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Effectiveness of Wetland Management by Modeling Song Sparrow Abundance

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Agriculture is one of the primary drivers for historical wetland loss after the Emergency Wetland Resources Act of 1986 was established (Dahl 2000). West Virginia particularly lost 24% of its historical wetland habitat due to anthropogenic change (Mitsch and Gosselink 1993). Wetland management practices have been implemented to increase habitat diversity and overall health. Agricultural conservation easement programs (ACEP) were introduced by the Natural Resources Conservation Service to provide resources for land owners to conserve agricultural lands and wetlands through restoration, protection, and enhancements (USDA 2014). Wetland structural heterogeneity promotes abundance and diversity of plants and animals; however, wetlands under restoration have been found to be less diverse and less abundant than reference wetlands (Moreno-Mateos et al. 2012). Alternatively, restored wetlands have been found to have more diverse and abundant populations, specifically anurans and birds (Stevens et al. 2002).

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Song sparrows (*Melospiza melodia*) are passerine birds that range from western Newfoundland to southeast Alaska and are found in all 48 contiguous United States and also commonly breed in Canadian territories including British Columbia, Manitoba, Ontario, and Northern Territories (IUCN 2016). Due to their extended range, song sparrows utilize various habitat types including, but not limited to grasslands, shrub lands, and inland wetland habitats (IUCN 2016). Because these birds are abundant throughout West Virginia, they can be used as a bioindicator to monitor effectiveness of wetland habitat management. In 2016, 13 reference and 23 ACEP wetlands were surveyed in West Virginia to compare song sparrow habitat use and investigate habitat characteristics that may explain occupancy.

OBJECTIVES

With this data, I will be investigating structural characteristics of these two wetland types to determine how effective ACEP wetlands are in increasing abundance in song sparrows. My specific objectives are as follows: 1) Compare wetland management types and 2) indicate which habitat characteristics are most indicative of song sparrow abundance in West Virginia.

I hypothesize that ACEP wetlands will have increased abundance in song sparrows compared to reference wetlands (similarly found in other literature). I hypothesize that water will not influence song sparrow abundance; however, I hypothesize shrub abundance will increase abundance. In addition, I hypothesize sky and wind conditions as well as noise disturbance will decrease detection probability.

METHODS

Field Methods

Thirteen reference and 23 ACEP wetland sites were visited twice per season (September to February), where transects were drawn across each wetland (avoiding open water) and point count surveys were conducted every 150 meters. Birds detected along transects between each point count were also noted. The number of point counts per site varied because of different wetland sizes; however, point counts were consistently conducted in 10 1-minute intervals.

Removal sampling eliminated possible pseudoreplication by only recording the first detection of each bird. Distance of detection from the observer in meters was also noted (1 = <50, 2 = 50-100, 3 = >100; Lewis et al. 2019). Along with bird detection and occupancy data, site data (e.g. vegetative structure of each wetland) and survey data (e.g. wind and sky condition according to the Beaufort scale, Table 1), date and time of day, air temperature (°C), and disturbance (dB)) at each visit were collected to explain differences in species occupancy, abundance, and richness between the ACEP and reference sites.

Analytical Methods

I used **pcount** and **unmarkedFramePCount** within the program unmarked in **R** to complete my N-mixture models to explain wetland structure influence on song sparrow abundance. When developing my N-mixture model, I assumed the response variables were abundance (λ) and detection probability (p), where $N_i \sim \text{Poisson}(\lambda)$ and $y_{ij} \sim \text{Binomial}(N_i,p_{ij})$ respectively. In this case, p_{ij} is the number of successful detections of song sparrows at site *i* on replicate *j*, assuming p_{ij} never exceeds N_i.

Because I fit an N-mixture model, I needed to account for both site and detection covariates in addition to the abundance values for each point count survey (Table 2). Due to the number of covariates for both site and detection that I accounted for, I did not fit all possible combinations to determine the best-fit model (n > 400 combinations). I began with the global fit model and determined candidate models using backward elimination (covariates where $p > 0.05$ for both abundance and detection, Table 3), and the best model was determined with Akaike's Information Criterion (AIC) values provided in unmarked. For investigative purposes, I ran models as Negative Binomial (NB) and Zero-Inflated Poisson (ZIP) models to compare AIC values.

RESULTS

Model Selection

All fit models and their resulting AIC values were reported in Table 4. Model-1-Poisson (M1P) resulted in the highest AIC value, while Model-3-ZIP (M3Z) resulted in having the lowest. Four additional models resulted with ΔAIC within the threshold of 0-2 established by Burnham and Anderson (2002), all of which were either NB or ZIP models. Poisson models ultimately resulted in the highest AIC values compared to NB and ZIP.

Model Covariates

As predicted, reference wetlands had less abundance than ACEP wetlands. In M3Z, reference wetland type had a log-expected count of 0.944 less than ACEP wetlands, and the covariate was significant ($p<0.001$). Shrub density within 1m and 5m were fit in the top model; however, only 25-75% of shrubs within 5m was significant ($p = 0.0392$), whereas 50-100% shrubs within 1m and 75-100% shrubs within 5m were insignificant ($p = 0.0926$ and 0.314, respectively). The detection probability of song sparrows was mostly influenced by noise disturbance followed by time (42.9% and 44.6%, respectively). Wind condition, on the other hand, improved detection probability (61.8%).

CONCLUSIONS

Model Selection

Zero-inflated Poisson regression is most appropriately used in data that excessively observes no-count data (IDRE 2019). In this case, with the single year song sparrow count data, NB or ZIP were necessary to analyze any model listed because 57% of counts across both visits throughout the year were zeros. The models tended to stay within the same order of accuracy according to AIC values regardless of the modeling type (model 3 < 4 < 2 < 6 < 5 < 1).

Model Covariates

Agricultural Conservation Easement Program wetlands had increased abundance than reference wetlands as hypothesized. Water did not influence song sparrow abundance as predicted, and 50-75% shrub density within 5m significantly increased abundance. Sky did not significantly decrease detection probability; however, noise disturbance decreased detection probability as predicted. In this model, wind had a positive correlation with detection probability, which ecologically is not the case as wind almost always decreases detection (Ralph et al. 1995). Birds are more likely to settle down rather than sing or fly around in increased wind events. Surveys should not be conducted when winds are over 11 km/hr because wind can be considered a noise disturbance and drown out calls, misrepresent proximity from observers, and potentially lead to misidentification (Ralph et al. 1995).

Song sparrows are generalist species; however, they favor more open habitat compared to forested habitat. This specification explains the difference between wetland management types in addition to the shrub effects. Increased structure provides more microhabitat and cover from potential predators; however, too much structure can deter song sparrows from utilizing the habitat. According to the model, 50-75% within 5m is the favorable level of structure heterogeneity, which could be equivalent to 3-4 bushes along a stream and could easily be managed in ACEP wetlands.

The effect of time was no surprise for detection probability. Birds typically sing from sunrise to four hours after (Ralph et al. 1995). Any time after may not be accurate for detection as singing may bring unnecessary attention to males (or calls from females could be the same idea, especially during nesting season). Noise disturbance more than likely had a greater effect on detection because of the time of year the surveys were conducted. Especially during the winter, because song sparrows only call using their “chint” calls, any noise disturbance can drown out calls. Temperature was likely not effective in detection despite evidence that suggests species abundance can be influenced by temperature fluctuations (Robbins 1981).

Management Implications

Agricultural Conservation Easement Program wetlands had greater song sparrow abundance than reference wetlands likely due to the surrounding landscape as well as habitat structure. Shrubs within 5m was significant in estimating abundance, which can indicate favorable structural heterogeneity that is required for song sparrow abundance in wetlands without being too similar to a forest structure. State and government agencies (e.g. West Virginia Conservation Agency) can quantify wetland structure and indicate whether wetlands should have cover treatments applied.

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TABLES

Table 1: Measuring parameters for sky, wind, and noise disturbance. Wind conditions follow the Beaufort scale.

	Abiotic Factors		
Numerical Code	Sky	Wind	Disturbance
0	Clear sky	Smoke rises vertically	No noise disturbance
1	Partly cloudy	Smoke drift indicates wind direction, still weathervane	Slight noise disturbance; does not prohibit the observer from detecting birds
2	Completely overcast	Wind felt on face, leaves rustle	External noises moderately prohibit the observer from detecting birds
3	Drizzle	Leaves and small twigs constantly moving	External noises severely prohibit the observer from detecting birds
4	Raining	Dust, leaves, and loose paper lifted, small tree branches move	N/A

Table 2: Covariates for detection and abundance (site-level) that were included in the global fit model.

Detection covariates	Site-level covariates
Sky	Wetland type
Wind	Wetland size
Time of day	Shrub cover within 1m
Temperature (°C)	Shrub cover within 5m
Noise disturbance (dB)	Water

Table 3: Candidate models for analysis using backward elimination of detection and abundance covariates. All models were ran three times (Poisson, Negative Binomial, and Zero-Inflated Poisson).

Model #	Detection covariates	Site-level covariates
1	time+temp+sky+dist+wind	Size+type+water+shr1+shr5
2	time+temp+dist+wind	Type+water+shr1+shr5
3	time+dist+wind	Type+shr1+shr5
4	time+dist+wind	Shr5
5	time+dist+wind	Type+shr1
6	time+dist	Type+shr1+shr5

Table 4: Fit models and their corresponding AIC values. Models ending in ‘Z’ are Zero-Inflated Poisson models, and models ending in ‘NB’ are negative-binomial models. Models ending in ‘P’ are Poisson models.

Model names	K	AIC	ΔAIC	AICwt
M3Z	10	410.7951	0	0.21
M4N	9	411.3976	0.602459	0.15
M2Z	12	411.6187	0.823539	0.14
M4Z	9	411.7952	1.000085	0.13
M3N	10	411.8019	1.006787	0.13
M6Z	9	413.043	2.247896	0.07
M5N	8	413.1849	2.389703	0.06
M6N	9	414.3265	3.531376	0.04
M2N	12	414.5787	3.783576	0.03
M5Z	8	414.9161	4.12095	0.03
M1Z	16	415.4377	4.642597	0.02
M1N	16	418.4658	7.670671	0.00
M3P	9	431.4852	20.69003	0.00
M4P	8	432.8765	22.08135	0.00
M2P	11	433.7599	22.96472	0.00
M6P	8	435.3196	24.52444	0.00
M5P	7	437.331	26.53587	0.00
M1P	15	437.6761	26.88092	0.00