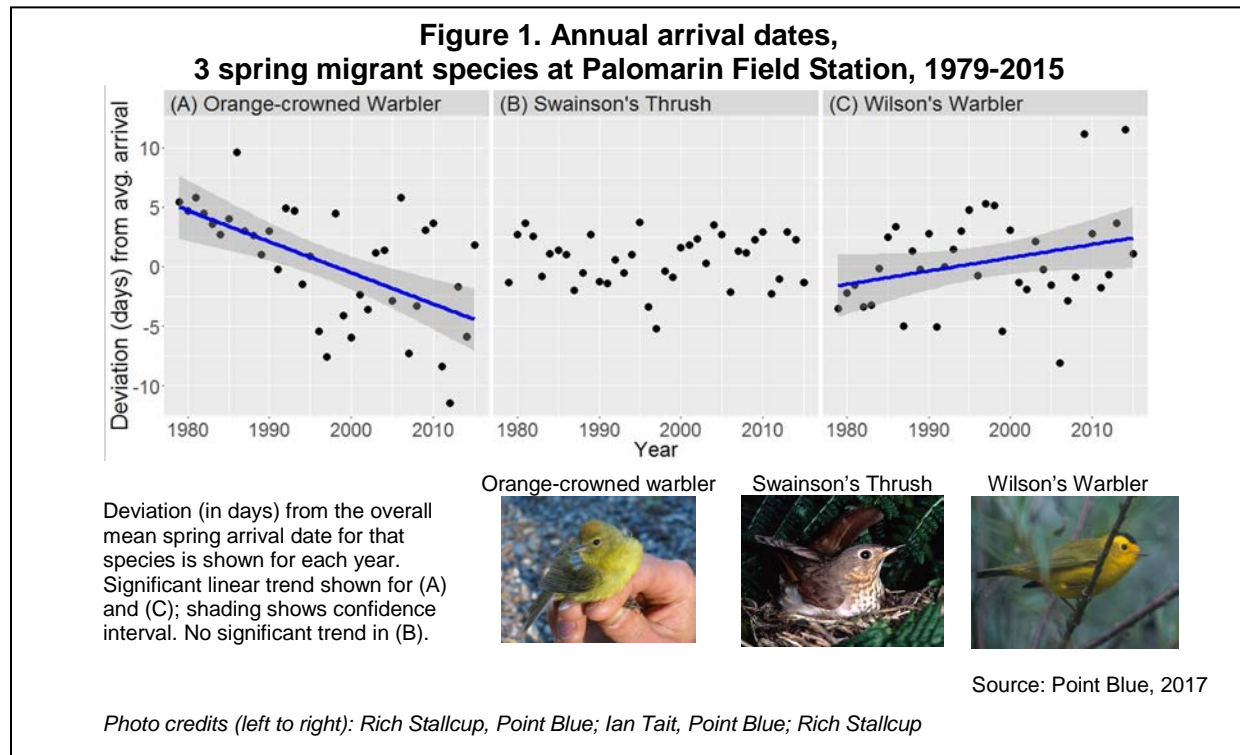


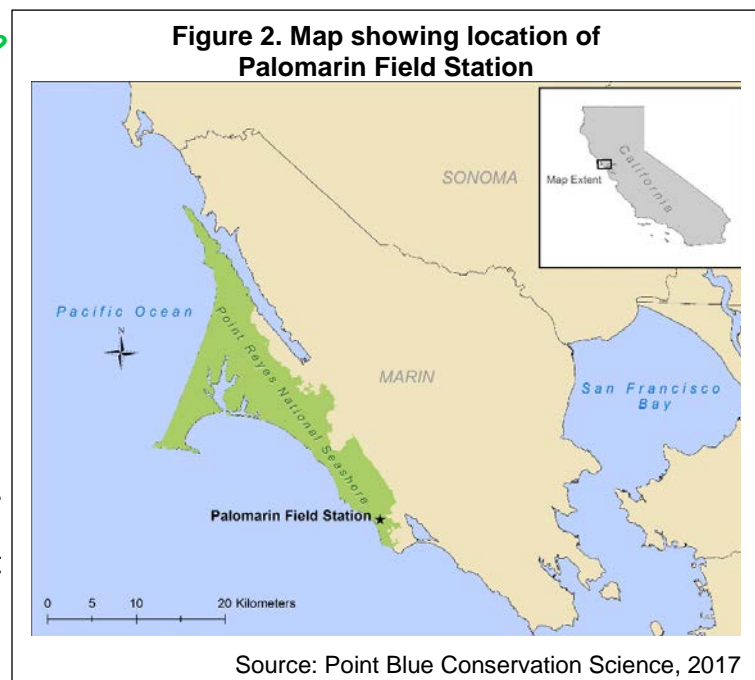
MIGRATORY BIRD ARRIVALS

Migratory songbird species are showing a diversity of changes in arrival dates. Of the three species studied that arrive at a coastal California site in the spring, two are showing opposite trends in timing (one shows no significant change). Of the four species that arrive in the fall, two have been arriving earlier over the past 35 years, while one has been showing a trend toward earlier arrival since 1995. The fourth species shows no significant change.



What does the indicator show?

Trends in spring and fall arrival dates of birds migrating to their breeding grounds in the spring (Figure 1) and their wintering grounds in the fall (Figure 3) differ among seven species of songbirds that spend part of the year at the Point Blue Conservation Science's Palomarin Field Station in Point Reyes National Seashore, Marin County, California (see Figure 2). Arrival dates are based on a 36-year record of observations at this location, where the habitat is



a mix of coastal scrub and mixed-evergreen hardwood forest with encroaching Douglas-fir forest.

As shown in Figure 1, of the spring species migrating to their breeding grounds, the Wilson's Warbler (*Wilsonia pusilla*) has been arriving later (1.1 days later per decade), while the Orange-crowned Warbler (*Oreothlypis celata*) has been trending towards earlier arrivals (2.6 days earlier per decade) over the past 36 years. No significant trend was observed for the Swainson's Thrush (*Catharus ustulatus*).

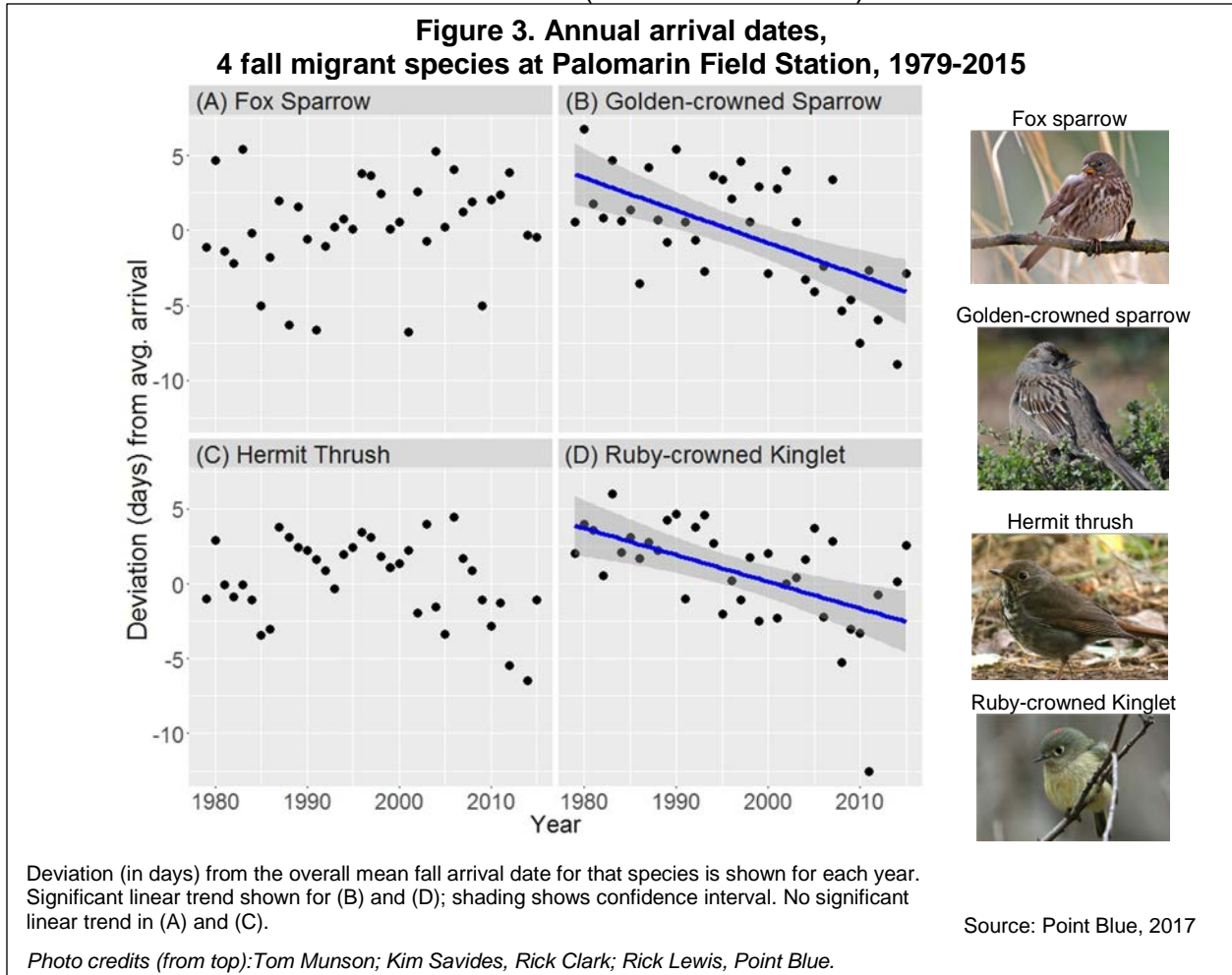


Figure 3 shows that, among species migrating to their wintering grounds in the fall, the Ruby-crowned Kinglet (*Regulus calendula*) and the Golden-crowned Sparrow (*Zonotrichia atricapilla*) have been arriving earlier (1.8 and 2.1 days per decade, respectively) since 1980. The overall linear trend over the 36-year period is not significant for the Hermit Thrush (*Catharus guttatus*); however, the data show a trend toward earlier arrival beginning in 1995. This response is similar to that of the Golden-crowned Sparrow, which has been arriving at increasingly earlier dates (the data show a significant acceleration in the past two decades). The Fox Sparrow (*Passerella iliaca*) shows no significant linear trend.



Globally, a general trend of earlier arrival of birds migrating in the spring has been reported, associated with warming temperatures and the earlier onset of spring and with it, the emergence of the plant and insect resources the birds rely on (Usui et al., 2017; Herbert and Liang, 2012; Parmesan, 2006). However, there is considerable variation, with different species (or even populations of the same species) exhibiting both earlier and later timing of spring migration. While there are less data on fall migration, some studies have indicated shifts to later arrivals (Jarjour et al., 2017).

Why is this indicator important?

Tracking changes in migratory bird arrivals adds to the body of evidence of how terrestrial species have responded to regional changes in climate. A growing number of studies have examined changes in the timing of migration in recent decades across the Northern Hemisphere. Changes in the timing of spring migration (Marra et al., 2005; MacMynowski et al., 2007; van Buskirk et al., 2009; Ward et al., 2015) and, to a lesser extent fall migration, have been documented (Cotton, 2003; Jenni and Kéry, 2003; Mills, 2005).

The timing of bird arrivals on breeding territories and wintering grounds is a key determinant of reproductive success and survival (Cotton, 2003). To the extent that migrating birds species are adapted to arrive at the optimum stage in the growth season — thus maximizing the availability of resources — shifts in migration timing can be expected to be disadvantageous (Travers et al., 2015). An analysis of changes in spring arrival dates among 48 bird species and the emergence of vegetation (spring “green-up” dates) across North America from 2001-2012 found that both have changed over time, usually in the same direction; however arrival of eastern species increasingly lagged behind greenup, while in the west, where green-up typically shifted later, birds arrived increasingly earlier (Mayor et al., 2017). These findings highlight mismatches in timing that may potentially lead to adverse consequences on bird populations.

Knowledge of how migratory birds are responding to changing climatic conditions is critical in assessing and projecting the impacts of those changes on bird populations. Of particular concern are species or populations that are unable to modify their arrival times; reduced genetic variability due to a decline in their population size could limit their ability to adapt to climate change, potentially hastening further population declines (Hurlbert and Liang, 2012) . A study of changes in spring migration timing among 100 European bird species found that population declines occurred in species that did not advance their spring migration in the period 1990-2000; those with stable or increasing populations advanced their migration considerably (Møller et al., 2008).

This indicator illustrates the value of long-term data, gathered in a systematic way, in revealing trends in spring and fall arrival dates of migratory songbirds. It adds California and western North American observations to the growing body of data describing temporal patterns in bird migration patterns (Seavy et al., in press). Such regional information helps improve the scientific understanding of factors that may be influencing the timing of migration and how these factors may be reflected in global trends. The data presented can serve as a baseline with which to compare future observations and



to develop long-term projections under future climate change scenarios. While there is no definitive explanation for why the responses of the seven species differ, this information can also help inform studies that seek to elucidate the mechanisms and consequences of these phenological changes — particularly studies that examine whether shifts in timing are synchronous with changes in the timing of optimal conditions in breeding or wintering grounds.

What factors influence this indicator?

Bird migrations are seasonal movements between wintering and breeding grounds that allow individuals to take advantage of abundant resources, or to avoid predators or exposure to harsh conditions. As environmental conditions change over time, birds can potentially adjust the timing of migration — a response that reflects the interactions among several intrinsic and extrinsic factors. Migratory birds exhibit seasonal physiological changes in preparation for migration, triggered by environmental cues such as photoperiod (the length of day or night) and temperature (Hurlbert and Liang, 2012).

Researchers have investigated the association between changes in migration timing and a number of factors. Species that migrate more slowly and over short distances, and that occupied broader climatic niches (that is, habitats with a wider range of physical and biological resources) were found to have advanced arrival dates the earliest in a study of 18 common bird species in eastern North America (Hurlbert and Liang, 2012). An analysis of over 70 published studies on the timing of spring migration of 413 species across five continents found that, correlated with warmer spring conditions on arrival grounds, short distance migrants advanced their arrival dates by more than long distance migrants; no relationship was found between species' habitat or diet and arrival time (Usui et al., 2017). In contrast, a study of 19 songbird species in Quebec, Canada from 2005 to 2015 found a significant association between changes in migration timing and feeding habits: 10 of 14 insectivores, and only one of five granivores showed evidence of a shift in migration (Jarjour et al., 2017); overall spring arrival dates shifted earlier, while fall departure dates varied considerably.

As fall temperatures increase, insects and plants may be available as food for longer, delaying fall departure as individuals improve their condition to increase survival during migration (Jarjour et al., 2017) Similarly, some species may be shifting their spring arrival timing in response to climatic conditions at their wintering grounds, which has been shown to affect the physiological condition of migrants and thus their departure dates (Marra et al., 2015).

Environmental conditions in the wintering or breeding grounds, stopover locations along the migration route, or in the final settling location — all of which affect arrival times — may, in turn be affected by factors operating on multiple spatial scales. The variety of factors and the multiplicity of temporal and spatial scales at which birds operate during migration undoubtedly contribute to the considerable inter-annual variation in arrival dates.



The earlier arrival of the Orange-crowned Warbler at Palomarin is not surprising. Earlier onset of spring conditions has been documented over much of the Northern Hemisphere (Root et al., 2005; Parmesan, 2006). This can influence the timing of migration and breeding (Gordo, 2007; Møller et al., 2010; Seavy et al., in press). However, Both and Visser (2001) found that changes in conditions on the breeding grounds influenced laying date but did not lead to changes in spring arrival dates for a long-distance migrant. The contrasting arrival patterns of the two warbler species — both small, insectivorous songbirds in the same taxonomic family — presents a paradox, however, and indicates the need for further research.

In contrast, less research has investigated fall arrival patterns of birds to their wintering grounds (Gallinat et al., 2015). Trends in fall arrival dates likely relate, in part, to spring breeding ground conditions elsewhere: If breeding conditions persist later in the season, fall arrivals could be delayed; if breeding conditions support earlier breeding or if drier conditions result in earlier cessation of breeding, fall arrivals could advance.

The species described here migrate to the Point Reyes area from different wintering or breeding locations. Among the spring arrivals to the Point Reyes area, Swainson's Thrushes (which show no trend in arrival dates) winter predominantly in western Mexico (Cormier et al., 2013); Wilson's Warblers, which have been arriving later, winter in a larger area covering Baja California as well as western Mexico (Ruegg et al., 2014). Baja California and western Mexico are characterized by different wintering habitats that may influence departure timing from the wintering grounds. The migratory pathways of Orange-crowned Warblers have not been documented; while their wintering range includes areas farther north than the other species (Gilbert et al., 2010), the wintering location of the population migrating to Palomarin is unknown.

The four species that arrive in the fall migrate from temperate regions. The Golden-crowned Sparrow (arriving earlier) and Fox Sparrow (no change in arrivals) both breed predominantly in the Gulf of Alaska (Seavy et al., 2012, Cormier et al., 2016; Point Blue unpublished data). The difference in these species' arrival patterns suggests that either conditions on the breeding grounds are not having a direct effect on timing of arrival or that the species are responding differently. Hermit Thrush, whose pattern is similar to Golden-crowned Sparrows (tendency to earlier arrival), breed in the Pacific Northwest, in particular, coastal British Columbia and the Olympic Peninsula of Washington (Nelson et al., 2016). It is not known where the population of Ruby-crowned Kinglets breed, although subspecies-related plumage patterns at Palomarin (Point Blue unpublished data) suggest that the majority are likely from either or both of the above two regions (Pacific Northwest and Gulf of Alaska), with some originating from interior Alaska or Canada (Swanson et al., 2008). Thus it is possible that either finer-scale differences in conditions at breeding grounds or along migratory stopover sites, or differential responses to shared conditions, may be influencing their arrival timing on their wintering grounds.



Technical Considerations

Data Characteristics

The data for this analysis consist of banding records of individual birds captured and marked as part of a constant-effort mist-netting program at the Palomarin Field Station (Ralph et al., 1993; Point Blue, 2016). Although mist-netting was initiated in 1966, the period of analyses was restricted to 1979, when constant-effort mist netting became fully standardized, through fall 2015. Fall 2013 was excluded due to a 15-day October hiatus in banding operations resulting from the federal government shutdown. This provides a 37-year dataset for spring arrivals and 36 years for fall arrivals.

The dataset was restricted to the first capture of each individual in each season. In spring, newly fledged birds were excluded from the analysis, thus all individuals analyzed were approximately 1 year or older; in the fall, all age classes were included, including immature birds that fledged earlier in the year (during the breeding season immediately preceding fall arrival).

The species selected for this analysis were chosen for their migratory status and high capture rates. These species differed somewhat from the previous iteration of this report (OEHHA, 2009), by including analyses of three species not previously reported, namely Hermit Thrush, Golden-crowned Sparrow and Orange-crowned Warbler, and the removal of three species due to modest sample sizes: Black-headed Grosbeak, Warbling Vireo, and Yellow Warbler.

The distribution of first capture dates for each species was assessed to determine species-specific “arrival windows.” The beginning of the arrival window was determined by the first captures; the end of the arrival period was determined by the date at which first captures had declined to relatively low “baseline” levels (see Nur et al., 2017 for details). Any further captures after the arrival window’s end-date were determined to be individuals that likely had been present in the study area but had avoided capture until then. Thus, the arrival window encompassed the first wave of captures during the season in its entirety.

Arrival window dates are as follows:

- Swainson’s Thrush: 6 April – 8 June
- Wilson’s Warbler: 12 March – 29 May
- Orange-crowned Warbler: 20 February – 19 May
- Ruby-crowned Kinglet: 8 September – 15 November
- Hermit Thrush: 13 September – 15 December
- Fox Sparrow: 29 August – 5 November
- Golden-crowned Sparrow: 6 September – 30 November

Of these species, two occur in the region in small numbers year-round. In addition to the overwintering population in this study, a small number of Hermit Thrushes also breed in the region and migrate south in the fall (Phillips, 1991); however, the small number of post-breeding individuals from this population that were captured in early fall did not overlap in time with the window for arrivals from the north. Similarly, in addition to the



breeding population of Orange-crowned Warblers studied here, a relatively small number of individuals winter in the region; again, the capture window allowed those few breeding individuals to be excluded from this study.

None of the species in this study are passage migrants at the Palomarin Field Station; rather, Palomarin is the final stopping location (either for breeding or wintering) for all 7 species. In addition, the arrival window was set to exclude individuals that may have been present at the location for some period of time in order to better identify the timing of the wave of migrants as they first arrive on their wintering or breeding grounds.

The 25th percentile of capture dates during the arrival window was used to track the initial wave of arrival of migrants. Linear models were then fit to the capture dates for each species to analyzing a linear-only trend (reported in Figures 1 and 3). To better analyze changes in trend, quadratic models were also fit to the same data (depicted as blue lines in Figures 1 and 3). Details on data processing and analysis are provided in the companion Technical Report (Nur et al., 2017).

One concern was that a change in population size could result in fewer captures which could affect measures of arrival date. Reduced sample size will bias the metric of the very earliest arrival date (Miller-Rushing et al., 2008). In order to provide a more robust metric, not biased by sample size, the 25th percentile value was used, though other quantiles could have been used, e.g., the median.

Strengths and Limitations of the Data

These data provide a long-term record of bird migration phenology. There were sufficient data to analyze these seven migrant songbirds, including both fall and spring migrants; species included came from four taxonomic families, thus providing taxonomic breadth. The time series is extensive for biological monitoring: 37 years as of 2015.

Monitoring efforts have been strictly standardized since 1979. In general, sampling efforts and net hours per season (where each “net hour” equals a single net open for one hour) have remained relatively stable during the period included in these analyses. Frequency of mist netting was generally three days per week (April through Thanksgiving) or 6 days per week (May through Thanksgiving), weather permitting; one significant change in effort was a switch from banding 6 days/week to 3 days/week in the month of April starting in 1989. This change, as well as the generally small variation in effort in other months due to weather and other variables, was addressed by standardizing the analysis with regard to bird captures per 1000 net hours (a full banding day at Palomarin results in 120 net hours) and pooling captures into 5-day periods.

The 2013 *Indicators of Climate Change in California* Report provided results for four of the seven species analyzed here, using the long-term mist-netting data from the Palomarin Field Station. For one of the species, Swainson’s Thrush, previous results are very similar to what is presented here. However, for the other three species (Wilson’s Warbler, Ruby-crowned Kinglet, and Fox Sparrow) there were noticeable



differences in trend. The principal reason for the differences was that the earlier analysis used 1971-1978 (which, as noted earlier, were excluded here because mist-netting was not fully standardized until 1979), while the current analysis included the years 2006-2015. These more recent years made a substantial difference in characterizing the trend. The bottom line is that most species analyzed demonstrate both year-to-year variability and a trend over time that is not constant over the entire time series and, therefore, two different time intervals can produce two different trend values.

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