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Breeding Season Survival of Female Lesser Scaup in the Northern Boreal Forest

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ABSTRACT. One hypothesis advanced to explain the decline in lesser scaup (*Aythya affinis*) populations during the past 20 years is that adult female survival has decreased. However, no survival probability estimates exist for the boreal forest, the region where most scaup breed. We captured and radio-marked female lesser scaup (n = 42) near Yellowknife, Northwest Territories, Canada, just before the breeding season in 1999 and 2000. Constant weekly survival probability was estimated using a Cormack-Jolly-Seber model (0.96). We extrapolate this rate to estimate survival probability for the nesting season (0.80, SE = 0.09), the period when females are at greatest risk of predation. Recent estimates of annual mortality (42%) suggest that about 50% of annual female mortality occurs during the breeding season, a result similar to recent conclusions from studies of prairie-nesting lesser scaup. Further, our survival estimate provides information required to produce preliminary models of population dynamics for boreal lesser scaup, a step that could greatly improve our understanding of decline in this species.

Key words: *Aythya affinis*, lesser scaup, boreal forest, breeding season survival, recapture probability, survival probability

RÉSUMÉ. Une hypothèse qui a été avancée pour expliquer le déclin des populations du petit fuligule (*Aythya affinis*) au cours des 20 dernières années est que la survie de la femelle adulte a baissé. Il n'existe cependant aucune estimation de la probabilité de survie pour la forêt boréale, région où se reproduisent la plupart des fuligules. Juste avant la saison de reproduction en 1999 et 2000, on a capturé, près de Yellowknife dans les Territoires du Nord-Ouest, des fuligules femelles (n = 42) qu'on a équipées de radio-émetteurs. À l'aide du modèle de Cormack-Jolly-Seber, on a estimé la probabilité de survie hebdomadaire (0,96) sur une base constante. On a extrapolé ce taux pour estimer la probabilité de survie pour la saison de reproduction (0,80, erreur-type = 0,09), période qui représente pour les femelles le plus grand risque de prédation. De récentes estimations de la mortalité annuelle (42 %) suggèrent qu'environ 50 % de cette dernière chez la population femelle se produit durant la saison de reproduction, ce qu'on retrouve aussi dans les résultats d'études récentes sur le fuligule nichant dans la prairie. De plus, notre estimation de la survie offre des renseignements qui sont nécessaires à l'élaboration de modèles préliminaires de la dynamique des populations chez le fuligule boréal, une étape qui permettrait d'améliorer considérablement notre compréhension du déclin de l'espèce.

Mots clés: *Aythya affinis,* fuligule, forêt boréale, survie durant la saison de reproduction, probabilité de recapture, probabilité de survie

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INTRODUCTION

Although more than 60% of North American lesser scaup (*Aythya affinis*; hereafter scaup) now breed in the boreal forest (Austin et al., 2000), this portion is the result of persistent decline over the past 20 years (Wilkins et al., 2001). Furthermore, proportions of female and young lesser scaup in the U.S. harvest also declined during this period (Allen et al., 1999), suggesting a decline in female survival, reproductive success, or both (Afton and Anderson, 2001). Several hypotheses have been advanced to explain the decline, but basic information about the portion of the population breeding in the boreal forest is lacking. One explanation is that increasing concentrations of toxic environmental contaminants in lesser scaup caused a decline in female fitness. Another suggests that a decline in food quality and abundance caused declines in productivity and survival (Austin et al., 2000; Afton and Anderson, 2001).

Variation in survival through the breeding season is known to be an important influence on population growth rates for relatively short-lived duck species like lesser scaup. Breeding-season survival has been ranked very highly as an influence on population growth rates, not only for lesser scaup (Allen et al., 1999; Koons, 2001), but also for prairie-breeding mallard (*Anas platyrhynchos*) females (Hoekman et al., 2002) and northern pintail (*Anas acuta*) breeding in boreal forest habitat in Alaska (Flint et al., 1998). Estimates of breeding-season survival are needed to further assess these hypotheses about scaup population

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decline (Allen et al., 1999; Afton and Anderson, 2001) and to develop population models that may be important to help understand the causes of decline (Horvitz et al., 1997; Caswell, 2000). Because such estimates are not available for boreal-breeding scaup, our objective was to estimate the survival probability of female scaup breeding in the northern boreal forest of western Canada.

STUDY AREA

Work was conducted approximately 16 km northwest of Yellowknife, Northwest Territories, Canada (62˚ N, 114˚ W). The 30.4 km^2 study area extended 48 km along Highway 3, encompassing 400 m on each side (Fournier and Hines, 1999). It is located in the transition zone between the taiga plain ecozone to the south and the taiga shield to the northeast (Ecoregions Working Group, 1989). Exposed rock outcrop covered about 25% to 30% of the landscape and was interspersed with stands of jack pine (*Pinus banksiana*), birch (*Betula papyrifera*), and aspen (*Populus tremuloides*) in dry areas and spruce (*Picea* spp.) in moister areas (Trauger, 1971). Wetlands, both natural and artificial, dominate the study area (575 wetlands on the 30.4 km^2 study area). Natural wetlands (262) range from less than 0.1 to 18.2 ha in area and borrow pits (313), built during highway construction in the 1960s, range from less than 0.1 to 1.1 ha. Willow (*Salix* spp.) is commonly found near the margins of natural and artificial wetlands. Floating sedge (*Carex* spp.) mats completely surrounding the open water characterize the natural wetlands, while other emergent vegetation, such as cattail (*Typha latifolia*) and horsetail (*Equisetum* spp.), dominates the borrow pits.

METHODS

We used floating decoy traps (Anderson et al., 1980) with live, captive lesser scaup females to capture wild females in May and June 1999 and 2000, prior to egg laying. Mean clutch initiation date was in mid-June in both years (Brook, 2002). The earliest initiation date recorded was 5 June (Brook, 2002). In 1999, we marked each female with a vinyl nasal saddle displaying a unique alphanumeric code, attached through the nares with a nylon pin (modified from Sugden and Poston, 1968). In 2000, we used unique colour and shape combinations of nylon nasal discs, attaching them through the nares with stainless steel pins (Lokemoen and Sharp, 1985; Howerter et al., 1997). Each female was also equipped with a 5.5 g radio transmitter (model RI-2B, Holohil Ltd., Carp, Ontario, Canada) implanted subcutaneously on the back, between and posterior to the scapulars, under local anesthetic (Custer et al., 1996; Brook and Clark, 2002). Radio-marked birds were located using telemetry every one to three days. A visual observation was attempted once a week, or when repeated telemetry fixes in the same location caused us to suspect that a bird was either nesting or dead. Three or four times per season, we located females on nearby molting grounds outside the study area by using radio telemetry from a boat or aircraft.

Statistical Analyses

We used the program MARK (White and Burnham, 1999) to estimate apparent survival and recapture probabilities for six 7-day intervals (from 26 May to 6 July each year), basing our estimate on a Cormack-Jolly-Seber (CJS) model (Pollock et al., 1990; Lebreton et al., 1992). We used the CJS model rather than a known fate model because the fate of each female was not known at each recapture period. Known fate models assume that the fate of each individual is known for each recapture period, though there is some latitude in this assumption (White and Burnham, 1999). The CJS model also allows estimation of the recapture rate, which is not available when using known fate models for analysis. The terrain and long, narrow shape of the study area made consistent recapture difficult even though females were radio-marked and lesser scaup have a relatively small home range (Austin et al., 1998). The study period included pre-nesting, egg-laying, and incubation (Trauger, 1971; Brook, 2002), stages when breeding female ducks are known to be at high risk of mortality (Sargeant and Raveling, 1992; Greenwood et al., 1995).

Apparent survival is the probability that a female alive at encounter period t is alive and present on the study area at encounter period $t + 1$. Recapture probability is the probability a female alive at t is seen (recaptured) at $t + 1$. We used staggered entry to construct encounter histories, and right-censored histories when females permanently left the study area and were observed alive on nearby molting areas. Data from the two years were pooled prior to analysis. As data were limited, we restricted our analysis to one simple model: constant weekly survival and recapture probability. Estimation of additional parameters (e.g., fluctuating weekly survival and recapture probability) was not justifiable given data limitations.

We evaluated goodness of fit using a parametric bootstrap routine in Program MARK (Arnold et al., 2002). We performed 1000 simulations, ranked them by model deviance, and calculated the percentage of simulations that had a larger deviance than the original model. A variance inflation factor (c-hat) was used to correct for overdispersion. This factor was calculated by dividing model deviance by the average deviance derived via bootstrapping. Period survival was calculated by raising the constant weekly survival estimate to the power of the number of observation intervals. We calculated standard errors using the delta method (Seber, 1973).

The project was approved by the University of Saskatchewan protocol review committee on animal care and supply (19990006), Environment Canada (CWS99-S003), and the Government of the Northwest Territories (WL002068, WL002753).

RESULTS

Forty-seven scaup were radio-marked, 12 in 1999 and 35 in 2000. Five females not seen again after marking were assumed to be migratory and omitted from analyses. We used encounter histories of 42 females (26 adults, 16 yearlings) to estimate apparent survival and recapture probability. Eight females were missing during one recapture period and were later recaptured, and another three were missing for two or more (range 2–3) recapture periods and were later recaptured. At the last recapture date, fates were known for 31 females, including six that were recovered dead during the study period. The time when 11 females missing at a previous recapture period were each presumed to have emigrated permanently from the study area varied from the third to the seventh recapture period. Of these 11 females, six were confirmed alive on nearby molting areas and their encounter histories were censored. The fate of the five remaining females was unknown.

From the appearance of the carcasses (all were partly eaten when found), we assumed that predation was the cause of death for all six females recovered dead, though we could not determine whether they had been scavenged by predators after dying of other causes. One female was known to have been incubating eggs prior to death, and three others had a localized pattern of habitat use, similar to that of females known to nest, as indicated by repeated telemetry locations. Breeding status of the two remaining dead females was unknown.

The constant-survival-and-recapture model fit the data marginally well ($p = 0.08$, c-hat = 1.21, QDev. = 69.80, 2 parameters). Apparent weekly survival probability was 0.964 (95% CI = 0.911–0.986), with a recapture probability of 0.879 (95% CI = 0.811–0.925). Scaup female survival probability, extrapolated from the weekly survival estimate for a 42-day period during breeding (26 May to 6 July), was 0.80 (SE = 0.09).

DISCUSSION

Our estimate of probability of female scaup survival during the breeding season was similar to or higher than estimates by Rotella et al. (2003; 0.82 ± 0.12 [SE], apparent survival) and Koons (2001; 0.72, true survival), suggesting similar survival probability throughout the scaup breeding range. Assuming that annual adult female survival is 0.58 (Rotella et al., 2003), about 50% (0.20/0.42) of total annual mortality of boreal-nesting scaup occurred during the breeding season. This percentage is comparable to the 42% estimated by Rotella et al. (2003) for breeding females in the aspen parkland of Canada. If this assumption is true, adult female breeding-season survival is likely an important factor influencing scaup population dynamics, as suggested for northern pintails nesting in Alaska (Flint et al., 1998). Spatiotemporal variation in survival probability is unknown for scaup; nevertheless, breeding-season survival could be important for population growth, as suggested by recent analyses of mallard population dynamics (Hoekman et al., 2002).

Estimates of apparent survival are, to some degree, confounded with permanent emigration because the two cannot be separated using CJS models (Lebreton et al., 1992; White and Burnham, 1999). However, we believe our estimates of apparent survival were comparable to true survival because, by using radio telemetry from aircraft and boat during and after the estimation period, we determined that half the females whose fate was unknown during the last recapture period were alive on nearby molting areas. Therefore we censored their recapture histories to account for this. The fates of only 12% of the females remained unknown at the last recapture period. The validity of our results also rests on the premise that trapping, handling, and marking (radio plus nasal tag) females had no adverse effects on survival probability. We do not believe that these procedures had a large impact on survival or behavior of females (Brook and Clark, 2002), but subtle effects likely exist (Murray and Fuller, 2000). If our methods had a deleterious effect on survival, the estimates of survival probability may be negatively biased. Conversely, if breeding probability and renesting were reduced in response to our interference, then estimates may be positively biased because non-nesting females may be less vulnerable to predation (e.g., Dufour and Clark, 2002). Continued assessment of the effects of trapping and marking are needed and should be a part of all waterfowl telemetry studies.

The applicability of survival estimates to surrounding areas depends on the degree to which those estimates are biased by unique local conditions. Our study area may support a higher density of predators because it is close to the city of Yellowknife (about 18 000 people, 16 km from the nearest boundary of the study area and 30 km from its core). Unfortunately, the density of predator species on the study area or for surrounding areas in the boreal forest is unknown, so we cannot speculate on the magnitude of a potential bias in our survival estimate. Because the city (and its garbage) likely support higher densities of both nesting-female predators (red fox, *Vulpes vulpes*) and nest predators (common raven, *Corvus corax*), which have possible opposite effects on survival rate, we cannot speculate on the direction of the difference between our survival estimates and those for other areas either.

There were no previous estimates of breeding survival probability for boreal scaup in this area, so we could not determine whether rates had changed. However, these rates provide a basis for preliminary population models (Brook, 2002) and can help direct further research. Results of this study suggest the need for further research on survival and other vital rates (e.g., breeding propensity, nesting success, and duckling survival) of boreal scaup. Analysis of survival covariates (female age, female size, breeding status) would also greatly contribute to our knowledge of scaup population dynamics. Indirect evidence of temporal variation in local predator abundance through predator-prey cycling (Brook et al., in press) also indicates the need for estimates of vital rates from other areas. We require a more comprehensive understanding of spatiotemporal variability and factors affecting survival, together with an improved understanding of other vital rates, to adequately model scaup population dynamics (Austin et al., 2000).

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