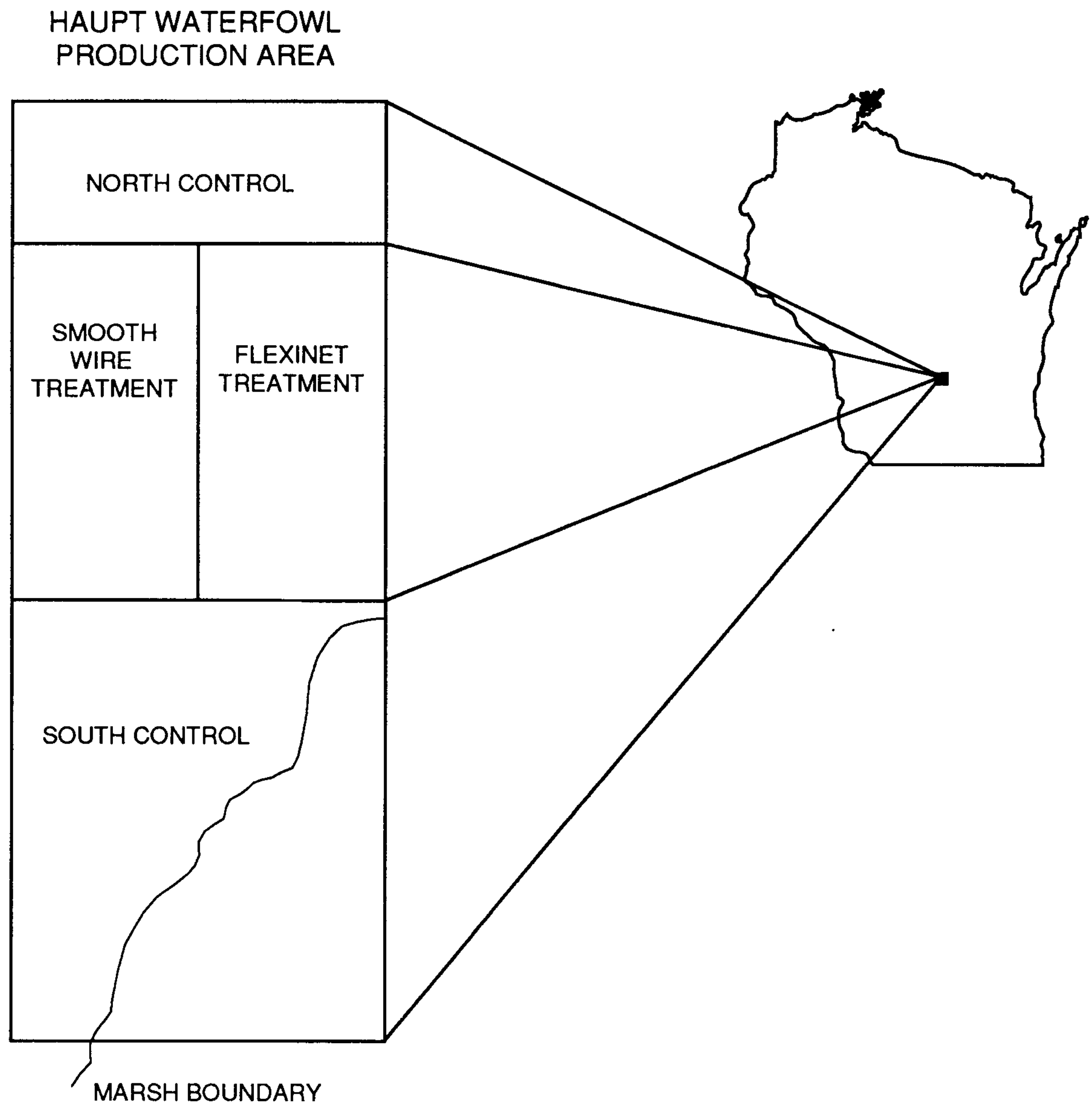


FIGURE 1. *Location of the Haupt Waterfowl Production Area, showing control and treatment plots.*

METHODS

Fence Construction and Maintenance

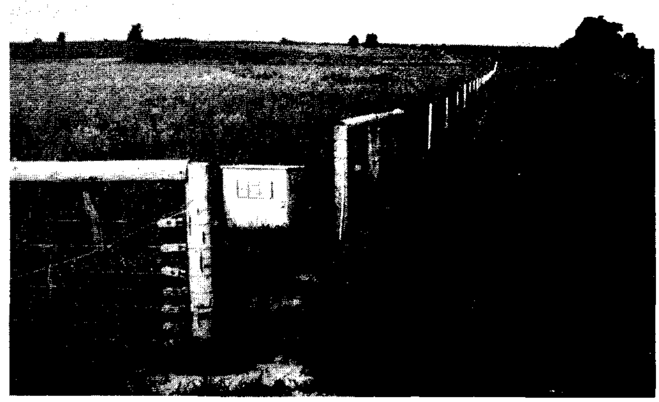
Electric fences were constructed in 1980 and maintained for a 3-year period on the 2 treatment plots. Each 20-acre plot was fenced with a different fence design for comparative purposes. The 2 fence designs were: (1) seven 15.5-ga high tensile, galvanized wires strained to 200 lb tension (Gates 1978, Gates et al. 1978), and (2) a polythene wire electric netting, Flexinet. A Flexinet "common fence" separated the 2 test plots during 1980, the first year of operation. The common fence was eliminated before the 1981 breeding season because of poor preliminary test results, and each plot was entirely enclosed with the respective fence designs.

The smooth wire fence consisted of alternating hot to ground wires beginning with a bottom hot wire. The lower 5 wires were spaced 4 inches apart, the 6th wire had a 5-inch spacing, and the 7th wire was separated by 7 inches. A 12-inch wide strip of 1-inch chicken wire was attached to the bottom 3 wires of the smooth wire fence in April 1981 in response to known predator penetration. The chicken wire was mounted 3 inches from the ground and electrified. The smooth wire fencing was constructed using fiberglass posts and stays, with wooden corner and brace posts. The total heights of the smooth wire and Flexinet fences were 32 and 33 inches, respectively.

The Flexinet netting had 6-inch spacing along the bottom, followed by 4 additional horizontal electroplastic wires with 4.5-inch spacing, and 9-inch spacing with the top wire. Modifications in April 1981 involved weaving Livestrand electroplastic twine horizontally through the bottom 2 segments of the netting to reduce access space between the conducting filaments, resulting in a 3-inch spacing from the ground to the bottom of the net.

The herbicide Pramitol (a soil sterilant) was applied pre-emergence (1 pt/1,000 ft^2) to control vegetation along a 1-m wide fencing right-of-way. Roundup, a post-emergent herbicide was occasionally used on troublesome vegetation with a hand-held sprayer (2.6 oz Roundup/1 gal water; a 2% solution). Herbicide carryover, evident in 1981, precluded chemical treatment during 1982. In addition, small gully erosion occurred during spring runoff in 1981 when water concentrated along vegetation-free fencelines. The problem was resolved by treating a smaller band along the fenceline (approximately 20 inches) in 1981, and filling in the gullies with adjacent soil. A 10-ft wide fence right-of-way was mowed in late 1979 prior to fence construction and maintained with mowings twice annually, or with more frequent mowing with a lawn mower when vegetation made contact with the bottom charged wires.

Flexinet fencing.

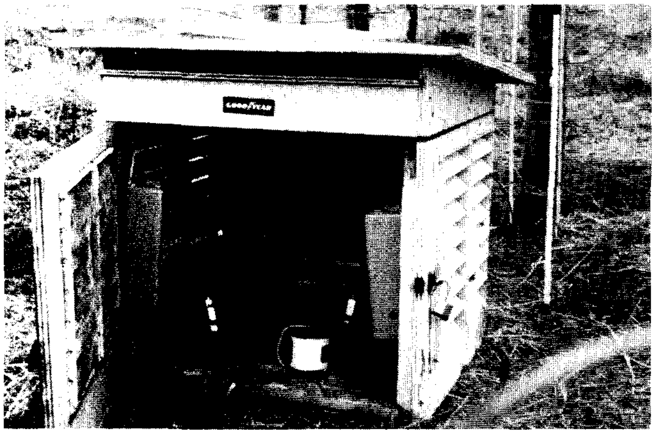


Smooth wire fence showing chicken wire addition at the bottom.

Two battery-powered energizers (Gallagher Electronics Ltd. Model E12) were used to electrify each fenced plot. A standard 12-volt, wet-cell car battery (480 amps) provided the power source for each energizer.

Energizers used combined high power with low impedance. Low impedance energizers provide a short, strong burst of power that literally flood small circuits, thus making it practical to electrify long fencelines. The combination of low impedance with high voltage (in excess of 4,000 volts) has been shown necessary to overcome voltage drains such as vegetation contact with charged wires (Nesbitt 1978). A final advantage of low impedance energizers is that they posed neither fire hazards nor shocks that were lethal or dangerous to animals that had contact with the fences.

Both energizers and batteries were enclosed within surplus weather stations consisting of well-ventilated, 3 ft^3 boxes. These provided protection against the weather and vandalism. Fences were inspected at 2- to 4-day intervals throughout the nesting season to ensure proper operation. Fences became operational



Surplus boxes, formerly used to house weather monitoring equipment, were used in this study to house fence energizers and batteries.

each spring (30 April 1980, 24 April 1981, 16 April 1982) and were maintained until the fates of all enclosed known nests were determined, usually mid-July.

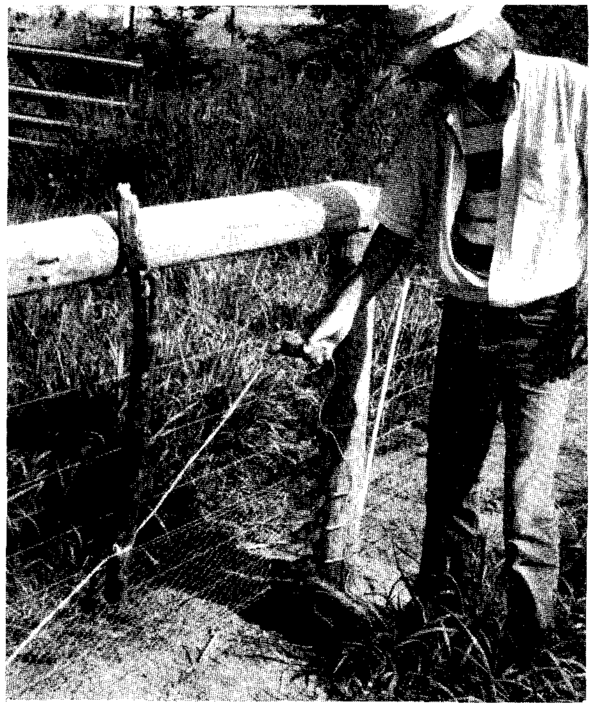
At the completion of each field season, the weather stations, energizers, batteries, and Flexinet fencing were removed from the study site and stored until the following breeding season. The smooth wire fencing remained in place for the entire 3-year study period to test the effects of weather and human encounters with the fence, and because the fence was more permanent, requiring considerable effort for removal on an annual basis.

Predator Track Counts and Trapping

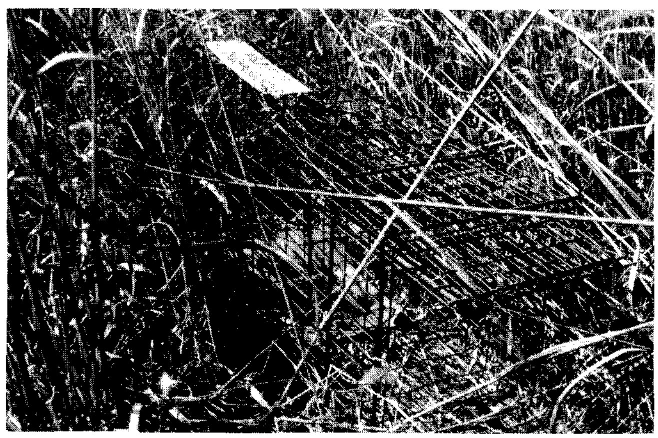
A relative index to mammalian predators on the HWPA was determined by late winter (March) track counts. Track counts were made 24-48 hours after a snowfall along a transect running diagonally on the study area. Mammal tracks were identified by species (Murie 1974).

The possibility of inadvertently enclosing predators within the fenced plot when the power was turned on each spring required the development of an effective removal procedure. In addition, the likelihood of mammalian predators penetrating the fence when temporarily down or gaining access through occasional spring washouts suggested continuous trapping would be necessary. Study design cautioned against killing any trapped predator since such activity would constitute predator reduction and could compromise the fence evaluation. Trapped animals were marked with fluorescent orange spray paint and released outside the fence.

Mammalian predators of primary concern were the striped skunk (*Mephitis mephitis*) and raccoon (*Procyon lotor*). Badger (*Taxidea taxus*) only rarely occurred in the area and were not considered a serious



Checking voltage. This and other fence maintenance accounted for 14% of annual electric fence operation cost.



Live traps were operated continuously within fenced plots during the periods that fences were charged in order to remove mammalian nest predators.

nest predator. Opossum (*Didelphis marsupialis*) were more common and potentially could have created problems. The fences were not designed to stop mink (*Mustela vison*), weasels (*Mustela* spp.), ground squirrels (*Spermophilus franklinii, S. tridecemlineatus*), or the red fox (*Vulpes vulpes*) which could potentially jump the short fence. The fence could have been modified to stop fox (a higher fence and/or addition of a trip wire along the outside edge), however, it was believed that fox would avoid the fence plots except for stress situations (e.g., an active den within the fence, being chased by humans or dogs). Red fox have not been clearly identified as a significant duck nest predator in Wisconsin (Livezey 1981, Wheeler et al. 1984).

Waterfowl Counts and Measures of Reproductive Success

Breeding waterfowl within 1 mile of the study area were counted from the ground once annually in mid-May using techniques outlined by Dzubin (1969). Pairs, lone drakes, and groups of 5 or less drakes were tallied as breeding pairs. Only dabbling duck species known to nest on the study area (Petersen et al. 1982) were counted.

Nest density and success of dabbling ducks were used to evaluate the effectiveness of electric fencing in reducing nest predation. Both natural and simulated nests were used. Natural nests were located with a cable-chain drag (Higgins et al. 1977). Fenced and control plots were searched 4 times annually: 1-15 May, 16-31 May, 1-15 June, and 16-30 June. Duck nests were marked according to methods described by Duebbert and Kantrud (1974), and the incubation stage of the eggs was determined after Weller (1956). Nests were examined after anticipated hatching date to determine their fate. Nest predators were identified using the techniques of Rearden (1951) and Einarsen (1956). A modified Mayfield estimator (Mayfield 1961, 1975) was used to estimate nest success (Miller and Johnson 1978), to correct biases associated with unrecognized differences in the probabilities of finding successful and unsuccessful nests.

Simulated nests were used to insure an adequate sample in evaluating the effectiveness of the fences. The placement and evaluation of simulated nests followed the techniques of Hammond (1966). Nests were placed at a density of 1 nest/acre in both the treated and control areas. Simulated nests were placed in a systematic pattern throughout the cover for a 21-day period from mid-May to early June. Mallard eggs, provided by the Max McGraw Wildlife Foundation, were used in the simulated nests. Three eggs were placed in each simulated nest and nest predation was indicated by 1 or more egg either being destroyed or missing. Simulated nests were not used during 1982 because natural nests provided a sufficient sample, and mallard eggs were not available.

Vegetation Measurements

Measurements were made of the residual switchgrass cover in April using Robel et al.'s (1976) method as modified by H. Duebbert (U.S. Fish and Wildl. Serv. pers. comm. 1978). The vegetation height at 100% coverage was measured systematically in each field to quantify the cover development on the HWPA. Potential nest cover within 1 mile of the study area was surveyed during May for comparative purposes.

RESULTS AND DISCUSSION

Nest Density

Cowardin et al. (1982, 1983) observed that nesting ducks are attracted to fields of tall, dense cover (i.e., DNC). Obstruction indices for vegetation in North Dakota averaged 15 inches at mallard nests, and 8 inches at blue-winged teal nests (U.S. Fish and Wildl. Serv. 1978). Obstruction indices taken annually on the HWPA suggest a deteriorating trend in residual vegetation standability (Table 1). Excessive snow cover during the 1981-82 winter is believed to have caused the low April 1982 means. The switchgrass seeding at Haupt was probably well established by 1980 as warm season grass plantings typically take 3-5 years to reach optimum growth form (Woehler 1979). Nest cover at HWPA was not homogeneous switchgrass, but a patchwork of switchgrass, cool season grasses and forbs, and small openings. Mean obstruction indices and the patchwork pattern therefore suggested a wide variety of potential nesting sites.

Nest density on the HWPA increased over the study period (Table 2). Estimated breeding pairs of mallards and blue-winged teal increased 46% from 1980

TABLE 1. *Relative quality of residual switchgrass vegetation in relation to snow depth, 1980-82.**

Year**	Maximum Monthly Snowfall Summary[a]	Height of 100% Visual Obstruction Fenced Plots	Height of 100% Visual Obstruction Control Plots
1980	15	12.4	13.7
1981	16	14.2	9.1
1982	47	7.7	6.3

* All measurements in inches (Robel et al. 1976).
** Year relates to April readings for vegetation and the preceding winter months for snow depth.
[a] Defined as the highest individual monthly snowfall during the indicated winter.

TABLE 2. *Estimated breeding duck pairs and associated nest densities, 1980-82.*

Year	Breeding Duck Pairs Within 1 Mile of HWPA*	No. Nests Calculated**			No. Nests Found		
		Fenced Plots	Controls	Total (nests/acre)	Fenced Plots	Controls	Total (nests/acre)
1980	112	17	10	27(0.3)	11	9	20(0.3)
1981	163	26	28	54(0.7)	23	21	44(0.6)
1982	171	47	65	112(1.4)	33	30	63(0.8)

* Breeding ducks includes only mallards and blue-winged teal; 1977-79 mean was 110 pairs.
**Calculated number of nests = number hatched nests found/Mayfield success estimator.

TABLE 3. *Relationship of duck nests on the HWPA to estimated breeding population, 1980-82.*

Year	Ratio of Located Nests to Pairs Within 1 Mile of HWPA	
	Mallard	Blue-winged Teal
1980	0.16	0.16
1981	0.38	0.22
1982	0.45	0.33
Mean	0.33	0.24

(combined 112 pair) to 1981 (163 pair), but only increased 5% from 1981 to 1982 (171 pair). The mean number of mallard and blue-winged teal pairs during 1977-79 was 110. A ratio of nesting ducks on HWPA to breeding pairs observed within 1 mile of the study area revealed an increased use of the Haupt tract (Table 3). The increased nest density was similar for both the fenced and unfenced plots, suggesting the entire study area was affected without regard to treatment.

Nest density within the Flexinet plot was far less than nest abundance in the smooth wire plot (3-year totals of 15 versus 41 nests). Fence design, however, was not believed to affect nest density, although high success over time (3-10 years) could produce higher densities. Site location appeared important. A small hill within the smooth wire plot consistently attracted more nesting ducks than any other site on the HWPA even though it did not differ vegetatively. Likewise, south- and eastern-facing slopes of approximately 12 degrees had more duck nests than flatter areas within the HWPA but what made these slopes attractive to ducks is not known.

Potential suitable nesting cover within 1 mile of Schoeneberg's Marsh during 1981 revealed approximately 7% of the land area contained quality nesting cover (switchgrass DNC and dry Type II wetlands) (Table 4). Over half of the 22% potential nest cover was hay field while upland retired cropland consisted of small, odd-shaped pieces with sparse vegetation. Cowardin et al. (1982) found that mallards showed a preference for rights-of-way, hayland, and odd areas for nesting in North Dakota. Wisconsin hay fields, however, are harvested in early June, while odd areas suffer excessive predation, negating their value for breeding ducks.

Nest cover and water conditions remained relatively stable over the study period, suggesting that the increased use of the HWPA by nesting ducks was not a function of improved nesting habitat. Increase in pair numbers did not correspond well with higher nest success of the previous years, therefore improved

TABLE 4. *Potential nest cover within 1 mile of Schoeneberg's Marsh, 1981.*

Cover Type	Acres	Percent of Nest Cover	Percent of Study Area
Switchgrass DNC	101	22	5
Upland retired*	67	15	3
Type II wetlands (dry)	35	8	2
Hay fields	250	55	12
Total	452	100	22

*Upland retired from agricultural use; mostly Kentucky bluegrass, nesting cover quality generally poor.

productivity cannot necessarily account for the higher population either. Also there was no apparent relationship between higher pair numbers and proportion nesting in the DNC plots in the previous year. Increased use of HWPA by nesting ducks was also not related to regional breeding indices (Hunt et al. 1982).

Nest Success

No difference in nest success was observed between fence designs, therefore nest data from fenced plots were pooled. Nest success was, however, directly related to Robel readings ($F = 15.25$, $R^2 = 0.79$, df = 1), and vegetation height-density may have influenced duckling survival.

The first year of study demonstrated the inadequacy of the original fencing design (Table 5). A 4-inch space between conducting elements apparently allowed easy predator access. During May-June 1980, 5 skunk were live-trapped inside the fenced areas and released outside the enclosures. Two of these skunk ran immediately back through the operating fence without hesitation, while an adult mink was observed passing through the Flexinet without any apparent difficulty. Both duck nests and simulated nests reflected easy predator access in 1980. As a result, nest success in that year was actually higher ($P < 0.015$ at df = 1, Chi-square = 7.88) in the control sites (50%) than in the fenced plots (24%).

Lokemoen (U.S. Fish and Wildl. Serv., pers. comm. 1980) reported similar predator penetration of electric fences in North Dakota and suggested fencing modifications that produced more desirable results in 1981 (Table 5). Duck nests within the treated plots had higher ($P < 0.05$) success (79%) than nests found outside the fence (14%). Further evidence of fence effectiveness was the complete lack of any predators trapped within the enclosures during 1981. All 3 duck nests preyed upon within the fenced plots were attributed to the ground squirrels. Simulated nests, however, suggested no difference ($P < 0.10$) in nest success between fenced (82%) and control (77%) plots. In 1980, however, both simulated nests and

Examining a broken up nest. The most prominent nest predator was skunk.

duck nests had higher nest success rates in the control plots although the success rates were substantially different. The great difference in success rates between artificial and duck nests on the same site suggests some limitations with Hammond's (1966) technique.

Mammalian predators forage chiefly by olfactory clues (Jackson 1961, Bowman and Harris 1980), and the scent of active duck nests would be constantly reinforced by the presence of the nesting hen. Conversely, even fresh mallard eggs in simulated nests should blend in with the surrounding odors over time, and would be less likely to be discovered in established nesting cover.

Nest success during 1982 was again not higher ($P < 0.10$) in the fenced plots than the control. Skunk were identified as the major predator, destroying 10 to 19 (53%) duck nests destroyed in the fenced plots. All nests destroyed by skunk were within the smooth wire plot, and all had very similar signs, i.e., bowl torn in a characteristic manner, and eggs not severely crushed. Diggings believed to be skunk were observed within the smooth wire plot in early May, although the skunk was not removed until 31 May. Circumstantial evidence would suggest the same individual skunk was

TABLE 5. *Comparison of duck nest success on fenced and unfenced DNC in Wisconsin, 1980-82.*[*]

	Fenced Plots			Control Plots		
Year	No. Nests	Daily Survival Rate	Percent Nest Success (± 2 SE)	No. Nests	Daily Survival Rate	Percent Nest Success (± 2 SE)
1980	9	0.9573	24 (6-84)	8	0.9795	50 (23-100)
1981	23	0.9927	79 (68-100)**	18	0.9345	14 (5-38)**
1982	28	0.9513	19 (9-41)	29	0.9311	10 (4-25)
Pooled	60	0.9671	41	45	0.9484	25

*Using Miller and Johnson (1978) 40% estimator.
** ($P < 0.05$) Z test.

involved. No skunk predation was observed after the removal of this animal.

Ground squirrels were identified as another major nest predator, destroying 8 of 19 (42%) nests within the fenced plots in 1982. Residual nest cover appears to encourage ground squirrel abundance (Jackson 1961, Klitz 1982, Lokemoen et al. 1982) and direct removal (poisoning) combined with fencing has been suggested (Madsen 1983). The remaining nest was destroyed by a raccoon live-trapped within the Flexinet plot in mid-May. Six single door, walk-in live traps (Tomahawk Model 207) were used in each treatment plot on a continuous basis, i.e., as long as the fences were charged. During the course of the study, it became apparent that predators quickly responded to access opportunities and once inside the fence, were capable of considerable nest predation in a relatively short period of time (5-8 days).

Lokemoen et al.'s (1982) estimate of nest success inside electric fences in North Dakota was higher (65%) compared to that in control plots (45%). Two test sites in Minnesota (60% and 35% inside versus 10% and 23% nest success outside fences) showed similar results (Lokemoen et al. 1982). Mean nest success for the HWPA (3 years pooled) fell within the range of success levels from North Dakota and Minnesota (Table 5).

Predator Abundance

When winter track counts were compared to similar baseline counts conducted in 1977-79 from Wisconsin WPA's (Petersen et al. 1982), heavy use was observed for mink, weasel, and fox on the HWPA, while only light use was recorded for skunk and raccoon. Counts suggest heavier than "normal" populations of mink, weasels, and fox, with low abundance of skunk and raccoon on the HWPA. Population indices, however, did not correspond to relative nest predation.

The most prominent nest predator was skunk, destroying 46% of 68 duck nests destroyed over the study period. Also important were ground squirrels (37%), followed by fox (10%), raccoon (4%), and mink (4%). There appeared to be little relationship between late winter track counts and the identified nest predators.

Mammalian foraging strategies may play a more dominant role than relative abundance (Bowman and Harris 1980). For example, mink and raccoon tend to forage during the spring in close proximity to wetland edges, while skunk are more frequently found in upland sites (Jackson 1961, Cowardin et al. 1983). In addition, research activities on the study area may have accelerated predation rates. Nest searching vehicles left wheel tracks in the nest cover and mowed fence lines provided travel lanes for possible use by foraging predators.

Cost Analysis

Lokemoen et al. (1982) estimated that the cost of fencing, including materials, labor, and equipment needs, varied from \$7.25 to \$9.25/rod. Cost estimates fluctuated with local topography and soil conditions. Fencing materials alone accounted for 70% of the total cost (\$5.07 to \$6.48/rod) and material needs were inversely related to plot size. Fencing costs go down as the size of the fenced area increases.

Fencing materials in Wisconsin on similar size plots were \$9.30/rod for both fence designs, with an additional \$6.82/rod needed for construction, annual maintenance (primarily labor costs estimated at \$11/hr including base salary plus fringe benefits), and equipment (e.g., fencing tools, transportation, etc.). Annual maintenance averaged 0.75 days/week for a 20-acre parcel or \$2.24/rod each breeding season. Total costs to operate an electric fence in Wisconsin therefore exceeded \$16/rod, or at least 75% more than Lokemoen et al. (1982) estimated. Maintenance costs, however, were not included in cost estimates for North Dakota and Minnesota fences.

Petersen et al. (1982) recommended that managed waterfowl nest cover in Wisconsin be established in blocks preferably 40 acres or more in size. Fencing costs amortized over a 20-year life of a 40-acre square fence would cost approximately \$34/acre/year. Overall fencing costs would be dramatically lowered with large fenced plots or longer lifetime estimates (Fig. 2).

Lokemoen et al. (1982) estimated the cost of additional ducklings produced varied from \$0.65 to

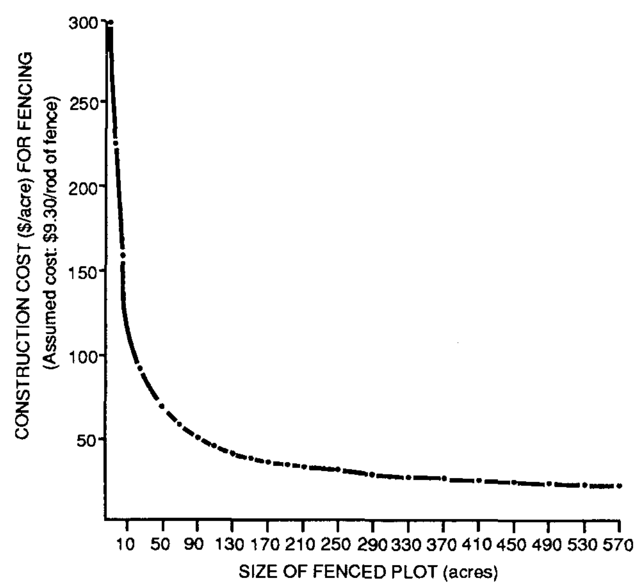


FIGURE 2. *Relation of size of fenced plot to per-acre construction costs. Cost is dramatically lower with large plots.*

$0.87, assuming a 20-year fence life and a nest density of 2.4-3.1 nests/acre. Nest density on the HWPA averaged 0.8 nests/acre annually. If nest densities in Wisconsin are only a third of the Lokemoen et al. (1982) low density estimate, the cost of additional ducklings produced on the HWPA would be $1.95 - $2.61 using cost estimates for North Dakota and Minnesota fences. If cost estimates based on the annual high for breeding ducks on HWPA (1.4 calculated nests/acre in 1982, 79% nest success in 1981) and Wisconsin fencing expenditures, each additional duckling produced would cost a minimum of $5.67.

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Cost estimates under the best conditions of nest densities and success for upland ducks in Wisconsin suggest it would cost $5.67 for each additional duckling produced with the use of electric fences to prevent predator access. Cost analyses for electric fences, however, must be used with caution. Research develops management techniques; consequently, resulting cost-benefit ratios are seldom optimal. Fencing techniques will be refined over time, and the cost of additionally produced ducklings should decline from the current levels estimated here.

Electric fences have been used to control wildlife for over 4 decades (McAtee 1939), yet additional refinement is still needed in these areas: (1) configurations necessary to prevent access by skunk-sized or smaller mammalian predators, (2) maintenance needs, (3) construction materials, and (4) placement within a complex of waterfowl habitat. The modern high voltage, low impedance energizers have revolutionized electric fencing, and have produced results that suggest electric fencing has potential as a waterfowl management tool (Lokemoen et al. 1982, Grunewald 1983). Subsequent to my study, a second electric fence research effort was initiated in Wisconsin with several fenced plots to examine geographic/ecological variation and different fence designs to reduce construction/maintenance costs, and to test an ability to increase breeding pairs over time with increased breeding success (Petersen 1983). Preliminary findings from this second study have indicated promising results (Gatti 1984*a*).[2] New fence configurations, both tested and new design concepts, suggest that maintenance costs can be virtually eliminated within the immediate future. Refinements are within sight, lending additional support for the use of electric fencing as a nest predator deterrent.

Cowardin et al. (1983) suggested the fencing of electric "islands" would duplicate the extraordinary high nest densities found on certain predator-free islands in several prairie lakes. For example, an 11-acre island in Miller Lake, North Dakota, annually produced 250 ducklings/acre of nest cover over a 5-year study period (Duebbert 1966, Duebbert et al. 1983). Mallards, the high priority duck in Wisconsin, possess the behavioral and physiological abilities for very high production under ideal conditions (Cowardin et al. 1983).

There are many public benefits that can be attributed to public ownership of wildlife lands. However, when the primary purpose is for waterfowl, the current duckling production from managed waterfowl nest cover in Wisconsin needs to be improved. Typically, an upland acre of managed waterfowl nest cover costs $1,000 to purchase and approximately $250 to develop. Combined with annual maintenance costs, an acre of managed nest cover would cost at least $2,000 over a 20-year period. Gatti (1984*b*) found an average of 0.12 upland duck nests/acre of managed cover over a broad region of Wisconsin. Mallards comprised 22% of the nests located and had an average of 32% nest success. At this rate, it would require 117 years for the average acre of managed cover to produce a successful mallard nest. Cost per fledging mallard would exceed $300/bird. Successfully operated electric fencing could help to improve this poor cost:benefit ratio.

[2] Final results of this study are reported in an upcoming Wisconsin Department of Natural Resources Technical Bulletin (in press) authored by R. C. Gatti, J. O. Evrard, and W. J. Vander Zouwen.

LITERATURE CITED

Balser, D. S., H. H. Dill, and D. K. Nelson
1968. Effect of predator reduction on waterfowl nesting success. J. Wildl. Manage. 32(4):669-82.

Bowman, G. B. and L. D. Harris
1980. Effect of spatial heterogeneity on ground-nest depredation. J. Wildl. Manage. 44(4):806-13.

Burley, M. W.
1964. The climate in Wisconsin. pp. 143-48 *in* H. R. Theobald and P. V. Robbins, eds. Wisconsin blue book. Wis. Legis. Ref. Bur., Madison. 900 pp.

Connolly, G. E.
1978. Predators and predator control. pp. 369-94 *in* J. L. Schmidt and D. L. Gilbert, eds. Big game of North America. The Stackpole Co., Harrisburg, and Wildl. Manage. Inst., Washington, D.C. 494 pp.

Cowardin, L. M. and D. G. Johnson
1979. Mathematics and mallard management. J. Wildl. Manage. 43(1):18-35.

Cowardin, L. M., A. B. Sargeant, and H. F. Duebbert
1982. Low waterfowl recruitment in the prairies: the problem, the reasons, and the challenge to management. pp. 16-18 *in* H. Boyd, ed. First western hemisphere waterfowl and waterbird symposium. Can. Wildl. Serv. 147 pp.
1983. Problems and potentials for prairie ducks. Naturalist 34:4-11.

Duebbert, H. F.
1966. Island nesting of the gadwall in North Dakota. Wilson Bull. 78:12-25.
1969. High nest density and hatching success of ducks on South Dakota CAP lands. Trans. North Am. Wildl. and Nat. Resour. Conf. 34:218-29.

Duebbert, H. F., E. T. Jacobson, K. F. Higgins, and E. B. Podoll
1981. Establishment of seeded grasslands for wildlife habitat in the prairie pothole region. U.S. Fish and Wildl. Serv. Spec. Sci. Rep. Wildl. No. 234. 21 pp.

Duebbert, H. F. and H. A. Kantrud
1974. Upland duck nesting related to land use and predator reduction. J. Wildl. Manage. 38(2):257-65.

Duebbert, H. F. and J. T. Lokemoen
1976. Duck nesting in fields of undisturbed grass-legume cover. J. Wildl. Manage. 40(1):39-49.
1980. High duck nesting success in a predator-reduced environment. J. Wildl. Manage. 44(2):428-37.

Duebbert, H. F., J. T. Lokemoen, and D. E. Sharp
1983. Concentrated nesting of mallards and gadwalls on Miller Lake Island, North Dakota. J. Wildl. Manage. 47(3):729-40.

Dzubin, A.
1969. Comments on carrying capacity of small ponds for ducks and possible effects of density on mallard production. pp. 138-60 *in* Saskatoon Wetlands Seminar. Can. Wildl. Serv. Rep. Ser. No. 6. 262 pp.

Einarsen, A. S.
1956. Determination of some predator species by field sign. Oreg. State Coll. Monogr. Stud. in Zool. No. 10. 34 pp.

Gates, N. L.
1978. Constructing an effective anti-coyote electric fence. U.S. Dep. Agric., Sci. Educ. Adm. Leafl. No. 565. 6 pp.

Gates, N. L., J. E. Rich, D. D. Godtel, and C. V. Hulet
1978. Development and evaluation of anti-coyote electric fencing. J. Range Manage. 31(2):151-53.

Gatti, R. C.
1984*a*. Electric fencing for duck and pheasant production. Prog. Rep. Study No. 126. pp. 63-79 *in* Wisconsin Department of Natural Resources. Wildlife research projects annual reports 1984. Pittman-Robertson Proj. W-141-R-19. Vol. 2. 271 pp.
1984*b*. Evaluation of switchgrass nest cover for pheasants and ducks. Prog. Rep. Study No. 127. pp. 71-78 *in* Wisconsin Department of Natural Resources. Wildlife research projects annual reports 1984. Pittman-Robertson Proj. W-141-R-19. Vol. 2. 271 pp.

Grunewald, T. R.
1983. Electric fencing: a technique designed to increase waterfowl nesting success. Univ. Wis.-Stevens Point. MS Thesis. 31 pp.

Hammond, M. C.
1966. Simulated nest study guide. U.S. Bur. Sport Fish. and Wildl. Resour. 22 pp.

Hammond, M. C. and W. R. Forward
1956. Experiments on causes of duck nest predation. J. Wildl. Manage. 20(3):243-47.

Higgins, K. F., L. M. Kirsch, H. F. Duebbert, A. T. Klett, J. T. Lokemoen, H. A. Miller, and A. D. Kruse
1977. Construction and operation of cable-chain drag for nest searches. U.S. Fish and Wildl. Serv. Wildl. Leafl. No. 512. 14 pp.

Hunt, R., D. Evenson, and M. Anderson
1982. Wisconsin breeding duck populations 1973-1982. Wis. Dep. Nat. Resour. unpubl. rep. 10 pp.

Jackson, H. H. T.
1961. Mammals of Wisconsin. Univ. Wis. Press, Madison and London. 504 pp.

Keith, L. B.
1961. A study of waterfowl ecology on small impoundments in southeastern Alberta. Wildl. Monog. No. 6. 88 pp.

Kirsch, L. M., H. F. Duebbert, and A. D. Kruse
1978. Grazing and haying effects on habitats of upland nesting birds. Trans. North Am. Wildl. Nat. Resour. Conf. 43:486-97.

Klitz, W.
1982. Habitat management to control ground squirrel populations. Cal-Neva Wildl. Trans. pp. 69-74.

Lokemoen, J. T., H. A. Doty, D. E. Sharp, and J. E. Neaville
1982. Electric fences to reduce mammalian predation on waterfowl nests. Wildl. Soc. Bull. 10:318-23.

Livezey, B. C.
1981. Duck nesting in retired croplands at Horicon National Wildlife Refuge, Wisconsin. J. Wildl. Manage. 45(1):27-37.

Madsen, C. R.
1983. Additional opportunities for duck management. Naturalist 34:25-7.

Mayfield, H.
1961. Nesting success calculated for exposure. Wilson Bull. 73(3):255-61.
1975. Suggestions for calculating nest success. Wilson Bull. 87(4):456-66.

McAtee, W. L.
1939. The electric fence in wildlife management. J. Wildl. Manage. 3(1):1-13.

Miller, H. W.
1971. Relationship of duck nesting success to land use in North and South Dakota. Trans. Int. Congr. Game Biol. 10:133-41.

Miller, H. W. and D. H. Johnson
1978. Interpreting the results of nesting studies. J. Wildl. Manage. 42:471-76.

Mitchell, M. J.
1978. Soil survey of Columbia County, Wisconsin. U.S. Dep. Agric., Soil Conserv. Serv. 156 pp.

Murie, O. J.
1974. A field guide to animal tracks. 2nd ed. Houghton Mifflin Co., Boston. 375 pp.

Nelson, H. K. and H. F. Duebbert
1974. New concepts regarding the production of waterfowl and other game birds in areas of diversified agriculture. Game Biol. 11:385-94.

Nesbitt, E. T. W.
1978. Modern electric fencing...the value of it! pp. 22, 24, 36 *in* Sheep breeder and sheepman. Ft. Collins, Col.

Petersen, L. R.
1983. Electric fencing for duck and pheasant production. Prog. Rep. Study No. 126. pp. 91-95 *in* Wisconsin Department of Natural Resources. Wildlife research projects annual reports 1983. Pittman-Robertson Proj. W-141-R-18. Vol. 1. 233 pp.

Petersen, L. R., M. A. Martin, J. M. Cole, J. R. March, and C. M. Pils
1982. Evaluation of waterfowl production areas in Wisconsin. Wis. Dep. Nat. Resour. Tech. Bull. No. 135. 32 pp.

Rearden, J. D.
1951. Identification of waterfowl nest predators. J. Wildl. Manage. 36:182-86.

Robel, R. J., J. N. Briggs, J. J. Cebula, N. J. Siluy, C. E. Viers, and P. G. Watt.
1976. Greater prairie chicken ranges, movements, and habitat usage in Kansas. J. Wildl. Manage. 34(2):286-306.

Smith, A. G.
1971. Ecological factors affecting waterfowl production in the Alberta parklands. U.S. Bur. Sport Fish. and Wildl. Resour. Publ. No. 98. 49 pp.

Steward, R. E. and H. A. Kantrud
1971. Classification of natural ponds and lakes in the glaciated prairie region. U.S. Bur. Sport Fish. and Wildl. Resour. Publ. No. 92. 57 pp.

Stoudt, J. H.
1971. Ecological factors affecting waterfowl production in the Saskatchewan parklands. U.S. Bur. Sport Fish. and Wildl. Resour. Publ. No. 99. 58 pp.

U.S. Fish and Wildlife Service
1978. Sport fisheries and wildlife research 1975-76. U.S. Gov. Print. Off., Washington, D.C. 140 pp.
1984. Federal aid in fish and wildlife restoration 1981. U.S. Gov. Print. Off., Washington, D.C. 80 pp.

Weller, M. W.
1956. A simple field candler for waterfowl eggs. J. Wildl. Manage. 20:111-13.

Weller, M. W. and C. E. Spatcher
1965. Role of habitat in the distribution and abundance of marsh birds. Iowa State Univ. Agric. Home Econ. Exp. Stn. Spec. Rep. No. 43. 32 pp.

Wheeler, W. E., R. C. Gatti, and G. A. Bartelt
1984. Duck breeding ecology and harvest characteristics on Grand River Marsh Wildlife Area. Wis. Dep. Nat. Resour. Tech. Bull. No. 145. 51 pp.

Woehler, E. E.
1979. Establishment of native warm season grasses in Wisconsin. Wis. Dep. Nat. Resour. Res. Rep. No. 102. 12 pp.

ACKNOWLEDGMENTS

This study was supported in part by funds supplied by the Federal Aid to Wildlife Restoration Act under Pittman-Robertson Project W-141-R. This report represents a Final Report for Study No. 121.

Acknowledgment is given to these manuscript reviewers: R. C. Gatti, J. R. March, R. T. Dumke, and S. M. Weston. E. L. Lange and R. C. Gatti provided assistance in statistical analysis. Wildlife managers P. H. Kaiser and L. Hansen provided equipment, manpower, and encouragement.

ABOUT THE AUTHOR

L. R. Petersen is currently buried in administrative work as Southern Wildlife Ecologist for the Bureau of Research. He lives on a small Sauk County farm with a collection of horses, dogs, and cats.

Production Credits

Susan Nehls, Technical Editor
Donna Mears, Copy Editor
Alice Miramontes, Figure Preparation
Georgine Price, Layout and Production Artist
Word Processors, WP/5

Wisconsin Department of Natural Resources
PUBL-RS-151 90