Population trends of birds wintering in the Central Valley of California

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Abstract: Since the 1970s, the Central Valley of California has seen a large investment in preservation and restoration of wetlands and riparian areas. At the same time, grasslands have been lost to vineyards, orchards, and residential development at an accelerating rate. To document population trends for birds wintering in this region, we analyzed data from 17 Christmas Bird Count circles that were surveyed regularly between the winters of 1978–79 and 2013–14. We selected 112 taxa (species or species groups) that were relatively abundant and widespread in the Central Valley during winter and used a hierarchical model to estimate annual rates of population change from the count data while accounting for varying survey effort. The proportion of taxa whose trend was positive (46%) was much larger than that for which it was negative (18%); about a third (36%) showed no detectable change. Habitats in the Central Valley in which the proportions of increasing taxa were highest were riparian corridors (59% increasing vs. 9% decreasing; $n = 32$), wetlands (49% vs. 11%; $n = 47$), and open water (44% vs. 0%; $n = 9$), likely reflecting not only the conservation efforts in these habitats during recent decades but also a diverse array of other factors. In contrast, more of the 25 taxa associated with grasslands and other open habitats showed decreases (48%) than showed increases (28%). As expected, trends of species that adapt well to areas of human habitation were stable or increasing. Such species with strong positive trends include the Anna's Hummingbird (*Calypte anna*), Black Phoebe (*Sayornis nigricans*), and recent Central Valley arrivals, Eurasian Collared-Dove (*Streptopelia decaocto*) and Great-tailed Grackle (*Quiscalus mexicanus*). Opportunistic scavengers such as the Turkey Vulture (*Cathartes aura*) and Common Raven (*Corvus corax*) also increased strongly. Trends in wintering populations were largely concordant with trends estimated from breeding areas in California and western North America. These data suggest that recent efforts to preserve and restore wetlands and riparian habitats are benefiting birds, although the dynamics are complex and variable among species. A similar focus on conservation of the Central Valley's remaining grasslands may be needed to maintain the birds of that habitat.

Keywords: Christmas Bird Count, crop conversion, grasslands, habitat associations, riparian, survey, wetlands, winter-flooded rice

Supplemental Online Material for this paper (Appendix S1) is available at www.wfopublications.org/Avifaunal_Change/Pandolfino-Handel/Pandolfino-Handel_SOM.pdf

The scale and degree of human-induced transformation of the habitats in California's Central Valley during the 20th century may be unequalled in any other area of North America (Schoenherr 1992). In the late 19th century the valley comprised vast areas of permanent and seasonal wetlands, extensive grasslands and oak savanna around its perimeter, and corridors of dense riparian woodland, in places tens of kilometers wide (Schoenherr 1992, Garone 2011). By the 1980s the Central Valley's wetlands were

reduced by over 90%, a proportion greater than in any other area in the United States (Dahl and Johnson 1991, Garone 2011). Riparian areas were also severely affected, with about 95% of the original habitat lost (Katibah 1984, Dawdy 1989, Nelson et al. 2003). The valley's grasslands were less dramatically affected, with just over half lost by the 1960s (Nelson et al. 2003).

Beginning in the 1970s, a combination of stronger environmental regulation and a growing conservation ethic halted or even reversed

Full citation: Pandolfino, E. R., and Handel, C. M. 2018. Population trends of birds wintering in the Central Valley of California, in *Trends and traditions: Avifaunal change in western North America* (W. D. Shuford, R. E. Gill Jr., and C. M. Handel, eds.), pp. 215–235. Studies of Western Birds 3. Western Field Ornithologists, Camarillo, CA; doi 10.21199/SWB3.12.

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some of these trends. The recent protection and restoration of the Central Valley's wetlands and the increase in rice fields flooded in winter have been well documented (Fleskes et al. 2005, CVJV 2006, Garone 2011). Riparian habitats are being preserved, and restoration of them is being proposed at unprecedented scales (RHJV 2004, CVJV 2006, Griggs 2009). Conversely, during this same period, the valley's grasslands and other agricultural lands have been urbanized at a rate higher than in any other region of the United States (Johnson and Hayes 2004, Leu et al. 2006). The state of California projects that the Central Valley's human population will continue to increase for at least the next few decades (CDOF 2018), an increase likely accommodated by continued conversion of grassland (Cameron et al. 2014). In addition, beginning in the 1980s, large portions of grassland were converted from cattle ranching and other relatively passive uses to more intensive agricultural practices such as vineyards and orchards (CDOC 2008, Volpe et al. 2010). Between 1984 and 2008 more than 100,000 ha (~6%) of the Central Valley's grasslands were urbanized or converted to intensive agriculture (cf. Cameron et al. 2014, DiGaudio et al. 2017).

Understanding the effects on wild bird populations of such extensive changes to land cover requires long-term data across broad landscapes. Begun in North America in 1900 as an alternative to the traditional Christmas hunt, the Audubon Christmas Bird Count (CBC) is the oldest citizen-science program in the world, now second only to eBird in terms of geographic scope and participation (Butcher et al. 1990, Silvertown 2009, Sullivan et al. 2014). The current method involves volunteers conducting a coordinated single-day count of birds within a circle of diameter 24 km (15 mi) within 12 days before or after 25 December (Butcher et al. 1990). Although survey coverage is not standardized, each party of volunteers records the number of hours in the field and distances covered on foot and by car. In addition, the locations of the ~2500 circles now surveyed annually were selected for social reasons rather than according to a statistical sampling design, limiting the applicability of statistical inference to areas broader than a single circle. However, robust analytical approaches have been developed to account for many of the CBC's methodological limitations (Link and Sauer 1999, Sauer et al. 2004, Link et al. 2006). As a result, CBC data have been used to assess long-term population trends, document distributional shifts at the

continental level, and examine finer spatial patterns in densities of wintering birds (e.g., Butcher et al. 1990, 2005, Koenig 1998, La Sorte and Thompson 2007).

In this study, we analyzed CBC data to estimate long-term rates of annual population change for 112 taxa of birds wintering in the Central Valley and examined each species' trend with respect to its primary habitat. To assess the potential importance of factors influencing these populations at broader geographic scales, we compared winter population trends in the Central Valley to those from the North American Breeding Bird Survey (BBS) in California and western North America. Finally, we assessed the potential effects that land-use changes in the valley may have had on wintering populations of species occupying various habitats, and we discuss implications for future conservation efforts.

METHODS

STUDY AREA

The Central Valley is the largest geographic feature in California, extending >600 km in length, averaging >60 km in width, and encompassing >4 million ha. It consists of two large river valleys (the Sacramento and San Joaquin valleys) and the Sacramento–San Joaquin River Delta, where these two river systems merge and flow into the San Francisco Bay estuary. The boundaries of the valley may be defined in many ways, on the basis of elevation, botanical factors, soils, geomorphic structure, and other characteristics; we used a definition based on geomorphic structure (Faunt et al. 2009). The 17 CBC circles included in our study are entirely or largely within the valley by this definition, although some extend into foothills of the Sierra Nevada or Coast Ranges (Figure 1).

Winters in the Central Valley are generally wet and mild. Most precipitation falls as rain between November and March, and the low temperatures rarely drop below freezing, as typified by the climate at Sacramento, California (www.usclimatedata.com/climate/sacramento/california/united-states/usca0967). These conditions, combined with a diverse array of land-cover types, make this area a prime location for both resident birds and winter visitors from throughout western North America. More than 170 species regularly winter in the valley (NAS 2010). During winter, the Central Valley hosts more than half of the waterfowl in the Pacific Flyway (CVJV 2006) and more shorebirds than in any other inland region of western North America (Shuford et al. 1998).

FIGURE 1. Location of 17 Christmas Bird Count circles in the Central Valley of California used for analysis of population trends. RE, Redding; RB, Red Bluff; CO, Chico; OR, Oroville; PV, Peace Valley; MA, Marysville; FO, Folsom; SM, Sacramento; PC, Putah Creek; BE, Benicia; ST, Stockton; WB, Wallace-Bellota; CW, Caswell-Westley; LW, LaGrange-Waterford; LS, Los Banos; LL, Lost Lake; BA, Bakersfield.

The valley also supports a diverse array of other waterbirds, including grebes, cormorants, cranes, gulls, and terns (CVJV 2006). Raptors migrate from all over western North America to winter in the valley, which hosts the continent's largest concentrations of wintering Red-tailed Hawks (Root 1988, Pandolfino and Sudekamp Wells 2009; see Table 1 for all scientific names of birds). The diversity of raptor species in the valley during winter is unequaled in any North American region, with the possible exception of the coastal plains of Texas (Pandolfino 2006). Finally, the Central Valley provides important winter habitat for a large complement of smaller landbirds, including hummingbirds, kingfishers, woodpeckers, and more than 50 species of songbirds (RHJV 2004, Dybala et al. 2015).

LAND-COVER TYPES

Dominant land-cover types in the region (see Davis et al. 1998, CDOC 2008, USDA 2008) include

Grassland and oak savanna. Grasslands occur around the edges of the Central Valley and encompass nearly 33% of its total area. Near the foothills of the Sierra Nevada and Coast Ranges, these open grasslands grade into oak savanna, which covers an additional 6–7% of the area. Grasslands and oak savanna are used almost exclusively for livestock grazing.

Orchards and vineyards. These represent the fastest-growing land-use types in recent decades and now cover >15% of the valley.

Forage crops. This type includes crops such as alfalfa, hay, and triticale (*Triticosecale* spp.; wheat/rye hybrid) and occupies approximately 12% of the valley.

Row crops. These cover 10–12% of the valley and include crops such as tomatoes, cotton, sugar beets, and soy beans. These crops are usually disked after harvest, leaving bare dirt fields during winter.

Developed areas. This land-cover type includes suburban, rural residential, and densely urbanized areas and accounts for approximately 9% of the valley.

Irrigated pastures. In contrast to the grasslands and oak savanna, which are not irrigated and generally support livestock only from fall through early spring, these areas (approximate 3% of the valley) are irrigated during the drier months and often support livestock year round.

Marshlands. These areas, mainly winter-flooded managed wetlands, make up less than 3% of the valley.

Rice. Rice fields, which occur mainly in the Sacramento Valley, cover nearly 3% of the Central Valley as a whole; approximately two-thirds are flooded during winter.

Other. The remaining 10–11% of the Central Valley area includes a wide variety of cover types such as riparian forest, chaparral, dairy farms, and lands used for other purposes.

CBC CIRCLES

Over the period of analysis—winter 1978–79 to winter 2013–14—more than 24 different CBC circles were surveyed in the Central Valley; each circle is 24 km in diameter and covers 45,000 ha. A few of these CBC surveys were started only recently, and others have been run intermittently. To reduce potential bias in estimates of trends over time, we used data only from those circles that were surveyed during at least 9 of the first 16 years of the analysis period and at least 9 of the last 16 years. The 17 circles that met these criteria included 8 along the valley floor, 8 that also sampled the foothills of the Sierra Nevada or Coast Ranges, and one that included portions of Suisun Bay (Figure 1). Relatively few circles were surveyed in the southern part of the valley, so composite estimates of trends could be biased if population trends varied spatially.

SPECIES AND HABITAT ASSOCIATIONS

To focus the analyses on species that are relatively abundant and widespread in the Central Valley, we analyzed data only for those species that (1) were detected at a rate greater than 1 bird per 10 party-hours per CBC during either the first half or the second half of the period of analysis and (2) were detected at that level on at least one-third of all 17 CBC circles. These criteria were met by 110 species and 2 species groups (*Aechmophorus* grebes and *Accipiter* hawks). We combined counts of the Western Grebe and Clark's Grebe and counts of the three species of *Accipiter* (Sharp-shinned Hawk, Cooper's Hawk, and Northern Goshawk) for analysis of trends because these species were often not distinguished in the field. The Cackling Goose was not formally recognized as a species distinct from the Canada Goose until 2003 (Banks et al. 2003); therefore, the numbers of those taxa found on CBCs prior to that are uncertain. In most of the circles, however, including those responsible for over 99% of all Cackling Geese recorded throughout the period, the Cackling Goose was regularly recorded as a subspecies before the split. Therefore, we used subspecific data available from CBC compilers

before 2004 for our analyses and analyzed these at the level of the species currently recognized.

We assigned each species to one or two habitat categories on the basis of its most common associations during winter in the Central Valley (Table 1). For these analyses, we defined the habitat types as follows:

Wetlands include marshlands, and surrogate wetlands of flooded rice fields and fields of some other crops, such as corn, flooded in winter after harvest.

Open water includes deep-water lakes, reservoirs, wastewater ponds, and wide sections of major rivers.

Riparian includes vegetated habitats along rivers and streams with canopy cover >40%. Dominant trees in these woodlands include valley oak (*Q. lobata*), cottonwood (*Populus fremontii*), and willow (*Salix* spp.). The understory may include a variety of native and nonnative shrubs, with Himalayan blackberry (*Rubus armeniacus*) among the most common.

Chaparral/Scrub is relatively uncommon in the Central Valley. Areas of the San Joaquin Valley with saline soils that support stands of salt-tolerant shrubs, mainly *Atriplex* and *Allenrolfea* spp., are also included in this habitat type. However, three of the CBC circles extend into the foothills of the Sierra Nevada, where shrubs such as manzanita (*Arctostaphylos* spp.), toyon (*Heteromeles arbutifolia*), and chamise (*Adenostoma fasciculatum*) dominate.

Oak savanna is found mainly at the edges of the region and consists of scattered trees (<30% canopy cover) in a grassland matrix. Blue oak (*Q. douglasii*) and valley oak dominate.

Grassland/Open habitats include grasslands, irrigated pastures, and fields of forage crops such as alfalfa and hay, as well as of row crops and other crops not flooded during winter (e.g., unflooded rice or corn fields).

Developed habitats include a wide variety of human-altered landscapes ranging from dense urban to suburban to rural residential areas.

General is included as a category reserved for species that could easily have been assigned to three or more different habitat associations and are commonly found in many of the habitats described above.

Using these eight categories, we characterized 47 (42%) of the 112 taxa as primarily associated with wetland habitats during winter in the Central Valley, 32 (19%) with riparian habitats, and 9 (8%) with open water (Table 1). We characterized 25 species (22%) as primarily associated with

grasslands and other open habitats, and smaller proportions of the avifauna as mainly associated with developed areas (20 species; 18%), oak savanna (14; 13%), or chaparral/scrub (9; 8%). We classified 7 species (6%) as habitat generalists because of their common associations with multiple habitats.

STATISTICAL ANALYSES

We used data from the National Audubon Society's online database of CBC results (NAS 2010) supplemented with data (~1%) obtained directly from CBC compilers to fill in some gaps in the database and to separate counts of the Canada Goose and Cackling Goose before their taxonomic split. To estimate population trends of birds from the CBC data, we used a hierarchical model that accounts for nonlinear effects of observer effort (Link et al. 2006). In this model, the count of a species on a CBC, $Y_{j,t}$ (j for circle, t for year), is considered an independent overdispersed Poisson random variable with mean $\lambda_{j,t}$ that is a log-linear function of explanatory variables:

$$\log(\lambda_{j,t}) = \alpha + \omega_j + \beta(t - t^*) + \gamma_t + B(\xi_{j,t}^p - 1)/p + \epsilon_{j,t}.$$

The intercept (α) and circle effects (ω_j) for abundance are additive on the log scale. Temporal variation in counts is modeled as log-linear change (β , relative to baseline year t^*) and by specific year effects (γ_t). The model also includes a variable for effort (party-hours) in each circle each year ($\xi_{j,t}$), whose expected effect on the count is modeled by two parameters (B , p) that allow counts to approach a limit as more effort is expended in a circle (Link et al. 2006). The model also includes a parameter for overdispersion effects ($\epsilon_{j,t}$) to account for lack of fit to the Poisson model. Following Link et al. (2006), we estimated annual indices to population size across the CBC circles in which the species occurred during the survey period as follows:

$$N_t = \exp[\alpha + \beta(t - t^*) + \gamma_t].$$

We then estimated the overall trend for the CBCs during the 35 years between winter 1978–79 and winter 2013–14 as $100(T - 1)\%$, where

$$T = (N_{2013-14}/N_{1978-79})^{1/35}.$$

T represents the geometric rate of change in the annual abundance index between the first and last winter, which accounts for modeled random effects of year in addition to the underlying trend.

Four species were not recorded on any of the CBCs until after the first winter of the study.

TABLE 1. Primary habitat associations, survey effort, and total numbers of individuals recorded for 112 taxa of birds analyzed from Christmas Bird Counts (CBC) in the Central Valley of California between the winters of 1978–79 and 2013–14. For each taxon we present the number of CBC circles on which it was recorded, the total number of party-hours of effort in those circles, and the total number of birds counted across all survey years.

Species	Scientific name	Primary habitat ^a	Survey effort		Total birds
			Circles	Party-hours	
Greater White-fronted Goose	<i>Anser albifrons</i>	Wet	17	56,617	1,081,896
Snow Goose	<i>Chen caerulescens</i>	Wet	17	56,674	3,402,634
Ross's Goose	<i>Chen rossii</i>	Wet	17	56,674	329,572
Cackling Goose	<i>Branta hutchinsii</i>	Wet, Grass/Opn	17	56,674	562,838
Canada Goose	<i>Branta canadensis</i>	Wet, Dev	17	56,674	558,352
Tundra Swan	<i>Cygnus columbianus</i>	Wet	17	56,674	936,412
Wood Duck	<i>Aix sponsa</i>	Wet, Rip	17	56,674	34,258
Gadwall	<i>Anas strepera</i>	Wet	17	56,674	933,259
American Wigeon	<i>Anas americana</i>	Wet	17	56,674	3,562,884
Mallard	<i>Anas platyrhynchos</i>	Wet	17	56,674	1,436,023
Cinnamon Teal	<i>Anas cyanoptera</i>	Wet	17	56,674	44,556
Northern Shoveler	<i>Anas clypeata</i>	Wet	17	56,674	2,505,828
Northern Pintail	<i>Anas acuta</i>	Wet	17	56,674	7,017,684
Green-winged Teal	<i>Anas crecca</i>	Wet	17	56,674	923,028
Canvasback	<i>Aythya valisineria</i>	Opn Wat	17	56,674	246,097
Ring-necked Duck	<i>Aythya collaris</i>	Opn Wat, Wet	17	56,674	143,127
Lesser Scaup	<i>Aythya affinis</i>	Opn Wat	17	56,674	62,746
Bufflehead	<i>Bucephala albeola</i>	Opn Wat, Wet	17	56,674	92,156
Common Goldeneye	<i>Bucephala clangula</i>	Opn Wat	17	56,674	126,016
Hooded Merganser	<i>Lophodytes cucullatus</i>	Wet, Rip	17	56,534	6329
Common Merganser	<i>Mergus merganser</i>	Wet, Rip	17	56,612	68,774
Ruddy Duck	<i>Oxyura jamaicensis</i>	Opn Wat	17	56,674	698,553
California Quail	<i>Callipepla californica</i>	Chap, Oak Sav	17	56,674	84,567
Ring-necked Pheasant	<i>Phasianus colchicus</i>	Grass/Opn	17	56,674	16,372
Wild Turkey	<i>Meleagris gallopavo</i>	Oak Sav	13	47,732	23,676
Pied-billed Grebe	<i>Podilymbus podiceps</i>	Wet	17	56,674	43,185
Eared Grebe	<i>Podiceps nigricollis</i>	Opn Wat	17	56,500	21,005
<i>Aechmophorus</i> grebe (Western Grebe and Clark's Grebe)	<i>A. occidentalis</i> and <i>A. clarkii</i>	Opn Wat	17	56,674	65,135
Rock Pigeon	<i>Columba livia</i>	Dev	17	56,674	339,559
Eurasian Collared-Dove	<i>Streptopelia decaocto</i>	Dev	17	56,489	7209
Mourning Dove	<i>Zenaidura macroura</i>	Gen	17	56,496	175,954
Anna's Hummingbird	<i>Calypte anna</i>	Dev, Chap	17	56,674	30,841
Common Gallinule	<i>Gallinula galeata</i>	Wet	17	56,562	11,146
American Coot	<i>Fulica americana</i>	Opn Wat, Wet	17	56,628	2,477,793
Black-necked Stilt	<i>Himantopus mexicanus</i>	Wet	14	49,652	49,193
Killdeer	<i>Charadrius vociferus</i>	Wet, Grass/Opn	17	56,510	181,601
Long-billed Curlew	<i>Numenius americanus</i>	Wet, Grass/Opn	15	48,088	51,635
Dunlin	<i>Calidris alpina</i>	Wet	16	53,873	175,128
Least Sandpiper	<i>Calidris minutilla</i>	Wet	17	56,674	111,659
Long-billed Dowitcher	<i>Limnodromus scolopaceus</i>	Wet	17	56,387	159,397
Wilson's Snipe	<i>Gallinago delicata</i>	Wet	17	56,674	21,252
Greater Yellowlegs	<i>Tringa melanoleuca</i>	Wet	17	56,568	21,639
Ring-billed Gull	<i>Larus delawarensis</i>	Wet, Dev	17	56,674	336,493
California Gull	<i>Larus californicus</i>	Wet, Dev	17	56,626	429,829
Herring Gull	<i>Larus argentatus</i>	Wet	17	56,674	79,789
Double-crested Cormorant	<i>Phalacrocorax auritus</i>	Wet, Rip	17	56,629	94,010
Great Blue Heron	<i>Ardea herodias</i>	Wet, Grass/Opn	17	56,502	23,962
Great Egret	<i>Ardea alba</i>	Wet, Grass/Opn	17	56,502	45,449
Snowy Egret	<i>Egretta thula</i>	Wet	17	56,502	20,112
Cattle Egret	<i>Bubulcus ibis</i>	Grass/Opn	15	48,159	8354
Black-crowned Night-Heron	<i>Nycticorax nycticorax</i>	Wet	17	56,624	44,918
White-faced Ibis	<i>Eudocimus albus</i>	Wet	13	42,806	115,348
Turkey Vulture	<i>Cathartes aura</i>	Gen	17	56,502	56,186
White-tailed Kite	<i>Elanus leucurus</i>	Wet, Grass/Opn	17	56,674	17,706
Northern Harrier	<i>Circus cyaneus</i>	Wet, Grass/Opn	17	56,393	28,363

POPULATION TRENDS OF BIRDS WINTERING IN THE CENTRAL VALLEY OF CALIFORNIA

Species	Scientific name	Primary habitat ^a	Survey effort		Total birds
			Circles	Party-hours	
<i>Accipiter</i> spp. (Sharp-shinned Hawk, Cooper's Hawk, and Northern Goshawk)	<i>A. striatus</i> , <i>A. cooperi</i> , and <i>A. gentilis</i>	Rip	17	56,476	8090
Red-shouldered Hawk	<i>Buteo lineatus</i>	Rip	17	56,421	12,036
Red-tailed Hawk	<i>Buteo jamaicensis</i>	Grass/Opn, Oak Sav	17	56,674	71,838
Belted Kingfisher	<i>Megasceryle alcyon</i>	Rip	17	56,674	11,605
Lewis's Woodpecker	<i>Melanerpes lewis</i>	Oak Sav	16	54,139	5701
Acorn Woodpecker	<i>Melanerpes formicivorus</i>	Oak Sav, Rip	17	56,674	58,240
Nuttall's Woodpecker	<i>Picoides nuttallii</i>	Oak Sav, Rip	17	56,674	31,085
Downy Woodpecker	<i>Picoides pubescens</i>	Rip	17	56,674	6622
Northern Flicker	<i>Colaptes auratus</i>	Gen	17	56,674	114,360
American Kestrel	<i>Falco sparverius</i>	Grass/Opn	17	56,674	48,384
Black Phoebe	<i>Sayornis nigricans</i>	Rip, Dev	17	56,674	47,096
Say's Phoebe	<i>Sayornis saya</i>	Grass/Opn	17	56,674	9527
Loggerhead Shrike	<i>Lanius ludovicianus</i>	Grass/Opn, Chap	17	56,638	14,846
California Scrub-Jay	<i>Aphelocoma californica</i>	Oak Sav, Dev	17	56,086	197,214
Yellow-billed Magpie	<i>Pica nuttalli</i>	Oak Sav, Dev	16	54,214	155,946
American Crow	<i>Corvus brachyrhynchos</i>	Gen	17	56,335	667,341
Common Raven	<i>Corvus corax</i>	Gen	17	56,674	21,918
Horned Lark	<i>Eremophila alpestris</i>	Grass/Opn	16	54,183	185,599
Tree Swallow	<i>Tachycineta bicolor</i>	Rip, Wet	16	53,973	63,259
Oak Titmouse	<i>Baeolophus inornatus</i>	Rip, Oak Sav	16	54,113	65,688
Bushtit	<i>Psaltiriparus minimus</i>	Rip, Chap	17	56,648	190,933
White-breasted Nuthatch	<i>Sitta carolinensis</i>	Rip, Oak Sav	16	54,029	19,433
House Wren	<i>Troglodytes aedon</i>	Rip	17	56,502	4267
Marsh Wren	<i>Cistothorus palustris</i>	Wet	17	55,690	19,825
Bewick's Wren	<i>Thryomanes bewickii</i>	Rip, Chap	17	56,452	14,471
Golden-crowned Kinglet	<i>Regulus satrapa</i>	Rip	17	56,674	5787
Ruby-crowned Kinglet	<i>Regulus calendula</i>	Rip, Dev	17	56,674	124,491
Western Bluebird	<i>Sialia mexicana</i>	Oak Sav, Grass/Opn	17	56,674	106,221
Hermit Thrush	<i>Catharus guttatus</i>	Rip	17	56,612	24,309
American Robin	<i>Turdus migratorius</i>	Rip, Dev	17	56,621	553,904
Varied Thrush	<i>Ixoreus naevius</i>	Rip	16	53,238	5585
Northern Mockingbird	<i>Mimus polyglottos</i>	Dev, Oak Sav	17	56,674	36,314
European Starling	<i>Sturnus vulgaris</i>	Dev, Grass/Opn	17	56,674	12,309,072
Cedar Waxwing	<i>Bombycilla cedrorum</i>	Rip, Dev	17	56,674	141,828
House Sparrow	<i>Passer domesticus</i>	Dev	17	56,674	165,191
American Pipit	<i>Anthus rubescens</i>	Grass/Opn	17	56,674	245,030
House Finch	<i>Haemorhous mexicanus</i>	Dev, Rip	17	56,569	662,113
Lesser Goldfinch	<i>Spinus psaltria</i>	Dev, Oak Sav	17	56,674	220,581
American Goldfinch	<i>Spinus tristis</i>	Dev, Grass/Opn	17	56,674	203,334
Orange-crowned Warbler	<i>Oreothlypis celata</i>	Rip	17	56,615	6657
Yellow-rumped Warbler	<i>Setophaga coronata</i>	Gen	17	56,674	295,577
Spotted Towhee	<i>Pipilo maculatus</i>	Rip, Chap	17	56,674	78,451
California Towhee	<i>Melospiza crissalis</i>	Rip, Chap	17	56,674	37,039
Lark Sparrow	<i>Chondestes grammacus</i>	Oak Sav, Grass/Opn	17	56,607	95,594
Savannah Sparrow	<i>Passerculus sandwichensis</i>	Grass/Opn	17	56,674	243,898
Fox Sparrow	<i>Passerella iliaca</i>	Rip	17	56,503	16,697
Song Sparrow	<i>Melospiza melodia</i>	Rip, Wet	17	56,674	55,429
Lincoln's Sparrow	<i>Melospiza lincolni</i>	Rip, Wet	17	56,397	19,829
White-crowned Sparrow	<i>Zonotrichia leucophrys</i>	Rip, Chap	17	56,674	885,697
Golden-crowned Sparrow	<i>Zonotrichia atricapilla</i>	Rip, Chap	17	56,674	282,411
Dark-eyed Junco	<i>Junco hyemalis</i>	Gen	17	56,674	356,898
Red-winged Blackbird	<i>Agelaius phoeniceus</i>	Grass/Opn, Wet	17	56,674	5,597,095
Tricolored Blackbird	<i>Agelaius tricolor</i>	Grass/Opn, Wet	17	56,674	187,376
Western Meadowlark	<i>Sturnella neglecta</i>	Grass/Opn	17	56,526	659,473
Brewer's Blackbird	<i>Euphagus cyanocephalus</i>	Grass/Opn, Dev	17	56,674	3,339,272
Great-tailed Grackle	<i>Quiscalus mexicanus</i>	Wet, Dev	14	50,414	3382
Brown-headed Cowbird	<i>Molothrus ater</i>	Grass/Opn	17	56,674	100,617

^aChap, Chaparral/Scrub; Dev, Developed; Gen, General; Grass/Opn, Grassland/Open; Oak Sav, Oak savanna; Opn Wat, Open water; Rip, Riparian; Wet, Wetland.

For these, we excluded the early years with zero counts from the analysis and calculated the rate of change on the basis of the first subsequent winter during which the species was recorded: Cackling Goose (1983–84), Wild Turkey (1981–82), Eurasian Collared-Dove (2005–06), and Great-tailed Grackle (1989–90). When plotting annual indices, we followed the CBC's convention of designating a winter by its second year (e.g., 1979 for winter 1978–79).

To enable a comparison of trends from the Central Valley's CBC data to regional trends in breeding populations, we obtained BBS data for 1978 to 2014 from California and the Western BBS Region (west of the Rocky Mountains, excluding Alaska and northern Canada), with trends and 95% CIs estimated by means of the log-linear hierarchical model described by Sauer et al. (2017a). We compared CBC and BBS trends for concordance (both significantly positive or negative) or discordance (both significant, with opposite signs). We evaluated any BBS estimate with low precision (95% CI too imprecise to be able to detect a long-term trend of 5% per year) to determine if its inclusion in these comparisons influenced a conclusion.

RESULTS

On the basis of 56,674 party-hours of effort from the winter of 1978–79 to 2013–14, the total number of individuals of the 112 species or species groups we analyzed ranged from about 3300 for the Great-tailed Grackle to more than 12 million for the European Starling (Table 1). Almost all species ($n = 98$; 88%) were recorded in all 17 circles; a few (2–8 species each) were recorded in 13–16 circles. Across all 112 taxa, the long-term population trend on the CBCs was positive for 52 (46%), negative for 20 (18%), and not significantly different from zero for 40 (36%) (Table 2). See Appendix S1 for the annual indices and associated 95% CIs for population trajectories during the study period for each of the 112 taxa.

Birds associated with wetlands, open water, and riparian habitats were much more likely to show a positive than a negative trend. Among the 47 wetland-associated species, 23 (49%) showed a positive trend but only 5 (11%) showed a negative trend (Figure 2). Four of 9 (44%) open-water species (diving ducks, grebes, and coots) showed a positive trend and none showed a negative trend (Figure 3). Among the 32 riparian species analyzed, 19 (59%) showed a positive trend and only 3 (9%) showed a negative trend (Figure 4). Increases were more frequent than decreases

FIGURE 2. Significant trends (% change per year) for species associated with wetlands, based on Christmas Bird Counts in the Central Valley of California between the winters of 1978–79 and 2013–14. Estimates are medians $\pm$ 95% credible intervals. Species marked with an asterisk were assigned to another primary habitat association in addition to wetlands.

among habitat generalists, species associated with oak savanna, and those associated with developed areas (Figures 5–7). By contrast, among the 25 species associated with grasslands and other open habitats, the trends of 12 (48%) were negative and only 7 (28%) were positive (Figure 8). Two of 9 chaparral/scrub-associated species showed a positive trend and 3 showed a negative trend (Figure 9).

We compared the trends we calculated for wintering birds in the Central Valley on the basis of the CBC to those for breeding birds available for California ($n = 93$ species) and the Western BBS Region ($n = 100$ species; Table 2) on the basis of the BBS. Among the 43 species whose trend on the CBCs was positive and for which California BBS data were available, the trend based on those BBS data was also positive in 23 (53%). Importantly, in only 5 species (12%) were

FIGURE 3. Significant trends (% change per year) for species associated with open water, based on Christmas Bird Counts in the Central Valley of California between the winters of 1978–79 and 2013–14. Estimates are medians $\pm$ 95% credible intervals. Species marked with an asterisk were assigned to another primary habitat association in addition to open water.

the trends contradictory (positive from our CBC analysis vs. negative from the BBS in California). Nineteen species that showed negative trends in our analysis of CBC data also had California BBS data available, and, of those, the trend according

FIGURE 4. Significant trends (% change per year) for species associated with riparian habitats, based on Christmas Bird Counts in the Central Valley of California between the winters of 1978–79 and 2013–14. Estimates are medians $\pm$ 95% credible intervals. Species marked with an asterisk were assigned to another primary habitat association in addition to riparian.

FIGURE 5. Significant trends (% change per year) for habitat generalists, based on Christmas Bird Counts in the Central Valley of California between the winters of 1978–79 and 2013–14. Estimates are medians $\pm$ 95% credible intervals. Each of these species was commonly associated with three or more habitat types.

to the BBS was also negative in 14 (74%). Only one species whose trend on Central Valley CBCs was negative, the American Goldfinch, had a contradictory (positive) trend on the BBS in California. When comparing trends on Central Valley CBCs with trends on the BBS in the Western BBS Region as a whole, we found that of the 49 species with a positive trend on Central Valley CBCs, 19 (39%) also had a concordant positive trend according to the BBS; 11 (22%) showed a discordant negative trend in the breeding population. Among the 19 species with a negative trend on CBCs in the valley, 17 (89%) had a concordant negative trend in the Western BBS Region and no species had a contradictory positive trend.

FIGURE 6. Significant trends (% change per year) for species associated with oak savanna, based on Christmas Bird Counts in the Central Valley of California between the winters of 1978–79 and 2013–14. Estimates are medians $\pm$ 95% credible intervals. Species marked with an asterisk were assigned to another primary habitat association in addition to oak savanna.

TABLE 2. Annual percent change in numbers of birds estimated from Christmas Bird Counts (CBC) in the Central Valley of California between the winters of 1978–79 and 2013–14 in comparison with annual percent change estimated from the North American Breeding Bird Survey (BBS) in California (CA) and the Western BBS Region (Western), 1978–2014 (Sauer et al. 2017a). For the CBC, we present the median and 95% credible intervals (CIs); boldface indicates that 95% CIs do not overlap zero. Estimates based on the BBS are presented only if the 95% CI does not overlap zero; NS = not significant; blanks indicate no estimates were available for that region.

Species	CBC—Central Valley, CA			BBS	
	Median	2.5%	97.5%	CA	Western
Greater White-fronted Goose	5.6	2.7	8.2		
Snow Goose	–1.3	–4.6	1.6		
Ross's Goose	1.8	–1.6	5.3		
Cackling Goose	13.9	7.7	21.3		
Canada Goose	2.0	–0.3	3.6	NS	5.5
Tundra Swan	–2.7	–6.6	0.1		
Wood Duck	4.0	1.9	5.6	3.9	NS
Gadwall	6.9	4.3	9.4	4.7	1.7
American Wigeon	2.7	0.3	5.2	NS	NS
Mallard	0.9	–0.5	2.3	2.1	NS
Cinnamon Teal	7.6	5.4	9.9	–2.6	–2.6^a
Northern Shoveler	6.9	3.8	9.3		
Northern Pintail	–3.8	–6.5	–1.5	–8.5	–4.2
Green-winged Teal	3.6	0.7	6.4	6.9	NS
Canvasback	–0.2	–2.7	2.4		NS
Ring-necked Duck	2.4	0.0	4.8	18.8^a	4.0
Lesser Scaup	0.7	–2.1	3.2		NS
Bufflehead	7.0	5.2	8.9		NS
Common Goldeneye	6.5	5.1	7.9		NS
Hooded Merganser	9.2	7.7	10.8		NS
Common Merganser	3.3	1.2	5.4	NS	–1.5
Ruddy Duck	–0.7	–2.0	0.5	NS	NS
California Quail	–2.1	–3.5	–0.8	NS	NS
Ring-necked Pheasant	–6.5	–8.0	–5.0	–3.4	–2.6
Wild Turkey	32.8	26.7	39.3	14.5	9.8
Pied-billed Grebe	–0.2	–1.0	0.6	NS	NS
Eared Grebe	1.8	–0.8	4.5	NS ^a	NS
<i>Aechmophorus</i> spp.	2.9	0.9	4.9	NS	NS
Rock Pigeon	1.9	0.8	2.8	NS	1.2
Eurasian Collared-Dove	92.3	69.7	121.4	55.8^a	39.7^a
Mourning Dove	1.1	–0.3	2.3	–0.9	–1.0
Anna's Hummingbird	4.5	3.7	5.4	2.2	2.6
Common Gallinule	1.0	–0.9	2.8	NS	NS
American Coot	0.3	–1.3	2.0	–2.9	–1.5
Black-necked Stilt	13.1	10.9	15.4	NS	NS
Killdeer	–1.2	–2.4	–0.1	–2.3	–3.0
Long-billed Curlew	0.0	–2.5	2.9	NS	1.3
Dunlin	0.2	–2.4	3.4		
Least Sandpiper	–0.2	–1.9	1.9		
Long-billed Dowitcher	–0.5	–3.1	2.4		
Wilson's Snipe	–1.9	–3.9	0.0	–3.0	–0.9
Greater Yellowlegs	2.9	1.5	4.4		NS
Ring-billed Gull	–0.3	–2.1	1.4	NS	NS
California Gull	5.5	3.5	7.5	–5.0	NS
Herring Gull	2.3	0.4	4.5		NS ^a
Double-crested Cormorant	11.9	9.3	14.6	4.0	3.6
Great Blue Heron	–0.6	–1.0	–0.1	NS	–0.6
Great Egret	2.6	1.6	3.5	5.6	4.2
Snowy Egret	4.8	3.2	6.3	4.7	NS
Cattle Egret	3.1	–1.4	8.0	7.4^a	NS ^a
Black-crowned Night-Heron	–1.4	–3.2	0.7	NS	NS
White-faced Ibis	30.6	23.2	39.2	37.9^a	10.4^a
Turkey Vulture	8.1	6.9	9.4	2.6	1.9

POPULATION TRENDS OF BIRDS WINTERING IN THE CENTRAL VALLEY OF CALIFORNIA

Species	CBC—Central Valley, CA			BBS	
	Median	2.5%	97.5%	CA	Western
White-tailed Kite	-1.1	-2.2	0.0	-2.6	-2.4
Northern Harrier	-0.3	-1.0	0.5	NS	-0.5
<i>Accipiter</i> spp.	0.4	-0.3	1.1	NS	NS
Red-shouldered Hawk	4.6	3.7	5.5	5.4	5.6
Red-tailed Hawk	0.8	0.3	1.3	0.9	1.3
Belted Kingfisher	0.2	-0.3	0.6	-2.2	-1.7
Lewis's Woodpecker	-2.3	-5.5	1.0	-3.2	-2.3
Acorn Woodpecker	1.3	0.4	2.2	NS	0.9
Nuttall's Woodpecker	1.8	1.2	2.4	1.4	1.4
Downy Woodpecker	1.1	0.3	1.9	NS	NS
Northern Flicker	-0.9	-1.5	-0.3	NS	-0.7
American Kestrel	-2.3	-2.8	-1.9	-1.0	-1.2
Black Phoebe	2.7	2.3	3.3	2.8	2.6
Say's Phoebe	2.2	1.4	3.2	NS	1.1
Loggerhead Shrike	-2.6	-3.5	-1.8	-2.3	-1.1
California Scrub-Jay	-0.1	-0.9	0.7	NS	NS
Yellow-billed Magpie	-3.5	-4.7	-2.3	-3.0	-3.0
American Crow	3.6	2.1	5.2	0.8	NS
Common Raven	12.8	11.5	14.1	5.0	2.6
Horned Lark	-3.0	-4.7	-1.2	-1.7	-1.4
Tree Swallow	5.3	1.6	8.7	1.0	NS
Oak Titmouse	0.3	-0.5	1.1	-1.7	-1.7
Bushtit	2.2	1.3	3.1	NS	NS
White-breasted Nuthatch	3.2	2.4	4.2	1.0	NS
House Wren	2.6	1.4	3.9	NS	NS
Marsh Wren	-0.1	-1.2	0.9	2.4	2.3
Bewick's Wren	-1.1	-1.6	-0.5	-0.8	-0.6
Golden-crowned Kinglet	1.7	-1.0	4.6	NS	-2.2
Ruby-crowned Kinglet	-0.5	-1.3	0.3	-6.0	NS
Western Bluebird	2.8	1.6	3.9	1.1	0.8
Hermit Thrush	2.4	1.1	3.6	NS	-0.7
American Robin	3.8	2.1	5.6	-0.4	-0.6
Varied Thrush	2.9	0.1	5.9	NS	-2.5
Northern Mockingbird	1.1	0.4	1.8	NS	-0.5
European Starling	0.2	-1.1	1.3	-0.9	-1.8
Cedar Waxwing	4.0	1.7	6.5		NS
House Sparrow	-1.5	-2.6	-0.5	-1.9	-2.3
American Pipit	-3.0	-4.1	-1.9		
House Finch	-2.4	-3.6	-1.3	-1.0	-0.6
Lesser Goldfinch	-1.1	-2.1	0.1	NS	1.2
American Goldfinch	-2.1	-3.9	-0.2	1.4	-1.6
Orange-crowned Warbler	2.5	1.5	3.4	-0.8	-0.9
Yellow-rumped Warbler	2.3	1.2	3.3	1.5	-0.6
Spotted Towhee	0.5	-0.4	1.3	NS	NS
California Towhee	0.5	-0.2	1.1	NS	NS
Lark Sparrow	-2.8	-3.9	-1.8	-1.3	NS
Savannah Sparrow	1.0	-0.2	2.3	NS	-1.3
Fox Sparrow	2.2	0.6	3.8	NS	-0.9
Song Sparrow	-0.9	-1.9	0.0	NS	-0.6
Lincoln's Sparrow	0.9	-0.5	2.3	NS	3.7
White-crowned Sparrow	-0.3	-1.1	0.6	NS	NS
Golden-crowned Sparrow	0.8	-0.1	1.7		
Dark-eyed Junco	-0.7	-1.6	0.3	NS	-1.3
Red-winged Blackbird	1.6	0.4	2.9	-1.7	-1.2
Tricolored Blackbird	3.3	-1.1	7.0	NS	
Western Meadowlark	-2.6	-3.4	-1.9	-2.3	-1.6
Brewer's Blackbird	-2.8	-3.6	-2.0	-2.1	-2.0
Great-tailed Grackle	43.4	30.3	56.9	19.9	6.2
Brown-headed Cowbird	2.4	0.6	4.3	NS	-1.6

^aEstimate imprecise; 95% CI was larger than that required to detect an annual change of 5% per year.

FIGURE 7. Significant trends (% change per year) for species associated with developed areas, based on Christmas Bird Counts in the Central Valley of California between the winters of 1978–79 and 2013–14. Estimates are medians $\pm$ 95% credible intervals. Species marked with an asterisk were assigned to another primary habitat association in addition to developed areas.

FIGURE 8. Significant trends (% change per year) for species associated with grasslands/open country, based on Christmas Bird Counts in the Central Valley of California between the winters of 1978–79 and 2013–14. Estimates are medians $\pm$ 95% credible intervals. Species marked with an asterisk were assigned to another primary habitat association in addition to grasslands.

FIGURE 9. Significant trends (% change per year) for species associated with chaparral/scrub, based on Christmas Bird Counts in the Central Valley of California between the winters of 1978–79 and 2013–14. Estimates are medians $\pm$ 95% credible intervals. Species marked with an asterisk were assigned to another primary habitat association in addition to chaparral/scrub.

For 7 species, estimates of trends from BBS data in one or both regions were not precise enough to detect a change of up to 5% per year (Table 2). Among these, the trend in the CBC data was discordant from that in the BBS data in only one species, the Cinnamon Teal. Its trend was positive on the winter CBCs but negative according to the BBS at both the regional level (low precision) and in California only.

DISCUSSION

WETLAND SPECIES

More than a century of urbanization and agricultural development across the Central Valley of California has resulted in the widespread degradation and loss of more than 90% of the region's historic wetlands (Katibah 1984, Nelson et al. 2003). During recent decades, however, there has been a marked reversal of this trend (Garone 2011). Emphasis on preservation, restoration, and creation has increased the valley's wetlands by an estimated 75% since the 1970s, although natural wetlands and seasonally flooded agricultural fields together currently cover only about 3% of the valley (CVJV 2006, Garone 2011, Fleskes et al. 2018). Since the mid-1990s, the proportion of rice fields flooded in winter has increased from less than 10% to nearly 70%, adding tens of thousands of hectares of winter habitat for wetland-associated birds (Elphick and Oring 2003, Fleskes et al. 2005, Sterling and Buttner 2011, Dybala et al. 2017, P. Buttner pers. comm.). This increase in available habitat has likely contributed to the proportion of wetland-associated species with positive trends (49%) being much greater than that with

negative trends (11%), although there is evidence for additional factors at play.

For example, for the Cackling Goose, the waterfowl species showing the greatest upward trajectory, it is important to note that its increase in abundance was due almost entirely to rebounding of the population of the Aleutian subspecies (*B. h. leucopareia*). This population has recovered dramatically from near extinction since the 1970s, following removal of arctic foxes (*Vulpes lagopus*) from its breeding islands in Alaska, a program of captive breeding and reintroduction, and subsequent management and protection of habitats where the geese stage and winter (Mini et al. 2011). Concomitant with the increase of the Aleutian goose population in the Central Valley was a pronounced decline in numbers of the other commonly wintering subspecies, the Cackling Goose proper (*B. h. minima*), whose primary winter distribution shifted northward during the early 1990s from the valley into Oregon and Washington (Pacific Flyway Council 2016). In the Central Valley, Aleutian geese are now much more often found in irrigated pastures, or in flooded fields of crops other than rice, than in marshes or flooded rice fields (Deuel 2005, ERP pers. obs.).

All waterfowl wintering in the region have likely benefited from conservation measures both inside and outside the Central Valley, such as harvest restrictions and intensive habitat management. These were initiated in the 1980s to assist in the recovery of the Cackling Goose and declining populations of several other geese and ducks (CVJV 2006, Pacific Flyway Council 2016, Fischer et al. 2018, Fleskes et al. 2018). Since most Cinnamon Teal winter south of the United States, increasing winter temperatures in the Central Valley may also have made this area more attractive to it and some other species, such as the Black-necked Stilt and Tree Swallow (Pandolfino 2012, W. D. Shuford pers. comm.). The anomalous negative population trend of the Northern Pintail, the most abundant species of waterfowl wintering in the valley, reflects its continent-wide decline, which has not yet been reversed (USFWS 2017, Fleskes et al. 2018).

The increase in numbers of the Double-crested Cormorant is not likely related to restoration of the Central Valley's wetlands, which are generally too shallow for this diving species; its positive trend is more likely linked to other ancillary factors (see below). Shuford et al. (1996) suggested that the large increase in numbers of the White-faced Ibis wintering in California may be linked to a westward shift in the species' breeding range

due to changing hydrological conditions in the Great Basin, in addition to an increase of habitat in the Central Valley. The rapid increase in numbers of the Great-tailed Grackle on the region's CBCs since the species was first recorded during winter 1989–90 reflects its swift range expansion throughout the western United States (Wehtje 2003). While likely aided in their recent colonization of the valley by increased wetlands, grackles also readily take advantage of human development and feedlots (Wehtje 2003, Pandolfino et al. 2009).

RIPARIAN SPECIES

Over the past 150 years, about 95% of the historical riparian habitat in the Central Valley has been lost or severely degraded, primarily as a result of agricultural development and urbanization (Katibah 1984, Nelson et al. 2003). Beginning in the 1990s, concerted efforts to preserve and restore natural riparian vegetation have increased the amount and ecological quality of this habitat, although it still covers less than 1% of the valley (RHJV 2004, CVJV 2006, Golet et al. 2008, 2011, Griggs 2009, Dybala 2017). Studies along the Sacramento River (Gardali et al. 2006, Golet et al. 2008, 2011) demonstrated that restoration has been effective in increasing both the abundance and diversity of birds using riparian habitats throughout the annual cycle, although local increases in breeding populations have not generally been reflected at broader spatial scales (Gardali et al. 2006). We infer that the disproportionately greater number of riparian-associated species with positive trends (19) than with negative trends (3) resulted at least in part from the efforts at restoration.

Other factors contributing to population changes in this guild, however, may be as diverse as the list of species. The four species that are relatively sedentary residents within riparian habitat—Nuttall's Woodpecker, Bushtit, White-breasted Nuthatch, and Bewick's Wren—may be the ones most likely to benefit from increases in the quality or extent of that habitat. Among these species, the trend was negative only for Bewick's Wren. Similarly, in oak woodland in the western foothills of the Sierra Nevada, Purcell and Mori (2018) found positive trends for Nuttall's Woodpecker and the White-breasted Nuthatch and a negative trend for Bewick's Wren, raising the possibility that trends in the Central Valley populations are being governed by factors operating at broader spatial scales. The increase in the Double-crested Cormorant, at a rate greater than for any

other riparian species in this study, may have more to do with its productivity at a few western breeding sites (Adkins et al. 2014, Shuford 2014) and recovery from the effects of DDT (Hatch 1995) than with improvements in winter habitat. Intensive nest-box programs have certainly aided increases in the Wood Duck (Hepp and Bellrose 2013) as well as abetted the expansion of the breeding range of the Hooded Merganser into the Central Valley (Pandolfino et al. 2006, Conard et al. 2012). Increasing numbers during winter of Tree Swallows in the valley (Pandolfino 2012) and House Wrens in southern California (Unitt 2004) are thought to be linked to increasing winter temperatures in recent decades. Cedar Waxwings also use developed areas, where increases in fruiting trees and shrubs have likely contributed to their increase (Witmer et al. 2014). A decline in House Finch populations throughout the United States has been linked to a high rate of conjunctivitis caused by *Mycoplasma gallisepticum* (Badyaev et al. 2012).

GRASSLAND/OPEN COUNTRY SPECIES

During the past 150 years, the Central Valley has lost about 60% of its historic grasslands (Katibah 1984, Nelson et al. 2003, DiGaudio et al. 2017). In contrast to the increases in wetland and riparian habitat noted above, in recent decades the valley's grasslands have continued to be lost at a significant rate (~5000 ha per year) to urbanization and conversion to vineyards and orchards (CDOC 2008, Volpe et al. 2010, Cameron et al. 2014). Across the continent, large expanses of native grasslands have been lost and degraded, and declines in grassland bird populations have been more widespread and more rapid than for any other avian guild (Peterjohn and Sauer 1999, McCracken 2005, Askins et al. 2007, Sauer et al. 2013, 2017b).

Most studies cite habitat loss and degradation as major factors in these declines (Scheiman et al. 2003, Brennan and Kuvlesky 2005). In a landscape-level analysis, Hill et al. (2014) suggested that trends of grassland birds' populations in the United States are most negatively related to the level of agricultural intensification, such as overgrazing and conversion to monocultures, and most positively related to the amount of agricultural land placed in the Conservation Reserve Program, in which farmers are paid to remove environmentally sensitive areas from production. Changes in specific agricultural practices have also contributed to negative trends. Clearing of shrubby or weedy edges of fields has been implicated

in declines of the Ring-necked Pheasant (Nielson et al. 2008). Clearing of brush and small trees in otherwise open habitats can reduce nest sites for the Loggerhead Shrike (Tyler 1992), and removing snags can eliminate nesting cavities for species such as the American Kestrel (Smallwood and Bird 2002). Because loss and degradation of grasslands have been so widespread, it is likely that declines on the breeding grounds of migratory grassland birds are contributing to these species' declines where they winter in the Central Valley.

Seven of the 19 grassland species for which we found a significant trend increased. Among these species, the Cackling Goose (which in the valley during winter now consists primarily of the Aleutian subspecies) also uses wetlands. Among open habitats, it uses mainly flooded crops and irrigated grasslands rather than unirrigated grasslands (Deuel 2005, ERP pers. obs.). The Great Egret and Red-winged Blackbird, while using grasslands extensively in winter, also make frequent use of wetlands. The Red-tailed Hawk and Western Bluebird also use oak savannas regularly. Thus the Say's Phoebe and Brown-headed Cowbird are the only grassland specialists that showed a significant positive trend. Thompson et al. (2016) found that during the breeding season the Brown-headed Cowbird was more abundant in grasslands where scattered trees, shelterbelts, and woodlots were retained than in those where they were experimentally removed. Thus the presence of such features may have contributed to local population increases in the Central Valley. Without knowing where the Say's Phoebes wintering in the valley breed, we find it difficult to postulate why this species has increased in winter. Perhaps the Say's Phoebe, as the only dedicated insectivore among the 24 birds assigned to this guild, has benefited from the same increase in winter temperatures noted above for the Tree Swallow.

COMPARISON OF TRENDS

When population trends based on different surveys are compared, it is important to recognize the inherent limitations of each method. BBS routes are randomly distributed roadside surveys but are dependent on the availability and willingness of volunteers. Therefore, the BBS covers very remote areas with few roads or with few potential volunteers only sparsely (Sauer et al. 2003, Handel and Sauer 2017). BBS routes can also be a poor source of data on species with patchy distributions, such as those nesting colonially (Robbins et al. 1986). CBC circles are nonrandomly located and also depend on volunteers. They are conducted as area

searches, but consistent coverage of the habitats within a given circle is limited by the degree of public access and lack of standardized methods and effort; furthermore, the nonrandom selection of circles restricts inference to the areas actually sampled (Sauer and Link 2002). Any comparison of results based on BBS and CBC data must also acknowledge that the nature of the habitats covered by each differs. CBC circles are concentrated in areas of denser human development (Dunn et al. 2005), whereas active BBS routes have the opposite bias because routes in urban areas tend to be abandoned as a result of high levels of noise and lack of volunteers (O'Connor et al. 2000). A visual examination of the locations of CBC circles (Figure 1) and currently active BBS routes (Sauer et al. 2013) in California illustrates this bias.

Aerial surveys of breeding or wintering waterfowl probably provide the best estimates for species found in open habitats and at high concentrations. Aerial surveys present identification issues for some species, resulting in some data for two species being lumped into one category (e.g., “white” geese, Cinnamon/Blue-winged Teal [*Anas discors*], scaup species, and goldeneye species). In an analysis of aerial survey data on waterfowl wintering in the Central Valley between 1973 and 2000, Fleskes et al. (2018) found a decrease in abundance (i.e., number of bird-use-days per winter) of the Northern Pintail and increases in the Green-winged Teal and Gadwall, all consistent with our findings for these three species. Other dabbling ducks, the Mallard, American Wigeon, and Northern Shoveler, showed stable numbers and/or shifts in distributions, while our data showed increases in the American Wigeon and Northern Shoveler. Fleskes et al. (2018) reported an increase of both diving ducks and geese, and increases of “dark” geese (Canada, Cackling, and Greater White-fronted geese) greater than those of “white” geese (Snow and Ross’s geese); these trends generally matched our findings of increases in diving ducks and most “dark” geese but stable numbers of “white” geese. The minor discrepancies between our findings and those of Fleskes et al. (2018) could be due to shifts in distribution within the valley relative to the areas sampled by the CBC circles, to the different time periods compared, or to some combination of factors. Our estimates of population increases may have been biased high for many waterfowl because the CBC circles are concentrated in the northern part of the valley, where abundance has recently increased in part because of northward distributional shifts (Fleskes et al. 2018).

Assessing whether trends based on the CBC should reflect those from the BBS and, if so, at what spatial scale requires information on how breeding and wintering distributions are linked. Except for a few relatively sedentary species such as the Bewick’s Wren and California Towhee and some waterfowl for which band recoveries are relatively frequent, we have only very general knowledge of the breeding locations of most birds that winter in the Central Valley. Even species that are found in the valley year round, such as the Red-tailed Hawk, Horned Lark, and Western Meadowlark, have their winter abundance dramatically increased by migrants from elsewhere. In some species the subspecies breeding in California are not commonly found in winter in the valley and so concordance of their trends should not be expected. Examples include the White-crowned Sparrow and Fox Sparrow. The primary subspecies of the White-crowned Sparrow (*Z. l. gambelii*) that winters in the Central Valley does not breed in California (Dunn and Alderfer 2017), and the only Fox Sparrow subspecies (“thick-billed”; *P. i. megarhyncha*, *stephensi*, and *brevicauda*) breeding in California (Weckstein et al. 2002) are very rarely found in the valley (ERP pers. obs.).

Nonetheless, trends of species that are undergoing widespread and substantial population changes should show some congruence across regional surveys, which is generally what we found when comparing results of our analysis of the CBC with trends based on the BBS from California and from western North America more broadly. In our comparison with California BBS data, we found a strong level of concordance in trends, with 61% of the species showing the same sign (positive, negative, or apparently stable) in the two surveys; an additional 32% showed only slight discrepancies, with populations being apparently stable (or the data were inadequate to detect a trend) in one survey but increasing or declining on the other. In only 6% of the species with data from both sources were trends based on the California BBS and Central Valley CBCs highly discordant (i.e., trends significant but opposite in sign). In comparison with data from the Western BBS Region the pattern was similar, 52% of the species having concordant trends, 37% slightly discrepant trends, and only 11% highly discordant trends.

It was striking that the strongest signal of concordance was found among species with declining trends: among the 19 species declining on the CBCs and for which BBS data were available, 14 (74%) were also declining in California as a whole and 17 (89%) were declining across the western

region, according to the BBS. Thus there appears to be general concordance between the trends revealed by CBC and BBS data, suggesting that the Central Valley's CBC data may reflect broader regional trends, particularly for declining species. Without more direct study, it is impossible to conclude whether the same factors were driving declines at both local and regional or continental scales.

In four species the trend on Central Valley CBCs is discordant with those based on the BBS in both California and the Western BBS Region: Cinnamon Teal, American Robin, Orange-crowned Warbler, and Red-winged Blackbird. In each case, a positive trend according to CBC data contrasts with a negative trend according to the BBS. Positive trends for the Cinnamon Teal and Red-winged Blackbird on CBCs may reflect increased attraction to restored valley wetlands during winter despite regional or statewide declines in breeding populations. Although the estimate of the negative trend of the Cinnamon Teal's breeding population in the Western BBS Region is highly imprecise, that for California alone is more precise and reliable, being based on a large sample (81 routes). As noted above, increasing winter temperatures in the Central Valley may have encouraged more Cinnamon Teal to overwinter there, and the Orange-crowned Warbler has apparently shifted its wintering range northward in California in recent decades (Unitt 2004). Without more understanding of the breeding locations and movements of American Robins and Orange-crowned Warblers that winter in the valley, we have no clear explanation why they should be increasing on CBCs, despite significant declines of populations breeding in California and/or the Western BBS Region. Possible drivers of this increase may include attraction to restored riparian habitats or a benefit from increased urban/suburban berry crops.

Trends based on Central Valley CBCs and California BBS routes were also discordant for the California Gull and American Goldfinch. The positive trend for the gull in CBC data likely reflects a positive response of wintering birds to restored wetlands in the valley. The negative trend according to the BBS, however, does not provide an accurate measure of the population's trajectory, since colonial species are often poorly monitored by the roadside survey (Robbins et al. 1986). Long-term monitoring at gull colonies in the western United States has revealed recent exponential increases at colonies near the Central

Valley (e.g., in San Francisco Bay) and evidence of westward and southward range expansion in California since 1980 (Burns et al. 2018, Doster and Shuford 2018). The trend for this species in the broader Western BBS Region was nonsignificant but slightly positive (0.3% per year) with a very wide confidence interval (−2.8 to 3.6% per year), which is consistent with high annual variability in abundance at nesting colonies (Doster and Shuford 2018). Thus interpretation of the California Gull's population trends is complicated by the species' clustered and constantly shifting distribution. A negative trend for the American Goldfinch on Central Valley CBCs vs. a positive trend on California BBS routes is perplexing because the subspecies breeding in California (*S. t. salicamans*) is believed to be resident (Dunn and Alderfer 2017), although there may be some local seasonal movements (W. D. Shuford pers. comm.).

Seven species with positive trends on the valley's CBCs had negative trends on the BBS in its Western Region but not in California alone. One of these species, the Yellow-rumped Warbler, is unusual in that its trend on California BBS routes is positive, in agreement with that on Central Valley CBCs, despite a negative trend in the data from the broader Western Region. This pattern could be due to a large proportion of the birds wintering in the Central Valley also breeding in California. However, beyond the fact that most Yellow-rumped Warblers wintering in the Central Valley represent *S. c. auduboni*, we know little about the breeding range of these birds.

On the basis of BBS data from California alone, none of the other six species, the Common Merganser, Hermit Thrush, Varied Thrush, Northern Mockingbird, Fox Sparrow, and Brown-headed Cowbird, showed a significant trend. As noted above for other species, our lack of knowledge about the breeding ranges of the Common Mergansers, Northern Mockingbirds, and Brown-headed Cowbirds wintering in the valley makes evaluation of potential causes of these discordant trends difficult. For the Common Merganser, however, male-mediated gene flow obscures any connectivity between breeding and wintering areas (Pearce et al. 2009) and so limits the utility of BBS data to explain local trends in wintering populations.

In contrast, Fox Sparrows and Hermit Thrushes show stronger migratory connectivity. Fox Sparrows wintering in the Central Valley are of the "Sooty" subspecies group, which breeds largely

outside the Western BBS Region (Weckstein et al. 2002). Thus a trend calculated from data from the Western BBS Region as a whole represents an amalgam of population trajectories and illustrates the potential pitfalls of comparing trends at inappropriate spatial scales. In an analysis of BBS data from Alaska, Handel and Sauer (2017) found a slight (<1% per year) but significant increase in abundance of Fox Sparrows breeding along the southern coast of Alaska (part of the “Sooty” group), a finding consistent with the increase of the population wintering in the Central Valley. Similarly, based on the breeding distribution of the subspecies wintering in California, the origin of Hermit Thrushes wintering in and around the Central Valley can be narrowed at least to Alaska (Grinnell and Miller 1944, Dellinger et al. 2012, P. Unitt pers. comm.), where breeding populations have been stable or increasing (Handel and Sauer 2017).

The conflict between positive trend for the Varied Thrush on Central Valley CBCs and the decline seen from regional BBS data can likely be explained by increases in the species’ highly irruptive occurrence in the Central Valley during winter (Pandolfino 2006; Appendix S1). However, these irruptions seem to be composed mostly of a subspecies (*I. n. meruloides*; Grinnell and Miller 1944, Pandolfino 2015) that does not breed in California, further confounding explanations of the seasonal discrepancy in trends, particularly since long-term surveys in Alaska suggest that populations breeding farther north have remained stable (Handel and Sauer 2017).

CONSERVATION IMPLICATIONS

The population trends we documented for species wintering in the Central Valley of California are mostly consistent with larger regional trends in breeding populations from BBS data. Therefore, the trends estimated from CBCs are likely to represent real changes in winter populations using the valley rather than anomalies of sampling. Because of our general lack of knowledge about the exact movements of individual migratory birds, it is difficult to separate the effects that may be occurring on the breeding grounds from those in the winter range. However, one can see consistency between the observed trends by habitat guild and the conservation priorities in the region in recent decades. In general, populations of birds having strong associations with wetlands, open water, riparian habitats, and human-altered landscapes are stable or increasing, whereas those of grassland birds are

more likely to be in decline. Bird conservation in the Central Valley has focused on wetlands and riparian areas, which have increased in extent and quality as a result. At the same time, the human footprint in the valley has continued to expand, mostly at the expense of grasslands (Cameron et al. 2014).

Except for vernal pool grasslands, which enjoy some protection through requirements for wetland mitigation and the presence of species of plants and invertebrates listed as endangered, grasslands are usually converted to other uses without any compensatory conservation (AECOM 2009, Cameron et al. 2014). Even mitigation for vernal pools tends to be on a small scale, focused on the pools alone, and not at the landscape scale that nearly all grassland birds require (VC and AECOM 2009). Preservation of grasslands at the scale needed to conserve grassland bird populations is clearly beyond the scope of public funding to acquire the necessary land. One key to retaining sufficient grasslands may be to retain cattle ranching as an economically viable enterprise (Cameron et al. 2014, M. Hammond pers. comm.). Effective initiatives could include more funding for conservation easements to keep ranches in operation, incentives for ranchers to keep land as rangeland (e.g., in the Grassland Reserve Program), and the sort of public–private partnerships that have made the Central Valley and Riparian Habitat joint ventures successful (RHJV 2004, CVJV 2006). Unless grasslands can be given a much higher priority for conservation, we can expect to see a continued loss of this habitat throughout the Central Valley, with continued declines of grassland-associated birds likely to follow.

Conservation initiatives to protect the valley’s grasslands would benefit from further research focused on (1) identifying and prioritizing habitat characteristics most important for conservation of declining species and (2) identifying grassland-management practices that enhance the quality of grasslands for birds while maintaining compatibility with ranching (Hammond et al. 2018). Controlled studies of grazed and ungrazed plots (e.g., Gennet et al. 2017) can serve to identify specific floristic and topographic features that are most conducive to use of managed lands by grassland birds. Demographic studies and identification of the breeding areas and migratory corridors of birds wintering in the valley would also be helpful in discerning the factors that govern long-term population trends. Continued monitoring of wintering populations through the CBC is useful

for all species but can provide critically important information for species such as the American Pipit that breed largely in northern North America and so are poorly monitored by other survey programs.

ACKNOWLEDGMENTS

We are indebted to the compilers of the Central Valley's CBCs who maintain these counts year after year, and to the many volunteers who gather these data. In particular, we thank CBC compilers who provided data to fill in gaps in the online database: Bruce Deuel, Cliff Hawley, and Jim Rowoth. Dave Shuford, Sid England, Robert Gill, John Pearce, and an anonymous reviewer provided many insightful recommendations that greatly improved the clarity and quality of the manuscript. Any use of trade, firm, or product names is for descriptive purposes and does not imply endorsement by the U.S. government.

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