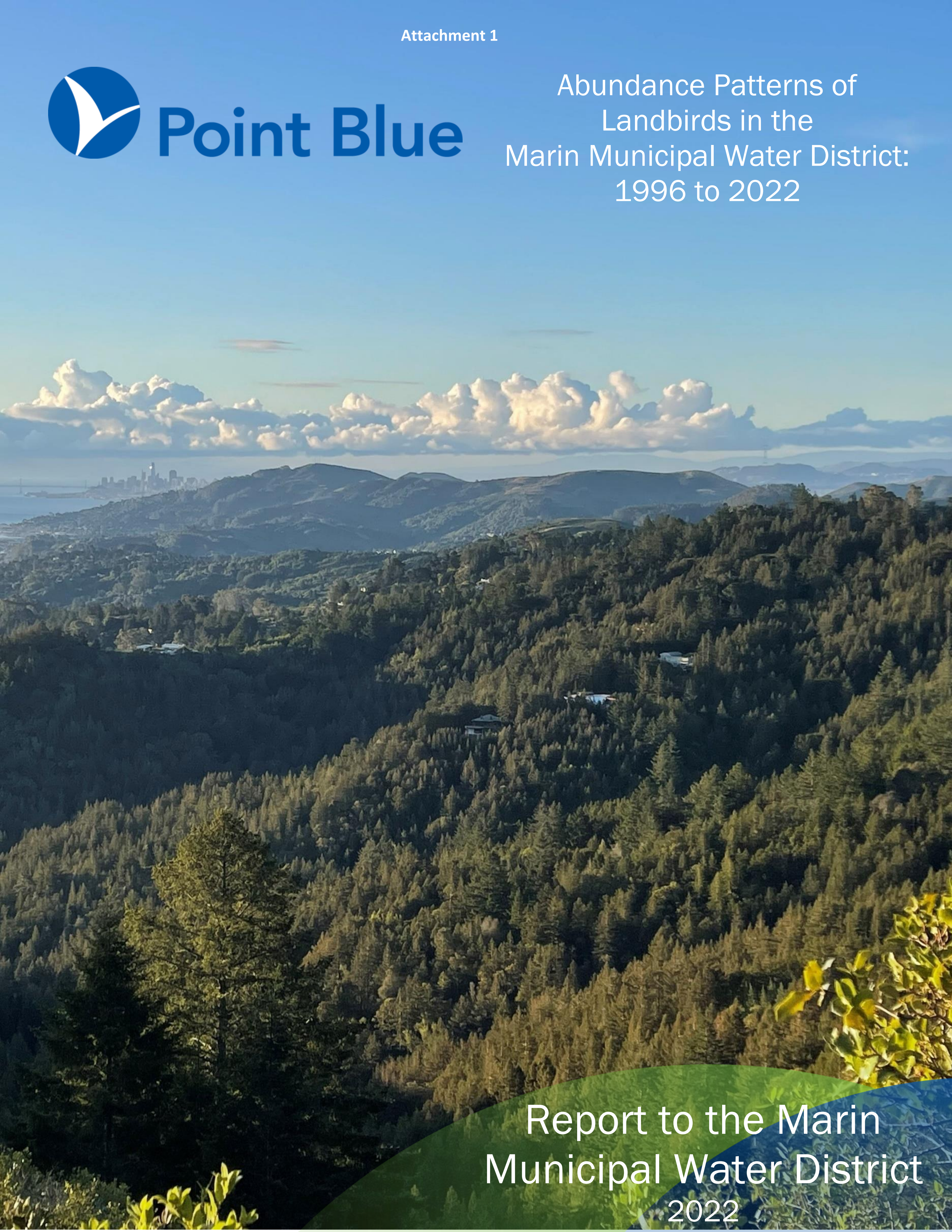
Attachment 1

Abundance Patterns of Landbirds in the Marin Municipal Water District: 1996 to 2022



Report to the Marin Municipal Water District

2022

Abundance Patterns of Landbirds in the Marin Municipal Water District: 1996 to 2022

Report prepared for the Marin Municipal Water District

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EXECUTIVE SUMMARY

Many species of birds, including those once considered common, have declined in recent decades. Therefore, monitoring programs that can detect changes in bird populations are important because they can help inform land managers when additional management action or research may be warranted to protect these species. Point Blue Conservation Science monitored the abundance of landbirds in the Marin Municipal Water District (Marin Water) from 1996 to 2022. Using these data, we analyzed trends in abundance for 56 species of birds present during the breeding season (55 native species, and the introduced European Starling). We used a different modelling approach from our previous analyses, which allowed us to evaluate an additional 15 species, and to be more likely to detect trends for species overall. We scored species population trends using an established protocol by Partners in Flight, and we then translated those scores to categories of concern: Least Concern, Uncertain/Caution, Caution, and Significant Concern. Twenty-eight (51%) of the 55 native species exhibited increasing trends or were considered stable (Least Concern); six species (11%) had either uncertain trends or small decreases (Uncertain/Caution); four species (7%) showed moderate to possible large decreases (Caution); and 17 species (31%) exhibited large decreases (Significant Concern). The non-native European Starling also exhibited a large decrease. We also evaluated trends for species grouped by their primary habitat association on Marin Water lands. We found that species primarily associated with forested habitat types (conifer and mixed hardwood, oak woodland, and species that used multiple forest types) had the highest proportion of species that were increasing or stable. The habitat guilds with the highest proportion of declining species were the generalists (species that used three or more habitat types on Marin Water lands) and riparian/wetland-associated species. The shrub/chaparral guild was only represented by four species and their trend results were mixed. We established additional grassland points in 2019 to increase our ability to assess birds in this habitat type, but we are not yet able to evaluate trends in grassland birds. Future analyses could be incorporated into these monitoring efforts to specifically evaluate response of birds to habitat changes as a result of management actions for Marin Water's Biodiversity, Fire, and Fuels Integrated Plan (which are mostly concentrated in forested habitats), including if there are differences in treated versus untreated areas. We recommend continued assessment of shrub/chaparral-associated species – whether or not it is their primary habitat affiliation – including for species that rely on shrubs in forested habitats. Finally, we recommend continued monitoring of the avian community at the long-term Marin Water monitoring sites in order to provide information to land managers about the status of these bird populations, what they indicate about habitat types on Marin Water lands, and determine if management action is warranted.

INTRODUCTION

In recent decades, many bird species have declined, including species that are considered common (Inger et al. 2015, Rosenberg et al. 2019). The declines may be attributed to multiple factors, including habitat loss and degradation, climate change, pesticide use, domestic or feral cat predation, and other causes (Calvert et al. 2013, Mineau and Whiteside 2013, Pearce-Higgins et al. 2015, Xu et al. 2019). In addition to studying birds because of concerns over these large declines, the sensitivity of birds to changing conditions makes them good indicators of ecological change (Carignan and Villard 2002). Monitoring programs are essential components to providing early warning of resource change and can be used to identify species of local or regional conservation concern. Furthermore, when changes are detected through monitoring, recommendations for management or further research may be identified (e.g., Strong et al. 2004).

The Marin Municipal Water District (Marin Water) encompasses over 21,000 acres of land in Marin County, including 18,900 on Mount Tamalpais, and 2,700 adjacent to Nicasio and Soulajule Reservoirs. These lands include a diversity of habitat types and wildlife. In 1996, Point Blue Conservation Science (Point Blue; formerly PRBO) and Marin Water implemented a three-year project to assess the status and distribution of landbird populations on watershed lands managed by Marin Water (Holmes et al. 1998). This was followed by the establishment of a long-term monitoring program, where it was determined that all 337 point count stations would be surveyed every third year beginning in 2001 (with a subset of points surveyed in 1999 for a different purpose and not included in long-term trend analysis). An additional 25 points were added in 2019 in grassland habitat (DiGaudio and Humple 2019), with six of those points selected for continued monitoring in 2022 and beyond, after evaluating their potential contribution to our understanding of grassland birds in the region. The principal goal of this long-term study is to monitor the abundance of landbird populations on Marin Water lands over time in order to provide managers with information on the overall status of this natural resource, which will in turn provide guidance on when management actions are warranted and research is needed.

In this report we present results from trend analysis for 56 passerine and near-passerine species (hereafter collectively called landbirds) within the study area using data from 1996 to 2022. We have updated the analysis approach used in previous reports in order to increase our ability to detect trends for all species, and to increase the number of species in the analysis; the most recent previous analysis of this dataset (1999-2019) included trends for 41 species (Cormier et al. 2020). Additionally, we assess trends for species grouped by their primary habitat association on Marin Water lands.

METHODS

Study area

In 2022, Point Blue Conservation Science biologists conducted bird surveys at 343 point count stations throughout Marin Water lands (Figure 1; Appendix A). Point count survey locations were first established for 337 of the points in 1996 by Point Blue, in collaboration with Marin Water. Points were placed on trails and fire roads throughout the Mount Tamalpais watershed with the goal of covering the major habitat types and geographic extent of the study area. General habitat types covered include conifer (including coast redwood) and mixed evergreen hardwood forest, oak woodland/savannah, scrub/chaparral, and grassland; a small portion of points are included in riparian or wetland (e.g., along lake edges) areas. In 2019, 25 additional point count survey locations were established in grassland habitat across Marin Water lands to assess grassland bird species in the One Tam footprint (DiGaudio and Humple 2019), and six of those points were selected for continued monitoring and surveyed in 2022, but not included in this analysis as there is not yet long-term data available for them.

The original 337 point count locations were selected by first randomly selecting locations that were distributed evenly throughout the study area. From each random location, the nearest unpaved fire road or trail was used for the first point count survey location of each transect. The direction of travel from the first established point of the transect was random when possible, and subsequent points for the transect were placed on the fire road or trail, generally spaced 200-400 m apart from one another (Figure 1). The new grassland point count survey locations were selected based on available grassland habitat and patch size, and were placed at least 50 m from the nearest non-grassland habitat edge and at least 250 m apart from other points (DiGaudio and Humple 2019).

Point Count Surveys

Point count surveys were conducted following the standardized point count protocol described in Ralph et al (1993 and 1995). At each point count location, an observer recorded all birds detected within a 5-minute survey window. The species of bird, type of detection (song, visual, or call), and the estimated distance of the bird from the observer were all recorded. Any individual that was determined to be juvenile was coded as such. Methods for recording distance have varied depending on the year and adhered to either a Fixed Radius method or the Variable Circular Plot (VCP) point count method. The Fixed Radius method was used in 1996 and for some sites in 1997 and 1998, where each bird was classified as being less than 50 m or greater than 50 m from the observer. For the VCP method, the distance to each bird is estimated to the nearest “distance band” from the observer. For the remaining points in 1997 and 1998, and for 2001, the VCP method was used with distance bands every 10 m out to 100 m; since 2004 we have used slightly broader VCP distance bands of 0-10 m, 10-20 m, 20-30 m, 30-50 m, 50-100 m, and greater than 100 m. Beginning in 2004, biologists used range finders to assist in the accurate determination of distance estimations; during all years, biologists regularly recalibrated their distance estimations. We were able to compare all years of this study by lumping all detections within 50 m of the observer into one distance band (0-50 m). In addition, birds detected flying over and not using the site were placed in a different category, flyovers, not in a distance band.

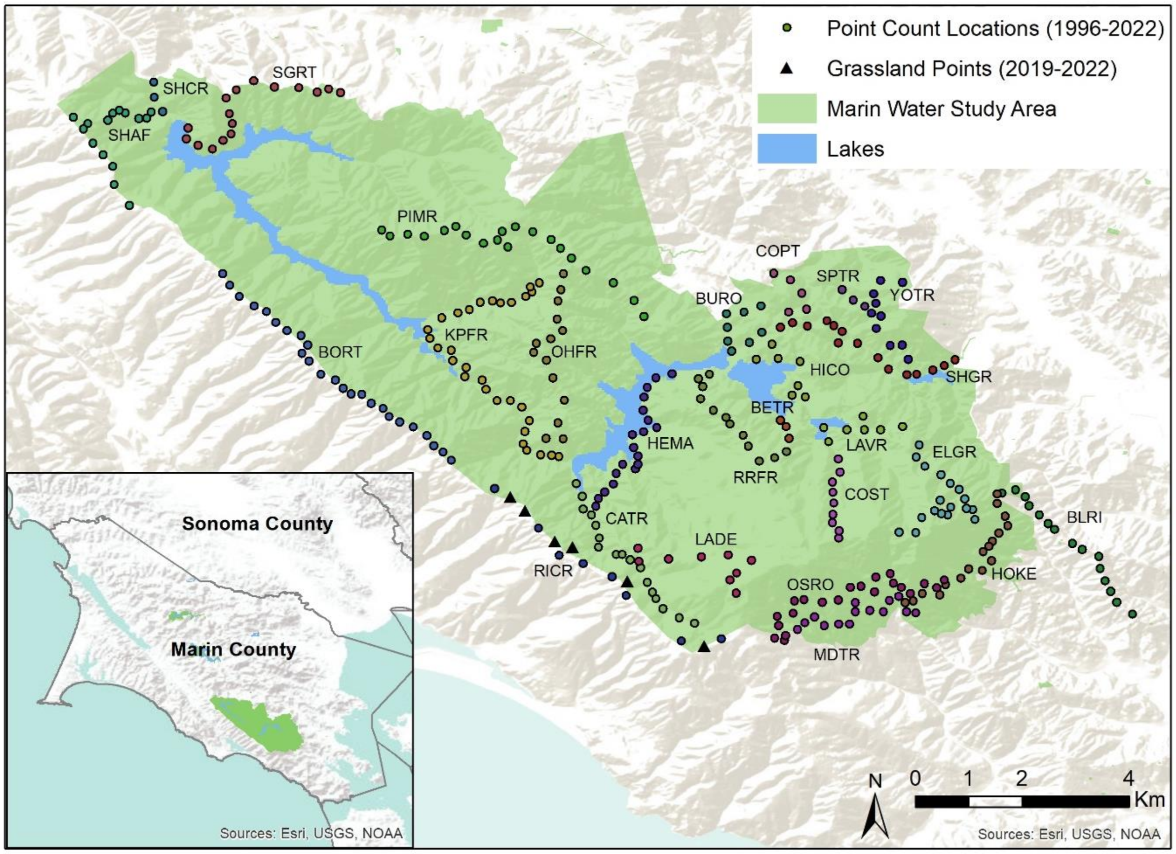

Figure 1. Map of 2022 point count locations conducted by Point Blue Conservation Science in the Marin Municipal Water District, Marin County, California. On top of the long-term point count stations (n=337) additional grassland point count stations (n=6) established in 2019 were also surveyed, but new grassland points are not included in the analysis. For the long-term points, each transect is represented by a different color.

Surveys began 15-30 minutes after local sunrise and were completed within four hours of sunrise to restrict the survey to peak singing hours. Counts were not conducted during rainy, excessively foggy, or windy conditions, where bird activity levels or detection probability was reduced. In most years, two surveys were conducted each year from mid-April through mid-July, and generally occurred in May and June, with the current protocol being to conduct the first survey in May and the second in June (see Appendix A for survey dates in 2022); see statistical methods for how we addressed the few instances of one or three surveys being conducted in year.

Data Management

All 2022 data were collected on data sheets and entered online. All years of data can be accessed at the password protected California Avian Data Center (CADC; http://data.prbo.org/cadc2/) by Point Blue staff and by Marin Water staff upon password request. CADC is a node of the Avian Knowledge Network (AKN), whose goal is to share observational bird data with as wide an audience as possible, while assuring data quality, validity, and metadata documentation, and simultaneously respecting the rights of data contributors and resource managers. All users of any AKN dataset are instructed to acknowledge the contribution of the data contributors. Each data set contributed to the AKN has an associated level of access to that data that can allow or restrict access (Ballard et al. 2008). The landbird data for the Marin Water project, post data-validation by a Point Blue data manager or project leader, is made available at a moderate level (Level 3, from 1-5). Level 3 availability allows the data to broadly be included with regional or national summaries of bird data (e.g., available for meta-analyses and range-wide maps and graphs). At the same time, it requires researchers or members of the public to request permission to access the detailed dataset itself, which will allow its uses to be tracked; Point Blue staff will receive any data requests and share those requests with Marin Water staff. This access level was determined based on the interests of Marin Water and can be increased or decreased at any time.

Personnel

Point Blue staff biologists trained in the songs and calls of the birds of the Marin Water study area conducted all surveys in 2022. They were Renée Cormier, Mark Dettling, Preston Duncan, Megan Elrod, and Diana Humple.

Statistical Analysis

Data cleaning and analysis were conducted in R version 4.1.3 (R Core Team 2022), primarily using the core “tidyverse” packages for data cleaning and “lme4” for modeling (Wickham et al. 2019, Bates et al. 2015). We included data from surveys conducted in 1996, 1997, 1998, 2001, 2004, 2007, 2010, 2013, 2016, 2019, and 2022; data from 1999 were excluded because sites surveyed were not consistent with other years. We analyzed individual species, excluding all waterbirds (e.g., ducks, herons, coots, grebes), shorebirds, owls, non-breeding migratory species, and other species not well sampled with the point count method such as non-territorial species, flocking species, and species with very large territories (e.g., swallows, ravens, crows, raptors; see Appendix B for common and scientific names of all species included in the analysis). We also excluded species with only a few detections (e.g., Blue Grosbeak, Brewer's Blackbird, California Thrasher, Lark Sparrow). We excluded Allen's Hummingbirds because it is not possible to visually distinguish most individual Allen's Hummingbirds from their close relative the Rufous Hummingbird (a migrant bird that does not breed in Marin County but is present during the survey period). We only analyzed data from 2004 to 2022 for Swainson's and Hermit thrushes because we suspect that one observer who conducted surveys during the earlier years of the study was not always distinguishing these species accurately.

We used data from two visits for each year. In 1997, three surveys were conducted, so we eliminated all data from one of the three visits for each transect; we excluded whichever visit (the first or third) was an outlier when compared to dates the same transect was surveyed in all other years. We dropped all individuals coded as juveniles from the analysis, and those that were coded as flyovers.

For every survey point, we used the maximum number of detections within 50 m of the survey point, for each species per year, across both visits included in the analysis; because the probability of detection of any species is not 100% during any given survey, we assumed that if a higher count occurred during one of the two visits in a year, then that represented a more accurate count of the true number of individuals in the area. This gave us one per-point-per-year abundance value for each species. There were a few points that were only surveyed once in a given year (22 instances across all points and years), so the number of detections on that single visit was used as the maximum count.

We evaluated the trend in abundance over time for each species by fitting a generalized linear mixed model with a Poisson error distribution to the per-point bird counts, with point ID (identification by transect and point number within the transect) as a random intercept (Bolker et al. 2009, Zuur et al. 2009). For each model, we confirmed model convergence, selecting alternate optimizers or increasing the number of iterations as needed. This analysis approach is different from our approach in previous years (e.g., Cormier et al. 2020) in that (1) we used the maximum count across the two visits at each point rather than the average count and (2) we modeled the average trend in the counts at each point (approximately 337 data points per year) rather than modeling the trend in the average count across all points (1 data point per year). This new modeling approach allowed us to include (and account for) survey data from points that were not surveyed every year, as well as model the trends for less common species that were absent from all points in one or more years, and ultimately resulted in a more sensitive model (i.e., more likely to detect changes). For each species, model results included the average annual growth rate, defined as the average percent change in abundance per year (positive or negative), across all points and years surveyed.

To interpret our model results and determine which species to consider as increasing, decreasing, or having no evidence of a trend, we adapted an established peer-reviewed approach to evaluating population trends used by Partners in Flight (PIF; Panjabi et al. 2020, Beissinger et al. 2000, Carter et al. 2000). The PIF species assessments incorporate several criteria to evaluate the regional and continental conservation status of bird populations and inform bird conservation strategy, including data on population trends as well as relative abundance, distribution, and known threats. Here, we adapted their protocol for evaluating population trends, which incorporates the direction and estimated total magnitude of population change over 50 years, as well as the precision and reliability of the trend results to rank species on scale of 1 to 5 (Panjabi et al. 2020). The advantage of adopting this PIF approach and its trend classification system is that it allows us both to apply a vetted interpretation of these model results, and to use the same language when comparing our trends to those at larger geographic scales. To apply this protocol to the results of our analyses, we used the models to predict the total % population change that would occur if the estimated trends continued over 50 years, combined with the p-values indicating whether the average annual growth rate was statistically different from zero, to assign each species to one of the population trend scores (Table 1). In this framework, p-values < 0.1 were considered statistically significant trends and p-values < 0.33 were considered to indicate possible trends. Importantly, this approach allows distinguishing stable population trends (score = 2) from those with uncertain population change (score = 3), based on whether the trend estimate is considered Reliable, meaning there were sufficient data to detect a trend.

Adapting the PIF criteria to our model results, we considered a trend estimate Reliable if the average count of the species per point was > 0.1 (indicating sufficient detections) and the precision of the average annual growth rate (half-width of the 95% confidence interval) was < 3% (indicating we should have been able to detect a trend of greater than +/- 3% growth). For interpretation purposes, we translated each population trend score to an assessment category for Marin Water that ranked species from Least Concern (score = 1 or 2) to Significant Concern (score = 5; Table 1). We note that these species assessment categories were based solely on population trend scores for the purposes of interpreting long-term population trends on Marin Water lands. However, they do not necessarily reflect the overall conservation status of each of these species in the region, because a very small population that is increasing or stable can still be a higher conservation concern than a very large population that is declining; a more complete conservation status assessments would also incorporate data on population size, distribution, known threats, and other factors (Panjabi et al. 2020).

Table 1. Population trend score descriptions and criteria used to assess species trends in the Marin Municipal Water District from 1996-2022, adapted from the Partners in Flight Avian Conservation Assessment Database Handbook (Panjabi et al. 2020). Total population change thresholds are based on the total magnitude of change if the average annual growth rates continued for 50 years; we also present the equivalent Annual Population Change (growth rate) that would be needed to reach the 50-year Total Population Change thresholds. Trend estimates were considered Reliable if the average count of the species per point was > 0.1 and the precision of the average annual growth rate was < 3%. The Assessment for Marin Water field puts the Trend Scores into context.

Trend Score	Description	P-value	Total Population Change (%)	Annual Population Change (%)	Reliable Trend[1]	Assessment for Marin Water
1	Statistically significant large increase	≤ 0.1	≥ 50	≥ 0.814	NA	Least Concern
2	Statistically significant small increase, or	≤ 0.1	0 to 50	0 to 0.814	NA	Least Concern
	Possible small or large increase, or	> 0.1 & ≤ 0.33	> 0	> 0	NA	
	Stable	> 0.33	> -15	> -0.325	Yes	
3	Statistically significant small decrease, or	≤ 0.1	-15 to 0	-0.325 to 0	NA	Uncertain / Caution
	Possible small decrease, or	> 0.1 & ≤ 0.33	-15 to 0	-0.325 to 0	NA	
	Uncertain population change (currently stable, leaning negative), or	> 0.33	< -15	< -0.325	Yes	
	Uncertain population change (insufficient data)	> 0.33	any value	any value	No	
4	Statistically significant moderate decrease, or	≤ 0.1	-50 to -15	-1.377 to -0.325	NA	Caution
	Possible moderate or large decrease	> 0.1 & ≤ 0.33	< -15	< -0.325	NA	
5	Statistically significant large decrease	≤ 0.1	≤ -50	≤ -1.377	NA	Significant Concern

[1]Only necessary to assess when P-value was > 0.33.

Finally, we assigned each species to a primary (dominant) habitat affiliation on Marin Water lands. Habitat types included 1) conifer forest that may include a mixed hardwood component; 2) forest (mixed) for species that use more than one type of forest; 3) oak woodland; 4) riparian and/or wetland, and 5) scrub/chaparral. If a species was known to use three or more habitat types on Marin Water lands, and one type was not predominantly used, we assigned that species to a sixth "generalist" category. See Appendix B for the habitat designations for each of the 56 species used in the analysis. To assess if there were any general population patterns by habitat type, we calculated the percent of species in each of the five population trend categories by habitat.

For the habitat trends, and for the trends summarized for all species grouped by population trend score, we present results for the 55 native species included in the analysis and exclude European Starling (an introduced species from Europe) from the community level assessments. We provide the results for the starling separately.

RESULTS

From the 55 native species analyzed, just over half (51%) were classified as increasing or stable and considered to be in the Least Concern categories (scores = 1 or 2; Figure 2; Appendix C). Thirty-one percent of species were classified as showing large declines (Significant Concern; score = 5), while another 7% of species were classified as having moderate or possibly large declines (Caution; score = 4). The remaining 11% of species either had relatively small declines, or there was not enough certainty in the model to determine if there was a trend (Uncertain/Caution; score = 3).

Of the 15 new species that were added to the analysis this year (all of which occur in relatively low numbers on Marin Water lands and were entirely absent in at least one survey year), four were increasing or stable (Least Concern; score = 1 or 2; Lesser Goldfinch, Pygmy Nuthatch, White-breasted Nuthatch, and Western Bluebird), seven were exhibiting large decreasing trends (Significant Concern; score = 5; American Goldfinch, Brown-headed Cowbird, Chipping Sparrow, European Starling, Lazuli Bunting, Red-winged Blackbird, and Western Wood-Pewee) and one was showing a possible moderate or large decrease (Caution; score = 4; Black-headed Grosbeak). The remaining three of the 15 newly-added species were classified as Uncertain/Caution (score = 3; Black Phoebe, Cassin's Vireo, and Nuttall's Woodpecker).

When comparing trends by habitat associations, the percent of species with large increases (score = 1; Least Concern) was higher for species associated with forested habitat types, including species that used conifer/mixed hardwood (50%), multiple forest types (42%), and oak woodland (56%), than species associated with riparian/wetland habitat (13%; relatively uncommon habitat types on Marin Water lands), and scrub/chaparral species (25%; Figure 3). The category with the most concerning pattern was the Generalist category, where all but Anna's Hummingbird (score = 1; Least Concern) exhibited large declines (score = 5; Significant Concern). The introduced European Starling, a non-native species in North America not included in Figures 2 and 3, had a large decreasing trend (Appendix C), and was designated as using multiple forest types ("Forest [mixed]") for its habitat affiliation.

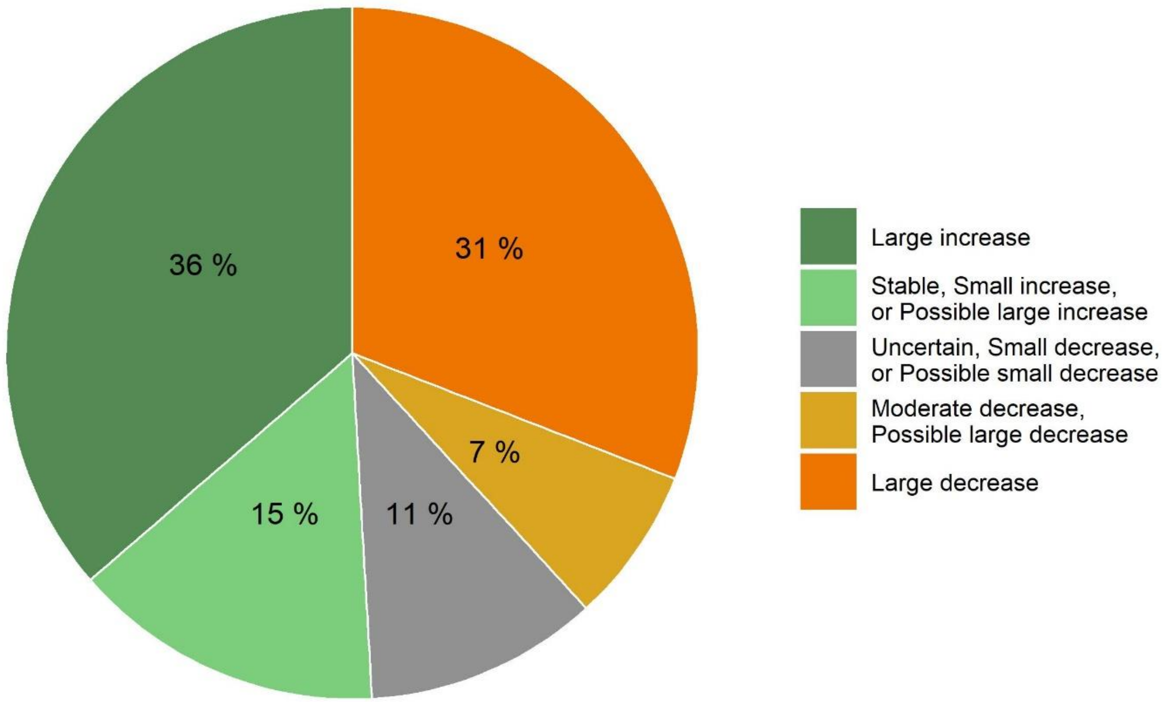

Figure 2. Percent of native breeding landbird species (n=55) on Marin Municipal Water District lands that were classified in the following population trend categories: 1) large increase, 2) small increase / possible increase / stable, 3) uncertain population change / possible small decrease / small decrease, 4) moderate-possible large decrease, and 5) large decrease. Trend categories are as defined in the Partners in Flight Avian Conservation Assessment Database Handbook (Panjabi et al. 2020). Data are from point count surveys conducted by Point Blue conservation Science, 1996-2022.

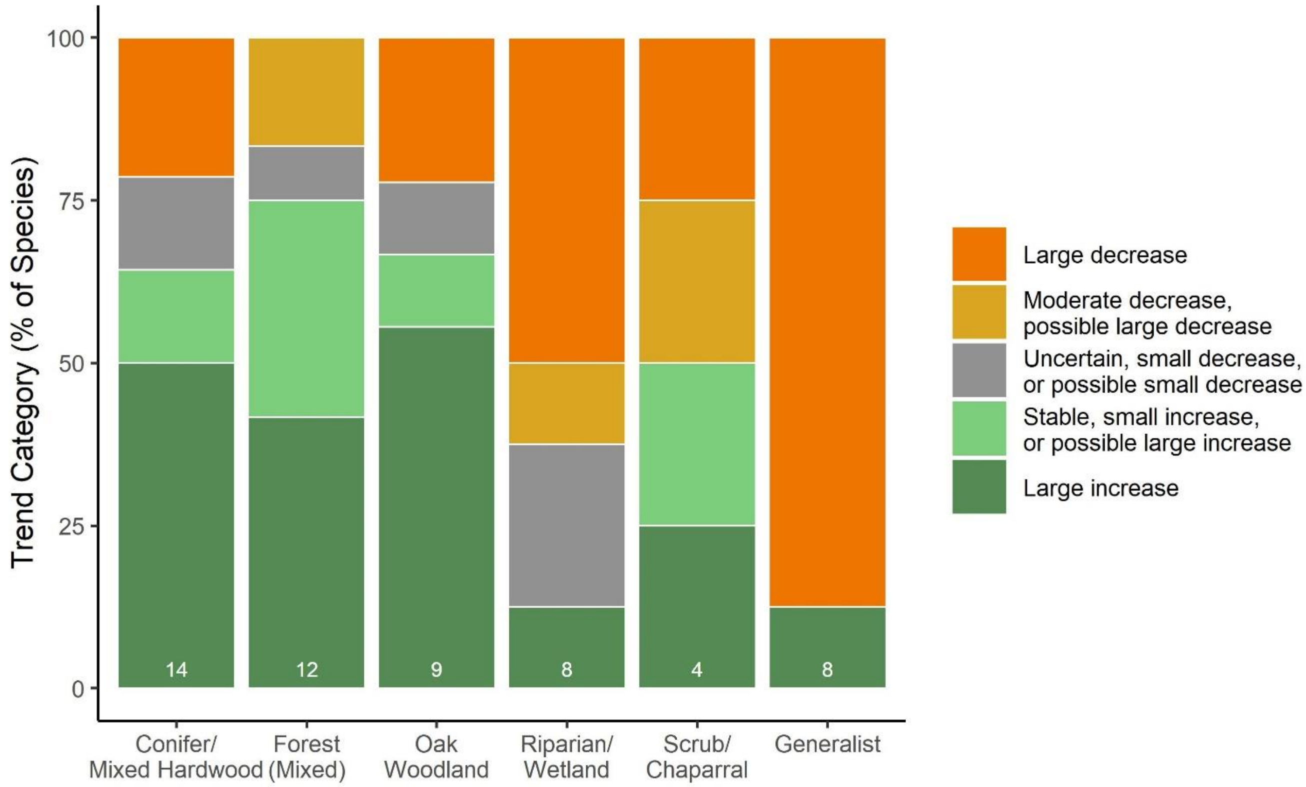

Figure 3. Percent of native breeding landbird species (n=55) by primary habitat affiliation on Marin Municipal Water District lands that were classified in the following population trend categories: 1) large increase, 2) small increase / possible increase / stable, 3) uncertain population change / possible small decrease / small decrease, 4) moderate-possible large decrease, and 5) large decrease. Trend categories are as defined in the Partners in Flight Avian Conservation Assessment Database Handbook (Panjabi et al. 2020). Data are from point count surveys conducted by Point Blue conservation Science, 1996-2022. Sample size (number of species) included in each habitat category is at the base of each bar.

DISCUSSION

Based on monitoring results from 1996 to 2022 for the 56 species included in the analysis, we found that approximately half of the species either were stable or exhibited increasing trends in abundance (Least Concern). Thirty-one percent of native species exhibited large declines (Significant Concern), and another 7% had moderate or possibly large declines (Caution). While there are more significant trends (both positive and negative) in 2022 than in previous analyses of this dataset (e.g., Cormier et al. 2020), this analysis included one additional year of data, and the new modeling approach allowed us to assess trends for 15 additional species, and increased our ability to detect trends for all species. During our last analysis with 41 species, 12% were considered to be decreasing or marginally decreasing (Cormier et al. 2020), which is roughly comparable to our Significant Concern or Caution scores, and all of those species are still decreasing in the current analysis; all species that were increasing or marginally increasing in the previous report (22% of 41 species) are all exhibiting large increases in the current analysis.

And although 66% of the 41 species were considered stable in Cormier et al. (2020) based on the lack of a statistically significant trend, we are now able to distinguish 17% with a score of 2 (stable or possible increase) and 7% with a score of 3 (uncertain or possible decrease); the remaining species that were considered stable in the last analysis are now roughly evenly split between exhibiting large increases (20%) and large (15%) or moderate to possible large (7%) decreases. For the 15 new species included in the analysis, there was a higher proportion decreasing species, with eight (53%) exhibiting moderate to large decreases (score of 4 or 5), four (27%) increasing or stable (score of 1 or 2), and three (20%) whose trends were uncertain (score of 3).

The population trends we identified, positive and negative, reflect the combined influence of a range of local, regional, and even continental factors, and the relative importance of each factor will vary depending on a species' life history, including their diet, habitat requirements, and migratory status. Thus, by comparing species with similar characteristics, or comparing these trend estimates to trends identified from other analyses, we can gain insights into some of the factors that may be contributing to these results. For example, if trends on Marin Water lands are similar to results from Breeding Bird Survey (BBS) data collected on a larger geographic scale than our study, the local trends may indicate that similar changes in habitat and/or environmental conditions are occurring on Marin Water lands as elsewhere throughout the region, while if trends are different between datasets, it might indicate that local conditions are playing a different or larger role. While we do not discuss trend results for all 56 species individually, the following sections include comparisons of Marin Water trends to other studies and some potential causes for the trends we have observed (the list is not exhaustive), with examples for select species.

Increasing Species. It is encouraging that at least half of the species were increasing or stable, and there are some notable species in this list. The Olive-sided Flycatcher is a California Bird Species of Special Concern (Shuford and Gardali 2008); this species is increasing in Marin Water lands (score = 1) but exhibited a large decreasing trend in the long-term (1970-2015) BBS data from the Bird Conservation Region (BCR32) that includes Marin Water lands (Partners in Flight 2021). The Olive-sided Flycatcher is also declining in riparian habitat in coastal Marin County (Dettling et al. 2021). Similarly, the Oak Titmouse and Swainson's Thrush both had large increases on Marin Water lands, but large decreasing trends in the BBS dataset (Partners in Flight 2021). Dettling et al. (2021) also found Swainson's Thrushes to be increasing at coastal Marin County riparian sites but did not evaluate Oak Titmouse. The growth in local abundance, especially for species that are declining elsewhere, suggests local habitat and environmental conditions for these species remain suitable or have improved since 1996.

Decreasing Species. Most of the species for which we estimated large decreasing trends are species that occur in the study area at relatively low numbers – and have occurred at a low abundance since the beginning of the study period – including seven of the 15 newly-added species to the analysis. Thus, these are likely species with habitat requirements that were not widely available on Marin Water lands in 1996, and have become even less common. For example, a small number of Lazuli Buntings used to be detected each year, but we have not detected any in the two most recent survey years; this species has also been documented as having long-term declines from the BBS dataset noted above (Partners in Flight 2021), suggesting the local declines may be part of a broader regional pattern of declining habitat quality or quantity for this species. Chipping and Rufous-crowned sparrows are two species that are typically only found in very localized areas within Marin Water lands and were also found to be declining. In the BBS dataset, Chipping Sparrows also exhibited large decreases, while Rufous-crowned Sparrows were increasing throughout BCR32 (Partners in Flight 2021), suggesting the local declines of this species may be more reflective of local habitat and environmental change. However, we also note that sparrows contributed significantly to the total cumulative loss of birds in North America in a recent analysis that estimated a net loss of nearly 3 billion birds (Rosenberg et al. 2019).

There were also relatively abundant species on Marin Water lands that have exhibited large declines since 1996. Both the California Scrub-Jay and Steller's Jay exhibited decreasing trends in the current analysis, in agreement with previous Marin Water analyses (Cormier et al. 2020, Cormier and Humple 2017, Cormier et al. 2014). Both species were either stable or had small increasing trends (PIF score=2) in the BBS dataset starting in 1970 (Partners in Flight 2021), but when looking at more recent abundance trends from eBird from 2007-2021, results for the jays in California were mixed depending on region (Fink et al. 2021), suggesting multiple factors are contributing to the variation in these trends. This may include impacts from Sudden Oak Death (see next section), or other factors (e.g., disease outbreaks such as West Nile Virus for which jays and other corvids are particularly susceptible; Wheeler et al. 2009). Additionally, California Scrub-Jays were found to be stable in riparian habitat of coastal Marin County (Dettling et al. 2021). Mourning Dove is another common species exhibiting decreasing trends on Marin Water lands that were also decreasing in the BBS dataset and range-wide in the eBird dataset (Fink et al. 2021, Partners in Flight 2021).

Sudden Oak Death. Sudden Oak Death (SOD; *Phytophthora ramorum*) has caused the mortality of many oak (*Quercus* sp.) and tanoak (*Notholithocarpus densiflorus*) trees in Marin County during the study period (McPherson et al. 2005), which has resulted in changes in the relative abundance of these tree species, and, in some cases, dramatic changes to the structure of the forests on Marin Water lands. The acorns provided by these species are an important food source for jays, particularly during winter (Greene et al. 1998, Curry et al. 2002). While SOD is impacting forests throughout California, some areas are more impacted than others (UC Berkeley Forest Pathology and Mycology Lab 2020) and declines mentioned above in California Scrub-Jays and Steller's Jays – both year-round residents in Marin – may be impacted by this disease. This may also explain why their populations were stable in the nearby coastal riparian areas of Marin County (Dettling et al. 2021) where SOD is less prevalent. However, acorns are also an important food source for other species that haven't shown the same pattern; for example, Acorn Woodpeckers have increased over the course of the study. Thus, if SOD is causing the decline in jays, it has not affected all bird species associated with acorns in the same way. On the other hand, changes in vegetation structure as a result of SOD may also explain some of the increasing trends for some species. For example, Olive-sided Flycatchers have been found to be positively associated with disturbance and fire (Bock and Lynch 1970, Fontaine et al. 2009) and forest openings in general (Altman and Sallabanks 2012), and therefore the many forest openings caused by SOD on Marin Water lands may have had a positive effect on Olive-sided Flycatcher or other species. This could also explain the differing pattern between Olive-sided Flycatchers in forests on Marin Water lands compared to the declines observed at Marin County coastal riparian sites (Dettling et al. 2021), as noted above.

Climate and Weather. Local climate and weather patterns may also be impacting the abundance of species on Marin Water lands. Rainfall has varied over the course of the study period and could be having either direct or indirect effects on population trends (e.g., via food availability, Dybala et al. 2013). In the early years of this study (late 1990s), winter rainfall amounts were generally at or above average levels in Marin County, while in the past 15 years, there have been more years with below-average rainfall (Marin Water 2022). Thus, increasing frequency of local drought may contribute to local population declines of many species.

***Food*.** Widespread declines in aerial insectivores have also been documented (Nebel et al. 2010), and Ash-throated Flycatchers and Western Wood-Pewees are aerial insectivores that breed locally and are both exhibiting large declines in this study. There are other aerial insectivores that breed on Marin Water lands that are not declining (e.g., Olive-sided Flycatcher, Pacific-slope Flycatcher), so if a decline in food availability is the cause, it is possible that they are not foraging on the same species of insects as the other flycatchers that breed in Marin. Furthermore, it is possible that the reduced rainfall in the latter years of the study (see above) influenced the timing of flowering and fruiting of plants, which can happen earlier in dry years (Oliff-Yang et al. 2020), impacting either the timing or availability of food resources for some species.

Annual Cycle. For migratory species such as the insectivores noted above, their populations are impacted by events and conditions happening throughout their annual cycle, and not only when they are in Marin County (Small-Lorenz et al. 2013). Additionally, the different migratory species that breed in Marin do not necessarily use the same stopover or wintering sites (e.g., Humple et al. 2020, Saracco et al. 2022). Differences among migratory species trends that we observed locally may by driven by factors occurring during other parts of their annual cycle. Among all species in the analysis, migratory and resident species had very similar proportions of species with moderate or large decreasing trends (scores 4 or 5).

Habitat. Marin Water lands are dominated by a mix of forested habitats, and species associated with forested habitat comprised more than half of the species represented in the dataset. While the trends for these species were predominantly positive, with most species in the Least Concern categories (score = 1 or 2), there were a few declining species. Several of the forest-associated species were declining on Marin Water lands and increasing in the BBS dataset, including the jays (see above), Ash-throated Flycatcher, and Pileated Woodpecker. It is possible the declines may be attributed to factors such as those noted above for the jays (SOD) and flycatcher (food, annual cycle), or that Marin Water forest habitat is not meeting the specific needs of these forest-associated species, even while it appears to successfully support the populations of many other forest-associated species. The Pileated Woodpecker is a species associated with older coniferous forests and have relatively large territories compared to many other species in our analysis; targeted research would be needed to understand what may be limiting this and other species, and whether declines are related to habitat or other factors.

Habitat conversion from grassland to shrub, and shrub to forest, has occurred along the central coast of California, including in Marin County, with causes including fire suppression and changes in grazing patterns, combined with climatic variables (Startin 2022, Hsu et al. 2012). In mapping the history of wildfires of Marin County, Dawson (2021) found that wildfire extent (number of acres) had decreased over time – particularly over the last century – and that the time in between fires that burned the same areas (fire return interval) had increased. Dawson (2021) documented the highest frequency of fire in the Mount Tamalpais area from 1852-2020, thus, an increase in fire suppression likely impacted these lands more than any other area in Marin County. In their study, Hsu et al. (2012) found that forested habitats expanded more broadly than any other habitat, and this may help to explain the general pattern of increasing forest species on Marin Water lands. Through their Biodiversity, Fire and Fuels Integrated Plan (BFFIP), Marin Water has been actively managing vegetation on their lands with the primary goal of protecting water quality, and also to reduce the risks of catastrophic wildfire (Panorama Environmental, Inc. 2019). Current activities through the BFFIP include fuelbreak construction and maintenance, forest fuel reduction, and Douglas fir thinning (in addition to projects involving invasive plant removal); much of this work is aimed at restoring vegetative conditions that would have occurred during an historic low intensity/high frequency fire regime. The vegetation management that has occurred in the past three years has mostly been concentrated in the southern edge of Marin Water lands along Ridgecrest Boulevard (RICR) and the LADE point count transect, and in the northeast around the BURO, COPT, HICO, and LAVR transects (Figure 1). While we do not yet have the capacity to assess trends in grassland bird species, the maintenance of grassland habitat around Ridgecrest should allow the potential for continued (and possibly enhanced) grassland birds in that area.

For species associated with scrub/chaparral, another relatively common habitat type on Marin Water lands, trend results were mixed but this habitat type was only represented by four species. There is understory/shrub removal occurring in some of the vegetation management plots by Marin Water; the one species with scrub/chaparral as their primary habitat with a large decreasing trend (Rufous-crowned Sparrow) is not found in the areas with active vegetation management, thus is unlikely to have been impacted. The Bewick's Wren, which was also decreasing to a lesser extent (score = 4; Caution), is found in shrubby areas throughout Marin Water lands, and may have responded to the changes in local vegetation management; alternatively, the lack of disturbance to most shrub habitat and the resulting habitat succession of both shrub and forested habitats may also be playing a role in the trends we observed for these and other species. The Bewick's Wren was also decreasing in both the BBS and eBird datasets (Partners in Flight 2021, Fink et al. 2021), so their local declines may be caused by larger scale factors, although they were found to be stable in riparian areas of coastal Marin County (Dettling et al. 2021). Like other declines noted above, these may also be attributed to other factors, such as drought or food availability, and while there were only four species with scrub/chaparral as their primary habitat in our analysis, many other species in the study area use shrubs or shrub habitats to some extent, and may be responding to vegetation changes.

Species associated with riparian/wetland habitat and generalist species (i.e., using at least three different habitat types) were more likely to be classified as Significant Concern or Caution. This result for generalist species was surprising, since we often associate generalist species with the ability to adapt and obtain resources from multiple habitats. However, Rosenberg et al. (2019) also found declines in habitat generalists and introduced species (we also found a decline in the one introduced species examined, the European Starling, which we ascribed as a mixed forest user but not an overall generalist). These local and continent-wide declines of generalists, and species considered common, show that the challenges faced by bird populations are not limited to rare and specialized species.

None of the species associated with riparian/wetland habitat have been very abundant in the study area over the course of the study – the habitat itself is not prevalent on these lands – but half of those species still exhibited declining trends. While riparian and wetland habitats generally have a relatively small footprint in any landscape, and that is particularly true on Marin Water lands (where these habitats have also been relatively stable during the study period, with little encroachment or other disturbances), they are biodiversity hotspots that play a disproportionately large role in supporting bird species and other wildlife in California (Knopf and Samson 1994), as well as contribute to water quality and other ecosystem services. With only a fraction remaining from historic levels (RHJV 2004), much attention has been given to birds associated with these habitats (e.g., Gardali et al. 2006, Dettling et al. 2021), and common reasons for declines in riparian habitat quality include changes in streamflow and vegetation structure and diversity, such as through conifer encroachment or the spread of invasive species. Western Wood-Pewee (riparian) and Red-winged Blackbird (wetland) are exhibiting large decreasing trends both in our study and in the longer-term BBS dataset, while Downy Woodpecker (riparian) showed marginal increases in the BBS dataset (Partners in Flight 2021). However, it should be noted that these species, while primarily considered riparian associates locally, do occur in other habitats on Marin Water lands. The decline of Downy Woodpecker on Marin Water lands – particularly while the Hairy Woodpecker, more strongly associated with conifer and mixed conifer habitats (Shuford 1993) is increasing – suggests that habitat succession has created conditions more favorable to the Hairy Woodpecker on Marin Water lands, and/or there may be some competition between the two species (e.g., Leighton et al. 2018).

Conclusions and Recommendations: The populations of many of the landbird species found on Marin Water lands during the breeding season have remained stable or are increasing since 1996, confirming that Marin Water lands continue to provide valuable habitat for many birds. However, the populations of over a third of the species we analyzed have declined over the course of the 26-year study. While there are many possible factors contributing to these population increases and decreases, vegetation management goals and decisions made by Marin Water will directly impact local habitat quality and quantity for bird species. Since 1996, habitat conditions have increasingly favored bird species associated with forested habitat, supporting large increases in many of their population sizes, and in alignment with the documented expansion of forested habitat (Hsu et al. 2012). However, implementation of the Biodiversity, Fire and Fuels Integrated Plan (BFFIP) may begin to alter this long-term trajectory, and while some forest-associated species may begin to decline or stabilize as a result of BFFIP implementation, others may respond positively. We expect that by creating a more diverse mosaic of habitat types and forest structure, Marin Water lands will ultimately be able to support a more diverse bird community.

We recommend continued long-term monitoring of landbirds on Marin Water lands (by species, and by habitat guild) to continue to inform vegetation management efforts. We also recommend the continuation of nesting bird surveys prior to vegetation management activities to avoid direct negative impacts to nests when management activities cannot be confined to the non-nesting season (Allen and Cormier 2021). Analyzing the response of birds to specific vegetation management practices occurring near each point was beyond the scope of this report, but could be incorporated into future monitoring efforts and analyses (e.g., to compare bird abundances treated versus untreated areas, and before versus after implementation of the BFFIP). And, while this monitoring program is focused on birds during the breeding season, a seasonally-shifting community of birds relies on Marin Water lands year-round, and an assessment of fall or wintering species could increase our understanding of the impacts of vegetation management on bird populations during other seasons.

In addition to the impacts of local vegetation management goals and decisions, local bird populations are also affected by changes in habitat and environmental conditions beyond the boundaries of Marin Water lands. In particular, climate change is predicted to, either independently or together with other threats, exacerbate widespread declines in landbird populations (Tingley et al. 2009, Jongsomjit et al. 2013, Seavy et al. 2018). Given this expectation, effective land stewardship will be even more important for protecting, enhancing, and managing high quality habitat, and the ability to detect changes in natural resources will continue to be essential to adaptive management. The long-term landbird dataset from Marin Water monitoring has played an important role in our understanding of local landbird populations, including in the One Tam region (Gardali et al. 2016; Humple et al. *in press*), where it is central to the understanding of how birds in the region are doing and is combined with data from other regional jurisdictions. This dataset has also been used for the Marin County Compass project (2021), a new performance management program in the County of Marin where the landbird data was one of the metrics of ecological health for the County. The extensive amount of diverse and protected habitat types on Marin Water lands contribute to the health of regional landbird populations beyond their boundaries, and for migratory species, can contribute to populations spanning the Pacific Flyway. Further research may be warranted for some of the habitats and species showing declines thus far. Continued monitoring of the avifauna of Marin Water will keep track of the status of individual species and the overall bird community, providing information needed for land managers to understand how this natural resource is doing and determine if additional monitoring, new research, or management action is warranted.

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APPENDICES

Appendix A. Dates and number of points for all point count transects surveyed by Point Blue Conservation Science in the Marin Municipal Water District in 2022.

Transect Name	Code	Number of Points	Visit 1	Visit 2
Berry/Bon Tempe Trail	BETR	3	6-May	6-Jun
Blithdale Ridge Road	BLRI	15	25-May	14-Jun
Bolinas Ridge Trail	BORT	25	21-May	19-Jun
Bull Frog/Bon Tempe Road	BURO	8	9-May	1 & 2-Jun
Cataract Trail	CATR	17	23-May	16-Jun
Concrete Pipe Trail	COPT	5	2-May	2-Jun
Colier Springs Trail	COST	9	18-May	10 & 15-Jun
Eldridge Grade	ELGR	18	27-May	23-Jun
Helen Mark Trail	HEMA	19	14-May	9-Jun
Hidden Cove/Pine Point	HICO	6	9-May	1-Jun
Hoo-Koo-E-Koo Road	HOKE	17	27-May	23-Jun
Kent Pump Road	KPFR	30	12-May	10 & 17-Jun
Laurel Dell/ Lagunitas-Rock Spring Road	LADE	9	17-May	22-Jun
Lakeview Road	LAVR	6	18-May	10-Jun
Matt Davis Trail	MDTR	14	17-May	13-Jun
Oat Hill Road	OHFR	13	9-May	7-Jun
Old Stage Road	OSRO	21	27-May	24-Jun
Pine Mountain Road	PIMR	20	21-May	15-Jun
Ridgecrest Blvd.[1]	RICR	8 + 6	25-May	22-Jun
Rocky Ridge/Lagunitas-Rock Spring Road	RRFR	12	6-May	6-Jun
San Geronimo Ridge Trail	SGRT	16	19-May	19-Jun
Shafter Grade/Peter's Dam	SHAF	15	21-May	22-Jun
Shafter Creek	SHCR	3	19-May	19-Jun
Shaver Grade	SHGR	15	19-May	3-Jun
Six Points Trail	SPTR	3	2-May	2-Jun
Yolanda Trail	YOTR	10	5-May	2-Jun

[1] The list of survey locations includes 6 new points established in 2019 in grassland habitat in the Ridgecrest Boulevard transect; new points were not included in this analysis.

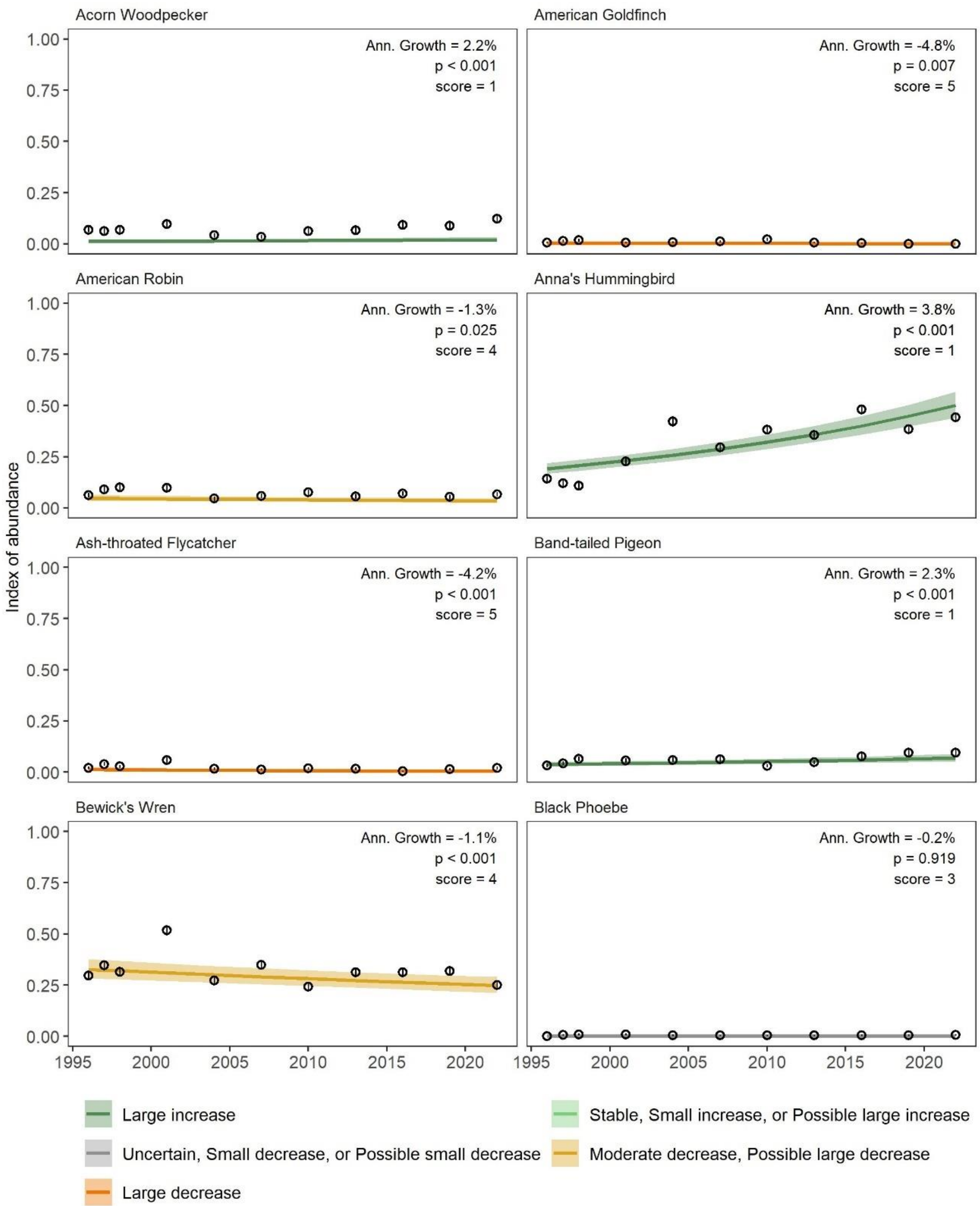
Appendix B. Common and scientific names, and assigned primary habitat affiliations, of bird species included in the analysis conducted by Point Blue Conservation Science for the Marin Municipal Water District (1996-2022).

Common Name	Latin Name	Primary Habitat Affiliation
Acorn Woodpecker	*Melanerpes formicivorus*	Oak Woodland
American Goldfinch	*Spinus tristis*	Generalist
American Robin	*Turdus migratorius*	Forest (Mixed)
Anna's Hummingbird	*Calypte anna*	Generalist
Ash-throated Flycatcher	*Myiarchus cinerascens*	Oak Woodland
Band-tailed Pigeon	*Patagioenas fasciata*	Forest (Mixed)
Bewick's Wren	*Thryomanes bewickii*	Scrub/Chaparral
Black Phoebe	*Sayornis nigricans*	Riparian/Wetland
Black-headed Grosbeak	*Pheucticus melanocephalus*	Riparian/Wetland
Black-throated Gray Warbler	*Setophaga nigrescens*	Forest (Mixed)
Blue-gray Gnatcatcher	*Polioptila caerulea*	Oak Woodland
Brown Creeper	*Certhia americana*	Conifer Forest-Mixed Hardwood Forest
Brown-headed Cowbird	*Molothrus ater*	Riparian/Wetland
Bushtit	*Psaltriparus minimus*	Generalist
California Quail	*Callipepla californica*	Generalist
California Scrub-Jay	*Aphelocoma californica*	Oak Woodland
California Towhee	*Melozone crissalis*	Generalist
Cassin's Vireo	*Vireo cassinii*	Conifer Forest-Mixed Hardwood Forest
Chestnut-backed Chickadee	*Poecile rufescens*	Forest (Mixed)
Chipping Sparrow	*Spizella passerina*	Generalist
Dark-eyed Junco	*Junco hyemalis*	Forest (Mixed)
Downy Woodpecker	*Picoides pubescens*	Riparian/Wetland
European Starling	*Sturnus vulgaris*	Forest (Mixed)
Golden-crowned Kinglet	*Regulus satrapa*	Conifer Forest-Mixed Hardwood Forest
Hairy Woodpecker	*Picoides villosus*	Conifer Forest-Mixed Hardwood Forest
Hermit Thrush	*Catharus guttatus*	Conifer Forest-Mixed Hardwood Forest
Hermit Warbler	*Setophaga occidentalis*	Conifer Forest-Mixed Hardwood Forest
House Finch	*Haemorhous mexicanus*	Riparian/Wetland
Hutton's Vireo	*Vireo huttoni*	Forest (Mixed)
Lazuli Bunting	*Passerina amoena*	Generalist
Lesser Goldfinch	*Spinus psaltria*	Oak Woodland
Mourning Dove	*Zenaida macroura*	Generalist
Northern Flicker	*Colaptes auratus*	Forest (Mixed)
Nuttall's Woodpecker	*Picoides nuttallii*	Oak Woodland
Oak Titmouse	*Baeolophus inornatus*	Oak Woodland
Olive-sided Flycatcher	*Contopus cooperi*	Conifer Forest-Mixed Hardwood Forest
Orange-crowned Warbler	*Oreothlypis celata*	Forest (Mixed)
Pacific Wren	*Troglodytes pacificus*	Conifer Forest-Mixed Hardwood Forest

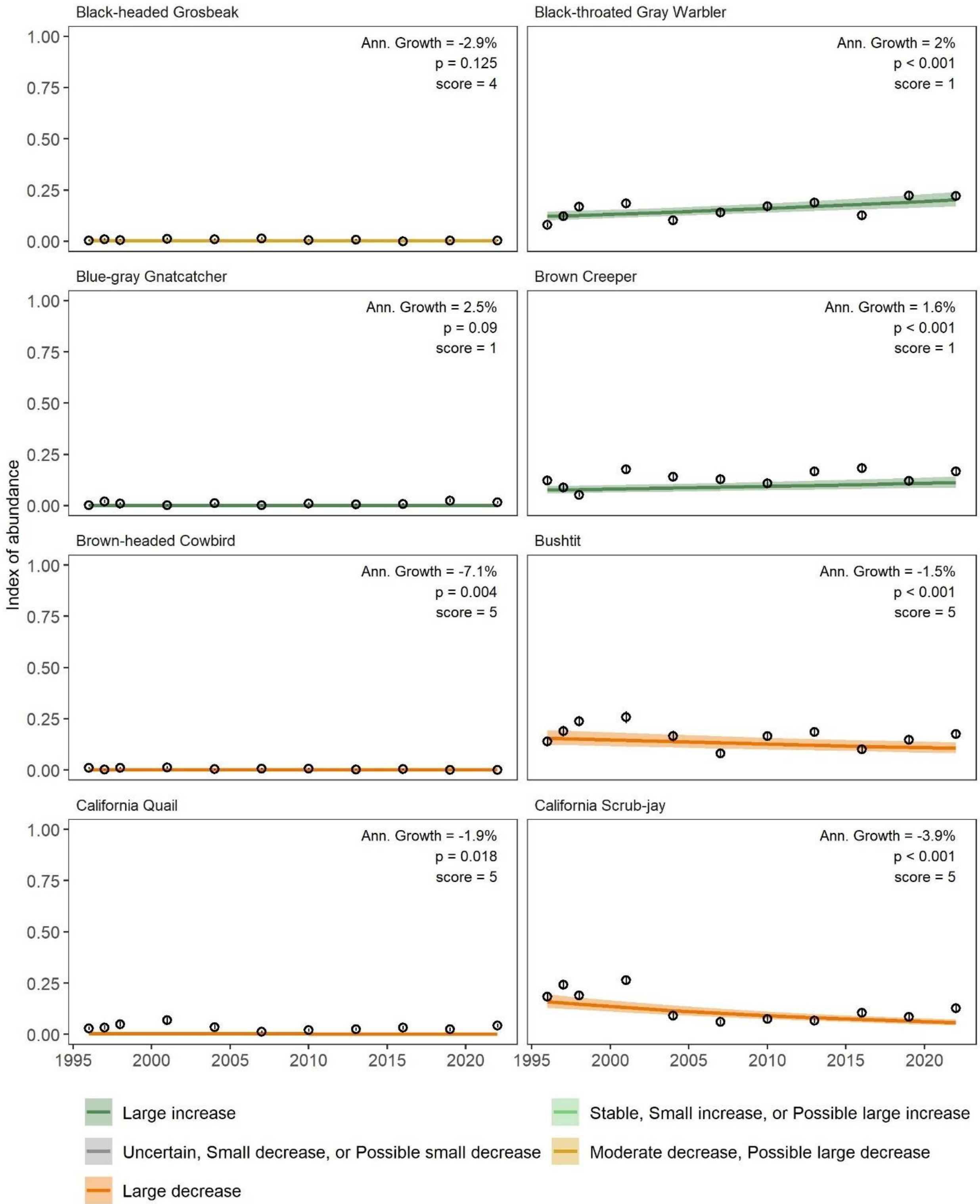
Appendix B (Continued).

Common Name	Latin Name	Habitat Affiliation
Pacific-slope Flycatcher	*Empidonax difficilis*	Conifer Forest-Mixed Hardwood Forest
Pileated Woodpecker	*Dryocopus pileatus*	Conifer Forest-Mixed Hardwood Forest
Purple Finch	*Haemorhous purpureus*	Forest (Mixed)
Pygmy Nuthatch	*Sitta pygmaea*	Conifer Forest-Mixed Hardwood Forest
Red-breasted Nuthatch	*Sitta canadensis*	Conifer Forest-Mixed Hardwood Forest
Red-winged Blackbird	*Agelaius phoeniceus*	Riparian/Wetland
Rufous-crowned Sparrow	*Aimophila ruficeps*	Scrub/Chaparral
Song Sparrow	*Melospiza melodia*	Riparian/Wetland
Spotted Towhee	*Pipilo maculatus*	Scrub/Chaparral
Steller's Jay	*Cyanocitta stelleri*	Conifer Forest-Mixed Hardwood Forest
Swainson's Thrush	*Catharus ustulatus*	Forest (Mixed)
Warbling Vireo	*Vireo gilvus*	Forest (Mixed)
Western Bluebird	*Sialia mexicana*	Oak Woodland
Western Wood-Pewee	*Contopus sordidulus*	Riparian/Wetland
White-breasted Nuthatch	*Sitta carolinensis*	Oak Woodland
Wilson's Warbler	*Cardellina pusilla*	Forest (Mixed)
Wrentit	*Chamaea fasciata*	Scrub/Chaparral
Yellow-rumped Warbler	*Setophaga coronata*	Conifer Forest-Mixed Hardwood Forest

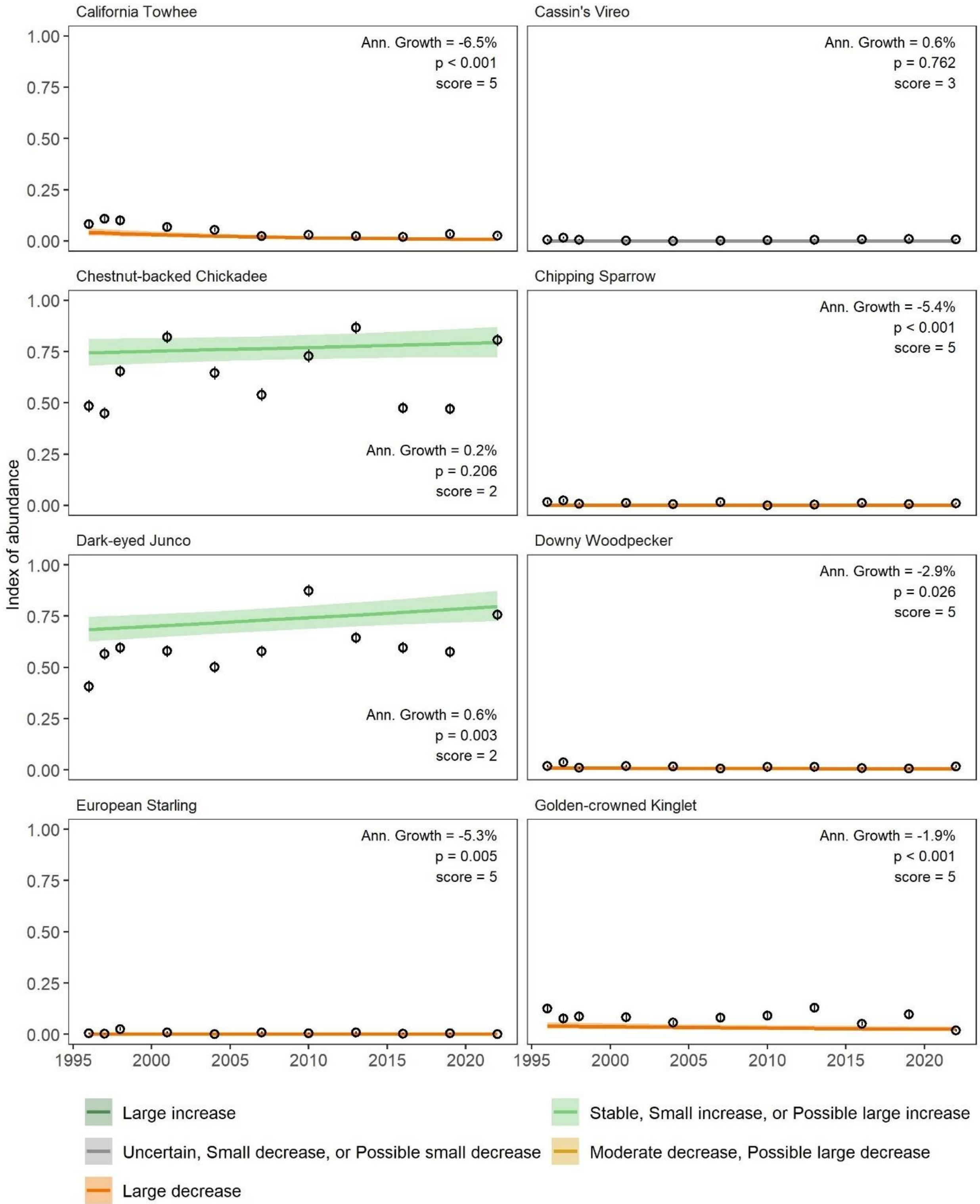
Appendix C (Panel 1 of 7). Annual growth rate estimates (% change per year) and 95% upper and lower confidence limits for each of the 56 species included in our analysis. Trend categories are color coded by score from dark green to dark orange: 1) large increase, 2) small increase / possible increase / stable, 3) uncertain population change / possible small decrease / small decrease, 4) moderate-possible large decrease, and 5) large decrease, adapted from the Partners in Flight Avian Conservation Assessment Database Handbook (Panjabi et al. 2020). P-values, average annual growth rate, and trend scores (1-5) are shown in the upper or lower right of each plot. To facilitate trend visualization, points and error bars represent the annual mean and standard error of the number of individuals counted at each point surveyed that year (n = 337 in most years), but note that models were fit to the underlying count data at each point.



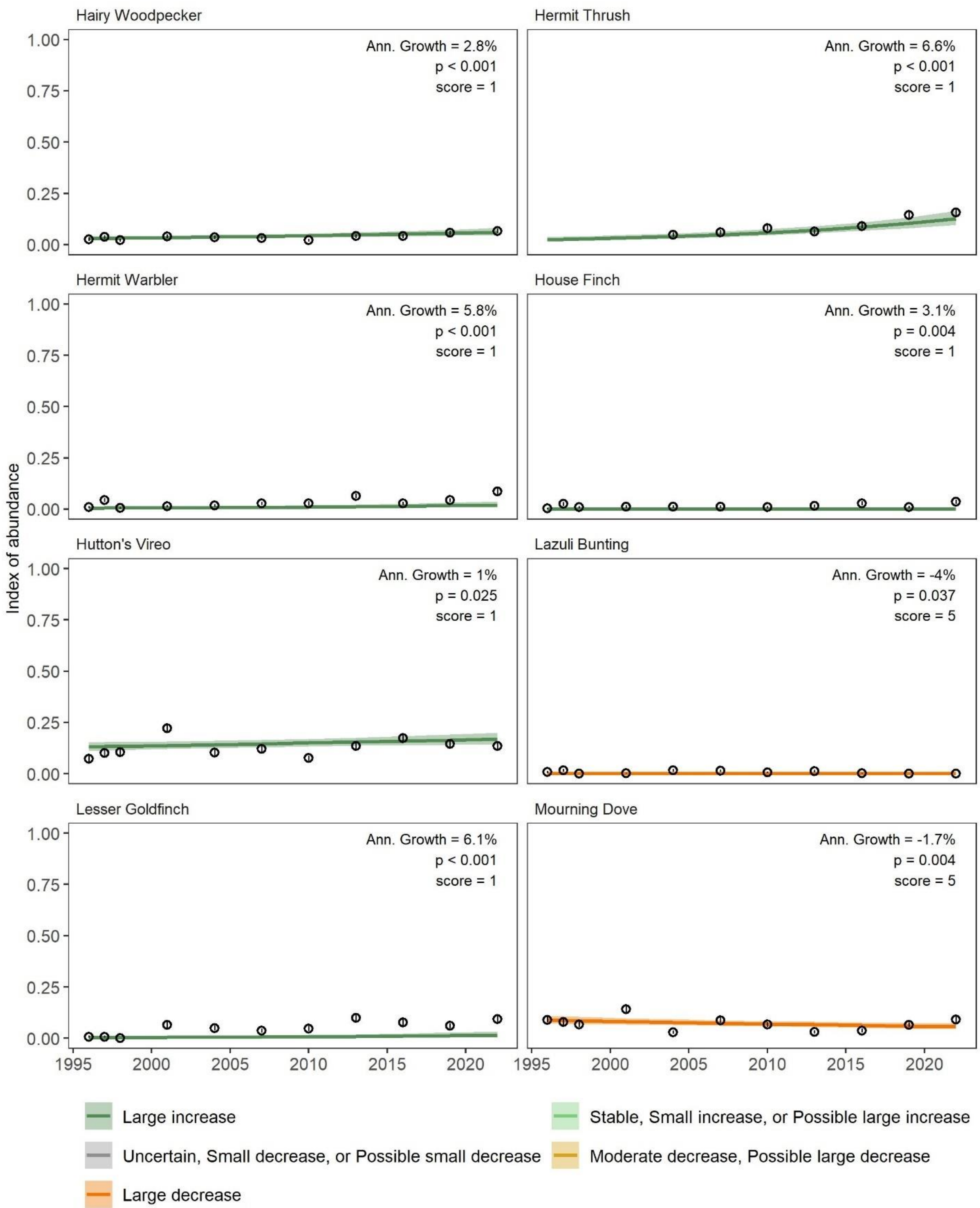
Appendix C (Continued, Panel 2 of 7).



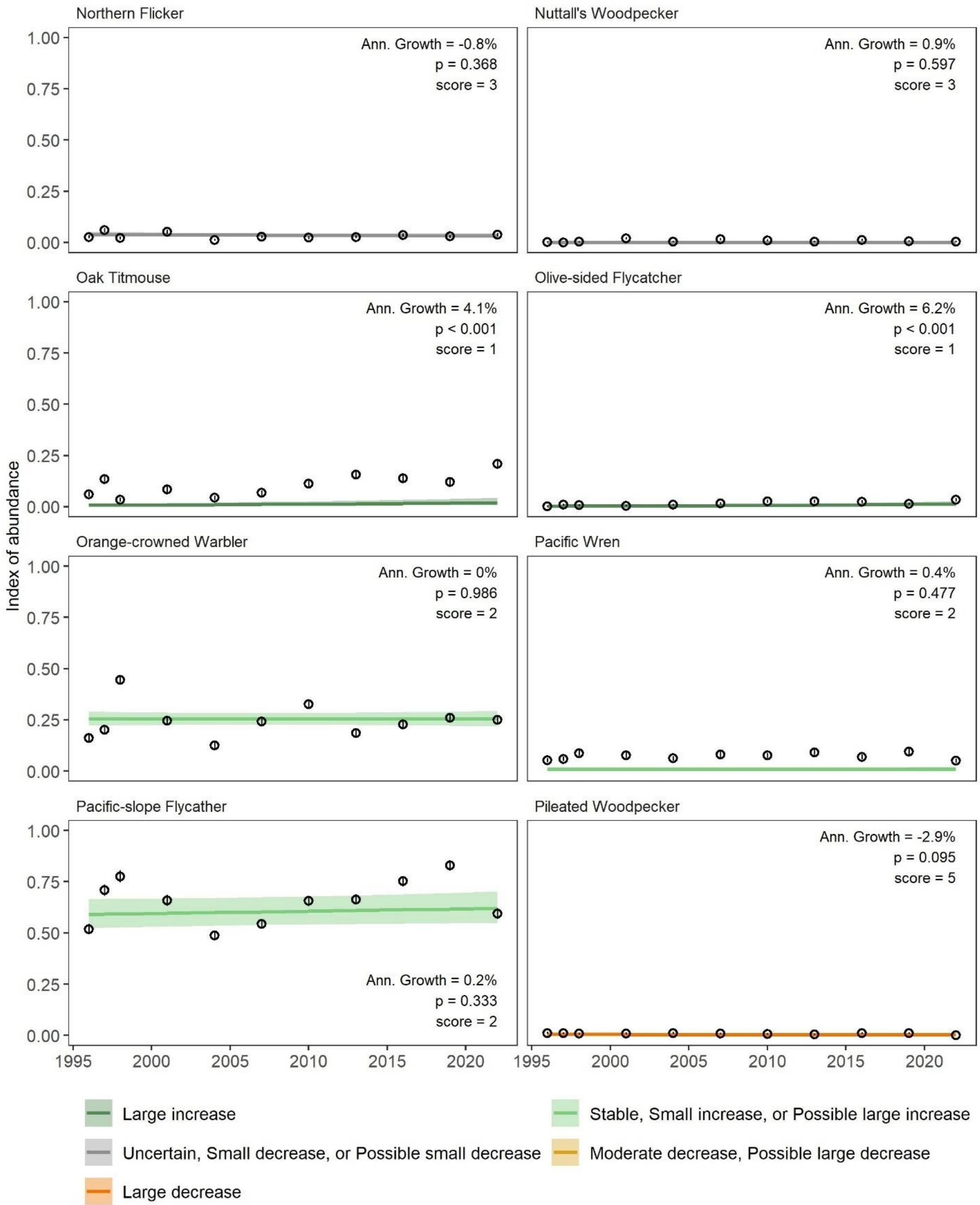
Appendix C (Continued, Panel 3 of 7).



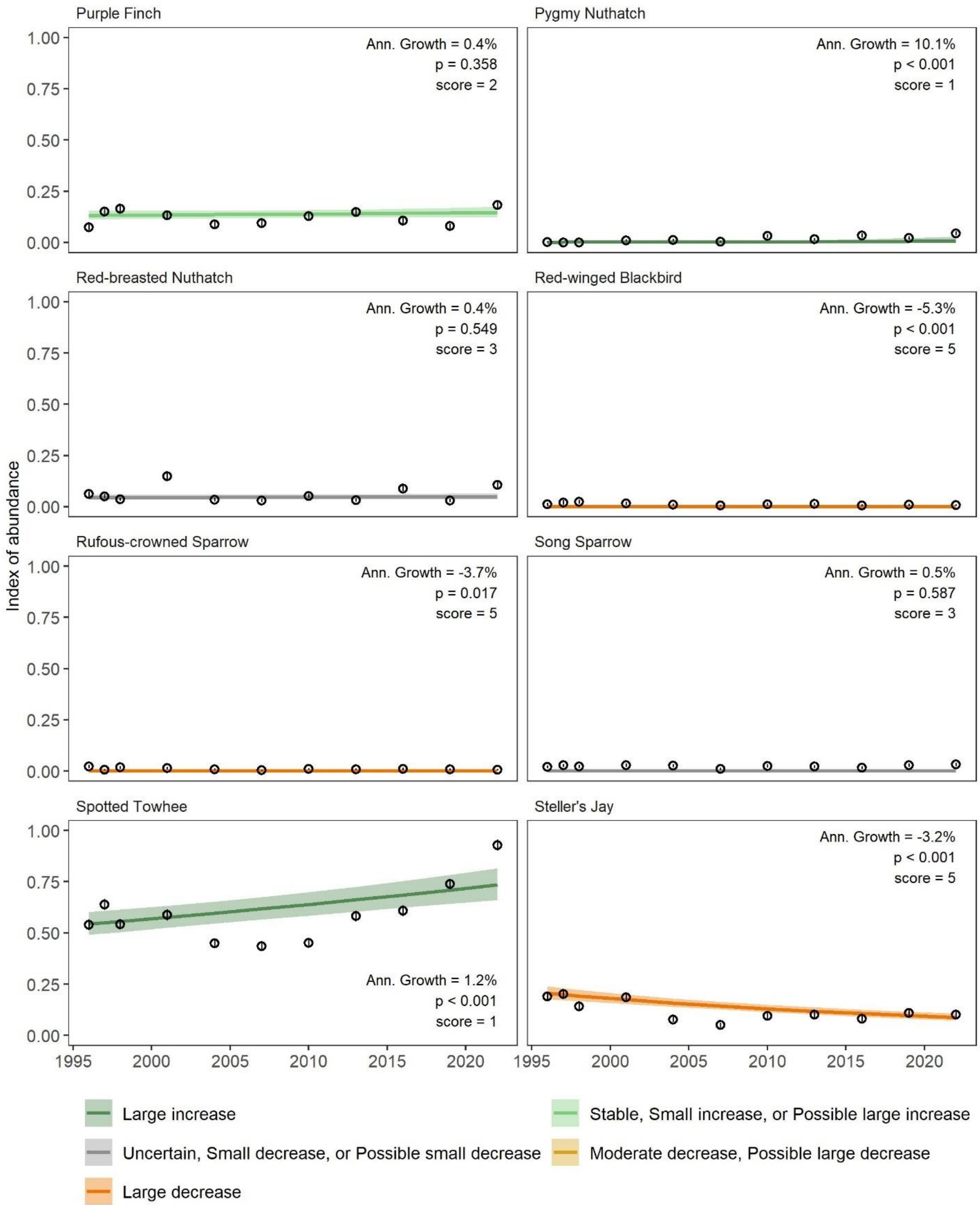
Appendix C (Continued, Panel 4 of 7).



Appendix C (Continued, Panel 5 of 7).



Appendix C (Continued, Panel 6 of 7).



Appendix C (Continued, Panel 7 of 7).