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Radio-transmitters do not affect seasonal productivity of female Golden-winged Warblers

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ABSTRACT. Investigating the potential effects of handling and marking techniques on study animals is important for correct interpretation of research results and to effect progress in data-collection methods. Few investigators have compared the reproductive output of radio-tagged and non-radio-tagged songbirds, and no one to date has examined the possible effect of radio-tagging adult songbirds on the survival of their fledglings. In 2011 and 2012, we compared several parameters of reproductive output of two groups of female Golden-winged Warblers (*Vermivora chrysoptera*) breeding in Minnesota, including 45 females with radio-transmitters and 73 females we did not capture, handle, or mark. We found no difference between groups in clutch sizes, hatching success, brood sizes, length of incubation and nestling stages, fledging success, number of fledglings, or survival of fledglings to independence. Thus, radio-tags had no measurable impact on the productivity of female Golden-winged Warblers. Our results build upon previous studies where investigators have reported no effects of radio-tagging on the breeding parameters of songbirds by also demonstrating no effect of radio-tagging through the post-fledging period and, therefore, the entire breeding season.

RESUMEN. **Radio trasmisores no afectan la productividad estacional en las hembras de *Vermivora chrysoptera***

Investigar los efectos potenciales de las técnicas de manipulación y marcaje en estudios de animales es importante para interpretar correctamente los resultados de las investigaciones y para llevar a cabo los avances en los métodos de colecta de datos. Pocos investigadores han comparado el rendimiento reproductivo de las aves paserinas con o sin radios trasmisores, y nadie hasta la fecha ha examinado el posible efecto en la supervivencia de los juveniles de aves marcadas con radios trasmisores. En el 2011 y 2012 comparamos varios parámetros reproductivos en dos grupos de hembras de *Vermivora chrysoptera* reproduciéndose en Minnesota, los cuales incluían 45 hembras con radio trasmisores y 72 hembras que no capturamos, manipulamos o marcamos. No encontramos diferencias entre los grupos en el tamaño de la nidada, éxito de eclosión, numero de polluelos, duración del periodo de incubación o polluelos, éxito de salida de los polluelos del nido o supervivencia de los juveniles hasta su independencia. En consecuencia, radio trasmisores no tienen un impacto apreciable en la productividad de hembras de *V. chrysoptera*. Nuestros resultados aportan ha estudios anteriores en donde investigadores no han encontrados efecto de los radio trasmisores sobre parámetros reproductivos de aves paserinas y también demuestra que no hay un efecto de los radio trasmisores sobre la supervivencia de los juveniles a lo largo del periodo después del abandono del nido, y por ende durante toda la temporada reproductiva.

Key words: methods, nest success, post-fledging survival, songbird, transmitter effect, *Vermivora chrysoptera*

A meta-analysis of the effects of radio-transmitters and other dataloggers on birds revealed that their negative impacts on behavior, survival, and productivity are widespread (Barron et al. 2010). However, that analysis was heavily weighted toward waterbirds (i.e., penguins, waterfowl, and seabirds), and Barron et al. (2010) acknowledged that there is likely a file-drawer effect (Rosenthal 1979) from under-publication of studies finding no effect of marking devices. Negative effects of transmitters on songbirds reported to date have been species- or technology-specific. For example, nestling Louisiana Waterthrushes (*Parkesia motacilla*) fitted with transmitters were expelled from nests by adults causing their death (Mattsson et al. 2006), and bulbous antenna tips left some endangered Palilas (*Loxioides bailleui*) dangling from antennas stuck in vegetation (Dougill et al. 2000). However, many studies of songbirds

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have revealed no apparent deleterious effects of transmitters (Neudorf and Pitcher 1997, Streby et al. 2009, Vitz and Rodewald 2011, but see Hill and Elphick 2011).

Detecting transmitter-induced changes in condition, behavior, survival, or productivity of songbirds is best accomplished by comparing marked and unmarked birds. However, the difficulty of observing unmarked songbirds is usually what necessitates radio-telemetry, likely explaining the rarity of such comparisons (Neudorf and Pitcher 1997, Hill et al. 1999, Anich et al. 2009, Gow et al. 2011, Townsend et al. 2012). These comparative studies have revealed no measurable effects of transmitters on songbirds. For example, radio-tagging had no effect on annual return rates of either adult male Swainson's Warblers (*Limnithlypis swainsonii*; Anich et al. 2012) or male and female Bicknell's Thrushes (*Catharus bicknelli*; Townsend et al. 2012). Townsend et al. (2012) also found that transmitters had no effect on the body condition of Bicknell's Thrushes during the non-breeding season. In addition, transmitters had no effect on clutch sizes, nest survival, or number of young fledged from nests of Common Blackbirds (*Turdus murela*; Hill et al. 1999) or Wood Thrushes (*Hylocichla mustelina*; Gow et al. 2011) or the provisioning rates of female Hooded Warblers (*Setophaga citrina*; Neudorf and Pitcher 1997).

An important component of productivity typically excluded from songbird studies is survival of fledglings after they leave nests, but remain under adult care, that is, the dependent post-fledging period (Streby and Andersen 2011).Differences between fledgling survival and nest survival can generate estimates of seasonal productivity (i.e., young raised to independence from adult care) that differ greatly from productivity estimates based on nesting data alone (Streby and Andersen 2011). Considering fledgling survival when estimating productivity is important because some stressors that have no apparent effect on nest success can have detrimental effects on fledging survival. For example, blowflies (*Protocalliphora* spp. and *Trypocalliphora braueri*) usually cause no reduction in fledging success, but can increase fledgling mortality rates (Streby et al. 2009). In addition, although many songbirds can successfully raise broods that include nestling Brown-headed Cowbirds (*Molothrus ater*), the burden of continuing to feed fledgling cowbirds might cause starvation of host fledglings (Rasmussen and Sealy 2006, Peterson et al. 2012) and reduce the number of young recruited into the breeding population (Payne and Payne 1998).Similarly, if effects of carrying a transmitter accumulate over time, fledgling survival may be impacted even if there was no apparent effect on nesting parameters. In the only previous study to assess the effects of transmitters on breeding songbirds through an entire breeding season, Gow et al. (2011) did not report fledgling survival, but did report no decline in physiological condition of adult Wood Thrushes through post-breeding molt. Such results suggest that songbirds can carry transmitters through the entire breeding season without deleterious effects, but the effects on fledgling survival remain untested.

We compared reproductive parameters of marked and unmarked female Golden-winged Warblers (*Vermivora chrysoptera*) during nesting and the dependent post-fledging period. Golden-winged Warblers are smaller (8.5–10.0 g) than species for which similar comparisons have been made, and our study extends the measure of productivity to include survival of dependent fledglings. If our capture and marking methods and the additional mass and aerodynamic effects of radio-transmitters negatively impacted condition or behavior of breeding females, then one or more measures of productivity should differ between marked and unmarked females. For example, physiological stress could result in smaller clutch sizes or lower quality eggs less likely to hatch. In addition, the increased energetic demands of the transmitter load could require birds to spend more time foraging, which might lengthen the incubation or nestling periods or reduce the number of eggs that hatch or number of young that fledge.

METHODS

We studied female Golden-winged Warblers at Tamarac National Wildlife Refuge (47°2′N, 95°35′W), Becker County, Minnesota, in 2011 and 2012. Golden-winged Warblers are small migratory songbirds of high conservation concern (Buehler et al. 2007). These warblers are a multi-nesting, single-brooded species, with females typically renesting after initial nest failure, but only producing one brood of fledglings per year. The short breeding season in our study area in the northern portion of the species range limits most females to one (rarely two) additional attempts after initial failure. This species has been considered sensitive to transmitter effects based on an unpublished pilot study (referenced in Confer et al. 2011), where two of four adult males were not seen again after radio-tagging. However, subsequent telemetry studies with larger numbers of male Golden-winged Warblers have revealed no apparent effects on survival (Streby et al. 2012, M. Frantz, unpubl. data).

We captured, handled, banded, and attached radio-transmitters to adult females to monitor their survival, find and monitor their nests, and to attach transmitters to nestlings and monitor fledgling survival. We captured female Golden-winged Warblers in mist nets from 13 to 20 May 2011–2012, after females arrived at our study area, but before most females initiated nests. Each captured female (hereafter marked) was banded with one U.S. Geological Survey aluminum band and a unique combination of three plastic color bands. In addition, we attached a 0.39-g (3.9–4.3% of body mass) radio-transmitter (Blackburn Transmitters, Nacogdoches, TX) using an elastic-thread, figure-eight harness modified from Rappole and Tipton (1991). Transmitter antennas were flexible and nylon-coated, and we trimmed antennas to ∼7 cm to avoid curling and kinking we observed in a pilot study that could potentially lead to entanglement. We did not attempt to capture, handle, or mark females in the unmarked group.

Nest searching and monitoring. We located marked birds using standard ground-based radio-telemetry methods once or twice daily until we found their nests during building, egg-laying, or early incubation. When tracking, we first triangulated the signal and then carefully approached until we observed the bird on the nest, flushed it from the nest, or observed that the bird was not at the nest. We found nests of unmarked birds by systematically searching the study area and by observing adult behavior. If a nest was discovered under construction and subsequently found to be the nest of a marked female ($N = 10$), then that female was included in the marked group and not in the unmarked group. Nests of marked and unmarked birds did not differ in nest concealment or canopy cover (S. M. Peterson, unpubl. data). We monitored all nests at 4-d intervals, and more frequently when events such as the onset of incubation and hatching were expected, so we could accurately determine clutch sizes, length of incubation and nestling periods, hatching success, and predict fledging dates.

Fledgling survival. We used radio-telemetry to monitor survival of fledglings from successful nests of marked and unmarked females. On the seventh day of the nestling period (1–2 d before typical fledging age), we banded nestlings with a standard U.S. Geological Survey leg band and attached a radio-transmitter to 1–4 (usually 2) nestlings per nest using the same methods as used with adults. We visited nests once or twice daily and monitored locations of radio signals from 5 to 10 m away to determine the day of fledgling. We monitored radio-marked adults and nestlings/fledglings to determine fates of nests because visual assessment of recently fledged or predated nests can lead to erroneous nest fate assignment in this species (Streby and Andersen 2013). We monitored each radio-tagged fledgling once daily (with an occasional 2-d interval for some birds) until it died or survived 24 d after fledging, the approximate age of independence. Importantly, only radio-tagged fledglings were included in our comparison of survival rates of fledglings of marked and unmarked females. Fledgling Golden-winged Warblers move beyond nesting territory boundaries soon after leaving nests (Streby and Andersen 2013), and often move >500 m from nests in unpredictable directions before independence from adult care (S. M. Peterson, unpubl. data). As a result, locating unmarked fledglings consistently is nearly impossible, and determining their fates is even harder (Streby and Andersen 2013).

Statistical analysis. Our methods were identical in both years and our estimates of population productivity were similar between years, so we combined data from both years for analysis. All comparisons were made between nests and fledglings of marked and unmarked females. We compared clutch and brood sizes, the length of incubation and nestling stages, number of fledglings, and possible interactions of those parameters between marked and unmarked females with an unbalanced MANOVA (Proc GLM; SAS Institute 2008). We monitored two consecutive nesting attempts for 7% of marked and 3% of unmarked females, so we averaged the values of each parameter from both nests for those females to avoid psuedoreplication. Only

Table 1. Reproductive parameters for female Golden-winged Warblers during 2011–2012 in Minnesota. Marked females were captured and marked with an aluminum leg band, three color bands, and a radio-transmitter weighing ~4% of body mass; unmarked females were not captured, handled, or fitted with transmitters. Hatching success and fledging success are shown as proportions; all others are means ± SE.

	Marked		Unmarked	
Parameter	*N*	Estimate	*N*	Estimate
Clutch size	45	4.7 ± 0.6	60	4.7 ± 0.6
Incubation-stage length (d)	17	11.6 ± 0.6	21	11.5 ± 0.8
Brood size	32	4.5 ± 0.7	49	4.6 ± 0.8
Nestling-stage length (d)	20	9.0 ± 1.0	27	8.7 ± 0.8
Number of fledglings	19	4.3 ± 1.0	31	4.4 ± 0.9
Hatching success	24	0.71	35	0.63
Fledging success	34	0.62	52	0.60
Fledgling daily survival[a]	19	0.981 ± 0.006	31	0.974 ± 0.006

[a]Sample sizes for fledgling survival reflect number of broods because brood was included as a random effect in those models to avoid pseudoreplication.

nests where a parameter of interest was known were included in each analysis. For example, nests that failed during laying were not included in the comparison of clutch size, and nests that failed during incubation were included in comparisons of clutch size and hatching success, but not of incubation-stage length. We compared hatching success and fledging success using chi-square tests of independence. We calculated daily survival for fledglings of marked and unmarked females from regression coefficients of a logistic exposure model (Shaffer 2004) for each group using the NLMIXED procedure in SAS. Both models included a random effect for brood because survival among brood-mates was found to be non-independent in preliminary analysis. We compared the resultant fledgling survival estimates for marked and unmarked females using a Z-test (Johnson 1979).

RESULTS

We monitored nests of 45 marked and 73 unmarked female Golden-winged Warblers, and monitored marked fledglings of 19 marked ($N=$ 35 fledglings) and 31 unmarked ($N = 61$ fledglings) females. Nest failures ($N = 70$) were due to predation (94%), females being predated by accipiters (3%), and apparent abandonment by unmarked birds that either died away from nests or abandoned nests (3%). Fledgling mortality ($N = 50$) was due to predation (98%), apparent exposure during an unusually cold and wet night (1%), and blunt-force-trauma to the head during a hailstorm (1%).

We found no differences between marked and unmarked females for any of the parameters measured (Table 1). Marking females had no effect on clutch size, brood size, the length of incubation or nestlings stages, or number of fledglings (Wilks' $\lambda = 0.8$, $F_{5,15} = 0.9$, $P = 0.51$; Table 1). In addition, we found no difference between marked and unmarked females in either hatching ($\chi^2 = 0.4$, $P = 0.52$) or fledging ($\chi^2 = 0.04$, $P = 0.84$) success (Table 1). Importantly, we also found no difference in survival of fledglings of marked and unmarked females ($Z = 0.8$, $P = 0.41$; Table 1). One aspect of productivity we could not compare was the probability of nesting. However, all 45 radio-tagged female Golden-winged Warblers in our study nested, indicating no reduction in nesting probability.

DISCUSSION

We found no effect of capturing, handling, banding, and attaching transmitters on the seasonal productivity of female Golden-winged Warblers. Similar results have been reported in previous studies of marked and unmarked songbirds (Neudorf and Pitcher 1997, Hill et al. 1999, Gow et al. 2011). In addition, our results suggest that radio-tagging females had no effect on fledgling survival, a critical component of seasonal productivity (Streby and Andersen 2011). Thus, our results, in combination with those of previous studies where investigators compared radio-tagged and non-radio-tagged songbirds during the breeding season (Neudorf and Pitcher 1997, Hill et al. 1999, Gow et al. 2011), indicate that many songbirds can carry radio-transmitters from spring arrival to the onset of fall migration without apparent deleterious effects on condition or seasonal productivity.

Our results add to the growing number of studies indicating that radio-transmitters do not influence songbird behavior (Neudorf and Pitcher 1997, Gow et al. 2011), body condition (Rae et al. 2009), or annual survival in breeding (Powell et al. 1998, Anich et al. 2009) and wintering (Townsend et al. 2012) areas. However, we caution that investigators should not assume transmitters will have no effect when beginning telemetry work in a new system. Deleterious effects of transmitters and other marking devices are usually identified when a species or age group is marked for the first time (e.g., Dougill et al. 2000, Mattsson et al. 2006) or when attachment techniques are being assessed for the first time (e.g., Sykes et al. 1990), and may also be related to researcher inexperience (Hill and Elphick 2011). All of these are important reasons to test new (to the researcher or to the species) marking techniques initially with extra caution, and to include empirical assessments of transmitter effects in publications.

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