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## Overview:

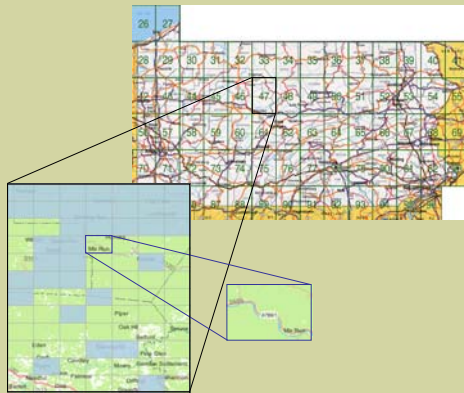
State of the art sampling design and protocols allow the 2<sup>nd</sup> Pennsylvania Breeding Bird Atlas to use sophisticated statistical modeling to estimate state-wide population sizes of territorial landbirds.

Here, we demonstrate the analyses with current data for Scarlet Tanager

- 1) using a new model combining distance data with time-to-detection,
- 2) using a fixed radius time-to-detection model,
- 3) and using a mark-recapture model.

## Spatial sampling design:

The geographical area of Pennsylvania was divided into a grid of more than 4,500 blocks (each approximately 25 sq. km). Eight point-count survey locations were chosen randomly along side roads within each survey block. By completion, this will provide a comprehensive spatial coverage for the entire state.



## Point-count protocol:

Each bird detected by song was recorded as within or beyond 75m from the observer during each of five consecutive 75-second time intervals. Significantly, observers also recorded if a bird was re-detected by song in subsequent time intervals. The surveys were conducted by highly skilled observers who received extensive evaluation and training beforehand.



## Statistical models:

We developed a new method combining removal sampling with distance information and compared the results with estimates from fixed-radius removal sampling and mark-recapture models. We analyzed data from Scarlet Tanager (*Piranga olivacea*) because Pennsylvania has a high regional conservation responsibility for this species and a robust sample. Each model was written in SURVIV by conditioning on the total birds counted.

### Combined approach with removal sampling and distance information:

Let us assume birds are distributed with uniform density ( $D$ ). Each bird has a per interval probability of singing ( $p$ ). Thus the probability it fails to sing (and can not be detected) is  $q = 1 - p$ . The probability a bird will be detected is a function of the probability it sings and the distance it is from the observer. Another way to look at this is that the probability a bird is not detected is the probability it fails to sing ( $q$ ) plus an increasing function of distance ( $r$ ) from the observer such that even if the bird sings, it is likely to be undetected the farther it is from the observer. We can define such a function as:

$$Q(r) = q + \left(\frac{r}{a}\right)^2$$

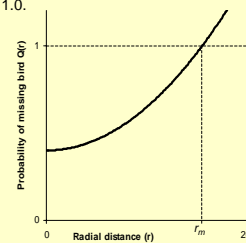
where  $q$  and  $a$  are parameters to be estimated. The maximum detection distance  $r_m$  can be estimated from these parameters by setting  $Q(r) = 1.0$ .

The expected values for the statistics are:

$$E(X_{1j}) = D\pi \int_0^{r_j} Q^{j-1}(1-Q)2rdr$$

$$E(X_{2j}) = D\pi \int_{r_c}^{r_j} Q^{j-1}(1-Q)2rdr$$

$$E(X_{..}) = D\pi \int_0^{r_m} (1-Q^5)2rdr$$



where  $X_{ij}$  is the number of birds counted in the  $j^{\text{th}}$  distance category during the  $i^{\text{th}}$  time interval. Here we have only two distance categories:  $r = 0$  to  $r_c$  and  $r = r_c$  to  $r_m$ . In our sampling design  $r_c = 75m$ . We also tested a two-point mixture model by dividing the population into two groups using a parameter  $c$  (proportion of population in group 1).

We tested models of heterogeneity & chose that with minimum AIC:

- $M_p$ : Full two-point mixture model. This models two groups of birds each with a separate  $Q$ . Thus 5 parameters ( $q_1, q_2, a_1, a_2$ , and  $c$ )
- $M_{p1}$ : No heterogeneity in maximum detectable distance. Constrain  $r_{m1} = r_{m2}$
- $M_{p2}$ : No heterogeneity in singing probability. Constrain  $q_1 = q_2$
- $M_{p12}$ : Partial mixture. Constrain  $q_2 = 0.0$
- $M_{p22}$ : Partial mixture. No heterogeneity in  $r_m$ . Constrain  $q_2 = 0.0; r_{m1} = r_{m2}$
- $M_{p1c}$ : No heterogeneity in singing frequency ( $q$ ) or maximum distance ( $r_m$ )

### Fixed radius removal sampling (time-to-detection):

We developed a removal (time-to-detection) model for 5 equal intervals such that the equations for the statistics were:

$$E(X_{..}) = Np(1-p)^{i-1}$$

$$E(X_{..}) = N[1 - (1-p)^5]$$

where  $N$  is the population within the area being sampled and  $p$  is the probability of being detected within any one time interval.

We tested three models & chose that with minimum AIC:

- $M_p$ : Full two-point mixture model (estimating  $p_1, p_2$ , &  $c$ ).
- $M_{p1}$ : Partial mixture model. One group with detectability 1 ( $p_1 = 1$ ; estimating  $p_2$  &  $c$ )
- $M_{p1c}$ : No heterogeneity ( $p_1 = p_2; c = 1$ )



### Fixed radius mark-recapture:

We used closed mark-recapture models based on the frequency ( $f$ ) of detection.

$$E(f_i) = \frac{5!}{i!(5-i)!} Np^i (1-p)^{5-i}$$

where  $f_i$  is the number of birds detected  $i$  times.

We tested two models & chose that with minimum AIC:

- $M_p$ : Full two-point mixture model (estimating  $p_1, p_2$ , and  $c$ )
- $M_{p1c}$ : No heterogeneity ( $p_1 = p_2; c = 1$ )

## Results:

Here we present analyses of data from the first three years (2004-2006) of this five-year project. A total of 13,252 point-count surveys were conducted. Our estimates of the population density ranged from 3.2 to 4.0 males per square kilometer, yielding estimates of the breeding population of Scarlet Tanagers in Pennsylvania ranging from 375,000 to 475,000 breeding pairs (Table 1).

**Table 1.** Comparison of population density estimates from three statistical models applied to 2<sup>nd</sup> Pennsylvania Breeding Bird Atlas data from 2004-2006.

Statistical Model	Model selected	Population density estimate (birds/km <sup>2</sup> )	95%CI	Statewide population estimate
Distance/removal	$M_{p1}$	3.69	1.72, 5.66	433,351
Fixed removal	$M_p$	4.04	2.92, 9.32	474,636
Mark/recapture	$M_{p1c}$	3.20	3.13, 2.27	375,432

## Discussion:

We are encouraged that our analyses are producing reasonable estimates for the state-wide population of Scarlet Tanagers. One advantage of the new model (distance & removal) is that it incorporates information from all 2,380 birds detected whereas the other two methods only analyzed the 684 birds detected within 75m of the observer.

Our estimation methods did not require the assumption that all observers have the same ability to detect birds (i.e., detection probability). However, previous analyses of these data failed to detect differences among observers and we do not address this source of variation in these analyses.

The sampling protocols adopted by the 2<sup>nd</sup> Pennsylvania Breeding Bird Atlas were designed to allow multiple methods of statistically rigorous analyses. Here we show preliminary results from three models using only Scarlet Tanager as a representative species. The approach should work for most of the common breeding species of landbirds in Pennsylvania. We also anticipate using this database to develop additional models. Specifically, we expect to develop a model that can combine information from the time of first detection, distance from observer, and re-detection history. Future work will also stratify analyses based on geographical information (e.g. habitat type, elevation, aspect, rainfall, etc.).