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Townsend's Big-Eared Bat Statewide Assessment

By

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STATEWIDE ASSESSMENT

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INTRODUCTION

The Townsend's big-eared bat (*Corynorhinus townsendii*, COTO) is generally regarded as a bat species at high risk of endangerment throughout its range in western North America. It is designated as a Species of Special Concern (SSC) and also a Species of Greatest Conservation Need (SGCN) by the California Department of Fish and Wildlife (CDFW) and was recently (2012-16) the subject of a petition for listing as threatened or endangered under the California Endangered Species Act (CESA). The only statewide field assessment of the species' status was conducted in the 1980s and 1990s. Based on their statewide survey effort, which ended in 1991, Pierson and Rainey (1998) concluded that COTO had undergone a substantial population decline over the previous 40 years (i.e., since about 1950), with a 55% decline in maternity colonies, a 44% decline in the number of roosts, a 55% decline in total abundance, and a 32% decline in average maternity colony size. As summarized by Pierson and Rainey (1998) and others, the species is highly sensitive to human disturbance, particularly of maternity colonies. In addition to disturbance, the number of alternate roosts has been declining due to mine closures, renewed mining, timber harvest, cave commercialization, and general recreational exploration (Pierson and Rainey 1998, CDFW 2016).

Although CESA listing of COTO was determined by the California Fish and Game Commission to be not warranted in 2016, to develop a comprehensive management plan would require a thorough survey of the current distribution and abundance of the species. A multi-state assessment and conservation strategy developed for COTO in the late 1990s (Pierson et al. 1999) recommended annual or biannual monitoring of selected sites across the species' range and monitoring of COTO numbers and roost conditions at all sites at 10 year intervals. Although some COTO roosts in California have been monitored at a variety of intervals in the past two decades, a comprehensive and extensive monitoring initiative at all known COTO sites in California has not been conducted for about 25 years.

This project aimed to quantify the current distribution of COTO in California by conducting a comprehensive roost assessment through a repeat of the previous statewide survey and a geographic expansion of that effort. This project constituted a comprehensive assessment of this SGCN using similar methods as were used for the first statewide survey project more than two decades earlier and thus generated a comparable data set, save for colony count data, which were not collected. The project also expanded coverage to newly documented and potential habitat locations. This assessment provided information to the Department's CESA Status Review and will provide baseline data and recommendations to support the Department and others to implement effective management actions that lead to conservation of the species

This report provides a summary on the distribution, abundance and condition of historical and currently occupied sites, (when feasible to obtain; refer to methods, below), and recommendations for maintaining or enhancing existing populations, as well as a discussion of likely future threats. Ancillary benefits of this study included increased jurisdictional interest in bats and associated habitat surveys, and additional public education on the status and value of bats through our contacts during surveys.

Objectives
Specific project objectives and tasks were:
1. Assess the occupancy, activity, and condition of all known (historical and current) COTO roost locations.
2. Design and conduct a stratified random sampling plan to determine occupancy of potential roosts based on known habitat features.
3. Determine the current status and trend of the species relative to historical assessments.
4. Develop recommendations for research and management designed to enhance persistence of the species.

METHODS

The sampling scheme consisted of two primary components. First, to the degree feasible, all historical and not known to be destroyed (e.g., mine closure) roost sites (maternity and hibernacula) were surveyed for current activity and condition. Second, a modification of a national bat survey protocol was used to generate a stratified random scheme for sampling to determine bat occupancy and abundance across its range in California. We initiated preliminary sampling following contract authorization in fall 2014 and field work continued through summer 2017, thus encompassing two complete winters (2014-15 and 2015-16) and three spring/summer/fall periods (2015 through 2017).

Historical Data

<u>Data Sources</u>

We searched the published and unpublished records and databases summarized below for records of COTO, and also communicated with biologists (private, government agency), cavers, and other individuals to gather previously unreported and new (based on ongoing field work) records of occurrence and potential locations.

- California Natural Diversity Database (CNDDB). We gathered all existing site locations for COTO from the CNDDB, and cross-checked those with the literature to ensure no known records were missed by us.

- Pierson and Rainey (1998) summarized existing records through about 1998. Here again we cross-checked their records with other known records (e.g., CNDDB, literature prior to 1998).

- Literature records after ~1994: Pierson and Rainey (1998) apparently gathered all literature prior to about 1994. Scott Osborn (personal communication) attempted to gather all known literature records for COTO, which we then reviewed and cross-checked with existing data (e.g., CNDDB, Pierson and Rainey 1998).

- Personal observations (unpublished records) from biologists (agency personnel, consultants, other individuals). We contacted State (e.g., CDFW, CDPR) and Federal (e.g., BLM, USFS, USFWS) agency personnel to gather unpublished location records of COTO observations and locations of potential roosts known to them. Additionally, we used existing bat information networks (e.g., Western Bat Working Group) to request location data.

- Inyo-White mountains and vicinity: We have been conducting intensive winter and summer surveys throughout the Inyo and White mountain ranges (Inyo and Mono counties) and the adjacent eastern slopes of the Sierra Nevada Mountains since 2010, as a follow-up to surveys initiated in the 1990s; this work is ongoing and is continuing as of summer 2018. These data were incorporated into the overall analyses for this study (described below).

Database development and data summary

All location records (COTO observations) were entered into a FileMaker (FileMaker, Inc.) database and coded such that records can be summarized and also displayed (GIS mapping) by various characteristics including: record type (maternity, hibernacula, unknown), protected (e.g., gated or administrative protection) or unprotected, and timeframes (i.e., categorize data by 5-year blocks). As noted below, all new locations (not known to be previously visited) were entered into the database. FileMaker can export data into an Excel workbook.

Survey Design

Selection of Study Cells: Occupancy

We used the basic sampling units developed first by the Pacific Northwest Bat Grid (Ormsbee et al. 2006) and subsequently incorporated into the North American Bat Monitoring Program (NABat) (Loeb et al. 2015) as the foundation of our survey. NABat is a multi-agency, multi-national effort with the goal of creating a continental-wide program to monitor bats at local to range-wide scales that will promote effective conservation decision-making and the long-term viability of bat populations across the continent. The statistical target populations of NABat are the summer populations and winter hibernacula and summer maternity colonies of North American bats from Alaska and northern Canada through Mexico. We focused on COTO hibernacula and maternity colonies; we did not attempt to sample general bat occurrence as is a goal of NABat.

NABat developed a multi-purpose sampling frame consisting of 10 x 10 km (100 km^2) grid cells that are the focal analytical unit for regional and range-wide assessments. This grain size is biologically appropriate given the scale of movement of most bat species and for modeling and mapping bat species distributions. Finer grain sizes may be informative for local-scale questions but are inefficient for broad, regional syntheses. Our use of the same geographic grid boundaries will also allow geographic or sampling comparisons between our data set and other studies using the NABat grid system.

We drew potential sampling cells by first dividing the state into Level III Ecoregions, and then randomly listing all cells in the state, prioritizing visits to the lower numbered grid cells within each region where suitable habitat could be identified. Because little is known regarding COTO use of different areas for inactive and active periods throughout much of California, we did not make separate draws for each period. Given the resources involved in statewide travel, feasibility and accessibility played a role in determining which of the sample grids received a visit, with a bias toward those grids that were along existing travel paths for field tours to historical sites or that contained land belonging to jurisdictions willing to provide survey access.

Parameters under 'broad scale' and 'meso scale' (below) were used to initially identify potential sampling cells per Ecoregion. After the initial set of potential sampling cells was selected, we screened each cell for the presence of potential roosts using GIS, visual examination of topographic maps, and Google Earth. Mine structures, including adits, shafts, and buildings, and other features such as publicly advertised caves are usually included on topographic maps. In our experience, about 5% of all mine structures are not included on these maps. It is unlikely, however, if multiple mine structures occur in a concentrated location they would have been completely missed by mapmakers. Pierson and Rainey (1998) also included structures such as water diversion tunnels, abandoned railroad tunnels, and older (pre-1960) highway bridges (they excluded more modern concrete box or steel I-beam bridges and brightly illuminated locations because of the general lack of suitable roosting site for COTO). Tools such as Google Earth are useful in some areas where lack of vegetation cover allows locating abandoned buildings and determining potential extent of a mine working (e.g., size of waste piles), although it is seldom possible to determine if the structure is open (i.e., portal not collapsed or otherwise accessible for occupancy by bats). Google Earth can also help identify structures not included on a topographic map. The proximity and location of old roads and trails are also helpful in indicating mine workings, bridges, and buildings; for example, visually following even faint trails and roads on Google Earth can lead to mine workings. As part of this desktop review process, where possible, we contacted jurisdictional biologists, land managers, recreational groups and private landowners for additional information about the presence of bats and habitat.

All cells with any indication of potential roosts were retained in the sampling, ensuring a conservative deletion process. Each cell was characterized as follows:

1. Winter:
   a. Not environmentally suitable (i.e., too warm, usually based on elevation or region)
   b. Environmentally suitable but no suitable roost sites
   c. Environmentally suitable with potential roost sites
2. Summer:
   a. Not environmentally suitable (i.e., too cold, usually based on elevation or region)
   b. Environmentally suitable but no suitable roost sites
   c. Environmentally suitable with potential roost sites

Cells identified as 1.c. and 2.c. were included in the sampling schedule. Because of logistics, we usually could not visit each cell in the order it was selected. Accessibility issues, study timeframe and logistical constraints combined with the unexpected number of "new historical" sites (potential Townsend's occurrence records known to various jurisdictions, land managers and the caving community but not included in the CNDDB database of original historical records) that emerged through our data compilation and records requests, meant that not all sites or target cells were visited. While access issues occurred in a variety of forms, few jurisdictions refused access outright, with Joshua Tree National Park the only jurisdiction to refuse a submitted research use request. We did not target cells or historical sites that fell within jurisdictions where monitoring for bats is formalized and ongoing, as is the case with several National and State Park jurisdictions, because we wanted to focus our field efforts where surveying was not being conducted, and we wanted to retain the integrity of our random sampling effort. Thus our results may represent a conservative estimate of the distribution and status of COTO.

To the extent possible we used the presence of COTO as the basis for implementation of an adaptive sampling strategy. We implemented this additional sampling strategy because we were focusing on a single bat species, and to mimic to some degree the search within 15 km conducted by Pierson and Rainey around maternity roost sites. In such an adaptive strategy, all cells that meet basic selection criteria (i.e., potential habitat) adjacent to the occupied cell (see occupancy definition, below) would be surveyed; any additional occupied cells would then serve as the focal point for surveying the adjacent cells; and so forth until no occupied cells are located. This strategy is appropriate if we think that the presence of even a few bats could indicate proximity to maternity colonies or hibernacula could be clustered for either availability or behavioral reasons. Given the presence of the species throughout the state in the winter, despite the lack of traditional hibernation conditions in all areas, we chose to maintain a broad definition of suitable habitat throughout both survey periods. Logistics also plays a role here. Because it is time consuming to locate and travel to individual cells, once "occupancy" is noted then it is more efficient to search within that area. This strategy would not change the initial selection of cells.

Indications of occupancy (e.g., guano; see below), acoustic identification, and visual identification can all indicate recent bat activity at a site. However, only certain methods provide reliable estimates of site bat abundance (e.g., internal counts of individuals; night emergence counts). Additionally, even one bat at a site is a measure of presence, but conveys very different information about the species in an area relative to presence of a maternity colony or large hibernaculum. For our initial sampling and implementation of the adaptive sampling scheme, we used the presence of even one bat to indicate occupancy of a sampling cell. Calculation of occupancy of sampling cells can later (after data collection) be determined using several different criteria for "presence" (see below under "Analyses").

Because we gathered at least two, and sometimes three, measures of presence (i.e., visual, guano, and rarely, acoustic) at each site, and never based occupancy assessment on acoustics alone, we minimized the probability of making false-positive acoustic detections in our occupancy estimation (Clement et al. 2014). As this study focused on point sources of occupancy (roosts) where visual determination would suffice in most situations, we used acoustic recording and analysis for the purpose of confirmation in a just small number of sites that had some expectation of COTO but were impractical for visual determination. Establishing occupancy for COTO using acoustic detection on a landscape level would require an extended effort to succeed because of the limited acoustic detection volume (perhaps as little as a 10 m radius; Stilz and Schnitzler 2012).

<u>Selection of Study Sites: Historical Sites</u>
Historical locations not known to be closed or otherwise uninhabitable were re-visited in the appropriate season, where access and feasibility allowed. Pierson and Rainey (1998) surveyed a 15-km radius around the original site if it was unoccupied; they deemed this an appropriate area because of the high site fidelity of colonies. This 15-km radius is moderately smaller (~707 km^2) relative to the 100 km^2 area of the 10 x 10 km blocks used for NABat. Rather than a priori set a sampling limit, we applied our adaptive sampling system (described above) regardless of current occupancy status; our sampling of areas adjacent to a former roost site was thus larger than that used by Pierson and Rainey because we did not restrict ourselves to a set radius.

Broad scale
The goal of establishing broad-scale sampling strata is to exclude locations that could not or would be unlikely to harbor COTO during any season. Seasonal activity of COTO varies depending on geographic location in California, with bats located on the west side of the Sierra Nevada and in closer proximity to the Pacific Ocean showing longer activity periods into the fall and more activity in the winter relative to bats on the east side of the Sierra Nevada and interior northern California; while understanding of COTO movements is limited, it is believed that migration between maternity and winter sites is also limited on the western side of the state relative to most eastern regions. Thus our sampling strategy incorporated differences in activity periods by geographic location (based primarily on ecoregions).

Variables used as the primary sampling strata to exclude potential sampling areas included areas known to be outside the COTO geographic range (this was a conservative filter, thus when in doubt the area was retained, leaving all of California within range), lakes, urban areas (the outskirts of cities were retained), and regions where COTO have not been shown to occur because of extreme seasonal conditions (e.g., high elevations in the Sierra Nevada).

Meso scale
We broke the initial broad-scale filter by “active” (spring/summer/fall) and “inactive” (winter/hibernating) periods. Meso-scale was thus a season-specific refinement of the broad-scale filter. Elevation was the primary factor separating potentially suitable priority locations between summer and winter; elevation is, of course, correlated with seasonal changes in temperature in many regions. There were locations where potential winter and summer locations overlapped. Temperature is too variable across space and time to be a selection criterion for sampling blocks.

Field Surveys
Surveys were conducted from fall 2014 through summer 2017, thus encompassing three active (2015 through 2017) and three inactive (2014-15, 2015-16, and 2016-17) periods; the majority of work occurred from fall 2014 through winter 2016-17. As logistically feasible, we attempted to sample an equal representation of geographic locations across the state each year (i.e., not concentrate in one geographic location each year).

Selected roost locations within a cell were visited in only the active or inactive season, but in most cases not both, unless the roost had characteristics that might serve for both seasons. A cell with substantial elevation gain, or potential roosts with favorable characteristics (e.g., cold air flow for winter), could be visited in both seasons. This is because, while male COTO will often spend the inactive season at lower elevations, they comprise a very small proportion of individuals and we could not expend the time and logistical effort to revisit locations that would potentially harbor only a few individuals. For example, in the Inyo-White mountains and adjacent Sierra Nevada (Inyo Co.), most (>95%) individuals hibernate >2500 m, whereas maternity roosts are <2000 m elevation. Here again, we were focusing our efforts on a broad spatial extent while recognizing we were missing some more local occupancy patterns. Because cells are only used as a basis for our general randomization as a basis for locating potential roosts, this strategy did not bias our survey in any substantial manner.

The Level III Ecoregions of California are listed below along with their USGS numerical designation (parentheses) and number of potential sampling cells.

Coast Range (1)—172
Cascades (4)—139
Sierra Nevada (5)—529
Southern/Central California Chaparral/Oak Woodlands (6)—805
Central California Valley (7)—467
Southern California Mountains (8)—158
Eastern Cascade Slopes and Foothills (9)—192
Central Basin and Range (13)—147
Mojave Basin and Range (14)—777
Klamath Mountains (78)—332
Northern Basin and Range (80)—50
Sonoran Basin and Range (81)—310
Southern California/Northern Baja Coast (85)—275

Visual surveys

Sampling occurred primarily throughout daylight hours by conducting internal surveys for the presence of bats or their sign. In few cases, we also conducted nighttime acoustic or visual (see below) exit surveys when safe entry of a site was not possible (see below). All bat species encountered were recorded. In addition to making an internal inspection for COTO, the occurrence of guano pellets or piles resembling COTO were recorded. When a cluster (group) of bats was encountered, we immediately exited the roost to minimize disturbance. We considered guano recognizable as COTO if it had unambiguous characteristic light golden patina and twisted shape, and more confidently when also occurring as a Gaussian-patterned pile below a domed section of a passage or other typical roost location. Such sign was considered indicative of maternity colony presence.

Acoustic surveys

In certain situations, when entry could not be safely made and the field schedule allowed remaining in the area for evening emergence work, we used Pettersson Elektronik ultrasonic detectors (various models) to determine if COTO were present during spring/summer/fall. We based the specific placement and number of detectors on site characteristics, such as number of portal or cave openings, or exits from a building. Although such recordings are not appropriate for determining absolute abundance, they can be used to establish presence. For example, a large number (e.g., >20) of separate recorded files at a portal near sunset during the appropriate time of year could suggest a maternity colony. Likewise, acoustic analysis during the late fall could indicate the potential location of large hibernacula; follow up internal surveys during winter could be conducted. COTO do not always echolocate, and when they do, their calls can be such low amplitude as to be nearly undetectable. Thus, a lack of acoustic detection, without corresponding visual confirmation of absence, was not used as confirmation of absence, nor were passively collected calls alone used to confirm the presence of a maternity colony.

Acoustic recordings were analyzed using SonoBat software to recognize bat call sequences and identify them to species using a hierarchical decision engine trained on multiple time-frequency and time-amplitude parameters extracted from a library of >10,000 species-known recordings (Szewczak 2010). We used automated identifications with manual confirmation of species identifications using known call characteristics (Szewczak et al. 2011). Manual vetting is of particular importance for COTO because it vocalizes with lower amplitude compared to other bats imparting lower automated acoustic detectability. Certain call variants from other species (e.g., approach phase calls of *Tadarida brasiliensis*) can also mimic the simple call shape of COTO. The situation is exacerbated with recordings done in potential roosts where we can expect additional echo distortions and unusual call variants (Parsons and Szewczak 2009).

Sampling of surveyed sites

The data listed under 'micro scale' (below) were collected for surveyed sites located within each sampling cell. These data provided descriptive information on occupied and unoccupied sites and can be evaluated in a habitat selection framework (see analyses section below). If a mine or cave could not be entered or fully explored, then an approximation of the variables was made (e.g., based on size of mine waste pile adit >100 m long) where possible; some variables could not be estimated (e.g., complexity). In cases where nearby landscape features could not be viewed in the field (such as distance to water) or where additional standardization is desired (such as with vegetation layers) these data can be obtained through post-process GIS analysis.

Micro scale (subset of meso scale; specific roost locations)

- Site name if known, Ecoregion, UTM coordinates
- If historical site (i.e., survey conducted >10 years previous)
- If protected in some manner (e.g., bat gating, access to area controlled)
- Surrounding predominant vegetation type
- External characteristics:
    - Roost structure
    - Ambient temperature and humidity
    - Aspect
    - If portal obstructed and by what material
    - Portal dimensions
    - Number of known openings into roost
    - Surrounding vegetation type
    - Presence of water; distance to water source
    - Distance to potential foraging site
- Internal characteristics:
    - Temperature and humidity
    - Air flow
    - Roost length and height
    - Presence of high ceilings
    - Internal complexity
    - Internal water
    - Level of human disturbance
- If bats present:
    - Species and number

- o Activity
- o Roost type
- o Identification method

The presence of concentrated guano piles often indicates the presence and long-term use of a maternity colony. Thus for sites we surveyed outside of the usual period when colonies are present and for which guano was indicative of recent activity, we tried to schedule a re-visit the following season.

Our data form is provided in Appendix A.

Other ongoing studies

We also gathered reports of the status of COTO surveys that were being conducted on a regular basis by resource agencies. In some cases we did not need to conduct our own surveys because that work was being accomplished. We did not include those data directly in our databases and this report because the data were not obtained within our sampling strategy. We do, however, report those data herein.

Analyses

Historical

Pierson and Rainey (1998) focused their survey on what they termed "significant maternity colonies," which they defined as >30 individuals. No definition was provided by them for hibernacula; rather they sampled "a selection of known hibernating sites." Thus we could not know how many smaller (i.e., ≤30 individuals) maternity colonies they did not survey. Based on our results that found relatively few maternity colonies of <30 bats, we doubt they excluded many sites. However, because they did not systematically look for previously unknown roost (maternity or hibernacula) sites, but rather focused on known (i.e., historical) sites, our direct comparison with their findings cannot be taken as an overall assessment of the status (i.e., declining, stable, increasing) of COTO in California. Rather, our comparison with Pierson and Rainey is only an assessment of change in status of the specific locations they surveyed and potential relocations of roost sites.

Occupancy

Basic occupancy was defined as the presence of ≥1 individual bat (visual detection, COTO guano, or acoustic identification) at a site within a cell. We present results on occupancy by several spatial extents (scales), including statewide (overall) and Level III Ecoregion. We also divide most data by season (active versus inactive). We summarized these data on the scale of the ecoregion (i.e., ≥1 cell met the above criteria), and also on the proportion of occupied versus unoccupied cells for each category for an Ecoregion.

Abundance

We did not attempt to count (e.g., exit or emergence surveys) maternity colony size because our goal was to survey for presence; counting would have focused our attention in fewer survey cells. Although we were able to more thoroughly survey roosts in the winter, time, safety, and general logistical constraints often prevented us from conducting a complete internal survey. As such we chose to categorize hibernacula into several classifications of bat abundance (i.e., solitary, >1 to 5, and >5 bats).

Pierson and Rainey conducted counts (emergence or internal) of number of individuals present at most of the maternity colonies they surveyed. Their counts were rough estimates, however, because they did not standardize when the counts occurred; that is, some colonies were counted prior to young emerging, whereas others were counted after young started emerging. Although they applied a correction factor, lack of standardization of counting period certainly complicated interpretation of results. In addition to the logistical limitations attempting to count individuals places on a study (see above), because of the number of locations we wanted to visit, we decided to forego counts at maternity roosts. Thus our presence-absence data provides location data on which future, more intensive studies of changes in abundance can be based.

RESULTS

Survey effort

Although it varied by Ecoregion, our initial screening of the potential suitability of grid cells for survey indicated that usually 50% to 70% of the cells were within adequate environmental parameters for the species to occur during summer or winter. In the Sierra Nevada Ecoregion, for example, we deemed ~70% of the cells to be within acceptable environmental parameters for summer occupancy, but upon detailed examination (e.g., using Google Earth, topographic maps), concluded that only ~25% contained potential roost sites that were identifiable through desktop review and outreach means. Similarly, for winter, only about 50% were acceptable environmentally, with about 15% containing identifiable potential hibernacula.

Based on our initial screening of cells, we surveyed 304 grid cells during this study, with 206 in summer and 98 in winter (Table 1). The geographically small Ecoregion in the northeast, Northern Basin and Range, received no direct survey effort because we determined the sites of the few historical records were no longer viable (e.g., hotel torn down), and lack of readily identifiable potential roost sites. Similarly, the Central California Valley region received little effort because of the lack of potential roost sites (i.e., region primarily commercial-residential-urban and agriculture) and the extent of private land representing identification and accessibility obstacles to such habitat as might exist, given the scope of the study. Across all Ecoregions this study visited and surveyed approximately 620 potential roost sites (Table 2).

Occupancy

We located Townsend's big-eared bats in all Ecoregions of California; recent anecdotal sightings indicate their presence in the Northern Basin and Range. Statewide (all Ecoregions combined), we located the species in 209 active season roost sites without evidence of a maternity colony, 84 maternity sites, and 80 hibernacula (Table 2). The Mojave Basin and Range contained the most roost sites and maternity colonies, while the Central Basin and Range contained the most hibernacula. These data do not include the roost sites (of all purposes) known for some federal properties, including especially National Parks and Monuments in the northern portion of the state (see below).

Maternity structures
About one-half of the maternity colonies were located in abandoned mines (Table 3). The bulk of the remaining colonies were in natural caves (29%), which included limestone and other rock caves and lava tubes. Buildings, bridges, culverts, water flumes, tree basal hollows, and other structures accounted for the remaining locations.

Site condition and disturbance
About 10% of all sites we visited had no potential roost habitat because of site removal (e.g., mine reclamation), portal collapse, structure removal or modification, regular human disturbance (e.g., recreational site), or other causes.

For all sites visited (with or without COTO or other bat species), few (2%) had continual disturbance, but 22% had what we considered identifiable signs of frequent disturbance (Table 4). The remainder had signs of no (42%) or slight (34%) disturbance. Excluding the Central California Valley and Northern Basin and Range ecoregions because of small sample size due to few visited COTO cells, sites with frequent disturbance ranged from between ~10% and 38% (Table 4). For active maternity sites, overall 24% showed evidence of frequent disturbance while 41% showed only slight disturbance; the remaining 35% showed no evidence of disturbance.

Historical sites
Overall historical
Based on all data sources available to us (e.g., CNDDB, unpublished reports, literature), we located the species at 53 of 80 (66%) historical sites in summer and 37 of 63 (58%) historical sites in winter (Table 5). Note these records include all roost purposes, including maternity, day and night roosts, and hibernacula. Ecoregions with the most historical occurrences indicated that about one-half to three-quarters of all historical roosts were still active (although the use of the roost could have changed; e.g., no longer maternity but some bats present). These data can best be viewed as a crude indication of continued availability of the roost site (e.g., mine still open).

Pierson and Rainey (1998)
We were able to determine the status of about two-thirds of the sites surveyed by Pierson and Rainey (1998) during the 1980-1990s period. Of those sites, we determined that about one-half remained active while the other half were inactive for a variety of reasons, including portal collapse or exclusion (i.e., permanently collapsed by management activity), commercialization of the site, or high human visitation (Appendix B). We were not able to determine the status of the remaining one-third of the sites for various reasons (e.g., insufficient resources, could not obtain access permission, could not locate site).

Abundance in hibernacula
Most (94%) hibernacula contained >1 individual, with the majority (63%) containing 1-5 bats (Table 6). Most relatively large (>5 bats) hibernacula were located in the Central Basin and Range (35%) and the Mojave Basin and Range (23%).

DISCUSSION
Pierson and Rainey (1998) summarized the known records of the species and reported that 46 maternity colonies were known prior to 1980, with most of the records made from the late 1940s

to the 1960s. They could not locate 24 of the known colonies either at the original previous roost site or within the 15 km radius they searched. They also identified an additional 18–21 colonies during their surveys and through other means, bringing the total colonies known to them to 39-43. We documented at least 84 maternity colonies, which excludes additional colonies known to exist on multiple government land holdings. In Appendix C we provide information we were able to obtain from other resource agencies that were conducting regular COTO surveys on their properties during our study period. These efforts revealed another 8 maternity colonies and, at a minimum, >1000 additional individual bats.

Of the Pierson and Rainey maternity colonies that we could survey or otherwise determine status, about one-half were active, while the other one-half were inactive because the known colony roost site was no longer suitable (i.e., collapsed, destroyed, high human use). Overall we did not determine the status of about one-third of their sites. Although our surveys identified substantially more maternity colonies than were known to Pierson and Rainey, we cannot conclude this indicates a substantial increase in site use because Pierson and Rainey were not able to cover the state in as intensive a manner as we could. As we did not count the number of bats in each of the extant colonies, we also cannot state whether the maternity colonies still present in historical locations have experienced any change in size. However, the fact there are twice or more colonies now known to exist establishes a new baseline for understanding and monitoring the species through time and provides a broad distribution of sites available as candidates for long-term monitoring efforts.

Based on the focus of Pierson and Rainey on known historical colonies, and lack of any randomization across potential roost locations, they could not draw a valid inference regarding the status of the species statewide. Thus, the Pierson and Rainey study is best viewed as an analysis of the status of previously known roosts, rather than a statewide assessment of status. Extension of their results statewide would require making the assumption that their sample is representative of conditions across a very broad spatial scale. Additionally, historical locations for most species are largely based on convenience sampling; that is, locations that are easy to access logistically. A sampling design based on an appropriate randomization method forces, in essence, observers to traverse rugged terrain and often visit remote locations. Because prior to our work no broad-scale survey that incorporated randomization had been conducted, the Pierson and Rainey survey is by design biased towards primarily readily accessible locations. As such, their design would also be biased towards human disturbance (because of ease of access) as a cause for roost abandonment.

Determining the overall trend of hibernacula or overwintering sites is problematic because Pierson and Rainey (1998) did not focus on the winter period. Additionally, although large hibernacula (i.e., >30 individuals in a single site) are known, most sites harbor far fewer individuals. Ongoing long-term research in the Inyo-White mountains is showing, for example, that individuals from a single maternity colony will scatter across the landscape and occupy multiple different hibernacula in numbers ranging from solitary individuals to several groups of up to 35 (M. Morrison, unpubl. data). Likewise, at Lava Beds National Monument, there were 91 known hibernacula in 2017 with only nine sites having a mean abundance of >30 bats (K. Smith, pers. comm.; see also Weller et al. 2014). Especially on the west side of the Sierra Nevada, the species is known to frequently emerge from hibernation for short periods during winter when weather conditions permit (i.e., warm temperature periods). On the east side, individuals do not seem to change roost sites as frequently but do relocate within a roost as conditions change (e.g., colder temperature near a roost entrance as the winter advances). The use of a large number of sites, as well as potential movements between sites, makes it difficult to make conclusions on the status of wintering sites.

Pierson and Rainey did not use Ecoregions but rather divided the state into what they designated as nine study areas known to harbor populations of the species. They found the majority of bat colonies occurred in what they termed the lava flow area of the northeast (their Area 3, which roughly corresponds to Ecoregions 4, 9, and 80); the limestone caves and old mines of the Mother Lode and western Sierra (Area 4; Ecoregion 5); the abandoned mine workings in the Eastern Sierra and Western White Mountain foothills (Area 5; Ecoregion 13); and at various sites in the northern coastal areas and inner coast range (Area 1; Ecoregion 1 and 78). We also found a substantial number of maternity colonies in the region corresponding to their Area 5, and to a lesser extent, Areas 4 and 1. We found relatively fewer colonies in the regions corresponding to their Areas 3, which is likely because we did not include colonies known to exist on public lands (especially National Parks and Monuments) that are under regular monitoring by agency personnel. We did find substantially more colonies in their Area 6, which corresponded in part to our Ecoregion 14, the Mojave Basin and Range, likely because they did not emphasize the deserts for survey effort.

The type of structure used for maternity colonies that we found was somewhat different than that reported by Pierson and Rainey (1998:Fig. 2). Whereas we found about half of our colonies in abandoned mines and ~29% in natural caves, they found ~39% in mines and 43% in caves. We think this difference was due primarily to the lesser survey effort they expended in the Central Basin and Range and especially the Mojave Basin and Range Ecosystems relative to our efforts, rather than any shift in structure use by the species. Additionally, we are including maternity colonies from the Central Basin and Range that are part of an ongoing research effort by Morrison; whereas we purposefully did not try to include known maternity colonies under study by others in north-central portions of the State. Thus there does not appear to have been any shift in overall structure use.

Overall for all sites surveyed including maternities, ~70% showed no or slight disturbance due to human activities. Thus, about 30% of sites experience what we considered frequent disturbance. It is commonly assumed that timing of the disturbance is the primary factor determining the influence of human activities on bat occupancy. Because we conducted a one-time survey, it is not possible for us to evaluate the impact disturbance is having on the species, although almost three-fourths of the sites—including maternities—receive little disturbance. Because COTO occupy a large number of abandoned mines, access is becoming increasingly difficult and time consuming because mining roads and trails are seldom maintained. For example, there were many historical sites that could be accessed by vehicle during the Pierson and Rainey survey that now require long (>10 km one-way hikes); many locations cannot even be accessed by modern off-road vehicles (e.g., ATVs).

Conclusion and Management Implications

CDFW (2016) published a status review of COTO, which included a comprehensive list of recommendations for research and management of the species. They summarized recommendations into seven broad categories: Research and monitoring needs, administrative actions, management of known roosts, landscape management actions, regulatory review of proposed development projects, public education and outreach, and health and disease issues. Although too extensive to explicitly include here, below we incorporated consideration of CDFW (2016) guidance as we summarized our recommendations related to our survey results (i.e., many of the CDFW recommendations cover topics not addressed in our study [e.g., contaminants]).

Our surveys, along with other data known to exist on the species, indicated Townsend's big-eared bat remains distributed across much of California. Because the species is able to use a wide variety of structures for roosting, it seems to be able to exist in suitable anthropogenic sites where naturally occurring structures are minimal in abundance or highly disturbed. Suitable anthropogenic habitat, whether mines or buildings, or even bridges in some cases where the bridge superstructure forms an appropriate cavern analog, appear to provide important resources for the species. Numerous other variables, however, play a role in the viability of a roost site, particularly for maternity roosts, such as distance to foraging habitat. Such evaluations are beyond the scope of this study, but must be considered in management approaches.

Unless actively managed, however, abandoned mines, and to a similar degree, buildings, will continue to decrease in number because of collapse. Of greatest concern regarding the use of mines is Ecoregions 13 (Central Basin and Range) and 14 (Mojave Basin and Range), where most maternity sites occur in abandoned mines. Based on the variety of structures used by the species, including buildings and bridges, we anticipate that some colonies will be able to relocate locally when a mine becomes unusable. However, we recommend that management entities consider use of artificial roost structures that have proved to be suitable alternative structures for COTO and closely related species, such as vertical concrete towers (e.g., Mering and Chambers 2014) or wooden buildings with long-term maintenance plans. Material and design would be matched to local climate considerations, as what will generate suitable thermal conditions for a roost in the desert may not do so on the north coast. Use of such alternative structures would be indicated when natural roost sites are unavailable or cannot be protected for use by bats. In the Mojave Desert and Central Basin and Range, for example, areas exist where natural caves are available but are frequently visited by humans for recreational use. Such sites could be closed from human visitation during the maternity season, while remaining available for human exploration during the inactive season (i.e., when not used as hibernacula, which is usually the case in these Ecoregions). Alternative structures also provide an opportunity for efficient monitoring and colony study.

Land management agencies, particularly the BLM, NPS, and USFS, have active programs for identifying, stabilizing, and protecting bat roost sites with an emphasis on the Townsend's big-eared bat. As emphasized by CDFW (2016), continuation and expansion of these programs provides a practical method of ensuring access to suitable roost sites by the species. Sites that are initially protected are, however, frequently vandalized by humans seeking entry into caves, mines and abandoned buildings for recreational purposes, and thus require regular inspection and repair. During our statewide survey we frequently encountered vandalized sites that had been "protected" by gates or locks, but likely had been open to the public for multiple years because agencies often lacked sufficient personnel and funding to conduct regular inspections. In addition to increasing the potential for bats to abandon such sites, many of the sites posed substantial risk of bodily harm to the public (e.g., falling into internal shafts). Thus, increased attention to previously protected sites would enhance conservation of COTO as well as other animals using the protected sites.

We were able to work with various private recreation groups, especially the caving community, in locating and accessing potential bat roosts. Because some individuals fear a loss of access to caving opportunities because of potential government actions, we encourage the relevant government agencies to work with these recreational groups to determine ways to allow continued site access while also protecting the bat resource (e.g., seasonal rather than permanent closures). Additionally, many roost sites exist on private lands, where identification of and communication with property owners-managers can require extensive time or prove futile. CDFW (2016) provided recommendations for enhanced public outreach and education, which we echo here. We recommend allocating resources so that individual owners-managers can be contacted and encouraged to work with agency personnel in protecting the bat resource in ways that do not infringe on personal property uses.

In several cases, we came across bat mitigation actions that either used bat survey equipment inappropriately, or applied results of bat surveys without suitable knowledge of bat life history (e.g., scheduling mine gating in the midst of maternity season). Level of knowledge regarding bats was also highly variable, while interest was often much higher than existing knowledge. While CEQA and other environmental regulatory requirements can provide reasonable conservation actions for COTO and other bat species (see CDFW 2016 for details), these processes are only effective if the surveyors and regulatory agencies involved have sufficient knowledge about bat survey techniques and bat ecology to collect the necessary data at the right time of year and apply these data to generate effective conservation actions. We recommend developing proactive outreach and high quality continuing education programs for federal and state land management personnel and consulting firm biologists to ensure that the California Environmental Quality Act (CEQA) and other environmental compliance processes are effective for COTO and other bat species in California. Our interactions throughout the state suggest that the audience would be receptive.

Standard regulatory review under CEQA) in cases where the process considers a project's impacts to colonial bat roosts often results in a mitigation strategy that requires only that the bats be evicted from the roost outside of maternity season. If roost habitat is lost, suitable replacement habitat is often not provided, and the fate of the colony is generally not monitored after the fact. Bats rely upon an interdependency of roosting and foraging resources (Altringham 1999, Kunz 2005). Roosting resources with appropriate spatial, temperature, and protection conditions are often limited. Simply avoiding immediate take by scheduling roost eviction outside of the maternity season without a mitigating roost replacement with similarly appropriate conditions does not provide a mitigating action any more than does eliminating a dependent foraging resource without appropriate replacement. For landscape management actions and regulatory review of projects with anticipated impacts on COTO roosts to play a role in conserving the species, we recommend that the process incorporate measures to address long-term viability of suitable roost structures and associated foraging habitats and mechanisms to monitor the post-mitigation fate of associated colonies.

Disease is another area of research and monitoring that should be emphasized in the future (CDFW 2016). Although we did not identify any apparent disease issues (e.g., abandoned colonies were usually due to human disturbance), and COTO is not known to develop white-nose syndrome, the causative fungus, *Pseudogymnoascus destructans (Pd),* has been detected on the species in other states, and we found potentially susceptible *Myotis* species sharing hibernacula with COTO. Several locations we visited in the state in the course of this study had a high level of visitation yet no interpretive or cautionary signs to raise awareness and help protect the sites from human-caused pathogen spread. Land managers also showed varying degrees of knowledge regarding the white-nose syndrome threat, with some locations indicating the lack of interpretive signs was due to white-nose syndrome not yet occurring in California, and thus not needing to inform visitors yet. Like CDFW (2016), we recommend a systematic educational outreach effort to land managers and support for interpretive signs and options for visitors with gear from contaminated states. Various entities have conducted research showing the effectiveness of properly designed interpretive signs in altering visitor behavior (e.g., Duncan and Martin 2002).

<u>Additional Recommendations</u>

We (see also CDFW 2016) suggest that additional efforts be made to more fully understand the current and likely future status of the Townsend's big-eared bat in California including:

- Continued efforts to survey additional locations to identify roost sites, including other known historical sites.
- Periodic monitoring of all maternity and selected hibernacula located during our survey; for example, all sites could be visited over a moving 5-year period.
- Expanded coordination by CDFW with all land management agencies to promote protection and subsequent monitoring of the status of roost sites.
- Expanded communication with recreational groups that regularly access known or potential roost sites.
- Expanded communication and outreach to private land owners and managers who have roost sites on their properties.
- Development of a centralized, regularly updated database to track all of the monitoring efforts and roost locations from the groups above. We found in many cases, these data were not shared with CDFW.

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Table 1. Number of grid cells sampled during Townsend's big-eared bat survey by Level III Ecoregion and season (different portions of cells with substantial elevation gain or other characteristics [see text] could be visited in both winter and summer).

Ecoregion (USGS no.)	No. cells in summer	No. cells in winter	No. cells total
Statewide	206	98	304
Coast Range (1)	11	5	16
Cascades (4)	9	5	14
Sierra Nevada (5)	36	20	56
Southern/Central California Chaparral/Oak Woodlands (6)	32	6	38
Central California Valley (7)	2	0	2
Southern California Mountains (8)	17	10	27
Eastern Cascade Slopes and Foothills (9)	10	1	11
Central Basin and Range (13)	8	27	35
Mojave Basin and Range (14)	42	12	54
Klamath Mountains (78)	28	7	35
Northern Basin and Range (80)	-[a]	-	-
Sonoran Basin and Range (81)	5	1	6
Southern California/Northern Baja Coast (85)	6	4	10

[a]Potential cells were excluded from survey based on pre-screening.

Table 2. Occupancy (no.) of sites surveyed for Townsend's big-eared bats (COTO) overall and by Ecoregion during active (bat[s] present, no maternity indicated; maternity roosts; no. surveyed) and inactive (bats present; bats not present; no. surveyed) seasons.

Ecoregion (USGS no.)	Active season			Hibernacula		
	Present	Maternity	No. surveyed	Present	Not present	No. surveyed
Statewide	209	84	668	80	246	326
Coast Range (1)	4	2	30	1	6	7
Cascades (4)	19	6	46	4	3	7
Sierra Nevada (5)	32	8	105	9	45	54
Southern/Central California Chaparral/Oak Woodlands (6)	19	9	69	8	29	37
Central California Valley (7)	0	0	9	0	0	0
Southern California Mountains (8)	24	2	56	9	26	35
Eastern Cascade Slopes and Foothills (9)	11	2	26	1	1	2
Central Basin and Range (13)	2	13[a]	36	26	58	84
Mojave Basin and Range (14)	70	23	214	16	55	71
Klamath Mountains (78)	16	9	62	2	15	17
Northern Basin and Range (80)	0	0	0	0	0	0
Sonoran Basin and Range (81)	7	4	15	1	1	2
Southern California/Northern Baja Coast (85)	5	6	23	3	7	10

[a]Includes 10 maternity roosts not obtained through random cell selection.

Table 3. Type of structure used by Townsend's big-eared bats for maternity roosts by Ecoregions.

Ecoregion (USGS no.)	Mine	Cave	Building	Other[a]
Statewide	44	25	10	7
Coast Range (1)		1	1	
Cascades (4)		6		
Sierra Nevada (5)	2	4	3	
Southern/Central California Chaparral/Oak Woodlands (6)	3	3	3	
Central California Valley (7)				
Southern California Mountains (8)	2			
Eastern Cascade Slopes and Foothills (9)		3		
Central Basin and Range (13)	11[b]	2[b]		
Mojave Basin and Range (14)	21	2	1	
Klamath Mountains (78)	2	4	2	
Northern Basin and Range (80)				
Sonoran Basin and Range (81)	3			1
Southern California/Northern Baja Coast (85)				6

[a]Bridges, culverts, water flumes, and other structures.

[b]Includes 10 maternity roosts not obtained through random cell selection.

Table 4. Level of disturbance at sites visited by Ecoregion for Townsend's big-eared bat, winter and summer combined. Approximate sample sizes are provided in Table 2.

Ecoregion (USGS no.)	Disturbance level (% of Sites)			
	None	Slight	Frequent	Continual
Statewide	42	34	22	2
Coast Range (1)	26	33	38	3
Cascades (4)	53	29	16	2
Sierra Nevada (5)	47	30	21	2
Southern/Central California Chaparral/Oak Woodlands (6)	46	32	22	0
Central California Valley (7)	22	0	56	22
Southern California Mountains (8)	49	30	20	1
Eastern Cascade Slopes and Foothills (9)	46	15	35	4
Central Basin and Range (13)	38	32	29	1
Mojave Basin and Range (14)	38	38	20	3
Klamath Mountains (78)	46	38	16	0
Northern Basin and Range (80)	-	-	-	-
Sonoran Basin and Range (81)	25	50	25	0
Southern California/Northern Baja Coast (85)	33	53	10	3

Table 5. Number of historic sites visited and determined to be active for summer and winter roosting Townsend's big-eared bats.

Ecoregion (USGS no.)	Summer		Winter	
	No. sites	No. active	No. sites	No. active
Statewide	80	53	63	37
Coast Range (1)	3	2	2	2
Cascades (4)	3	2	1	1
Sierra Nevada (5)	8	6	5	2
Southern/Central California Chaparral/Oak Woodlands (6)	12	6	5	3
Central California Valley (7)	0	0	0	0
Southern California Mountains (8)	6	6	7	3
Eastern Cascade Slopes and Foothills (9)	4	2	1	1
Central Basin and Range (13)	5	3	27	14
Mojave Basin and Range (14)	19	12	8	5
Klamath Mountains (78)	13	8	3	3
Northern Basin and Range (80)	0	0	0	0
Sonoran Basin and Range (81)	2	2	0	0
Southern California/Northern Baja Coast (85)	5	4	4	3

Table 6. Summary of hibernacula surveyed by roost size category (1, 1-5, >5 bats) by Ecoregions for Townsend's big-eared bat.

Ecoregion (USGS no.)	Number of sites 1	1-5	>5
Statewide	5	52	26
Coast Range (1)		1	
Cascades (4)		2	4
Sierra Nevada (5)		9	
Southern/Central California Chaparral/Oak Woodlands (6)	2	3	3
Central California Valley (7)			
Southern California Mountains (8)		9	1
Eastern Cascade Slopes and Foothills (9)			1
Central Basin and Range (13)		18	9
Mojave Basin and Range (14)	3	6	6
Klamath Mountains (78)			2
Northern Basin and Range (80)			
Sonoran Basin and Range (81)		1	
Southern California/Northern Baja Coast (85)		3	

Rev. June 29, 2016

Appendix A.1 California State-wide Bat Survey

*Historic Status:	H	M	B	SO	U		# COTO_______
*Current Status:	H	M	B	SO	U	ND	

General Information

B= Bachelor/non-reproductive summer; SO = sign only; U = unknown; ND = No detection of bats or sign on day of visit

Site Name /reference: ______________________________ *Temp Site ID for Data Entry (YYYYMMDD-xx–initials)*_______________

Flag for follow up? Y TBD (discuss) **Reason:** Emergence Worthy Season Locked/Access Long Hike Other _____________

Date:	**Region:**	**XUTM:**	**Survey Type(s):** Visual Intern Extern Ac.	
Start Time:	**GridID:**	**YUTM:**	**Historically Present:** Y N U	
End Time:	**LocID:**	**Elevation (m):**	**Protected:** Y N	[1]**Type:**
Observer:	**SubLocID:**	**Winter Summer**	**Bat Survey Possible:** Y N Partial	

[1]**Protection type = Administrative (A), Gated (G)**

External Characteristics

[1]**Roost Type:**	**% Obstructed______ [3]Type______**	**Surrounding Veg Type:**		**Dist to Potential Foraging Site (m):**
Ambient Temp:	**Portal Height (m):**	**Presence of Water:** Y N	**Dist to Water (m):**	
Relative Humidity:	**Portal Width (m):**	**Type of Water Source:**	**Stream River Natural Pond Natural Lake Cattle Pond Other_____________**	**Potential Foraging Site Type:**
[2]**Aspect:**	**Number of known openings:**			

[1]**Roost Type = Adit (AD), Cave (CA), Building (BU), Bridge (BR), Tree (T), Lava Tube (LT), Boulder Cave (BC), or Other (OT); [2]Aspect looking out from the roost; [3]Gate (G), Vegetation (V), Rock (R), Other (OT)**

Internal Characteristics (Record midway if there are no bats present)

Temperature (C):	**Max Roost Length (m):**	**Internal Complexity:**	**Simple (No branching tunnels/1 floor)** **Moderate (Branching tunnels or <3 levels/floors/rooms)** **Complex (Multiple tunnels or > 3 levels/floors/rooms)**		**Sign of Internal Disturbance:** **None** **Slight** **Frequent** **Continual**
Relative Humidity (%):	**Max Roost Height (m):**				
Air Flow: **None** **Light** **Moderate/High**	**Presence High Ceilings:** **None** **1-2** **>2**	**Internal Water:**	**None** **Floor Only**	**Ceiling Only** **Both**	

Photo ID: _____________ **Location stored:** __________________ **Description:**____

Photo ID: _____________ **Location stored:** __________________ **Description:**____

Bat Data

Species	Number of Bats	Sex[1]	Age[2]	Reproductive Status[3]	Height of Bat (m)	Temp at Bat (C)	Relative Humidity at Bat (%)	Roost Type[4]	ID Method[5]

[1]Sex = Male (M), Female (F), Unknown (U)
[2] Age = Adult (A), Juvenile (J), Unknown (U)
[3]Reproductive Status = Non-reproductive (N), Pregnant (P), Testes/Epidid % score (T/E-x), Lactating (L), Postlactating (PL) Unknown (U)
[4]Roost Type = Day (D), Night (N), Courtship (C), Hibernaculum (H), Maternity (M) , (UP) unknown but sign present, nondiagnostic.
[5]ID Method = Visual (V), Guano (G), Carcass (C), Insect Parts (I), Acoustic (A), Other (Indicate Method)

Comments:

Appendix A.2				
General		**Data Type**	**Data source**	**Definitions**
field added summer 2016	Site Name/reference	Text description of formal/informal site name (e.g., Crystal Cave/Excelsior Mine Adit 1/Unnamed Adit 3 in Copper King Mine Group) or other descriptive reference to quickly identify general location of work (e.g., Yosemite NP bridge 1, Central Coast BLM North of LA Adit 3)	Field	
field added summer 2016	Temp site ID for Data Entry	YearMonthDate-serial number-initials (E.g., 20160601-02-LSH for Leila Harris second site of the day on June 1). Necessary to streamline data entry & QAQC process.	Field	
field added summer 2016	Flag for follow up	Yes, TBD-discuss. Something about site warrants a return visit or discussion with team	Field	
field added summer 2016	Reason (for follow up)	Emergence Worthy (significant potential but no or incomplete internal access; needs emergence survey), Season (potential habitat for other season visit), Locked/Access (need road or bat gate key, door key, private property permission, etc. Include situation details and contacts in Comments field), Long Hike (road not passable; site promising but would require planning for long hike), Other (E.g., special request from jurisdiction or property owner, other. Explain)	Field	
	Survey Date	Day/Month/Year (e.g., 01/04/2014)	Field	
	Survey Start Time	24-hr (e.g., 1300)	Field	
	Survey End Time	24-hr (e.g., 1300)	Field	
	Observer	Initials (e.g., AML)	Field	
	Region	Level III Ecoregion ID (2-digit code; e.g, 01, 85)	Desktop	
	GridID	Grid Cell ID (5- or 6-digit number, no common; e.g., 86372)	Desktop	
	LocationID	≤ 3-digit number to represent the site	Field	Identified by a unique number within each grid cell
	SublocationID	Passage or Side Tunnel (Single letter; e.g., mine with LocationID 31 and a single passage = 31A)	Field	Identified by single letter A-Z
	XUTM	6-digits	Field	
	YTUM	7-digits	Field	
	Elevation	m (≤ 6 digits)	Field	
data values added summer 2015 (U), and summer 2016 (B, SO)	Record Type	Maternity, Hibernaculum, Bachelor (nonreproductive summer roost, male or female); SO = sign only; U = unknown. Can circle more than one, e.g., (Maternity determined by sign only)	Field (And groundtruth v historical)	
Field added sumer 2015, values added summer 2016	Current status	Maternity, Hibernaculum, Bachelor (nonreproductive summer roost, male or female); SO = sign only; U = unknown, ND= No detection of bats or sign on day of visit. Can circle more than one, e.g., (Maternity determined by sign only)		
Field added summer 2016	COTO #	Total number of individuals visually observed (summary from back of sheet)		
Data values added summer 2016	Survey Type	Visual, Internal, External, Acoustic. Can circle more than one, e.g., visulal internal; external acoustic only, or external night vision only, external acoustic and NV, etc.	Field	
data value added summer 2016	Historically Present?	Y/N/U	Desktop	
	Protected?	Y/N	Field	Is the potential roost protected?
	Protection Type	Administrative, Gated	Field	What type of protection?
Additional values added summer 2016	Survey Possible?	Y/N/Partial. Note partial when only able to survey part of habitat (e.g., entry into mine but did not explore entire workings due to safety or assumption that no bats were present beyond certain point, etc.). Explain if partial only, e.g. Unsafe/Assume unsuitable further in/locked gate part way in/ran out of time/etc.	Field	
	PhotoID	Per device. Label with site ID (or temp site ID if grid cell unknown) and serial number of photo when uploaded to project drive or sent in to LSH	Field with desktop follow up	
Field added summer 2015	Photo storage location	Whose camera/phone/GPS unit are photos on	Field	
Field added summer 2015	Photo description	E.g., portal; view W from portal, internal guano circle, etc.	Field	
External Characteristics				
	Roost Type	Adit, Cave, Building, Bridge, Tree, Lava Tube, Boulder Cave, Other	Field	
	Ambient Temperature	C	Field	
	Relative Humidity	%	Field	
	Aspect	Deg	Field	Determined looking out from the opening
	Percent Obstructed	%	Field	Percent of the opening that is covered by vegetation, rocks, gates, etc.; estimated to nearest 10%
	Obstruction Type	Gate, Vegetation, Rocks	Field	
	Portal Height	m	Field	Estimated to nearest 0.1m
	Portal Width	m	Field	Estimated to nearest 0.1m
Field added summer 2016	Number of known openings			
	Surrounding Veg Type	Type - E.g., Pinyon-juniper Woodland	Field	
	Presence of Water	Y/N	Field and Desktop	Estimated to nearest 0.25km
	Distance to Nearest Water Source	m	Field and Desktop	Estimated to nearest 0.25km
	Type of Water Source	Stream, River, Natural Pond, Natural Lake, Cattle Pond, Other	Field and Desktop	
	Distance to Potential Foraging Site	m	Field and Desktop	Estimated to nearest 0.25km
	Potential Foraging Site Type	Type - E.g., Pinyon-juniper Woodland	Field and Desktop	
	Road Density	Primary, Secondary, Tertiary	Desktop	Per grid cell
	Distance to Nearest Road	m	Desktop	Per grid cell
	Impervious cover	%	Desktop	Per grid cell
	Surface area of vegetation	%	Desktop	Per grid cell
Internal Characteristics				
	Temperature	C	Field	
	Relative Humidity	%	Field	
	Air Flow	None, Light, Moderate/High	Field	
	Max Roost Length	m	Field	Estimated to nearest 1m
	Max Roost Height	m	Field	Estimated to nearest 0.5m
	Presence High Ceilings	None, 1-2, >2	Field	>3m

	Internal Complexity	Simple (No branching tunnels), Moderate (Branching tunnels or <3 levels), Complex (Multiple tunnels or >3 levels) Summer 2016: Rooms and floors added to more consistently categorize building sites	Field	
	Internal Water	None, Floor Only, Ceiling Only, Both	Field	
	Internal Disturbance	None, Slight, Frequest, Continual	Field	
Bat Data				
	Species	4-letter code; e.g., COTO	Field	
	Number of Bats		Field	If feasible, enter number of groups and number per group
	Sex	Male (M), Female (F), Unknown (U)	Field	
	Age	Adult (A), Juvenile (J), Unknown (U)	Field	
	Reproductive Status	Non-reproductive (N), Pregnant (P), Testes (T), Lactating (L), Postlactating (P) Summer 2016: Unknown (U)	Field	
	Height of Bat	m	Field	Estimated to the nearest 0.25m
	Temperature at Bat	C	Field	
	Humidity at Bat	%	Field	
	Roost Type	Day (D), Night (N), Courtship (C), Hibernaculum (H), Maternity (M), Sign present but roost type undetermined (UP)	Field	
	ID Method	Visual (V), Guano (G), Carcass (C), Insect Parts (I), Acoustic (A), Other (Indicate Method)	Field	*should be able to select >1 indicator in the database
Comment Section				

Appendix B. Pierson and Rainey (1998) survey site (1980-1990 period) activity and known status (2014-2017) for Townsend's big-eared bat.

Colony	**County**	**1980_90s_Count**	**2015-17 Maternity**
Aetna Springs	NAP	0	Not surveyed.
Albion	MEN	0	Habitat gone.
Westport	MEN	0	Habitat gone.
Covelo	MEN	0	Not surveyed.
Butter Creek	TRI		No access at time of study.
Calistoga	NAP	15	Not surveyed.
Inverness	MRN	93	Habitat gone.

Olema	MRN	160	Site is monitored by USGS. Maternity colony present.[1]
Bolinas	MRN	230	Site is monitored by USGS. Maternity colony present.[1]
Knoxville	NAP	105	Maternity active 2014. Survey conducted by E. West separate to this assessment.[2]
Sulfur Creek	COL	145	Maternity active 2014. Survey conducted by E. West separate to this assessment.[2]
Yorkville	MEN	65	Not surveyed.
Cecilville	SIS	100	Winter survey only. No diagnostic maternity sign observed.
Somes Bar	SIS	50	Surveyed. Maternity sign present.
Fremont	ALA	0	Surveyed. No maternity colony. Heavy disturbance noted.
Berkeley	ALA	0	Not surveyed.
Mt Diablo	CCA	0	Not surveyed.
Woodside	SCL	0	Not surveyed. (Barn in general area reported to hold COTO contains *Antrozous pallidus.*[3])
Carmel	MNT	0	Not surveyed.
Willow Creek	MNT	0	Surveyed. No maternity colony.
Cave Gulch	SCR	0	Surveyed. No maternity colony. Heavy disturbance.
Santa Inez	SBA	150	Not surveyed (site could not be identified).
Gazos Creek	SMT	175	Habitat gone
Samwell	SHA	0	Habitat gone (excluded).[4]
Lava Beds 1	SIS	175	Three maternity colonies currently described and monitored by Lava Beds National Monument.[5]
Lava Beds 2	SIS	240	Three maternity colonies currently described and monitored by Lava Beds National

1 Kleeman, P. pers comm, July 6, 2015. United States Geologic Survey unpublished data.
2 West, E. pers. comm, February 2, 2015.
3 Johnston, D. pers comm., Sept 12, 2017.
4 Rogers, B. pers comm. August 3, 2016.
5 Smith, K., pers. comm. June 25, 2018. National Park Service unpublished data.

			Monument.[6]
Bat Cave	SIS	100	Other species. Not a COTO maternity site.[5]
Tennant Cave	SIS	400	Surveyed. Maternity colony present.
Weed	SIS	152	Surveyed. No maternity colony.
Dunsmuir	SIS	75	Not surveyed.
Gazelle	SIS		No access at time of study.
Clough Cave	TUL	0	No access at time of study.
Moss Cave	AMA	1	Not surveyed.
Bower Cave	MPA	0	No access for internal survey. COTO present; undetermined reproductive status.
Cave City	CAL	0	Not surveyed (commercial).
Mercer Caverns	CAL	0	Not surveyed (commercial).
Boyden Cave	FRE	25	No access at time of study.
Bodfish Cave	KRN	33	No access at time of study.

6 Smith, K., pers. comm. June 25, 2018. National Park Service unpublished data.

Murphys Caves	CAL	19	Surveyed. Maternity colony present.
Music Hall Cave	CAL	12	No access. Caver reports suggest active as of 2014; species unconfirmed.
Sequoia Cave	TUL	200	No access at time of study.
Jamestown 1	TUO	11	Not surveyed.
Jamestown 2	TUO	25	Not surveyed.
Yaney Mine	INY	55	Surveyed. No colony. Abandoned for 1 year.
Poleta Mine	INY	215	Surveyed. Maternity colony present.
Snowflake Mine	INY	55	Surveyed. Main Snowflake adit collapsed. Maternity colony now in neighboring adit.
Wilson Canyon Mine	INY	0	Not surveyed
Mt. Spring Mine	INY	300	Not surveyed
Josephine Mine	INY	100	Surveyed. Maternity colony present.
Little Lake Mine	INY	71	Surveyed. Maternity colony present.
Haiwee Reservoir	INY	75	Not surveyed. Active per LADWP

Blind Spring Mine	MNO	100	Maternity colony present.
Death Valley Mine	INY	100	Not surveyed. Active per National Park Service.
Briggs Mine 1	INY	120	Active. R. Sherwin monitors
Briggs Mine 2	INY	115	Active. R. Sherwin monitors
Mitchell Cavern	SBT	0	Surveyed. No Maternity. Regular disturbance despite closure.
Macedonia Mine	SBT	75	Not surveyed
Hart Mine	SBT		Not surveyed (no historical maternity).
Alice Mine	RIV	0	Not surveyed.
Senator Mine	IMP	0	Active 2014-15, per surveys conducted by P. Brown separate to this assessment.
Mountaineer Mine	RIV	50	Active 2014-15, per surveys conducted by P. Brown separate to this assessment.

Ramona	SDG	0	Not surveyed
Mussey	SDG	0	Not surveyed
Julian	SDG	0	Not surveyed (specific location could not be identified)
Barrett Flm.	SDG	0	Surveyed. Maternity colony present.
Noble Canyon	SDG		Surveyed. No maternity colony.
Santa Cruz Island	SBA	65	Monitored by NPS. Colony is considered stable though smaller in size than in the 1990s[7].

7 P. Brown, personal communication, September 2018

Appendix C.

Status of Key Jurisdictions with Regular Monitoring Efforts for *Corynorhinus townsendii.*

Not surveyed, due to existing monitoring programs, and not included in survey results analysis:

1. Lava Beds National Monument.

Lead monitoring contact: Katrina Smith, Acting Chief, Division of Natural Resources Management.

Latest available summary on nature of monitoring effort and COTO status (K. Smith pers comm June 25, 2018):

> Three maternity colonies use several cave systems and are referred to as Cave Loop colony, Caldwell colony, and Elmer's colony. They are assumed to remain for hibernation.
>
> COTO colony size estimates are 50-200 individuals
>
> Maternity season surveys are for presence/no detection to avoid disturbance. Hibernation surveys include population counts.

2. Pinnacles National Park

Lead Monitoring Contact: Paul Johnson, Wildlife Biologist.

Latest available summary on nature of monitoring effort and COTO status (P. Johnson, pers comm Sept 4, 2018):

> Two maternity colonies are known and are assumed to be the same colonies that overwinter. One colony is protected through interpretive material and seasonal closure of associated summer and winter sites; the other is protected through its remote, undisclosed locations.
>
> Combined, the total COTO count is roughly estimated at 300-400 individuals.
>
> Surveys are limited to avoid disturbance, and seasonal site occupancy is not always predictable, resulting in occasional gaps in survey data. Results are approximate, but the counts appear stable.

Sites we visited (and included in our analyses) that have ongoing jurisdictional monitoring and management efforts:

1. Hearst Castle, California State Parks

Lead Monitoring Contact: Regena Orr, Environmental Scientist

Latest available summary on nature of monitoring effort and COTO status.

> One maternity colony here with approximately 400-600 individuals. At least a small number of bats (<10) assumed to overwinter in same location (R. Orr pers comm. 12/13/2017)
>
> Outflight surveys conducted annually. Internal surveys not conducted to avoid disturbance. Rare disturbance for maintenance work.

2. Two building roosts on Point Reyes NP jurisdiction managed by USGS

Lead Monitoring Contact: Patrick Kleeman, Ecologist, USGS

Latest available summary on nature of monitoring effort and COTO status.

> Two maternity colonies with a combined total of roughly 600 individuals (P. Kleeman pers comm July 6, 2015). At least a small number of bats assumed to overwinter in same sites.
>
> Outflight surveys conducted annually. Internal surveys conducted rarely to avoid disturbance. Vandalism has been sporadic issue.

Individual ongoing research

We understand that some individuals have ongoing research or monitoring projects at specific sites/areas with potential for significant COTO presence. These data sets may be refined and become available in the future:

Rick Sherwin, maternity and hibernation surveys, Death Valley National Park

Winnifred Frick, hibernation surveys, Sequoia-Kings Canyon National Park