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Density and abundance of Wilson's snipe *Gallinago delicata* in winter in the Lower Mississippi Flyway, USA

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Wilson's snipe *Gallinago delicata* is one of the least studied North American game birds, and information on snipe populations and abundance is mostly unknown. We conducted roadside surveys stratified at the township level in the lower Mississippi Alluvial Valley (LMAV) in Arkansas, Mississippi and Louisiana, as well as the Red River Region, and the Gulf Coastal Plain of Louisiana during winters of 2009 and 2010. We identified observer, vegetation cover, and water cover as important covariates in estimating snipe densities. We detected 2915 snipe along 814 line transects (1450 km) for 2009 and 2010 combined. We estimated snipe densities of 8.05 individuals km^{-2} (95% CI: 4.57–14.17) in 2009, and 2.13 individuals km^{-2} (95% CI: 1.47–3.08) in 2010. We used the resulting snipe density estimates within the study area to calculate abundance estimates of 1 026 431 (95%CI: 582 707–1 806 774) in 2009, and 271 590 (95%CI: 187 435–392 722) in 2010 for the LMAV. Our data indicate that a road transect survey method is effective for estimating wintering snipe density and abundance in the lower Mississippi Flyway.

The Wilson's snipe *Gallinago delicata* (hereafter snipe) is an important webless game bird of wetlands in North America for which the population size is poorly understood (Tuck 1972, Arnold 1994). No statistically rigorous regional or North American population trend estimates exist (Mueller 1999). Current North American population estimates are largely educated guesses of around two million (Delaney and Scott 2006) while a regional estimate for the lower Mississippi Alluvial Valley (LMAV), an important migrating and wintering area for snipe, is around two thousand (Elliot and McKnight 2000). However, this estimate of snipe abundance in the LMAV seems to be low, given that recent harvest estimates show that Louisiana recorded the highest estimated snipe harvest in the LMAV (24 100 ± 108%) in 2010, and that 40 200 (± 60%) snipe were estimated to have been harvested in the entire Mississippi Flyway in 2010 (Raftovich et al. 2011). No statistically rigorous surveys targeting snipe exist in North America; however, snipe are included in both the Christmas Bird Count (CBC) and the Breeding Bird Survey (BBS) (Butcher et al. 2005, Sauer et al. 2012). Decisions concerning snipe harvest regulations at the flyway level presently are based on both the CBC and BBS data (Mississippi Flyway Council Technical Section Webless Migratory Game Bird Committee 2010 unpubl.). Both of the large-scale surveys produce questionable results for snipe in part because snipe are cryptic, snipe breed at high latitudes and so are not surveyed well by the BBS (Robbins et al. 1986), and snipe are thought to move regionally during December (Tuck 1972) when the CBC is conducted. For these and other reasons, a statistically-based large-scale survey on which to base future snipe harvest regulation decisions is needed (Mueller 1999).

Tuck (1972) suggested three methods for estimating trends in snipe populations: 1) wing surveys, 2) breeding population surveys, and 3) winter population surveys. The US Fish and Wildlife Service recently stopped soliciting snipe wings from hunters in their Parts Collection Survey (R. Raftovich, USFWS, pers. comm.). Thus, while an age ratio based on wing surveys can be calculated for past years, this alternative is no longer an option. Tuck (1972: 380) considered breeding population surveys "impractical because of the extent and remoteness of most of the breeding range". The third option offered was considered the best alternative by Tuck (1972) where he suggested conducting a winter survey in southern states in early February when the population was relatively stable spatially before commencing spring migration.

Our objectives were to assess whether a line transect method along roads, recommended by Tuck (1972), was feasible for surveying wintering snipe at a regional level. We chose road transects because we had a narrow window of time available for surveying, the study area was large, obtaining permission to survey on private lands at the study area scale was impractical, and aerial surveys have not produced reliable results (Robbins 1956). We investigated the feasibility of the roadside method, and covariates that we thought important in reducing variation around detection probabilities and therefore density estimates.

Material and methods

Study area

The lower Mississippi Alluvial Valley (LMAV) regions of Arkansas, Mississippi and Louisiana, the Red River Valley of Louisiana, and the West Gulf Coastal Plain of Louisiana are important wintering areas for snipe (Tuck 1972, Root 1988). These regions comprised our study area (Fig. 1), totaling127 507 km^2 based on land area calculations performed in ArcGIS 9.2 (Environmental Systems Research Institute, ESRI, 2009). Wilson's snipe commonly use agricultural habitats on the wintering grounds (Taft and Haig 2005), such as rice fields and pastures (Tuck 1972). Shorebirds in the region also frequently use soybean fields (Twedt et al. 1998). Most of the land use in the study area is agriculture (Gardiner and Oliver 2005, Karstensen and Sayler 2009). The two predominant crop types are soybeans

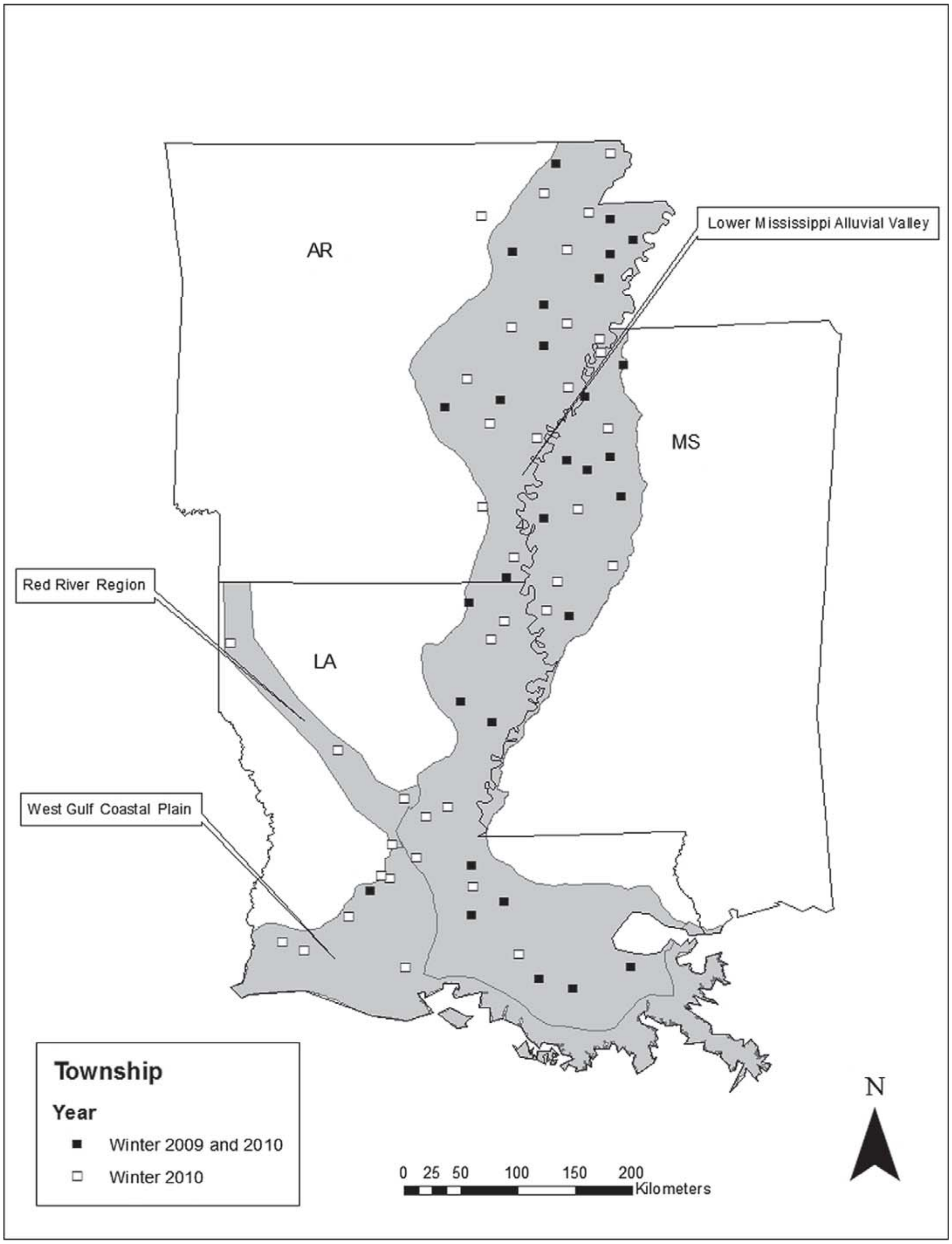

Figure 1. Study area (shaded) and townships surveyed for wintering Wilson's snipe in the Lower Mississippi Alluvial Valley, the Red River region and the west Gulf Coastal Plain of Louisiana, USA.

and rice but other common crops include cotton, corn, winter wheat and sugarcane (USDA 2010). In 2010, 17442 km², 7810 km² and 14236 km² acres of soybeans, cotton, corn and winter wheat were planted in Arkansas, Louisiana and Mississippi, respectively, with soybeans accounting for about 66% of those crops (USDA 2010).

Precipitation varies throughout the LMAV, with the northern and southern portions receiving an average of 115 cm and 150 cm per year, respectively (Reinecke et al. 1989). The climate in the LMAV is typified by mild winters, with freezing temperatures occurring periodically in the northern reaches, and rarely in the southern reaches of the region (Reinecke et al. 1989). In general, the winter of 2009–2010 had much higher precipitation than did the winter of 2008–2009 in the LMAV (Advanced Hydrologic Prediction Center 2010), particularly in the Arkansas Delta, Grand Prairie of Arkansas, and a large portion of the Mississippi Delta (National Weather Service Forecast Office 2009). December 2009, just prior to the 2010 field season, was the third wettest December on record for Little Rock, Arkansas (National Weather Service Forecast Office 2009), and parts of southern Louisiana received 200% more precipitation than normal during the same time period (Advanced Hydrologic Prediction Center 2010).

Survey design

We used ArcGIS 9.2 (ESRI 2009) and the Hawth's Analysis Tools application (Beyer 2004) to randomly select 31 townships (~15-km² units of land) which were allocated proportional to the number of townships available in each state (Fig. 1). The 2009 sample included 12 townships in Arkansas, 11 in Louisiana and 8 in Mississippi (Fig. 1). In 2010 we increased our sampling effort by adding an additional 38 townships to our sample (14 in Arkansas, 17 in Louisiana and 7 in Mississippi, Fig. 1). We decided to increase our sample size in 2010 to increase the precision of our abundance estimates, and because it was logistically feasible to do so.

We used distance sampling (Buckland et al. 2001) in a road-based line transect approach to model detection and derive density and abundance estimates for snipe in the study area. Similar to other protocols for surveying webless migratory game birds, such as the American Woodcock Singing Ground Survey (Cooper and Rau 2013) and Mourning Dove Call-count Survey (Seamans et al. 2013), we surveyed snipe along secondary roads (i.e. lightly traveled state or county roads). We randomly located nine 1.8-km road transects per township. We conducted 250 road transects (440 km) in 31 townships during 2009 (21 January – 24 February), and 564 (1010 km) in 69 townships during 2010 (21 January – 27 February). Transects were traversed at < 15 km h^{-1} by truck. Typically snipe are detected individually or in small flocks (i.e. clusters) (Vogrin 2001). We defined a cluster as all individuals ≤ 5 m of an estimated center point. We trained observers on the basics of distance sampling methodology, protocols for surveying snipe, and the use of rangefinders prior to starting surveys. Observers avoided double counting snipe by communicating to each other if a flushed snipe flew into the other observer's portion of the transect. Similar sized vehicles of the same make and model were used during both years, and each observer alternated between driver and passenger position every day. We conducted surveys from sunrise to sunset as Hoodless et al. (1998) found that other than crepuscular periods of the day, common snipe *G. gallinago* movement was minimal during winter in southwest England. Surveys were not conducted during moderate or heavy precipitation or during dense fog. We recorded the unlimited perpendicular distance (m) to each snipe or cluster of snipe using optical equipment, the overall transect length (km), the segment length (m) for each classified habitat type (e.g. row crop, residential; National Agriculture Imagery Program Mosaic, NAIP, USDA 2006), and the associated habitat characteristics (percent water cover, percent vegetation cover and vegetation height score) for that habitat segment during each transect survey. We scored vegetation height as: 1) $\leq$height of a snipe, 2) $>$height of a snipe, or 3) $>$ than double the height of a snipe.

Statistical analyses

We elected to left truncate the data at 15 m and right truncate the data at 225 m based on our exploratory analyses in which we examined distance histograms and detected possible outliers (Buckland et al. 2001). We set truncation values to include as much data as possible to investigate covariate effects without requiring extra adjustment terms (Marques et al. 2007).

Tuck (1972) and Cline and Haig (2011) observed that winter snipe movement varied across years over large geographic areas most likely due to variable weather conditions and changes in habitat availability, particularly water coverage. We accounted for this possible variation in density by analyzing each year separately. We used Program DISTANCE ver. 6.0 (Thomas et al. 2010) to estimate detection probabilities, densities (individuals km^{-2}), and abundances. We modeled detection probabilities by analyzing clusters as our detection unit, rather than each individual observation. We did not detect a sufficient number of snipe to estimate densities at the township or transect level. We were unable to include habitat type in combination with observer as factor covariates because the large number of parameters that needed to be estimated resulted in poor fit (Marques et al. 2007). Therefore, we developed models that included only observer or only habitat as covariates and assessed their plausibility. We only used habitat types that had > 60 detections (Buckland et al. 2001) which eliminated residential, developed, open water and wooded habitats. Thus, we only included row crops, rice fields, and pasture lands when estimating habitat-specific densities; overall densities at the state and study area levels were estimated across all habitat types recorded with the eliminated habitat types being categorized as 'other'.

We developed a set of a priori models to identify which detection factors were necessary to better estimate density and abundance (Table 1, 2). We included observer as a factor covariate and percent water cover, percent vegetation cover, and vegetation height score as non-factor covariates. We included these non-factor covariates because we believed that differing visual obstruction at survey locations might have affected detection.

Table 1. Most plausible candidate models of Wilson's snipe density including only single factor or non-factor covariates during winter, 2009 and 2010 in the lower Mississippi Flyway, North America. Covariates included observer, water cover, vegetation cover, and vegetation height. K is the number of parameters, and models are ranked within years using AIC score. Only models with an ΔAIC score within 10 of the most plausible model are shown.

Candidate model[a] (key + covariates)	K	ΔAIC	AIC	CV[b]
HRC + obs	6	0.00	9816.16	0.162
HNC + obs	6	6.86	9823.02	0.163
HNHP + obs	7	9.65	9825.81	0.163

[a] Hazard rate cosine (HRC), half normal cosine (HNC) and half normal hermite polynomial (HNHP) key functions.
[b] Coefficient of variation.

We modeled detection using the Multiple Covariate Distance Sampling (MCDS) engine in Program DISTANCE 6.0 (Thomas et al. 2010). MCDS adjusts the scale parameter (σ) of a half normal or hazard rate key function and analyzes it as a function of covariates. We tested models for goodness-of-fit using a Kolmogorov–Smirnov test (Marques et al. 2007). We used Akaike's information criterion (AIC) (Burnham and Anderson 2002) to rank candidate models.

To estimate detection probabilities and snipe density at the state level (within the study area) we modeled detection and estimated stratum-specific density for Arkansas, Louisiana and Mississippi in 2009 and 2010. We used ArcGIS 9.2 (ESRI 2009) to calculate abundance by year by multiplying the study area (127 507 km^2) by the respective density estimates (Marques et al. 2007).

Results

In 2009 we detected 768 snipe, while in 2010 we detected 2147 snipe. We detected 56% of snipe as individuals, 34% of snipe in a clusters of 2–5 birds, and 10% of snipe in clusters of >5 birds. In 2009 we detected 71% of the snipe in Arkansas, 22% in Louisiana and 7% in Mississippi; while in 2010 we detected 38% of snipe in Arkansas, 12% of snipe in Louisiana and 50% in Mississippi.

In 2009 we detected more snipe (57%) in habitats with 25–50% water cover than in any other water cover category, and in 2010 we detected more snipe (56%) in habitats with $<25\%$ water cover than in any other water cover category. In 2009 and 2010 we detected more snipe (45%, 40% respectively) in habitats with 75–100% vegetation cover than in any other vegetation cover category. In 2009 and 2010 we detected more snipe (67%, 74%, respectively) in habitats with a vegetation height category of 1 than in any other vegetation height category.

We found no evidence for a lack of fit for the selected 2009 and 2010 models (Kolmogorov–Smirnov test: $D^n = 0.051$, $p = 0.28$; $D^n = 0.038$, $p = 0.40$; respectively). Models with observer only as a factor covariate had more support than any other single covariate models for all models (Table 1).

Top models included observer as a factor covariate, and vegetation cover, water cover, and vegetation height included as non-factor covariates in both 2009 and 2010 (Table 2). For modeling detection and estimating density by state, we found that observer as a factor covariate and vegetation cover, vegetation height, and water cover as non-factor covariates accounted for the most plausible model during each year (Table 3). Both beta parameter estimates for water cover in 2009 (0.014, SE = 0.004) and 2010 (0.007, SE = 0.002) were positive, indicating that snipe were more difficult to detect as water cover increased. However, beta parameters for vegetation cover and height varied between years. Beta parameters for vegetation cover were negative in 2009 (–0.003, SE = 0.002), and positive in 2010 (0.001, SE = 0.009), indicating that snipe were more difficult to detect with decreasing vegetation cover in 2009, but more difficult to detect with increasing vegetation cover in 2010. Beta parameters for vegetation height were positive in 2009 (0.635, SE = 0.20), and negative in 2010 (−0.28, SE = 0.06), indicating that snipe were more difficult to detect with increasing vegetation height in 2009, but more difficult to detect with decreasing vegetation height in 2010.

State-specific density estimates did not differ among Arkansas, Mississippi or Louisiana in 2009, but density estimates of snipe were greater for Mississippi than either

Table 2. Most plausible candidate models of Wilson's snipe density during winters of 2009 and 2010 in the lower Mississippi Flyway, North America. K is the number of parameters, and models are ranked within years using AIC score. Only models with an ΔAIC score within 10 of the most plausible model are shown.

Year	Candidate model[a] (key + covariates)	ΔAIC	AIC	K	Density[b] Ind. km^{-2}	95% CI
2009	HRC + obs + veg cov + veg height + wat cov	0.00	3736.32	7	8.05	4.57–14.17
	HNC + obs + veg cov + veg height + wat cov	2.30	3738.62	6	7.24	4.10–12.78
2010	HNC + obs + veg cov + veg height + wat cov	0.00	5539.80	8	2.13	1.47–3.08
	HNC + obs + veg height + wat cov	0.19	5539.99	7	2.15	1.50–3.11
	HRC + obs + veg height	2.31	5542.11	7	2.80	1.93–4.05
	HRC + obs + wat cov + veg cov + veg height	3.70	5543.50	9	3.24	2.23–4.69
	HRC + obs + veg height + wat cov	4.01	5543.81	8	3.40	2.34–4.92
	HRC + obs + veg height	7.61	5547.41	6	2.23	1.54–3.22
	HNC + obs + wat cov	7.96	5547.76	6	2.36	1.63–3.41
	HNC + obs + wat cov + veg cov	9.30	5549.10	7	2.33	1.61–3.37

[a] Half normal cosine (HNC), hazard rate cosine (HRC) key functions with observer (obs), vegetation cover (veg cov), vegetation height (veg height) and water cover (wat cov) as covariates.

Table 3. Model selection results and corresponding Wilson's snipe density estimates post-stratified by state, during winters 2009 and 2010 in the lower Mississippi Flyway, North America. Results are based on the most plausible model ranked by AIC score. The most plausible model for 2009 is a hazard rate key function, cosine series expansion with observer, vegetation cover, vegetation height, and water cover as covariates. The most plausible model for 2010 is a half normal key function, cosine series expansion with observer, vegetation cover, vegetation height, and water cover as covariates.

Year	State	Effort (km)	Density[a] (ind km^{-2})	95% CI	CV[a]
2009	Arkansas	209	10.43	5.43–20.07	0.34
	Louisiana	117	8.30	2.70–25.5	0.62
	Mississippi	114	1.13	0.44–2.91	0.50
2010	Arkansas	419	1.44	0.85–2.43	0.27
	Louisiana	371	0.85	0.49–1.49	0.29
	Mississippi	220	5.5	3.15–9.61	0.29

[a] Coefficient of variation.

Arkansas or Louisiana in 2010 (Table 3). We calculated wintering abundance in the study area as 1 026 431 (95%CI: 582 07–1 806 774) in 2009 and 271 590 (95%CI: 187 435–392 722) in 2010.

Discussion

Developing an effective survey for the continental population of snipe will require knowledge of their distribution, phenology, and the intended survey approach. Tuck (1972) described the general distribution and migration phenology of snipe in the continental United States. Different survey approaches require different tradeoffs. Road-based surveys of bird populations are potentially biased because the habitat surveyed adjacent to the road may not be representative of habitats located a further distance from the road (Downs 1998, Harris and Haskell 2007, Niemuth et al. 2007, Jorgensen et al. 2008). Many studies have found that habitats along roads are biased compared to habitats located distant from roads with the general finding that road placement avoids larger water bodies, while roadsides are associated with fragmented and developed land-use (Harris and Haskell 2007). In the case of surveying snipe, the placement of roads distant from larger water bodies and along more urban habitats are of less concern because snipe do not use deeper water or urban habitats (Tuck 1972). The greater prevalence of fragmented habitats (edge effect) along roads is more problematic for snipe if those fragmented habitats extend some distance from the road. A low proportion of suitable habitat along roads could result in biased estimates due to lower quality habitat being oversampled. We tried to address the possible immediate edge effects by truncating the first 15 m from the road. We examined the probability distribution function of snipe detected beyond 15 m and found little evidence indicating a systematic habitat problem extending from the road (unpublished data). Another aspect supporting the use of a roadside-based survey for snipe was that > 90% of snipe detected were in croplands. Our study area had a relatively high proportion of cropland (USDA 2010), and we surveyed croplands and other habitat types in accordance with availability (unpublished data). Croplands are not a habitat type located with some systematic bias away from roads (Harris and Haskell 2007, Niemuth et al. 2007). Thus, as Jorgensen et al. (2008) concluded for sampling buff-breasted sandpipers *Tryngites subruficollis* along roads in the eastern Rainwater Basin, Nebraska, we believe a roadside-based survey in the lower Mississippi Flyway samples representative snipe habitats available there.

Logistically, using a roadside-based survey is effective because we could conduct a large number of surveys over a short period of time, we could detect a large number of snipe, and we could survey privately-owned lands from public roads. Roadside surveys are economical because they are more efficient than surveys conducted off roads (Hanowski and Niemi 1995). Also, winter surveys occur when most crops were harvested resulting in bare fields or fields with low amounts of vegetation (e.g. soybean stubble or actively growing winter wheat). Jorgensen et al. (2008) found that conducting roadside surveys when fields were bare or before crops began to grow allowed for increased detection distances and subsequently enabled observers to detect birds at longer distances from the road. Vegetation height can have direct impacts on detection if it is tall enough to obstruct the view of snipe. However, because most fields were harvested prior to our survey period, we believe this impact was minimal. When comparatively taller vegetation was encountered, it usually was patchily distributed in pastures. Our variable beta parameter estimates for vegetation height and cover indicate that future research may be needed to differentiate the degree to which vegetation covariates impact detection as well as density.

Certain habitat variables were related to density and detection as indicated by their relative support in individual covariate models (Table 1) and their presence in our top candidate models (Table 2). Observer had more support than any other single covariate models for both years pooled when individually ranked. For multiple covariate models, the most supported models included observer, vegetation cover, vegetation height and water cover. Thus, we suggest that, at a minimum, observer effects be included as a covariate in future surveys and if possible, vegetation cover, water cover and vegetation should be included as covariates too.

Snipe densities were higher in 2009 compared to 2010 (Table 2). The approximately 120% increase in survey effort across random townships during 2010 may provide a more precise assessment of snipe abundance, as shown by the much narrower confidence intervals for the 2010 estimates, but still does not fully explain the large differences in abundance between years. Tuck (1972) commented that higher surface water availability across the landscape resulted in greater relative abundances of snipe in Louisiana, and that dry winters can force snipe to seek habitat elsewhere. Our density estimates are contrasting to this notion given that we observed greater snipe densities during 2009, which was a substantially drier year than 2010. Water cover was a covariate included in our top candidate model for each year indicating that it had some influence on snipe density and detection; however, more years of surveys and data collection would be needed to assess trends in snipe density relative to regional precipitation fluctuations.

Downs (1998) recommended that for breeding snipe, surveys spaced at 5–10 year intervals are appropriate because more frequent surveys would reflect snipe movements due to differing environmental conditions. The propensity of snipe to shift habitats in response to changing conditions also occurs on the wintering grounds (Hoodless et al. 1998, Cline and Haig 2011). Therefore, the decision to change the frequency of surveying snipe needs to weigh the relative change in distribution both within a year and among years (Robbins 1952, Tuck 1972, Arnold 1994). Within-year snipe redistribution could be addressed by increasing the scale of the survey to include all four Flyways. Doing so should address within year redistributions unless the relative distribution of birds changes within year between the United States and more southerly wintering areas (Tuck 1972, Mueller 1999). Tuck (1972) suggested that the majority of North American snipe winter in Louisiana, but noted that some portion of the population can winter as far south as Mexico and northern Venezuela in certain years. Assessments of snipe populations on the periphery of the southern wintering range could only be addressed by further increasing the scale to include Central and northern South America. If snipe shift wintering areas between the United States and more southerly wintering areas among years, then changing the frequency of surveys would not solve this problem – only changing the scale would.

The efficiency of line transects and the detections they provide make them advantageous for studies at the regional level (Wilson et al. 2000). Our data indicate that a road transect survey method is effective for estimating wintering snipe density and abundance in the lower Mississippi Flyway. Tuck's (1972) survey recommendations and our method will eventually allow a trend estimate to be produced, to support better harvest management decisions. Future research efforts should investigate how water availability on the landscape and weather variables influence snipe abundances over space and time.

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