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Evaluation of the Delta Waterfowl Foundation's Adopt-A-Pothole Project

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EVALUATION OF THE DELTA WATERFOWL FOUNDATION'S ADOPT-A-POTHOLE PROJECT

by

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ABSTRACT

Evaluation of the Delta Waterfowl Foundation's

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by

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Utah State University, 1996

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The establishment of dense nesting cover (DNC) for breeding waterfowl is a common management practice on large blocks of former agricultural land. The Delta Waterfowl Foundation's Adopt-A-Pothole (AAP) program establishes DNC adjacent to small wetland complexes to increase waterfowl use and productivity. I evaluated waterfowl use and nesting success on AAP lease sites in southwestern Manitoba in 1993-94 and compared the relative amount and success of overwater and upland nesting by mallards using these sites.

Diving duck breeding pair densities were higher on treatment sites in both 1993 and 1994 ($\underline{P}$ = 0.02 and 0.02, respectively). Dabbling duck breeding pair densities did not differ between sites. Upland nesting success did not differ between control and treatment sites in 1993 ($\underline{P}$ = 0.16) and was higher on control sites in 1994 ($\underline{P}$ = 0.02). Overwater nesting success did not differ between treatment and control sites in 1993 or 1994 (P = 0.66 and 0.08, respectively). Brood use was difficult to quantify because of high water levels in both years.

Overwater nests comprised 31% (n = 58) of the total mallard (*Anas platyrhynchos*) nests found in 1993-94. Mallard overwater and upland nest success was not different (P = 0.39). Mallards nested in shallower water than ruddy ducks (*Oxyura jamaicensis*), canvasback (*Aythya valisineria*), and redhead (*A. americana*) ($P < 0.0005$). Mallards nested closer to shore than redheads (P = 0.02). Ruddy duck and canvasback daily survival rates were highest, followed by redhead and mallard (P = 0.06 to 0.18). Overwater nests located in < 30 cm of water were predated more often than expected ($P < 0.0025$).

Deeper water may provide greater security from predators for overwater nesting ducks than shallower water. The importance of overwater nesting by mallards probably varies regionally and annually. Wetlands, primarily seasonal and semi-permanent, appear to provide attractive mallard nesting habitat. The establishment of DNC adjacent to small wetland complexes located in agriculturally dominated landscapes may provide relatively secure and attractive waterfowl nesting habitat. However, other factors, including the presence and abundance of potential nest predators, may influence the effectiveness of this practice.

(86 pages)

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CHAPTER I

INTRODUCTION

Waterfowl recruitment rates are influenced by the size of the breeding population, hen success, nesting success, and brood survival (Greenwood et al. 1987). Nest success may be the most critical component of waterfowl breeding with regard to fall flight size (Cowardin and Johnson 1979). Cowardin et al. (1985), using a simulated model of mallard (Anas platyrhynchos) recruitment, suggested a nest success rate of 15% is necessary for population maintenance. Numerous nesting studies have reported mallard nest success at or below maintenance levels in the prairie pothole region (PPR) of North America (Cowardin et al. 1985, Duebbert et al. 1986, Greenwood et al. 1987, Klett et al. 1988).

Human activities in the PPR have altered natural postglacial landscapes. Wetland drainage and intensive agricultural operations have created a landscape containing < 50% of the historic wetland base and greatly reduced upland habitats (Kiel et al. 1972, Sugden and Beyersbergen 1984). Wetlands critical to waterfowl breeding have been drained and converted to other uses. Most large blocks of prairie habitat have been converted to cropland (Canadian Wildlife Service and U. S. Fish and Wildlife Service 1986). Predator species abundance and distribution has changed since European settlement (Sargeant et al. 1993). Large native predators that fed upon ungulates were eliminated and replaced by smaller generalist predators that prey extensively on nesting birds and their eggs (Sargeant et al. 1993).

Higgins (1977) concluded that sustained waterfowl production on prairie potholes is dependent upon nesting success on untilled lands. The amount and quality of untilled habitat influence annual production for both upland and overwater nesting ducks (Hochbaum 1944, Bellrose 1976, Stoudt 1982). Although typical agricultural lands produce few ducks (Duebbert and Kantrud 1974, Higgins 1977), Boyd (1985) suggested the tilling of marginal agricultural lands presented a serious threat to nesting waterfowl.

Habitat degradation in the PPR, primarily the result of agricultural encroachment, may force ducks to nest in fewer and smaller habitat patches (Clark and Diamond 1993). Numerous authors have suggested smaller habitat patches lead to higher predation rates and subsequent population declines (Sargeant et al. 1984, Cowardin et al. 1985, Greenwood et al. 1987, Klett et al. 1988, Pasitschniak-Arts and Messier 1995). Agriculturally based habitat fragmentation reduces habitat amount and increases the amount of habitat edge (Laurance and Yensen 1991). Presumably, additional edges lead to increased numbers of generalist predators and increases predator foraging efficiency (Wilcove et al. 1986, Burkey 1993). Therefore, management on small blocks could negatively affect nesting ducks by attracting more hens and exposing them to greater predation risk. This "ecological trap" hypothesis has been thoroughly tested in forest ecosystems but rarely in grassland and prairie ecosystems (Johnson and Temple 1986, Burger et al. 1994, Pasitschniak-Arts and Messier 1995).

Historically, continental waterfowl numbers have fluctuated in response to changes in wetland quality and abundance (Canadian Wildlife Service and U. S. Fish and Wildlife Service 1986). These fluctuations have been attributed to drought, extensive habitat loss, and predation. Continued declines in waterfowl populations and habitat have generated significant interest in continental restoration efforts (Canadian Wildlife Service and U. S. Fish and Wildlife Service 1986).

In 1986, the United States, Canada, and Mexico signed the North American Waterfowl Management Plan (NAWMP), which committed these countries to the restoration of declining waterfowl populations through the protection of critical wetland habitats. Management for breeding ducks under the NAWMP has focused on strategies that reestablish large blocks (60 ha and larger) of prime waterfowl habitat. The establishment and maintenance of seeded dense nesting cover (DNC) on agricultural lands with good wetland complexes is a typical practice used on these large management units.

Additional NAWMP strategies include the purchase of land in fee title and the use of leases (easements) to secure wetlands and surrounding upland habitat. Wetland easements are an attractive wetland preservation alternative that provide short-term relief for farm debts (Higgins and Woodward 1986).

The Adopt-A-Pothole (AAP) Project developed by the Delta Waterfowl Foundation (DWF) is an example of a wetland easement approach that focuses on habitat blocks smaller than the traditional management units. This program attempts to enhance waterfowl production on at-risk wetlands. Risks to these wetlands may include drainage, tillage, burning, and/or sedimentation. The AAP program leases wetlands and small (1-20 ha) patches of upland habitat that surround them. Adjacent agricultural lands included in the lease are then seeded to DNC. AAP leases cover 5 years. The landowner agrees not to drain the wetland or till any of the upland or improved (seeded) land surrounding the wetland during the lease period. In return, the landowner receives annual rental payments from the DWF. At the end of the 5-year lease, the landowner may renew the contract or allow it to expire.

Although habitat management for nesting mallards usually focuses on the establishment and maintenance of dense upland vegetation, the frequency and success of overwater nesting mallards may significantly contribute to recruitment rates of local mallard populations. Sixty-six percent of mallard nests found in southcentral North Dakota were overwater (Krapu et al. 1979). Overwater nest success was 54% compared to 14% for upland nests. Arnold et al. (1993) reported mallard overwater nesting success was 4 times higher than upland nesting success in southwestern Manitoba. Gates (1965) reported an early season peak for mallards nesting in emergent vegetation in Wisconsin. Wingfield (1951) and Reeves (1954) reported high percentages of mallards nesting in emergent vegetation in Utah and southeastern Idaho, respectively.

Foraging predators, especially striped skunks (Mephitis mephitis) and red foxes (Vulpes vulpes), may encounter duck nests by chance. Physical barriers (e.g., dense vegetation, water, or nest dispersal) may reduce the chance of an encounter. Arnold et al. (1993) suggested higher survival rates for overwater nests may be a general phenomenon for waterfowl. Locating nests in deep water may help nesting females reduce risk from terrestrial predators. Red fox and striped skunk, the primary waterfowl nest predators in the PPR, avoid entering water to forage (Sargeant et al. 1993). Raccoon (Procyon lotor) and mink (Mustela vison), the predators most likely to encounter overwater nests, are relatively uncommon in the Canadian PPR (Sargeant et al. 1993).

I evaluated breeding waterfowl use and nest success on AAP leases to determine the merit of leasing small habitat patches for breeding waterfowl. I also quantified the relative importance of overwater nesting by mallards and specific overwater nest site habitat characteristics and their relationship to predation rates.

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CHAPTER II

EVALUATION OF THE DELTA WATERFOWL FOUNDATION'S ADOPT-A-POTHOLE PROGRAM

Abstract: The establishment of dense nesting cover (DNC) for breeding waterfowl is a common management practice on large blocks of former agricultural land. The Delta Waterfowl Foundation's Adopt-A-Pothole (AAP) program establishes DNC on small wetland blocks in an effort to increase waterfowl use and productivity on private land. I evaluated waterfowl use and success on AAP lease sites in southwestern Manitoba in 1993-94. Breeding pair counts, nesting success, and brood use were measured. Diving duck breeding pairs were higher on treatment sites in both 1993 and 1994 ($\underline{P} = 0.02$ and 0.02, respectively). Dabbling duck breeding pairs did not differ between sites. Upland nesting success did not differ between control and treatment sites in 1993 ($\underline{P} = 0.16$) and was higher on control sites in 1994 ($\underline{P} = 0.02$). Overwater nesting success did not differ between treatment and control sites in 1993 or 1994 ($\underline{P} = 0.66$ and 0.08, respectively). Brood use was difficult to quantify due to high water levels in both years. The establishment of DNC surrounding smaller wetland complexes appeals to breeding waterfowl and may provide relatively secure habitat in some years. Predation, the primary cause of nest loss on all sites, varied locally and annually. Local predator abundance and distribution may ultimately dictate the success of nesting waterfowl.

INTRODUCTION

Human disturbance (primarily agriculture) in the prairie pothole region (PPR) of the northcentral United States and Canada (Fig. 1) has altered natural postglacial landscapes. Wetland drainage and intensive agricultural operations have resulted in a landscape containing less than 50% of historic wetlands and greatly reduced upland habitats (Kiel et al. 1972, Sugden and Beyersbergen 1984). Predator species abundance and distribution have also been greatly altered since European settlement (Sargeant et al. 1993). The quality of remaining habitat for both overwater nesting ducks and upland nesting ducks plays a vital role in determining waterfowl production (Hochbaum 1944, Bellrose 1976, Stoudt 1982).

Continental waterfowl populations have historically fluctuated with changing wetland quality and abundance. Recent declines have been attributed to drought, extensive habitat loss, and predation. Decreasing populations and habitat have generated significant interest in prairie waterfowl and their habitat (Canadian Wildlife Service and U. S. Fish and Wildlife Service 1986). In response to these concerns, the United States, Canada, and Mexico signed the North American Waterfowl Management Plan (NAWMP) in 1986, which committed these countries to the restoration of declining waterfowl populations through the protection of critical wetland habitats.

A common management strategy employed to create habitat for breeding waterfowl is the purchase of large blocks (60 ha or larger) of agricultural land containing good wetland complexes. The establishment and maintenance of seeded dense nesting cover (DNC) is a typical practice on these large management units (Duebbert and Lokemoen 1976). In addition to purchasing land, NAWMP strategies include the use of long-term easements to preserve wetlands and surrounding upland habitat. Wetland easements

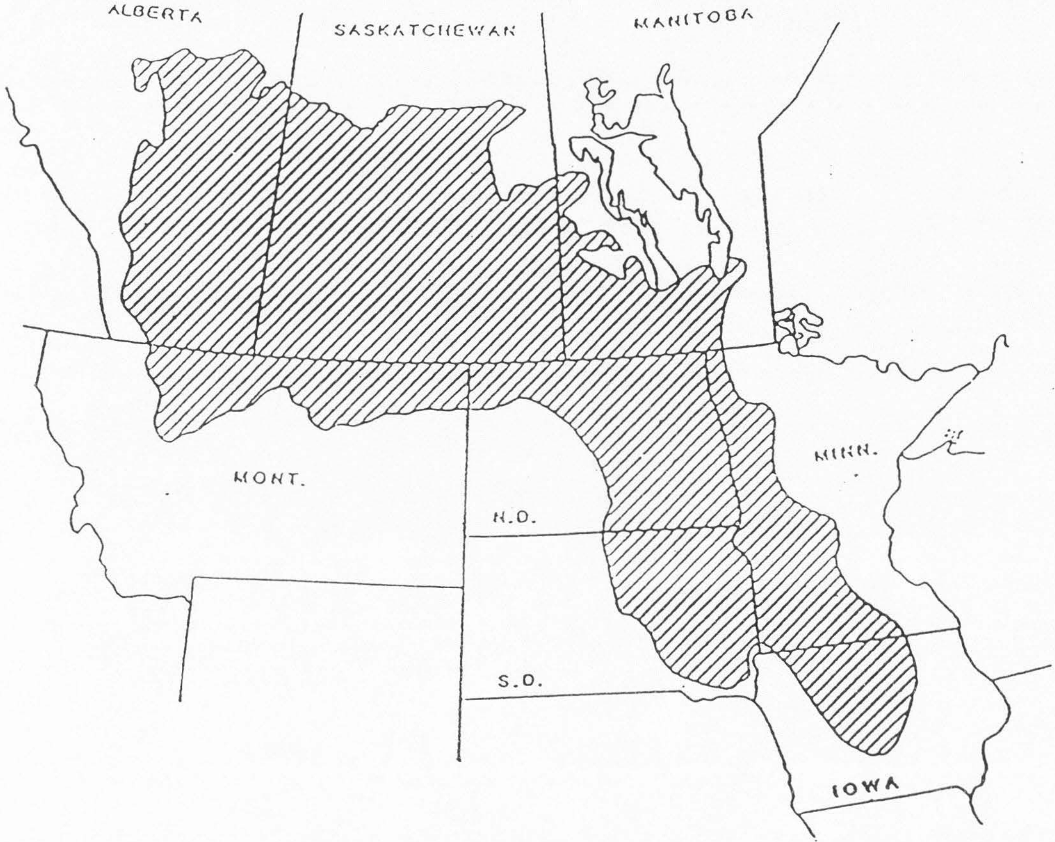

Figure 1. The prairie pothole region (PPR) of central North America. The PPR produces nearly 70% of North American ducks.

provide an attractive wetland preservation alternative while providing landowners with short-term relief for farm debts (Higgins and Woodward 1986).

The Adopt-A-Pothole (AAP) project, developed by the Delta Waterfowl Foundation (DWF), is an alternative wetland easement approach that leases habitat blocks smaller than traditional management units. This program attempts to enhance waterfowl production on privately owned wetlands at risk from agricultural drainage, tillage, burning, and/or sedimentation. The AAP program leases wetlands and small (1-20 ha) patches of upland habitat that surround them. Adjacent agricultural lands included in the lease are then seeded to DNC. AAP leases cover 5 years. During the lease period, the landowner agrees not to drain the wetland or till any of the upland or improved (seeded) land surrounding the wetland(s). In return, the landowner receives annual rental payments from DWF. At the end of the lease period, the landowner may renew the contract or allow it to expire.

I evaluated AAP leases for breeding waterfowl use and nest success to determine the merit of leasing small habitat patches for breeding waterfowl. The Delta Waterfowl Foundation and the Utah Agricultural Experiment Station provided the funding and support necessary to complete this research.

LITERATURE REVIEW

Cowardin and Johnson (1979) concluded that nest success is the most critical component of waterfowl breeding in determining fall flight size. Waterfowl recruitment rates are influenced by the size of the breeding population, hen success, nesting success, and brood survival. Cowardin et al. (1985), using a model to simulate mallard (Anas platyrhynchos) recruitment, suggested that a nest success rate of 15% is necessary for population maintenance. Later nesting ducks, such as blue-winged teal (A. discors) and gadwall (A. streptera) may require a success rate near 20% for population maintenance (Klett et al. 1988). Numerous nesting studies have reported mallard nest success below population maintenance levels in the PPR (Cowardin et al. 1985, Duebbert et al. 1986, Greenwood et al. 1987, Klett et al. 1988). Higgins (1977) concluded that sustained waterfowl production on prairie potholes is dependent upon water conditions and nesting success on untilled lands.

The number of breeding pairs in an area ultimately limits local waterfowl recruitment (Cowardin et al. 1985). Factors explaining why breeding waterfowl settle in a particular area may include the amount of surface water, amount and quality of nesting cover, available food resources, and philopatric behavior (Johnson and Grier 1988). The pond-pair regression model (Cowardin 1991) predicts the density of breeding duck pairs using a wetland basin based upon the amount of available surface water. The simulation model used by Cowardin et al. (1988) assumes the size of the breeding mallard population is a function of the amount of available wetland habitat.

Dense upland cover attracts the highest densities of upland nesting waterfowl (Duebbert and Kantrud 1974, Kirsch et al. 1978, Klett et al. 1988). The density of residual vegetation influences nest site selection for early nesting waterfowl (Leopold 1933, Martz 1967, Duebbert and Lokemoen 1976, Kirsch et al. 1978, Higgins and Barker 1982). It is not clear, however, if larger, denser patches of nesting cover or if smaller, isolated pockets of habitat are more productive for waterfowl (Clark and Nudds 1991, Clark and Diamond 1993).

Most large blocks of prairie grassland habitat have been converted to cropland. Wetlands critical to waterfowl breeding were drained and converted to other uses (Canadian Wildlife Service and U. S. Fish and Wildlife Service 1986). These new agricultural lands produce few ducks (Duebbert and Kantrud 1974). In addition, large native predators that fed upon ungulates were eliminated and replaced by smaller predators that prey extensively on nesting birds and their eggs (Sargeant et al. 1993). Mammalian predator communities in fragmented agricultural environments are often dominated by red fox (Vulpes vulpes) (Greenwood et al. 1995). Sargeant et al. (1984) estimated that red fox annually killed over 800,000 adult ducks, primarily female dabblers, in the PPR.

Boyd (1985) suggested the tilling of marginal agricultural lands presented a serious threat to nesting waterfowl. Intensive agriculture fragments waterfowl habitat, concentrating nesting ducks and reducing alternate prey abundance (Sargeant et al. 1993). Management on these smaller blocks of habitat may be counterproductive as predation rates may be high (Greenwood et al. 1995). Predation has been implicated as a primary factor limiting nest success or waterfowl production (Duebbert and Lokemoen 1980, Greenwood et al. 1987, Greenwood et al. 1995). Larger pastures with little human activity are more attractive to coyotes (Canis latrans), which may exclude or reduce red fox populations and subsequently reduce predation rates (Sargeant et al. 1993, Greenwood et al. 1995).

Numerous authors have reported positive correlations between cover density and nesting success (Duebbert and Kantrud 1974, Gjersing 1975, Duebbert and Lokemoen 1976, Mundinger 1976, Kirsch et al. 1978, Crabtree et al. 1989, Klett et al. 1988, Gregg et al. 1994). Several studies on artificial nests further support this correlation (Angelstam 1986, Mankin and Warner 1992, Pasitschniak-Arts and Messier 1995). Presumably, increasing the amount of available habitat decreases predation risks to nesting birds and subsequently increases nest success (Greenwood et al. 1987, Klett et al. 1988, Burger et al. 1994).

Gatti (1987) and Nour et al. (1993) suggested other factors may influence predation rates. The relationship between habitat patch size and nesting success may vary spatially and temporally, possibly due to local predator composition (Nour et al. 1993, Sargeant et al. 1993), availability of alternate prey (Crabtree and Wolfe 1988), weather (Hammond and Johnson 1984), and other factors (Clark et al. 1991).

Two studies have found a positive correlation between increased nesting cover density and higher predation rates (Milonski 1958, Keith 1961). Milonski (1958), Keith (1961), and Crabtree and Wolfe (1988) found that striped skunks (Mephitis mephitis) prefer to forage in dense cover. Martz (1967) and Clark et al. (1991) reported low nest success (due to predation) in DNC parcels. Clark and Nudds (1991) suggest heavy cover is necessary for successful nesting only in areas with potentially high avian predation rates.

STUDY AREA

Research was conducted from mid-April through early August, 1993-94, on a 690-

km^2 study area surrounding Minnedosa, Manitoba, Canada (50°06'N; 99°50'W) (Fig. 2). Minnedosa lies within the aspen (Populus spp.) parklands of the PPR. The Minnedosa region is characterized by heavily cultivated uplands and numerous wetland basins (up to $50/km^2$), which vary in size, permanence, depth, vegetation, and surrounding land use. This wetland density and diversity attracts large numbers of breeding ducks (Kiel et al. 1972, Stoudt 1982). Small grains (wheat, barley, and rye) and canola are the predominant crops grown. Most farms consist of 130-780 ha of land. The combination of intensive agriculture, numerous smaller farming operations, and large numbers of wetland complexes provided an opportunity for the DWF to initiate a number of AAP leases around Minnedosa.

The DNC mixture used on AAP leases included tall wheatgrass (Agropyron elongatum), slender wheatgrass (A. trachycaulum), pubescent wheatgrass (A. trichophorum), and alfalfa (Medicago sativa). DNC stands were generally dominated by tall wheatgrass. Existing wild vegetation on lease sites consisted of predominantly introduced (Bromus spp.) and native (Agropyron spp., Poa spp., and Scholochloa festucacea) grassland habitat, intermixed with small areas of grass-shrub (Rosa spp. and Symphoricarpos spp.) habitat. Wooded areas (primarily Populus spp. and Salix spp.) constituted approximately 10% of the total lease area. Dominant wetland vegetation included sedges (Carex spp.), cattails (Typha spp.), bulrushes (Scirpus spp.), and rushes (Juncus spp.).

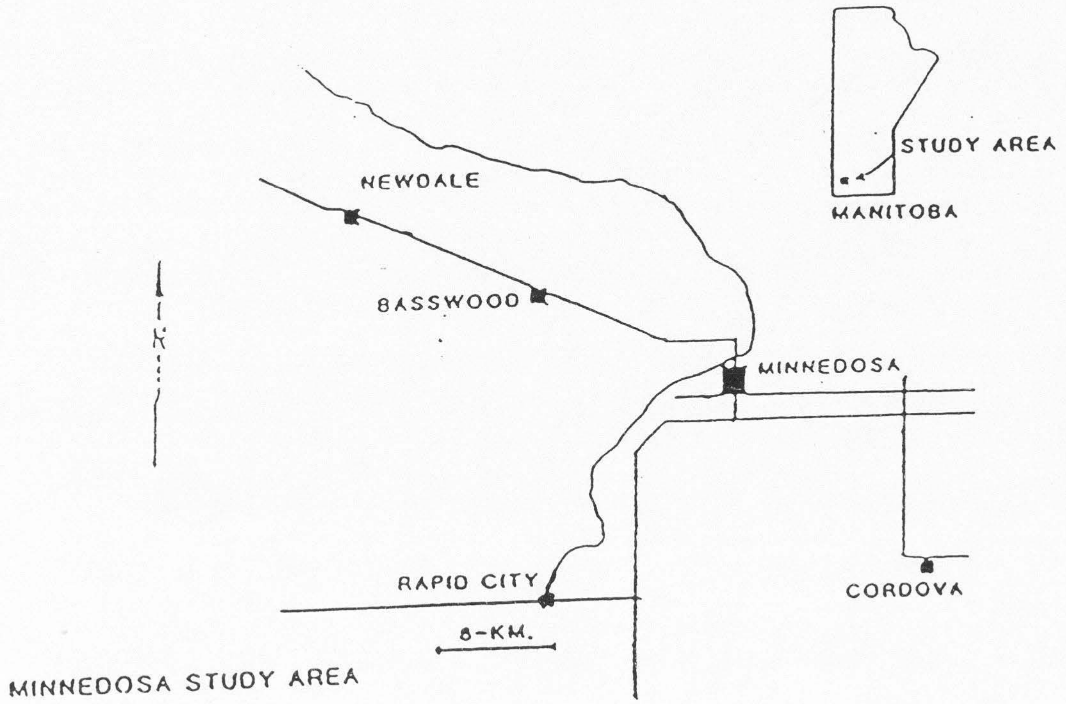

Figure 2. The Minnedosa study area (adapted from Stoudt 1982)

STUDY METHODS

Study Sites

A study site was defined as a wetland or wetland complex surrounded by agricultural land. Each study site contained ≥ 1 temporary, seasonal, semi-permanent, or permanent wetland (Stewart and Kantrud 1971). Treatment sites consisted of a leased wetland or wetland complex with contiguous inter-wetland upland cover and a portion of the surrounding agricultural land seeded to DNC. Contiguous cover did not include fence rows, field approaches, roadside ditches, or drainage ditches. Control sites consisted of a wetland or wetland complex (not necessarily contiguous) surrounded by cropland. Control sites had no DNC established on adjacent uplands. Each treatment site was paired with 2 control sites, based upon: (1) number, size, class, and type of wetlands; (2) amount and type of upland habitat; and (3) proximity to other study sites. If > 1 potential treatment site was contained within 1.6 km^2, 1 site was randomly selected. Spatial separation of study sites was maintained to avoid duplication in breeding pair counts.

Control sites were identified using a list of landowners who had either shown an interest in the AAP program or signed a lease but not yet seeded DNC. Sites that met study parameters were randomly paired with possible treatment sites. To increase statistical power, 2 control sites were selected for each treatment. If a wetland or wetland complex initially selected as a control site was within 1.6 km of a previously selected study site, it was eliminated from the sample universe.

Data Collection

<u>Breeding Pair Counts</u> .--Breeding pair counts (Dzubin 1969, Hammond 1969) were conducted between 0800 and 1200 hours and between 1400 and 2000 hours (local standard time) from the last week in April until the first week in May and again from the last week in May until the first week in June. Each site was surveyed twice. Time constraints necessitated evening counts. Because overcast, cold, and windy weather tends to affect waterfowl dispersion and visibility (Dzubin 1969), counts were not conducted under such conditions.

Pair count data were analyzed by individual species and grouped as dabbling ducks and diving ducks. Differences between species and groups were tested using a 1-tailed, 2-sample t-test. Unless otherwise noted, the acceptable level of statistical significance was $\alpha = 0.05$.

<u>Nesting Success Estimates</u> .--Nesting success was estimated for both over-water and upland nesting ducks. A nest was defined as a bowl or platform with $\geq$ 1 eggs in it (Klett et al. 1986). Upland nest searches were conducted 3 times annually during each field season. The first searches began in early May, the second in late May, and the third in mid-June. These dates accommodated both early and late nesting ducks (Dzubin 1969, Klett et al. 1986). Search order was determined randomly for the first series and completed in the same order for the next 2 searches.

Upland nests were located by dragging a 30-m chain between two all terrain vehicles (ATV) through upland habitat (Klett et al. 1986). If circumstances did not allow the use of ATV's (i.e., brush or pockets of habitat unreachable by ATV), searches were completed using a chain hand drag. Searches were completed before 1200 hours, local standard time, as laying hens are more likely to be off their nests after this time (Klett et al. 1986, Gloutney et al. 1993). Upland nests were marked with a thin green bamboo stake placed 5 paces away from the nest, toward a readily identifiable landmark. The location of each nest was plotted on an aerial photograph of the study site and the direction of the stake noted on a nest data card. At each upland nest site, a vegetation visual obstruction reading (VOR) was taken (Robel et al. 1970, Higgins and Barker 1982). A chi-square test of independence was used to evaluate the relationship between nest site VOR and nest success. Dominant plant species within 1 m^2 of each nest were recorded.

Overwater nests were visually located by wading through emergent vegetation. Each study site was searched twice annually for overwater nests. Locations of over-water nests were marked by placing a small piece of flagging tape 5 paces away from the nest on a stand of emergent vegetation. Nest locations and flagging tape directions were plotted on aerial photographs. If the hen was not present when a nest was discovered, species identification was made using eggs, breast feathers, and down as clues (Bellrose 1976, Klett et al. 1986).

At each overwater nest, a measurement of water depth and an estimate of distance to shore were made. Dominant vegetation around the nest and the primary material in nest platform was recorded. The number of parasitic eggs present, if any, were noted.

For both overwater and upland nests, incubation stage at the time of discovery was determined by field candling one or more eggs (Weller 1956). Assuming a hen lays 1 egg per day (Bellrose 1976), the initiation date and anticipated hatch date were calculated.

Nests were checked every 7-10 days and immediately after the estimated hatch date to determine fate. Nest data were recorded on a nest information card developed by Northern Prairie Science Center, Jamestown, ND.

A nest was considered successful if ≥ 1 egg hatched (Girard 1939). Nests that were not successful were classified as predated, abandoned, destroyed (other than predation), and searcher-influenced. Nests that were abandoned due to observer influence or destroyed by searching techniques were included in the total nests found but not used in nest success calculations.

Nesting success was estimated by species and nest location using the Mayfield method (Mayfield 1961, Mayfield 1975). Daily survival rates were compared using a 1-tailed, 2-sample $\underline{Z}$ statistic.

Brood Counts .--Brood counts were conducted in early morning and late evening, beginning in late June. Counts were conducted from a quiet observation point that afforded maximum visibility and minimal disruption (Evans and Black 1956, Keith 1961). Species, age, and number of young in the each brood observed were recorded. Observations were made for 30 min or longer at each site as hens may lead their young into emergent vegetation to avoid detection (Evans and Black 1956). In addition, incidental brood sightings made during other research activities were recorded. Systematic brood counts were conducted only in 1993.

Vegetation Transects .--One permanent, 25 station transect was set up on each treatment site to measure the vegetative density of the seeded cover. Measurements were taken using a modified Robel pole every meter along the transect to obtain an average

VOR value for the DNC stand. VOR values were recorded to the nearest 0.5 dm. Vegetation transects were conducted before green-up (early May) to measure residual vegetation and after complete green-up (mid-July) to measure new growth. Average VOR values for each stand were compared to average nest site VOR values of each dabbling duck species using a 2-sample $\underline{t}$-test.

RESULTS

Study Sites

In 1993, 18 treatment sites and 33 control sites were monitored (Table 1). In 1994, 19 treatment sites and 37 control sites were monitored. The upland habitat on 3 selected control sites was destroyed by fire in 1993. These sites were eliminated from the study. A suitable control site could not be identified from the control pool for 1 treatment site during the 1994 study season.

Breeding Pair Counts

Dabbling duck breeding pair densities on treatment plots averaged 0.35 pairs per wetland ha in 1993 and 0.41 pairs per wetland ha in 1994. Dabbling duck breeding pair densities on control sites averaged 0.42 pairs per wetland ha in 1993 and 0.33 pairs per wetland ha in 1994. Total dabbling duck breeding pair densities did not differ between treatment and control sites in either year (Table 2). Gadwall breeding pair densities were higher on control sites in 1993 ($\underline{t}$ = -1.78, $\underline{P}$ = 0.04). No differences in individual dabbling

Table 1. Area amounts (ha) by habitat types for treatment and control sites near Minnedosa, MB, 1993-94.

	Treatment		Control	
	1993	1994	1993	1994
Habitat Type	n = 18	n = 19	n = 33	n = 37
Native Upland	86.9	88.3	135.8	120.8
DNC	58.0	45.6	0.0	0.0
Wetland Area	34.8	34.8	47.1	57.4
Wetland Basins	65	65	93	116

duck species were recorded in 1994 (Table A.1 in appendix).

Diving duck breeding pair densities on treatment plots averaged 0.21 pairs per wetland ha in 1993 and 0.27 pairs per wetland ha in 1994 (Table 2). Diving duck breeding pair densities on control sites averaged 0.08 pairs per wetland ha in 1993 and 0.13 pairs per wetland ha in 1994. Total diving duck densities were significantly higher on treatment sites in both 1993 and 1994 (t = 2.26 and 2.08, P = 0.02 and 0.02, respectively). Ruddy duck (Oxyura jamaicensis) pair densities were higher on treatment sites in 1993 (t = 1.96, P = 0.03). Redhead (Aythya americana) pair densities were higher on treatment sites in 1994 (t = 1.81, P = 0.04) (Table A.2 in appendix).

Table 2. Mean breeding pair densities per wetland ha of dabbling and diving ducks on treatment and control sites near Minnedosa, MB, 1993-94.

Ducks	Year	Study Site	$\bar{X}$	SE	t	df	P
Dabbling	1993	Treatment	0.35	0.08	-0.58	44	0.68
		Control	0.42	0.09			
	1994	Treatment	0.41	0.08	0.69	48	0.24
		Control	0.33	0.08			
Diving	1993	Treatment	0.21	0.05	2.26	30	0.02
		Control	0.08	0.02			
	1994	Treatment	0.27	0.06	2.08	36	0.02
		Control	0.13	0.03			

Appendices A.1 and A.2 contain breeding pair densities by species

Power Analysis

Power for dabbling duck breeding pair analysis was 0.11 for both 1993 and 1994. Diving duck breeding pair density power was 0.30 and 0.22 for 1993 and 1994, respectively. Increasing the total number of treatment sites to 35 raised power for dabbling ducks densities by 0.02. Increasing the number of treatment and control sites to 50 each raised power to 0.14 (Number Cruncher Statistical System -- Power Analysis and Sample Size handbook 1990).

Nesting Success

Daily survival rates for upland nesting ducks on treatment and control sites did not differ in 1993 ($\underline{P} = 0.15$) (Table 3). Daily survival rates were higher on control sites in 1994 ($\underline{Z} = -2.12$, $\underline{P} = 0.02$). Gadwall daily survival rates were higher on control sites in

Table 3. Mayfield nest success estimates for upland and overwater nesting ducks on treatment and control sites near Minnedosa, MB, 1993-94.

Group	Year	Study Site	n	Days	Losses	DSR	SE	Mayfield
Upland	1993	Treatment	40	484.0	26	0.9463	0.0102	15.0
		Control	42	457.0	32	0.9300	0.0119	8.4
	1994	Treatment	30	294.5	24	0.9185 [a]	0.0159	5.3
		Control	35	449.0	19	0.9577 [a]	0.0095	23.0
	Pooled	Treatment	70	778.5	50	0.9358	0.0088	10.5
		Control	77	906.0	51	0.9437	0.0077	13.9
Overwater	1993	Treatment	33	351.0	20	0.9430	0.0124	13.0
		Control	30	360.5	18	0.9500	0.0115	16.5
	1994	Treatment	19	346.0	1	0.9971	0.0029	90.3
		Control	29	479.0	5	0.9896	0.0046	69.2
	Pooled	Treatment	52	697.0	21	0.9699	0.0065	34.3
		Control	59	839.5	23	0.9726	0.0056	37.8

[a] pair of values is significantly different ($\alpha = 0.05$)

Appendices A.3. and A.4. contain daily survival rates grouped by species

1994 ($\underline{Z}$ = -2.61, $\underline{P}$ = 0.005; Table A.3 in appendix). Upland nest success estimates for the 2 years combined did not differ.

Overwater nest success did not differ between treatment and control sites in 1993 or 1994 ($\underline{P}$ = 0.34 and 0.08, respectively). Overwater nest success by individual species did not differ (Table A.4 in appendix). Overwater nest success estimates for the 2 years combined did not differ. Predation accounted for 96% of upland nest losses ($\underline{n}$ = 101) and 64% of overwater nest losses ($\underline{n}$ = 44). Abandonment (due to unknown causes) accounted for the other 4% of upland losses and 16% of overwater losses. Flooding accounted for 20% of overwater nest losses.

Brood Surveys

Systematic brood surveys were conducted in 1993 only. Canvasback (Aythya valisireria) were the only consistently visible broods. High water that flooded emergent vegetation resulted in inconsistent and low counts in both years. Brood observations made while carrying out other field activities were recorded but not tested. Due to small sample sizes, no data on brood counts are presented.

VOR Readings

Mallard, gadwall, and American wigeon (Anas americana) nested in denser vegetation than other upland nesting ducks ($\underline{P}$ < 0.05) (Table 4). These results compare to Duebbert et al. (1986) and Barker et al. (1990). Cover provided by mature DNC exhibited VOR values higher than nesting cover selected by blue-winged teal (Anas discors), northern shoveler (A. clypeata), green-winged teal (A. crecca), or pintail (A.

Table 4. Mean VOR readings (dm) for upland nesting ducks on study sites near Minnedosa, MB, 1993-94.

Species	n	$\bar{x}$[a]	SE
Blue-winged Teal	53	3.07 x	0.12
Mallard	38	4.92 y	0.35
Gadwall	20	5.39 y	0.53
Northern Shoveler	15	3.20 x	0.18
Green-winged Teal	9	4.03 x	0.69
Northern Pintail	6	3.23 x	0.50
American Wigeon	4	5.22 y	0.24

[a] Values with the same letter are not significantly different

acuta). Only DNC stands < 1 year old were attractive to these birds. There was no relationship between nesting cover density and nest success ($\chi^2 = 0.56$, $P > 0.25$).

Predator Incidence

Potential waterfowl predators observed on study sites included red fox, striped skunk, coyote, mink (Mustela vison), raccoon (Procyon lotor), Franklin's ground squirrel (Spermophilis franklinii), and badger (Taxidea taxus). Potential avian predators included northern harrier (Circus cyaneaus), red-tailed hawk (Buteo jamaicensis), Swainson's hawk

(B. swainsoni), great horned owl (Bubo virginianus), American crow (Corvus brachyrhynchos), common raven (Corvus corvax), black-billed magpie (Pica pica), and ring-billed gull (Larus delawarensis).

Other Wildlife

Six mourning doves (Zenaida macroura) nests were found in young (< 1 year) stands of DNC. In addition, 4 sharptailed grouse (Tympanuchus phaisianellus) and 3 northern harrier nests were located in DNC. White-tail deer (Odocoileus virginianus) fawns also utilized stands of DNC for bedding sites.

DISCUSSION

Breeding Pairs

Cowardin (1991) suggested wetland surface water is the primary attractor for breeding ducks. If this hypothesis is accurate, increasing the amount of potential nesting cover surrounding a wetland or wetland complex should have little effect on breeding pair densities. Dwyer (1970) suggested abundant, undisturbed nesting cover may attract larger numbers of breeding dabbling ducks than sparse cover in an agricultural environment, given equal wetland conditions. I found the addition of upland vegetation surrounding a wetland complex did not increase dabbling duck breeding pairs. While the breeding pair data support Cowardin (1991), the probability of type II error in the analysis was quite high. The high variability of breeding pair densities within treatment and control sites significantly reduced the ability to detect differences between them.

Dzubin (1969) and Hammond (1969) discussed the difficulty in accurately assessing breeding populations of diving ducks. However, inaccurate breeding pair indices of diving ducks may be overcome by employing consistent count procedures and meticulous assessments of bird behavior.

It seems unlikely that the higher diving duck breeding pair densities I observed were a direct result of the treatment. The most plausible explanation involves philopatric behavior by successful females. Nesting ducks, especially canvasbacks, often exhibit homing tendencies (Stoudt 1982). AAP lease site selection criteria may be biased in selecting for semi-permanent wetlands that were attractive to diving ducks prior to leasing. Returning successful hens, along with their progeny, may have increased local breeding populations.

Nesting Success

Habitat degradation, primarily the result of agricultural encroachment, may force ducks to nest in fewer and smaller habitat patches (Clark and Diamond 1993). Numerous authors have suggested smaller habitat patches lead to higher predation rates and subsequent population declines (Sargeant et al. 1984, Cowardin et al. 1985, Greenwood et al. 1987, Klett et al. 1988, Pasitschniak-Arts and Messier 1995). Agriculturally based habitat fragmentation reduces habitat amount and increases the amount of habitat edge (Laurance and Yensen 1991). Presumably, additional edges lead to an increase in the number of generalist predators and increases predator foraging efficiency (Wilcove et al. 1986, Burkey 1993). Therefore, management on small blocks could negatively affect nesting ducks by attracting more hens and exposing them to greater predation risk. This "ecological trap" hypothesis has been thoroughly tested in forest ecosystems but rarely in grassland and prairie ecosystems (Johnson and Temple 1986, Burger et al. 1994, Pasitschniak-Arts and Messier 1995).

Clark and Nudds (1991) determined the relationship between waterfowl nesting success and habitat patch size varies depending on nest density, local predator composition, and alternate prey availability. Pasitschniak-Arts and Messier (1995) suggested waterfowl nest success rates are site-specific, driven by local predator composition. Clark and Diamond (1993) hypothesized that medium-sized habitat patches may experience low nest success rates because birds are attracted to them in relatively high densities and are preyed heavily upon by efficient predators that encounter abundant prey. Smaller and larger habitat patches may have higher success rates due to lower nest densities and subsequently lower profitability for foraging predators.

Recent evidence suggests variable but low nest success in small areas of managed cover (Higgins et al. 1992, Howerter et al. 1992). Total upland nest success estimates for both treatment and control sites in this study were below Cowardin et al.'s (1985) suggested 15% population maintenance rate. The annual variability in nest success rates between treatment and control sites observed in this study provides no conclusive evidence regarding the relationship between small patches of improved nesting habitat and nesting success. However, it is clear that habitat improvements on small wetland complexes did not attract larger numbers of upland nesting birds and subsequently expose them to greater predation risk than unmanaged wetland complexes. The inability to detect patterns in success rates may be a function of low statistical power and local predator guilds varying spatially and annually.

RESEARCH AND MANAGEMENT CONSIDERATIONS

AAP-leased wetlands support greater breeding diving duck densities than unmanaged wetlands in the Minnedosa region. The potential increases in local recruitment rates resulting from the protection of deeper semi-permanent wetlands may stimulate local population growth. However, semi-permanent wetlands preferred by nesting diving ducks are less likely to be drained for agricultural purposes than more transitory wetland types preferred by dabbling ducks (Johnson and Grier 1988).

Most nesting waterfowl utilizing deeper wetlands are diving ducks. Because dabbling ducks do not utilize deeper wetlands as often as shallower, more ephemeral wetlands, the presence of upland nesting cover adjacent to semi-permanent wetlands may not be critical except in the driest years. However, semi-permanent wetlands are important to all waterfowl broods, especially in dry years (Stoudt 1982).

The proportion of ducks nesting in DNC on treatment sites was small (< 20%). Thus, the relative importance of DNC regarding potential increases in nest success is unclear. Numerous authors have reported nesting hens select the densest upland cover available, regardless of predation rates (Higgins 1977, Kirsch et al. 1978, Duebbert et al. 1986). I found > 50% of the breeding dabbling ducks on AAP leases were species that selected sparser cover than provided by post green-up DNC stands (blue-winged teal, northern shoveler, northern pintail). In addition, annual snowpack often left DNC stands matted and in poor condition prior to green-up. The development and implementation of a DNC mixture that appeals to a wider variety of breeding waterfowl may increase nesting efforts in seeded cover.

The establishment and maintenance of isolated DNC patches is not cost effective with regard to mallard production (Lokemoen 1984). I recommend the use of nesting structures in areas with good wetland quality but low upland nest success and minimal amounts of available upland habitat to effectively produce mallards at lower costs than small-scale upland habitat improvements.

Small wetland complexes such as AAP lease sites are attractive to breeding ducks (Cowardin 1991). Wetland complexes with good mixes of wetland types will likely attract the most breeding pairs of waterfowl (Johnson and Grier 1988, Cowardin 1991). The identification of wetland complex sizes and configurations that are most attractive to breeding waterfowl (Clark and Nudds 1991) will help the DWF select lease sites that provide the most benefit to breeding waterfowl.

The majority of wetlands located in the Minnedosa study area were situated in cropland or hayfields. Intensive agriculture negatively impacts wetlands via agrichemical runoff and sedimentation (Grue et al. 1989). Numerous herbicides and pesticides are known toxins to young waterfowl (Grue et al. 1986, 1989, Brewer et al. 1988, Forsyth 1989) and may negatively impact invertebrate abundance (Borthwick 1988, Grue et al. 1988). In addition, sedimentation resulting from agricultural runoff may reduce invertebrate abundance and diversity. Clark and Diamond (1993) suggested increased pesticide and herbicide use in the Canadian prairies may have strong direct and indirect effects on waterfowl production and survival. Upland vegetation surrounding a wetland may buffer the wetland against agricultural runoff (Forsyth 1989, Grue et al. 1989). Unfortunately, these wetland margins and basins are often tilled and directly treated with agrichemicals, especially in drought years (Brace and Caswell 1985, as cited by Grue et al. 1989). Therefore, reduced agricultural impacts resulting from a program such as AAP may benefit waterfowl broods and waterfowl recruitment.

Island biogeographic theory (Shafer 1990) suggests habitat patches in high densities ("archipelagos") will be more beneficial to breeding birds than isolated small patches. In addition, larger patches may be more beneficial than small patches (Shafer 1990, Clark and Diamond 1993). I recommend researchers undertake projects that compare waterfowl nesting success on large (> 160 ha) and smaller blocks of habitat in spatially and temporally similar scales. While the landscape composition patterns most beneficial to breeding waterfowl are not known (Clark and Nudds 1991, Clark and Diamond 1993), my results suggest that isolated regions of protected wetland habitat and improved upland habitat will not increase recruitment rates across the PPR. However, these sites did not constitute "ecological traps," as nest success for the 2 study years did not differ between treatment and control sites. Predation, the primary cause of nest loss on all sites, varied locally and annually. Because local predator guild composition and abundance may ultimately dictate nest success, management strategies such as the AAP project need to address habitat issues at a landscape level to positively impact waterfowl populations.

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CHAPTER III

OVERWATER NEST SITES AND NEST PREDATION

Abstract: Site-specific habitat characteristics at overwater duck nests may influence nest predation rates. I monitored overwater nests of canvasbacks (Aythya valisineria), redheads (A. americana), ruddy ducks (Oxyura jamaicensis), and mallards (Anas platyrhynchos) and compared the relative amount and success of overwater and upland nesting by mallards in southwestern Manitoba in 1993-94. Mallards nested in shallower water than ruddy ducks, canvasback, and redhead ($P < 0.0005$). Mallards nested closer to shore than redheads ($P = 0.02$). Mallards and canvasbacks initiated nests earlier than redheads and ruddy ducks ($P < 0.0005$). Ruddy duck and canvasback daily survival rates were highest, followed by redhead and mallard ($P = 0.06$ to 0.18). Nests in < 30 cm of water were predated more often than expected ($P < 0.0025$). Overwater nests comprised 31% ($n = 58$) of the total mallard nests found. Overwater nesting mallards initiated earlier than upland nesting mallards ($P = 0.05$). Overwater mallard and upland mallard nest success was not significantly different. A model describing the relationship between water depth at nest sites and predation rates is presented. The amount of overwater nesting by mallards probably varies regionally and annually. Wetlands, primarily seasonal and semi-permanent, may provide attractive and relatively secure nesting habitat for mallards. Managers and biologists should consider the importance of overwater environments and nest site characteristics when evaluating habitat for nesting ducks.

INTRODUCTION

Predation on nesting hens, eggs, and young limits waterfowl production in the prairie pothole region (PPR) (Cowardin et al. 1985, Greenwood et al. 1987, Klett et al. 1988, Johnson et al. 1992). The impacts of predators on upland nesting waterfowl are well documented (Sargeant et al. 1993). Predator impacts on overwater nesting ducks are not as well studied.

Although red fox and striped skunk generally avoid entering water to forage (Sargeant et al. 1993), Stoudt (1982) reported both entered shallow water to reach nests. Raccoon (Procyon lotor) and mink (Mustela vison), the mammalian predators most likely to encounter overwater nests, are relatively uncommon in the Canadian PPR (Sargeant et al. 1993). Krasowski and Nudds (1986) could not discriminate between successful and unsuccessful overwater nests based upon water depth at nest sites and nest concealment. The relationship between nest success and microhabitat is often hard to quantify (Krasowski and Nudds 1986). Foraging predators, especially striped skunks (Mephitis mephitis) and red fox (Vulpes vulpes), may encounter duck nests by chance. Physical barriers (e.g., dense vegetation, water, or nest dispersal) may reduce the chance of an encounter. Nesting in deep water and greater distances from wetland edges may reduce a nesting hen's risk from terrestrial predators. Arnold et al. (1993) suggested higher survival rates for overwater nests may be a general phenomenon for waterfowl.

Cowardin et al. (1985) suggested a 15% nesting success threshold for mallard (Anas platyrhynchos) population maintenance. Management of nesting habitat for breeding mallards usually focuses on the establishment and maintenance of tall, dense upland vegetation (Duebbert and Kantrud 1974, Higgins 1977, Kirsch et al. 1978). The contribution of overwater nesting to mallard recruitment is often overlooked. Krapu et al. (1979) found 66% of mallard nests in southcentral North Dakota in marsh environments. Overwater nest success was 54% compared to 14% for upland nests. Arnold et al. (1993) reported mallard overwater nesting success was 4 times higher than upland nesting success. Gates (1965) reported an early season peak of mallards nesting in emergent vegetation in Wisconsin. Wingfield (1951) and Reeves (1954) reported a high percentage of mallards nesting in emergent vegetation in Utah and southeastern Idaho, respectively.

Information on overwater nesting ducks was collected as part of a research program evaluating waterfowl use and production on small prairie wetland complexes. The objectives of this research were (1) to determine if site specific characteristics influence nest success of overwater nesting ducks and (2) to quantify the relative amount of overwater nesting by mallards. The Delta Waterfowl Foundation and Utah Agricultural Experiment Station provided the funding and support necessary to conduct this research.

STUDY AREA AND METHODS

Research was conducted from mid-April through early August, 1993-94, on a 690-km^2 area near Minnedosa, Manitoba, Canada (50°06'N; 99°50'W). The Minnedosa study area lies within the aspen (Populus spp.) parklands of the PPR. The Minnedosa region is characterized by heavily cultivated uplands and numerous wetland basins (up to 50/km^2), which vary in size, permanence, depth, and vegetation (Stewart and Kantrud 1971). Small grains (wheat, barley, and rye) and oil seeds (canola and flax) are the predominant crops grown. Livestock and hay production were light in the area (Stoudt 1982). Wetland water levels were high in 1993-94, with 1993 rainfall amounts approaching record levels. In 1993, 51 sites, encompassing 158 wetland basins and 82 ha, were surveyed. In 1994, 56 sites, encompassing 181 wetland basins and 92 ha, were surveyed.

Nests were located by wading through emergent vegetation and flushing hens and/or observing unattended nests. Data recorded at each nest included total eggs, incubation stage, vegetative type, and depth of water and distance to shore for overwater nests. Nests were visited every 7-10 days until termination. A nest was considered successful if ≥ 1 egg hatched. Nests that were abandoned due to investigator disturbance or destroyed by flooding were not used in success calculations.

Differences in nest site characteristics between species were compared using a 1-way analysis of variance. Nest success estimates were calculated using the Mayfield method (Mayfield 1961, 1975) and compared using a 2-sample Z-test. Relationships between nest site characteristics and predation rates were tested using a chi-square test of independence. Significant relationships were modeled using ordinal logistic regression (SAS Institute 1989). Unless otherwise noted, the acceptable level of statistical significance was $\alpha = 0.05$.

RESULTS

Overwater Nest Characteristics

Primary overwater nesting ducks in the study area were canvasback (Aythya valisineria), redhead (A. americana), ruddy duck (Oxyura jamaicensis), and mallard.

Mallards and canvasbacks initiated nests earlier than redheads and ruddy ducks ($\underline{P} < 0.0005$) (Table 5). Mallards nested in shallower water than ruddy ducks, canvasback, and redhead ($\underline{P} = 0.0005$; Table A.5). Mallards nested closer to shore than redheads ($\underline{P} = 0.02$). Ruddy duck and canvasback daily survival rates were highest, followed by redhead and mallard ($\underline{P} = 0.06$ to 0.18) (Table 6). Nests located in < 30 cm of water were predated more often than expected ($\chi^2 = 10.01$, $\underline{P} < 0.0025$). The relationship between water depth at nest sites and predation rates is presented in Fig. 3 (see Tables A.6 and A.7). There was no relationship between distance from shore and nest predation, nest initiation date and nest predation, or species and nest predation.

Predation accounted for 64% of nest losses ($\underline{n} = 44$). Abandonment (due to unknown causes) accounted for 16% of losses. Flooding accounted for 20% of nest losses. Most predation appeared to be mammalian, probably raccoon and mink. Mink and mink sign were frequently observed in deep water. Red fox or striped skunks were never observed in water, although skunk sign was occasionally found in emergent vegetation.

Overwater and Upland Mallard Nests

I monitored 34 and 24 mallard nests in 1993 and 1994, respectively. Overwater nests constituted 29% and 33%, respectively, of the total mallard nests found. Nest success was not different for overwater and upland nests ($\underline{P} = 0.61$) (Table 7). Overwater mallard nesting success was lower than overwater nests for other species, although the differences were not significant ($\underline{P} = 0.12$).

Upland mallard nesting success did not differ from the success of other upland

Table 5. Average nest site characteristics of overwater nesting ducks near Minnedosa, MB, 1993-94.

Species	Mean Initiation[abc]	Mean Depth (cm)[bc]	Mean Distance from shore (m)[bc]
Mallard	129 ± 12.7 q	31.2 ± 16.7 v	10.6 ± 11.0 y
Canvasback	133 ± 9.7 q	54.9 ± 13.4 x	13.4 ± 9.0 yz
Redhead	149 ± 14.8 r	54.3 ± 15.5 x	16.8 ± 8.4 z
Ruddy duck	160 ± 12.2 s	60.2 ± 15.9 x	14.7 ± 7.5 yz

[a] Mean Julian date of first egg

[b] $\bar{X}$ ± SD

[c] within a column, values with the same letter are not significantly different ($P > 0.05$)

Table 6. Nest success of overwater nesting ducks near Minnedosa, MB, 1993-94.

Species	n	Exposure Days	Losses	DSR[a]	SE	Mayfield
Canvasback	40	654.5	13	0.9801 x	0.0055	49.5
Redhead	35	506.0	16	0.9684 x	0.0078	32.5
Ruddy Duck	17	227.0	4	0.9824 x	0.0087	55.7
Mallard	18	115.0	6	0.9478 x	0.0207	15.3

[a] values with the same letter are not significantly different

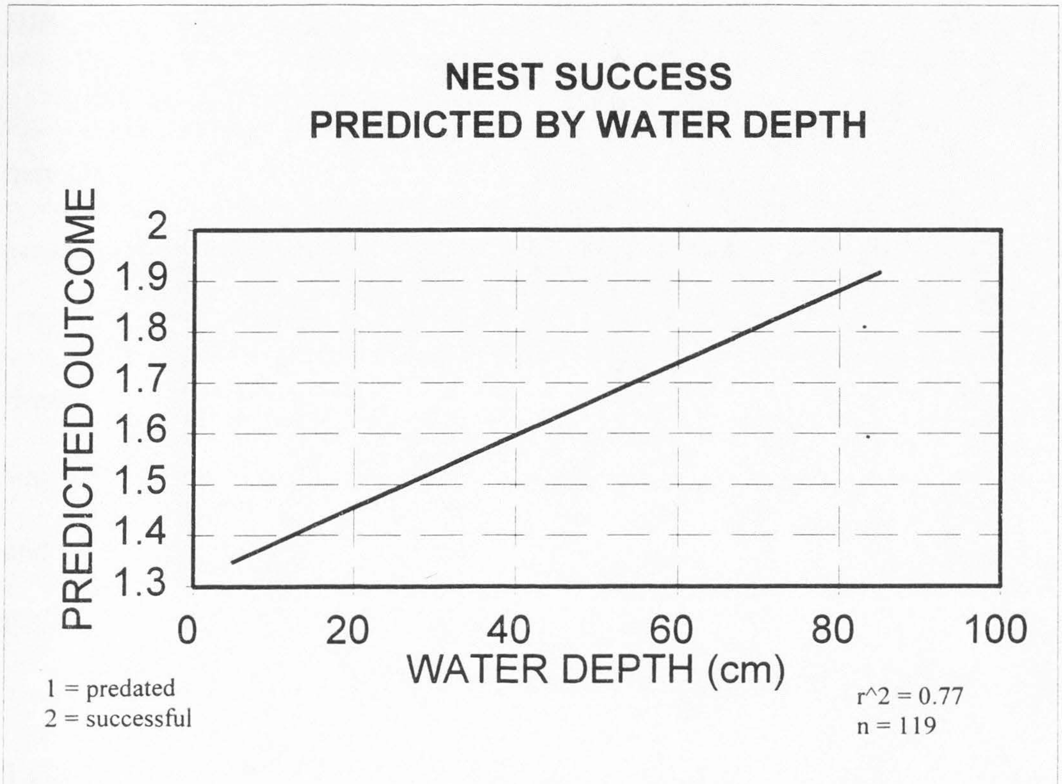

Figure 3. Expected nest outcomes for canvasback, redhead, ruddy duck, and mallard predicted by water depth at a nest site.

nesting ducks in the study area ($\underline{Z}$ = 0.18, $\underline{P}$ = 0.57). Overwater mallards initiated nests earlier than upland nesting mallards (upland mean = 5/17, overwater mean = 5/9; $\underline{t}$ = 2.01, $\underline{P}$ = 0.03).

DISCUSSION

Species differences observed in water depth and distance from shore at nest sites may be a result of different wetland types utilized for nesting. Ruddy ducks and canvasbacks prefer to nest in class IV and V, type III wetlands (Stewart and Kantrud 1971). These wetlands types have relatively deep, semi-permanent to permanent water, rimmed with a band of emergent vegetation. Potential nest sites are limited to the vegetation surrounding the wetland. Mallards and redheads primarily selected class III and IV, type II wetlands for nesting. Water in these wetlands is less permanent. Emergent vegetation occupies a larger portion of the total wetland area (Stewart and

Table 7. Nest success of mallards in overwater and upland habitats near Minnedosa, MB, 1993-94.

				Number of		Daily survival		Mayfield
Location	Year	Habitat	Nests	Days	Losses	Rate[a]	SE	success
Manitoba	1993-94	Upland	40	371.5	22	0.9408	0.0122	11.8
		Overwater	18	115.0	6	0.9478	0.0207	15.3

[a] values are not significantly different

Kantrud 1971), resulting in increased dispersion of potential overwater nest sites.

Krasowski and Nudds (1986) indicated nonrandom placement of nests in small prairie wetlands had no effect on nest outcome. However, Featherstone (1975) reported overwater nests at more concealed sites in large wetlands were more likely to be successful, presumably because of greater nest dispersal. Krasowski and Nudds (1986) suggested overwater nesting ducks utilizing emergent bands surrounding small prairie wetlands were more susceptible to foraging predators than birds nesting in larger wetlands.

My results suggest predation risk for overwater nesting ducks likely varies with nest location and local predator regimes. In the northern and western portions of the PPR, aquatic predators tend to be less abundant than terrestrial predators (Sargeant et al. 1993). Lower populations of aquatic predators may further reduce predation risk for overwater nesting ducks.

In the Minnedosa area, ducks utilizing deeper water for nest sites reduce predation risk from terrestrial predators. Mallard nesting success was lower than the 3 other overwater nesting species observed. Mallards tended to nest in the transition area between aquatic and terrestrial environments, potentially exposing them to both aquatic and terrestrial predators. The relatively shallow water (< 30 cm) and proximity to shore for most overwater mallard nests exposed them to higher predation risks than overwater nests of other ducks located in deeper water (> 30 cm) (i.e., canvasback, redhead, ruddy duck). Lower daily survival rates for overwater nesting mallards reflect this increased predator risk.

The intensively farmed upland habitats and high water that flooded much of the remaining upland habitat in 1993-94 may have contributed to the amount of overwater nesting observed in mallards. Predation pressure in upland environments may also increase the frequency of overwater nesting (Sargeant et al. 1984). In 1994, combined nesting success for all overwater nests (mallard, redhead, canvasback, and ruddy duck) was 3 times higher than nesting success for upland nesters.

Because overwater nests exhibited higher daily survival rates than upland nests, Krapu et al. (1979) suggested overwater mallard nests are more likely to be found by researchers than upland mallard nests. Daily survival rates for overwater nests I observed were not higher than survival rates for upland nests. In addition, overwater mallard nests were usually well concealed. Therefore, I believe the relative percentages of mallard nests found overwater in this study probably underestimate the true number.

MANAGEMENT IMPLICATIONS

Arnold et al. (1993) suggested the higher success of overwater nesting versus upland nesting may be a general phenomenon for waterfowl, possibly due to low densities of potential nest predators and greater nest dispersal. The abundance and distribution of aquatic predators (raccoon, mink) may influence predation rates on overwater nests. Intensive agriculture and high water levels, resulting in the reduction of available upland foraging areas, may increase predation rates by forcing other predators (striped skunk, red fox) to forage in wet environments.

Krasowski and Nudds (1986) suggested the potential benefits of nonrandom nest placement by overwater nesting ducks were negated when nesting cover consisted of vegetation fringes surrounding prairie wetlands. Limited nesting cover reduces nest dispersal and presumably increases predation risk. In addition, increased edge habitat may increase predator foraging efficiency (Pasitschniak-Arts and Messier 1995). However, my research suggests nonrandom nest site selection may benefit overwater nesting waterfowl in an agriculturally dominated landscape. Increasing raccoon densities across the Canadian prairies (Stoudt 1982, Sargeant et al. 1993) may eventually negate the benefits of nonrandom nest site selection.

The importance of overwater nesting for mallards probably varies regionally and temporally. Arnold et al. (1993) felt wetland drainage and spring burning reduced overwater nesting habitat for mallards. Krapu et al. (1979) suggested a large portion of the remaining wetland habitat in the prairies provides potential nesting cover for mallards. Tall residual emergent vegetation found in prairie wetlands is attractive to early nesting birds. The rigid physical structure and relatively low palatability of residual emergent vegetation imparts more resilience towards heavy snow and grazing than upland vegetation (Kantrud 1986).

Early initiating mallards are presumably faced with a landscape containing limited suitable nesting sites. Wooded areas and emergent vegetation often provide the tallest cover available. From 1993-1995, 14% of nests from radio-marked hen mallards in western Manitoba were found in woodland habitat (D.W. Howerter, Ducks Unlimited Canada, pers. comm. 1995). A comparable number of mallards probably utilized wooded areas in my study area. I agree with Arnold et al.'s (1993) conclusion that radio-marking hens is the best way to obtain unbiased estimates of the relative percentages of mallard nests in a given habitat.

The dense stands of emergent vegetation preferred by mallards for nesting do not provide adequate loafing or foraging sites for waterfowl (Kantrud 1986). Since mallards are quite flexible in their nesting cover selection, management strategies directed toward overwater nesting mallards should first consider the habitat needs of other breeding and migrant waterfowl.

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CHAPTER IV

SUMMARY AND CONCLUSIONS

DISCUSSION

Breeding Pairs

Cowardin (1991) suggested wetland surface water is the primary attractor for breeding ducks. If this hypothesis is accurate, increasing the amount of nesting cover around a wetland or wetland complex should have little, if any, effect on breeding pair densities. Dwyer (1970) suggested abundant, undisturbed nesting cover may attract larger numbers of breeding dabbling ducks than sparse cover in an agricultural environment, given equal wetland conditions. I found the addition of upland vegetation surrounding a wetland complex did not increase dabbling duck breeding pairs. While the breeding pair data support Cowardin (1991), the probability of type II error in the analysis was quite high. The high variability of breeding pair densities within treatment and control sites significantly reduced the ability to detect differences between them.

Dzubin (1969) and Hammond (1969) discussed the difficulty in accurately assessing breeding populations of diving ducks. However, inaccurate breeding pair indices of diving ducks may be overcome by employing consistent count procedures and meticulous assessments of bird behavior.

It seems unlikely that the higher diving duck breeding pair densities I observed were a direct result of the treatment. The most plausible explanation involves philopatric behavior by successful females. Nesting ducks, especially canvasbacks, often exhibit homing tendencies (Stoudt 1982). AAP lease site selection criteria may be biased in selecting for semi-permanent wetlands that were attractive to diving ducks prior to leasing. Returning successful hens, along with their progeny, may have increased local breeding populations.

Nesting Success

Habitat degradation, primarily the result of agricultural encroachment, may force ducks to nest in fewer and smaller habitat patches (Clark and Diamond 1993). Numerous authors have suggested smaller habitat patches lead to higher predation rates and subsequent population declines (Sargeant et al. 1984, Cowardin et al. 1985, Greenwood et al. 1987, Klett et al. 1988, Pasitschniak-Arts and Messier 1995). Agriculturally based habitat fragmentation reduces habitat amount and increase the amount of habitat edge (Laurance and Yensen 1991). Presumably, additional edges lead to an increase in the number of generalist predators and increase predator foraging efficiency (Wilcove et al. 1986, Burkey 1993). Therefore, management on small blocks could negatively affect nesting ducks by attracting more hens and exposing them to greater predation risk. This "ecological trap" hypothesis has been thoroughly tested in forest ecosystems but rarely in grassland and prairie ecosystems (Johnson and Temple 1986, Burger et al. 1994, Pasitschniak-Arts and Messier 1995).

Clark and Nudds (1991) determined the relationship between waterfowl nesting success and habitat patch size varies depending on nest density, local predator composition, and alternate prey availability. Pasitschniak-Arts and Messier (1995) suggested waterfowl nest success rates are site-specific, driven by local predator composition. Clark and Diamond (1993) hypothesized that medium-sized habitat patches may experience low nest success rates because birds are attracted to them in relatively high densities and are preyed heavily upon by efficient predators that encounter abundant prey. Smaller and larger habitat patches may have higher success rates due to lower nest densities and subsequently lower profitability for foraging predators.

Recent evidence suggests variable but low nest success in small areas of managed cover (Higgins et al. 1992, Howerter et al. 1992). Total upland nest success estimates for both treatment and control sites in this study were below Cowardin et al.'s (1985) suggested 15% population maintenance rate. The annual variability in nest success rates between treatment and control sites observed in this study provides no conclusive evidence regarding the relationship between small patches of improved nesting habitat and nesting success. The inability to detect patterns in success rates may be a function of statistical power and local predator guilds varying spatially and annually. However, habitat improvements on the small wetland complexes in this study did not attract larger numbers of upland nesting birds and did not expose nesting hens to predation risk greater than that on unmanaged wetland complexes.

Overwater Nests and Nest Predation

Species differences observed in water depth and distance from shore at nest sites may be a result of different wetland types utilized for nesting. Ruddy ducks and canvasbacks most often nested in class IV and V, type III wetlands (Stewart and Kantrud

1971). These wetlands types have relatively deep, semi-permanent to permanent water, rimmed with a band of emergent vegetation. Potential nest sites are limited to the vegetation surrounding the wetland. Mallards and redheads primarily selected class III and IV, type II wetlands for nesting. Water in these wetlands is less permanent. Emergent vegetation occupies a larger portion of the total wetland area (Stewart and Kantrud 1971), resulting in increased dispersion of potential overwater nest sites.

Krasowski and Nudds (1986) indicated nonrandom placement of nests in small wetlands had no effect on nest outcome. However, Featherstone (1975) reported overwater nests at more concealed sites in large wetlands were more likely to be successful, presumably because of greater nest dispersal. Krasowski and Nudds (1986) suggested overwater nesting ducks utilizing emergent bands surrounding small prairie wetlands were more susceptible to foraging predators than birds nesting in larger wetlands.

My results suggest predation risk for overwater nesting ducks likely varies with nest location and local predator regimes. In the northern and western portions of the prairie pothole region, aquatic predators tend to be less abundant than terrestrial predators (Sargeant et al. 1993). Lower populations of aquatic predators may further reduce predation risk for overwater nesting ducks.

In the Minnedosa area, ducks utilizing deeper water for nest sites reduce predation risk from terrestrial predators. Mallard nesting success was lower than the 3 other overwater nesting species observed. Mallards tended to nest in the transition area between aquatic and terrestrial environments, potentially exposing them to both aquatic and terrestrial predators. The relatively shallow water (< 30 cm) and proximity to shore for most overwater mallard nests exposed them to higher predation risks than overwater nests of other ducks located in deeper water (> 30 cm) and further from shore (i.e., canvasback, redhead, ruddy duck). Lower daily survival rates for overwater nesting mallards reflect this increased predator risk.

The intensively farmed upland habitats and high water that flooded much of the remaining upland habitat in 1993-94 may have contributed to the amount of overwater nesting observed in mallards. Predation pressure in upland environments may also increase the frequency of overwater nesting (Sargeant et al. 1984). In 1994, combined nesting success for all overwater nests (mallard, redhead, canvasback, and ruddy duck) was 3 times higher than nesting success for all upland nests.

Because of higher daily survival rates for overwater nests, Krapu et al. (1979) suggested overwater mallard nests are more likely to be found by researchers than upland mallard nests. I observed no difference between daily survival rates for overwater and upland nests. Therefore, I believe the relative percentages of overwater mallard nests found in this study probably underestimates the true number.

RESEARCH AND MANAGEMENT CONSIDERATIONS

Overwater Nesting

Arnold et al. (1993) suggested the higher success of overwater nesting versus upland nesting may be a general phenomenon for waterfowl, possibly due to low densities of potential nest predators and greater nest dispersal. The abundance and distribution of aquatic predators (raccoon, mink) influence predation rates on overwater nests. Intensive agriculture and high water levels, resulting in the reduction of available upland foraging areas, may force other predators (striped skunk, red fox) to forage in wet environments.

Krasowski and Nudds (1986) suggested the potential benefits of nonrandom nest placement by overwater nesting ducks were negated when nesting cover consisted of vegetation fringes surrounding prairie wetlands. Limited nesting cover reduces nest dispersal and presumably increases predation risk. In addition, increased edge habitat may increase predator foraging efficiency (Pasitschniak-Arts and Messier 1995). However, my research demonstrates nonrandom nest site selection may benefit overwater nesting waterfowl in an agriculturally dominated landscape. Increasing raccoon densities across the Canadian prairies (Stoudt 1982, Sargeant et al. 1993) may eventually negate the benefits of nonrandom nest site selection.

The importance of overwater nesting for mallards probably varies regionally and temporally. Arnold et al. (1993) felt wetland drainage and spring burning reduced overwater nesting habitat for mallards. Krapu et al. (1979) suggested a large portion of the remaining wetland habitat in the prairies provides potential nesting cover for mallards. Tall, residual emergent vegetation found in prairie wetlands is attractive to early nesting birds. The rigid physical structure and relatively low palatability of residual emergent vegetation imparts more resilience towards heavy snow and grazing than upland vegetation (Kantrud 1986).

Early initiating mallards are presumably faced with a landscape containing limited suitable nesting sites. Wooded areas and emergent vegetation often provide the tallest cover available. From 1993-1995, 14% of nests from radio-marked hen mallards in western Manitoba were found in woodland habitat (D.W. Howerter, Ducks Unlimited Canada, pers. comm. 1995). A comparable number of mallards probably utilized wooded areas in my study area. I agree with Arnold et al.'s (1993) conclusion that radio-marking hens is the best way to obtain unbiased estimates of the relative percentages of mallard nests in a given habitat.

The dense stands of emergent vegetation preferred by mallards for nesting do not provide adequate loafing or foraging sites for waterfowl (Kantrud 1986). Since mallards are quite flexible in their nesting cover selection, management strategies directed toward overwater nesting mallards should first consider the habitat needs of other breeding and migrant waterfowl.

AAP Program

AAP-leased wetlands support greater breeding diving duck densities than unmanaged wetlands in the Minnedosa region. The potential increases in local recruitment rates resulting from the protection of deeper semi-permanent wetlands may stimulate local population growth. However, the semi-permanent wetlands preferred by nesting diving ducks are less likely to be drained for agricultural purposes than more transitory wetland types preferred by dabbling ducks (Johnson and Grier 1988).

Most nesting waterfowl utilizing deeper wetlands are diving ducks. Because dabbling ducks do not utilize deeper wetlands as often as shallower, more ephemeral wetlands, the presence of upland nesting cover adjacent to semi-permanent wetlands may not be critical except in the driest years. However, semi-permanent wetlands are important to all waterfowl broods, especially in dry years (Stoudt 1982).

The proportion of ducks nesting in DNC on treatment sites was small (< 20%). Thus, the relative importance of DNC regarding potential increases in nest success is unclear. Numerous authors have reported nesting hens select the densest upland cover available, regardless of predation rates (Higgins 1977, Kirsch et al. 1978, Duebbert et al. 1986). I found > 50% of the breeding dabbling ducks on AAP leases were species that selected sparser cover than provided by post green-up DNC stands (blue-winged teal, northern shoveler, northern pintail). In addition, annual snowpack often left DNC stands matted and in poor condition prior to green-up. The development and implementation of a DNC mixture that appeals to a wider variety of breeding waterfowl may increase nesting efforts in seeded cover.

The establishment and maintenance of isolated DNC patches is not cost effective with regard to mallard production (Lokemoen 1984). I recommend the use of nesting structures in areas with good wetland quality but low upland nest success and minimal amounts of available upland habitat to produce mallards at lower costs than small-scale upland habitat improvements.

Wetland complexes with good mixes of wetland types will likely attract the most breeding pairs of waterfowl (Johnson and Grier 1988, Cowardin 1991). The identification of wetland complex sizes and configurations that are most attractive to breeding waterfowl (Clark and Nudds 1991) will help the DWF select lease sites that provide the most benefit to breeding waterfowl.

The majority of wetlands located in the Minnedosa study site were situated in cropland or hayfields. Intensive agriculture negatively impacts wetlands via agrichemical runoff and sedimentation (Grue et al. 1989). Numerous herbicides and pesticides are known toxins to young waterfowl (Grue et al. 1986, 1989, Brewer et al. 1988, Forsyth 1989) and may negatively impact invertebrate abundance (Borthwick 1988, Grue et al. 1988). Sedimentation resulting from agricultural runoff may reduce invertebrate abundance and diversity. Clark and Diamond (1993) suggested increased pesticide and herbicide use in the Canadian prairies may affect waterfowl production and survival. Upland vegetation surrounding a wetland may buffer the wetland against agricultural run-off (Forsyth 1989, Grue et al. 1989). However, many wetland margins and basins are tilled and directly treated with agrichemicals, especially in drought years (Brace and Caswell 1985, as cited by Grue et al. 1989). Therefore, protected and/or increased upland habitat provided by the AAP program may benefit waterfowl broods and waterfowl recruitment by reducing the impacts associated with intensive agriculture.

Island biogeographic theory (Shafer 1990) suggests habitat patches in high densities ("archipelagos") will be more beneficial to breeding birds than isolated small patches. In addition, larger patches may be more beneficial than small patches (Shafer 1990, Clark and Diamond 1993). I recommend researchers undertake projects that compare waterfowl nesting success on large (> 160 ha) and smaller blocks of habitat in spatially and temporally similar scales. While the landscape composition patterns most beneficial to breeding waterfowl are not known (Clark and Nudds 1991, Clark and

Diamond 1993), my results suggest that isolated regions of protected wetland habitat and improved upland habitat will not increase recruitment rates across the PPR. However, these sites did not constitute "ecological traps," as pooled nest success rates did not differ between treatment and control sites. Predation, the primary cause of nest loss on all sites, varied locally and annually. Because local predator guild composition and abundance may ultimately dictate nest success, management strategies such as the AAP project need to address habitat issues at a landscape level to positively impact waterfowl populations.

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APPENDIX

Table A. 1. Mean dabbling duck breeding pairs per wetland ha on study sites near Minnedosa, MB, 1993-94.

		1993					1994				
Species	Site	$\bar{x}$	SE	t	df	P	$\bar{x}$	SE	t	df	P
Blue-winged teal	Treatment	0.13	0.05	0.00	40	>0.25	0.10	0.05	0.37	33	>0.25
	Control	0.13	0.04				0.08	0.02			
Mallard	Treatment	0.15	0.05	0.00	40	>0.25	0.14	0.04	1.12	36	0.12
	Control	0.15	0.04				0.09	0.02			
Gadwall	Treatment	0.02	0.01	-1.78	46	0.04	0.10	0.05	0.57	33	>0.25
	Control	0.06	0.02				0.07	0.02			
Northern shoveler	Treatment	0.02	0.01	-0.71	43	0.21	0.02	0.01	-1.41	48	0.07
	Control	0.03	0.01				0.04	0.01			
Green-winged teal	Treatment	0.01	0.01	0.00	43	>0.25	0.03	0.02	0.00	48	>0.25
	Control	0.01	0.01				0.03	0.02			
Northern pintail	Treatment	0.00	0.00	-1.00	29	0.16	0.02	0.01	0.00	48	>0.25
	Contrtol	0.02	0.02				0.02	0.01			
American wigeon	Treatment	0.00	0.00	-1.00	29	0.16	0.01	0.01	0.00	48	>0.25
	Control	0.01	0.01				0.01	0.01			
Total dabblers	Treatment	0.35	0.08	-0.58	44	0.68	0.41	0.08	0.69	48	0.24
	Control	0.42	0.09				0.33	0.08			

Table A. 2. Mean diving duck breeding pairs per wetland ha on study sites near Minnedosa, MB, 1993-94.

		1993					1994				
Species	Site	$\bar{x}$	SE	t	df	P	$\bar{x}$	SE	t	df	P
Canvasback	Treatment	0.04	0.02	1.34	33	0.09	0.08	0.02	1.41	48	0.07
	Control	0.01	0.01				0.04	0.02			
Redhead	Treatment	0.03	0.02	0.00	33	>0.25	0.14	0.06	1.81	24	0.04
	Control	0.03	0.01				0.03	0.01			
Ruddy Duck	Treatment	0.13	0.05	1.96	24	0.03	0.03	0.01	0.00	48	>0.25
	Control	0.03	0.01				0.03	0.01			
Ring-necked duck	Treatment	0.00	0.00	-			0.01	0.01	0.00	48	>0.25
	Control	0.00	0.00				0.01	0.01			
Bufflehead	Treatment	0.00	0.00	-			0.00	0.00	-1.00	36	0.16
	Control	0.00	0.00				0.01	0.01			
Lesser Scaup	Treatment	0.01	0.01	0.00	43	>0.25	0.01	0.01	1.00	18	0.16
	Control	0.01	0.01				0.00	0.00			
Total Diving Ducks	Treatment	0.21	0.05	2.26	30	0.02	0.27	0.06	2.08	36	0.02
	Control	0.08	0.02				0.13	0.03			

Table A. 3. Mayfield nest success estimates for upland nesting ducks on study sites near Minnedosa, MB, 1993-94.

		1993						1994					
Species	Site	n	Days	Losses	DSR	SE	Mayfield	n	Days	Losses	DSR	SE	Mayfield
Blue-winged teal	Treatment	19	245.0	13	0.9469	0.0143	15.7	9	109.0	7	0.9358	0.0235	10.5
	Control	14	128.5	12	0.9066	0.0257	3.6	11	113.5	9	0.9207	0.0254	6.0
Mallard	Treatment	10	86.5	7	0.9191	0.0293	5.2	7	51.5	4	0.9223	0.0373	5.9
	Control	13	159.5	8	0.9498	0.0173	16.5	8	74.0	4	0.9459	0.0263	14.3
Gadwall	Treatment	5	67.0	1	0.9851[a]	0.0148	59.1	8	62.0	8	0.8710[a]	0.0426	1.0
	Control	3	26.0	3	0.8846	0.0627	1.4	4	77.5	1	0.9871	0.0128	63.5
Northern shoveler	Treatment	2	33.5	1	0.9701	0.0294	35.7	5	65.0	4	0.9385	0.0298	11.5
	Control	4	59.5	2	0.9664	0.0234	31.3	4	55.5	2	0.9640	0.0250	28.7
Green-winged teal	Treatment	4	52.0	4	0.9231	0.0369	7.1	0	-	-	-	-	-
	Control	3	49.0	2	0.9592	0.0283	25.3	2	26.0	0	1.000	0.0000	100.0
Northern pintail	Treatment	0	-	-	-	-	-	0	-	-	-	-	-
	Control	3	14.5	3	0.7931	0.1064	0.0	3	55.0	1	0.9818	0.0180	55.6
American wigeon	Treatment	0	-	-	-	-	-	1	7.0	1	0.8571	0.1323	1.0
	Control	1	11.5	1	0.9130	0.0831	5.0	3	47.5	2	0.9579	0.0291	24.2
Lesser Scaup	Treatment	0	-	-	-	-	-	0	-	-	-	-	-
	Control	1	8.5	1	0.8824	0.1105	1.3	0	-	-	-	-	-
Total Upland Nest	Treatment	40	484.0	26	0.9463	0.0102	15.0	30	294.5	24	0.9185[a]	0.0159	5.3
	Control	42	457.0	32	0.9300	0.0119	8.4	35	449.0	19	0.9577	0.0095	23.0

[a] pair of values is significantly different

Table A. 4. Mayfield nest success estimates for overwater nesting ducks on study sites near Minnedosa, MB, 1993-94.

		1993						1994					
Species	Site	n	Days	Losses	DSR[a]	SE	Mayfield	n	Days	Losses	DSR[a]	SE	Mayfield
Canvasback	Treatment	10	137.0	6	0.9562	0.0175	19.9	7	137.0	0	1.0000	0.0000	100.0
	Control	12	205.5	5	0.9757	0.0107	41.1	11	175.0	2	0.9886	0.0080	66.0
Redhead	Treatment	11	134.5	6	0.9554	0.0178	20.2	6	110.0	1	0.9909	0.0091	72.6
	Control	8	70.0	7	0.9000	0.0359	2.5	10	191.5	2	0.9948	0.0052	83.3
Ruddy duck	Treatment	7	65.0	6	0.9077	0.0359	4.1	3	71.0	0	1.0000	0.0000	100.0
	Control	3	43.5	2	0.9535	0.0319	21.6	4	75.5	1	0.9868	0.0131	64.4
Mallard	Treatment	4	8.5	1	0.8824	0.1105	1.3	3	28.0	0	1.0000	0.0000	100.0
	Control	7	41.5	4	0.9036	0.0458	2.9	4	37.0	1	0.9730	0.0266	38.3
Total Overwater													
Nests	Treatment	33	351.0	20	0.9430	0.0124	13.0	19	346.0	1	0.9971	0.0029	90.3
	Control	30	360.5	18	0.9500	0.0115	16.5	29	479.0	5	0.9896	0.0046	69.2

[a] no values in table are significantly different

Table A.5. ANOVA tables for nest site characteristics.

Distance to shore

Source Variation	SS	df	MS	F	P value	F-crit
Between Groups	4076.72	3	1358.91	16.73	<0.0005	2.649
Within Groups	16242.71	200	81.21			
Total	20319.43	203				

Depth at nest site

Source Variation	SS	df	MS	F	P value	F-crit
Between Groups	63326.60	3	21108.87	42.85	<0.0005	2.65
Within Groups	98525.33	200	492.63			
Total	161851.94	203				

Nest Initiation

Source Variation	SS	df	MS	F	P value	F-crit
Between Groups	241641.43	3	80547.14	28.84	<0.0005	2.66
Within Groups	446852.34	160	2792.82			
Total	688493.77	163				

Table A.6. Ordinal logistic regression output from nest predation model.

DEPTH AND DISTANCE ON PREDATION
Response: New Column
Iteration History

Iter	LogLikelihood	Step	Delta-Criterion	Obj-Criterion
1	-74.53704008	Initial	3075.64739	2.41e+306
2	-70.17794748	Newton	0.15744063	0.062106
3	-70.12663853	Newton	0.00827415	0.00073156
4	-70.12656542	Newton	0.00001899	0.00000104

Converged by Gradient

WHOLE-MODEL TEST

Source	**DF**	**-LogLikelihood**	**ChiSquare**	**Prob>ChiSq**
Model	2	4.41075	8.820949	0.012149
Error	116	70.126565		
C Total	118	74.537040		

Rsquare (U)	0.0592
Observations (or Sum Wgts)	119

LACK OF FIT

Source	**DF**	**-LogLikelihood**	**ChiSquare**	**Prob>ChiSq**
Lack of Fit	91	50.011746	100.0235	0.242901
Pure Error	25	20.114819		
Total Error	116	70.126565		

PARAMETER ESTIMATES

Term	**Estimate**	**Std Error**	**ChiSquare**	**Prob>ChiSq**
Intercept	1.16813701	0.7123912	2.69	0.1011
Depth	-0.0282769	0.0136451	4.29	0.0382
Distance	-0.035895	0.0268517	1.79	0.1813

EFFECT TEST

Source	**Nparm**	**DF**	**Wald ChiSquare**	**Prob>ChiSq**
Depth	1	1	4.2945050	0.0382
Distance	1	1	1.7870034	0.1813

Table A.7. Regression output from nest predation model using predicted values.

Linear Fit
Summary of Fit

Rsquare	0.76729
Rsquare Adj	0.765301
Root Mean Square Error	0.061811
Mean of Response	1.680672
Observations (or Sum Wgts)	119

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	1.4738982	1.47390	385.7716
Error	117	0.4470160	0.00382	Prob > F
C Total	118	1.9209142		
0.0000				

Parameter Estimates

Term	Estimate	Std. Error	t Ratio	Prob > t
Intercept	1.3132123	0.01955	67.18	0.0000
Depth	0.0071044	0.00036	19.64	0.0000