



Original Article

Canada Goose Nest Survival at Rural Wetlands in North-central Iowa

BRENNAN N. NESS,^{1,2} *Department of Natural Resource Ecology and Management, Iowa State University, 339 Science Hall II, Ames, IA 50011, USA*

ROBERT W. KLAVER, *U.S. Geological Survey, Iowa Cooperative Fish and Wildlife Research Unit, Iowa State University, 339 Science Hall II, Ames, IA 50011, USA*

ABSTRACT The last comprehensive nest survival study of the breeding giant Canada goose (*Branta canadensis maxima*) population in Iowa, USA, was conducted >30 years ago during a period of population recovery, during which available nesting habitat consisted primarily of artificial nest structures. Currently, Iowa's resident goose population is stable and nests in a variety of habitats. We analyzed the effects of available habitat on nest survival and how nest survival rates compared with those of the expanding goose population studied previously to better understand how to maintain a sustainable Canada goose population in Iowa. We documented Canada goose nest survival at rural wetland sites in north-central Iowa. We monitored 121 nests in 2013 and 149 nests in 2014 at 5 Wildlife Management Areas (WMAs) with various nesting habitats, including islands, muskrat (*Ondatra zibethicus*) houses, and elevated nest structures. We estimated daily nest-survival rate using the nest survival model in Program MARK. Survival was influenced by year, site, stage, presence of a camera, nest age, and an interaction between nest age and stage. Nest success rates for the 28-day incubation period by site and year combination ranged from 0.10 to 0.84. Nest survival was greatest at sites with nest structures ($\beta = 17.34$). Nest survival was negatively affected by lowered water levels at Rice Lake WMA (2013 $\beta = -0.77$, nest age $\beta = -0.07$). Timing of water-level drawdowns for shallow lake restorations may influence nest survival rates. Published 2016. This article is a U.S. Government work and is in the public domain in the USA.

KEY WORDS *Branta canadensis maxima*, giant Canada goose, habitat, Iowa, nest survival, Program MARK, rural.

The giant Canada goose (*Branta canadensis maxima*) was extirpated from most of its range in the early 1900s as a result of overharvest of the birds and their eggs, as well as habitat destruction through wetland drainage (Schrader 1955, Bishop 1978, Hanson 1997). Restoration efforts in Iowa, USA, were initiated in 1964 by confining flocks of flightless geese to 15 wetland areas across the state (Bishop and Howing 1972, Zenner and LaGrange 1998a). These efforts were very successful and by the end of the century, giant Canada geese (hereafter, Canada geese) were nesting in every county in Iowa.

The first reintroduction sites were in north-central Iowa (Iowa DNR 2002), which lies within the southernmost portion of the Prairie Pothole Region (PPR). The PPR is characterized by shallow lakes and marshes that serve as highly productive waterfowl nesting habitat (Shaw and Fredine 1956). Restored goose populations flourished and geese now nest there in high densities (Zenner and LaGrange 1998b). Canada goose reintroduction sites were rural wetlands that provided ideal

nesting habitats (Iowa DNR 2002). Iowa's Canada goose population is currently stable, but most reintroduction sites remain closed to Canada goose hunting (Iowa DNR 2002). The goal of goose management in Iowa is to maintain a sustainable population for maximum recreational opportunities while keeping goose numbers at socially acceptable levels (Iowa DNR 2002).

Rural wetland sites in Iowa's PPR provide a variety of nesting habitats for Canada geese. Multiple lakes and marshes contain islands; muskrat (*Ondatra zibethicus*) activity in marshes produces additional nest sites; and the Iowa Dept. of Natural Resources (DNR) has erected nest structures for geese on some areas. Islands provide refuge from mammalian predators, but host limited numbers of geese because of the birds' territorial behavior (Vermeer 1970, Ewaschuk and Boag 1972, Giroux 1981). Muskrat houses and cattail (*Typha* spp.) mounds provide isolated nest sites generally safe from predators, but can be susceptible to flooding. Nest structures are highly secure nest sites, but require upkeep to remain usable (Mackey et al. 1988, Ball 1990, Zenner et al. 1992).

We selected 5 rural wetland sites to monitor Canada goose nest survival in Iowa's PPR during the 2013 and 2014 nesting seasons. Drought conditions in 2012 provided an opportunity to renovate Rice Lake, one of our selected study sites. These conditions prompted the Iowa DNR to lower Rice

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¹E-mail: brennatorwery@gmail.com

²Present address: 315 Main Street, Odessa, DE 19730, USA

Lake's water levels to expose mudflats and revegetate shallow-water zones. This management decision created an unexpected circumstance for our research, but presented an opportunity to evaluate the effects of water level manipulation on island-nesting Canada geese. We predicted that the lowered water levels would negatively affect nest survival if islands became accessible to terrestrial predators, considering islands are typically selected as nest sites because of the security that they inherently provide (Cooper 1978, Eichholz and Elmberg 2014).

Our objective was to determine how habitat and other factors influence Canada goose nest survival at rural wetlands in north-central Iowa. More specifically, we were interested in how nest survival varied across available nesting habitat types and determining the relative effects of vegetation density and other environmental factors on nest survival. We hypothesized that nest structures would produce the greatest survival rates, followed by islands and muskrat houses. Elevated nest structures are highly secure because they protect nests from terrestrial predators and flooding (Cooper 1978, Nigus 1979). Muskrat houses and islands, however, often leave nests exposed to these types of threats. We also hypothesized that vegetation density surrounding nests may influence nest-survival rates. Canada geese are highly territorial (Naylor 1953, Giroux 1981, Pannetier Lebeuf and Giroux 2014), but selected nest sites often incur high nest densities, resulting in an increase in territorial interactions and nest desertion rates (Klopman 1958, Ewaschuk and Boag 1972, Zenner and LaGrange 1998a, Eichholz and Elmberg 2014). There is evidence that vegetation density around a nest is inversely correlated to the frequency of territorial interactions with nearby nesting geese (Ewaschuk and Boag 1972). Understanding how these factors are currently influencing nest survival will allow managers to better maintain a sustainable Canada goose population in Iowa.

A comprehensive Canada goose nest-survival study has not been conducted in Iowa for >30 years (Nigus 1979). During Nigus' (1979) study, Iowa's breeding goose population was

still recovering. Because of this, we were interested in how nest survival rates of Iowa's currently stable goose population compared with those of the expanding goose population studied by Nigus (1979). We hypothesized that nest survival would be lower during our study than during Nigus' (1979) because there is evidence of density-dependent effects on waterfowl reproduction (Kaminski and Gluesing 1987). We also compared our nest survival estimates to those reported for Canada geese in other regions of the PPR.

STUDY AREA

We monitored Canada goose nests at Rice Lake Wildlife Management Area (WMA) and Big Wall Lake in 2013 and Rice Lake WMA, Big Wall Lake WMA, East Twin Lake WMA, Union Hills Waterfowl Production Area (WPA), and Lower Morse WPA in 2014. The sites were located in Winnebago, Worth, Hancock, Cerro Gordo, and Wright counties in north-central Iowa (Fig. 1). These counties were within the southernmost portion of the PPR, which historically supported large densities of nesting Canada geese.

All sites were located outside of municipality boundaries and each provided a particular nesting habitat for geese. Rice Lake WMA consisted of Rice Lake and the adjacent Joice Slough. Rice Lake was a 409-ha, shallow, natural lake with a maximum depth of 3 m that contained 20 natural islands ranging in size from 0.04 ha to 3.9 ha. The Joice Slough was a 73-ha marsh with a maximum depth of 1 m that contained 15 islands ranging in size from 0.02 ha to 3.19 ha and separated from Rice Lake by a narrow road. Both Rice Lake and Joice Slough were permanently flooded impoundments classified as a lacustrine system with an unconsolidated bottom (L1UBHh, L1UBH; Cowardin et al. 1979).

In 2006, the Iowa DNR implemented a Shallow Lakes Initiative to improve water quality, wildlife habitat, fish populations, and recreational opportunities at various natural lakes throughout the state (Evelsizer and Fisher 2006). Drought conditions in 2012 provided an opportunity to renovate Rice Lake, the water quality of which had become

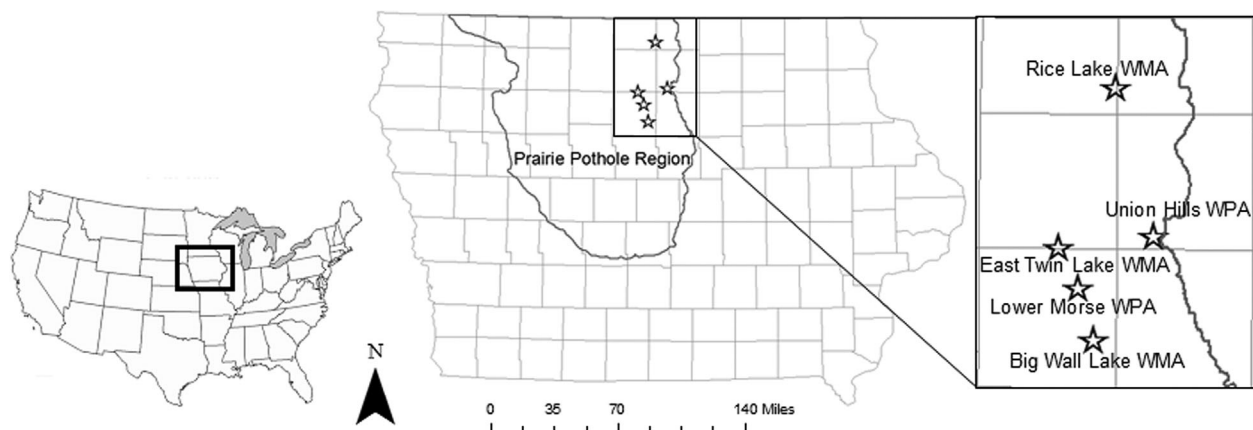


Figure 1. Map of rural wetland study sites for estimating nest success of giant Canada geese in Winnebago, Worth, Wright, Cerro Gordo, and Hancock counties in north-central Iowa, USA, during 2013–2014.

highly degraded because of a lack of aquatic vegetation, the presence of invasive fish species, and inadequate water-level management capabilities (Iowa DNR 2013). In April 2013, near the start of the Canada goose nesting season, the DNR lowered Rice Lake's water level by 1 m to expose mudflats and revegetate shallow-water zones. As a result of this manipulation, not all islands were completely surrounded by water during the study. The water level continued to decrease throughout the 2013 nesting season and was considerably lower late in the nesting period than it was early in the nesting period. By June 2013, only 4 islands remained surrounded by water. Island nest conditions were similar during the 2014 nesting season when water levels remained 1 m below crest. The Joice Slough's water level was not manipulated by the Iowa DNR, but natural fluctuations resulted in only 6 islands surrounded by water during this study.

East Twin Lake was a 197-ha, impoundment with various water regimes that contained both lacustrine and palustrine habitats with unconsolidated bottom and emergent vegetation (L1UBHh, L2UBGh, PEMFh, PEMCh, PUBGh; Cowardin et al. 1979). Big Wall Lake was a 363-ha, permanent lake with both lacustrine and palustrine habitats containing unconsolidated bottom and emergent vegetation (L1UBH, PEMF; Cowardin et al. 1979). Both East Twin Lake and Big Wall Lake were shallow, natural lakes that contained dense stands of cattails. Muskrats had constructed houses and feeding platforms from the cattails, which provided elevated insular nest sites for Canada geese (Kiviat 1978). Union Hills and Lower Morse WPAs were wetland complexes where the Iowa DNR has installed similar numbers of nest structures for Canada geese (19 and 20 structures, respectively). The structures at these sites were post structures, which consisted of a fiberglass tub or wire mesh basket attached to a 2–3-m steel pipe mounted over the water and filled with straw nesting material. We monitored nests at 5 discrete management areas, but because Rice Lake WMA included 2 separate wetlands, our study consisted of 6 rural wetland sites.

METHODS

Nest Searches

We began nest searches at our selected sites on 6 April 2013 and 18 April 2014 and continued searches through late May. At Rice Lake WMA, we systematically searched all accessible islands. We explored East Twin Lake and Big Wall Lake via canoe. We located nests by flushing the incubating adult, by sighting a goose on a nest, or by searching muskrat houses for active nests. An effort was made to search the entirety of each wetland site, including areas that were difficult to access.

Upon locating a nest, we recorded its spatial coordinates in a GPS unit and assigned the nest a unique identification number. At Rice Lake WMA, we marked nests with a natural-colored, wooden tongue depressor because of high nest densities on islands. Markers were inconspicuous and not expected to attract nest predators (Hammond and

Forward 1956). We placed camera-traps at 29 nests (1–2 m away) at Rice Lake WMA to identify nest predators at these sites.

We recorded the number of eggs present in each nest and their developmental age (in days) to predict hatch date at all sites. We determined the embryonic developmental age using a field candling device. This method was most practical for field use and similar in accuracy to weighing or floating eggs (Weller 1956, Walter and Rusch 1997, Reiter and Andersen 2008). Egg handling procedures and other study methods were approved by the Iowa State University Institutional Animal Care and Use Committee (protocol #11-12-7460-Q).

Canada geese are often seen nesting in close proximity to each other, especially on islands (Klopman 1958, Ewaschuk and Boag 1972, Zenner and LaGrange 1998a). At high nest densities, territorial geese can exhibit aggression toward other nesting geese, potentially causing nest desertion (Naylor 1953, Giroux 1981, Pannetier Lebeuf and Giroux 2014). Ewaschuk and Boag (1972) reported that vegetation height surrounding a nest was inversely correlated to the frequency of territorial interactions with nearby nesting geese. To determine whether nest survival was influenced by vegetation, we recorded visual obstruction readings (VOR) using a Robel pole during the initial visit at ground nests (Robel et al. 1970, Toledo et al. 2008). The Robel pole was placed just outside of the nest bowl and readings were taken from the 4 cardinal directions and averaged for each nest.

We checked nests 3 times during the nesting period and once posthatch to determine nest fate; nests terminated prior to hatch had fewer checks. We used a Welch's *t*-test to compare initiation and hatch dates between years and sites. We considered a nest successful if ≥ 1 egg hatched (Mayfield 1961); we identified hatched eggs by the presence of eggshell fragments and detached intact membranes in the nest (Girard 1939, Cooper 1978). We considered nests depredated if any eggs appeared to have been eaten; we considered them to be abandoned if the eggs were cold and uncovered.

Nest Survival Modeling

When modeling nest survival, individual nest covariates typically produce more robust estimates of survival and can explain potential sources of variation in daily survival rates (Dinsmore et al. 2002). We included VOR mean and variance as covariates because we hypothesized that vegetation height could affect nest survival by decreasing intraspecific aggression. We also incorporated nest age as a covariate because we hypothesized that survival increased with age as a result of increased attentiveness of the incubating goose (Klett and Johnson 1982, Dinsmore et al. 2002). We placed trail cameras at 29 nests at Rice Lake WMA, so we included a covariate denoting the presence of a camera to determine whether cameras had an effect on survival.

We developed models using the nest survival model in Program MARK to produce an estimate of daily survival rate (DSR; White and Burnham 1999, Dinsmore et al. 2002). We grouped nest data by site, stage (egg laying and

Table 1. Number of giant Canada goose nests monitored during the egg-laying and incubation stages at 6 study sites in north-central Iowa, USA, 2013–2014.

Year	Site	Egg-laying	Incubation
2013	Rice Lake	31	50
	Joice Slough	13	22
	Big Wall Lake	1	28
2014	Rice Lake	8	26
	Joice Slough	9	41
	Big Wall Lake	2	24
	East Twin Lake	0	25
	Union Hills	0	14
	Lower Morse	0	12

incubation), and year to account for potential variation in survival due to different habitat types at sites, behavioral differences during each stage, and annual variation in weather and site conditions, respectively. We developed models hierarchically by first testing group effects, then adding time effects to the best group model, and finally adding each covariate individually to the top model (Dinsmore and Dinsmore 2007). We hypothesized that groups with similar primary nesting habitats would have similar nest survival, so we first compared 2 models, one that tested the effect of each wetland site individually and one that combined sites with similar nesting habitat. In other words, nests at Rice Lake and the Joice Slough were combined into one group, those at Big Wall Lake and East Twin Lake into a second group, and Union Hills and Lower Morse WPAs into a third group. Time effects tested whether daily survival varied with nest age or whether daily survival varied across the nesting season. Nest age effects may be due to behavioral changes in the incubating goose; a day effect may be due to temporal variation within the

season or other indirect effects. We tested the quadratic function of these effects as well. We assessed model fit using Akaike's Information Criterion (AIC; Akaike 1973). We considered parameters that were not included in the top model to be uninformative (Arnold 2010). We calculated nest success by raising DSR to a power equal to the incubation period (28 days; Cooper 1978). We calculated the variance of the nest success estimates using the delta method, which is a technique developed for demographic parameters that have been transformed (Seber 1982, Powell 2009).

RESULTS

We monitored 121 nests in 2013 and 149 nests in 2014 for 270 total Canada goose nests during the course of the study (Table 1). The mean initiation date across all sites was similar between 2013 (16 Apr) and 2014 (13 Apr; $t_{259} = 1.09$, $P = 0.28$). The mean initiation date for nest structures in 2014 (7 Apr) was >1 week earlier than nests on islands or muskrat houses (16 Apr) in the same year ($t_{49} = -6.10$, $P < 0.001$). The mean hatch date across all sites was 19 May in 2013 and 16 May in 2014 ($t_{91} = 2.10$, $P = 0.04$). The mean hatch date for nest structures in 2014 was 8 May compared to 18 May for nests at other sites in the same year ($t_{59} = -4.87$, $P < 0.001$). All nest attempts were completed by 17 June in both years.

Geese nested on 10 of the 20 islands at Rice Lake in 2013 and 3 islands in 2014. Geese nested on 7 of the 15 islands on the Joice Slough in 2013 and 6 islands in 2014. Camera-traps at these sites revealed nests were destroyed by coyotes (*Canis latrans*), raccoons (*Procyon lotor*), American crows (*Corvus brachyrhynchos*), and, in 2 instances, local farm dogs (*C. lupus familiaris*). In 2014, 16 (80%) of the 20 nest structures available at Lower Morse WPA were used by nesting geese

Table 2. Models of daily survival rate for giant Canada goose nests monitored at rural wetlands in north-central Iowa, USA, 2013–2014. Models are listed in descending order by Akaike's Information Criterion (AIC) weight. Models were created in Program MARK using 15 groups (3 sites for 2 yr with 2 stages and 3 sites for 1 yr and 1 stage) and the following covariates: mean and variance of visual obstruction readings using a Robel pole at the nest (VOR and VORvar), an effect of a nest's age (Age), a stage by age effect (Stage \times Age), a linear and quadratic effect of day within the nesting season (Day and Day²), and an effect of a camera on a nest (Cam). Sites with similar primary nesting habitats were grouped together, which condensed the number of site groups from 6 to 3.

Model ^a	ΔAIC^b	w_i^c	K^d	Deviance
Yr + Site(3) + Stage + Age + Stage \times Age + Cam	0.00	0.88	11	490.32
Yr + Site(3) + Stage + Age + Stage \times Age + VOR	5.20	0.07	12	493.50
Yr + Site(3) + Stage + Age + Stage \times Age	6.00	0.04	10	498.34
Yr + Site(3) + Stage + Age + Stage \times Age + VORvar	8.68	0.01	12	496.99
Yr + Site(3) + Stage + Age	14.88	0.00	9	509.23
Yr + Site(3) + Stage + Age ²	17.85	0.00	12	506.16
Yr + Site(3) + Stage + Day	27.73	0.00	9	522.07
Yr + Site(3) + Stage	27.85	0.00	6	528.23
Yr + Site(3) + Stage + Day ²	27.96	0.00	12	516.26
Yr + Site(3)	64.63	0.00	5	567.01
Site(6)	78.40	0.00	6	580.78
Site(3)	78.72	0.00	3	585.11
Constant survival	96.36	0.00	1	606.76

^a Yr = 2013, 2014; Site(6) = Rice Lake, Joice Slough, Big Wall Lake, East Twin Lake, Union Hills, Lower Morse; Site(3) = grouped sites with similar primary nesting habitat (Rice Lake + Joice Slough, Big Wall Lake + East Twin Lake, and Union Hills + Lower Morse); Stage = egg laying, incubation.

^b Top-ranked model had an AIC value of 522.86.

^c w_i = model wt.

^d K = no. of parameters.

Table 3. Intercept and slope estimates from the top model for the predicted daily survival rate of giant Canada goose nests at Rice Lake (RL), Joice Slough (JS), Big Wall Lake (BW), East Twin Lake (ET), Union Hills (UH) Waterfowl Production Area (WPA), and Lower Morse (LM) WPA in north-central Iowa, USA, 2013–2014. The standard error (SE), lower 95% confidence limit (LCL) and upper 95% confidence limit (UCL) are also reported. The best model included a group effect for sites with similar primary nesting habitats, a year effect, an effect of nesting stage, a linear effect for nest age, a stage by age effect, and an effect of a camera on a nest (informative parameters in bold).

Parameter	Estimate	SE	LCL	UCL
Intercept (RL + JS, 2014, incubation stage)	5.40	0.43	4.55	6.25
2013 (RL + JS)	−0.77	0.23	−1.22	−0.32
Egg-laying stage (RL + JS)	−3.65	0.53	−4.68	−2.62
Age (RL + JS)	−0.08	0.02	−0.11	−0.05
Egg-laying stage × Age (RL + JS)	0.13	0.04	0.05	0.21
Camera	1.01	0.40	0.22	1.80
Intercept (BW + ET, 2014)	3.60	0.69	2.25	4.94
2013 (BW + ET)	0.30	0.39	−0.46	1.07
Age (BW + ET)	−0.01	0.03	−0.07	0.04
Intercept (UH + LM, 2014)	17.34	15.63	−13.29	47.98
Age (UH + LM)	−0.42	0.50	−1.39	0.56

and 12 (63%) of the 19 structures at Union Hills WPA were used by nesting geese.

The model with the lowest AIC value indicated that nest survival was influenced by the year, site, stage, presence of a camera on the nest, age of the nest, and an interaction between nest age and stage (Tables 2 and 3). The top model had 12 times more support than the next best model; VOR mean and variance were uninformative covariates.

There was no difference in support between the model that combined sites with similar nesting habitat and the model that kept the 6 sites separate, so we continued building models with similar sites combined, for the sake of simplicity. The most parsimonious model indicated that there was a nest site effect on nest survival, but the strength of the effect differed among sites (Table 4). Sites with nest structures (Union Hills and Lower Morse) had the greatest daily survival rates during the nesting period; however, the site effect indicated no difference in nest survival among sites with muskrat houses and islands, as evidenced by the beta estimates and confidence intervals. Other group effects indicated nest survival was lower in 2013 than in 2014 and lower during the egg-laying stage than during the incubation stage at Rice Lake and the Joice Slough (Table 3). Year and stage effects at other sites were not supported by the model.

Daily survival rates were influenced by the nest age and trail camera covariates, but only at Rice Lake and the Joice Slough. Cameras were only used at Rice Lake and Joice Slough and our model indicated that their presence resulted in greater nest-survival rates, but this is likely due to

nonrandom placement of cameras on nests. The effect of nest age on daily survival rate was not informative for nests at sites with structures and muskrat houses. Model results indicated daily survival declined with nest age at sites with islands ($\beta = -0.078$, 95% CL = -0.111 , -0.046 ; Fig. 2). Nest survival at Rice Lake and the Joice Slough was 0.10 (SE = 0.03) in 2013 and 0.36 (SE = 0.07) in 2014 during the 28-day incubation period. Nest survival was 0.46 (SE = 0.11) at Big Wall Lake in 2013 and from 0.35 (SE = 0.08) at Big Wall Lake and East Twin Lake in 2014 during the 28-day incubation period. Nest survival was 0.84 (SE = 0.09) at Union Hills and Lower Morse in 2014 during the 28-day incubation period.

DISCUSSION

Our primary finding was that nest structures produced greater nest survival than islands and muskrat houses, and manipulating the water level for lake renovation had a negative effect on nest survival at Rice Lake WMA. Nest structures are inherently secure nest sites and many studies have reported increased nest-survival rates for geese that utilize them (Craighead and Stockstad 1961, Brakhage 1965, Cooper 1978, Nigus 1979, Kadlec and Smith 1992). Muskrat houses and islands are less secure nest sites because of 1) increased exposure to predators and 2) flooding caused by spring runoff (Klopman 1958, Cooper 1978, Giroux 1981).

Although nest structures produced increased nest survival, not all structures at Union Hills and Lower Morse WPAs were used. Sertle and Eichholz (2006) reported zero use of nest structures by Canada geese in Illinois, USA, and suggested that geese had not yet “learned” to use them because they had recently been installed. This could have been the case for geese nesting at Union Hills and Lower Morse WPAs. Nest structures, moreover, require annual maintenance and without this geese are less likely to use them for nesting (Mackey et al. 1988, Ball 1990, Zenner et al. 1992). Proper placement and installation of the structure is essential, as a lack of nest material in the tub or basket or placement of the structure at a wetland with highly variable water levels could potentially deter a goose from nesting in a

Table 4. Intercept and slope estimates of the site effect for the most parsimonious nest-survival model comparing sites with similar nesting habitats in north-central Iowa, USA, 2013–2014. Rice Lake (RL) and Joice Slough (JS) sites had islands, Big Wall Lake and East Twin Lake had muskrat houses, and Union Hills WPA and Lower Morse WPA had nest structures. The standard error (SE), lower 95% confidence limit (LCL) and upper 95% confidence limit (UCL) are also reported.

Parameter	Estimate	SE	LCL	UCL
Intercept (RL and JS)	3.19	0.10	2.99	3.39
Union Hills and Lower Morse	2.75	1.01	0.78	4.73
Big Wall and East Twin	0.22	0.21	−0.19	0.62

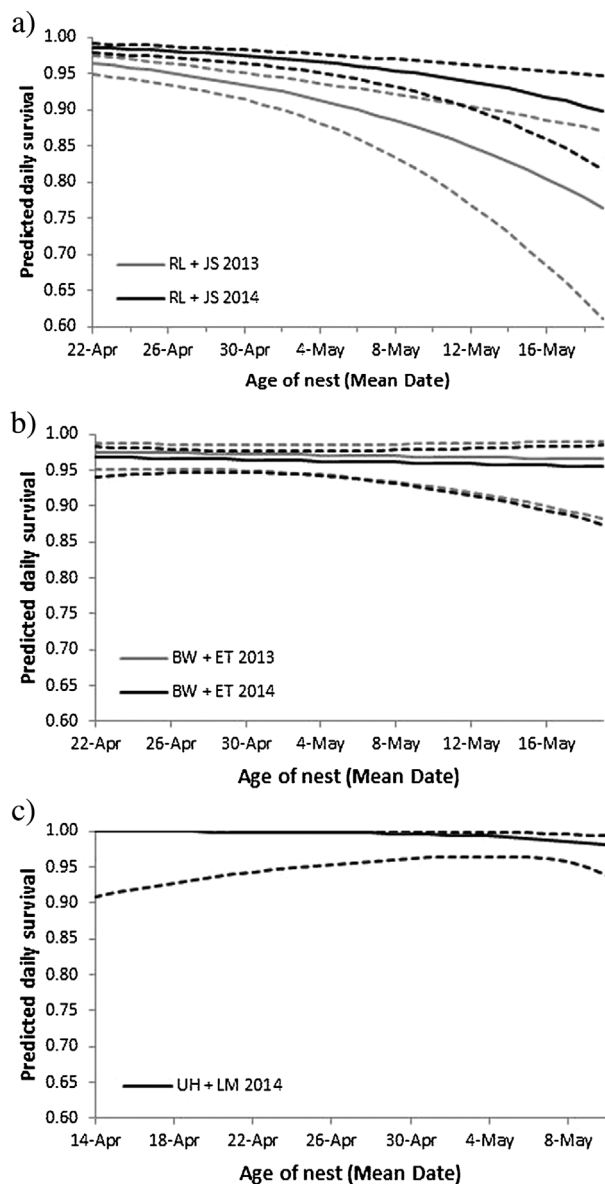


Figure 2. Predicted daily survival rates (with 95% CIs) for giant Canada geese nesting at (a) Rice Lake (RL) and Joice Slough (JS), (b) Big Wall Lake (BW) and East Twin Lake (ET), and (c) Union Hills (UH) WPA and Lower Morse (LM) WPA in north-central Iowa, USA. Age of nest corresponds to mean incubation dates during 2013 and 2014.

structure (Zenner et al. 1992). Advantages of structures are they are easy to install, inexpensive, and commercially available. Most importantly nest structures are valuable for goose production because they are nearly predator-proof (Brakhage 1966, Zenner et al. 1992).

We found no evidence that nest survival differed between sites with muskrat houses versus islands, which suggests that neither habitat type provides better nesting conditions for Canada geese than the other. Nest survival rates are likely to exhibit greater variability from year to year if geese are relying on muskrat houses for nest sites (Nigus 1979). Maintaining muskrat populations requires intensive wetland management. Consistently high water levels and absence of the natural wet-dry cycle will cause wetland habitats to degrade,

resulting in a decline in muskrat populations (McLeod 1948, Ervin 2011). Habitat management for muskrats involves water-level manipulation, which promotes nutrient cycling and regrowth of emergent vegetation upon which muskrats rely for food and lodging (Weller and Fredrickson 1973, Clark 2000, Erb and Perry 2003). These management practices are currently being implemented by the Iowa DNR under the Shallow Lakes Initiative Project (Evelsizer and Fisher 2006), which has been beneficial for fish and wildlife populations, as well as for the general public. The project, however, has involved intensive and long-term monitoring and sampling efforts with annual water-level manipulations, all of which are necessary to maintain water quality and wetland health (Iowa DNR 2013).

Under the right conditions, islands are stable and secure nest sites; however, not all islands provide quality nesting habitat. Other studies have shown that various factors, such as island slope, distance from the mainland, nest density, and a balance of adequate cover and visibility contribute to the appeal of an island nest site (Kaminski and Prince 1977, Cooper 1978, Giroux 1981, Eichholz and Elmsberg 2014). All of these factors add a layer of complexity to nest survival. Understory vegetation characteristics influence the level of cover versus visibility, but maintaining the right balance often requires habitat management. Rice Lake and Joice Slough islands have become dominated by shrubs and trees over time, which have reduced nest densities (Lokemoen and Messmer 1994, Towery 2015). Habitat management tools, such as clear cuts, herbicide, and controlled burns, can be used to regulate ecological succession on islands (Lokemoen and Messmer 1994). Habitat management can be costly and labor intensive, and potentially affect other species, but islands are a valuable resource to nesting geese (Giroux 1981, Pannetier Lebeuf and Giroux 2014), particularly in rural environments.

Although lowering water levels is important for emergent vegetation propagation, our results demonstrated that water level manipulations can negatively affect nest survival on islands if low water levels allow islands to become attached to the mainland. Nest survival at Rice Lake WMA was lower in 2013 than in 2014 and declined with nest age, likely as a result of the drastic fluctuation and manipulation of water levels in spring of 2013. Drought conditions in 2012 prompted the Iowa DNR to manually lower the water level at Rice Lake for renovation in April 2013, just when geese were beginning to nest (Iowa DNR 2013). The unnaturally rapid decline in water level at Rice Lake (from 0.5 m below crest in Apr 2013 to 1.1 m below crest in May 2013) permitted terrestrial predators to access many islands after geese had begun nesting, resulting in a decline in nest survival. Our nest-survival model results indicated that the age of a nest had an effect on daily survival rates. The drastic change in habitat conditions throughout the nesting season suggests that perhaps the day within the season should have had more of an effect on DSR than the nest age, but these 2 effects can be difficult to separate unless all nest ages are represented across the entire nesting season. There is likely confounding between these 2 parameters, but the nest age covariate

explained at least some variation in the DSR. Regardless, it was apparent that the water level manipulation lowered nest survival. Adaptations in Canada goose nesting behavior and stable water-level conditions resulted in an improvement in nest survival at Rice Lake WMA in 2014 (Towery 2015). It is often recommended that major habitat manipulations that may negatively affect nesting waterfowl (e.g., lowering water levels or mowing) be postponed until after the nesting period (Meeks 1969). Modifications to the timing of future lake-renovation activities in Iowa could help keep Canada goose populations stable.

Contrary to results reported by Ewaschuk and Boag (1972), we found that vegetation density surrounding goose nests had no effect on nest survival. Ewaschuk and Boag (1972) indicated that vegetation density influenced the frequency of intraspecific interactions between geese, which may have resulted in nest abandonment. We found abandonment rates were low and vegetation density was quite variable among nests regardless of fate. Visual obstruction readings were taken on the day a nest was found, which meant readings for some nests were taken prior to leaf-out, which could have resulted in a misrepresentation of the vegetation density surrounding those nests later in incubation. Studies of other ground-nesting avian species have reported a positive correlation between vegetation structure and nest survival (Fondell and Ball 2004, Kolada et al. 2009, Kerns et al. 2010, Conover et al. 2011), primarily due to reduced predation. Canada geese, however, are large birds and have fewer predation risks than other ground-nesting avian species, particularly when nesting on islands or in elevated structures. Other studies have also indicated that vegetation structure surrounding nests may be more important for duck species rather than geese because of differences in life-history traits (Clark and Shutler 1999, Haffele et al. 2013, Eichholz and Elmberg 2014). Canada geese are a large, long-lived species, which suggests they may be less concerned with concealment or visibility because they can defend themselves or their nest against most predators or other geese.

One of the assumptions of nest survival analysis is that nest fates are independent (Bart and Robson 1982, Dinsmore et al. 2002). This assumption may have been violated for nests on islands at Rice Lake WMA, which could have resulted in an underestimate of the sampling variance (Flint et al. 1995, Dinsmore and Knopf 2005). No empirical test or goodness-of-fit procedure has been developed to deal with this particular dependence issue. Fortunately, survival estimates typically remain unbiased (Dinsmore and Knopf 2005).

Our nest survival estimates (0.10–0.84) for Canada geese nesting in north-central Iowa are comparable to other estimates of Canada geese nesting in the PPR. Although apparent estimates of nest success were calculated in early studies, Ewaschuk and Boag (1972) reported success rates ranging from 0.27 to 0.69 in Alberta, Canada, during 1967–1969, Cooper (1978) reported rates ranging from 0.39 to 0.43 in Manitoba, Canada, during 1969–1971, and Giroux (1981) reported a 0.70 success rate in southeast Alberta during 1976–1978. Dieter and Anderson (2009) reported a

Table 5. A comparison of nest survival rates during 2013–2014 (north-central IA) and apparent nest success rates reported by Nigus (1979) during 1977–1978 (northwest IA) for Canada geese using artificial nest structures, natural islands, and muskrat houses or cattail mounds as nest sites in Iowa, USA. Values are reported as percentages.

Study and year	Artificial nest structures	Natural islands	Muskrat houses or cattail mounds
Nigus 1977	73	0	44
Nigus 1978	86	80	0
This study 2013	n/a	10	46
This study 2014	84	36	35

0.63 nest success rate in eastern South Dakota, USA, using the Mayfield method. Similar to this study, Dieter and Anderson (2009) found no difference in survival among ground-nest habitat types.

We compared our estimates of nest survival to apparent nest success reported by Nigus (1979); our hypothesis that nest survival would be lower during our study than during Nigus' (1979) study was not supported (Table 5). During 1977–1978, Nigus (1979) monitored Canada goose nests at 11 wetlands in northwestern Iowa for use of 379 artificial nest structures erected by the Iowa DNR. Apparent nest success rates were high for geese using these structures (73% and 86% in 1977 and 1978, respectively); but nest success was much more variable on natural islands and muskrat houses, ranging from 0% to 80% (Nigus 1979). During Nigus' (1979) study, muskrat populations were low and few muskrat houses were available for nesting geese. During both this study and Nigus (1979), low water levels resulted in some islands being connected to the mainland. Few geese nested on these islands, and those that did were exposed to predator activity. These findings suggest that nest survival is not influenced by population status, but by availability and condition of nesting habitat. Natural nest sites (e.g., islands and muskrat houses) experienced highly variable nest-survival rates likely due to increased exposure to environmental factors, such as changing water levels or declining muskrat populations. Artificial nest structures produced consistently high rates of nest survival during both ours and Nigus' (1979) studies. Efforts by the Iowa DNR to erect artificial nest structures during the 1970s contributed to the successful restoration of Canada geese throughout the state (Zenner and LaGrange 1998a), and these structures continue to be highly valuable nesting habitats for geese. Although islands are a selected nest site for Canada geese (Kaminski and Prince 1977, Hanson 1997), our study provided evidence that islands do not reliably provide refuge from terrestrial predators when water levels change rapidly during the nesting season or islands become exposed to the mainland.

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