Abundance Patterns of Landbirds in the Marin Municipal Water District: 1996 to 2013


Olive-sided Flycatcher by Tom Grey

Renée L. Cormier, Nathaniel E. Seavy, and Diana L. Humple

19 January 2014

Point Blue Conservation Science (formerly PRBO)
3820 Cypress Drive #11
Petaluma, CA 94954
415.868.0655
www.pointblue.org

TABLE OF CONTENTS

Abstract. Landbird populations of many species have declined in recent decades. Thus, monitoring programs that can detect changes are important because they can help inform landowners when additional management action or research may be warranted to protect these species. Point Blue Conservation Science monitored the abundance of landbirds on Marin Municipal Water District (MMWD) lands from 1996 to 2013. Using these data, we analyzed trends in abundance for 44 species. Of the 44 species, two were significantly ($P < 0.05$) declining: Western Scrub-Jay (*Aphelocoma californica*) and California Towhee (*Melozone crissalis*); and two were significantly increasing: Anna's Hummingbird (*Calypte anna*) and Olive-sided Flycatcher (*Contopus cooperi*). Two additional species showed marginal ($P < 0.10$ and > 0.05) declines: Pileated Woodpecker (*Dryocopus pileatus*) and Steller's Jay (*Cyanocitta stelleri*); and five species showed marginal increases: Chestnut-backed Chickadee (*Poecile rufescens*), Oregon Junco (*Junco hyemalis*), Audubon's Warbler (*Setophaga coronata*), Hermit Warbler (*S. occidentalis*), and Wilson's Warbler (*Cardellina pusilla*). For the remaining 33 species (75%) there was no statistical evidence ($P > 0.10$) of changes in their populations over the 17 year study period. While we don't know the cause of the declines, the timing corresponds with the emergence of West Nile Virus and Sudden Oak Death Syndrome (SODS), to which the jays may be particularly susceptible. When we compared MMWD trends to trends estimated from Breeding Bird Surveys (BBS) for all of California, we found more of these species to be stable or increasing on MMWD lands than statewide, and many species that are declining across California are stable on MMWD lands. Only one species, the Pileated Woodpecker, was increasing on BBS surveys, but declining on MMWD lands. Because the overwhelming majority of birds on MMWD lands had stable or increasing trends, we suggest that protected lands of MMWD area are important for maintaining a diverse breeding bird community in Marin County.

INTRODUCTION

Many species of landbirds have declined over the past few decades, both globally (Robbins et al. 1989, Sanderson et al. 2006), and locally in Marin County (Ballard et al. 2003). These declines may be attributed to multiple factors, including habitat loss and degradation, disease, and climate change (Wormworth and Mallon 2006, Shuford and Gardali 2008), and the sensitivity of landbirds 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 conservation concern. Furthermore, when changes are detected through monitoring, recommendations for management or further research may be provided (e.g., Strong et al. 2004).

The Marin Municipal Water District (MMWD) 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 the MMWD implemented a three-year project to assess the status and distribution of landbird populations on watershed lands managed by the MMWD (Holmes et al. 1998). This was followed by the initiation of a long-term monitoring program, where it was determined that all point count stations would be surveyed every third year. The principal goal of this long-term study is to monitor the abundance of landbird populations on the MMWD lands over time in order to provide managers with information about when management actions are warranted and research is needed.

In 2011, we presented the results for the monitoring from 1996 to 2010, showing that relatively few species (7 of 42) showed statistically significant trends in abundance during the monitoring period (Cormier et al. 2011). In this progress report, we present results from trend analysis for 44 species of passerines (i.e., songbirds) and near passerines (hereafter collectively called landbirds) within the study area from 1996 through 2013.

METHODS

Study Area

Point count survey locations were first established in 1996 on trails and fire roads throughout the MMWD watershed with the goal of covering the major habitat types and geographic extent of the study area. General habitat types covered include mixed evergreen hardwood forest, oak woodland/savannah, coast redwood forest, chaparral, and grassland/edge.

Point count transect starting points were randomly stratified according to habitat type and distributed throughout the study area. From each random start point, the nearest unpaved road or trail was used for the transect, and the direction of travel was also random when possible. Individual survey points were clumped into transects, and points within a transect were generally spaced 200-400 meters apart from one another (Figure 1 and Table 1).

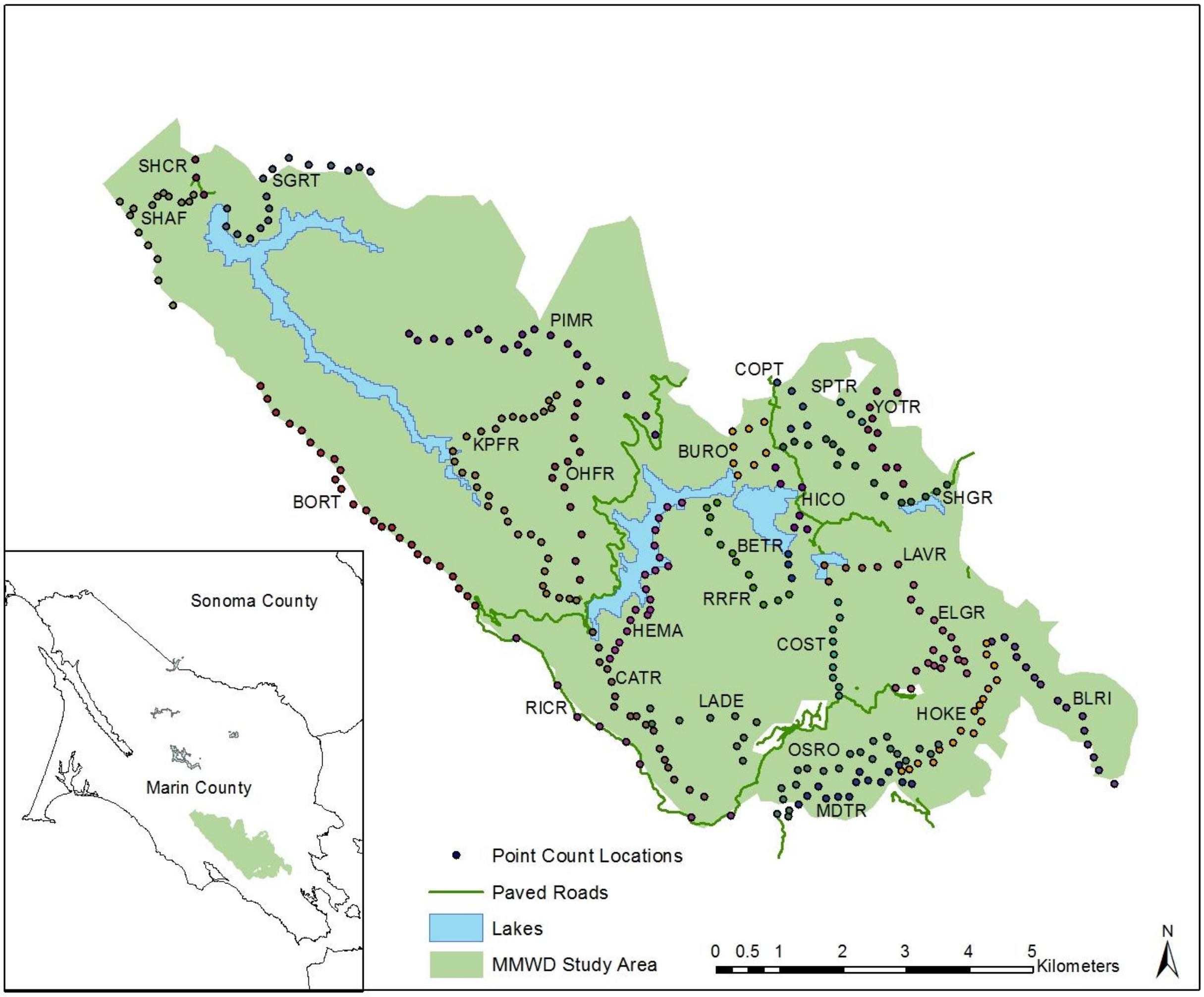


Figure 1. Point count locations along MMWD trails in Marin County, California, 1996-2013.

Point Count Surveys

Point count surveys were conducted following the standardized point count protocol described in Ralph et al (1993 and 1995). Depending on the year, we used either a Fixed Radius method or the Variable Circular Plot (VCP) point count method during a 5-minute survey at each point. 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; in 2004, 2007, 2010, and 2013, we 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, all 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).

The type of detection (song, visual, or call) was noted. Surveys began within a half hour after local sunrise and were completed within four hours of sunrise in order to restrict the survey to peak singing hours. Counts were not conducted during excessively rainy, 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 occurring in May and June (see Appendix A for survey dates in 2013). In 1997, three surveys were conducted; however, only two were included in analysis (details in statistical methods).

Data Management

All 2013 data were entered online, and 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 MMWD 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 MMWD, 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 MMWD staff. This level was determined based on the interests of the MMWD, but at any time the Data Availability Level can be increased or decreased.

Personnel

Point Blue staff biologists trained in the songs and calls of the birds of the MMWD study area conducted all surveys in 2013. They were Renée Cormier, Ryan DiGaudio, Megan Elrod, Diana Humple, and Samuel Roberts. For a list of personnel during previous survey years, see Holmes et al. (1998), Flannery et al. (2002), Humple and Gardali (2005), Cormier and Gardali (2008), and Cormier et al. (2011). Diana Humple provided project oversight in 2013.

Table 1. Point count transects conducted in 2013.

Transect Name	Transect Code	No. of Points
Berry/Bon Tempe Trail	BETR	3
Blithedale Ridge Road	BLRI	15
Bolinas Ridge Trail	BORT	25
Bull Frog/Bon Tempe Road	BURO	8
Cataract Trail	CATR	17
Colier Springs Trail	COST	9
Concrete Pipe Road	COPT	5
Eldridge Grade	ELGR	18
Helen Markt Trail	HEMA	19
Hidden Cove/Pine Point	HICO	6
Hoo-Koo-E-Koo Road	HOKE	17
Kent Pump Fire Road	KPFR	30
Lakeview Road	LAVR	6
Laurel Dell/ Lagunitas-Rock Spring Road	LADE	9
Matt Davis Trail	MDTR	14
Oat Hill Fire Road	OHFR	13
Old Stage Road	OSRO	21
Pine Mountain Road	PIMR	20
Ridgecrest Boulevard	RICR	8
Rocky Ridge/Lagunitas-Rock Spring Road	RRFR	12
San Geronimo Ridge Trail	SGRT	16
Peter's Dam/Shafter Grade	SHAF	15
Shafter Creek	SHCR	3
Shaver Grade	SHGR	15
Six Points Trail	SPTR	3
Yolanda Trail	YOTR	10
Total		337 points

Statistical Analysis

We included data from 1996, 1997, 1998, 2001, 2004, 2007, 2010, and 2013. Data from 1999 were excluded because sites surveyed were not consistent with other years. Of the 337 points surveyed each year, two points (SGTR 16 and SHGR 15) were dropped from analysis because they were not surveyed in all years.

We excluded all waterbirds (e.g., ducks, herons, coots, grebes), shorebirds, owls, non-breeding migratory species (e.g., Ruby-crowned Kinglets, Fox Sparrows), and 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) from the analysis (see Appendix B for common and scientific names of all species mentioned in this report). We also excluded birds with a low number of detections, including some years with none detected: Black Phoebe, Blue Grosbeak, Brewer's Blackbird, California Thrasher, Cassin's Vireo, Chipping Sparrow, European Starling, Lark Sparrow, Lazuli Bunting, Lesser Goldfinch, Nuttall's Woodpecker, Pine Siskin, Pygmy Nuthatch, Western Bluebird, Western Wood Pewee, and White-breasted Nuthatch. 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). We only analyzed data from 2004 to 2013 for Swainson's and Hermit thrushes because we strongly suspect that one observer who conducted surveys during the earlier years of the study was not distinguishing these species accurately (i.e., identified many Hermit Thrushes as Swainson's Thrushes).

Data cleaning and analysis were done in R version 2.15.2 (R Development Core Team 2012). We used data from two visits for each year, unless the point was only visited once, in which case the point was included with only that single visit. 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. Appendix C includes R code for dropping third visits in 1997 and other data proofing code.

To summarize the two visits to each point in a year, we averaged the number of detections for the two visits. There were a few points that were only surveyed once in a given year, so the number of detections on that single visit was used in place of the average. We then calculated the mean number of detections for each species and year by averaging across all points. This gave us one per-point abundance value for each species during each year of the study. To evaluate the trend over time, we used natural log transformation on the abundance values and used linear regression to describe the relationship between species abundance and year, such that the slope (β) of this line represented the annual change in the number of detections. We used $\alpha = 0.05$ to evaluate if the slope was statistically different from 0. We also discuss species for which the P-value for the slope was between 0.05 and 0.1, as these trends may be biologically significant (see Appendix D for analysis code).

To compare results at the MMWD to larger-scale trends in bird abundance, we used trends estimated from the Breeding Bird Survey (BBS) for all of California (Sauer et al. 2012). We conducted the Regional Trend Analysis using the hierarchical Bayesian model approach, available for analytical processing on their website (Sauer et al. 2012). We looked at BBS trends over two temporal scales: the entire BBS dataset (1966 to 2011), and a time period that most closely matched our study (1996-2011). Because BBS data is only available through 2011, this period did not exactly match our monitoring window. BBS results are presented as a percent change per year, so we transformed our point count trend estimates from natural log values to a percent change per year using the following formula: $(e^{\beta} - 1)*100$. The trend estimates from the BBS trends estimates are presented with a 95% credible interval (CI). Because credible intervals are similar to confidence intervals, we assumed that if the 95% CI did not include zero, the trend was statistically significant in a manner that was comparable to our MMWD trends that were significant at $\alpha = 0.05$.

RESULTS

For 33 of the 44 (75%) species analyzed there was little evidence ($P > 0.10$) that the trends were significantly different from zero. For these species, we assume that populations are generally stable on the MMWD study area (Appendix E).

Two species (5%) showed statistically significant ($P < 0.05$) declines between 1996 and 2013 surveys: Western Scrub-Jay ($\beta = -0.083$; -8.0% per year; $P = 0.007$), and California Towhee ($\beta = -0.101$; -9.6% per year; $P = 0.001$; Figure 2). Two additional species (5%), Pileated Woodpecker ($\beta = -0.044$; -4.3% per year; $P = 0.06$) and Steller's Jay ($\beta = -0.061$; -5.9% per year; $P = 0.057$), showed a marginally significant ($P > 0.05$ and $P < 0.1$) decrease in abundance (Figure 2).

Two species (5%), Anna's Hummingbird ($\beta = 0.077$; +8.0% per year; $P = 0.008$) and Olive-sided Flycatcher ($\beta = 0.125$; +13.3% per year; $P = 0.01$), exhibited significant ($P < 0.05$) increases over the study period, while five species (11%) showed marginally significant ($P > 0.05$ and $P < 0.1$) increases in abundance: Audubon's Warbler ($\beta = 0.125$; +13.3% per year; $P = 0.094$), Chestnut-backed Chickadee ($\beta = 0.021$; +2.1% per year; $P = 0.076$), Hermit Warbler ($\beta = 0.098$; +10.3% per year; $P = 0.058$), Oregon Junco ($\beta = 0.02$; +2.0% per year; $P = 0.08$), and Wilson's Warblers ($\beta = 0.036$; +3.7% per year; $P = 0.033$; Figures 3 and 4).

Using the entire BBS dataset (1966 to 2011), we found that 13 of the 44 (30%) species we examined had declining trends, while 5 (11%) species were increasing. Using the BBS dataset closest to our study period (1996 to 2011) we found that 9 of 44 (20%) species had declining trends, and 4 (9%) were increasing (Table 2).

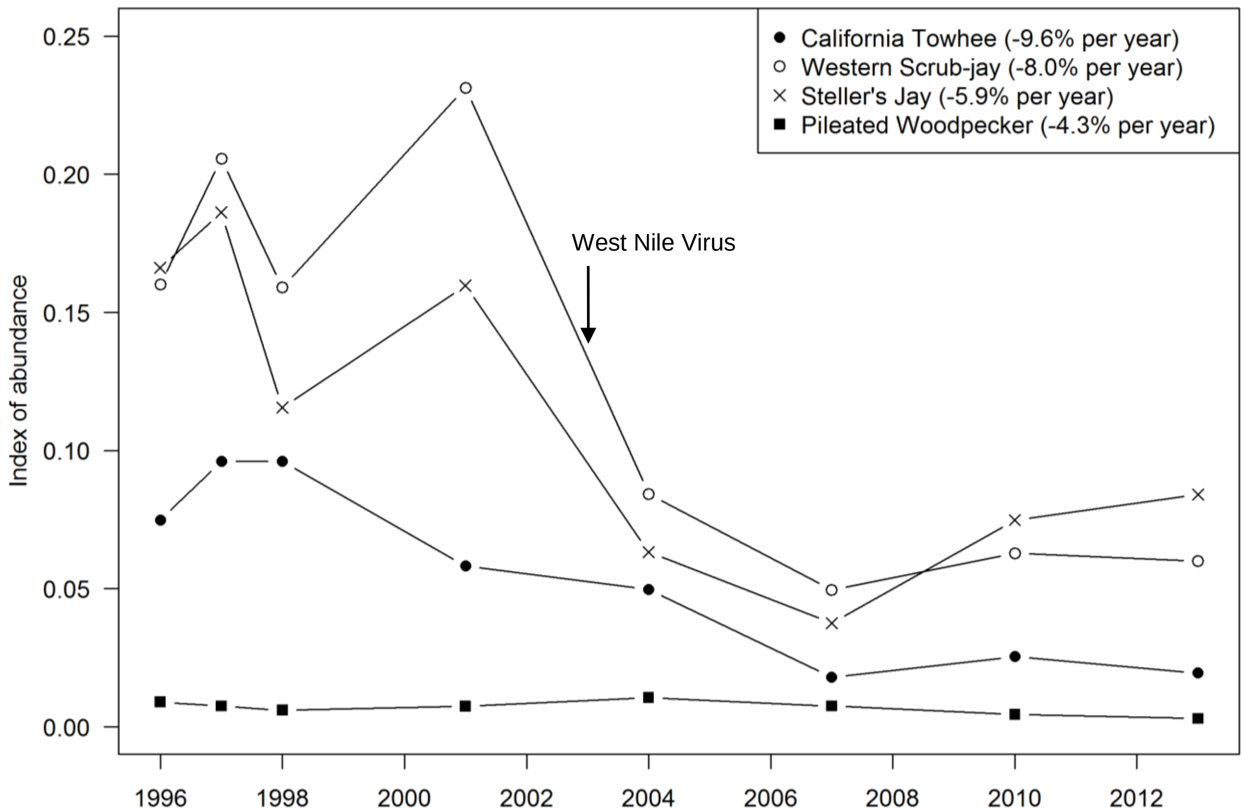


Figure 2. Mean abundance per point of declining species (California Towhee, Western Scrub-Jay, Steller's Jay, and Pileated Woodpecker) in the MMWD study area from 1996 to 2013. Arrow denotes timing of isolation of West Nile Virus in California. Percent change per year calculated using a natural log transformation on the abundance values and linear regression to describe the relationship between species abundance and year – the slope (β) of the regression represents the annual change in abundance; we then calculated the percent change per year using the formula: $(e^{\beta} - 1)*100$.

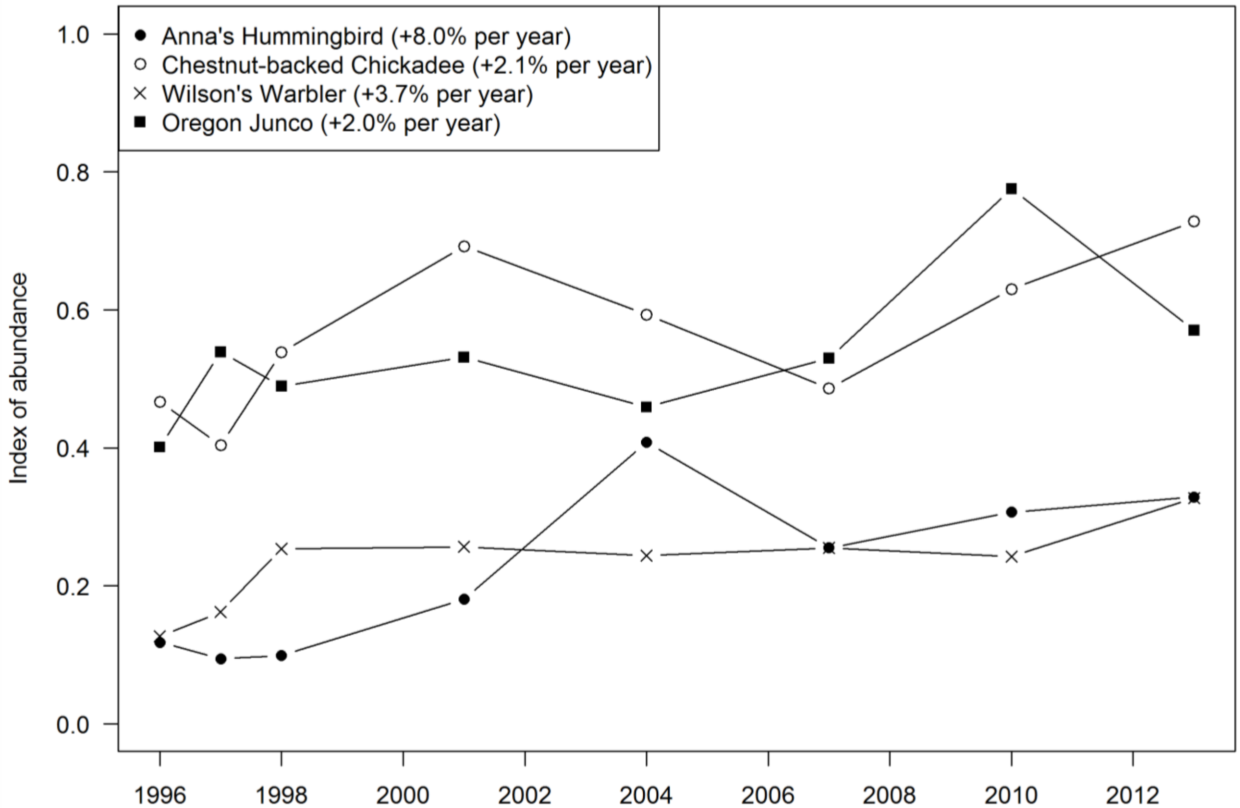


Figure 3. Mean abundance per point of 4 of 7 increasing species (Anna's Hummingbird, Chestnut-backed Chickadee, Wilson's Warbler, and Oregon Junco) in the MMWD study area from 1996 to 2013. Percent change per year calculated using a natural log transformation on the abundance values and linear regression to describe the relationship between species abundance and year – the slope (β) of the regression represents the annual change in abundance; we then calculated the percent change per year using the formula: $(e^{\beta} - 1)*100$.

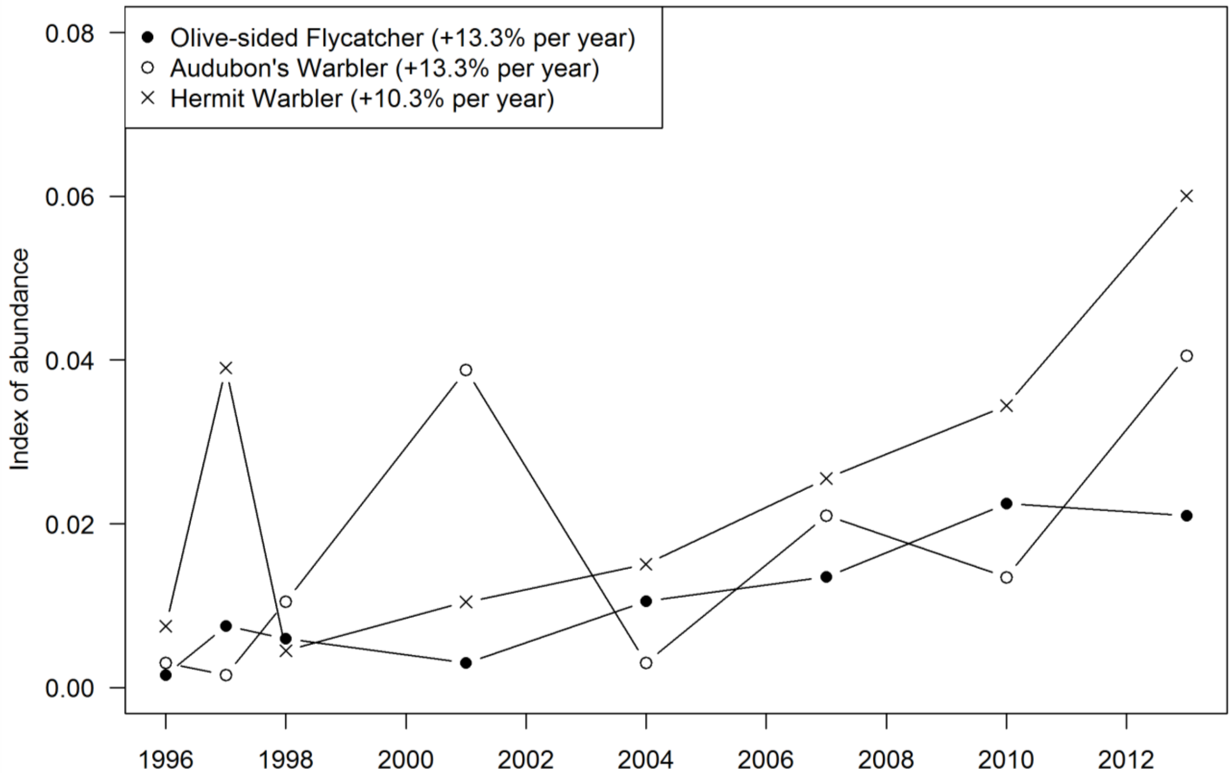


Figure 4. Mean abundance per point of 3 of 7 increasing species (Olive-sided Flycatcher, Audubon's [Yellow-rumped] Warbler, and Hermit Warbler) in the MMWD study area from 1996 to 2013. Percent change per year calculated using a natural log transformation on the abundance values and linear regression to describe the relationship between species abundance and year – the slope (β) of the regression represents the annual change in abundance; we then calculated the percent change per year using the formula: $(e^{\beta} - 1)*100$.

Table 2. Species with significant trend results on MMWD lands or BBS surveys (Sauer et al. 2012), of the 44 species examined. Direction of trend shown as + (increasing) or -- (declining). For MMWD surveys, P-value < 0.05 without parenthesis and P-value < 0.1 in parenthesis. BBS trends considered positive or negative if the 95% credible interval did not include 0.

Species	MMWD 1996 to 2013	BBS 1996 to 2011	BBS 1966 to 2011
American Goldfinch		+	
American Robin			--
Anna's Hummingbird	+	+	+
Audubon's (Yellow-rumped) Warbler	(+)	+	+
Blue-gray Gnatcatcher			+
California Towhee	--		
Chestnut-backed Chickadee	(+)		--
Hairy Woodpecker			+
Hermit Warbler	(+)		
House Finch		--	--
Mourning Dove			--
Oak Titmouse		--	--
Olive-sided Flycatcher	+	--	--
Oregon (Dark-eyed) Junco	(+)	--	--
Pacific-slope Flycatcher			--
Pileated Woodpecker	(--)	+	+
Purple Finch		--	--
Red-winged Blackbird		--	--
Steller's Jay	(--)		
Warbling Vireo		--	--
Western Scrub-Jay	--	--	
Wilson's Warbler	(+)		--
Wrentit		--	--

DISCUSSION

Based on monitoring results from 1996 to 2013 for 44 species, we found that only two species exhibited statistically significant declines and two additional species exhibited marginally significant declines. This was in comparison to previous MMWD results from 1996 to 2010 (Cormier et al. 2011) when we found four species with significant declines and none with marginally significant declines. We found two species with significant increases and five with marginally significant increases, compared to two and one species, respectively, in previous MMWD results (Cormier et al. 2011). The other 33 breeding landbirds on MMWD lands showed relatively little evidence of change.

The two species with significant declines in this analysis were the Western Scrub-Jay and California Towhee, both year-round residents that also had significant declines in the 1996 to 2010 analysis (Cormier et al. 2011). The Steller's Jay and Spotted Towhee also had significant declines in 2010: as a result of increased abundance in 2013, the decline of the Spotted Towhee is no longer significant, and the decline in the Steller's Jay has shifted from significant to marginal. As a result of adding the 2013 data, the only shift of a species toward a more significant decline was the Pileated Woodpecker, which went from a non-significant negative trend in 2010 to a marginally significant negative trend in 2013.

In this analysis, two species, Anna's Hummingbird and Olive-sided Flycatcher, were significantly increasing on MMWD lands, while five additional species had marginally increasing trends: Chestnut-backed Chickadee, Oregon Junco, Audubon's Warbler, Hermit Warbler, and Wilson's Warbler. The Anna's Hummingbird and the Olive-sided Flycatcher also had significant increases from 1996 to 2010, and the Oregon Junco also had a marginally significant increase in the previous analysis (Cormier et al. 2011). The remaining four species with marginally significant increases in this analysis did not have significant or marginally significant trends from 1996 to 2010 (Cormier et al. 2011), although the patterns suggested they might be increasing.

This pattern of stable or increasing populations of landbirds on MMWD lands is promising, particularly when many of these are undergoing declines at larger spatial scales or in other areas. For example, Warbling Vireo is a common species detected during MMWD landbird surveys and is currently stable on MMWD lands (Appendix E), but declining in California (Sauer et al. 2012). Previous studies in Marin County reported declines of Warbling Vireo during the breeding season and fall (Gardali et al. 2000, Ballard et al. 2003), but a more recent report found their breeding population to be stable in riparian habitat on National Park Service (NPS) lands in Marin County during a similar study period to ours (1997 to 2011; Humple and Porzig 2012).

Other species show encouraging patterns on MMWD lands compared to regional patterns. The Olive-sided Flycatcher is a California Bird Species of Special Concern (Shuford and Gardali 2008) that shows a declining trend on BBS surveys in California (Sauer et al. 2012) and in riparian habitat in other parts of Marin County on NPS lands (Humple and Porzig 2012). The Chestnut-backed Chickadee and Wilson's Warbler are relatively common on MMWD lands, but both species showed declines on BBS routes in California between 1966 and 2011 and the Oregon Junco showed a declining trend on California BBS routes during both time periods we examined (Table 2; Sauer et al. 2012).

Likewise, there are a few species that have been stable or increasing on the California BBS routes, but have decreased in the MMWD. These are Pileated Woodpecker, Steller's Jay, and California Towhee (Table 2; Sauer et al. 2012).

There are multiple factors that may have influenced the declining species in this study. Loss or changes in habitat, specifically in vegetation structure and species composition, have often been cited as causes for changes in bird abundance (Holmes and Sherry 2001). Disease, weather, and climate may also be influencing the species in our study (Koenig et al. 2007, Shuford and Gardali 2008). Below, we discuss three hypotheses that may explain some of the population trends for MMWD landbirds.

West Nile Virus.

One disease affecting birds in California is West Nile Virus (WNV, *Flaviviridae*, *Flavivirus* spp.), which was first isolated in the state in 2003 (Reisen et al. 2004; LaDeau et al. 2007). While Marin County has not had a relatively high incidence of WNV, there were documented cases in wild birds, including 6 confirmed cases in dead birds in 2013 (California Department of Public Health 2013).

Corvids (e.g., jays and crows) tend to have high incidence and susceptibility to WNV, and in a study of the impacts of WNV on California birds, Wheeler et al. (2009) found that in a sample of dead birds turned in by the public from 2004 to 2007, 59% of Western Scrub-Jays and 34.8% of Steller's Jays tested positive for WNV, while 12.6% of California Towhees tested positive. Koenig et al. (2007) found high incidences of WNV, and declines in abundance for most species of corvids in California (Western Scrub-Jay, Steller's Jay, American Crow, and Yellow-billed Magpie).

In the MMWD, during our study period, the declines of Western Scrub-Jay and Steller's Jay appeared to have started between our survey in 2001 and the subsequent survey in 2004. This corresponds well to the arrival of WNV in California (Figure 2; Reison et al. 2004). This year, the abundance of Western Scrub-Jay and Steller's Jay was similar to or greater than their abundance in 2010, suggesting that the dramatic decline has slowed or possibly reversed.

In summary, it seems likely that WNV is a contributing factor to the decline of the Western Scrub-Jay and the marginal decline (significant for 1996-2010) of the Steller's Jay. Although there is less evidence that this is an important factor for the declines of the California Towhee or Pileated Woodpecker.

Sudden-oak Death: Changes in Food Supply and Vegetation Structure.

The emergence of Sudden Oak Death Syndrome (SODS; *Phytophthora ramorum*) has caused mortality of many oak (*Quercus* sp.) and tanoak (*Lithocarpus densiflorus*) trees in Marin County during our monitoring period (McPherson et al. 2005). The symptoms that define SODS were first observed in Marin County in 1994-1995, just before our study began, and grew substantially over the next few years (Rizzo and Garbelotto 2003). This 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 MMWD lands. Additionally, the acorns provided by these species are an important food source for jays, particularly during winter (Greene et al. 1998, Curry et al. 2002). However, if the decline in acorns were the sole cause of decline of the jay species, we would have expected declines in Acorn Woodpeckers, who also rely on this food source, and this species has been stable over the course of the study. Therefore, if SODS is causing the decline, it has not affected all bird species associated with acorns in the same way.

Changes in vegetation structure as a result of SODS may also explain some of the increasing trends for some species. For example, Olive-sided Flycatchers have been positively associated with disturbance and fire (Bock and Lynch 1970, Fontaine et al. 2009) and other forest-openings (Altman and Sallabanks 2012). It is possible that the many forest openings caused by SODS on MMWD lands has had a positive effect on Olive-sided Flycatcher. This may also explain the differing pattern between Olive-sided Flycatchers in forests on MMWD lands compared to the declines observed in Marin County NPS riparian habitat (Humple and Porzig 2012), which was not surrounded by habitat vulnerable to SODS, and throughout their range in California (Sauer et al. 2012). Oregon Juncos are also associated with forest edge and openings (Shuford 1993), and may also be responding positively to the same changes.

Other Vegetation Changes and Climate Change.

Anna's Hummingbirds are found in many habitat types in Marin County, including forest, shrub, and suburban garden areas (Shuford 1993). Because Anna's Hummingbirds have been shown to increase with an increase in food sources, such as flowering plants and feeders (Russell 1996, Wethington and Russell 2003), it is possible that there has been an increase in food in Marin County, if residents of the county are planting more flowering plants, or putting out hummingbird feeders. This could contribute to the overall regional population, even though many MMWD study sites are not adjacent to these residential areas.

Habitat conversion from shrub to forest along the central coast of California has recently been documented, with possible causes including conifer encroachment resulting from fire suppression and other factors, combined with climatic variables (Hsu et al. 2012). The Landsat imagery shown in that document suggests this change is occurring within the MMWD lands as well. This may account for some of the changes we observed (decline in shrub-associated species Western Scrub-Jay and California Towhee; increase in forest-associated species Audubon's Warbler, Chestnut-backed Chickadee, Hermit Warbler, and Oregon Junco). However, not all changes can be attributed to more forest and less scrub habitat (e.g., the decline in the forest-associated Pileated Woodpecker).

Pileated Woodpecker habitat requirements include large trees and snags for roosting, nesting, and excavating for food; they eat insects (especially ants), woodboring beetle larvae, fruits and nuts (Bull and Jackson 1995). We do not know how or if these might be changing on MMWD lands, but factors influencing these variables in the landscape could be behind the observed marginal decline in Pileated Woodpecker.

There is a growing body of knowledge that predicts climate change will, either independently or together with other threats, exacerbate changes in songbird populations (Tingley et al. 2009, Jongsomjit et al. 2013). In light of this, effective land stewardship will be augmented by being able to effectively detect changes in natural resources. Our results show that although many landbird species are declining in California, most species on MMWD lands are either stable or increasing. This suggests that the extensive amount of diverse and protected habitat types on MMWD lands are important to landbirds, and likely to other species that also depend on these lands.

ACKNOWLEDGMENTS

We are grateful to the MMWD for their support of these monitoring efforts. We would especially like to acknowledge Janet Klein and Mike Swezy for their continued support throughout this project and for logistical assistance. We would also like to thank the past and present Point Blue biologists and volunteers for their efforts and careful attention to detail during the surveys. This is Point Blue contribution number 1975.

LITERATURE CITED

Altman, B., and R. Sallabanks. 2012. Olive-sided Flycatcher (*Contopus cooperi*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology; Retrieved from the Birds of North America Online: http://bna.birds.cornell.edu.bnaproxy.birds.cornell.edu/bna/species/502 doi:10.2173/bna.502

Ballard, G., G. R. Geupel, N. Nur, and T. Gardali. 2003. Long-term declines and decadal patterns in population trends of songbirds in western North America, 1979-1999. Condor 105: 737-755.

Ballard, G., M. Herzog, M. Fitzgibbon, D. Moody, D. Jongsomjit, D. Stralberg. 2008. The California Avian Data Center. [web application]. Petaluma, California. www.prbo.org/cadc. (Accessed: Date [e.g., February 2, 2009]).

Bock, C. E., and J. F. Lynch. 1970. Breeding bird populations of burned and unburned conifer forest in the Sierra Nevada. Condor 72: 182-189.

Bull, E. L., and J. E. Jackson. 1995. Pileated Woodpecker (*Dryocopus pileatus*). *In* The Birds of North America, No. 148 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, PA, and The American Ornithologists' Union, Washington, D.C.

California Department of Public Health. 2013. California West Nile Virus Website: http://www.westnile.ca.gov/.

Carignan, V., and M. A. Villard. 2002. Selecting indicator species to monitor ecological integrity: A review. Environmental Monitoring and Assessment 78: 45-61.

Cormier, R., and T. Gardali. 2008. Landbird Monitoring in the Marin Municipal Water District: 2007 Summary Report. PRBO unpublished report.

Cormier, R., N. Seavy, S. Jennings, and T. Gardali. 2011. Abundance patterns of landbirds in the Marin Municipal Water District over fifteen years: 1996 to 2010. PRBO unpublished report.

Curry, R. L., A. T. Peterson, and T. A. Langen. 2002. Western Scrub-Jay (*Aphelocoma californica*). *In* The Birds of North America, No. 712 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Flannery, M., M. S. Wipf, and G. R. Geupel. 2002. Songbird Monitoring on Watershed Lands Managed by the Marin Municipal Water District: Summary Report of the 2001 Field Season. PRBO unpublished report.

Fontaine, J. B., D. C. Donato, W. D. Robinson, B. E. Law, and J. B. Kauffmann. 2009. Bird communities following high-severity fire: Response to single and repeat fires in a mixed evergreen forest, Oregon, USA. Forest Ecology and Management 257: 1496-1504.

Gardali, T., G. Ballard, N. Nur, and G. R. Geupel. 2000. Demography of a declining population of Warbling Vireos in coastal California. Condor 102: 601-609.

Greene, E., W. Davison, and V. R. Muehter. 1998. Steller's Jay (*Cyanocitta stelleri*). *In* The Birds of North America, No. 343 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Holmes, A. L., G. R. Geupel, and G. Ballard. 1998. Distribution, abundance, and diversity of songbirds on watershed lands managed by the Marin Municipal Water District. PRBO unpublished report.

Holmes, R. T., and T. W. Sherry. 2001. Thirty-year bird population trends in an unfragmented temperate deciduous forest: Importance of habitat change. Auk 118: 589-609.

Hsu, W., A. Remar, E. Williams, A. McClure, S. Kannan, R. Steers, C. Schmidt, and J. W. Skiles. 2012. The changing California coast: relationships between climatic variables and coastal vegetation succession. ASPRS 2012 Annual Conference, Sacramento CA.

Humple, D., and T. Gardali. 2005. Landbirds in the Marin Municipal Water District: An examination of population change from 1996 to 2004. PRBO unpublished report.

Humple, D. L., and E. L. Porzig. 2012. Riparian landbird monitoring in Golden Gate National Recreation Area and Point Reyes National Seashore: analysis report through winter 2011-12. PRBO Report to the National Park Service.

Jongsomjit, D., D. Stralberg, T. Gardali, L. Salas, and J. A. Wiens. 2013. Between a rock and a hard place: the impacts of climate change and housing development on breeding birds in California. Landscape Ecology 2: 187-200.

Koenig, W. D., L. Marcus, T. W. Scott, and J. L. Dickinson. 2007. West Nile Virus and California breeding bird declines. EcoHealth 4: 18-24.

LaDeau, S. L., A. M. Kilpatrick, and P. P. Marra. 2007. West Nile virus emergence and large-scale declines of North American bird populations. Nature 447: 710-713.

McPherson, B. A., S. R. Mori, D. L. Wood, A. J. Storer, P. Svihra, N. M. Kelly, and R. B. Standiford. 2005. Sudden oak death in California: Disease progression in oaks and tanoaks. Forest Ecology and Management 213: 71-89.

R Development Core Team. 2012. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Ralph, C. J., G. R. Geupel, P. Pyle, T. E. Martin, and D. F. DeSante. 1993. Field methods for monitoring landbirds. USDA Forest Service publication, PSW-GTR 144, Albany, CA.

Ralph, C. J., J. R. Sauer, and S. Droege. 1995. Monitoring bird populations by point counts. USDA Forest Service publication, PSW-GTR 149, Albany, CA.

Reisen, W., H. Lothrup, R. Chiles, M. Madon, C. Cossen, L. Woods, S. Husted, V. Kramer, and J. Edman. 2004. West Nile Virus in California. Emerging Infectious Diseases 10: 1369-1378.

Rizzo, D. M., and M. Garbelotto. 2003. Sudden oak death: endangering California and Oregon forest ecosystems. Frontiers in Ecology and the Environment 1: 197-204.

Robbins, C. S., J. R. Sauer, R. S. Greenberg, and S. Droege. 1989. Population declines in North American birds that migrate to the Neotropics. Proceedings of the National Academy of Sciences of the United States of America 86: 7658-7662.

Russell, S. M. 1996. Anna's Hummingbird (*Calypte anna*). *In* The birds of North America, No. 226 (A. Poole and F. Gill, eds.). The Academy of Natural Sciences, Philadelphia, and The American Ornithologists' Union, Washington, DC.

Sanderson, F. J., P. F. Donald, D. J. Pain, I. J. Burfield, F. P. J. van Bommel. 2006. Long-term population declines in Afro-Palearctic migrant birds. Biological Conservation 131: 93-105.

Sauer, J. R., J. E. Hines, J. E. Fallon, K. L. Pardieck, D. J. Ziolkowski, Jr., and W. A. Link. 2012. The North American Breeding Bird Survey, Results and Analysis 1966 - 2011. Version 07.03.2013. USGS Patuxent Wildlife Research Center, Laurel, MD. http://www.mbr-pwrc.usgs.gov/bbs/.

Shuford, W. D. 1993. The Marin County Breeding Bird Atlas: A Distributional and Natural History of Coastal California Birds. California Avifauna Series 1. Bushtit Books, Bolinas, CA.

Shuford, W. D., and T. Gardali, editors. 2008. California Bird Species of Special Concern: A ranked assessment of species, subspecies, and distinct populations of birds of immediate conservation concern in California. Studies of Western Birds 1. Western Field Ornithologists, Camarillo, California, and California Department of Fish and Game, Sacramento.

Strong, C. M., L. B. Spear, T. P. Ryan, and R. E. Dakin. 2004. Forster's Tern, Caspian Tern, and California Gull colonies in San Francisco Bay: habitat use, numbers and trends, 1982-2003. Waterbirds 27: 411-423.

Tingley, M. W., W. B. Monahan, S. R. Beissinger, and C. Moritz. 2009. Birds track their Grinnellian niche through a century of climate change. Proceedings of the National Academy of Sciences of the United States of America 106: 19637-19643.

Wheeler, S. S., C. M. Barker, Y. Fang, M. V. Armijos, B. D. Carroll, S. Husted, W. O. Johnson, and W. K. Reisen. 2009. Differential impact of West Nile Virus on California birds. Condor 111: 1-20.

Wethington, S. M., and S. M. Russell. 2003. The seasonal distribution and abundance of hummingbirds in oak woodland and riparian communities in southeastern Arizona. Condor 105: 484-495.

Wormworth, J., and K. Mallon. 2006. Bird species and climate change: The global status report, version 1.0. Climate Risk Pty Limited (Australia), Level 1, 36 Lauderdale Ave., NSW 2094. Available at http://assets.panda.org/downloads/birdsclimatereportfinal.pdf

Appendix A. Dates of all point count surveys at the MMWD study area in 2013.

Transect Name	Code	Visit 1	Visit 2
Berry/Bon Tempe Trail	BETR	17-May	6-Jun
Blithdale Ridge Road	BLRI	23-May	28-Jun
Bolinas Ridge Trail	BORT	14-May	28-Jun
Bull Frog/Bon Tempe Road	BURO	3-May	1-Jun
Cataract Trail	CATR	13-May	13-Jun
Concrete Pipe Trail	COPT	21-May	5-Jun
Colier Springs Trail	COST	20 & 25 May	26-Jun
Eldridge Grade	ELGR	24-May	21-Jun
Helen Mark Trail	HEMA	14-May	3-Jun
Hidden Cove/Pine Point	HICO	3-May	1-Jun
Hoo-Koo-E-Koo Road	HOKE	21-May	11-Jun
Kent Pump Road	KPFR	18, 22 & 27 May	8 & 16 Jun
Laurel Dell/ Lagunitas-Rock Spring Road	LADE	8-May	28-Jun
Lakeview Road	LAVR	20-May	26-Jun
Matt Davis Trail	MDTR	24-May	30-Jun
Oat Hill Road	OHFR	28-May	13-Jun
Old Stage Road	OSRO	25-May	15-Jun
Pine Mountain Road	PIMR	29-May	27-Jun
Ridgecrest Blvd.	RICR	25-May	28-Jun
Rocky Ridge/Lagunitas-Rock Spring Road	RRFR	17-May	6-Jun
San Geronimo Ridge Trail	SGRT	16-May	17 & 19 Jun
Shafter Dam	SHAF	15-May	15-Jun
Shafter Creek	SHCR	16-May	19-Jun
Shaver Grade	SHGR	24-May	6-Jun
Six Points Trail	SPTR	21-May	5-Jun
Yolanda Trail	YOTR	20-May	5-Jun

Appendix B. Common and scientific names of bird species presented in this report, MMWD 1996-2013.

Common Name	Genus	Species
Acorn Woodpecker	*Melanerpes*	*formicivorus*
Allen's Hummingbird	*Selasphorus*	*sasin*
American Goldfinch	*Spinus*	*tristis*
American Robin	*Turdus*	*migratorius*
Anna's Hummingbird	*Calypte*	*anna*
Ash-throated Flycatcher	*Myiarchus*	*cinerascens*
Audubon's (Yellow-rumped) Warbler	*Setophaga*	*coronata*
Band-tailed Pigeon	*Patagioenas*	*fasciata*
Bewick's Wren	*Thryomanes*	*bewickii*
Black Phoebe	*Sayornis*	*nigricans*
Black-headed Grosbeak	*Pheucticus*	*melanocephalus*
Black-throated Gray Warbler	*Setophaga*	*nigrescens*
Blue Grosbeak	*Passerina*	*caerulea*
Blue-gray Gnatcatcher	*Polioptila*	*caerulea*
Brewer's Blackbird	*Euphagus*	*cyanocephalus*
Brown Creeper	*Certhia*	*americana*
Brown-headed Cowbird	*Molothrus*	*ater*
Bushtit	*Psaltriparus*	*minimus*
California Thrasher	*Toxostoma*	*redivivum*
California Towhee	*Melozone*	*crissalis*
Cassin's Vireo	*Vireo*	*cassinii*
Chestnut-backed Chickadee	*Poecile*	*rufescens*
Chipping Sparrow	*Spizella*	*passerina*
Downy Woodpecker	*Picoides*	*pubescens*
European Starling	*Sturnus*	*vulgaris*
Fox Sparrow	*Passerella*	*iliaca*
Golden-crowned Kinglet	*Regulus*	*satrapa*
Hairy Woodpecker	*Picoides*	*villosus*
Hermit Thrush	*Catharus*	*guttatus*
Hermit Warbler	*Setophaga*	*occidentalis*
House Finch	*Carpodacus*	*mexicanus*
Hutton's Vireo	*Vireo*	*huttoni*
Lark Sparrow	*Chondestes*	*grammacus*
Lazuli Bunting	*Passerina*	*amoena*
Lesser Goldfinch	*Spinus*	*psaltria*
Mourning Dove	*Zenaida*	*macroura*
Nuttall's Woodpecker	*Picoides*	*nuttallii*
Oak Titmouse	*Baeolophus*	*inornatus*
Olive-sided Flycatcher	*Contopus*	*cooperi*

Common Name	Genus	Species
Orange-crowned Warbler	*Oreothlypis*	*celata*
Oregon (Dark-eyed) Junco	*Junco*	*hyemalis*
*Pacific Wren	*Troglodytes*	*pacificus*
Pacific-slope Flycatcher	*Empidonax*	*difficilis*
Pileated Woodpecker	*Dryocopus*	*pileatus*
Pine Siskin	*Spinus*	*pinus*
Purple Finch	*Carpodacus*	*purpureus*
Pygmy Nuthatch	*Sitta*	*pygmaea*
Red-breasted Nuthatch	*Sitta*	*canadensis*
Red-shafted (Northern) Flicker	*Colaptes*	*auratus*
Red-winged Blackbird	*Agelaius*	*phoeniceus*
Ruby-crowned Kinglet	*Regulus*	*calendula*
Rufous-crowned Sparrow	*Aimophila*	*ruficeps*
Rufous Hummingbird	*Selasphorus*	*rufus*
Song Sparrow	*Melospiza*	*melodia*
Spotted Towhee	*Pipilo*	*maculatus*
Steller’s Jay	*Cyanocitta*	*stelleri*
Swainson’s Thrush	*Catharus*	*ustulatus*
Warbling Vireo	*Vireo*	*gilvus*
Western Bluebird	*Sialia*	*mexicana*
Western Scrub-Jay	*Aphelocoma*	*californica*
Western Wood-Pewee	*Contopus*	*sordidulus*
Wilson’s Warbler	*Cardellina*	*pusilla*
Wrentit	*Chamaea*	*fasciata*

*formerly called Winter Wren (*Troglodytes troglodytes*)

Appendix C: R code for Data Proofing

```
##CUSTOM FUNCTIONS FOR PROOFING##
############
#AS.PC.DATA#
############
as.pc.data<-function(data){
data<-data
##Create an ID_CODE field##
data$PT<-formatC(data$SITE,flag="0",width=2)
data$ID_CODE<-as.factor(paste(data$STATION,data$PT,sep=""))
data$SURVEY<-as.factor(paste(data$ID_CODE,data$DATE,"V",data$VISIT,sep=""))
data$YEAR<-years(as.chron(as.numeric(data$DATE)))

##Break detection_type, distance, and duration into their own fields##
#data$DTYPE<-as.factor(substr(as.character(data$DATA),1,1))
#data$DIST<-as.factor(substr(as.character(data$DATA),2,4))
#data$DUR<-as.factor(substr(as.character(data$DATA),5,5))
#data$COUNT<-1

return(data)
}

###############
#YEARLY.EFFORT#
###############

yearly.effort<-function(data,by="point",year="all",station="all"){

if (year=="all") data1<-data
if (year!="all") data1<-subset(data,YEAR==year)

if (station=="all") data2<-data1
if (station!="all") data2<-subset(data1,STATION==station)
data2<-drop.levels(data2,reorder=FALSE)

##THIS SUMMARIZES BY SITE##
if (by=="point"){
effort<-subset(data2,duplicated(SURVEY)==FALSE)

effort2<-table(effort$ID_CODE,effort$YEAR)}

##THIS SUMMARIZES BY STATION##
if (by=="station"){
effort<<-subset(data2,duplicated(data2[c("STATION","VISIT","YEAR")])==FALSE)
effort2<-table(effort$STATION,effort$YEAR)}
return(effort2)
}
```

```
####################
##SUMMARIZE.SURVEYS##
####################

summarize.survey<-function(data){
species<-aggregate(data$COUNT,list(data$SPEC,data$SURVEY),sum)
names(species)<-c("SPEC","SURVEY","COUNT")

covars<-subset(data,duplicated(SURVEY)==FALSE)
covars<-subset(covars,select=c(STATE,REGION,STATION,DATE,INITIALS,VISIT,TIME,ID_CODE,SURVEY,YEAR))

final<-merge(species,covars,by="SURVEY")
return(final)
}

#############
##ADD.ZEROS##
#############
add.zeros<-function(sum.data){

wide <- reshape(sum.data, v.names="COUNT", idvar="SURVEY",timevar="SPEC", direction="wide")
first<-wide[,1:10] ##THIS APPEARS TO BE PROBLEM##
second<-wide[,11:length(wide[1,])]
second0 <- second
second[] <- lapply(second,function(x) replace(x, is.na(x), 0))
final<-as.data.frame(cbind(first,second))
narrow<-
reshape(final,idvar="SURVEY",varying=list(names(final)[11:length(final[1,])]),direction="long",times=names(final)[1
1:length(final[1,])],v.names="COUNT",timevar="SPEC")
narrow$SPEC<-as.factor(substr(narrow$SPEC,7,10))
row.names(narrow)<-NULL
return(narrow)
}

##############
##MULT.VISITS##
##############

mult.visits<-function(narrow,summary="mean"){

##mean of multiple visits##
if (summary=="mean") {
species<-aggregate(narrow$COUNT,list(narrow$SPEC,narrow$ID_CODE,narrow$YEAR),mean)
names(species)<-c("SPEC","ID_CODE","YEAR","STAT")
}

##max of multiple visits##
if (summary=="max") {
species<-aggregate(narrow$COUNT,list(narrow$SPEC,narrow$ID_CODE,narrow$YEAR),max)
names(species)<-c("SPEC","ID_CODE","YEAR","STAT")
}

##present/absent over multiple visits##
```

```
if (summary=="presence") {
species<-aggregate(narrow$COUNT,list(narrow$SPEC,narrow$ID_CODE,narrow$YEAR),max)
names(species)<-c("SPEC","ID_CODE","YEAR","STAT")
species$STAT <- as.numeric(as.logical(species$STAT>0))
}

return(species)
}

####################################################################

#######################
##Load required packages##
#######################
		library(foreign)
		library(chron)
		library(gdata)
		library(reshape)

########################
##ACTUAL DATA CLEANING##
########################

##Read in the data##
mmwd.a<-
read.dbf("Z:/Terrestrial/programs_and_projects/mmwd/MMWD2013/Data/MMWD_allpc_NO99_96to2013.dbf")

##Create a field for year##
##note that the SITE field may be a character field when downloaded from CADC - it should be a numeric field
mmwd.a$year<-years(as.chron(mmwd.a$DATE))
mmwd.1<-as.pc.data(mmwd.a)

#3 visits were done in 1997. To take out the same ones that were taken out in the 2004 report; note changes to
table names
mmwd.b<-subset(mmwd.1, year!="1997" | STATION!="BETR" | VISIT!=1)
mmwd.c<-subset(mmwd.b, year!="1997" | STATION!="BLRI" | VISIT!=1)
mmwd.d<-subset(mmwd.c, year!="1997" | STATION!="BORT" | VISIT!=3)
mmwd.e<-subset(mmwd.d, year!="1997" | STATION!="BURO" | VISIT!=1)
mmwd.f<-subset(mmwd.e, year!="1997" | STATION!="CATR" | VISIT!=1)
mmwd.g<-subset(mmwd.f, year!="1997" | STATION!="COPT" | VISIT!=1)
mmwd.h<-subset(mmwd.g, year!="1997" | STATION!="COST" | VISIT!=1)
mmwd.i<-subset(mmwd.h, year!="1997" | STATION!="ELGR" | VISIT!=3)
mmwd.j<-subset(mmwd.i, year!="1997" | STATION!="HEMA" | VISIT!=3)
mmwd.k<-subset(mmwd.j, year!="1997" | STATION!="HICO" | VISIT!=1)
mmwd.l<-subset(mmwd.k, year!="1997" | STATION!="HOKE" | VISIT!=3)
mmwd.m<-subset(mmwd.l, year!="1997" | STATION!="KPFR" | VISIT!=1)
mmwd.n<-subset(mmwd.m, year!="1997" | STATION!="LADE" | VISIT!=1)
mmwd.o<-subset(mmwd.n, year!="1997" | STATION!="LAVR" | VISIT!=3)
mmwd.p<-subset(mmwd.o, year!="1997" | STATION!="MDTR" | VISIT!=1)
mmwd.q<-subset(mmwd.p, year!="1997" | STATION!="OHFR" | VISIT!=3)
mmwd.r<-subset(mmwd.q, year!="1997" | STATION!="OSRO" | VISIT!=1)
mmwd.s<-subset(mmwd.r, year!="1997" | STATION!="PIMR" | VISIT!=3)
mmwd.t<-subset(mmwd.s, year!="1997" | STATION!="RICR" | VISIT!=1)
```

```
mmwd.u<-subset(mmwd.t, year!="1997" | STATION!="RRFR" | VISIT!=1)
mmwd.v<-subset(mmwd.u, year!="1997" | STATION!="SGRT" | VISIT!=3)
mmwd.w<-subset(mmwd.v, year!="1997" | STATION!="SHAF" | VISIT!=3)
mmwd.x<-subset(mmwd.w, year!="1997" | STATION!="SHCR" | VISIT!=3)
mmwd.y<-subset(mmwd.x, year!="1997" | STATION!="SHGR" | VISIT!=1)
mmwd.z<-subset(mmwd.y, year!="1997" | STATION!="SPTR" | VISIT!=3)
mmwd<-subset(mmwd.z, year!="1997" | STATION!="YOTR" | VISIT!=3)

##Drop sites not visited in all years##
mmwd.za<-subset(mmwd, STATION!="SHGR" | SITE!=15)
mmwd<-subset(mmwd.za, STATION!="SGRT" | SITE!=16)

##Standardize species names
mmwd$SPEC<-replace(mmwd$SPEC,mmwd$SPEC=="NOFL","RSFL")
mmwd$SPEC<-replace(mmwd$SPEC,mmwd$SPEC=="WEFL","PSFL")
mmwd$SPEC<-replace(mmwd$SPEC,mmwd$SPEC=="YRWA","AUWA")
mmwd$SPEC<-replace(mmwd$SPEC,mmwd$SPEC=="DEJU","ORJU")

##CHECK THE NUMBER OF TIMES EACH STATION WAS VISITED##
yearly.effort(mmwd)

##########################################
##created a file to look at survey effort.
eff_summ<-yearly.effort(mmwd)
write.csv(eff_summ,"Z:/Terrestrial/programs_and_projects/mmwd/MMWD2013/Data/eff_sum.csv")
##########################################

#create a field called "bin" which will either have L (<50m), "G (>50m), "J (juv) or F (flyover).
mmwd$bin<-as.factor(substr(as.character(mmwd$DATA),2,2))

#create table with just detections<50m, no flyovers and no juv
mmwd.l50<-subset(mmwd, bin=="L")

#Creat a variable called count - indicates that each record is one bird##
mmwd.l50$COUNT<-1

##Use summarize.surveys to make one record per species##
mmwd.l50sum<-summarize.survey(mmwd.l50)

##Add zeroes to the data set##
mmwd.l50sum_zeroes<-add.zeros(mmwd.l50sum)

##Use mult.visits to get mean detections per point across multiple visits
mmwd.l50sum_zeroes_mv<-mult.visits(mmwd.l50sum_zeroes,summary="mean")

##Calculate mean per point per year##
final<-
aggregate(mmwd.l50sum_zeroes_mv$STAT,list(mmwd.l50sum_zeroes_mv$SPEC,mmwd.l50sum_zeroes_mv$YEA
R),mean)
names(final)<-c("SPEC","YEAR","ABUNDANCE")

##Write the final data to disk##
write.csv(final,"Z:/Terrestrial/programs_and_projects/mmwd/MMWD2013/Data/MMWD_pc_final.csv")
```

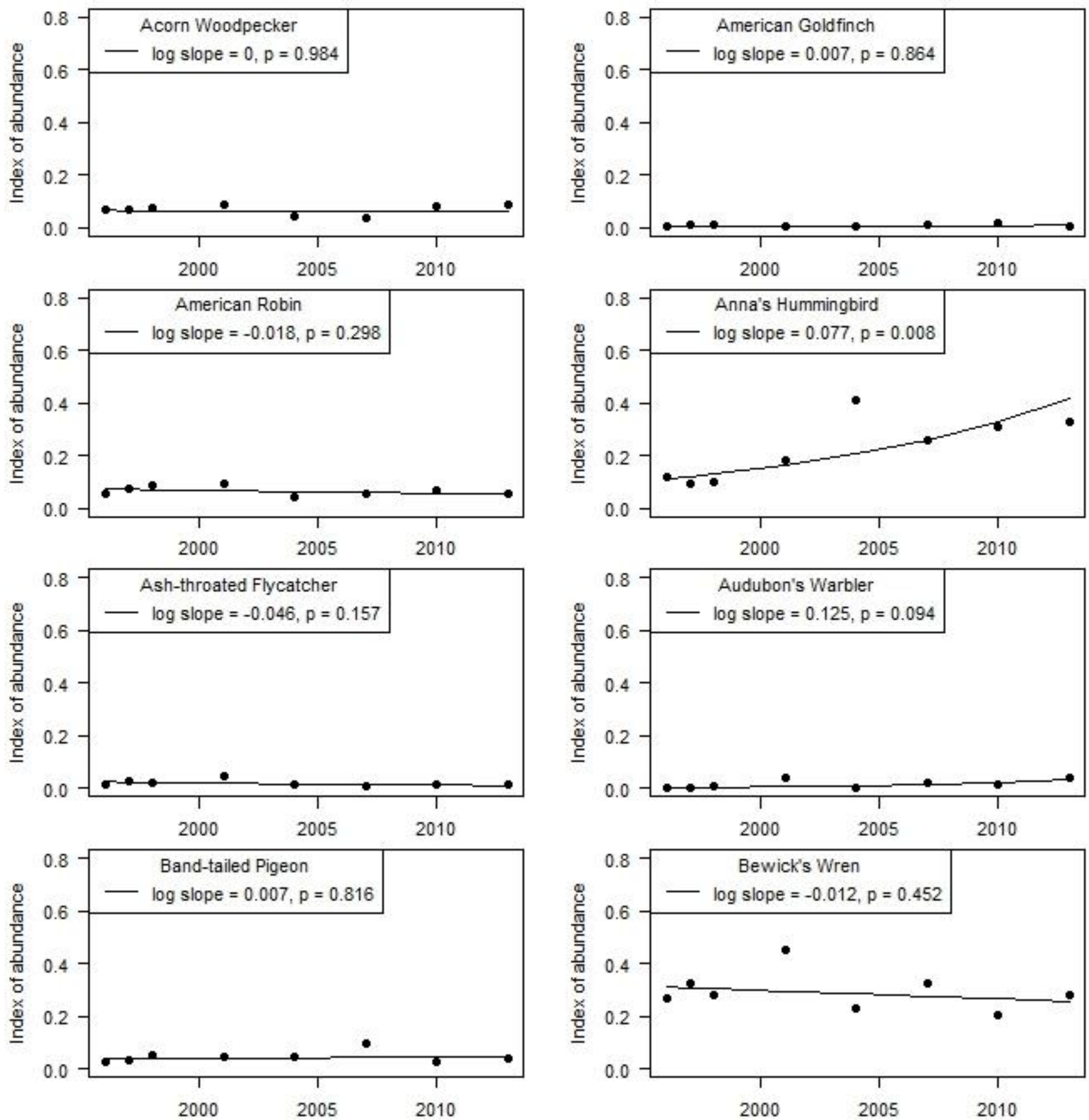
Appendix D: R code for data analysis and figures.

```
##Read in the data##

data<-read.csv("Z:/Terrestrial/programs_and_projects/mmwd/MMWD2013/data/MMWD_pc_final.csv")

##species trend list:
mmwd.trnd.spp<-subset(data, SPEC=="ANHU" | SPEC=="ACWO" | SPEC=="AMRO" | SPEC=="ALHU" |
SPEC=="ATFL" | SPEC=="AUWA" | SPEC=="BEWR" | SPEC=="BGGN" | SPEC=="BHCO" | SPEC=="BHGR" |
SPEC=="BLPH" | SPEC=="BRCR" | SPEC=="BTPI" | SPEC=="BTYW" | SPEC=="BUSH" | SPEC=="CALT" |
SPEC=="CAQU" | SPEC=="CAVI" | SPEC=="CBCH" | SPEC=="CHSP" | SPEC=="DOWO" | SPEC=="GCKI" |
SPEC=="HAWO" | SPEC=="HETH" | SPEC=="HEWA" | SPEC=="HOFI" | SPEC=="HUVI" | SPEC=="LASP" |
SPEC=="LAZB" | SPEC=="LEGO" | SPEC=="MODO" | SPEC=="NUWO" | SPEC=="OATI" | SPEC=="OCWA" |
SPEC=="ORJU" | SPEC=="OSFL" | SPEC=="PAWR" |SPEC=="PIWO" | SPEC=="PUFI" | SPEC=="PYNU" |
SPEC=="RBNU" | SPEC=="RCSP" | SPEC=="RSFL" | SPEC=="SOSP" | SPEC=="SPTO" | SPEC=="STJA" |
SPEC=="SWTH" | SPEC=="WAVI" | SPEC=="WEBL" | SPEC=="WESJ" | SPEC=="WEWP" | SPEC=="WIWA" |
SPEC=="WREN" |SPEC=="PSFL"|SPEC=="BTPI"|SPEC=="RWBL"|SPEC=="AMGO"|SPEC=="PISI")

##############################################################################

#doing log (ln) linear model only
trend_llm<-
function(data,species,label,newdat=data.frame(YEAR=c(1996,1997,1998,2001,2004,2007,2010,2013)),position="to
pleft"){
	spec<<-subset(data,data$SPEC==species)
	plot(spec$YEAR,spec$ABUNDANCE,ylim=c(0,0.8),las=1,main="", ylab="Index of
abundance",xlab="",pch=16)
	spec_llm<-lm(log(ABUNDANCE)~YEAR,data=spec)
	spec_llm_sum<-summary(spec_llm)
	newdat$pred_log<-exp(predict(spec_llm,newdata=newdat))
	points(newdat$YEAR,newdat$pred_log,type="l")
	log<-paste("log slope = ", round(spec_llm_sum$coefficients[2,1],3),", ","p =
",round(spec_llm_sum$coefficients[2,4],3),sep = "")
	legend(position,lty=c("solid"),
		legend=c(log),title=label)
}

######################################################################
#Figures for Appendix

#Panel Figure A - 8 species
par(mfrow=c(4,2),mar=c(2, 4, .5, 2)) #mar=c(b,l,t,r)
trend_llm(mmwd.trnd.spp,"ACWO","Acorn Woodpecker")
trend_llm(mmwd.trnd.spp,"AMGO","American Goldfinch")
trend_llm(mmwd.trnd.spp,"AMRO","American Robin")
trend_llm(mmwd.trnd.spp,"ANHU","Anna's Hummingbird")
trend_llm(mmwd.trnd.spp,"ATFL","Ash-throated Flycatcher")
trend_llm(mmwd.trnd.spp,"AUWA","Audubon's Warbler")
trend_llm(mmwd.trnd.spp,"BTPI","Band-tailed Pigeon")
trend_llm(mmwd.trnd.spp,"BEWR","Bewick's Wren")


#Panel Figure B - 8 species
```

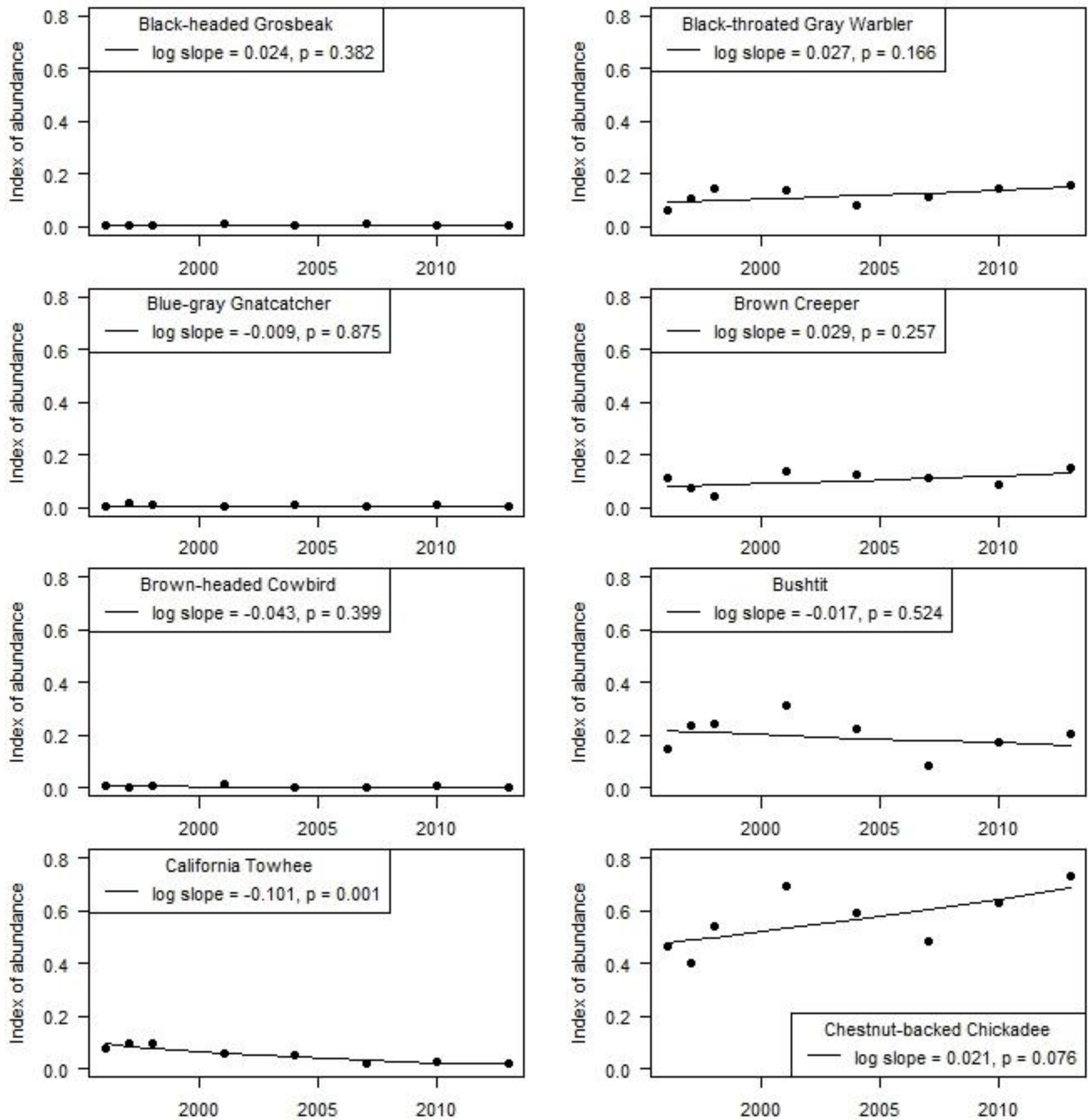
```
par(mfrow=c(4,2),mar=c(2, 4, .5, 2)) #mar=c(b,l,t,r)
trend_llm(mmwd.trnd.spp,"BHGR","Black-headed Grosbeak")
trend_llm(mmwd.trnd.spp,"BTYW","Black-throated Gray Warbler")
trend_llm(mmwd.trnd.spp,"BGGN","Blue-gray Gnatcatcher")
trend_llm(mmwd.trnd.spp,"BRCR","Brown Creeper")
trend_llm(mmwd.trnd.spp,"BHCO","Brown-headed Cowbird")
trend_llm(mmwd.trnd.spp,"BUSH","Bushtit")
trend_llm(mmwd.trnd.spp,"CALT","California Towhee")
trend_llm(mmwd.trnd.spp,"CBCH","Chestnut-backed Chickadee",position="bottomright")

#Panel Figure C - 8 species
par(mfrow=c(4,2),mar=c(2, 4, .5, 2)) #mar=c(b,l,t,r)
trend_llm(mmwd.trnd.spp,"DOWO","Downy Woodpecker")
trend_llm(mmwd.trnd.spp,"GCKI","Golden-crowned Kinglet")
trend_llm(mmwd.trnd.spp,"HAWO","Hairy Woodpecker")
trend_llm(mmwd.trnd.spp,"HETH","Hermit Thrush",newdat=data.frame(YEAR=c(2004,2007,2010,2013)))
trend_llm(mmwd.trnd.spp,"HEWA","Hermit Warbler")
trend_llm(mmwd.trnd.spp,"HOFI","House Finch")
trend_llm(mmwd.trnd.spp,"HUVI","Hutton's Vireo")
trend_llm(mmwd.trnd.spp,"MODO","Mourning Dove")

#Panel Figure D - 8 species
par(mfrow=c(4,2),mar=c(2, 4, .5, 2)) #mar=c(b,l,t,r)
trend_llm(mmwd.trnd.spp,"OATI","Oak Titmouse")
trend_llm(mmwd.trnd.spp,"OSFL","Olive-sided Flycatcher")
trend_llm(mmwd.trnd.spp,"OCWA","Orange-crowned Warbler")
trend_llm(mmwd.trnd.spp,"ORJU","Oregon Junco", position="bottomright")
trend_llm(mmwd.trnd.spp,"PAWR","Pacific Wren")
trend_llm(mmwd.trnd.spp,"PSFL","Pacific-slope Flycatcher", position="bottomright")
trend_llm(mmwd.trnd.spp,"PIWO","Pileated Woodpecker")
trend_llm(mmwd.trnd.spp,"PUFI","Purple Finch")

#Panel Figure E - 8 species
par(mfrow=c(4,2),mar=c(2, 4, .5, 2)) #mar=c(b,l,t,r)
trend_llm(mmwd.trnd.spp,"RBNU","Red-breasted Nuthatch")
trend_llm(mmwd.trnd.spp,"RSFL","Red-shafted Flicker")
trend_llm(mmwd.trnd.spp,"RWBL","Red-winged Blackbird")
trend_llm(mmwd.trnd.spp,"RCSP","Rufous-crowned Sparrow")
trend_llm(mmwd.trnd.spp,"SOSP","Song Sparrow")
trend_llm(mmwd.trnd.spp,"SPTO","Spotted Towhee", position="bottomleft")
trend_llm(mmwd.trnd.spp,"STJA","Steller's Jay")
trend_llm(mmwd.trnd.spp,"SWTH","Swainson's Thrush",newdat=data.frame(YEAR=c(2004,2007,2010,2013)))

#Panel Figure F - 4 species
par(mfrow=c(4,2),mar=c(2, 4, .5, 2)) #mar=c(b,l,t,r)
trend_llm(mmwd.trnd.spp,"WAVI","Warbling Vireo")
trend_llm(mmwd.trnd.spp,"WESJ","Western Scrub-jay")
trend_llm(mmwd.trnd.spp,"WIWA","Wilson's Warbler")
trend_llm(mmwd.trnd.spp,"WREN","Wrentit")


##Decreasing Species Figure
```

```
CALT<-subset(mmwd.trnd.spp,mmwd.trnd.spp$SPEC=="CALT")
WESJ<-subset(mmwd.trnd.spp,mmwd.trnd.spp$SPEC=="WESJ")
STJA<-subset(mmwd.trnd.spp,mmwd.trnd.spp$SPEC=="STJA")
PIWO<-subset(mmwd.trnd.spp,mmwd.trnd.spp$SPEC=="PIWO")

x <- c(1996, 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012)

plot(CALT$YEAR,CALT$ABUNDANCE,ylim=c(0,0.3),las=1,main="",
			ylab="Index of abundance",xlab="",pch=16,typ="b",xaxt="n")
			axis(at=x, side=1)
		points(WESJ$YEAR,WESJ$ABUNDANCE,pch=1,typ="b")
		points(STJA$YEAR,STJA$ABUNDANCE,pch=4,typ="b")
		points(PIWO$YEAR,PIWO$ABUNDANCE,pch=15,typ="b")

		legend("topright",text.width=7,pch=c(16,1,4,15),legend=c("California Towhee (-9.6% per year)","Western Scrub-jay (-8.0% per year)","Steller's Jay (-5.9% per year)","Pileated Woodpecker (-4.3% per year)"))

##Increasing Species Figure A
ANHU<-subset(mmwd.trnd.spp,mmwd.trnd.spp$SPEC=="ANHU")
OSFL<-subset(mmwd.trnd.spp,mmwd.trnd.spp$SPEC=="OSFL")
CBCH<-subset(mmwd.trnd.spp,mmwd.trnd.spp$SPEC=="CBCH")
ORJU<-subset(mmwd.trnd.spp,mmwd.trnd.spp$SPEC=="ORJU")

x <- c(1996, 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012)

plot(ANHU$YEAR,ANHU$ABUNDANCE,ylim=c(0,1.0),las=1,main="",
			ylab="Index of abundance",xlab="",pch=16,typ="b", xaxt="n")
			axis(at=x, side=1)
		points(OSFL$YEAR,OSFL$ABUNDANCE,pch=1,typ="b")
		points(CBCH$YEAR,CBCH$ABUNDANCE,pch=4,typ="b")
		points(ORJU$YEAR,ORJU$ABUNDANCE,pch=15,typ="b")

		legend("topleft",pch=c(16,1,4,15),text.width=8,legend=c("Anna's Hummingbird (+8.0% per year)","Olive-sided Flycatcher (+13.3% per year)","Chestnut-backed Chickadee (+2.1% per year)", "Oregon Junco (+2.0% per year)"))

##Increasing Species Figure B
AUWA<-subset(mmwd.trnd.spp,mmwd.trnd.spp$SPEC=="AUWA")
HEWA<-subset(mmwd.trnd.spp,mmwd.trnd.spp$SPEC=="HEWA")
WIWA<-subset(mmwd.trnd.spp,mmwd.trnd.spp$SPEC=="WIWA")

x <- c(1996, 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012)

plot(AUWA$YEAR,AUWA$ABUNDANCE,ylim=c(0,0.4),las=1,main="",
			ylab="Index of abundance",xlab="",pch=16,typ="b", xaxt="n")
			axis(at=x, side=1)
		points(HEWA$YEAR,HEWA$ABUNDANCE,pch=1,typ="b")
		points(WIWA$YEAR,WIWA$ABUNDANCE,pch=4,typ="b")

		legend("topleft",pch=c(16,1,4),text.width=8,legend=c("Audubon's Warbler (+13.3% per year)","Hermit Warbler (+10.3% per year)","Wilson's Warbler (+3.7% per year)"))
##END
```

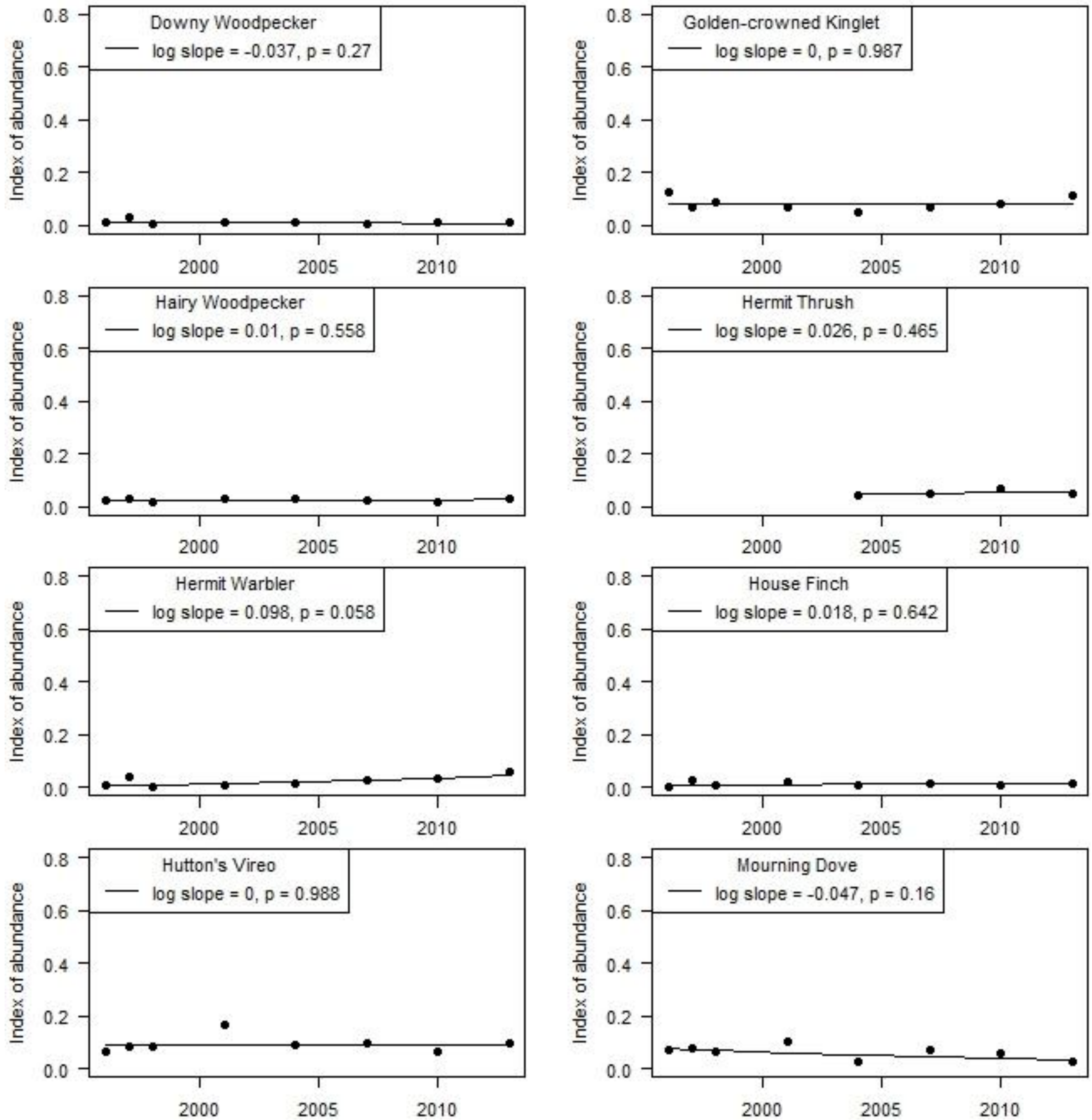
Appendix E. Trend results for 44 species of landbirds on MMWD lands, 1996-2013, Point Blue Conservation Science. Trends calculated using a natural log transformation on the abundance per point values and linear regression to describe the relationship between species abundance and year. Significant and near-significant trends are also detailed in Figs. 2-4.



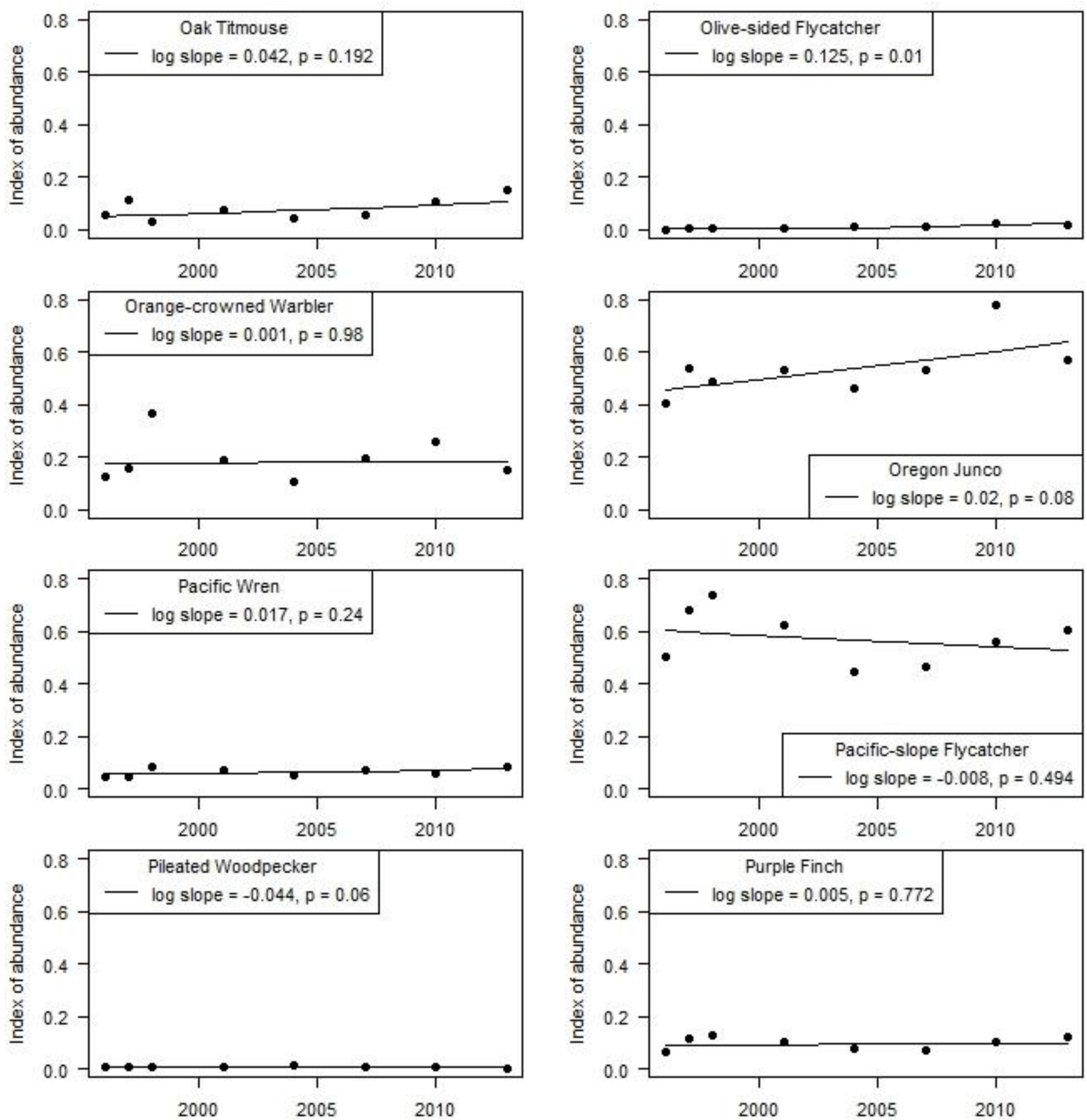
Appendix E (continued). Trend results for 44 species of landbirds on MMWD lands, 1996-2013, Point Blue Conservation Science.



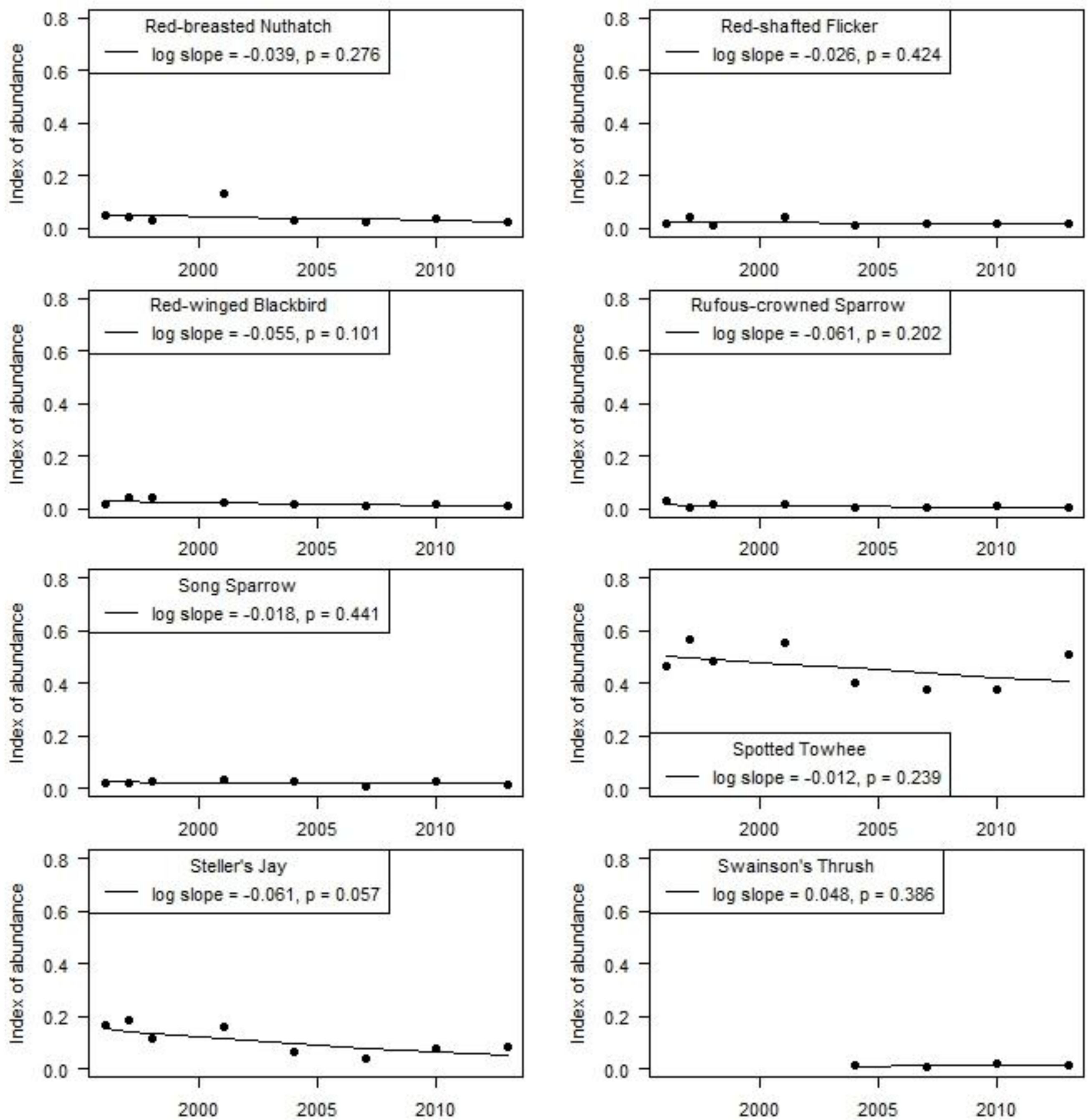
Appendix E (continued). Trend results for 44 species of landbirds on MMWD lands, 1996-2013, Point Blue Conservation Science.



Appendix E (continued). Trend results for 44 species of landbirds on MMWD lands, 1996-2013, Point Blue Conservation Science.



Appendix E (continued). Trend results for 44 species of landbirds on MMWD lands, 1996-2013, Point Blue Conservation Science.



Appendix E (continued). Trend results for 44 species of landbirds on MMWD lands, 1996-2013, Point Blue Conservation Science.