Distribution and abundance of Minnesota-breeding Ring-necked Ducks *Aythya collaris*

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Abstract

Concerns about Ring-necked Duck *Aythya collaris* breeding numbers in Minnesota suggested a population survey was needed; however, knowledge of the species' distribution and abundance was poor. Existing waterfowl survey data were used to define an aerial sampling frame, and a habitat model incorporating land-cover imagery was used to develop a survey to describe breeding pair distribution and abundance in 2004–2007. In 2004, a stratified random sample was used to estimate pair numbers for plots having moderate to high potential for breeding ducks, and a sensitivity analysis was used to estimate pair numbers for the remaining un-surveyed plots. Pairs occurred throughout the survey area, primarily on small (median = 8.3 ha) wetlands with open, bog-like margins, with greatest concentrations in the west. The 2004 estimate was of ~20,000 breeding pairs, with sensitivity analysis suggesting that half of these occupied plots assumed to have few if any Ring-necked Ducks. Incomplete habitat model definitions and shortcomings in land-cover imagery contributed to stratification failure in 2004. Habitat definitions were refined and survey plots were re-stratified in 2005–2007. A second survey replaced the sensitivity analysis to better estimate pairs in plots assumed to have few ducks. Breeding pair estimates from both surveys combined were of 11,000–15,000 pairs in 2005–2007. Survey development is used to illustrate how an adaptive approach can better ensure survey success. By focusing first on development, shortcomings in the untested habitat model, land-cover imagery, and initial stratification were revealed and changes leading to more precise population estimates were made. Issues encountered in survey development likely typify those experienced when initiating large-scale monitoring efforts of little studied species.

Key words: *Aythya collaris*, breeding pairs, Gap Analysis Programme, habitat models, pilot surveys.

Concerns about Ring-necked Ducks *Aythya collaris* prompted interest in a survey providing biologists and administrators with information to help manage Minnesota's resident breeding population. The species was recently identified as a forest indicator because of its unique habitat associations (Minnesota Department of Natural Resources 2006a). Unfortunately, little was known about the breeding distribution and abundance of resident Ring-necked Ducks because existing waterfowl surveys were inadequate. Ten wetlands have been surveyed as part of the Bemidji area Ring-necked Duck survey since 1969 (Zicus *et al.* 2004), but the geographical extent of this survey is limited. However, counts from these wetlands have declined by ~70% since the start of this survey, suggesting the Minnesota population might be declining despite continental increases (U.S. Fish and Wildlife Service 2008; Fig. 1).

A survey was developed using existing survey data, remotely-sensed land use imagery, and a geographic information system (GIS) habitat model. The survey was developed to describe the distribution and abundance of resident Ring-necked Ducks in Minnesota. This much-needed information is presented here, together with a general description of the wetlands occupied by the ducks during the nesting season. The results provide a case study illustrating how surveys of poorly studied species occupying relatively inaccessible landscapes at low densities can be developed adaptively. Further, they demonstrate how precision of survey estimates can be increased. The issues encountered in survey development are likely typical of those experienced when initiating large-scale monitoring efforts of little studied species.

Methods

Defining the survey area

Eighty-seven percent of Minnesota was identified as being part of the Ring-necked Duck breeding range by the Minnesota GAP Analysis Project (MNGAP) (Minnesota Department of Natural Resources, unpublished report). Previously, a more limited range that did not extend as far south or west had been described by Moyle (1964) and by Hohman & Eberhardt (1998). After examining waterfowl survey data from southern and western Minnesota, the sampling frame was restricted to 55% of the state (Fig. 2) that was considered primary range (D. Hertel, U.S. Fish and Wildlife Service, unpublished data; Zicus *et al.* 2005). Ecological Classification System (ECS) sections (Minnesota Department of Natural Resources 2006b) were used to help define ecologically-based spatial strata for the primary range.

Identifying breeding habitat using a habitat model

Habitat specifications in the untested MNGAP Ring-necked Duck habitat model (Minnesota Department of Natural Resources, unpublished report) were reviewed before initiating the survey. The model incorporated MNGAP level 4 (i.e., 30-m resolution satellite imagery) land-cover data (U. S. Geological Survey 2003; Minnesota Department of Natural Resources 2004). Breeding habitat was comprised of two land-cover components:

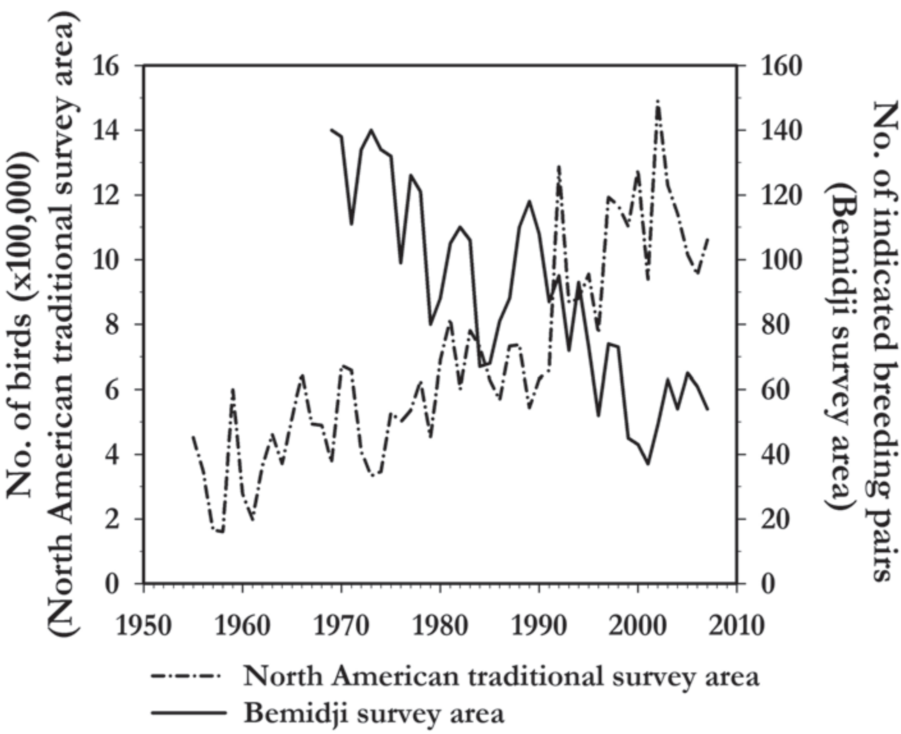

Figure 1. Number of indicated Ring-necked Duck breeding pairs counted on 10 wetlands during Minnesota's Bemidji area breeding-pair survey (1969–2007) and the number of breeding Ring-necked Ducks reported in strata 1–18, 20–50, and 75–77, of the North American Waterfowl Breeding Population and Habitat Survey (1955–2007). Data updated from Zicus *et al.* (2004) and derived from U.S. Fish and Wildlife Service (2008).

1) nesting cover and 2) near-shore water. Nesting cover included sedge meadow (MNGAP class 14) or broad-leaf sedge-cattail (MNGAP class 15) cover adjoining a patch of open water (MNGAP class 12) and within 250 m of the water. Near-shore water was any area of open water within 250 m of a shoreline. The model's stated minimum size for water patches (3.0 ha) was believed too large because Ring-necked Ducks use small water areas during the nesting season (Mendall 1958; Maxson & Riggs 1996). The minimum patch size was arbitrarily reduced to 0.63 ha because this size was believed to be more realistic.

Stratification and sampling in 2004

Public Land Survey (PLS) sections (~2.6–km^2 plots, range = 1.2– 3.0 km^2) were used as primary sampling-units because preliminary flights indicated Ring-necked Ducks could be counted on section-sized plots without redistributing them. Plots were selected using a stratified random

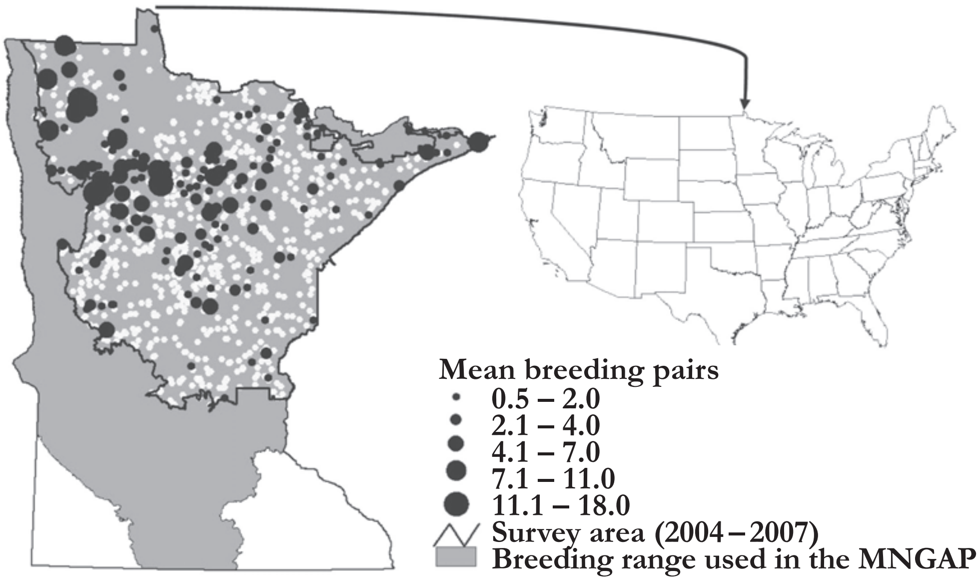

Figure 2. Minnesota Ring-necked Duck breeding range, as defined by the Minnesota Department of Natural Resources' Gap Analysis Project (grey shading), and the Minnesota survey area, June 2004–2007. Black dots indicate the location and mean number of indicated breeding pairs observed on plots during the surveys. White dots indicate plots where no pairs were seen during the surveys.

sampling design with 24 strata based on all combinations of six ECS sections and four habitat classes (representing different levels of breeding habitat defined by the habitat model). ECS sections ensured sample plots were dispersed spatially, and it was hoped that habitat classes would help increase the precision of the population estimate by focusing the sampling in areas where Ring-necked Ducks were most likely to be found. ArcInfo and ArcView software (Environmental Systems Research Institute, Inc., Redlands, California, USA) were used to assign each PLS section to one of four model-based habitat classes. Plots with at least the median amount of nesting cover were assumed to have high potential (habitat class 1) for Ring-necked Ducks with plots having some nesting cover but less than the median amount assumed to have moderate potential (habitat class 2). Plots with no nesting cover but with near-shore water were assumed to have low potential (habitat class 3), and those without breeding habitat were assumed to have no potential (habitat class 4).

Two hundred plots (determined by expected survey costs) were apportioned using the relative amounts of nesting cover within the six ECS sections, with sample plots further allocated proportionately between habitat classes 1 and 2 within each

ECS section. Sample plots were selected randomly. Plots in classes 3 and 4 were not sampled because few Ring-necked Ducks were assumed to occur on these plots. Importantly, data were recorded by quarter section within sample plots to examine the assumption about class 3 and 4 plots without spending limited resources sampling these habitat classes in the first survey year. Surveys were conducted using helicopters because the visibility of Ring-necked Ducks from fixed-wing aircraft was poor in most habitats. The locations of ducks observed during the surveys were recorded on aerial photographs; indicated breeding pairs were defined as pairs, lone males, or males in flocks of ≤5 birds. Lone females, males in flocks of >5, or birds in mixed-sex flocks were not considered to indicate breeding pairs.

Evaluating the Ring-necked Duck habitat model

A sensitivity analysis of Ring-necked Duck counts from the 2004 survey demonstrated that pairs were frequently located on class 3 and 4 plots, which had been assumed to have few if any breeding pairs. Thus, it seemed the habitat model and land cover data failed to identify class 3 and 4 plots well (Zicus *et al.* 2005). A second survey, therefore, was deemed necessary to obtain a population estimate for plots in these habitat classes. The MNGAP cover types associated with the plotted locations of all indicated pairs counted in 2004 and 2005 surveys were tabulated yearly to evaluate habitat definitions for the following year. Habitat definitions in the model were refined when needed in 2005 and 2006.

The size of any wetland basins containing Ring-necked Ducks was estimated along with the size of the actual water patch within the wetland where Ring-necked Ducks were observed. This was done because of uncertainty about the appropriate water patch size specification in the model and because little quantitative information exists for this aspect of Ring-necked Duck ecology. These estimates were made by digitising U.S. Department of Agriculture 2003 Farm Service Agency true colour aerial photography because these were the most current photos and wetland conditions in the survey area changed little during the survey years.

Surveys in 2005–2007

The 2004 survey was less expensive than anticipated, allowing 250 plots to be sampled each year in 2005–2007. For the second survey directed at class 3 and 4 habitat in 2005–2007, 20–50 class 3 and 4 plots were sampled. The remaining 200–230 plots were allocated to habitat classes 1 and 2 on the basis of relative amounts of nesting cover within each ECS section as in the first year of the survey. Sampling effort for each habitat class changed among years because the relative number of class 1–4 plots changed as a result of habitat definitions that were refined as the survey was developed.

Double sampling for stratification (Thompson 2002) was used for class 3 and 4 plots. One thousand class 3 and 4 plots were randomly selected as the first sample, disregarding ECS sections. These plots were visually inspected using 2003 Farm Service Agency photos and identified as having some or no potential for breeding Ring-necked Ducks. Plots containing any open water except for very small streams were considered as having Ring-necked Duck potential. The proportion of plots with Ring-necked Duck potential was used as an estimate of the proportion of all class 3 and 4 plots having potential for pairs. The second sample was selected randomly from the potential Ring-necked Duck plots in the first sample.

Population estimation

Habitat class 1 and 2 strata. The SURVEYMEANS procedure (SAS 1999) was used to estimate the breeding pair population size for class 1 and 2 plots by ECS section in 2004–2007 using both stratified simple random sample and ratio estimators. Ratio estimators that accounted for variable sized plots and variable amounts of within-plot nesting cover were nearly identical (point estimates and standard errors) to estimates obtained from the stratified estimator (Zicus *et al.* 2005), so we only report the later estimates.

Habitat class 3 and 4 strata. The number of pairs occupying the un-surveyed habitat class 3 and 4 plots in 2004 was estimated using a sensitivity analysis of the quarter-section level data collected in the surveyed habitat class 1 and 2 plots (see also Zicus *et al.* 2005). First, each quarter section in the surveyed class 1 and 2 plots was assigned to a habitat class using the MNGAP model. The mean number of pairs for those quarter sections classified as either habitat class 3 or 4 was determined and this number was then multiplied by the total number of quarter sections in the un-surveyed habitat class 3 and 4 plots.

The number of breeding pairs (τ) for class 3 and 4 plots in 2005–2007, when a second survey was conducted, was estimated as follows:

$$\hat{\tau} = \hat{P} * \bar{x} * N,$$

where $\hat{P}$ = proportion of plots classified as having Ring-necked Duck potential after visual inspection of the 2003 Farm Service Agency photos,

$\bar{x}$ = mean number of breeding pairs detected on sampled class 3 and 4 plots, and

N = total class 3 and 4 plots in the sampling frame.

The variance of $\hat{\tau}$ was estimated using the delta method (Casella & Berger 1990) as:

$$\hat{\text{var}}(\hat{\tau}) = N^2[\hat{P}^2 \, \hat{\text{var}}[\bar{x}] + \bar{x}^2 \, \hat{\text{var}}(\hat{P})].$$

Estimates for class 1 and 2 plots were combined with those for class 3 and 4 plots to produce a population estimate for the survey area.

Aerial visibility

Aerial waterfowl surveys usually rely on the assumption that the proportion of the population of interest observed from the air is known or can be estimated (Smith 1995). Surveys using helicopters usually assume that virtually all individuals are seen (Ross 1985; Cordts *et al.* 2002). In fact, counts of Ring-necked Duck pairs in boreal wetlands made from helicopters were similar to those made when walking around wetlands or by traversing wetlands in a canoe (Ross 1985). This assumption was also examined by comparing counts made from boats at 14 wetlands in the current Bemidji area Ring-necked Duck survey (Zicus *et al.* 2004) with counts from helicopters of these wetlands in 2004–2006.

Results

The survey was conducted from 6–17 June, 12–24 June, 6–16 June, and 5–13 June and it entailed 13, 11, 10, and 11 survey-crew days in 2004–2007, respectively. Ring-necked Ducks were observed on 327 water patches within 255 wetland basins during the 4 years. Water patches were small (median = 0.7 ha, range = <0.1–158) as were most basins (median = 8.3 ha, range = 0.1–4,048) containing them. Ducks actually observed as pairs represented 57, 36, 44, and 56% of the total indicated breeding pairs tallied in 2004–2007, respectively. In comparison, breeding pairs indicated by flocked males represented 24, 36, 27, and 20% of the total indicated breeding pairs in 2004–2007, respectively.

Refining habitat definition

The habitat model used in 2004 was untested, and model definitions of Ring-necked Duck breeding habitat were refined for 2005 based on the data gathered in 2004 (Table 1). The MNGAP open-water class alone did not adequately identify water patches where indicated pairs were seen, so a floating aquatics cover class (MNGAP class 13) was added to open water. Further, the water patch size was reduced from 0.63 to 0.18 ha (*i.e.*, the computational minimum in the GIS) and the width of near-shore water was reduced from 250 to 100 m. These changes were made because most Ring-necked Ducks were observed in very small open-water areas, and they were close to shorelines wherever they were seen.

Table 1. Habitat definitions used in the Minnesota Gap Analysis Project Ring-necked Duck habitat model during the Minnesota Ring-necked Duck breeding pair survey, June 2004–2007.

	Definitions		
Habitat component	**2004**	**2005**	**2006–2007**
Water patch cover classes[a]	Class 12	Classes 12, 13	Classes 12,13
Nesting cover classes[a]	Classes 14, 15	Classes 14, 15, 10	Classes 14, 15, 10[b]
Minimum water patch size (ha)	0.63	0.18	0.18
Width of near-shore water (m)	250	100	100

[a] Minnesota GAP level 4 land cover data. Class 10 = lowlands with <10% tree crown cover and >33% cover of low-growing deciduous woody plants such as alders and willows. Class 12 = lakes, streams, and open-water wetlands. Class 13 = water bodies whose surface is covered by floating vegetation. Class 14 = wetlands with <10% tree crown cover that is dominated by emergent herbaceous vegetation such as fine-leaf sedges. Class 15 = wetlands with <10% tree crown cover that is dominated by emergent herbaceous vegetation such as broad-leaf sedges and/or cattails. Cover is within 250 m of a water patch and adjoins the patch.

[b] Classes 10, 14, and 15 cover, associated with lakes having a General or Recreational Development classification under the Minnesota Shoreland Management Programme, were excluded when defining nesting cover in 2006 and 2007.

Table 2. Habitat classes assigned to Public Land Survey (PLS) plots, survey area composition, and corresponding sample sizes in the Minnesota Ring-necked Duck breeding pair survey, June 2004–2007.

Habitat class	Definition[a]	% of survey area[b]			No. of sampled PLS plots		
		2004	2005	2006–2007	2004	2005	2006–2007
1	Plots with ≥ the median amount of Ring-necked Duck nesting cover (*i.e.* high pair potential).	15.3	24.5	21.5	105[c]	117[c]	102[c]
2	Plots with < the median amount of Ring-necked Duck nesting cover (*i.e.* moderate pair potential).	15.3	24.5	21.5	95[c]	113[c]	98[c]
3	Plots with Ring-necked Duck breeding habitat but no nesting cover (*i.e.* low pair potential).	25.2	7.7	13.5	0	20[d]	50[d]
4	Plots with no Ring-necked Duck breeding habitat (*i.e.* believed to have no pair potential).	44.2	43.3	43.5	0		

[a] Plots are Public Land Survey sections and quarter sections. Breeding habitat can include nesting cover or near-shore water or both.
[b] Percent of the survey area. Relative composition changed annually as habitat definitions were refined.
[c] PLS sample plots were apportioned among the six Ecological Classification System sections using the relative amounts of nesting cover within the six sections.
[d] Based on double sampling for stratification where 1,000 class 3 and 4 plots were randomly selected as the first sample (disregarding Ecological Classification System sections), and the second sample was selected randomly from the potential Ring-necked Duck plots in the first sample (see Methods).

Nesting cover was also redefined in 2005 to include lowland deciduous shrub cover (MNGAP class 10) because many Ring-necked Ducks were seen in wetlands surrounded by this type of vegetation.

Observations from the 2004 and 2005 surveys supported the belief that breeding Ring-necked Ducks do not generally occupy lakes with game fish or those with seasonal and permanent shoreline dwellings. These lakes are typically classified as General or Recreational Development under the Minnesota Shoreland Management Programme (Minnesota Department of Natural Resources 2006c), and a GIS layer was constructed to remove this cover when quantifying breeding habitat in 2006 and 2007 (Table 1).

Changes that were made to the MNGAP model used in 2004 also affected the habitat class composition of the survey area, and the relative sampling effort was adjusted annually to address these changes (Table 2).

Observed distribution and estimated population size

Ring-necked Ducks were observed throughout the survey area (Fig. 2). The median sampling rate for plots in habitat classes 1 and 2 was 1.4% in 2004 and 1.0% in 2005–2007. Habitat class 3 and 4 plots were not sampled in 2004, but ~0.3% of these plots was sampled in 2005–2007. The estimated breeding pair population for the entire survey area was 19,535 in 2004, but this number is not directly comparable with estimates for 2005–2007 (Table 3) because the class 3 and 4 estimate was based on the sensitivity analysis of quarter-section data from the surveyed class 1 and 2 plots. Estimated population size in 2005–2007 ranged from a low of 11,328 breeding pairs in 2005 (90% confidence interval = 5,359–17,298) to a high of 15,631 in 2006 (11,221–20,041). Importantly, the numbers of pairs estimated for habitat class 3 and 4 plots declined from ~52% of the overall estimate in 2004 to an average of ~8.5% in 2006–2007, and the coefficient of variation for the overall estimate declined from 32% in 2005 to an average of ~17% in 2006 and 2007.

Aerial visibility

Counts from boats in the Bemidji area Ring-necked Duck survey generally agreed with aerial counts on the same wetlands (Fig. 3). Boat counts in 2004 were conducted from 14–18 June and the aerial survey of these wetlands was on 17 June. In contrast, boat counts in 2005 were conducted from 15–21 June with the aerial surveys made on 24 June. In 2006, boat counts were conducted from 8–13 June with the aerial survey flown on 12 June. Poorer agreement between the two surveys in 2005 was likely due to the greater time that had elapsed between the boat counts and aerial surveys.

Discussion

Ring-necked Ducks occurred throughout the survey area, which corresponded roughly with Minnesota's forested region. Densities were modest except in localised areas, being generally greater in the western ECS sections and lower in the eastern sections. The Ring-necked Duck was believed to be Minnesota's second most abundant forest-breeding duck as recently as the 1960s (Moyle 1964), ranking behind only

Table 3. Estimated number of Ring-necked Duck breeding pairs in the Minnesota survey area, June 2004–2007.

				Indicated breeding pairs	
Year	**Habitat class**	**Estimator**	**No. of pairs**	**(90% confidence interval)**	**CV(%)**
2004	1,2	Stratified random	9,443	(6,667 – 12,220)	17.8
	3,4	Sensitivity analysis[a]	10,092		
	1,2,3,4	Total	19,535		
2005	1,2	Stratified random	7,496	(5,022 – 9,971)	20.0
	3,4	Two-phase simple random	3,832	(7 – 9,269)	86.3
	1,2,3,4	Total	11,329	(5,359 – 17,298)	32.0
2006	1,2	Stratified random	14,770	(10,465 – 19,076)	17.6
	3,4	Two-phase simple random	861	(3 – 1,908)	74.0
	1,2,3,4	Total	15,631	(11,221 – 20,042)	17.2
2007	1,2	Stratified random	12,787	(9,049 – 16,525)	17.7
	3,4	Two-phase simple random	1,721	(267 – 3,176)	51.4
	1,2,3,4	Total	14,508	(10,514 – 18,503)	16.7

[a] Sensitivity analysis estimate based on data assigned to quarter sections within the sampled habitat class 1 and class 2 survey plots.

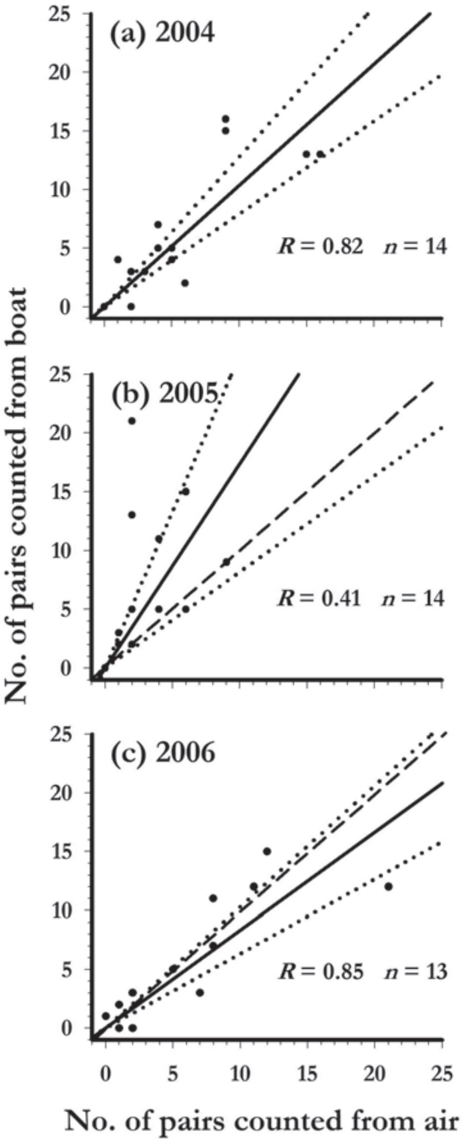

Figure 3. Regression lines (solid lines) and 95% confidence bands (dotted lines) comparing the numbers of indicated breeding pairs of Ring-necked Ducks counted from a boat and from the air on 14 wetlands during the Bemidji area Ring-necked Duck survey, June 2004–2006. Dashed lines indicate equal boat:air counts.

the Mallard *Anas platyrhynchos*. This relative rank is now unlikely. The local Bemidji area Ring-necked Duck survey has been conducted since the late 1960s in the core Ring-necked Duck range, where the highest breeding pair densities were observed in this helicopter survey. If a trend similar to that observed in the Bemidji area survey (*i.e.*, ~70% decline) has occurred throughout Minnesota's forested regions, the state's breeding Ring-necked Ducks have declined substantially. Other waterfowl species have not been surveyed throughout the forested region, but numbers of breeding Wood Ducks *Aix sponsa* have increased in the north central parts of the United States since the 1960s (Bellrose & Holm 1994), and Mallard numbers in southern and western Minnesota have increased during this period as well (Minnesota Department of Natural Resources 2007). As a result, Wood Duck and Mallard are now likely the most abundant breeding duck species in Minnesota's forested region. We believe that the Ring-necked Duck is now far less common and that it ranks among Common Goldeneye *Bucephala clangula*, Blue-winged Teal *Anas discors*, and perhaps Hooded Merganser *Lophodytes cucullatus* in abundance.

Ring-necked Ducks were observed on small wetlands bordered by emergent and floating vegetation dominated by sedges (Cyperaceae), grasses (Gramineae), and cattails *Typha* sp. Water-tolerant woody species such as Speckled Alder *Alnus rugosa*, Swamp Birch *Betula pumila*, willows *Salix* sp., Black Spruce *Picea mariana*, and Tamarack *Larix laricina*, while often present in the bog-like margins, were not a dominant component of the wetland shoreline.

Breeding Ring-necked Ducks used similar wetlands in Maine (Mendall 1958) and in a small study area at the western edge of the survey area (Maxson & Riggs 1996). Historically, these wetland types and their surroundings have been a low conservation priority in Minnesota, but their value and the need for regulatory protection has received more recognition recently (Minnesota Forest Resources Council 2007). Ring-necked Ducks were never observed on streams, even if they had riparian borders similar to those around wetlands on which breeding pairs were observed.

Existing waterfowl data from southern and western Minnesota (D. Hertel, U.S. Fish and Wildlife Service, unpublished data) were useful as a starting point to identify portions of the MNGAP breeding range that had few if any Ring-necked Ducks and to define an appropriate sampling frame. Likewise, the untested MNGAP model allowed stratification of the survey area despite limitations that became obvious during survey development. MNGAP satellite imagery was acquired in 1992 (Minnesota Department of Natural Resources 2004) as the State recovered from severe drought (Minnesota Department of Natural Resources 1989). Lingering drought effects caused some cover types to be misclassified because the imagery did not detect small water patches important to Ring-necked Ducks. This shortcoming combined with incomplete habitat definitions initially caused inappropriate habitat classes to be assigned to some survey plots.

An important feature of adaptively developed surveys, and one that is often unappreciated, is that the initial data need not produce a valid population estimate or meet other survey objectives. Sampling was restricted in 2004 to plots where assumed Ring-necked Duck nesting cover existed (*i.e.*, habitat classes 1 and 2), which provided much needed information on the relative distribution of Ring-necked Ducks but resulted in a biased population estimate. Data collection at two scales (*i.e.* PLS quarter section and section) allowed a sensitivity analysis to evaluate the assumption regarding class 3 and 4 plots and to provide a rough population estimate for class 3 and 4 plots. Refined definitions of Ring-necked Duck habitat and resulting survey changes reduced the bias and variance of subsequent estimates.

Initially, appropriate survey timing was also unknown because waterfowl breeding chronology varies widely among species and locations. For dabbling ducks, survey timing is often considered optimal when the ratio of pairs to lone males to flocked males that indicate breeding pairs is 1: 1: 1 (U.S. Geological Survey 2006). However, Ring-necked Duck sex ratios are often skewed compared to dabbling ducks (Bellrose *et. al* 1961). This survey was conducted in mid-June because Ring-necked Duck nest establishment peaks towards the end of May in Minnesota (Hohman & Eberhardt 1998). Survey timing proved to be appropriate because an average 50% of the estimated total indicated breeding pairs were counted as actual paired birds and 26% as pairs indicated by flocked males. Survey timing for ducks is generally considered optimal when most birds are counted as pairs and not in flocks (Smith 1995). Survey timing could have been changed using the adaptive approach that was employed had there been a need.

This survey provided much needed information regarding both the spatial distribution and abundance of Ring-necked Ducks. Unfortunately, a single survey is unlikely to address both objectives equally well (Conroy & Smith 1994). Through the changes that were made, the breeding pair estimates became more precise and adequate for preliminary surveys (*i.e.* CVs < 25%; Krebs 1999), but increased precision would be needed for management decisions requiring detection of population trends (Krebs 1999; Gibbs 2000). This objective would be best accomplished by periodically re-sampling the same plots (Kish 1987), an approach similar to that used in the Bemidji area survey but on a much larger scale. Although the Bemidji area survey suggests Ring-necked Ducks have been declining significantly, estimates of range-wide trends from surveys with limited extents can sometimes be misleading (Villard *et al.* 1998; Gibbs 2000; Holt & Keitt 2005). Additional gains in precision could be realised by increasing the sample size, through more focused sampling, or by reducing the population sampling frame to exclude difficult areas to survey or those unlikely to contain Ring-necked Ducks. In this survey, plots in northeastern Minnesota could be eliminated because they are remote, proved to be expensive to survey, and had few breeding pairs. Lastly, although aerial counts agreed well with boat counts on wetlands in the Bemidji area, future-planning efforts should consider whether collecting additional information and adjusting for detection is likely to be cost-effective in helping to achieve long-term survey goals (Johnson 2008).

Lack of knowledge about a species can often hamper design of an efficient and appropriate survey. In such cases, pilot studies are a logical first step (Garton *et al.* 2005). Management agency decisions can preclude an adaptive approach to survey development because of perceived expense or the belief that the immediate need for population data is paramount. Such decisions may come with unappreciated risks and costs. Surveys providing reliable estimates of population abundance and distribution across time and space require careful development. If target populations are not defined thoughtfully and sample sizes are inadequate, survey results can be uninformative at best or misleading at worst. Most wildlife surveys rely on key assumptions about habitat associations or animal detection. Surveys need to be designed so that these assumptions can be evaluated even if estimates from the initial surveys are unreliable. The additional expense associated with adaptively developed surveys will be almost certainly trivial considering expected data improvements and the duration of operational surveys.

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