

Sampling to Estimate Population Size and Detect Trends in Tricolored Blackbirds

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The Tricolored Blackbird (*Agelaius tricolor*) is a medium-sized passerine that nests in the largest colonies of any North American landbird since the extinction of the passenger pigeon (*Ectopistes migratorius*) over 100 years ago (Beedy and Hamilton 1999). The species has a restricted range that occurs almost exclusively within California, with only a few hundred birds scattered in small groups in Oregon, Washington, Nevada, and northwestern Baja California, Mexico (Beedy and Hamilton 1999). Tricolored Blackbirds are itinerant breeders (i.e., breed more than once per year in different locations) and use a wide variety of nesting substrates (Hamilton 1998), many of which are ephemeral. They are also insect dependent during the breeding season, and reproductive success is strongly correlated with relative insect abundance (Meese 2013). Researchers have noted for decades that Tricolored Blackbird's insect prey are highly variable in space and time; Payne (1969), for example, described the species as a grasshopper follower because they are preferred food items, and high grasshopper abundance is often associated with high reproductive success (Payne 1969, Meese 2013). Thus, the species' basic reproductive strategy is tied to rather infrequent periods of relatively high insect abundance in some locations followed by much longer periods of range-wide relatively low insect abundance and poor reproductive success. Of course, anthropogenic factors such as habitat loss and insecticide use may be at least partly responsible for these patterns (Hallman et al. 2014, Airola et al. 2014).

The Tricolored Blackbird was formerly considered to be one of the most abundant land birds in California (Beedy and Hamilton 1999), and it is likely that 2-3 million birds remained into the 1930s (estimated by extrapolation of Neff 1937, see Meese 2015). The alarming decline in abundance, especially in the past decade, to only 145,000 birds in 2014 (Meese 2014) led to an emergency listing of the species as endangered under the California Endangered Species Act (CESA) in December 2014 (State of California 2014).

It is inherently difficult to assemble enough information on rare species to enable robust evidence-based recovery efforts. In some ways, Tricolored Blackbirds pose particular problems in that they breed in rather small numbers of large, somewhat ephemeral colonies that, over time, come and go across the landscape (Holyoak et al. 2014). As a result, classic random sampling is likely to miss large colonies, or to produce unreliable estimates of total population size. On the other hand, the future of the species may rest on the success or failure of a fairly small number of large and conspicuous colonies which are intensively monitored and that may have the greatest reproductive success (Meese 2013). Thus, the species' unusual biology makes it a challenging study subject, and as a consequence, creates a special need for science to inform conservation efforts.

Here we describe the problems inherent in estimating total population size and temporal trends in population size for Tricolored Blackbirds. In order to reliably survey the birds and to estimate their numbers, it is of strategic importance to locate their breeding colonies and to count them during the breeding season. While at their breeding colonies, the birds are relatively fixed in space and their behaviors make them conspicuous and relatively easy to locate and count (Beedy and Hamilton 1999). To introduce the problems of sampling total population size and trends, we review previous efforts both in the form of early surveys of limited geographic extent as well as Statewide Surveys, and then describe an approach for estimating the statewide population from a statistical sample of sites.

EARLY SURVEYS

From the 1930s until the mid-1990s, the status of the Tricolored Blackbird was assessed by intensive surveys undertaken during the entire breeding season in a portion of the species' range that emphasized the Sacramento Valley (Neff 1937, DeHaven et al. 1975). Early workers conducted fieldwork alone or in small teams and intensively surveyed appropriate habitats from public roads. Most knowledge of the birds' distribution and colony locations relied on a few experts. As Meese (2015) described, inconsistencies in methodology and survey effort difficult it hard to compare the early surveys and to know how reliable they were at indicating total population size of the species.

STATEWIDE SURVEYS

Since 1994, the size of the statewide population has been estimated by the Tricolored Blackbird Statewide Survey (Beedy and Hamilton 1997, Meese 2015), a mostly triennial volunteer effort that occurs over a 3-day interval. The Statewide Survey differs from previous efforts to determine the status of the species in the following ways.

- It occurs during a 3-day period rather than the entire breeding season in an attempt to minimize the potential for double-counting the same birds in more than one location.
- It attempts to count birds throughout their range in California.
- It relies upon numerous volunteers, rather than a few experts.
- Participants survey all known breeding colony locations.

Early Statewide Surveys conducted in 1994, 1997, 2000, 2001, and 2005 utilized volunteers and a single statewide coordinator to provide extensive geographical coverage that sought to estimate of the entire California population. More recent Statewide Surveys conducted in 2008, 2011, and 2014 utilized both a statewide coordinator and individual county coordinators to take better advantage of local knowledge and to reduce the burden of coordinating an effort that included over 35 counties and over 100 volunteer participants (Meese 2015).

The Tricolored Blackbird Statewide Survey provides an estimate of the number of birds in the entire state; however it is not without limitations (Meese 2015):

- It is extremely labor intensive and consequently occurs only every third year.
- There is a risk of participant fatigue, which over time may limit the size of the participant pool. This fatigue can negatively affect the effort if the most experienced persons cease to participate.
- It utilizes volunteers with diverse levels of experience in Tricolored Blackbird biology and in estimating the numbers of birds at breeding colonies.
- Despite best efforts to provide a complete census of the species in California, it is at best an estimate because it is impossible to cover all areas of suitable habitat and precisely count every individual.
- Prior to 2008, the Statewide Survey made no attempt to measure or quantify potential sources of counting error, such as variations in survey coverage and imperfect and variable rates of colony detection.

As a result, these early surveys lack error estimates or confidence intervals around the population size estimates. Beginning in 2008, the survey methods improved to report results for all sites surveyed (whether occupied or not). Also, a small number of sites was surveyed by more than one observer to provide a means to quantify error.

ESTIMATES FROM A STATISTICAL SAMPLE

With the emergency listing of the Tricolored Blackbird under CESA in December 2014, and petition for federal listing under consideration, the conservation of the species should receive far greater attention by State and

Federal agencies. An increase in the frequency and statistical rigor of the population estimate will help agencies to monitor the status of the population and its responses to conservation actions. Three developments have provided an opportunity to more rigorously examine Tricolored Blackbird population trends.

- Knowledge of sampling designs and understanding of statistical considerations in general have increased.
- The size of the data set of tricolor numbers and locations provided by scientists and concerned citizens is rapidly increasing.
- Data management capabilities have recently improved.

Increases in both data quantity and quality have resulted from the development of the Tricolored Blackbird Portal in 2008 and its web-based data entry and data standardization capabilities. These improvements provide a new opportunity to apply statistical considerations to a population estimate derived from a sample of breeding colony locations.

Key desirable attributes of the new sample-based scheme for estimating populations include:

- the feasibility to conduct surveys annually;
- random selection of sampling sites that are stratified by important factors (habitat type, bioregion, etc.);
- quantifiable sources of variability, including the detectability of colonies and variability of observer estimates of number of birds at occupied sites;
- the ability to generate estimates of population size, population change, and breeding colony size;
- the ability to calculate confidence limits of estimates; and
- the ability to estimate the probability of colony detection.

We emphasize that the subset sampling approach will produce less information than does the census approach and the population size estimate will not be better than that produced by a more complete census, but the sampling approach aims to improve existing population information by:

- improving information collection during the years between the triennial Statewide Surveys;
- producing estimates that can be compared to the full triennial Statewide survey estimates, without the intense effort that is required for the full Survey;
- providing more complete information on temporal changes, including trends and inter-annual variation; and
- increasing opportunities for conducting double-observer surveys, which will enhance the reliability of error estimates and confidence intervals.

The application of statistical considerations to an annual sampling effort will allow biologists to rigorously estimate the number of birds in California with a far smaller number of field workers. The sample-based scheme will provide determinations of the amount of uncertainty in the estimates of the total number of birds and in the numbers at individual colonies. Although there has been a recent, dramatic downward trend in the sizes of the largest colonies (Meese 2015), the largest errors in the estimates of the numbers of breeding birds may be expected to be associated with the largest colonies. Therefore, a sample survey at a subset of known sites selected according to a carefully designed scheme should try to include those sites having the highest measurable expectation of supporting large colonies.

Surveying a sample of colonies will help to alleviate participant fatigue and allow an annual, rather than a triennial, population estimate and thus allow an annual estimate of the trend in the number of birds while providing confidence intervals of the estimates. Annual estimates would allow rapid assessments of any continued population declines and help biologists to assess the results of conservation actions.

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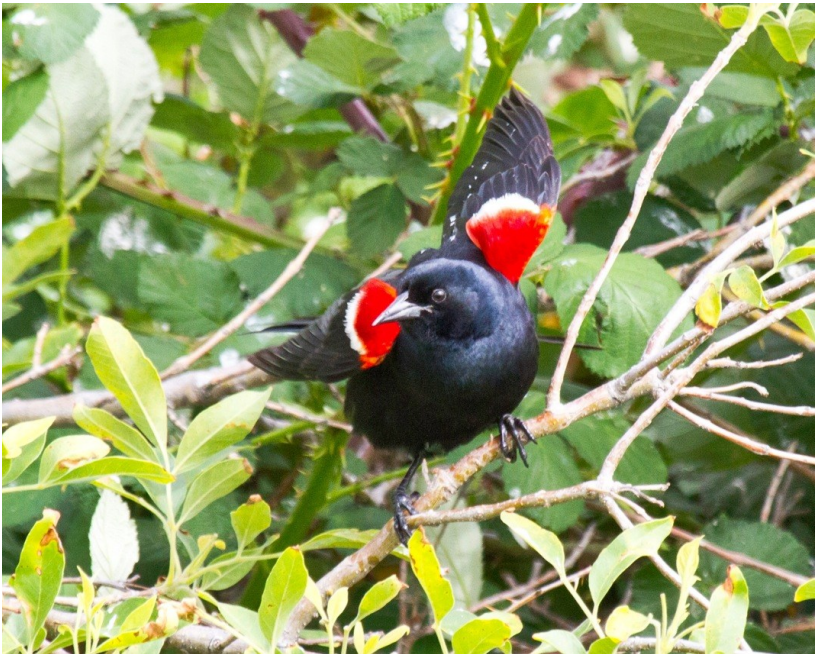
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Tricolored Blackbird (*Agelaius tricolor*). 14 April 2014. Sacramento County, California. Photo © Phil Robertson.