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Estimation of Female Home-range Size During the Nestling Period of Dark-eyed Juncos

Dustin G. Reichard^{1,2} and Ellen D. Ketterson¹

ABSTRACT.—Studies of spatial activity of songbirds during the nesting cycle have largely focused on male activity and neglected female space use, particularly outside the fertile period. We estimated the home-range size of seven female Dark-eyed Juncos (*Junco hyemalis*) 3 days after their nestlings had hatched. We used radiotelemetry to track female movements for 2 hrs on the afternoon of day 3 of nestling life, and 2 hrs on both the morning and afternoon of days 4 and 5. Female location and behavior were recorded every 10 min for the

duration of tracking. Females exhibited a mean home-range size of 0.833 ha (range = 0.156–2.450 ha). Our estimate of home-range size during the nestling period was significantly smaller than a previous estimate of female home-range size during the fertile period in the same junco population. Home-range size varied greatly between individuals, and the observed differences may be attributable to variation in resource availability. Received 2 November 2011. Accepted 25 February 2012.

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The home-range size of temperate songbirds (Passeriformes) during the breeding season can have profound effects on access to resources and

reproductive success of both males and females (Zack and Stutchbury 1992, Both and Visser 2000, Rolando 2002). Males defend territories with song and active monitoring, presumably to protect resources for their offspring and to guard against extra-pair fertilizations (EPFs), while also moving outside of their defended territory to potentially seek their own EPFs or other resources (Møller 1987, 1991). Males of most socially monogamous species also contribute to care of young, but females often perform a larger portion of parental care including incubation, brooding, and provisioning (Trivers 1972, Bennett and Owens 2002). Male spatial activity and home-range size, despite differing in territorial and parental behavior from females, have received much more attention than female home-range size, particularly during incubation and nestling provisioning (Whitaker and Warkentin 2010).

Female songbirds encounter a variety of challenges during the nesting cycle. Females are not limited in use of space by incubation or nestling care during their fertile period and should have their largest home ranges at that time (Møller 1987, 1990). Females of many species are known to undertake 'forays' outside of their mate's territory in addition to foraging and nest building during the fertile period, potentially resulting in EPFs as well as female home ranges that are much larger than territories defended by their social mates (Neudorf et al. 1997, Pedersen et al. 2006, Stapleton and Robertson 2006, Evans et al. 2008; but see Akçay et al. 2011).

Female home-range size is predicted to decrease as incubation begins as females no longer seek copulations and make shorter movements off the nest to forage and engage in nest defense. However, the abundance and proximity of resources to the nest can affect home-range size, and females may maintain larger home ranges depending on food availability (Møller 1990). The subsequent transition from eggs to nestlings marks a period of increased effort as females begin to forage for nestlings in addition to themselves and may continue to devote a large amount of time to brooding. This increase in time spent foraging during the early nestling period predicts an increase in female activity but presents contrasting predictions about home-range size. Females may forage close to the nest and maintain smaller home ranges than during the fertile period to minimize energy expenditure and maximize time spent regulating nest temperature through brood-

ing, which can impact nestling fitness (Dawson et al. 2005, Butler et al. 2009). Conversely, females may increase their home-range size to use a variety of foraging locations or to gather higher quality food items (Zach and Falls 1979, Grundel 1992, Garcia-Navas and Sanz 2010).

We quantified female home-range size during the nestling period for Dark-eyed Juncos (*Junco hyemalis*) to examine if female home-range size declines between the fertile and nestling periods. We compared our home-range estimate to previously published data from Neudorf et al. (2002), collected from the same junco population, which estimated female home-range size during the fertile period.

METHODS

Study System and Site.—This research was conducted at Mountain Lake Biological Station (MLBS) and adjacent grounds of Mountain Lake Hotel in Pembroke, Virginia (Giles County; 37° 22' N, 80° 32' W), USA between 29 April and 24 July 2007. Vegetation on the study site was largely mixed deciduous and coniferous forest that supports an abundant population of Dark-eyed Juncos (*J. h. carolinensis*) (Chandler et al. 1994). All juncos on the study site received unique color bands and the population has been continuously monitored since 1983.

Dark-eyed Juncos are socially monogamous (28% of 187 offspring sampled in our study population were sired by an extra-pair father, Ketterson et al. 1998) and only females incubate and brood while both sexes contribute to provisioning of nestlings (Nolan et al. 2002). Juncos spend the majority of the breeding season near the ground as they are a ground-nesting species and forage for seeds and insects in the leaf litter as well as in the understory vegetation (Nolan et al. 2002).

Radiotelemetry.—Radiotelemetry has been used in previous studies to monitor activity of both male and female juncos (Chandler et al. 1994, 1997; Smulders et al. 2000; Neudorf et al. 2002). We used a modified leg-loop harness (Rappole and Tipton 1991) to attach BD2A transmitters (Holohil Systems Ltd., Woodlawn, ON, Canada) to seven female juncos in the morning (0500–1000 hrs EST) when their nestlings were 3 days post-hatch. The average (\pm SE) combined weight of the transmitter and harness was 0.9 ± 0.005 g and average female mass was 21.5 ± 0.38 g. We tracked females opportunistically to maximize our sample and all

TABLE 1. Home-range size of female Dark-eyed Juncos and metrics of tracking effort and female characteristics, Mountain Lake Biological Station, Pembroke, Virginia, USA. The effect of implant type was tested using a Kruskal-Wallis test (χ^2). All other relationships were tested using a Spearman's Rho Correlation (r).

Home-range size (ha)	No. of locations	Tracking time (hrs)	Julian date	Age	Nesting attempt	Implant
0.156	53	8.17	202	2	4	Control
0.350	65	10.00	149	1	1	Control
0.390	62	9.84	197	1	3	Control
0.613	65	10.00	188	1	3	Testosterone
0.657	59	9.00	150	1	1	Testosterone
1.215	65	10.00	175	4	2	Control
2.450	65	10.00	189	1	1	None
r or χ^2	0.493	0.493	-0.214	-0.045	-0.543	2.89
P	0.261	0.261	0.645	0.924	0.208	0.235

females receiving transmitters had a brood size of three.

We used a TRX 1000-S receiver with a three-element Yagi antenna (Wildlife Materials Inc., Carbondale, IL, USA) to track each female via homing for 10 hrs, 2 hrs on the afternoon of day 3 of nestling life (1300–1800 hrs EST) and 2 hrs on the morning (0800–1200 hrs EST) and afternoon (1300–1800 hrs EST) of days 4 and 5 of nestling life. We did not track during periods of heavy rain and collected <10 hrs of data for three females (mean = 9.56 hrs, range = 8.17–10.0 hrs). Transmitters were removed on the morning of day 6 of nestling life. We chose to track during the early-to-mid nestling period (nestling juncos typically fledge at 11–12 days post-hatch) as opposed to the mid-to-late nestling period in an effort to maximize our sample as nests are frequently depredated even after reaching the nestling stage. We only sampled females for 3 days to limit the amount of time that each female carried the transmitter and to ensure the transmitters could be removed without fledging the nestlings early.

DGR recorded female location and behavior every 10 min for the duration of tracking. We marked location points with flagging tape after the female had moved at least 15 m distant to avoid affecting the female's movements. The 10-min interval between observation points was chosen to ensure our total number of observation points ($n = 65$) per female was similar to the mean number of points per female reported by Neudorf et al. (2002; 71.5 points/female) to facilitate a meaningful comparison of home-range size between our studies.

Six of the seven females received a subcutaneous implant on the left flank, consisting of a 7-mm (1.47 mm internal diam, 1.96 mm outside diam)

Silastic® tube (Dow Corning Corp., Midland, MI, USA) filled with 5 mm (~ 0.1 mg) of crystalline testosterone (Sigma-Aldrich Inc., St. Louis, MO, USA) or an empty tube filled with air as part of a separate study investigating the impact of elevated plasma testosterone on female reproductive behavior (O'Neal et al. 2008). Implants were inserted at least 2 weeks prior to attachment of a transmitter to allow females to recover and adjust physiologically to the implant. Female juncos receiving implants in this study and previous studies had full mobility immediately after implantation and remained active breeders for the duration of the breeding season, suggesting the implantation process had limited effects on the activity of our subjects (Clotfelter et al. 2004, O'Neal et al. 2008). Previous studies of the effect of elevated testosterone on male spatial activity successfully implanted males with larger testosterone implants than those used in our study and attached transmitters of a similar size without any noticeable adverse effects on male body mass, activity, or survival (Chandler et al. 1994, 1997; Smulders et al. 2000). All methods used were reviewed and approved by the Indiana University, Bloomington, Institutional Animal Care and Use Committee (BIACUC Protocol # 06-242) prior to data collection.

Estimating Home-range Size.—We attempted to obtain 65 observation points for each female (Table 1), which were translated into coordinates using a Trimble Pathfinder Pro XRS Global Positioning System (GPS) unit (Trimble Navigation Limited, Sunnyvale, CA, USA) with an accuracy of <1 m. GPS positions were differentially corrected using GPS Pathfinder Office 2.90 (Trimble Navigation Limited, Sunnyvale, CA, USA) with correction data from the Blacksburg,

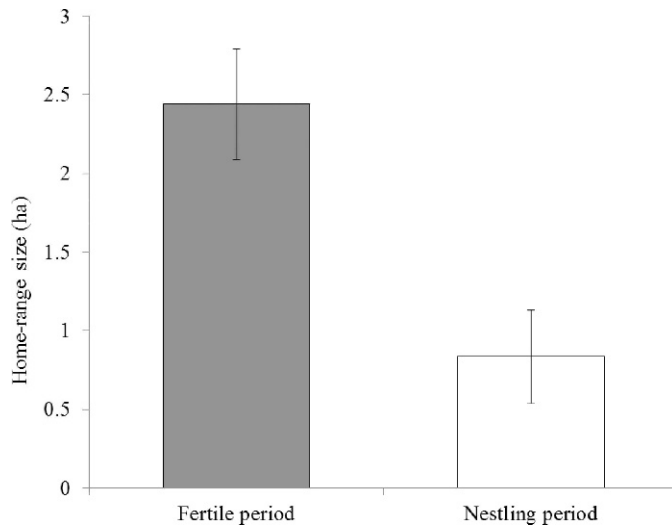


FIG. 1. Female Dark-eyed Junco home-range size during the fertile and nestling periods. There was a significant difference in female home-range size between periods ($P = 0.011$; fertile period, $n = 8$; nestling period, $n = 7$). Error bars represent ± 1 SE. Fertile period data from Neudorf et al. (2002).

Virginia base station ($37^{\circ} 12' N$, $80^{\circ} 25' W$). The corrected coordinates were projected in shapefile format into Universal Transverse Mercator (UTM) zone 17, NAD 83, using the Geographic Information System (GIS) Program ArcGIS 9.2 (ESRI 2007). A home-range area (in ha) for each female was estimated using minimum convex polygons (MCP) in Hawth's Tools 3.26 (Beyer 2004).

The MCP method (Harris et al. 1990 provides a comparison of common methods of home-range estimation) was chosen to allow for an equivalent comparison with previously published data on female home-range size during the fertile period (Neudorf et al. 2002). We used a nonparametric Mann-Whitney U -test to compare home-range sizes, and a Spearman's Rho Correlation to test for relationships between home-range size and methodological effects. A Kruskal-Wallis test was used to examine differences between implant types. All tests were performed in SPSS 11.5 (SPSS 2002).

RESULTS

We had an average of 62 (range = 53–65) observation points per female, and the total number of observation points did not correlate with home-range size ($r = 0.493$, $P = 0.261$; Table 1). We found substantial variation (mean \pm SD) in female home-range size during the nestling period with females maintaining a mean home range of 0.833 ± 0.788 ha (Table 1). Home-range size was not significantly correlated with duration

of tracking ($r = 0.493$, $P = 0.261$), Julian date ($r = -0.214$, $P = 0.645$), female age ($r = -0.045$, $P = 0.924$), or nesting attempt ($r = -0.543$, $P = 0.208$) (Table 1). We were unable to make strong statistical comparisons about the effect of elevated testosterone on female home-range size due to our small sample size (testosterone-implant = 2, control-implant = 4) and a low effect size (Observed Effect Size [δ] from Retrospective Power Analysis = 0.050). The two females that received testosterone implants had intermediate size home ranges, and did not differ detectably from females receiving control implants (Table 1; $\chi^2 = 2.89$, $P = 0.235$).

DISCUSSION

Female home range was significantly smaller during the nestling period than during the fertile period when comparing our data to Neudorf et al.'s (2002) fertile period home-range estimate collected at the same study site from different individuals (Fig. 1; $Z = 0.008$; $P = 0.011$). We collected a mean of 62 (range = 53–65) observation points per female, similar to the number collected by Neudorf et al. (2002) (mean = 71.5 points/individual, range = 54–77) during the fertile period. Thus, variation in the number of observation points between studies likely had minimal impact on our comparison.

The difference in home-range size between the fertile and nestling periods may also be confounded

by between-year variation in types of females sampled, population density, and other aspects of resource abundance and predation pressure (McLoughlin and Ferguson 2000). We cannot rule out these possible effects, but the density of the study population as measured by the total number of nests found (1998 = 154; 1999 = 163; 2007 = 120) and number of breeding pairs (1998 = 75; 1999 = 78; 2007 = 72) was slightly higher during the fertile period study (1998, 1999) than during the nestling period study (2007). We predicted decreased density to cause larger home ranges due to decreased competition for space (Hooper et al. 1982, Anich et al. 2010), but females still had significantly smaller home ranges during the nestling period despite lower densities.

The decline in female home-range size between the fertile and nestling stages can potentially be attributed to a transition from nest building and seeking copulations during the fertile period, which often causes females to leave their social mate's territory (Stapleton and Robertson 2006, Whitaker and Warkentin 2010), to focus on parental care and nest defense during the nestling period. We quantified female movements from days 3 to 5 of nestling life, likely before nestlings could thermoregulate independently (Dawson et al. 2005) and females were still frequently brooding. The junco nestling period lasts 11 to 12 days before fledging, and females are known to decrease their time spent brooding by as much as 75% between days 4 through 7 and days 8 through 10 of nestling life (Wolf et al. 1990). Female home-range size may expand during the second half of the nestling period as females spend less time brooding and potentially take advantage of more distant resources.

Previous estimates of male Dark-eyed Junco home-range size in our study population indicated that males do not differ detectably in home-range size across the nesting cycle (Chandler et al. 1994, 1997), which contrasts with our result for females. Male home-range size (mean \pm SD) during the nestling period (1.31 ± 0.525 ha; Chandler et al. 1994) was larger than our estimate of female home range during the nestling period (0.833 ± 0.788 ha), but this difference was not statistically significant (Two-sample Kolmogorov-Smirnov Test; $Z = 1.220$; $P = 0.102$). Male and female juncos perform approximately an equal amount of provisioning throughout the nestling period (Ketterson et al. 1992), which may contribute to the similarity in home-range size. Female juncos

maintained a slightly larger (mean \pm SD) home-range size during the fertile period (2.44 ± 0.992 ha; Neudorf et al. 2002) than males (2.11 ± 0.539 ha; Chandler et al. 1997), which may explain why females have a significant decline in home-range size between the fertile and nestling stages while males do not.

Female juncos exhibited substantial individual variation in home-range size during the nestling period suggesting not all females were minimizing distance traveled from the nest, despite the increased energetic costs and potential spatial constraints associated with nestling care. The observed variation could be a product of among home-range variation in resource availability (Møller 1990, Rolando 2002). The largest and smallest home ranges in our study were in the same general area of the study site (~ 350 m apart) and no large-scale differences (e.g., hotel property vs. mature forest) in habitat characteristics were observed between these two territories. There may be finer scale differences in habitat quality contributing to these large differences in home-range size. For example, juncos are known to roost exclusively in coniferous trees (Chandler et al. 1995) and, in our study, females appeared to preferentially forage in and around hemlock (*Tsuga* spp.) (DGR, pers. obs.). One explanation for the large differences in home-range size over a relatively small spatial scale may relate to differences in distribution of hemlock. Thus, identifying the relative importance and distribution of limited resources within a home range, such as hemlock trees, is an important topic for future studies of avian spatial activity. Future studies should also compare the spatial activity of individual females across the nesting cycle to control for individual variation between females and years.

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