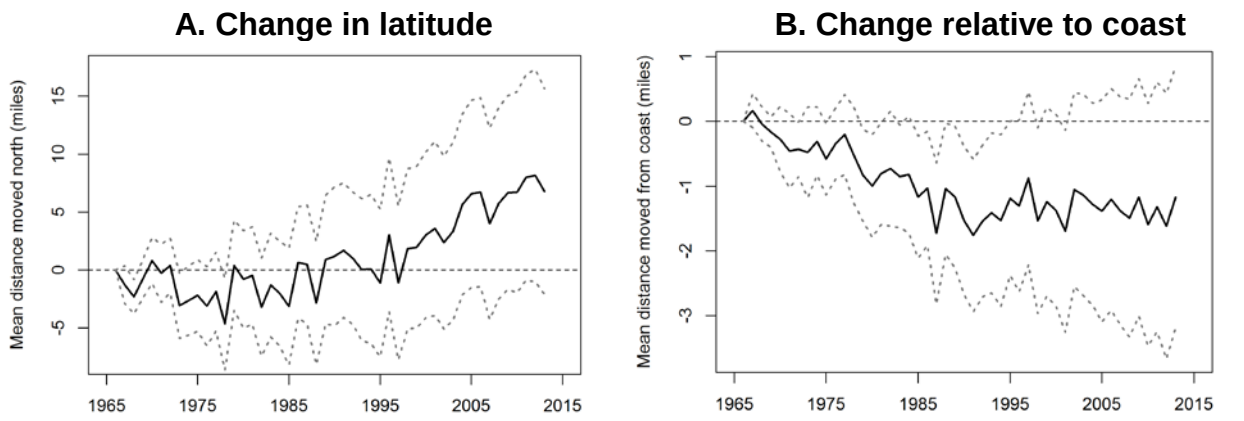
BIRD WINTERING RANGES

Over the past 48 years, wintering bird species have collectively shifted their range northward and closer to the coast in California.

Figure 1. Changes in wintering bird center of abundance in California (1966-2013)



Source: Michel et al., 2017

Note: The dashed lines show the likely range of each year's values based on the number of observations and the precision of the methods used.

What does the indicator show?

This indicator examines changes in the ranges of 234 migratory and resident wintering California bird species between 1966 and 2013 and shows, in aggregate, a shift northward. Data for this indicator are the California subset of observations from the Christmas Bird Count (CBC), managed by the National Audubon Society. The CBC consists of observations recorded from December 14 to January 5 each year by over 50,000 volunteers across the Western Hemisphere, following a specified methodology. It is the longest-running census of birds that relies on public participation and collaboration (often referred to as "citizen science").

The graphs show the position of the center of abundance (the center of the population distribution) for each year relative to the winter of 1965-1966, averaged across the species for latitude (Figure 1A) and for distance from the coast (Figure 1B). An overall northward movement of about seven miles was observed between 1966 and 2013, as birds moved a farther distance north than south (Figure 1A). Over the same time period, a shift of approximately 1 mile toward the coast occurred (Figure 1B).

The center of abundance is a common way to characterize the general location of a population. In terms of latitude, half of the individuals in the population live north of the center of abundance and the other half live to the south. Similarly, in terms of distance to coast, half of the individuals live closer to the coast than the center of abundance, and the other half live further from the coast.

Why is this indicator important?

Monitoring changes in the geographic distribution of birds provides scientists with a way to track which birds may be responding to a changing climate — one of many factors that are threatening bird populations. A better understanding of these responses will help inform conservation strategies. As the climate continues to change, its pace may exceed many bird species' capacities to migrate to more favorable habitats (La Sorte and Jetz, 2012). The predicted increase in extreme weather events, such as severe storms, might also impact the ability of birds to make these range shifts. Birds that cannot adapt to changing conditions could experience a population decline as a result.

Birds are a particularly good indicator of environmental change for several reasons:

- Each species of bird has adapted or evolved to favor certain habitat types, food sources, and temperature ranges. In addition, the timing of certain events in their life cycles — such as migration and reproduction — is driven by cues from the environment. For example, many North American breeding birds follow a regular seasonal migration pattern; moving north to feed and breed in the summer, then moving south to spend the winter in warmer areas. Changing conditions can influence the distribution of both migratory and non-migratory birds as well as the timing of important life cycle events (La Sorte and Thompson, 2007).

- Birds are relatively easy to identify and count, and thus there is a wealth of scientific knowledge about their distribution and abundance. People have kept detailed records of bird observations for more than a century.

- There are many different species of birds living in a variety of habitats, including water birds, coastal birds, and land birds. If a change in behavior or range occurs across a range of bird types, it suggests that a common external factor might be the cause.

When bird wintering ranges shift, human and ecological communities lose not just the birds themselves, but also the valuable functions and services they provide. For example, western bluebirds eat insects that damage crops, nectar-eating birds like hummingbirds pollinate flowers, and birds like woodpeckers build roosting cavities in trees that other bird and mammal species use (Kearns et al., 1998; Sekercioglu, 2006; Jedlicka et al., 2011). The movement of a species to places where it was not previously present, or where it was present in lower numbers, may also disrupt complex ecosystem interactions. For example, a newcomer species may compete for food or other resources with species that already inhabit the area (Kearns and Inouye, 1997).

What factors influence this indicator?

In the Northern Hemisphere, a changing climate has been associated with shifts in the habitat ranges of certain animals toward more northern latitudes and higher elevations (Field et al., 2014; Ralston et al., 2016; Moritz et al., 2008). Warming temperatures may cause species to expand their wintering ranges further north into regions that were, until recently, too cold to support populations, and away from regions that are now too hot.

A continental-scale analysis of 305 bird species found that their wintering ranges moved approximately 40 miles north between 1966 and 2013, and that this change was related to warming winter temperatures (National Audubon Society, 2009; USEPA, 2013). In California, the seven-mile northward shift in bird wintering ranges was found to be closely associated with warmer minimum December temperatures.

The movement of species toward the coast in California is the opposite of both what was expected and what was observed in the continental-scale study. The latter analysis found that bird wintering ranges moved about 13 miles away from the coast — a shift associated with a warming climate and a decrease of extreme cold inland. In California, in contrast, birds moved closer to the coast as temperatures increased. The California trend may be the result of the combined influence of climate and topography. Inland areas of the state, already drier compared to the coast, are further drying due to warming temperatures, causing birds to move towards the coast to seek wetter conditions.

Both the continental and the California analysis found no significant longitudinal movement. This is not surprising given that there are no clear longitudinal gradients in temperature or precipitation, which instead vary in response to topographical features (e.g., elevation or location relative to mountain ranges).

Latitudinal range movement varied among the California species: 87 species (37 percent) moved northward, 74 species (32 percent) moved southward, and 73 (31 percent) showed no significant change. Some bird species moved farther than others. Snow goose showed the greatest northward shift of 326 miles, while Ross' goose showed the greatest southward shift of 242 miles. Similarly, distance shifted relative to the coast ranged from 84 miles towards the coast by Canada goose to 60 miles inland by Barrow's goldeneye. Eighty-six species (37 percent) moved towards the coast, while 86 other species moved inland and 62 (26 percent) showed no significant change. While equal numbers of species moved inland and towards the coast, the range shifts towards the coast involved greater distances than inland, resulting in an overall shift toward the coast. These differences in range shifts are not surprising. Species have been found to respond to environmental change in a highly variable and idiosyncratic fashion, reflecting the complex interplay between land cover, climate, species interactions, and other factors.

Many factors can influence bird ranges, including food availability, habitat alteration, and interactions with other species, and these factors may also be influenced by climate change. Some of the birds covered in this indicator might have moved northward or inland for reasons other than changing temperatures. Responses to climate change may also vary among different types of birds. However, within California, there were no differences in average movements north or towards the coast between birds differing in habitat use, diet, body size, life expectancy, clutch size, age at sexual maturity, or urban affiliation. Though moderate- and short-distance migrants moved slightly further north than year-round residents, migratory status did not influence movement towards the coast.

Technical Considerations

Data Characteristics

This indicator is based on data collected by the annual Christmas Bird Count (CBC), managed by the National Audubon Society. Data are collected in a citizen science activity by volunteer birdwatchers who systematically survey certain areas and identify and count all bird species they encounter within a specified area. Bird surveys take place each year in approximately 2,000 different locations throughout the contiguous 48 states and the southern portions of Alaska and Canada. This indicator used only data from CBC circles within the state of California. All local counts take place between December 14 and January 5 of each winter. Each local count takes place over a 24-hour period in a defined "count circle" that is 15 miles in diameter. A variable number of volunteer observers separate into field parties which survey different areas of the count circle and tally the total number of individuals of each species observed (National Audubon Society, 2009).

CBC data starting in 1966 are used, as data prior to 1966 lack sufficient quality and quantity for a North American-scaled analysis. At the end of the 24-hour observation period, each count circle tallies the total number of individuals of each species seen in the count circle. Audubon scientists then run the data through several levels of analysis and quality control to determine final count numbers from each circle and each region. Data processing steps include corrections for different levels of sampling effort — for example, if some count circles had more observers and more person-hours of effort than others. Population trends over the 48-year period of this indicator and annual indices of abundance were estimated for the entire survey area with hierarchical models in a Bayesian analysis using Markov chain Monte Carlo techniques (Soykan et al., 2016).

This indicator covers 234 bird species, listed in Table 1 (Appendix). These species were included because they are widespread, occur within California, and meet specific criteria for data availability. Information on study methods is available on the National Audubon Society website at: http://web4.audubon.org/bird/bacc/techreport.html and in Soykan et al. (2016). Methods are largely based on those used for an earlier analysis, which is documented in the National Audubon Society (2009) report: *Northward Shifts in the Abundance of North American Birds in Early Winter: A Response to Warmer Winter Temperatures?*. For additional information on CBC survey design and methods, see Soykan et al. (2016) and the reports classified as "Methods" in the list at: http://www.audubon.org/conservation/christmas-bird-count-bibliography.

Strengths and Limitations of the Data

Although the indicator relies on human observation rather than precise measuring instruments, the people who collect the data are skilled observers who follow strict protocols that are consistent across time and space. These data have supported many peer-reviewed studies, a list of which can be found on the National Audubon Society's website at http://www.audubon.org/christmas-bird-count-bibliography.

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Uneven effort between count circles, such as inconsistent level of effort by volunteer observers, could lead to data variations. However, these differences are carefully

corrected in Audubon's statistical analysis (Soykan et al., 2016). Rare or difficult-to-observe bird species could lead to increased variability. Gregarious species (i.e., species that tend to gather in large groups) can also be difficult to count, and they could be either overcounted or undercounted, depending on group size and the visibility of their roosts. These species tend to congregate in known and expected locations along CBC routes, however, so observers virtually always know to check these spots. Locations with large roosts are often assigned to observers with specific experience in estimating large numbers of birds. For this analysis, the National Audubon Society included only 234 widespread bird species that met criteria for abundance and the availability of data to enable the detection of meaningful trends.

The tendency for saltwater-dependent species to stay near coastlines could impact the change in distance to coast calculation for species living near the Pacific Ocean. By integrating these species into the distance to coast calculation, Figure 2 may understate the total extent of coastward or inland movement of species.

This indicator is based solely on shifts in the center of abundance of birds observed within the state of California. As a result, it represents only a small portion of the wintering range of many species, and may either overestimate or underestimate distances moved across the species' entire wintering ranges.

Figures 1 and 2 show average distances moved north and towards the coast, based on an unweighted average of all species. Thus, no adjustments are made for population differences across species. No attempt was made to estimate trends prior to 1966 (i.e., prior to the availability of complete spatial coverage and standardized methods), and no attempt was made to project trends into the future. The entire study description, including analyses performed, can be found in National Audubon Society (2009), Soykan et al. (2016), and references therein. Information on this study is also available on the National Audubon Society website at: http://web4.audubon.org/bird/bacc/techreport.html.

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APPENDIX

Table 1. Bird species included in the California wintering bird range shift climate change indicator analysis.

Common name	Scientific name
Acorn Woodpecker	*Melanerpes formicivorus*
American Avocet	*Recurvirostra americana*
American Bittern	*Botaurus lentiginosus*
American Coot	*Fulica americana*
American Crow	*Corvus brachyrhynchos*
American Dipper	*Cinclus mexicanus*
American Goldfinch	*Spinus tristis*
American Kestrel	*Falco sparverius*
American Pipit	*Anthus rubescens*
American Robin	*Turdus migratorius*
American Wigeon	*Anas americana*
Anna's Hummingbird	*Calypte anna*
Arctic and Pacific Loon¶	*Gavia arctica and G. pacifica*
American Tree Sparrow	*Spizelloides arborea*
American White Pelican	*Pelecanus erythrorhynchos*
Bald Eagle	*Haliaeetus leucocephalus*
Baltimore Oriole	*Icterus galbula*
Band-tailed Pigeon	*Patagioenas fasciata*
Barrow's Goldeneye	*Bucephala islandica*
Barn Owl	*Tyto alba*
Bell's and Sagebrush Sparrow††	*Amphispiza belli and A. nevadensis*
Belted Kingfisher	*Megaceryle alcyon*
Bewick's Wren	*Thryomanes bewickii*
Black-and-white Warbler	*Mniotilta varia*
Black-bellied Plover	*Pluvialis squatarola*
Black-billed Magpie	*Pica hudsonia*
Black-capped Chickadee	*Poecile atricapillus*
Black-crowned Night-Heron	*Nycticorax*
Blue-gray Gnatcatcher	*Polioptila caerulea*
Blue-headed, Cassin's, and Plumbeous Vireo‡‡‡	*Vireo solitarius, V. cassini, and V. plumbeus*
Blue-winged Teal	*Anas discors*
Brown-headed Cowbird	*Molothrus ater*
Black Brant	*Branta b. nigricans*
Black Phoebe	*Sayornis nigricans*
Black Rail	*Laterallus jamaicensis*
Black Scoter	*Melanitta americana*
Black Turnstone	*Arenaria melanocephala*
Black-necked Stilt	*Himantopus mexicanus*
Bonaparte's Gull	*Chroicocephalus philadelphia*
Brewer's Blackbird	*Euphagus cyanocephalus*

Common name	Scientific name
Brown Creeper	*Certhia americana*
Bufflehead	*Bucephala albeola*
Burrowing Owl	*Athene cunicularia*
Bushtit	*Psaltriparus minimus*
Cackling and Canada Goose†	*Branta hutchinsii and B. canadensis*
Cactus Wren	*Campylorhynchus brunneicapillus*
California and Canyon/Brown Towhee#	*Melozone crissalis and M. fuscus*
California Gull	*Larus californicus*
California Quail	*Callipepla californica*
Canvasback	*Aythya valisineria*
Canyon Wren	*Catherpes mexicanus*
Caspian Tern	*Hydroprogne caspia*
Cassin's Finch	*Haemorhous cassinii*
Cattle Egret	*Bubulcus ibis*
Cedar Waxwing	*Bombycilla cedrorum*
Chestnut-backed Chickadee	*Poecile rufescens*
Chipping Sparrow	*Spizella passerina*
Chukar	*Alectoris chukar*
Cinnamon Teal	*Anas cyanoptera*
Clapper Rail	*Rallus crepitans*
Clark's Nutcracker	*Nucifraga columbiana*
Clark's and Western Grebe§§§	*Aechmophorus clarkii and A. occidentalis*
Common Goldeneye	*Bucephala clangula*
Common Ground-Dove	*Columbina passerina*
Common Loon	*Gavia immer*
Common Merganser	*Mergus merganser*
Common Moorhen	*Gallinula galeata*
Common Murre	*Uria aalge*
Common Raven	*Corvus corax*
Common Yellowthroat	*Geothlypis trichas*
Cooper's Hawk	*Accipiter cooperii*
Dark-eyed Junco	*Junco h. hyemalis*
Double-crested Cormorant	*Phalacrocorax auritus*
Downy Woodpecker	*Picoides pubescens*
Dunlin	*Calidris alpina*
Eared Grebe	*Podiceps nigricollis*
Eastern and Spotted Towhee‡‡	*Pipilo erythrophthalmus and P. maculatus*
Eastern and Western Screech-Owl¶¶¶	*Megascops asio and M. kennicottii*
European Starling	*Sturnus vulgaris*
Evening Grosbeak	*Coccothraustes vespertinus*
Ferruginous Hawk	*Buteo regalis*
Forster's Tern	*Sterna forsteri*
Fox Sparrow	*Passerella iliaca*
Gadwall	*Anas strepera*
Gambel's Quail	*Callipepla gambelii*

Common name	Scientific name
Glaucous Gull	*Larus hyperboreus*
Glaucous-winged Gull	*Larus glaucescens*
Golden Eagle	*Aquila chrysaetos*
Golden-crowned Kinglet	*Regulus satrapa*
Golden-crowned Sparrow	*Zonotrichia atricapilla*
Gray Jay	*Perisoreus canadensis*
Great Blue Heron	*Ardea herodias*
Great Egret	*Ardea alba*
Great Horned Owl	*Bubo virginianus*
Greater Roadrunner	*Geococcyx californianus*
Greater Scaup	*Aythya marila*
Greater White-fronted Goose	*Anser albifrons*
Greater Yellowlegs	*Tringa melanoleuca*
Green Heron	*Butorides virescens*
Green-tailed Towhee	*Pipilo chlorurus*
Green-winged Teal	*Anas crecca*
Hairy Woodpecker	*Picoides villosus*
Harlequin Duck	*Histrionicus histrionicus*
Harris's Sparrow	*Zonotrichia querula*
Hermit Thrush	*Catharus guttatus*
Herring Gull	*Larus argentatus*
Hooded Merganser	*Lophodytes cucullatus*
Horned Grebe	*Podiceps auritus*
Horned Lark	*Eremophila alpestris*
House Finch	*Haemorhous mexicanus*
House Sparrow	*Passer domesticus*
House Wren	*Troglodytes aedon*
Hutton's Vireo	*Vireo huttoni*
Iceland and Thayer's Gull §	*Larus glaucoides and L. thayeri*
Inca Dove	*Columbina inca*
Juniper and Oak Titmouse[##]	*Baeolophus ridgwayi and B. inornatus*
Killdeer	*Charadrius vociferus*
Ladder-backed Woodpecker	*Picoides scalaris*
Lapland Longspur	*Calcarius lapponicus*
Lark Sparrow	*Chondestes grammacus*
Least Bittern	*Ixobrychus exilis*
Least Sandpiper	*Calidris minutilla*
Lesser Goldfinch	*Spinus psaltria*
Lesser Scaup	*Aythya affinis*
Lesser Yellowlegs	*Tringa flavipes*
Lewis's Woodpecker	*Melanerpes lewis*
Lincoln's Sparrow	*Melospiza lincolnii*
Little Blue Heron	*Egretta caerulea*
Loggerhead Shrike	*Lanius ludovicianus*
Long-billed Dowitcher	*Limnodromus scolopaceus*

Common name	Scientific name
Long-eared Owl	*Asio otus*
Long-tailed Duck	*Clangula hyemalis*
Marbled Godwit	*Limosa fedoa*
Marbled Murrelet	*Brachyramphus marmoratus*
Marsh Wren	*Cistothorus palustris*
Merlin	*Falco columbarius*
Mew Gull	*Larus canus*
Mountain Bluebird	*Sialia currucoides*
Mountain Chickadee	*Poecile gambeli*
Mourning Dove	*Zenaida macroura*
Nashville Warbler	*Oreothlypis ruficapilla*
Northern Cardinal	*Cardinalis cardinalis*
Northern Goshawk	*Accipiter gentilis*
Northern Harrier	*Circus cyaneus*
Northern Flicker	*Colaptes a. cafer*
Northern Mockingbird	*Mimus polyglottos*
Northern Pintail	*Anas acuta*
Northern Pygmy-Owl	*Glaucidium gnoma*
Northern Saw-whet Owl	*Aegolius acadicus*
Northern Shoveler	*Anas clypeata*
Northern Shrike	*Lanius excubitor*
Orange-crowned Warbler	*Oreothlypis celata*
Osprey	*Pandion haliaetus*
Palm Warbler	*Setophaga palmarum*
Pelagic Cormorant	*Phalacrocorax pelagicus*
Peregrine Falcon	*Falco peregrinus*
Pied-billed Grebe	*Podilymbus podiceps*
Pileated Woodpecker	*Dryocopus pileatus*
Pine Siskin	*Spinus pinus*
Pinyon Jay	*Gymnorhinus cyanocephalus*
Prairie Falcon	*Falco mexicanus*
Purple Finch	*Haemorhous purpureus*
Pygmy Nuthatch	*Sitta pygmaea*
Red Crossbill	*Loxia curvirostra*
Redhead	*Aythya americana*
Red Knot	*Calidris canutus*
Red-breasted Merganser	*Mergus serrator*
Red-breasted Nuthatch	*Sitta canadensis*
Red-necked Grebe	*Podiceps grisegena*
Red-shouldered Hawk	*Buteo lineatus*
Red-winged Blackbird	*Agelaius phoeniceus*
Ring-billed Gull	*Larus delawarensis*
Ring-necked Duck	*Aythya collaris*
Ring-necked Pheasant	*Phasianus colchicus*
Rock Sandpiper	*Calidris ptilocnemis*

Common name	Scientific name
Rock Wren	*Salpinctes obsoletus*
Ross's Goose	*Chen rossii*
Rough-legged Hawk	*Buteo lagopus*
Royal Tern	*Thalasseus maximus*
Ruby-crowned Kinglet	*Regulus calendula*
Ruddy Turnstone	*Arenaria interpres*
Rufous-crowned Sparrow	*Aimophila ruficeps*
Sanderling	*Calidris alba*
Sandhill Crane	*Antigone canadensis*
Savannah Sparrow	*Passerculus sandwichensis*
Say's Phoebe	*Sayornis saya*
Semipalmated Plover	*Charadrius semipalmatus*
Sharp-shinned Hawk	*Accipiter striatus*
Short-billed Dowitcher	*Limnodromus griseus*
Short-eared Owl	*Asio flammeus*
Snow Goose	*Chen caerulescens*
Snowy Egret	*Egretta thula*
Snowy Plover	*Charadrius nivosus*
Song Sparrow	*Melospiza melodia*
Sora	*Porzana carolina*
Spotted Sandpiper	*Actitis macularius*
Steller's Jay	*Cyanocitta stelleri*
Surfbird	*Calidris virgata*
Surf Scoter	*Melanitta perspicillata*
Swamp Sparrow	*Melospiza georgiana*
Townsend's Solitaire	*Myadestes townsendi*
Townsend's Warbler	*Setophaga townsendi*
Tree Swallow	*Tachycineta bicolor*
Tricolored Heron	*Egretta tricolor*
Tundra Swan	*Cygnus columbianus*
Turkey Vulture	*Cathartes aura*
Varied Thrush	*Ixoreus naevius*
Verdin	*Auriparus flaviceps*
Vermilion Flycatcher	*Pyrocephalus rubinus*
Vesper Sparrow	*Pooecetes gramineus*
Virginia Rail	*Rallus limicola*
Western Bluebird	*Sialia mexicana*
Western Meadowlark	*Sturnella neglecta*
Western Scrub-Jay	*Aphelocoma californica*
Whimbrel	*Numenius phaeopus*
White-breasted Nuthatch	*Sitta carolinensis*
White-crowned Sparrow	*Zonotrichia leucophrys*
White-tailed Kite	*Elanus leucurus*
White-throated Sparrow	*Zonotrichia albicollis*
White-winged Dove	*Zenaida asiatica*

Common name	Scientific name
White-winged Scoter	*Melanitta fusca*
Wild Turkey	*Meleagris gallopavo*
Willet	*Tringa semipalmata*
Williamson's Sapsucker	*Sphyrapicus thyroideus*
Wilson's Snipe	*Gallinago delicata*
Wilson's Warbler	*Cardellina pusilla*
Winter Wren	*Troglodytes hiemalis*
Wood Duck	*Aix sponsa*
Yellow-bellied Sapsucker	*Sphyrapicus varius*
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*
Yellow-rumped Warbler	*Setophaga coronata*

Notes:

† Since the Cackling and Canada Goose (*Branta hutchinsii* and *B. canadensis*) were not distinguished in CBC counts until after 1966, the two species were lumped for trend analyses.

§ Since the Iceland and Thayer's Gull (*Larus glaucoides and L. thayeri*) were not distinguished in CBC counts until after 1966, the two species were lumped for trend analyses.

¶ Since the Arctic and Pacific Loon (*Gavia arctica* and *G. pacifica*) were not distinguished in CBC counts until after 1966, the two species were lumped for trend analyses.

Since the California and Canyon/Brown Towhee (*Melozone crissalis* and *M. fuscus*) were not distinguished in CBC counts until after 1966, the two species were lumped for trend analyses.

‡‡ Since the Eastern and Spotted Towhee (*Pipilo erythrophthalmus* and *P. maculatus*) were not distinguished in CBC counts until after 1966, the two species were lumped for trend analyses.

†† Since the Bell's and Sagebrush Sparrow (*Amphispiza belli* and *A. nevadensis*) were not distinguished in CBC counts until after 1966, the two species were lumped for trend analyses.

Since the Juniper and Oak Titmouse (*Baeolophus ridgwayi* and *B. inornatus*) were not distinguished in CBC counts until after 1966, the two species were lumped for trend analyses.

‡‡‡ Since the Blue-headed, Cassin's, and Plumbeous Vireo (*Vireo solitarius*, *V. cassini*, and *V. plumbeus*) were not distinguished in CBC counts until after 1966, the three species were lumped for trend analyses.

§§§ Since the Clark's and Western Grebe (*Aechmophorus clarkii* and *A. occidentalis*) were not distinguished in CBC counts until after 1966, the two species were lumped for trend analyses.

¶¶¶ Since the Eastern and Western Screech-Owl (*Megascops asio* and *M. kennicottii*) were not distinguished in CBC counts until after 1966, the two species were lumped for trend analyses.