Experimental evaluation of duck nesting structures in Prairie Parkland Canada

Matthew D. Chouinard, Richard M. Kaminski, Patrick D. Gerard, and Stephen J. Dinsmore

Abstract Overwater nesting structures for ducks have been used primarily to increase mallard (*Anas platyrhynchos*) production where success of ground-nesting hens was low (<15%), such as in the Prairie Pothole Region (PPR) in North America. However, managers have inquired about recommended numbers of nest structures for small wetlands (i.e., <2 ha) based on duck-production and benefit–cost evaluations, but such data were not available. Therefore, we conducted an experiment in the PPR in Manitoba, Canada, in 2001 and 2002 to test the effects of different treatment numbers of nest structures/wetland (1, 2, or 4) and wetland area (≤0.4 or 0.45–1.5 ha) on use of structures by nesting ducks, nest success, and number of ducklings produced, as well as to evaluate cost–benefits of the structures. Across duck species, mean use of structures by nesting hens increased 56% between years ($F_{1,107}=14.29$, $P<0.001$); however, by year 2 use did not differ among treatment numbers of structures and averaged 78% ($t_{157}=$–0.15–1.08, $P\geq0.28$). Apparent nest success averaged 99% across treatment numbers of structures in 2001, but it did not differ among treatments ($F_{2,72}=0.93$, $P=0.40$) and decreased to an overall 48% in 2002, largely due to egg predation by corvids. Mean number of ducklings departing structures did not vary between years ($F_{1,54}=2.38$, $P=0.13$), but treatment number of structures influenced mean number of ducklings (pooled over 2001 and 2002) exiting structures ($F_{2,54}=4.54$, $P=0.02$). Mean numbers of ducklings departing 1 and 2 structures/wetland did not differ ($t_{54}=0.29$, $P=0.77$; pooled $\bar{x}=4.61$ ducklings), but each respective mean was nearly twice that from 4 structures/wetland ($t_{54}=2.26$–2.51, $P\leq0.03$). Neither wetland area nor any interactions influenced any analysis ($F_{1-2,54-157}=0$–1.11, $P\geq0.33$). We concluded that 2 structures/wetland was cost-effective ($2.16/fledged duck [U.S.]) for consideration among other management strategies to increase nest success of mallards in the PPR; however, managers should monitor duckling production from structures to determine whether our initial recommendation from a single study area warrants change.

Key words *Anas platyrhynchos*, Canada, ducklings, mallard, Manitoba, nest structure, nest success, Prairie Parkland Region

Breeding populations of most species of North American ducks exceeded goals of the North American Waterfowl Management Plan during the late 1990s and early 2000s (United States Fish and

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Wildlife Service 2004). For example, mallard (*Anas platyrhynchos*) populations averaged 8.7 million breeding birds from 1995-2004, which was 16% above the 1955–2004 average (United States Fish and Wildlife Service 2004). However, drought regularly occurs in the Prairie Pothole Region (PPR), the primary breeding grounds for ducks in North America. Subsequently, continental populations decline in response to decreased wetland habitat in this extensive region. Additionally, much grassland in this region has been converted to agricultural land (Doty et al. 1975, Cowardin et al. 1985, Greenwood et al. 1995). Therefore, dabbling ducks often use remnant cover for nesting, including roadside and wetland edges, fence rows, croplands, pastures, and forests (Klett et al. 1988, Greenwood et al. 1995). In these fragmented habitats, dabbling duck nest success may be <15% due to predation of eggs and hens (Klett et al. 1988, Greenwood et al. 1995). Because nest success >15% has been demonstrated to sustain populations, some local populations may have inadequate annual recruitment to compensate for mortality of birds produced in these areas (Cowardin et al. 1985).

Management strategies designed to reduce predation of eggs and hens may have the greatest potential to increase recruitment of mallards and other ground-nesting ducks (Hoekman et al. 2002). Mallard hens have been found nesting on muskrat (*Ondatra zibethicus*) lodges and in emergent vegetation (Bishop and Barratt 1970, Kaminski and Weller 1992); these hens have exhibited increased nest success (32–63%; Arnold et al. 1993). Mallards also have used artificial structures in wetlands at rates >60% (Doty and Lee 1974, Eskowich et al. 1998, Chouinard 2003) and have experienced nest success above the threshold necessary to sustain populations (34–100%; Bishop and Barratt 1970, Johnson et al. 1994, Chouinard 2003). Additionally, because successful nesting female mallards returned at high rates (34–77%) to breeding sites (Bishop et al. 1978, Lokemoen et al. 1990, Yerkes 1999), nest structures may increase local production and population size (Eskowich et al. 1998).

Waterfowl managers have inquired frequently whether there was a recommended number of nest structures for small wetlands (<2 ha) in the PPR. However, the effects of number of nest structures in wetlands and wetland size on use of structures by nesting hens, nest success, and number of ducklings produced and successfully departing structures have not been tested. Therefore, our objective was to evaluate mallard and other duck use, nest success, duckling production, and cost–benefits associated with cylindrical nest structures placed at 3 densities in wetlands of 2 size categories in the PPR near Minnedosa, Manitoba, Canada, where nest success was typically low (2–12%) due to predation of eggs and hens by mammalian and avian predators (Arnold et al. 1993, Greenwood et al. 1995, IWWR 2002).

Study area

We conducted our study within a 31-km^2 area 3 km northeast of Minnedosa, Manitoba, Canada (50º24´ N, 99º52´W). This area, located in the PPR (i.e., breeding waterfowl survey stratum 40; United States Fish and Wildlife Service and Canadian Wildlife Service 2003), was comprised of wetlands interspersed with agricultural lands, hayfields, stands of trembling aspen (*Populus tremuloides*) and burr oak (*Quercus macrocarpa*), and human structures (Kowalchuk 1996, Brasher et al. 2002). Chouinard (2003: 3) presented additional details about the study area.

Methods

Selection of wetlands

In 2001 we identified all wetland basins in our study area on 1993 black-and-white aerial photographs and visited all apparent semi-permanent and permanent wetlands (Stewart and Kantrud 1971). We did not have an alternative means of inventorying wetlands in our study area; moreover, the 1993 imagery proved accurate during field reconnaissance. We selected these wetland types because nesting duck use of structures was greatest in these wetlands (Bishop and Barratt 1970); they provided suitable brood rearing habitat (Duebbert and Frank 1984) and contained water except during extreme droughts (Stewart and Kantrud 1971). We used a transparent grid overlaying the aerial photo to estimate wetland area and divided wetlands into 2 classes (i.e., ≤0.4 ha and 0.45–1.5 ha) based on median wetland size (0.42 ha). We randomly selected 30 wetlands in each size class to receive experimental nest structures. We excluded wetlands >1.5 ha ($n = 6$), because ice movement in wetlands of this size tends to destroy nest structures (Bishop and Barratt 1970, Artmann 1999). Additionally, we excluded 3 wetlands with existing nest structures, because philopatry by ducks to these wetlands and

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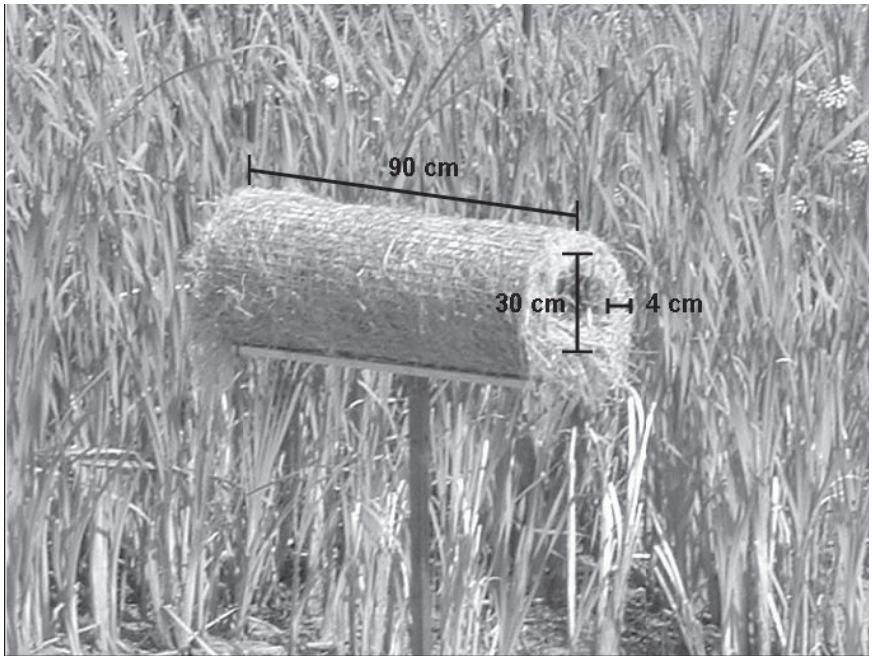

Figure 1. A cylindrical duck nest structure (length, 90 cm; inside diameter, 30 cm; outer flax layer, 4 cm) depicted in a typical location within a wetland near Minnedosa, Manitoba, Canada, during 2001–2002.

structures could have biased our data on structure use and other reproductive variables.

Nest structures

We used cylindrical nest structures (Eskowich et al. 1998, Artmann et al. 2001, Stafford et al. 2002). Nest cylinders are frequently used by mallards in the Minnedosa area and are preferred over nest baskets by mallards in Saskatchewan (Eskowich et al. 1998). We constructed nest structures by rolling a 2.29-m length of welded wire fencing (12.75-cm^2 apertures) into 2 cylinders, with a 4-cm gap between the inner and outer cylinders, which was filled with flax straw (Figure 1). We used flax instead of other vegetation or outdoor carpet to avoid reduced initial use of structures by mallards (Artmann 1999), and because flax typically lasted longer than other straw types (P. Ward, Delta Waterfowl and Wetlands Research Station, personal communication). Our structures had a 30-cm inside diameter, were 90 cm in length without a landing platform, and erected on 2.4-m steel poles (Figure 1).

Allocation and location of structures

We randomly assigned 1, 2, or 4 nest structures to each of 10 randomly selected wetlands within each of 2 wetland size classes. Therefore, we erected 140 structures in 60 wetlands. We erected structures in March 2001 when wetlands were ice-covered; this period facilitated access to entire wetland basins and placement of structures. We used a gas-powered ice auger to drill through ice and a post pounder to embed steel poles into wetland substrates. We filled inner cylinders with natural grasses as nest material in late March 2001 and 2002. For wetlands receiving 1 or 2 structures each, we randomly selected 1 or 2 of the 4 cardinal directions for placement of each structure along the shoreline of the selected direction. For wetlands receiving 4 structures, we placed 1 structure along the north, south, east, and west shorelines. In all wetlands we placed structures approximately midway along a shoreline, ~1 m from the edge of emergent vegetation (Figure 1), 1 m above ice surface, and oriented an entrance toward open water (Bishop and Barratt 1970, Doty et al. 1975). We used the same structures in 2001 and 2002 and refurbished each in March 2002.

Local breeding mallard populations

In May 2001 and 2002, we conducted weekly surveys of indicated breeding mallards (i.e., pairs, lone males, and males in groups of ≤4 individuals) on wetlands in our study area within 200 m of either side of navigable roads (United States Fish and Wildlife Service and Canadian Wildlife Service 1987, Brasher et al. 2002). We conducted breeding mallard surveys because mallard pair densities influence use of nest structures in North Dakota (Artmann et al. 2001) and we were interested in observing relative changes in use of nest structures by ducks and annual breeding populations.

Nest searching and monitoring

We visited nest structures at 3-week intervals

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beginning 10 May and ending 31 July 2001 and 2002. During each visit we checked for signs of nesting activity (i.e., presence of a hen, nest bowl, eggs, feathers) and nest depredation (Sargeant et al. 1998). When a female was present, we flushed her and counted and candled all eggs to estimate stage of incubation and predicted hatch date (Weller 1956). We deemed a structure used if it contained ≥1 eggs or a down-lined nest bowl during any inspection (Klett et al. 1986). We checked nests after predicted hatch date to determine their fate (Klett et al. 1986). We used apparent nest success (i.e., ≥1 eggs hatched) because we were able to find each nest within all structures (Johnson 1979, Klett et al. 1986). At the final visit, we counted egg-shell membranes in successful nests to estimate number of ducklings that departed structures (Davis et al. 1998).

Statistical analysis

Indicated breeding mallards. We estimated weekly breeding mallard density by dividing total number of indicated breeding mallards by area surveyed each week (i.e., strip 400-m wide × length of road driven) and extrapolated the estimate to our study area. We calculated mean weekly indicated breeding mallard density and its standard error (SE) for May 2001 and 2002.

Structure use and nest success. We treated use of nest structures and nest success as binary variables, each with unequal subsample sizes (i.e., nest structures) among experimental units (i.e., wetlands). We used a generalized linear mixed model (GLMM) with the GLIMMIX macro to account for unbalanced subsample size (Littell et al. 1996). The GLMM was analogous to a logistic regression model with fixed and random effects and was necessary due to our multi-level analysis of binary variables. We used this approach to test the fixed effects of number of structures/wetland, wetland size class, and year; we treated wetland and wetland by year interaction as random effects (Littell et al. 1996). We also evaluated all interactions of fixed and random variables. Our nest success data from 2001 did not meet convergence criteria of GLIMMIX due to high nest success (64 of 65 nests hatched), so we designated wetland as the random effect and only analyzed 2002 data. We tested for differences within significant ($P \leq 0.05$) main effects using the PDIFF option (Littell et al. 1996: 423–460) in the least-squares means statement (PROC MIXED, SAS Institute 1999).

Duckling production. We determined the mean number of ducklings that departed structures within each wetland and year. We deemed the wetland as the experimental unit and structures as subsamples within wetlands because treatment numbers of structures were applied to wetlands. We used analysis of variance (ANOVA) to test the fixed effects of number of structures/wetland, wetland size class, and year; we designated wetland as a random effect (Littell et al. 1996). We also tested all interactions of fixed and random variables. We weighted the mean number of ducklings/wetland by the number of structures in the wetland (1, 2, or 4; PROC MIXED, SAS Institute 1999). We tested for differences within significant ($P \leq 0.05$) main effects using the PDIFF option in the least-squares means statement (PROC MIXED, SAS Institute 1999).

Cost per duckling. Because installation and refurbishment of nest structures took place within easily accessible wetlands within a contiguous study area (31 km^2), our time estimates to complete these tasks, though included, were minimal due to reduced travel among wetlands and structures. Additionally, we completed installation and refurbishment of structure treatments concurrently within our study area; thus, we could not partition costs/structure among treatments.

Based on our records, we estimated time to build and install nest structures in wetlands at 0.6 and 0.8 hours/structure, respectively. We refurbished structures in 0.15 hours on average; therefore, we multiplied this value times 9 to calculate maintenance costs over a 10-year period. We used a wage rate of $8.00 (U.S.)/hour; thus, total labor cost for each structure was $22.00 (i.e., 0.6 + 0.8 + 9[0.15] = 2.75 hrs × $8.00/hour). Adding material costs/structure ($21.00 for hardware, lumber, steel poles, straw, welded wire fencing) to the labor estimate ($22.00), our total estimated cost per structure was $43.00. We calculated relative cost per duckling by dividing estimated total cost per structure by the mean number of ducklings that departed treatment numbers of structures. Additionally, we calculated cost per fledged duckling by dividing the cost per duckling that departed structures by an available estimate of mallard duckling survival to fledging in 1998 for the Minnedosa, Manitoba region (43%; IWWR 2002). We divided both duckling cost estimates by 10 to express cost per duckling over a decade, the assumed longevity of a structure receiving annual maintenance.

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Results

Indicated breeding mallards

During May 2001 and 2002, we estimated mean weekly densities of 13.2 (SE=1.08, n=4 weeks) and 15.7 (SE = 1.33, n = 4) breeding mallards/km^2, respectively, which represented a 19% increase between years in our study area. In contrast, the annual breeding waterfowl survey recorded a 16% decrease between years from 11.3 to 9.5 breeding mallards/km^2 in stratum 40, which contained our study area (United States Fish and Wildlife Service and Canadian Wildlife Service 2003).

Use of structures

We found duck nests in 61 (44%) and 105 (75%) of 140 nest structures in 2001 and 2002, respectively. We also found 5 (4%) structures used twice by nesting ducks in 2001, 18 structures (13%) used twice in 2002, and 2 structures (1%) used 3 times in 2002, for a total of 193 nests in both years combined. Most nests were by mallards (>98%); however, we found 1 redhead (*Aythya americana*) and 1 canvasback (*A. valisineria*) nest in 2001 and 2 redhead nests in 2002. Mean use of structures increased between years ($F_{1,107}$=14.29, P<0.001) from 60% to 86%, 55% to 73%, and 34% to 74% for 1, 2, and 4 structures, respectively (Table 1). In 2001 mean percentage use of 1 and 2 structures per wetland did not differ (60% vs. 55%, respectively; t_{157}=0.35, P=0.72), but use of 4 structures per wetland (34%) was less than the other 2 treatments (t_{157}=1.99–2.03, $P\leq$0.05; Table 1). In 2002 mean percentage use of 1, 2, and 4 structures per wetland did not differ, ranging on average from 73–86% (t_{157}=–0.15–1.08, $P\geq$0.28;Table 1). We detected neither an effect of wetland size class nor any interactions on percentage use of structures by nesting ducks in either year ($F_{1-2,107-157}$=0.00–1.11, $P\geq$ 0.33).

Nest success

Nest success ranged from 96–100% among treatment numbers of structures per wetland in 2001 but decreased between years from 100% to 50%, 96% to 60%, and 100% to 34% in 1, 2, and 4 structures/wetland, respectively (Table 1). In 2002 mean nest success did not differ among treatments and averaged 48% ($F_{2,72}$=0.93, P=0.40). Using criteria by Sargeant et al. (1998), we determined that most unsuccessful nests (61%, n = 68) in 2002 were destroyed by crows (*Corvus brachyrhynchos*) or ravens (*C. corax*). Other causes of nest loss in 2002 included mammalian predators (23%), abandonment (8%), and unknown causes (8%). We determined that all abandonment in 2002 was due to partial clutch depredation or unknown causes but found no evidence that abandonment was observer induced. In 2002, we detected neither an effect of wetland size class nor any interactions on nest success ($F_{1-2,72}$=0.28–0.83, $P\geq$0.44).

Duckling production

We estimated that 541 mallard, 7 redhead, and 7 canvasback ducklings departed nest structures in 2001; 426 mallard ducklings exited structures in 2002. There was an average exodus of 3.5 ducklings per structure per year. The number of ducklings that departed structures did not vary between years ($F_{1,54}$ = 2.38, P = 0.13); thus, we pooled data across years and determined that number of ducklings exiting structures was related to number of structures per wetland ($F_{2,54}$ = 4.54, P = 0.02). We did not detect a difference between mean numbers of ducklings departing 1 and 2 structures per wetland (t_{54} =

Table 1. Mean and 95% confidence intervals (CI) for percentage use of structures by nesting female ducks, nest success (%), and number of ducklings exiting structures for 3 densities of nest structures per wetland in Manitoba, Canada, 2001–2002.

		Number of structures/wetland								
		1			2			4		
Variable	Year	$\bar{x}$	CI	n[a]	$\bar{x}$	CI	n	$\bar{x}$	CI	n
Use (%)[b]	2001	60A[c]	38–79	20	55A	39–70	40	34B	24–46	80
	2002	86A	63–95	20	73A	56–85	40	74A	62–84	80
Success(%)[b]	2001	100	73–100	12	96	79–100	24	100	86–100	29
	2002	50A	21–78	21	60A	32–82	40	34A	15–59	66
Ducklings	Pooled	4.75A	3.19–6.31	40	4.46A	3.34–5.58	40	2.71B	1.93–3.49	40

[a] n = number of structures available and used by nesting ducks for percentage use and nest success, respectively; n = number of wetlands for ducklings/structure (pooled across 2 wetland size classes and both years).

[b] Means and 95% CIs for percentage use and nest success in 2002 were back-transformed from logits. Nest success values for 2001 were calculated from raw data because nest success approximated was 95%.

[c] Means with unlike letters within rows differ ($P \leq 0.05$) based on pairwise comparisons of least squares means.

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0.29, $P=0.77$), which averaged 4.61 ducklings per structure. A mean of 2.7 ducklings exited 4 structures per wetland (Table 1), which was nearly half that from either 1 or 2 structures per wetland ($t_{54}=2.26–2.51$, $P\leq0.03$). We detected neither an effect of wetland size nor any interactions on numbers of ducklings departing structures ($F_{1–2,54}=0.00–0.19$, $P\geq0.77$).

Cost per duckling

We calculated average cost/duckling from 1 and 2 structures per wetland combined across years because mean number of ducklings departing per structure did not differ between either these 2 treatments or years. Assuming a functional longevity of 10 years per structure, cost per duckling per structure for 1 and 2 structures per wetland combined was \$0.93 compared to \$1.59 for 4 structures per wetland. Assuming that duckling survival to fledging was 43% (Institute for Wetland and Waterfowl Research [IWWR] 2002), cost per fledged duckling per structure was \$2.16 for 1 and 2 structures per wetland combined and \$3.70 for 4 structures per wetland.

Discussion

Use of structures

Between years, use of structures by all duck species combined increased 56%, on average, among treatment numbers of structures per wetland, but nearly 100% of the use was by mallards. An unknown portion of the increase in use between years may have been attributed to the 19% increase in density of indicated breeding mallards in our study area between 2001 and 2002 despite the 16% decrease in breeding mallard density between years in the general region (United States Fish and Wildlife Service and Canadian Wildlife Service 2003). Although we did not have data from a marked population of mallards, we speculate that philopatry by adult females and their female offspring also may have contributed to the observed increase in use of structures between years (Bishop et al. 1978, Lokemoen et al. 1990, Yerkes 1999). Continued monitoring of nest structures in the Minnedosa region has revealed that mallard use of 67 and 70 structures averaged 88% over 2003 and 2004, respectively (D. Coulton, University of Saskatchewan, personal communication). Thus, in areas such as Minnedosa with established populations of mallards nesting in artificial structures, high use of structures may be expected several years after establishment similar in pattern to local wood duck (*Aix sponsa*) populations (Bellrose and Holm 1994).

Nest success

Greenwood et al. (1995), Hoekman et al. (2002), and others have reported that nest success was a limiting factor for mallard production and population growth; these authors have recommended management intervention to increase nest success. Indeed, justification for use of nest structures was to increase nest success of mallards in areas like the Minnedosa region, where ground nest success was generally below the 15% level necessary to sustain populations (Arnold et al. 1993, Greenwood et al. 1995, IWWR 2002). Nest success in our structures averaged 99% and 48% in 2001 and 2002, respectively. Continued monitoring of nest structures in the Minnedosa area in 2003 and 2004 revealed that mallard nest success was 49% and 63%, respectively (D. Coulton, University of Saskatchewan, personal communication), suggesting stabilization of nest success by mallards using structures in this area ($\bar{x}=53\%$, 2002–2004). These percentages exceeded the 15% threshold but were lower in 2002–2004 than rates observed in previous studies of nest structures (70–100%; Bishop and Barratt 1970, Eskowich et al. 1998, Artmann et al. 2001). Nonetheless, we speculate that recent levels of nest success by females using structures in the Minnedosa area also may be contributing to philopatry and high use of structures in this area.

Additionally, nest success was only 11% due to egg predation in 35 structures in a 4-km^2 portion of the study area in 2002. Because nest structures were conspicuous, predators may have investigated ≥1 structures within a wetland and nearby wetlands. A common raven was witnessed searching all 4 structures within a wetland in 2002 (Chouinard 2003). Although we did not detect a difference in mean nest success among treatment numbers of structures in 2002, nest success in 4 structures per wetland (34%) was 38% lower than the average nest success for 1 and 2 structures per wetland combined (55%). Moreover, when ≥1 nests were depredated in wetlands with 4 structures in 2002, nest success in this subgroup was 22% ($n=53$). Thus, nest success and resulting duckling production may be depressed by avian and other predators (e.g., possibly raccoon [*Procyon lotor*]) attracted by multiple, conspicuous nest structures

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in wetlands. Davis (2001) also reported that aggregations of wood duck nest boxes may have attracted predators and reduced recruitment rates.

Duckling production

Although the estimated number of ducklings produced per wetland increased with number of structures (4.8, 8.9, and 10.8 ducklings/wetland for 1, 2, and 4 structures/wetland, respectively), the number of ducklings departing individual structures determines the efficiency of structures. The estimated number of ducklings produced per structure was greater for 1 and 2 structures per wetland (by approximately 2 additional ducklings/structure) than for 4 structures per wetland. Structure use and nest success did not differ among treatment numbers of structures in 2002; however, relatively lower nest success in 4 than 1 and 2 structures per wetland contributed to reduced duckling production from this treatment in 2002. Artmann et al. (2001) emphasized the importance of achieving high-use rates of structures to improve efficiency of nest structures. However, high nest success also must occur to produce ducklings, but this outcome does not ensue when predators locate and depredate clutches.

Cost per duckling

Estimated cost per fledged duckling from 1 and 2 structures per wetland (i.e., $2.16) was 42% less than that from 4 structures per wetland ($3.70) and 60% lower than recent estimates for covered baskets ($5.35; Stafford 2000). Although not directly comparable due to different calculation methods, cost per fledged duckling from 1, 2, and 4 structures per wetland was less than 1980 estimates for managed nesting cover ($7.89–$24.05/fledged duckling; Lokemoen 1984).

Management implications

Artificial nest structures for ducks should not replace efforts to manage and restore habitat for ground- and cavity-nesting ducks (e.g., mallard, wood duck). However, where secure ground-nesting habitat may be lacking but suitable brood habitat exists, we conclude that nest structures, as evaluated in this study, represented a cost-effective management option to consider for mallard production. Based on our results, we suggest that managers initially place 2 structures in wetlands ≤2 ha in the Prairie Parkland and Pothole Regions. Further, we suggest that managers monitor nesting duck use, success, and duckling production in structures to determine whether additional structures and predator shields may be needed within certain wetlands or locally in general.

Bishop and Barratt (1970) reported that ice movement in wetlands damaged overwater nest structures. Though we found no damaged structures in wetlands ≤0.4 ha, ice movement and high winds toppled 11 (16%) structures in wetlands between 0.41–1.5 ha. Nine of the damaged structures were on the south or east side of a wetland, suggesting that prevailing northwest winds contributed to this damage. To reduce damage to structures, we recommend that managers place them along upwind shores of wetlands and in coves sheltered from the wind by vegetation or topography.

We also suggest that managers refurbish nest structures annually in late winter to ensure that structures are suitable and nest material present when breeding ducks arrive. Additionally, we recommend that managers revisit structures in this region in late May–early June (i.e., earliest hatch date during our study was 29 May 2002) to check and clean structures, replenish nesting material, and determine nest success. Previous studies of use of wood duck boxes suggested that removing unhatched eggs and down feathers during the nesting season increased use and production by nesting hens (Utsey and Hepp 1997, Davis 2001).

Duckling survival is important to recruitment (Johnson et al. 1992, Hoeckman et al. 2002). Stafford et al. (2002) reported that survival of mallard ducklings hatched in nest structures in South Dakota wetlands ranged from 42–73%. However, we were not aware of any research in Prairie Parkland Canada that estimated survival of mallard ducklings hatched in nest structures. We encourage biologists to estimate survival of ducklings produced from nest structures and determine whether this rate differed from ground-nesting mallards in the Minnedosa region and elsewhere in Prairie Parkland Canada (IWWR 2002). By combining data from multiple life-history stages (e.g., hatching success, duckling and juvenile survival, and philopatry), biologists may gain knowledge of the long-term contribution of nest structures to recruitment. Such information would increase accuracy of benefit–cost evaluations of nest structures to enhance nest success.

We found that use of structures by nesting ducks increased with decreasing distance to the nearest

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road (Chouinard 2003). Structures used by nesting ducks in our study were approximately 90 m closer to roads than structures not used. Although we randomly selected wetlands for installation of nest structures, this inverse relationship may be related to managers' tradition in the Minnedosa region of placing nest structures in wetlands near roads and subsequent search images by hens for such nesting sites. Because regular maintenance of structures was necessary (this study, Artmann et al. 2001), we suggest that placement of structures in wetlands near roads was reasonable to facilitate access and maintenance. Nonetheless, we recommend that managers monitor nest success to determine whether avian and mammalian predators were attracted to structures in wetlands near roads.

Overall nest success in our study was lower in 2002 largely due to egg predation by corvids. Thus, we recommend that researchers conduct benefit–cost evaluations of anti-perching devices such as "porcupine wire" (i.e., Nixalite™, Nixalite of America Inc., East Moline, Ill.; Hygnstrom et al. 1994, Avery and Genchi 2004) or other devices designed to deter avian predators.

Acknowledgments. We thank the Delta Waterfowl Foundation, through the Delta Waterfowl and Wetlands Research Station, and the Forest and Wildlife Research Center (FWRC) and College of Forest Resources, Mississippi State University, for supporting our research and the senior author during this study. We also thank M. (Eiswerth) Chouinard, D. Coulton, J. Fisher, S. Lariviére, R. Olson, A. Pearse, F. Rohwer, and J. Stafford for their assistance with this research. This paper has been approved for publication as FWRC Journal Article WF-198.

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Associate editor: *Haukos*

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