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Effects of Predator Reduction on the Survival and Movements of Northern Shoveler Broods

John M. Zimmer
Louisiana State University and Agricultural and Mechanical College

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EFFECTS OF PREDATOR REDUCTION ON THE SURVIVAL AND
MOVEMENTS OF NORTHERN SHOVELER BROODS

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in

The School of Forestry, Wildlife, and Fisheries

by

John M. Zimmer
B.S. University of New Hampshire, 1993
August, 1996
MANUSCRIPT THESES

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ACKNOWLEDGEMENTS

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I express sincere appreciation to those who assisted me in the field. Barb “Wrongway” Lercel, Lea Craig, “Canadian” Mike Gendron, “Mississippi” Mike Brasher, “American” Mike Artmann, and Al Fontaine. Without their advice and ability to find shed transmitters, this study would not have been possible. To Ben “Skinny Guy” Mense, my friend and adversary on the whiffle ball field, for keeping things light when the field season became hectic. Thanks to Rob Holbrook, for his insightful commentaries at lab lunch and for keeping me sane in an office which sometimes resembled a menagerie. To David Smith for allowing me to experience some of the best duck hunting in North America. To Rob Meade, whose skeleton is still being detained at the International Peace Garden. A special thanks to Tina Yerkes, who taught me the importance of diligence and organization in the field and to not get angry when your technician releases one of your birds.

I am grateful to my family for their support throughout my academic career. To my father, who has taught me that an appreciation of wildlife and the outdoors is a prerequisite of being a sportsman, and to my mother, for caring enough to relocate and raise another child when she should be enjoying her retirement.
Most importantly, to my wife Elizabeth, for her love, support, and willingness to let me spend my summers 1500 miles away. It’s been a long, hard road, but we’re almost home.
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ABSTRACT

I studied the effects of predator removal on survival and movements of Northern Shoveler (Anas clypeata) broods in the prairie pothole region of North Dakota. The study was conducted from April through August 1995. No treatment effects were found on brood survival as both 14 and 30 day survival estimates were statistically equivalent. Experimental sites had higher brood and duckling survival and produced twice as many fledglings per successful nest than control sites. Cumulative movement distance had no effect on duckling survival. While survival rates of Northern Shoveler broods and ducklings were higher than most species of prairie nesting ducks, Shovelers exhibited similar mortality patterns over the 30 day period.

Predator reduction did not affect overland movements by Northern Shoveler broods. Frequency and cumulative distances traveled over 30 days did not differ between experimental and control sites. Distance moved between wetlands was significantly different between treatments, but it is unclear whether this was a result of predator reduction. Nest site selection and initial movements did not differ between control and experimental sites. Using pooled data, there was a highly significant difference was found between the mean distance from nest sites to the closest wetlands (41 m) and initial movements to water (555 m). Broods made similar numbers of movements during the first 15 days after hatch as days 16-30 after hatch. Densities of available wetlands did not differ for broods on experimental and control sites.

Radio telemetry is a valuable tool in many studies of waterfowl ecology, but effects on behavior and survival of marked individuals, inadequate radio retention rates, and poor signal range potentially limit its usefulness. I used 8 g anchor transmitters and
modified glue and suture attachment methods which were previously used on Mallards (Anas platyrhynchos), but had poor retention rates with Northern Shovelers. For smaller species of waterfowl, which have thinner skin than larger species, use of smaller anchor transmitters and avoidance of cyanoacrylate glue as an attachment supplement would most likely yield better retention rates.
INTRODUCTION

Three major areas in North America are vital to breeding waterfowl: the prairie pothole region, northern watersheds and deltas, and northern forests and tundra. Of these, the prairie pothole region is by far the most significant. Although this region comprises only ten percent of the total waterfowl breeding habitat on the continent, it has historically produced over 50 percent of the ducks in an average year (Smith et al. 1968). However, over the past 35 years, nest success of ducks in the prairie pothole region has declined markedly (Caithamer et al. 1995, Beauchamp et al. 1996). Many factors have contributed to this decline, including loss of habitat and fluctuating water levels, but the main cause appears to be elevated levels of predation (Sargeant and Raveling 1992).

Predatory mammal species including red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*), and striped skunk (*Mephitis mephitis*) are abundant in the prairie pothole region and negatively impact nest success of breeding ducks (Duebbert and Lokemoen 1980, Sargeant and Raveling 1992). Over broad areas in the prairie pothole region, Greenwood et al. (1987) and Beauchamp et al. (1996) found that less than 15 percent of all duck nests hatched at least one egg without active management. Ducklings from successful nests experience greater than 50 percent mortality before fledging (Duebbert and Lokemoen 1980). Increased predator populations may contribute significantly to this high mortality rate.

Waterfowl management on the breeding grounds is largely focused on ways to alleviate predation losses. One direct approach used to increase nest success has been the reduction of potential predator populations. Prior work has shown that reducing
predator numbers can dramatically increase nest success (Balser et al. 1968, Chesness et al. 1968, Lynch 1972, Duebbert and Kantrud 1974, Garrettson et al. 1996). Indeed, some areas with predator removal have nest success rates as high as 95 percent (Kirsch 1975, Duebbert and Lokemoen 1980).

Predator reduction can also lead to a decrease in mortality of adult females. As more females initiate and successfully hatch nests, there is potential for greater numbers of fledged broods to be added to the fall flight (Sargeant et al. 1984). Brood sizes on areas with predator reduction were greater than on untreated areas (Balser et al. 1968, Duebbert and Kantrud 1974), but survival and mortality of ducklings during the pre-fledging period are poorly understood (Talent et al. 1983). Unfortunately, few studies have focused on brood survival and never in conjunction with an active management strategy such as predator removal.

My objectives in this study were (1) to determine whether predator removal affects the survival and movement patterns of northern shoveler (Anas clypeata) broods in prairie North Dakota, and (2) to obtain basic brood ecology information, as little previous work had been done on the species. I also collected valuable information on anchor transmitters, which are a relatively new attachment method for radio packages used with birds.

Throughout this text I used both English and scientific nomenclature proposed by the American Ornithologists' Union (1983) in references that regard birds. Nomenclature for mammals followed that of the American Society of Mammalogists.
The Chapters of this thesis are written so they can stand alone. Therefore, some of the methods sections are somewhat repetitive. Due to its applicability to all chapters, information on study area and study species have been consolidated into sections proceeding the first chapter.
STUDY AREA

This study was conducted in the drift prairie landscape of north-central North Dakota (Talent et al. 1983). Although this area is intensively farmed for small grains, there is considerable acreage (~30%) enrolled in the Conservation Reserve Program (CRP). Eight study sites were chosen in this area based on the abundance of wetlands and a relatively high percentage of land in CRP. Each site was a contiguous square block of 4,100 ha, had gently rolling topography, and contained an abundance of wetland complexes. Four sites were randomly chosen for predator removal (experimental) and the four remaining non-removal sites were used as controls.
STUDY SPECIES

Northern Shovelers were chosen as the study species for several reasons. Shovelers have shown a sustained increase in populations since the early 1980’s while populations of other species have, until recently, remained stable or decreased (Caithamer et al. 1995). Prior work suggested that Northern Shovelers are more amenable to nest trapping and handling than other species of upland nesting waterfowl such as mallards (Anas platyrhynchos) and show lower nest abandonment when fitted with a radio package (Rohwer pers. comm. 1994). Shovelers also tend to use more open habitat for feeding than many other dabbling ducks, which improves the probability of observing marked females with broods. Little research has been done on basic brood ecology of northern shovelers, therefore, one aim of this study was to attain information on brood movements and survival.
EFFECTS OF PREDATOR REDUCTION ON SURVIVAL OF NORTHERN SHOVELER BROODS

Recruitment in waterfowl is the addition of young to the fall population by reproduction from adults in the spring population (Cowardin and Blohm 1992). Two key components of reproduction that most influence recruitment are nest success and brood survival (Johnson et al. 1992). While both of these factors impact production in waterfowl, managers have traditionally focused on improving nest success. Cowardin and Johnson (1979) stressed that measurement of brood survival is essential for calculating recruitment, yet brood survival studies exist for only a handful of species (Cowardin and Blohm 1992).

Prior to the early 1990’s, nest success in the prairie pothole region had declined steadily (Beauchamp et al. 1996), leading to reduced populations of several species of waterfowl (Caithamer et al. 1995). Nest success over much of the prairies during the 1970’s and 1980’s was below 15%, which modeling efforts suggest is the minimum necessary for maintaining stable populations (Klett et al. 1988). Nest success declined due to a combination of three factors: (1) decreased nesting cover due to intensive agricultural practices; (2) lack of seasonal wetlands due to fluctuating water levels; and (3) an increase in density of mammalian nest predators.

Several management strategies have been used on the prairies to increase nest success, but the effects on brood survival are usually ignored. Establishment of upland nesting cover through Waterfowl Production Areas and Conservation Reserve Program grasslands has increased both nest density and success (Livezey 1981, Klett et al. 1984, Kantrud 1986, Kadlec and Smith 1992, Luttschwager et al. 1994). However, small,
isolated patches of planted nesting cover may lure higher densities of ducks to nest in areas that are more easily searched by predators (Kadlec and Smith 1992). Construction of nesting islands often attract large numbers of nesting ducks, which have increased nest success due to scarcity of mammalian predators (Browne et al. 1983, Wilms and Crawford 1989, Kadlec and Smith 1992). However, survival rates of broods produced from island nesting situations are largely unknown. Use of electric fences to exclude predators from areas of nesting habitat regularly increases nest success (Sargeant et al. 1974, Lokemoen et al. 1982, Greenwood et al. 1990) but intensive maintenance and problems with brood exodus limit the efficiency of fences (Pietz et al. 1994, Trottier et al. 1994, LaGrange et al. 1995).

Control of nest predation rates is clearly the underlying theme of the majority of management techniques aimed at increasing recruitment. Direct predator reduction has been used to dramatically increase nest success in the past (Balser et al. 1968, Lynch 1972, Duebbert and Kantrud 1974, Doty and Rondeau 1988), but only recently have large scale predator removal studies been undertaken with replicates and without the use of poisons (Sargeant et al. 1995, Garrettson et al. 1996). As with most other efforts to enhance recruitment, research on predator reduction has focused on assessing impacts on nest success.

Predator reduction appears to increase nest success, but its effects on brood and duckling survival are still unknown. Brood size and density were greater on areas with predator reduction (Balser et al. 1968, Duebbert and Kantrud 1974, Garrettson et al. 1996), but survival and mortality patterns during the pre-fledging period are poorly
understood. This study aimed to examine the effects of active reduction of mammalian predator populations on the survival of Northern Shoveler (Anas clypeata) broods.

Brood survival is the probability of at least one hatchling surviving to fledging (Duncan 1986). Brood and duckling survival are codependent, since duckling survival is the probability of a duckling within a successful brood surviving from hatch to fledging. Overall survival to fledging is a product of brood and duckling survival and represents the probability of any hatched duckling surviving to fledging. Total brood mortality events account for the majority of overall duckling mortality (Talent et al. 1983, Rotella and Ratti 1992a, Grand and Flint 1996), and failure to account for total brood mortality events would greatly overestimate recruitment (Ball et al. 1975, Talent et al. 1983).

Most brood and duckling mortality occurs within the first two weeks after hatch (Talent et al. 1983, Duncan 1986, Orthmeyer and Ball 1990, Rotella and Ratti 1992a, Grand and Flint 1996, Korschgen et al. 1996). Exact timing of mortality is not known, but ducklings may be particularly vulnerable when making overland movements between wetlands (Dzubin and Gollop 1972, Bellrose 1980, Johnson et al. 1992, Rotella and Ratti 1992a). In this study we removed upland predators which may play a role in mortality as ducklings travel overland (Sargeant and Raveling 1992). Red Fox (Vulpes vulpes) and Striped Skunk (Mephitis mephitis) are not known to be active in wetland areas where broods are found when not making overland movements.

Based on the above, I predicted that predator removal would affect brood survival more than duckling survival. Several factors such as exposure and exhaustion can reduce duckling survival, yet most total brood mortality is a direct result of depredation (Johnson et al. 1992, Sargeant and Raveling 1992). I also hypothesized that
brood and duckling survival patterns would be comparable to those of other prairie nesting species, as Northern Shovelers have similar nesting and brood rearing habits (Afton 1983, Ankney and Afton 1988).

**METHODS**

**Predator Reduction**

Reduction of mammalian predators from the experimental sites was initiated in late March, 1995 and continued until July 31, 1995, and was conducted under permit from the North Dakota Game and Fish Department by four professional trappers. One trapper was responsible for each of the treatment sites. Removal methods included leg hold traps, box traps with a connibear, snares, and shooting. Trapping focused on Red Fox (*Vulpes vulpes*), Striped Skunk (*Mephitis mephitis*), and Raccoon (*Procyon lotor*). Minor numbers of Badger (*Taxidea taxus*), Long-tailed Weasel (*Mustela erminea*), Coyotes (*Canis latrans*), and Mink (*Mustela vison*) were also taken. Avian predators were not controlled.

**Nest Searching**

Nest searching was performed by dragging a 67 m long, 1 cm diameter chain between two tractors or all-terrain vehicles (Klett et al. 1986). Searching was conducted between 0700 and 1400 CST to maximize the probability of locating nests and minimize the amount of nest abandonment (Gloutney et al. 1993). Northern Shoveler nests were identified by observing the flushing female or by examining egg and feather characteristics in the nest. Incubation stage of eggs was determined using a field candler (Weller 1956), and nests were rechecked at least once before trapping to monitor nest survival. Nest checks were performed by one person to reduce the likelihood of nest
abandonment (Livezey 1980). Nests on the control sites were encircled by wire fencing that had 4.5 cm square mesh and a 25 m diameter as a means of reducing nest predation (Krapu and Luna 1991).

**Trapping**

Females were trapped late in incubation (16-24 days) based upon the 23 to 25 day incubation period (Bellrose 1980). Trapping occurred between May 28, 1995 and July 25, 1995. Capture was initially attempted using a long-handled net. If this was unsuccessful, an automatic nest trap was employed (Weller 1957). To decrease abandonment and stress on the females, trapping was not performed on days of inclement weather. Captured females were marked with radio transmitters, nasal disks (Lokemoen and Sharp 1985), and U.S. Fish and Wildlife Service leg bands.

**Transmitter Design and Attachment**

Anchor transmitters had crystal-controlled frequencies and were designed for 45 days of battery life (Advanced Telemetry Systems, Isanti, Minnesota). Transmitters had a minimum line of sight range of 2.5 km using four-element yagi antennas and did not have mortality switches. The transmitter was circular with a 23 mm diameter flat base and 12 mm height. The stainless-steel anchor extended 11 mm from the anterior base, and the posterior antenna extended 23.5 cm at a 45 degree angle from the base. The package weighed approximately 8 g, which was <0.5% of average adult female body mass of Northern Shovelers (Ankney and Afton 1988).

Upon retrieval from the net or trap, a facial cover was fitted over the eyes to pacify the bird. Next, a U.S. Fish and Wildlife Service leg band was placed on the right
Transmitters were attached mid-dorsally, anterior to the shoulder joints, with three polypropylene sutures and a subcutaneously inserted wire anchor.

The transmitter site was prepared by trimming feathers from a patch of skin slightly larger than the base of the transmitter. The transmitter was then used as a guide to mark suture and anchor incision sites with a permanent pen. The mark for the anchor incision was made at the midpoint of the anchor stem, so the anchor would lie anterior to the incision when under the skin. The trimmed area, transmitter, and all surgical instruments were sterilized using Glutacide. A local anesthetic, Lidocaine without epinephrine, was injected into several points around the trimmed area before the sutures and wire anchor were inserted.

Three polypropylene sutures were first threaded through the skin along the three guide marks and left slack. Next, a 2-3 mm incision was made along the mark made at the midpoint of the anchor stem by holding a fold of skin with forceps, piercing the skin with a number 11 surgical blade and cutting away from the body. A blunt probe was then inserted into the incision to detach the skin from muscle. The anchor portion of the transmitter was threaded under the skin, and the three sutures were fed through the body of the transmitter. Sutures were tightened and tied off with two or more square knots. Drops of cyanoacrylate glue were placed on each knot and between the base of the transmitter and the skin to aid in retention.

Once the transmitter was firmly secured, the facial cover was removed and a unique nasal marker was attached. The bird was then brought to a medium state of anesthesia using methoxyflourane (Rotella and Ratti 1990), weighed to the nearest 5 g, and placed back upon the nest.
Techniques used in this study were approved by the Louisiana State University Animal Care Committee. Attachment procedures were based upon those used by Pietz et al. (1995), but modified based on consultation with other researchers using similar equipment. Guidelines for use of wild birds in research set forth by the American Ornithologists’ Union (1988) were followed.

Radio Tracking and Observation

Survival to fledging is defined as survival from hatching to 30 days of age and is the product of brood survival and duckling survival. Brood survival is the proportion of broods with at least one duckling surviving to 30 days after hatching. Duckling survival is the proportion of ducklings that survive to 30 days in successful broods. Due to small sample sizes on individual sites, data were pooled within experimental and control sites respectively. Both 15 and 30 day time period were used in brood and duckling survival analyses.

Females with their broods were tracked over a 30 day period post-hatch. Survival to 30 days is indicative of survival to fledging as greater than 75% of duckling mortality occurs within the first three weeks of life (Evans et al. 1952, Ball et al. 1975, Ringleman and Longcore 1982, Duncan 1986, Rotella and Ratti 1992a). Each female was located at least once every three days, and a count of ducklings was attempted at least once per seven days. Tracking ended after: (1) completion of the 30 day period; (2) transmitter loss or failure; (3) predation of the marked female, or (4) total brood loss.

Radio tracking was done using truck-mounted four-element yagi antennas and hand-held three-element yagi antennas. When tracking occurred, the individual was located specifically to the site, section, quarter section, and pond. This was
accomplished by obtaining an estimated location using truck-mounted antennas, followed by walking in on the signal using hand-held units and aerial photographs to determine exact locations.

Brood observations were accomplished by two methods. First, whenever possible, marked females in open water were observed from a distance using binoculars or a spotting scope, and ducklings were counted. If a female was utilizing a particularly densely vegetated wetland, I would enter the wetland and attempt to flush the hen and ducklings into open water. If no ducklings were seen, but the female performed distraction displays, I assumed that at least one duckling was still alive and present. Total brood loss was assumed if no ducklings were seen after two observations and if the female did not attempt to distract the observer or the female was associating with a group of birds.

Statistical Analyses

For the purposes of estimating 15 and 30 day brood survival, radio telemetry data were placed into one of four categories: (1) successful (2) total brood loss (3) shed radio package, and (4) brood movement off study site. The last two categories were entered into the survival model, but right censored since final brood fate could not be determined.

Survival analyses were based on procedures developed by Kaplan and Meier (1958) and modified by Pollock et al. (1989) to allow for staggered entry of individuals. This method allows for right censoring, which, in this study, was caused by transmitters being shed and broods moving off study sites to private lands that were not accessible. The LIFETEST module in SAS (SAS Inst. Inc. 1989) was used to determine brood
survival rates and to test potential differences between resulting brood survival distributions. Treatment group, fate, number of days tracked, and cumulative movement by each brood from hatch to 15 days were entered into the module, resulting in estimates of daily brood survival. Effects of predator reduction on 15 and 30 day brood survival estimates for experimental and control sites were tested using a Chi-Squared test (Sauer and Williams 1989).

Timing of brood mortality or duckling mortality was assigned to the date halfway between radio tracking events. Mortality dates were then categorized into one of four time periods: (1) hatch to 7 days; (2) 8 to 15 days; (3) 16 to 22 days; or (4) 23 to 30 days. This was done for total brood mortality and for duckling mortality, which did not include individuals that died in total brood mortality events. Differences in duckling mortality from hatch to 15 days was compared with duckling mortality from 16-30 days using a t-test.

Maximum clutch size was determined by counting eggs at the time of trapping. The number of ducklings hatched per nest was determined by counting egg membranes in the nest after hatch. Clutch size and number of hatchlings per nest on experimental and control sites were compared using t-tests. Duckling counts for successful broods were determined by visual observations and the proportion of hatched ducklings that survived to 15 and 30 days were compared between treatment groups using standard t-tests.

RESULTS

I radio marked 70 Northern Shoveler females in this study. For the 37 females marked on experimental sites, I determined fates for 26 broods. Nine females were lost
due to shed transmitters or movement off of study sites, and two females were
depredated before hatch. Four broods incurred total mortality, while 22 broods
produced at least one 15 day old duckling. Thirty-one females were marked on the
control sites, and subsequent fates were determined for 21 broods. Ten females were
lost before the 30 day period had expired due to shed transmitters or movement off of
study sites, and five females were depredated post-hatch contributing to six total brood
losses. Fifteen broods produced at least one 15 day old duckling.

Brood survival rates to 30 days were 0.68 on control sites and 0.84 on
experimental sites, but not significantly different ($X^2=1.72, P=0.19$) (Table 1). Fifteen
day brood survival rates were 0.76 for control and 0.89 for experimental sites,
respectively ($X^2=1.62, P=0.20$). All brood mortality on control and experimental sites
occurred within the first two weeks post-hatch. Duckling mortality was also
concentrated during this period (96% con., 92.5% exp.), with over 70% of overall
mortality occurring during the first week after hatch. Effects of cumulative movement
distance over the 30 period on brood survival were determined through a log rank test
and were found to be nonsignificant ($X^2=1.33, P=0.25$).

The proportion of ducklings that survived to 15 days was 0.86 for experimental
sites and 0.77 for control sites ($t=0.89, P=0.43$), while the proportion of ducklings
surviving to 30 days was 0.84 and 0.73, respectively ($t=1.29, P=0.28$). Total brood
mortality was responsible for 63% of all duckling mortality on experimental sites and
72% on control sites.

Clutch size was nearly equivalent for both treatments, but experimental nests
hatched slightly more ducklings per nest than did control sites (Table 2). Successful
Table 1: Summary statistics of treatment effects on duckling and brood survival estimates.

<table>
<thead>
<tr>
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<th>Control</th>
<th>Experimental</th>
<th>Test Statistic</th>
<th>P*</th>
</tr>
</thead>
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<tr>
<td>Brood Survival (15 day)</td>
<td>0.76</td>
<td>0.89</td>
<td>1.62^b</td>
<td>0.20</td>
</tr>
<tr>
<td>Brood Survival (30 day)</td>
<td>0.68</td>
<td>0.84</td>
<td>1.72^b</td>
<td>0.19</td>
</tr>
<tr>
<td>Duckling survival (15 day)</td>
<td>0.77</td>
<td>0.86</td>
<td>0.89^c</td>
<td>0.43</td>
</tr>
<tr>
<td>Duckling Survival (30 day)</td>
<td>0.73</td>
<td>0.84</td>
<td>1.29^c</td>
<td>0.28</td>
</tr>
<tr>
<td>Survival to Fledging (15 day)</td>
<td>0.59</td>
<td>0.77</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Survival to Fledging (30 day)</td>
<td>0.50</td>
<td>0.71</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

^a Critical value = 0.05
^b X^2 test
^c T-test
N/A = Not available
Table 2: Summary statistics of clutch size, hatch rates, and duckling survival within broods on experimental and control sites.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Experimental</th>
<th>Test Statistic&lt;sup&gt;b&lt;/sup&gt;</th>
<th>&lt;sup&gt;P&lt;/sup&gt; &lt;sup&gt;a&lt;/sup&gt;</th>
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</thead>
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<tr>
<td>Average clutch size</td>
<td>10.5</td>
<td>10.7</td>
<td>0.60</td>
<td>0.55</td>
</tr>
<tr>
<td>Average # of ducklings hatched per nest</td>
<td>9.1</td>
<td>9.8</td>
<td>1.04</td>
<td>0.39</td>
</tr>
<tr>
<td>Average # ducklings produced per successful brood</td>
<td>6.1</td>
<td>8.6</td>
<td>1.61</td>
<td>0.12</td>
</tr>
<tr>
<td>Duckling production per successful nest&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.7</td>
<td>6.4</td>
<td>1.71</td>
<td>0.10</td>
</tr>
</tbody>
</table>

<sup>a</sup>Critical value = 0.05
<sup>b</sup>T-test
<sup>c</sup>Includes total brood mortality
broods on control sites lost approximately twice as many ducklings over the 30 day period (3.1 vs. 1.7) as did experimental broods, but this difference was not significant (t=1.60, P=0.12). Average production per hatched nest, which combined differences in ducklings hatched per nest, total brood mortality, and duckling mortality was 6.44 ducklings on experimental sites and 3.67 on control sites (t=1.71, P<0.10).

**DISCUSSION**

Predator reduction did not appear to affect Northern Shoveler brood and duckling survival. Duckling survival within successful broods was not statistically different between treatment sites, as most successful broods fledged greater than 50% of its ducklings. Brood survival had a greater impact than duckling survival on production of fledged young, evidenced by brood mortality accounting for over 70% of all duckling losses. As expected, predator reduction had a greater influence on brood survival than duckling survival, as more broods were able to fledge at least one duckling on experimental sites than control sites.

As predicted, Northern Shovelers exhibited many of the same brood and duckling mortality patterns as other species in the prairie pothole region. Mortality was greatest during the first two weeks after hatch, concuring with previous studies of brood and duckling mortality (McGilvrey 1969, Ball et al. 1975, Ringleman and Longcore 1982, Talent et al. 1983, Duncan 1986, Orthmeyer and Ball 1990, Rotella and Ratti 1992a, Grand and Flint 1996, Korschgen et al. 1996). Total brood loss accounted for the majority of overall duckling loss, as it does in most ducks (Table 3).

Overland movement by Northern Shoveler broods did not appear to affect duckling survival. Successful broods that traveled longer distances during their first 15
Table 3: Summary of brood and duckling survival estimates and influence of total brood loss on overall duckling deaths.

<table>
<thead>
<tr>
<th>Species</th>
<th>Brood Survival (%)</th>
<th>Duckling Survival (%)</th>
<th>Total Brood Loss (%)</th>
<th>Partial Loss in Successful Broods (%)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Shoveler</td>
<td>68^b</td>
<td>73^a</td>
<td>72</td>
<td>28</td>
<td>This Study</td>
</tr>
<tr>
<td>Blue-winged Teal</td>
<td>89^c</td>
<td>67</td>
<td>27</td>
<td>73</td>
<td>Rohwer (1985)</td>
</tr>
<tr>
<td>Northern Pintail</td>
<td>33</td>
<td>10</td>
<td>72</td>
<td>28</td>
<td>Grand and Flint (1996)</td>
</tr>
<tr>
<td>Mallard</td>
<td>67</td>
<td>44</td>
<td>44</td>
<td>56</td>
<td>Ball et al. (1975)</td>
</tr>
<tr>
<td>Mallard</td>
<td>48</td>
<td>35</td>
<td>68</td>
<td>32</td>
<td>Talent et al. (1983)</td>
</tr>
<tr>
<td>Mallard</td>
<td>63</td>
<td>40</td>
<td>60</td>
<td>40</td>
<td>Orthmeyer and Ball (1990)</td>
</tr>
<tr>
<td>Mallard</td>
<td>49</td>
<td>22</td>
<td>54</td>
<td>46</td>
<td>Rotella and Ratti (1992a)</td>
</tr>
<tr>
<td>Mallard</td>
<td>49</td>
<td>35</td>
<td>54</td>
<td>46</td>
<td>Mauser et al. (1994a)</td>
</tr>
<tr>
<td>Canvasback</td>
<td>35</td>
<td>38</td>
<td>56</td>
<td>44</td>
<td>Korschgen et al. (1996)</td>
</tr>
<tr>
<td>American Black Duck</td>
<td>81</td>
<td>42</td>
<td>33</td>
<td>67</td>
<td>Ringleman and Longcore (1982)</td>
</tr>
<tr>
<td>Wood Duck</td>
<td>76</td>
<td>41</td>
<td>43</td>
<td>57</td>
<td>Ball et al. (1975)</td>
</tr>
</tbody>
</table>

^a These two columns sum to 100%.
^b Results are from control sites only.
^c Results from all experimental broods (See Table 3; Rohwer 1985)
days after hatch did not incur greater duckling mortality than more sedentary broods. Although several studies imply a negative relationship between movements and survival (Dzubin and Gollop 1972, Ball et al. 1975, Paulus 1984, Rotella and Ratti 1992b, Mauser et al. 1994b), results from this study concur with previous work that found no correlation between distance moved and duckling survival (Talent et al. 1983, Duncan 1986, Duncan 1987).

This study took place during an exceptionally wet breeding season in the prairie pothole region. The number of available wetland complexes on the study sites often numbered over 100 per square mile. Talent (1980) stated that the pattern and magnitude of duckling survival probably varies during wet-dry cycles on the prairies, and several studies have found that survival is positively correlated to wetland density (Stoudt 1971, Rohwer 1985, Batt et al. 1989, Rotella and Ratti 1992a). Depredation of ducklings may be influenced by wetland abundance and availability during the first two weeks post hatch (Korschgen et al. 1996). Use of predator reduction as a management tool may become more important once the prairie pothole region enters another dry cycle.

Wetlands in the glaciated prairie region undergo wide fluctuations in water conditions due to annual variations in precipitation (Duebbert and Frank 1984), but the problems associated with lack of suitable brood rearing habitat may be offset by reducing numbers of potential brood predators.

Both 30-day brood and duckling survival of northern Shovelers are higher than that of the majority of published accounts for other species of prairie nesting ducks (Table 3). It is especially interesting to note this in conjunction with breeding population estimates. Mallard and Northern Pintail populations have declined over the past 35 years
while Northern Shoveler and Gadwall (*Anas strepera*) populations have increased (Caithamer et al. 1995). Although nest success rates of these species have declined at approximately the same rate, Gadwalls and Shovelers have consistently higher (20-25%) success rates than do Mallards or Northern Pintails (10-15%) (Beauchamp et al. 1996). Brood and duckling survival in Northern Shovelers and Gadwalls are also higher than for Mallards and Northern Pintails (Table 3) leading to the conclusion that, if population increases associated with Gadwalls and Northern Shovelers are breeding ground related, they may be the result of a combination of higher nest success and brood survival than species with declining populations.

Although a statistically significant influence of predator reduction on brood survival was not detected, the overall impact of brood and duckling survival on recruitment can not be overlooked. To emphasize this point, an example was created to show the effects of predator reduction on Northern Shoveler recruitment (Table 4). Production from a hypothetical sample of 100 nests on both control and treatment sites was based on brood and duckling data from this study and nest success rates from Garrettson et al. (1996). Nest success was twice as high on experimental sites, but projected fledging rates were 3.5 times greater on experimental sites compared to control sites. This example, however, potentially underestimates the effects of predator reduction on brood and duckling survival. Ducks will readily recycle when a nest is destroyed and produce another clutch (Johnson et al. 1992). Through renesting, females can partially compensate for low nest success. However, depredation of a brood results in reproductive failure for an entire breeding season since renesting after brood loss is
Table 4: Effect of predator reduction on estimated Northern Shoveler recruitment based on combination of nest success and brood survival.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Experimental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Initial Nests</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Nest Success(^a)</td>
<td>0.24</td>
<td>0.53</td>
</tr>
<tr>
<td>Clutch Size</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Probability of Brood Survival</td>
<td>0.76</td>
<td>0.89</td>
</tr>
<tr>
<td>Ducklings per Successful Brood(^b)</td>
<td>6.11</td>
<td>8.58</td>
</tr>
<tr>
<td>Overall Duckling Production</td>
<td>111</td>
<td>405</td>
</tr>
</tbody>
</table>

\(^a\)Pooled upland nesting ducks from Garrettson et al. (1996).
\(^b\)Based on 14 day results for Northern Shovelers from this study.
exceptionally rare. Increases in brood survival resulting from predator reduction can substantially augment improvements in nest success and lead to dramatic increases in nest success.

CONCLUSION

Although survival rates for both broods and ducklings were higher on experimental sites, lack of statistical significance precludes any definitive conclusions to the effectiveness of predator reduction as a means of increasing survival. Loss of transmitters created analysis problems, as sample sizes were not large enough to test potential treatment differences with adequate statistical power ($X^2=3.84$, power = 0.31). Sample sizes of over 80 birds per treatment would have been necessary to detect differences in brood survival based on resulting variances from this study. Fifteen day survival estimates were used for two reasons: (1) sample sizes were twice as large as those used in 30-day analyses; and, (2) previous studies have shown that most mortality occurs within the first two weeks post-hatch (Evans et al. 1952, Ball et al. 1975, Duncan 1986, Rotella and Ratti 1992a, Grand and Flint 1996, Korschgen et al. 1996).

The question of whether predator management can increase brood survival was not answered definitively by this study. Both brood and duckling survival rates over the 30 day period were consistently higher on experimental sites than control sites. While brood and duckling survival may not be affected by predator reduction, they are still important factors in estimating production. Overall production per successful nest reinforces this fact, as twice as many fledged ducklings per nest were produced on experimental sites. Shovelers appear to have high brood survival without management, therefore species with traditionally lower brood survival such as Mallard or Northern
Pintail may be affected to a greater degree by predator reduction. Brood survival on predator removal areas with a lower abundance of quality breeding and brood rearing habitat may be increased, and this is another area which could benefit from further research.

Further research is also needed on causes of duckling mortality. Predation is only one of several sources of potential brood and duckling mortality. Radio marking ducklings would be a way to obtain this information. Larger sample sizes on each site would be beneficial, as they would increase statistical power of comparisons.

The objective of this study was to determine the effects of predator reduction on brood survival of Northern Shoveler broods. Although the results were not conclusive, valuable information was gained concerning basic survival rates. Shovelers have high brood survival regardless of predator management, and this is an important consideration when examining the long-term increase in Shoveler populations.
EFFECTS OF PREDATOR REDUCTION ON OVERLAND MOVEMENTS BY NORTHERN SHOVELER BROODS

Brood habitats in the prairie pothole region must provide food, water, and escape cover for the adult female and her growing ducklings (Sedinger 1992). Females readily move broods overland (Baker 1983, Duncan 1983, Smith and Flake 1985, Mauser et al. 1994b), presumably to get to wetlands with preferred cover and food (McKnight and Low 1969, Patterson 1976, Afton and Paulus 1992). Movements begin within a few hours after hatch, and it is evident that females do not always choose to lead their broods to wetlands closest to the nest site (Libby 1972, Joyner 1977, Eriksson 1978, Talent et al. 1983, Cowardin et al. 1985, Rotella and Ratti 1992b). Movements between wetlands often involve several kilometers of travel (Evans and Black 1956, Gates 1962, Duncan 1987), and these movements expose ducklings to several potential sources of mortality, including predation, exhaustion, and disorientation (Dzubin and Gollop 1972, Ball et al. 1975, Rotella and Ratti 1992a).

With current emphasis on increasing recruitment to waterfowl populations through improving nest success, effects of management practices on brood ecology are being overlooked. Management techniques such as planting dense nesting cover (Kadlec and Smith 1992), fencing nesting areas (Sargeant et al. 1974, Lokemoen et al. 1982, Greenwood et al. 1990), and creation of islands in large lakes (Browne et al. 1983, Wilms and Crawford 1989, Kadlec and Smith 1992) attempt to increase recruitment by concentrating nesting ducks in areas where nest success is elevated. These efforts, however, may induce extensive brood movements due to greater distances between nest sites and wetlands and because of the need for spacing between broods (Makepeace and Patterson 1980, Afton 1983, Paulus 1984). An alternative to these approaches is to reduce predator populations over large, contiguous blocks of upland habitat. Although much is known about the effects of predator reduction on nest success (Duebbert and Kantrud 1974, Doty and Rondeau 1988, Sargeant et al. 1995, Garrettson et al. 1996), no studies have examined its effects on brood movements.

The objective of this study was to examine the effects of predator removal on movement patterns of broods. Predator reduction allowed me to test alternative hypotheses about causes of brood movements. The disturbance hypothesis suggests that overland movements from nest site to wetland or wetland to wetland are a response to disturbance by potential nest predators, such as Red Fox (Vulpes vulpes), Striped Skunk (Mephitis mephitis), Raccoon (Procyon lotor), or Mink (Mustela vision). The latter two species seem most likely because they tend to forage in wetland margins where broods also forage. The disturbance hypothesis predicts that frequency and distance of brood movements would be reduced if predators were scarce.
An alternative is the risk hypothesis, which suggests brood females can assess predator abundance and thereby gauge the potential risks of overland movement. This hypothesis predicts more frequent and longer movements when the risks of encountering a mammalian predator on an overland movement are reduced. A second alternative is the food limitation hypothesis, which suggests that aquatic invertebrate abundance in wetlands is the primary determinant of tenure on a wetland and that predator abundance has little short-term influence on brood movements. I tested these hypotheses by examining the number of movements and distances moved by Northern Shoveler broods.

**METHODS**

Nest Searching, Trapping, and Marking

Nest searching was performed by dragging a 67 m long, 1 cm diameter chain between two tractors or all-terrain vehicles (Klett et al. 1986). Searching was conducted between 0700 and 1400 CST to maximize the probability of locating nests and minimize the amount of nest abandonment (Gloutney et al. 1993). Northern Shoveler nests were determined by visually identifying the female upon flushing or by egg and feather characteristics in the nest. Incubation stage of eggs was determined using a field candler (Weller 1956), and nests were rechecked at least once before trapping to monitor nest survival. Nest checks were performed by one person to reduce the likelihood of nest abandonment (Livezey 1980).

Females were trapped late in incubation (16-24 days) based upon the 23 to 25 day incubation period (Bellrose 1980). Trapping occurred between May 28, 1995 and July 25, 1995. Initial trapping attempts were made using a long-handled dip net. If this was unsuccessful, an automatic nest trap was employed (Weller 1957).
abandonment and stress on the females, trapping was not performed on days of inclement weather. Captured females were radio-marked with 8g anchor transmitters, nasal markers (Lokemoen and Sharp 1985), and U.S. Fish and Wildlife Service leg bands.

Radio Tracking and Brood Observation

Radio tracking was done using truck-mounted four-element yagi antennas and hand-held three-element yagi antennas. When tracking occurred, the individual was located specifically to the site, section, quarter section, and pond. This was accomplished by obtaining an estimated location using truck-mounted antennas and then walking in on the signal using hand-held units and aerial photographs to determine exact locations. Females with their broods were tracked over a 30 day period post-hatch. Tracking ended after: (1) completion of the 30 day period; (2) transmitter loss or failure; (3) predation of the marked female; or (4) total brood loss.

Each female was located at least once every three days, and a count of ducklings was attempted at least once per seven days. Brood counts were made whenever ducklings and marked females could be observed using binoculars or a spotting scope. If a female and brood were utilizing a particularly densely vegetated wetland, I would enter the wetland and attempt to flush the hen and ducklings into open water. If no ducklings were seen, but the female performed distraction displays, I assumed that at least one duckling was still alive and present. Total brood loss was assumed if no ducklings were seen after two observations and the female did not attempt to distract the observer or the female was associating with a group of birds.
Statistical Analyses

Analyses were separated into two sections. Comparisons were made between experimental and control sites. Data from all experimental sites were pooled as were all control site data due to small sample sizes on several of the sites. T-tests were used to contrast control and experimental sites in number of movements per week, average distance per secondary movement of successful broods, nest site to closest and to initial wetland, and number of movements per 30 days, and the number of ponds available to broods.

In the absence of treatment effect, I pooled data to describe brood movements. Distances from nest site to closest wetland were tested against nest site to first wetland with a t-test. T-tests were also used to compare differences in frequency and distances of movements between two time periods: hatch to 15 days and 16 to 30 days. Number of movements and cumulative distances moved were examined with a Pearson correlation to test whether broods that made more movements also traveled greater distances.

RESULTS

Movement data were collected from 28 broods on experimental sites and 21 broods on control sites. Broods on experimental sites moved 17-1645 m from the nest to the first wetland used, made 1-6 secondary moves between wetlands, and traveled 18-2032 m during inter-wetland moves. Broods on control sites moved 6-2610 m from nest to first wetland, made 1-5 secondary moves between wetlands, and traveled 9-2352 m during inter-wetland moves.
Nests on control sites were located an average of 34 m from the closest wetland margin, while nests on experimental site nests were located 47 m from wetlands on average (t=-1.00, P=0.33). Females with their broods traveled an average of 678 m to reach their initial brood pond on control sites and 431 m on experimental sites (t=1.39, P=0.17).

Successful broods on experimental sites made an average of 3.1 inter-wetland moves over the 30 day monitoring period, which did not differ significantly from the 2.2 moves on control sites. (Table 5). Average distance traveled between wetlands was significantly different for experimental and control sites (t=1.96, P=0.05) (Table 5). Cumulative distances moved by successful broods did not differ between treatment groups over either the 15 day (t=0.87, P=0.39) or 30 day (t= -0.43, P=0.67) periods. Average pond densities available to broods on experimental and control sites (180 vs. 173) were similar (t=0.39, P=0.70).

Data from both experimental and control sites were pooled to examine overall differences between nest site selection and initial movements, and secondary movements in relation to proximity of non-utilized wetlands. The overall average distance from nest site to closest wetland was 40 m. This differed greatly from the initial movement average of 536 m (t=-5.32, P=0.0001). Only 9 of 47 broods moved initially to the wetland closest to the nest.

Overall movement patterns of Northern Shoveler broods did not change over the course of the 30 day period (Table 6). Broods made an average of 2.0 secondary movements during the first two weeks post hatch compared to 1.5 during the second two weeks of life. Cumulative distances moved over these periods were not statistically
Table 5: Summary statistics of nest site and movement patterns of Northern Shoveler broods in relation to predator reduction.

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Experimental</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance from Nest to Closest Wetland</td>
<td>34.0</td>
<td>47.0</td>
<td>0.33</td>
</tr>
<tr>
<td>Distance of Initial Movement</td>
<td>678.0</td>
<td>431.0</td>
<td>0.17</td>
</tr>
<tr>
<td>Available Wetlands per Brood</td>
<td>173.0</td>
<td>180.0</td>
<td>0.70</td>
</tr>
<tr>
<td>Average Secondary Movement Distance(^a)</td>
<td>697.0</td>
<td>468.0</td>
<td>0.05(^b)</td>
</tr>
<tr>
<td>Total Movements per 30 Days</td>
<td>2.2</td>
<td>3.1</td>
<td>0.09</td>
</tr>
</tbody>
</table>

\(^a\)All distances in meters
\(^b\)Critical value = 0.05
Table 6: Effect of brood age on frequency and distance of overland movements

<table>
<thead>
<tr>
<th></th>
<th>Hatch to 15 Days</th>
<th>16 to 30 Days</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency$^a$</td>
<td>2.0</td>
<td>1.48</td>
<td>0.13</td>
</tr>
<tr>
<td>Distance (m)</td>
<td>1174.2</td>
<td>890.8</td>
<td>0.35</td>
</tr>
</tbody>
</table>

$^a$Movements per brood
different (Table 6). The frequency of movements followed a normal distribution (Figure 1), and movement distance strongly correlated with distance traveled to reach wetlands ($R^2 = 0.47$, $P=0.04$) (Figure 2). Movement distance from first to a secondary wetland averaged seven times greater than the distance to the two ponds closest to where the brood had been located. This average secondary distance (579 m) was significantly different ($t=6.88$, $P=0.001$) than the average distance to the two closest wetlands (80 m).

**DISCUSSION**

Predator reduction can increase nest success (Garrettson et al. 1996) and may elevate brood survival, but it does not appear to affect brood movements. Broods on both control and experimental sites had similar frequency of movements and movement distances between initial wetlands and nest sites. Only total distance of secondary movements differed between treatments.

Results appeared to best fit the disturbance hypothesis. Lowered predator populations could lower brood disturbance, which would lead to broods in experimental sites moving less frequently between wetlands and making shorter cumulative movements. Although they moved with similar frequency to control site broods, broods on experimental sites moved significantly shorter distances during wetland to wetland movements than control broods, but the main prediction about reduced movement frequency was not upheld. The risk hypothesis, where females and broods would move more frequently and greater distances between wetlands on experimental sites due to reduced risk of detection by a mammalian predator, was not impacted.

Lack of differences in frequency and cumulative distance of movements would lend support to the food limitation hypothesis. Experimental site broods moved more
Figure 1: Overall frequency of Northern Shoveler brood movement over 30 day period.
Figure 2: Number of movements and cumulative distances moved for all successful Northern Shoveler broods.
than control site broods, but the difference was non-significant. The increased movement distances of control broods may be related to wetland selection rather than a result of predator reduction. Without wetland classifications and knowledge of wetland preferences, however, it was not possible to test this hypothesis.

Prairie nesting ducks will lead their broods long distances to suitable brood rearing areas (Talent et al. 1983, Cowardin et al. 1985, Rotella and Ratti 1992b). Long brood movements are also common for Northern Shovelers. Numbers of movements initiated by successful broods were positively correlated to cumulative distance moved. High abundance and close proximity of nearby wetlands may increase frequency of movement and decrease distance of overland movements (Keith 1961); yet density of wetlands did not appear to impact movement distance in this study. Although corresponding wetland classifications were unavailable, distances moved by Shoveler broods to initial wetlands and subsequently between wetlands suggested that active habitat selection was taking place. Only 19% of all broods went initially to the wetland closest to the nest site, and less than 25% of secondary movements were made to wetlands other than the two that were closest to the wetland that had been used.

Broods of several species of prairie nesting ducks tend to select seasonal and semi-permanent wetlands (Talent et al. 1983, Mulhern et al. 1985, Duncan 1987, Rotella and Ratti 1992b) due to high abundance of aquatic invertebrates (Afton and Paulus 1992). My observations suggest that Northern Shoveler broods prefer seasonal wetlands with much emergent vegetation. Poston (1969), however, suggested that Shoveler broods use permanent wetlands with an abundance of open water due to their feeding specialization of straining plankton. Within the first two weeks of life, which are the
most important in terms of duckling survival, Northern Shoveler ducklings probably have not developed the bill specializations for plankton straining and likely forage for aquatic invertebrates similar to ducklings of other prairie nesting species.

During incubation recesses, Shoveler females may be assessing nearby wetlands for potential brood rearing habitat and will subsequently lead their broods to high quality ponds instead of closer wetlands (Afton 1983, Haland 1983, Gauthier 1987). There was no relationship between Northern Shoveler brood and duckling survival and overland movement (See Chapter 1). This concurs with several previous brood ecology studies (Evans et al. 1952, Talent et al. 1983, Duncan 1987, but see Rotella and Ratti 1992b). Total brood loss was greatest during the first two weeks post-hatch (Duncan 1986, Rotella and Ratti 1992a, Grand and Flint 1996, Korschgen et al. 1996), yet broods that fledged at least one duckling did not have significantly different movement patterns than those with total brood mortality.

This study provided information about brood movements previously undocumented in Northern Shovelers. The distance and number of movements by Shoveler broods are similar to other prairie nesting species such as Mallard (Rotella and Ratti 1992b), Northern Pintail (Duncan 1987), and Canvasback (Korschgen 1996). Studies of prairie breeding ducks have documented brood use of up to 10 different wetlands and movements of up to nine km (Dzubin and Gollop 1972, Talent et al. 1983, Duncan 1983, Smith and Flake 1985, Austin and Serie 1991, Rotella and Ratti 1992b).

**CONCLUSION**

Predator management has little impact on movement ecology of Northern Shoveler broods. Nest site selection, initial movement distances, and frequency and
cumulative distances over 30 days did not differ significantly between the two treatments. Cumulative travel distances between wetlands was the only factor that differed significantly between control and experimental sites, and it was not likely a result of predator reduction.

Shoveler broods tend to have similar movement frequency and distance patterns as other prairie nesting ducks. However, one factor that is apparently unique to Shovelers is the lack of change in frequency of movements over time. Mallards (Talent et al. 1983, Rotella and Ratti 1992b) and Northern Pintail (Duncan 1987) have a decreased frequency of movement as broods mature. Shovelers exhibit no difference in either movement frequency or distance over the first 30 days after hatch.

Brood movement patterns of prairie ducks can be influenced by several factors including proximity of the nest site to water, wetland density and type, surrounding upland habitats, and predator abundance (Duncan 1987, Afton and Paulus 1992, Sedinger 1992). Understanding aspects of basic brood ecology such as movement patterns and habitat usage are important when planning management strategies, yet techniques aimed at increasing recruitment to waterfowl populations often overlook effects on brood ecology (Pietz and Krapu 1994, Trottier et al. 1994).

The main objective of this study was to determine whether predator reduction affects survival and movements of Northern Shoveler broods. Several aspects of Shoveler brood ecology remain unknown, and further research into these areas is needed. Estimates of habitat usage would be beneficial, as it appears Shovelers are not permanent wetland specialists as has been suggested (Poston 1969). Analysis of duckling food habits would also lead to better understanding of Shoveler brood ecology.
POOR RETENTION RATES OF 8g ANCHOR TRANSMITTERS BY NORTHERN SHOVELERS

The ability to dependably relocate breeding females makes radio telemetry a valuable tool for studies of waterfowl ecology. Unfortunately, several problems persist regarding use of radio telemetry, including: 1) effects on survival and behavior of marked birds; 2) inadequate radio retention time for some packages; and 3) poor signal range of small transmitters. Traditional backpack harness packages (Dwyer 1972) have good retention time and the elevated external antenna maximizes signal range, but this design negatively affects behavior and reproductive output of captive and free-ranging ducks (Houston and Greenwood 1993, Pietz et al. 1993, Rotella et al. 1993). Abdominally implanted transmitters are a useful alternative (Olsen et al. 1992), especially in diving ducks, which will not tolerate backpacks. However, signal strength is compromised, and the surgical process requires expensive materials and increased handling time (Korschgen et al. 1984).

Transmitters attached with sutures and glue (Wheeler 1991) have negligible behavioral effects on marked individuals and better signal strength than implants, but retention time is inadequate for many types of studies, including those assessing reproductive success or brood survival (Houston and Greenwood 1993, Rotella et al. 1993). Mauser and Jarvis (1991) designed a transmitter for use on ducklings that supplemented the suture and glue attachment with an anchor that was inserted subcutaneously for added retention. Pietz et al. (1995) tested an enlarged (4g) and modified anchor radio package on breeding adult mallards (Anas platyrhynchos) and gadwalls (A. strepera) and found better retention rates than glue and suture mounts, with
no detectable effect on behavior of marked individuals. In this paper, I report on retention rates of an 8g anchor radio package that was used on breeding adult northern shovelers (*Anas clypeata*) in a study examining the effects of predator reduction on brood survival.

**METHODS**

Study Area, Nest Location, and Trapping

Nests were located using chain drags (Klett et al. 1986) on eight study areas located in the prairie pothole habitat of North-Central North Dakota. Forty-two northern shoveler females were trapped late in incubation (18-23 days) at the nest using either a long-handled dip net or a walk-in trap (Weller 1957). Anchor transmitters, nasal markers (Lokemoen and Sharp 1985), and U.S. Fish and Wildlife Service leg bands were used to mark each individual female. To decrease abandonment associated with capture and handling, methoxyflourane was used to anesthetize birds just before they were released on their nest (Rotella and Ratti 1990). Each brood female was tracked every three to five days over a 30 day interval to assess brood survival. Animal care guidelines were strictly followed (American Ornithologists' Union 1988).

Transmitter Design and Attachment

Design and attachment methods were modifications of existing procedures. Anchor transmitters were designed for 45 d of battery life, had a line of sight range of 2.5 km using four-element yagi antennas, and did not have mortality switches. The transmitter was circular with a 23 mm diameter, flat base and 12 mm height. The stainless-steel anchor extended 11 mm from the anterior base, and the posterior antenna
extended 23.5 cm at a 45 degree angle from the base. The complete package weighed approximately 8 g, which was <0.5% of the average adult female body mass of northern shovelers (Bellrose 1980).

The trimmed attachment area was swabbed with Glutacide (a sterilant) and injected with a local anesthetic, Lidocane without epinephrine, before the sutures were threaded through the skin. Surgical instruments were also sterilized using Glutacide. Cyanoacrylate glue was used to secure suture knots and was placed between the skin and the underside of the transmitter to aid in retention. See Pietz et al. (1995) for a more complete description of the attachment process.

Statistical Analyses

Daily transmitter retention and female survival rates were calculated using the Mayfield (1961, 1975) method as described in Pietz et al. (1995). Interval retention and survival rates were calculated over the period for hatch to 30-d post hatch. This was the period used to estimate brood survival to fledging. Confidence intervals (95%) for survival and retention rates were calculated using methods described in Johnson (1979).

RESULTS AND DISCUSSION

Of 42 radio transmitters attached, 20 were shed before the 30-day interval had expired. Daily transmitter retention rate for Northern Shoveler females was 0.9803, (95% CI = 0.9716, 0.9890) (Johnson 1979), extrapolating to a 30d retention rate of 0.55 (Mayfield 1961, 1975). Daily survival rates for radio marked northern shoveler individuals were 0.9971 (95% CI = 0.9937, 1.0), which expands to a 0.92 probability of survival over the 30 day interval.
I discounted predation as the major cause of radio loss for three reasons. First, 5 nasal marked females with broods were observed after their transmitters had been recovered. Second, 18 of 20 transmitters were relocated in wetlands at depths ranging up to 1.5 meters, only 6 of 20 transmitters had tissue attached, and none of the transmitters recovered had tooth marks. Finally, there was a relative absence of mink (*Mustela vision*), on the study areas, as they comprised less than 1% of the total take by trappers on the experimental areas.

Modifications of transmitter size and attachment methods are believe to have resulted in poor radio retention. Skin thickness, transmitter size and shape, and use of cyanoacrylate glue may have combined to compromise retention rate. Transmitters used in this study were approximately twice as large in both width and height as those used by Pietz et al. (1995). Enlarged radios may have induced behavior such as pulling on the transmitter and elevated the risk of transmitter loss due to contact with foreign material. Transmitter bases were flat, leading to increased movement due to a poor fit around the backbone. Heavier transmitters may have stressed the anchor incision and sutures and delayed healing of skin or made it more susceptible to tearing. All of these factors would allow the anchor to work its way out from under the skin with less resistance.

Northern shoveler females probably have thinner skin than larger species such as mallard or gadwall. Needle contact with muscle tissue, caused by threading sutures under larger radios, led to subcutaneous bleeding. This may have led to a greater risk of bacterial infection, though birds tend to be less susceptible to sepsis than mammals.
(Cooper and Eley 1979). Thin skin may also allow for sutures to move out of tissue faster through normal growth and be more susceptible to tearing from transmitter movement.

Cyanoacrylate glue, which has been used to attach transmitters in several studies (Martin and Bider 1978, Perry and Carpenter 1981, Wheeler 1991) may have been an even more significant factor affecting transmitter loss. Cyanoacrylate glue apparently causes some types of suture material to become brittle as well as making the contacted skin rigid. By applying glue to the knots and under the transmitter (where it also may have contacted sutures), I potentially increased the likelihood of suture breakage. It is not clear whether rigidity of glued skin hastens skin or transmitter loss. The combined effects of glue on sutures and the factors already described above may best explain the transmitter loss experienced in this study.

CONCLUSION

This study was not designed to evaluate transmitter retention rates, so comparisons with other studies concerning effects of radio transmitters on nesting waterfowl are not possible. Use of 8g anchor transmitters on northern shoveler females attending broods resulted in inadequate retention rates for a 30 day study. What appeared to be minor modifications in transmitter design and attachment had serious consequences on radio retention rates. Smaller anchor transmitters, such as those employed by Pietz et al. (1995), and the avoidance of cyanoacrylate glue would likely yield better retention rates on birds smaller than mallards. Small alterations of published
methodology may have significant impacts on the efficiency of radio mounts. Prior to making such alterations, discussion with other researchers who have experience with similar methods may yield vital, unpublished practical information.
SUMMARY

Predator reduction did not appear to affect survival of Northern Shoveler broods. Brood and duckling survival, and production per successful nest were higher on experimental areas, but differences were not statistically significant. No correlation was found between length of movement distance and overall brood survival. Northern Shoveler brood and duckling survival rates are higher than published accounts of other species, but mortality patterns are similar to other species of prairie nesting ducks. Most mortality occurred within the first two weeks after hatch, and brood mortality constituted the majority of duckling mortality.

Overland movements of Northern Shoveler broods were not influenced by predator reduction. Broods on experimental and control sites showed similar frequencies and cumulative distances of movements over the 30 day tracking period. Nest site selection and distances traveled to initial wetlands were also equivalent. There was no difference in densities of wetlands available to broods between treatments. Pooled results found that Shovelers exhibit habitat selectivity, as they do not always travel to the closest available wetlands. Although average frequency and distance of movements was comparable to other prairie nesting species, Shovelers showed no change in frequency or distance over the 30 day period.

Radio telemetry was the primary technique used to monitor survival and movements of Northern Shoveler broods. Retention rates of 8g anchor transmitters were not adequate to assess 30 day survival with required statistical power. Modified attachment techniques, specifically use of cyanoacrylate glue and increased transmitter size and weight, resulted in compromised retention rates.
LITERATURE CITED


VITA

John M. Zimmer was born on October 5, 1971 in Quincy, Massachusetts. John grew up in the town of Scituate, Massachusetts, along with his brother and two sisters. By the age of six, he had fallen in love with the sport of ice hockey, which continues to this day. During his youth, when not on the ice or the baseball diamond, John’s appreciation for the outdoors was fostered through hunting and fishing trips with his father and brother.

John graduated from Boston College High School in Dorchester, Massachusetts, in May of 1989, and entered the University of New Hampshire that fall to pursue a bachelor of science degree in wildlife management. Although it took him four and a half years and a change of major or two, he graduated from the University of New Hampshire cum laude in 1993. It was while at the University of New Hampshire that John was bitten by a radioactive duck. Foregoing a promising career as a masked crime fighter, John instead focused his newly found powers on the field of waterfowl management. He lists among his life’s highlights as marrying his high school sweetheart and being able to skate in Boston Garden.

John aspired to continue his education, and, in March of 1994, he got his chance. After a summer working as a Webster Fellow at the Delta Waterfowl and Wetlands Research Station, John entered the School of Forestry, Wildlife, and Fisheries at Louisiana State University in August of 1994 where he is currently fighting for the rights of underprivileged species of waterfowl known as sea ducks while also being a candidate for the degree of Master of Science in Wildlife which will be awarded in August of 1996.
Candidate: John M. Zimmer

Major Field: Wildlife

Title of Thesis: Effects of Predator Reduction on the Survival and Movements of Northern Shoveler Broods

Approved:

[Signatures]

Major Professor and Chairman
Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination:

May 17, 1996