# Tricolored blackbird survey methods

June 6, 2024

## REVIEW PAPER

**Daniel Airola[1]*, Edward C. Beedy[2], Susan Sanders[3], and Joseph Medley[4]**

[1] *Conservation Research and Planning, Sacramento, CA, USA*
https://orcid.org/0000-0001-6725-4230
[2] *Beedy Environmental Consulting, 12213 Half Moon Way, Nevada City, CA 95959, USA*
[3] *AECOM, 2020 L Street, Suite 300, Sacramento, CA 95811, USA*
[4] *USDA Forest Service, Bass Lake Ranger District, 57003 Road 225, North Fork, CA 93643, USA*

**Corresponding Author: **d.airola@sbcglobal.net***

Published 6 June 2024 • doi.org/10.51492/cfwj.110.6

# Abstract

Surveys for the tricolored blackbird (*Agelaius tricolor*), a California-listed threatened species, are needed to provide essential information about its status and distribution to support conservation efforts. Surveying for the species, however, poses challenges because of its colonial nesting habits, large flock sizes, and frequent interannual movements among colony sites. We present standardized approaches for tricolored blackbird surveys to accommodate a variety of goals, including determining potential for occurrence, detecting colonies, estimating population numbers, and assessing nesting success. Pre-survey research should assess overlap with the species' geographic range and include database searches for recent and historical occurrences. Site surveys should assess availability of sufficient suitable foraging habitat (grasslands, irrigated pasture, shallow wetlands, agricultural fields) within 5 km of potential nesting habitat and nearby drinking water. Confirming presence or absence of nesting at a historical colony site, or at an area within the range of the tricolored blackbird that provides suitable nesting and foraging habitat, requires at least three surveys conducted about three weeks apart during the breeding season, generally April, May, and June in most of the species' range. Colonies can be located by searching for foraging flocks and following them to colonies and by checking for nesting activity at suitable nesting substrates, especially those used in the past. Surveyors can estimate numbers from counts of foraging flocks departing and arriving at colonies, average density and area occupied by the nesting colony, and post-nesting density transects. Colony nesting success (i.e., whether a colony successfully fledged some young), is easily determined and is often the only feasible metric to attain on reproduction. Determining reproductive success (the average number of young fledged per occupied nest) may be feasible under ideal and intensive surveys but is impractical at many colonies due to accessibility limitations.

**Key words:** *Agelaius tricolor*, breeding, colonial, occurrence, population survey, reproductive success, survey methods, tricolored blackbird

**Citation:** Airola, D., E. C. Beedy, S. Sanders, and J. Medley. 2024. Tricolored blackbird survey methods. California Fish and Wildlife Journal 110:e6.

**Editor:** Shannon Skalos, Wildlife Branch

**Submitted:** 28 October 2023; **Accepted:** 29 January 2024



**Competing Interests:** The authors have not declared any competing interests.

# Introduction

The tricolored blackbird (*Agelaius tricolor*) was listed as a threatened species under the California Endangered Species Act (CESA) in 2019 because of habitat loss, nest losses to agricultural harvest, and insecticide use (Clipperton 2018; Beedy et al. 2023). The species' conservation and legal status necessitates surveys and monitoring for a variety of purposes, including monitoring population status, determining potential for land use conflicts, and monitoring effectiveness of conservation actions. Surveys may also be required to support impact assessments for proposed projects on public and private lands to comply with CESA, the California Environmental Quality Act (CEQA), and other environmental laws and regulations.

A variety of tricolored blackbird survey protocols have been developed for specific purposes, including methods for the statewide tricolored blackbird survey that has been conducted in California since 1994 (Kelsey 2008; Riverside County 2018; Meese 2017; Colibri Ecological Consulting 2022). Here we present standardized methods at various intensities to provide a consistent approach to tricolored blackbird surveys that can be applied throughout the species' range.

Various types of surveys are applicable depending on goals that may include determining habitat suitability, colony detection, estimating numbers, and assessing nesting status and success. These methods may be employed sequentially, such that a site may first be evaluated for suitability and then, if found to be suitable, surveyed for presence or absence of a colony, colony size, and reproductive success. Some presented methods here, especially for colony detection and estimating numbers, overlap with the approach used in the statewide tricolored blackbird survey (Meese 2017; Colibri Ecological Consulting 2022). However, that one-weekend survey is intended primarily to acquire a statewide population number rather than definitively characterize occupation, numbers of breeders, and breeding success at individual sites, as is our focus here. We focus mostly on surveys for breeding colonies, but also offer advice for conducting surveys for winter-roosting tricolored blackbirds (**Table 1**).

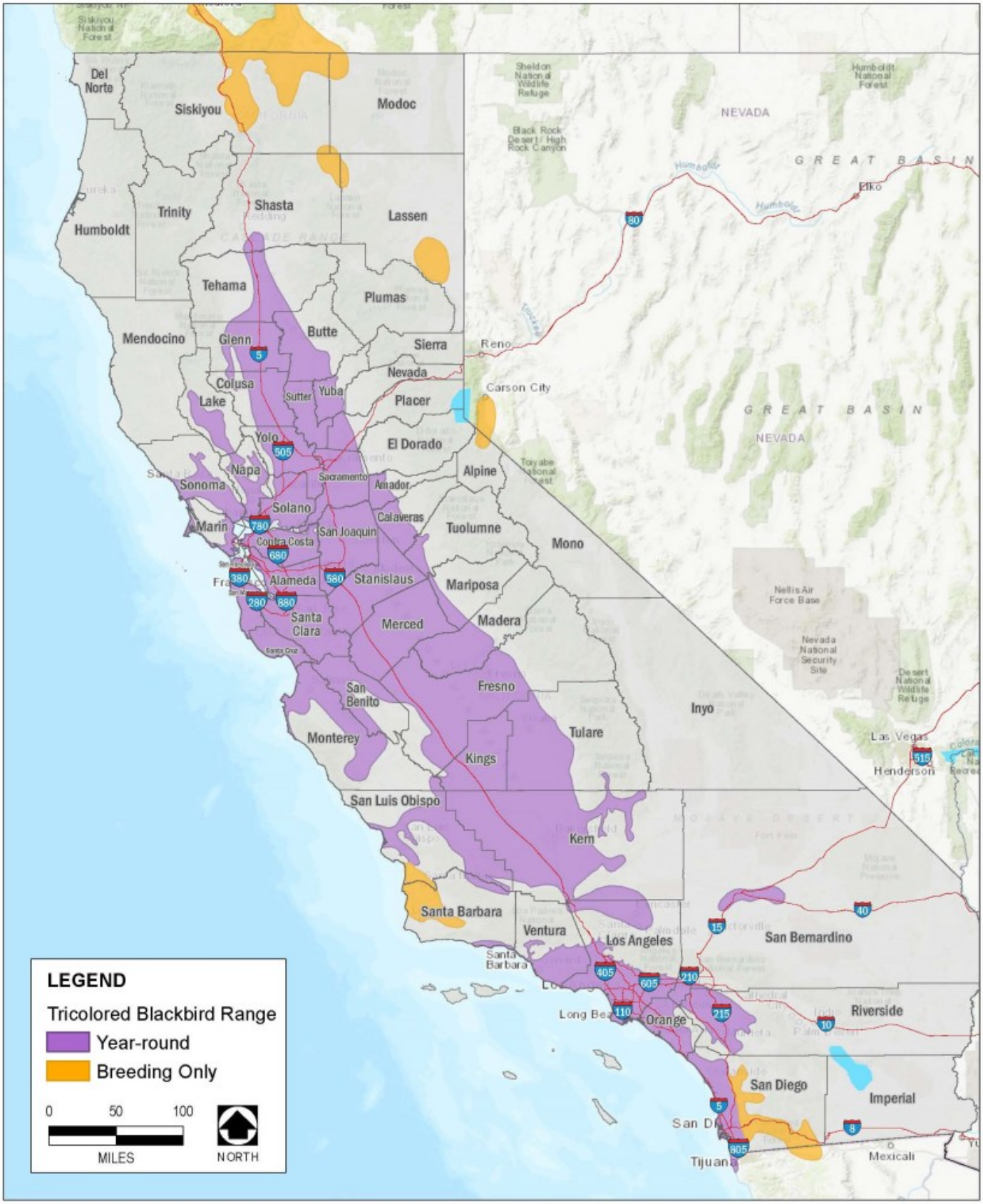
**Table 1.** Summary of tricolored blackbird survey methods and key actions for various survey goals.

| Survey Goal | Method | Key Actions |
|---|---|---|
| Determining Potential for Occurrence | Pre-survey research | Check geographic range, general habitat conditions, and elevation |
| Determining Potential for Occurrence | Reconnaissance site visit and habitat assessment | Review aerial imagery for adequate suitable open foraging habitatCheck site and nearby areas for suitable nesting habitat and available surface water |
| Detecting Colonies | Determining past site use | Review historical and recent records in CNDDB, eBird, and Tricolored Blackbird Portal |
| Detecting Colonies | Focused surveys to assess presence/absence of nesting colony and suitable foraging habitat | Conduct at least 3 surveys ~ 3 weeks apart over the breeding season within 5 km of project sitesEvaluate suitability of foraging habitat |
| Detecting Colonies | Colony detection surveys | Survey known colony sites, suitable nesting habitat, and search suitable open foraging habitat areas for foraging flocks |
| Estimating Numbers | Direct counts | Focus counts on lines of departing and arriving birds during the settlement and nestling stagesAdjust counts for estimates of birds remaining in colonies or away foraging. |
| Estimating Numbers | Estimates from passage rates | Count numbers flying per sample period and multiply by the duration of departure or arrival events |
| Estimating Numbers | Estimates from area occupied | Estimate area of occupied nesting habitat and multiply by standard density estimates |
| Estimating Numbers | Estimates from nest density transects | Conduct sample transects after colony fledging and multiply density by occupied area and by sex ratio correction factor (0.67) |
| Estimating Numbers | Counting large colonies | Generate a collective estimate from multiple observers' estimates, area occupied, and typical density |
| Determining Nesting Success | Colony success | Search for fledged young or presence of feces in empty nests |
| Determining Nesting Success | Reproductive success | Count fledglings at 4–6-day intervals after first fledglings observedDivide number of fledglings by the product of number of breeding birds x 0.67 (to account for 2:1 sex ratio) |
| Surveying Winter Roosts | Counts at roosts | Count in areas of dense emergent vegetation at duskRecognize that little is known about night roosting habits and habitats |

# Determining Potential for Occurrence

## Pre-Survey Research

The first step in evaluating the potential for tricolored blackbird occurrence is to examine the species' geographic range in relation to the site of interest and consult databases for historical and recent records of occurrence. The tricolored blackbird occurs primarily in California (**Figure 1**), but its geographic range is shown in its entirety by Beedy et al. (2023). Relevant databases include eBird (**https://science.ebird.org/en**), the California Department of Fish and Wildlife's (CDFW's) California Natural Diversity Database (CNDDB; **https://wildlife.ca.gov/Data/CNDDB**), and the Tricolored Blackbird Portal (**https://tricolor.ice.ucdavis.edu/**).




Source: BirdLife International and Handbook of the Birds of the World (2022)

**Figure 1.** Tricolored blackbird breeding and year-round range in California. (Map created by AECOM)

The species' geographic range generally occurs in regions with extensive open grasslands and agricultural lands. Most colonies occur at lower elevations (e.g., primarily below 200 m elevation in the Central Valley and adjacent foothills), but where suitable conditions exist, nesting can occur at elevations up to 1,200 m in the foothills of the Sierra Nevada. Transverse Ranges, and Coast Range (Airola et al 2023a; Beedy et al. 2023).

## Reconnaissance Site Visit and Habitat Assessment

If the survey or project area is within the range of tricolored blackbirds, aerial imagery (e.g., Google Earth) should be reviewed to assess whether extensive foraging habitat is available within 5 km of the project area. Tricolored blackbird foraging flight distances vary considerably over the course of a breeding season due to shifting food availability and the nutritional demands of nestlings and fledglings. Most foraging occurs within 1 km from colony sites, but adults have been recorded foraging up to 8.6 km away(Hamilton and Meese 2006). We consider 5 km from the nesting colony as the most relevant distance within which to assess habitat conditions because it is consistent with typical foraging distances reported (Orians 1961; Crase and DeHaven 1977; Hamilton and Meese 2006; Wilsey et al. 2019; Airola et al. 2023a).

In the Sierra Nevada foothills where concentrated food sources such as feed lots, dairies, and organically farmed rice fields are mostly absent, areas in which at least 60% of the area within 5 km (i.e., 2,400 ha) support suitable foraging habitat (described below) could support a tricolored blackbird colony (Airola et al. 2023a) and warrant reconnaissance surveys. The minimum amount of foraging habitat to support colonies is not well documented in other portions of the species' range, but we recommend reconnaissance surveys there if several hundred hectares of suitable foraging habitat, and especially concentrated food sources, are present within 5 km of a project site. Although tricolored blackbirds have modified their foraging and nesting behaviors to accommodate anthropogenic habitat changes within their range, certain key habitat components described below must be present to support nesting colonies, including suitable foraging and nesting habitat and surface water for drinking and bathing (Meese and Beedy 2015).

*Open Foraging Habitat and Concentrated Food Sources.*—Tricolored blackbirds are birds of open habitats that forage almost entirely on the ground for seeds and invertebrates. They generally prefer to feed as near as possible to colonies, but regularly travel up to 5 km (and infrequently up to 10 km) from colonies to exploit concentrated food sources.

Suitable foraging habitat generally consists of grazed grasslands, irrigated pasture, shallow wetlands, and agricultural fields, especially fields with annual seed crops such as rice (particularly organic crops), alfalfa, ripening or cut oats, milk-stage barley, wheat, and storage bins of livestock food (Crase and DeHaven 1977; Skorupa et al. 1980; Meese 2013; Beedy et al. 2023). Tricolored blackbird colonies require large quantities of insects to feed their young. Nestlings are fed almost entirely insects for the first nine days after hatching (Skorupa et al. 1980), so colonies depend on dense concentrations of invertebrate prey such as grasshoppers, lepidoptera larva, and flies, including those produced in dairy operations (Goodward and Diaz 2023), to meet protein-rich food requirements. Denser concentrations of invertebrate prey tend to occur in small portions of the overall suitable foraging habitat and are often ephemeral, thereby necessitating multiple foraging sites over the course of a nesting season and in different years. As a result, tricolored blackbirds require large areas of suitable foraging habitat within

which they can find these food-rich areas.

Airola et al. (2023a) found a strong relationship between the amount of suitable foraging habitat with a 100 $km^2$ area and the probability of colony occurrence in the grasslands of the Sierra Nevada foothills. Colonies were most likely to occur where at least 80% of the area within 5 km of a potential colony site contained suitable foraging habitat, and no areas where foraging habitat comprised less than 60% were used for nesting. Because patch sizes of nesting habitat used may be so small as to not be mapped in existing vegetation mapping data (Airola 2021), areas that support extensive foraging habitat with concentrated prey sources and suitable nesting habitat within 5 km should be assumed to have potential for occurrence of tricolored blackbirds unless otherwise determined.

*Suitable Nesting Habitat.*—Tricolored blackbirds nest in a variety of vegetation types, but most breeding colonies occur in emergent cattail (*Typha* sp.) and tule (*Schoenoplectus* sp.) marshes, non-native Himalayan blackberry (*Rubus armeniacus*), and agricultural fields, especially triticale (*Triticum X Secale*) grown for dairy silage (Meese and Beedy 2015; Airola 2021; Beedy et al. 2023; Castañeda et al. 2023).Patch sizes of nesting habitat used by tricolored blackbirds may be very small (i.e., 0.04–1.1 ha; Airola 2021) and therefore may not be depicted in existing large-scale vegetation mapping data. Most areas that support extensive foraging habitat provide an adequate amount of nesting habitat to support colonies, but its availability should be verified.

*Water.*—Surface water for daily drinking and bathing is a key habitat requirement (Wilsey et al. 2019; Beedy et al. 2023). A variety of water sources are used, including natural streams and wetlands and vernal pools in grasslands, as well as anthropogenic sources such as farm and field ditches, flood irrigation, irrigation sprinklers, and drip irrigation (Beedy et al. 2023). Little quantitative information on distance from nesting areas to water is available, but some colonies at dairies or in uplands (especially milk thistle [*Silybum marianum*]) may be >100 m from the nearest water (Beedy et al. 2023). Many plants used as nesting habitat, including cattail, tule, and Himalayan blackberry, are associated with open water or saturated soils (Meese and Beedy 2015; Wilson et al. 2016; Airola 2021) or regular irrigation (triticale and other crops; Castañeda et al. 2023), which typically provide a nearby water source. Therefore, most areas that support suitable nesting habitat are also likely to provide adequate drinking water.

In summary, the most important criterion for determining whether a site containing potential nesting habitat could support a tricolored blackbird colony is the presence of an adequate amount of suitable foraging habitat within 5 km of suitable nesting habitat. Areas with adequate foraging habitat will generally, but not always, provide adequate nesting habitat and drinking water and thus could potentially support a nesting colony.

# Detecting Colonies

## Determining Past Site Use

Some survey efforts may seek to determine if a nesting colony is present or if it could be present at a site in the future. In addition to evaluating suitability based on existing habitat conditions, potential colony sites can be identified from past records of occurrence at or near a site. Tricolored blackbirds are itinerant breeders and often rotate colony locations among different sites in a region (Airola et al. 2023a).

Breeders tend to be philopatric to more than one site (Hamilton 1998); banding studies found that nearly one-fourth of 2,972 recaptured birds were recaptured in the same location where they were banded and nearly 40% were recaptured in the same county (Beedy et al. 2023). Colony sites in the Sierra Nevada foothills, mostly in patches of Himalayan blackberry, were occupied in subsequent years only about 50% of the time, although the birds appeared to relocate to other nearby areas and often returned to previously used sites in later years (Airola et al. 2018). Colony sites may shift in response both to changes in the abundance of preferred prey and interannual differences in nesting habitat suitability (Graves et al. 2013; Airola et al. 2016). Therefore, the presence of a past colony indicates a likelihood of future re-use of the site or a nearby area if it retains suitable nesting and foraging conditions.

Locations of previously used colony sites are available from CNDDB and the Tricolored Blackbird Portal. Of course, not all past colony sites have been found, in part because many areas with suitable habitat are inaccessible on private lands. Also, over time new areas of suitable nesting habitat become available due to changes in maintenance or farming practices, rainfall, and growth of nesting substates. Conversely, previously occupied, and suitable areas can become unsuitable especially due to land uses change (i.e., development or conversion to crops such as orchards and vineyards that are unsuitable for foraging and breeding (Cook and Toft 2005; Airola et al. 2023a,b). Therefore, the current suitability of previously occupied sites needs to be verified by focused surveys.

## Focused Surveys to Assess Presence/Absence of a Nesting Colony and Foraging Habitat

To comply with CEQA assessment requirements or certain permit conditions (e.g., a CDFW Lake and Streambed Alteration Agreement) it is often necessary to determine if a proposed project site supports an active tricolored blackbird nesting colony or provides foraging habitat that is important to a nearby active colony. If the proposed project site is near a historical nesting record it may also be necessary to confirm whether that site is occupied or unoccupied.

To assess nesting presence or absence at a historical colony site, or at an area within the range of the tricolored blackbird that provides suitable nesting and foraging habitat, at least three surveys should be conducted approximately three weeks apart during the breeding season (**Table 2**). Surveys should cover suitable habitat within the entire project area and an area within 5 km of the proposed project area, at least to the extent to which access permission can be acquired or lands can be viewed from publicly accessible or authorized areas. Surveys should be conducted by biologists who are experienced in identifying tricolored blackbirds by sight and sound, and knowledgeable about their biology, especially about the habitat types needed for foraging and nesting and foraging behavior.

**Table 2.** Tricolored blackbird nesting periods by region.

| Region | Nesting Period | Source |
|---|---|---|
| Baja California | Late March – Early June | Erickson et al. 2021 |
| Southern California | Late March – Early June | Beedy et al. 2023 |

| Region | Nesting Period | Source |
|---|---|---|
| San Joaquin Valley and adjacent areas | Late March – Early June | Beedy et al. 2023 |
| Central California coast | Early April – early July | Wilson et al. 2016 |
| Central Sierra Nevada foothills | Early April to Late June | Airola et al. 2015; D. Airola unpublished data |
| Sacramento Valley | Early April – Mid-August | Orians 1961; Colibri Ecological Consulting 2022 |
| Northeastern California and Nevada | Mid-April – Mid-August | Extrapolated from other locations |
| Oregon and Washington | Early April – Mid-August | Gilligan et al. 1994; McCormick 2022 |

Typically, colony surveys should occur in April, May, and June (**Table 2**), but in more northerly locations the last of the three surveys should start later and may need to extend to mid-August. In more southerly locations nesting may be initiated as early as March, and even exceptionally in February in the southern San Joaquin Valley (Beedy et al. 2023). Notably, under recent warming climate conditions, breeding is occurring earlier, so the timing of breeding may continue to shift toward earlier dates. The timing of nest initiation by different colonies in a small region may vary by as much as six weeks during a single year, and the timing of nesting may vary among years by up to three weeks or more depending on weather (D. Airola, unpublished data).

Three surveys spread throughout the tricolored blackbird nesting season will adequately cover the typical 41–45-day breeding period for a successful nesting pair (**Table 3**; Beedy et al. 2023) and variation in timing of breeding (**Table 2**). Understanding of tricolored blackbird nesting phenology and behavior, and resulting detectability, is important for conducting effective surveys. Incubating females are typically silent while on the nest during incubation, and males often remain inconspicuous, so active colonies may appear to be largely deserted then. Smaller and highly synchronous colonies are especially inconspicuous during this period and may be overlooked or their size underestimated (Beedy et al. 2023).

**Table 3.** Tricolored blackbird breeding phenology[a].

| Activity | Duration | Comments |
|---|---|---|
| Colony Prospecting and Pair Formation | 12–17 days before nesting building begins | Males typically arrive before females and perch conspicuously on top of vegetation; may begin singing as early as late February; most males mate with two females. |
| Nest Building | Average 4 days, range 3–5 days | Timing of nest building may vary within colony, so may extended beyond the per-nest duration reported here. |
| Egg Laying | 1 egg laid/day for 1–5 days | Egg-laying may begin as early as the 2nd day after nest initiation but typically starts about 4 days after settlement. Clutch size typically 3–4. |

| Activity | Duration | Comments |
|---|---|---|
| Incubation | 11–12 days | Only females brood and begin incubating with laying of last egg or on the next day. Females are mostly silent on nest, while males perch inconspicuously below vegetation or away from colony. |
| Nestlings | 9–10 days | Males and females feed nestlings; mean interval for foraging trips varies but is about 15 min for females, 30 min for males. |
| Fledging | 11–14 days | By day 4 after fledging, young fly to trees or other tall vegetation within 500 m of colony. By day 6, young typically disperse from colonies and join adults to fly to water and foraging areas. |

[a] Sources: Orians 1961; Payne 1969; Beedy et al. 2023

Nesting can extend beyond the typical 41–45-day period for several reasons. Newly arrived pairs may join a colony for up to several weeks after colony establishment and so nesting phenology may vary within a colony (Beedy et al. 2023; Wilson et al. 2016). Also, adults may breed twice or even three times at a colony site if conditions are favorable (Schackwitz et al. 2020; Beedy et al. 2023).

The presence/absence conclusions from the surveys are applicable only to the year in which they were conducted. If construction or other nest-disturbing activities are proposed to occur in years after the survey, then the focused surveys described above should be repeated.

## Colony Detection Surveys

Colonies are generally located in two ways: 1) searching for foraging flocks and then following them to colonies and 2) checking known and suitable nesting habitats.

*Search for foraging flocks*.—Tricolored blackbird flocks tend to occur in two different configurations during the breeding season: as migratory or pre-settling flocks and as foraging flocks from colonies. Because of their itinerant breeding pattern (i.e., tendency to nest more than once per year at different locations, first in the south and then further north; Hamilton 1998), migratory or prospecting flocks regularly move through breeding habitats during the breeding season in search of suitable nesting areas or while on their way to other breeding areas to the north. Migratory or non-breeding tricolored blackbirds tend to fly in a distinctive “wing-tip to wing-tip” flock structure that is wider than it is long.

In contrast, tricolored blackbirds associated with colonies fly in long lines (or “strings”) between the colony site and foraging areas. Foraging flocks from colonies also tend to fly lower than migrating or prospecting flocks. These flocks are relatively easy to locate in areas with adequate access (i.e., from public roads) and open, visible conditions because of their size and cohesion. Flocks can often be seen as far away as 1.5 km (Airola et al. 2015) and can readily be tracked to their nesting site if it is visible and accessible. Many areas of potential habitat, however, are on inaccessible private lands or not visible due to topography and vegetation screening.
*Direct Searching for Colonies.*—A second strategy for locating colonies is to check suitable nesting

substrates, especially previously used ones. Occupancy can often be determined at sites from the loud song choruses early in the season (Schackwitz et al. 2020; Beedy et al. 2023; Honig and Schackwitz 2023), swarming activity during settling and nest building, and by observing adults returning to colonies with food for nestlings. A caution for direct observation is that activity can be very low during the incubation period, such that activity at occupied colonies may be subtle and detected only by experienced observers or in later visits.

The statewide survey, typically conducted on one weekend every three years (Meese 2017; Colibri Ecological Consulting 2022), checks past colony locations and locates new colonies while travelling between previously used sites. The statewide survey, however, is intended to estimate the statewide population, and results are not always definitive in determining whether individual surveyed sites are active or inactive because sites occupied during the one-time surveys may be abandoned before nesting begins, or unoccupied sites may become active after the survey date (Airola et al. 2023b).

# Estimating Numbers

The tricolored blackbird forms the largest colonies of any North American passerine. Breeding colony sizes range from several hundred to tens of thousands of individuals (and historically hundreds of thousands; Neff 1937). Colonies of 15,000–25,000+ have been recorded in dairy silage fields in recent years (Colibri Ecological Consulting 2022), as numbers have started to rebound in the San Joaquin Valley (Castañeda et al. 2023), although colony sizes in the Sierra Nevada foothills generally average 1,500–2,500 birds (Airola et al. 2023b).

Determining numbers of tricolored blackbirds at nesting colonies is challenging for several reasons. The occurrence of birds in large numbers presents its own counting challenge. Dense nesting substrates impedes visibility, and the long-distance movements from colonies to foraging areas (regularly up to 5 km) means that at any given time a substantial proportion of the colony may not be present to be counted at the colony site. Thus, colony size estimation is an inexact science, with estimates typically believed to be within a range of 20% above or below actual values (Castañeda et al. 2023).

Despite the limitations on counting, reasonably accurate counts can be made by applying one or more of several methods alone or in combination. The main methods include direct counts, estimates from passage rates, and area counts (Audubon California 2008; Colibri Ecological Consulting 2022). Ideally, multiple counts and methods should be used and then compared to produce the best possible estimate. Counting accuracy can be improved through practice, by estimating numbers of tricolored blackbirds or other species or objects in the field and then counting them. Surveyors also can take photos of large flocks, estimate numbers, and then count numbers in the image and compute count-biases that can be used to adjust field estimates (Fulton and Kajrys 2019).

## Direct Counts

Direct counts are best conducted during settlement and nestling stages when birds typically leave the colony sequentially in “lines” of birds to foraging areas and then return in lines to the colony. Departures from colonies often occur over a period of 5–20 minutes or can be continuous, with birds coming and going multiple times to feeding areas. Departure rates vary depending on the size of the colony at rates of <1/sec to 50, 100, or even more birds per second.

Under these circumstances, counts are best made by waiting for birds to return to the colony, finding a lull in returns, and then counting departing birds by fives, 10s, 20s, 50s, or 100s (depending on the number of birds departing; Fulton and Kajrys 2019). At times, nearly all colony occupants may depart before any birds return. At other times, a substantial proportion of birds depart, while others remain at the colony. Finally, some birds often may begin returning to the colony before all birds have left, creating a challenge in deciding when to terminate counts to avoid double counting those birds that leave, return, and then leave again. One can also choose to count only arriving birds using the same procedures as for departing birds.

Counting departing birds provides a minimum estimate of numbers. The count can then be adjusted intuitively to account for birds that appear to have remained at the colony or those that may have left before the count was initiated. The result is an estimate, not an exact count, but one that is better than a simple guess or an order-of-magnitude approximation.

## Estimates from Passage Rates

Using passage rates to estimate numbers has been included in several previous protocols (Audubon California 2008; Colibri Ecological Consulting 2022). This method is similar to direct counts, but it samples departing or arriving birds for a prescribed period and multiplies the passage rate by the duration of flights to calculate an abundance estimate. Using passage rates is problematic because the rates of departure or arrival at colonies are seldom uniform. Since the use of passage rates requires remaining at the site throughout the flight period to determine the duration of flights, it is relatively easy and more accurate to just count continuously throughout the flight period. Therefore, we do not recommend using passage rates as an estimation method.

## Estimates from Area Occupied

This method involves mapping the area occupied by nesting birds (e.g., using Google Earth) and multiplying the area by an average density. This method relies on a critical assumption about nest spacing within colonies. Some colonies nesting in Himalayan blackberry have nesting densities of up to 6 nests/$m^2$, and a colony in Tulare County nesting in a triticale field had up to 12 nests/$m^2$ (Beedy et al. 2023). The average nest density in colonies in the Sierra Nevada foothills, however, is only 0.45/$m^2$ (D. Airola, unpublished data). In applying this method, it is important not to simply assume that all suitable habitat at a site is occupied, but rather to verify which area(s) are occupied by observing singing, arriving, and departing birds. With experience, a sense of likely population based on size of occupied area can be a useful check on estimates made through direct counts.

## Estimates from Nest Density Transects

Conducting nest transects to determine numbers of breeders can be effective but has limitations. Transect counts of nests are used to calculate nest densities of known sampled area, which is then applied to the entire area occupied by the colony to estimate a colony total. Nest counts can only be made after confirming that all nesting activity has been completed to avoid disturbing active nests and causing nest abandonment because nestlings will jump from nests when disturbed (Payne 1969; Kyle and Kelsey 2011). Triticale is typically very dry after nesting and often flattened or harvested, impeding nest

detection and resulting in underestimates. The nest-transect method also can only be conducted in accessible nesting substrates (i.e., not in the dense, spiny Himalayan blackberry). Transects should record only those nests that show signs of having been used (presence of unhatched eggs, nestling feces) as tricolored blackbirds often will construct and then abandon nests before egg-laying. The number of nests is converted to number of breeders by multiplying by 1.5, to reflect the typical male to female sex ratio of 1:2 in colonies (Orians 1961; Payne 1969).

## Counting Large Colonies

Counting colonies with more than 5,000 individuals is especially challenging because of the difficulty in estimating the sizes of multiple large groups of birds leaving and returning to the colony, often simultaneously from different directions. General guidelines for counting large colonies are as follows:

- Generate a "collective" estimate based on multiple observations throughout the colonization, settlement, incubation, nestling, and fledging stages. Keep a rough estimate of colony size at each visit and update the estimates as the colony grows or contracts.
- Estimate numbers in the morning when lighting is favorable and before temperatures rise and create heat waves. Avoid counting in windy or rainy conditions when birds may remain hidden in cover in silage or other vegetation.
- Be aware of random events, such as a predator or a large airplane flying over, that may cause large groups of birds to flush and fly, and use such occasions to conduct counts.
- Conduct surveys with at least two experienced observers who work together to develop an estimate. Multiple surveyors observing from different vantages can regularly communicate what they are seeing and then confer when estimates differ. This collaborative approach fosters discussions as to why differences in estimates might have occurred and whose observations are most complete and allows readjustment of estimates.
- Large flocks of birds in flight are commonly undercounted and the extent of undercounting typically increases as flock size increases. Fulton and Kajrys (2019) describe several techniques to address and compensate for the undercount bias in large flocks.
- Perform nest transect counts, where feasible, and calculate numbers independently based on the occupied area.

# Determining Nest Success

Two measures can be used to describe nesting success of colonies: colony success and reproductive success (also often referred to as "productivity").

## Colony Success

Colony success describes whether a colony successfully fledged at least some young. This measure is general but is easy to determine and often may be the best information that can be determined for a colony. Colonies are considered successful when fledglings are observed at or near the colony or feces are seen in an empty nest. Monitoring via vocalizations also can be used to determine if young have

reached fledgling age (Schackwitz et al. 2020; Beedy et al. 2023; Honig and Schackwitz 2023). Less direct evidence that indicates that a colony was likely successful includes repeated observations of adults feeding young at the colony over a 10-day period (**Table 3**; Beedy et al. 2023).

Bioacoustic monitoring is a new tool that can provide detailed information on reproductive phenology and breeding success of tricolored blackbird colonies (Schackwitz et al. 2020; Honig and Schackwitz 2023). The technique involves recording tricolored blackbird colonies and analyzing them to detect the timing of six vocalizations—male song, male chorus, female song, hatchling call, nestling call, and fledgling call (Honig and Schackwitz 2023). These calls provide detailed information about breeding phenology and success, including dates of courtship; onset of nest building, incubation, and nestling hatching; and fledgling departure from nesting colonies. The tool assesses colony success or failure and numbers of separate nesting cohorts (or "waves") while avoiding colony disturbance from frequent nest colony visits. The method is currently used mainly for testing and research but may be more widely available soon to determine project-related needs such as for determining when colonies have completed nesting (W. Schackwitz, pers. comm.).

## Reproductive Success

Reproductive success is defined as the average number of young fledged per occupied nest. Determining reproductive success of tricolored blackbird colonies is challenging, and in fact impractical at many colonies for several reasons. First, nests should not be inspected while adults and young are present (i.e., to count young close to fledgling age) to avoid disturbance, premature fledging, abandonment, and resulting nestling mortality. Also, many colony sites are not accessible to count fledglings because of lack of access to private lands. Even where colonies are accessible, nestling, and fledgling counts are often impeded by the impenetrability of the nesting substrate (i.e., in Himalayan blackberry or dense, flooded cattails or tules) or limited visibility of the entire surface of the vegetation within which fledglings may be perched. Placing video cameras to monitor nests can cause disturbance, and it is often impractical to place enough recorders to accurately characterize an entire colony. Visibility for drone surveillance is impeded by foliage and could disturb active nests. Monitoring via vocalizations can determine if fledglings are present but cannot be used to estimate fledgling numbers (Schackwitz et al. 2020). As a result of the challenges of avoiding colony disturbance during surveys and the potential inaccuracy of results, many researchers do not attempt to go beyond determining colony success.

Notwithstanding the challenges, the best available method for determining reproductive success involves direct counting of fledglings in and around the colony as they wait to be fed by adults. Multiple counts, however, are required because fledging at a colony may occur over a period of up to several weeks. In general, fledglings are believed to remain at the colony site for an average of four days after fledging (Beedy et al. 2023). By day 6, young typically disperse from colonies to fly to water and foraging areas. Fledglings from colonies in isolated triticale fields or other nest substrates lacking nearby tall vegetation do not show this developmental sequence and may remain in a colony for at least 2 weeks before making their first long-distance flight (Beedy et al. 2023). Thus, fledgling counts should be conducted every four to six days (starting with the first observation of fledged young) until they are no longer present. Reproductive success is then calculated by the equation:

*Average number of young/nest* **=** *# fledglings / (# breeding birds x 0.67 nests/breeding bird)*

The 0.67 nests per breeding coefficient incorporates the fact that most males breed with two females (Orians 1961; Payne 1969).

# Surveying Winter Roosts

Studies of winter roosting by tricolored blackbirds are in their infancy. A few roosts have been detected recently in Butte and Sacramento counties, but it is unknown if they are longstanding or only recently been established (R. Meese, unpublished data; Beedy et al. 2023). The functions and benefits of winter roosts are unknown but may include reducing metabolic demands (based on their location near water which remains warmer than land on cold nights), maintaining social cohesion, and predator detection and avoidance.

Knowledge of the specific characteristics of roosts and of roost use is incomplete. Roosts in Sacramento County have been in dense, flooded emergent wetlands within suburban areas in Folsom and along the American River Parkway, but they could occur in a variety of other settings. There is little information for use in predicting where roosts are likely to occur.

Counting roosting tricolored blackbirds has its own set of challenges. Birds sometimes circle and stage before entering the roost, but they may also arrive at roost sites near dusk and dive immediately into dense cover. Also, sometimes other species, especially red-winged blackbirds (*Agelaius phoeniceus*), Brewer's blackbirds (*Euphagus cyanocephalus*), and European starlings (*Sturnus vulgaris*) roost with them. The best method to estimate numbers is to count groups as they arrive, usually by 10s, 100s, or 1000s.

# Conclusion

This tricolored blackbird survey methodology identifies standardized approaches to serve a variety of purposes, including determining potential for occurrence of nesting colonies, detecting colonies, estimating population numbers, and assessing nesting success and winter roosts. It also provides a starting point for testing and improving survey methods. Application of these methods should improve our understanding of tricolored blackbird distribution, abundance, reproduction, and habitat selection and thus contribute to the protection of the species and its habitat from the wide range of existing threats (Meese et al. 2015; Airola et al. 2023a,b; Beedy et al. 2023). California's tricolored blackbird populations would also benefit by development of standardized guidance for avoidance and minimization measures to protect nesting colonies and by creation of a statewide framework for compensatory mitigation to offset the ongoing loss of tricolored blackbird nesting and foraging habitat.

# Acknowledgments

Thanks to the many tricolored blackbird researchers and monitors who have contributed to refinement of survey methods over the years, including W. J. Hamilton III, R. Meese, N. Clipperton, S. Fraser, J. Harris, C. Swarth, D. Ross, W. Schackwitz, E. Graves, R. Cook, R. Erickson, X. Castañeda, S. Arthur, J. Davis, J. Baum, and C. Conard. Thanks also to AECOM and L. Clement for preparing the Figure. We thank anonymous reviewers and Shannon Skalos for review comments. We gratefully acknowledge BirdLife International and the Cornell Lab of Ornithology for providing the shapefiles from the Birds of the World

tricolored blackbird account we used to create the range map.

# Literature Cited


- Airola, D. A. 2021. Importance of non-native Himalayan blackberry as nesting habitat for the tricolored blackbird in the Sierra Nevada foothills, California. Central Valley Birds 24:1–14.
- Airola, D. A., T. Collins, M. Lozano, C. McColl, B. J. Furnas, and D. R. Krolick. 2023a. Foraging habitat and its effects on tricolored blackbird distribution and abundance in the Sierra Nevada foothills, California. Western Birds 54:19–31.
- Airola, D. A., J. Harris, C. Conard, L. A. Douglas, and E. C. Beedy. 2023b. Breeding population status of the tricolored blackbird in the foothills of the central Sierra Nevada, 2014–2022. Central Valley Birds 26:53–68.
- Airola, D. A., R. J. Meese, E. C. Beedy, D. Ross, D. Lasprugato, W. Hall, C. Conard, C. Alvarado, J. Harris, M. Gause, L. Pittman, K Smith, L. Young, and J. Pan. 2015. Tricolored blackbird breeding status in 2015 in the foothill grasslands of the Sierra Nevada, California. Central Valley Bird Club Bulletin 18:96–113.
- Airola, D. A., C. W. Swarth, J. Harris, E. C. Beedy, G. Woods, K. Smith, D. Ross, and D. Lasprugato. 2018. Breeding status of the tricolored blackbird in the foothill grasslands of the Sierra Nevada, California. Central Valley Bird Club Bulletin 21:1–24.
- Airola, D. A., D. Ross, C. Swarth, R. J. Meese, D. Lasprugato, and M. L. Marshall. 2016. Breeding status of the tricolored blackbird in the grassland-dominated region of the Sierra Nevada, California in 2016. Central Valley Bird Club Bulletin 19:82–109.
- Airola, D. A., R. J. Meese, and D. Krolick. 2015. Tricolored blackbird conservation status and opportunities in the Sierra Nevada foothills of California. Central Valley Bird Club Bulletin 17:57–78.
- Audubon California. 2008. 2008 Tricolored blackbird survey protocol. Audubon Society, Sacramento, CA, USA.
- Beedy, E. C., W. J. Hamilton, III, R. J. Meese, D. A. Airola, W. S. Schackwitz, and P. Pyle. 2023. Tricolored blackbird (*Agelaius tricolor*) version 2.0. In P. G. Rodewald and B. K. Keeny, editors. The Birds of the World. Cornell Lab of Ornithology, Ithaca, NY, USA.
- Cook, L. F., and C. A. Toft. 2005. Dynamics of extinction: population decline in the colonially nesting tricolored blackbird Agelaius tricolor. Bird Conservation International 15:73–88.
- Castañeda, X., N. Clipperton, D. A. Airola, S. Arthur, and P. Sousa. 2023. Effectiveness of recent public-private efforts to protect tricolored blackbird breeding colonies on agricultural lands in the San Joaquin Valley, California. Western Birds 54:2–18.
- Clipperton, N. 2018. A status review of the tricolored blackbird (*Agelaius tricolor*) in California. Report to the Fish and Game Commission. California Department of Fish and Wildlife, Sacramento, CA, USA.
- Colibri Ecological Consulting. 2022. 2022 tricolored blackbird statewide survey. California Department of Fish and Wildlife, Sacramento, CA, USA.
- Crase, F. T., and R. W. Dehaven. 1977. Food of nestling tricolored blackbirds. Condor 79:265–269.
- Erickson, R. A., H. de la Cueva, and B. B. Zarmora-Herdandez. 2021. Requiem for the tricolored blackbird in Mexico? Western Birds 52:207–221.
- Fulton, J., and G. Kajrys. 2019. The art of counting: how to estimate flock sizes. Central Valley Birds 22:16–24.
- Gilligan, J. D., M. Rogers, A. Smith, and A. Contreras. 1994. Birds of Oregon: Status and Distribution. Cinclus Publications, McMinnville, OR, USA.
- Goodward, D. M., and R. A. Diaz. 2023. Tricolored blackbirds' reliance on insects from dairies. Western Birds 54:181–195.

- Graves, E. E., M. Holyoak, T. R. Kelsey, and R. J. Meese. 2013. Understanding the contribution of habitats and regional variation to long-term population trends in tricolored blackbirds. Ecology and Evolution 3:1–14.
- Hamilton, III, W. J. 1998. Tricolored blackbird itinerant breeding in California. Condor 100:218–236.
- Hamilton, III, W. J., and R. J. Meese. 2006. Habitat and population characteristics of tricolored blackbird colonies in California: 2005 final report. California Department of Fish and Game, Sacramento, CA, USA.
- Honig, M., and W. Schackwitz. 2023. Manual versus semiautomated bioacoustical analysis methods of multiple vocalizations in tricolored blackbird colonies. Journal of Fish and Wildlife Management 14:225–238.
- Kelsey, R. 2008. Results of the tricolored blackbird 2008 census. Landowner Stewardship Program, Audubon California, Winters, CA, USA.
- Kyle, K., and R. Kelsey. 2011. Results of the 2011 tricolored blackbird statewide survey. Audubon California, Sacramento, CA, USA.
- McCormick, A. J. 2022. The tricolored blackbird in Washington state: a first assessment of status and distribution. Western Birds 53:186–198.
- Meese, R. J. 2013. Chronic low reproductive success of the colonial tricolored blackbird from 2006 to 2011. Western Birds 44:98–113.
- Meese, R. J. 2017. Results of the 2017 tricolored blackbird statewide survey. University of California, Davis, and California Department of Fish and Wildlife, Sacramento, CA, USA.
- Meese, R. J., D. A. Airola, E. C. Beedy, and R. Cook. 2015. Recovering the tricolored blackbird in California. Central Valley Bird Club Bulletin 17:97–109.
- Meese, R. J., and E. C. Beedy. 2015. Managing nesting and foraging habitats to benefit breeding tricolored blackbirds. Central Valley Bird Club Bulletin 17:79–96.
- Neff, J. A. 1937. Nesting distribution of the tri-colored red-wing. Condor 39:61–81
- Orians, G. H. 1961. The ecology of blackbird (*Agelaius*) social systems. Ecological Monographs 31:285–312.
- Payne, R. B. 1969. Breeding seasons and reproductive physiology of tricolored blackbirds and red-winged blackbirds. University of California Publications in Zoology 90:1–137.
- Riverside County. 2018. 2018 Tricolored blackbird survey protocol. Western Riverside County Multispecies Habitat Conservation Plan Biological Monitoring Program. **https://www.wrc-rca.org/species/survey_protocols/2018_Tricolored_Blackbird_Survey_Protocol.pdf**
- Schackwitz, W. S., D. A. Airola, A. Greene, and J. Woodruff. 2020. Bioacoustic monitoring reveals details of tricolored blackbird breeding phenology. Journal of Fish and Wildlife Management 11:518–530.
- Skorupa, J. P., R. L. Hothem, and R. W. DeHaven.1980. Foods of breeding tricolored blackbirds in agricultural areas of Merced County, California. Condor 82:465–467.
- Wilsey, C., N. Michel, K. Krieger, L. Taylor, L. Lee, S. Arthur, and N. Clipperton. 2019. Defining spring foraging habitat and prioritization of conservation sites for tricolored blackbirds in California. Condor 121:1–13.
- Wilson, C. R., R. J. Meese, and A. C. Wyckoff. 2016. Breeding chronology, movements, and life history observations of tricolored blackbirds in the California Central Coast. California Fish and Game 102:162–174.