Impact of the Four Year California Drought on Select Chaparral Birds

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ABSTRACT

The impact of the four year drought (2012-2015) in California on seven birds breeding in the chaparral habitat of southern California was analyzed. Six species, Spotted Towhee (Pipilo maculatus), *California Towhee* (Melozone crissalis), *Song Sparrow* (Melospiza melodia), *Bewick's Wren* (Thryomanes bewickii), *Common Yellowthroat* (Geothlypis trichas), *and Lesser Goldfinch* (Spinus psaltris), *are year-round residents. The seventh, Black-headed Grosbeak* (Pheucticus melanocephalus), *is a breeding summer migrant. Overall capture rates (birds/100 nh) did not decline until the third and fourth year of the drought (19.9%). The decline in HY birds (productivity) declined 25.5% during the first two years of the drought and 71.7% during the second two years. Some species (Bewick's Wren, Common Yellowthroat, Lesser Goldfinch) had began having reduced productivity in the first two years of the drought, while other species (Spotted Towhee, Song Sparrow, Black-headed Grosbeak) did not begin to respond until the third year of the drought. The numbers of adult birds generally did not decline until the second two years of the drought (20.8%), while breeding birds declined 36.5% during the second two years. The primary reason for bird population decline was found to be reproductive failure.*

INTRODUCTION

Numerous studies have found that droughts can lower bird population numbers compared to pre- and post-drought years (Errington and Hamerstrom 1938, Cody 1981, Smith 1982, George et al. 1992, Lindsey et al. 1997, Chan 1999, Christman 2002, Morrison and Bolger 2002, Bolger et al. 2005), since water is important to birds for hydration, cover, and food (Albright et al. 2010). Some of these studies looked at individual bird species, while others looked at the avifauna of an area. While most studies examined populations only during the year of the drought (e.g., Verner and Purcell 1999), a few studies have examined long-term impacts (DeSante and Geupel 1987, Massey et al. 1992, Johnson and Geupel 1996, Chase et al. 1997). The general pattern of these studies has been that there was a marked decline in the number of individuals in a drought year, but numbers returned to pre-drought conditions the following year with the end of the drought (e.g., George et al. 1992).

California has been in a long-term, four-year drought which began in 2012. Newspapers had bombarded the people of California with pictures and stories of near-empty reservoirs; water districts had been warning the public of impending water shortages (*Los Angeles Times* 2014b). Public officials were legislating mandatory water rationing (*Los Angeles Times* 2014a). California's Governor Brown had imposed an executive order mandating the state's first ever water restriction (*Los Angeles Times* 2015).

Herein I present the impact of California's four year drought on selected chaparral birds, based on a comparison with baseline information collected four years prior to the present drought. My objectives were to assess hatching year productivity of birds and after hatching year captures to determine if there have been any significant impacts of the recent drought on populations of chaparral-breeding birds.

METHODS

My study site is the Zuma Canyon bird banding station, which is located in the Santa Monica Mountains outside of greater Los Angeles (34 01′ 54" N, 118 48′ 44" W). Banding has been conducted here from 1995 to the present. Zuma Canyon is in the National Park Service's (NPS) Santa Monica Mountains National Recreation Area and is a south-facing drainage emptying into the Pacific Ocean. The banding station is 1.5 km (one mi) from the ocean, situated in the parking lot at the trail head.

The vegetative cover of the area is a mixture of coastal sage scrub (California sagebrush [*Artemisia* *californica*], several species of sage [*Salvia* spp]), hard chaparral (laurel sumac [*Malosma laurina*], coyote bush [*Baccharis pilularis*]), riparian woodland (western sycamore [*Platanus racemosa*], black walnut [*Juglans california*], coast live oak [*Quercus agrifolia*]), and a ruderal field (wild oats [*Avena sativa*], black mustard [*Brassica nigra*]). Mixed into this are areas of chaparral restoration that have been put in place by the NPS over the past 1-2 decades.

Banding cycles were approximately every two weeks for this year-round, constant-effort bird banding station. Ten to 17 twelve-meter mist nets were used, depending upon availability of personnel. Banding always began at sunrise and lasted for six hours. Starting in 2008, birds were processed approximately following the MAPS (Monitoring Avian Productivity and Survivorship) protocol (DeSante et al. 1993); i.e., birds were aged as Hatching Year (HY) or After Hatching Year (AHY) by skulling, molt, and other characteristics (Pyle 1997). Birds were determined to be in breeding condition based on cloacal protuberance (CP) or brood patch (BP) (Pyle 1997).

To measure the impact of drought on birds breeding in Zuma Canyon, I analyzed total numbers of HY and AHY birds caught annually from 2008 to 2015 for six non-migratory bird species and one breeding Neotropical migrant. The residents were selected because they were sufficiently abundant, year round, and bred in the canyon: Spotted Towhee [*Pipilo maculatus*], California Towhee [*Melozone crissalis*], Song Sparrow [*Melospiza melodia*], Bewick's Wren [*Thryomanes bewickii*], Common Yellowthroat [*Geothlypis trichas*], and Lesser Goldfinch [*Spinus psaltris*].The Black-headed Grosbeak [*Pheucticus melanocephalus*], which is a summer migrant breeding in Zuma Canyon, also was analyzed. Wrentits [*Chamaea fasciata*] were not considered, as there are problems ageing this species (Sakai 2016). Bushtits [*Psaltriparus minimus*] also were not considered because ageing and sexing become difficult later in the year (Pyle 1997); and House Finches [*Haemorphous mexicanus*] were not considered because they are synanthropes and less affected by droughts than other species (Albright et al. 2010).

For determining numbers of each species each year, if an individual bird was encountered more than once in a year, it was only counted once. The numbers of captured males and females in breeding condition were added together. No attempt was made to determine if there were breeding pairs or if one member of a pair was captured.

Rainfall data were taken from the National Oceanic and Atmospheric Administration for downtown Los Angeles (http://www.cnrfc.noaa.gov/rainfall_data.php). The water year begins on 1 Oct and ends 30 Sep. In southern California, about 80% of precipitation falls in the months of December to March (Felton 1967). The long-term average precipitation at this weather station was 37.46 cm/yr. (14.75 in./yr.). Annual precipitation totals are presented in Table 1 for 2008 to 2015. Precipitation for 2007 is also shown, which was the lowest precipitation total ever recorded for downtown Los Angeles.Note that six out of the eight years of this study had below-average precipitation. The present California drought began in 2012 and, by 2015, was in its fourth year.

Table 1. Summary of banding effort, bird enountered, and rainfall at downtown Los Angeles, CA weather station from 2007-2015,

Year	Net Hours	No. Birds Encountered	b/100nh	Rains (cm)
2007	1456	801	55.01	**9.47**
2008	1304	705	54.06	33.05
2009	2299	926	40.28	23.06
2010	2027	1037	51.16	41.55
2011	2208	900	40.76	51.26
2012	1914	948	49.53	22.10
2013	2171	944	43.48	15.06
2014	2202	742	33.70	15.34
2015	2078	752	36.19	28.55

Rainfall in 2007 (bold face) is the lowest ever recorded since 1877.

RESULTS

For brevity, the Alpha Codes for the birds are used: Spotted Towhee (SPTO), California Towhee (CALT), Song Sparrow (SOSP), Bewick's Wren (BEWR), Common Yellowthroat (COYE), Black-headed Grosbeak (BHGR), and Lesser Goldfinch (LEGO).

The total numbers of all birds encountered/year are presented in Table 1. There was some variability in the annual effort, especially early on in the study, so capture data were converted to birds per 100 net-hours (b/100 nh). The average number of birds captured pre-drought (2008-2011) was 46.56 b/100 nh. During the first two years of the drought (2012-2013), the average number of birds captured was almost identical to pre-drought years (46.50 birds/100 nh). However, in the third and fourth year of the drought, there was a marked decline in birds with an annual average of 34.95 b/100 nh or a 25.5% decline in the number of birds captured per 100 nh.

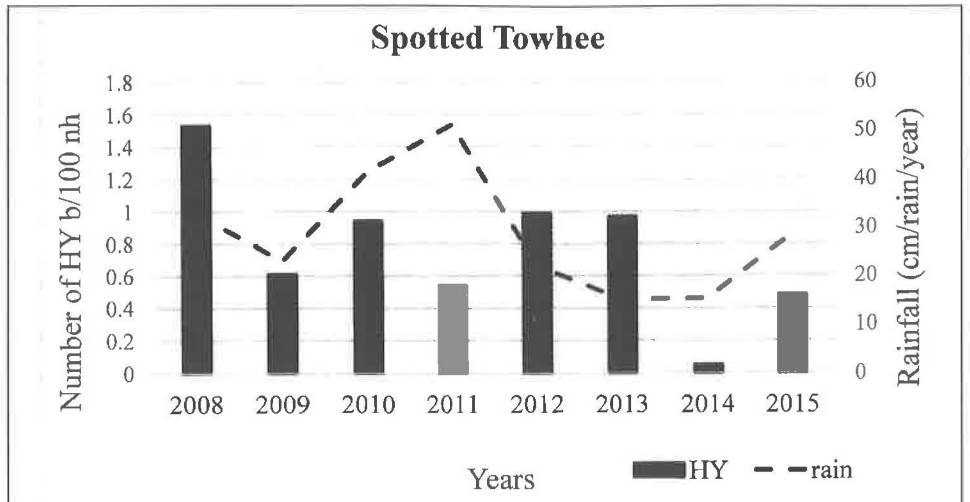

Fig. 1. Number of HY Spotted Towhees captured (bars) and rainfall (dashed line) by year from 2008-2015. Average = 0.76 HY SPTO/100 nh/year.

There was an average of 0.76 HY SPTO/100 nh/year captured from 2008 to 2015 (Fig. 1). In the third year of the drought (2014), only one HY (0.05 b/100nh) SPTO was captured and banded. There was a rise in the number of HY birds in 2015 to 0.48 b/100nh, but the two-year average for 2014-15 was 0.29 b/100nh. There was a 72.2% decline in HY captures between 2008-2013 and 2014-2015.

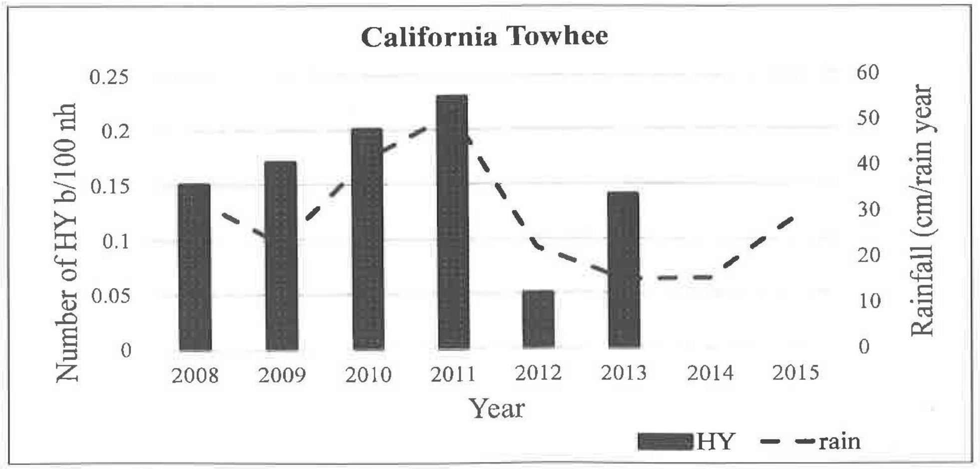

Fig. 2. Number of HY California Towhees captured (bars) and rainfall (dashed line) by year from 2008-2015. Average = 0.12 CALT/100 nh/year.

CALT were captured in lower abundances (0.12 HY b/100 nh/year) from 2008-2015 (Fig. 2). In 2014 and 2015, we captured no HY birds, a 100% decline in HY birds during the second two years of the drought.

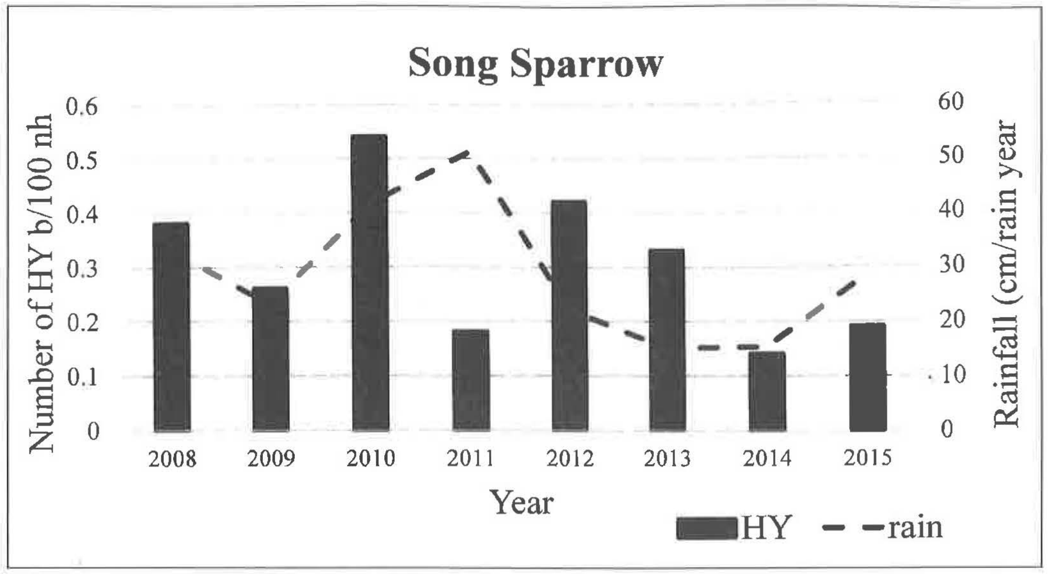

Fig 3. Number of HY Song Sparrows captured (bars) and rainfall (dashed line) by year from 2008-2015. Avarage = 0.30 HY SOSP/100 nh/year.

From 2008 to 2015, 0.30 HY SOSP/100 nh/year were captured per year (Fig. 3). The number of HY birds/ 100 nh captured during the first two years of the drought were higher than the average, but this number dropped to 0.16 HY b/100 nh/year during 2014-2015, the second two years of the drought. This was a 46.7% decline in HY b/100nh.

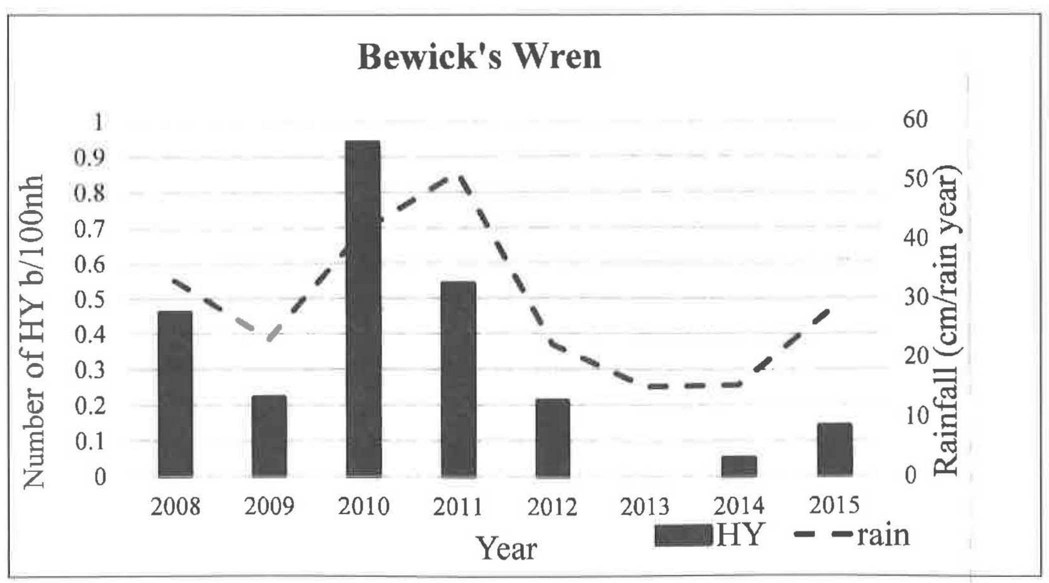

Fig. 4. Number of HY Bewick's Wrens 100 nh captured (bars)and rainfall (dashed lines) by year from 2008 - 2015. Average = 0.32 BEWR/100 nh/year.

There was an average of 0.32 HY BEWR/100 nh/year from 2008 to 2015 (Fig. 4). The average for 2014 to 2015 was 0.1 HY b/100nh/year (two birds, representing a 75.0% decline in HY birds captured/year). The impact of the drought on BEWR appears to have begun during the first year of the drought (2012) with no HY birds in 2013. Between 2008-2011 vs 2012-2015, the decline in HY BEWR was 80.9%

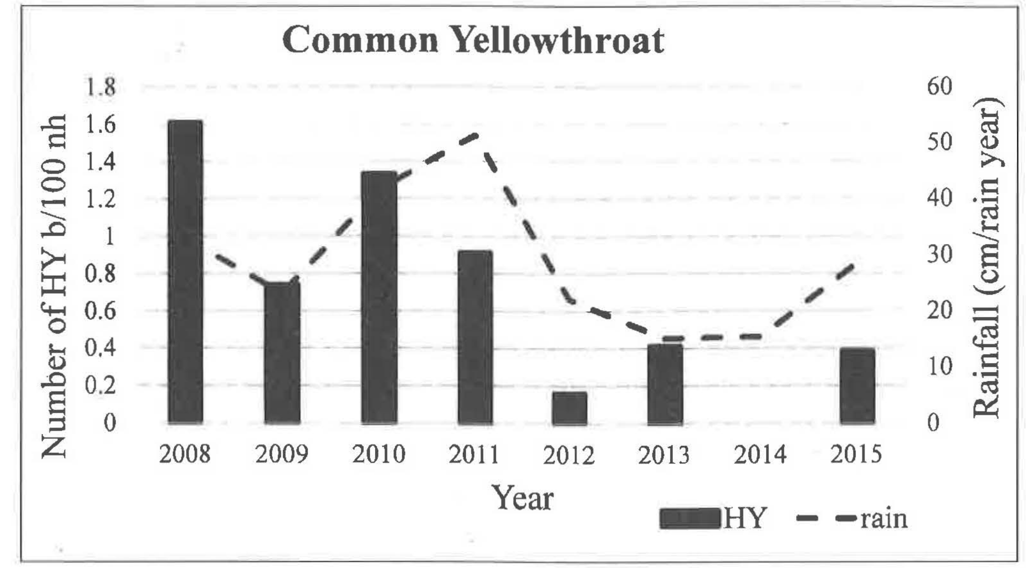

Fig. 5. Number of HY Common Yellowthroats/100nh captured (bars) and rainfall (dashed line) by year from 2008 - 2015). Average = 0.69 HY COYE/100 nh/year.

An average of 0.69 HY COYE/100 nh/year was captured from 2008-2015 (Fig. 5). COYE seems to have responded similarly to BEWR, as the number of HY birds dropped to 0.16 HY b/100 nh (three birds) in the first year of the drought (2012), and there were no HY birds in 2014. During the four-year drought (2012-2015), there was 0.13 HY b/100nh/year captured, representing a 72.1% decline from before the drought.

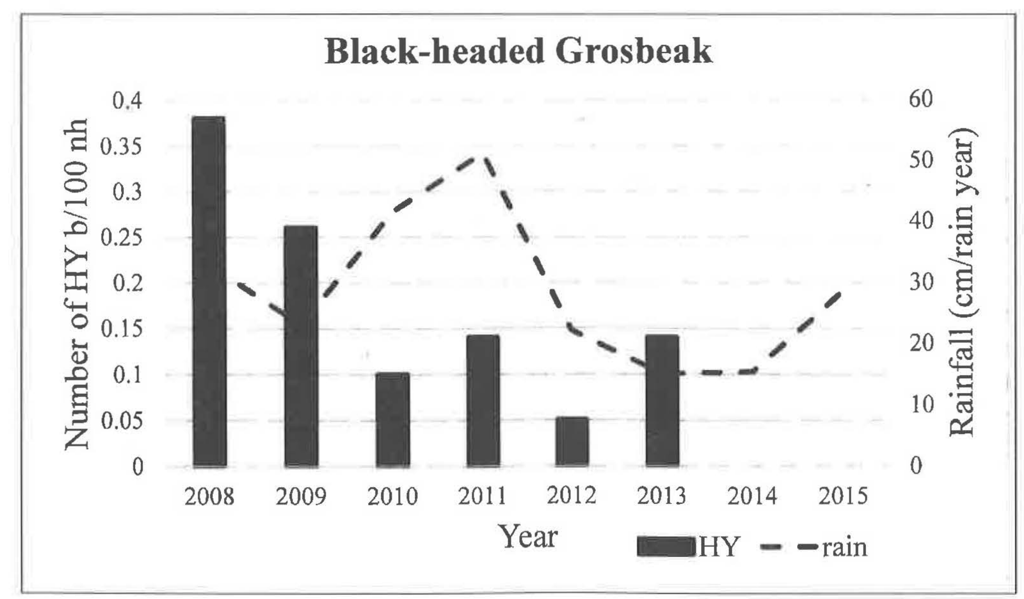

Fig. 6. Number of HY Black-headed Grosbeak captured (bars) and rainfall (dashed line) by year from 2008-2015. Average = 0.13 HY BHGR/100 nh/year.

There were 0.13 HY BHGR/100 nh/year captured from 2008-2015 (Fig. 6). There were no HY birds captured in 2014 and 2015, the third and fourth year of the drought, representing a 100% decline in HY birds.

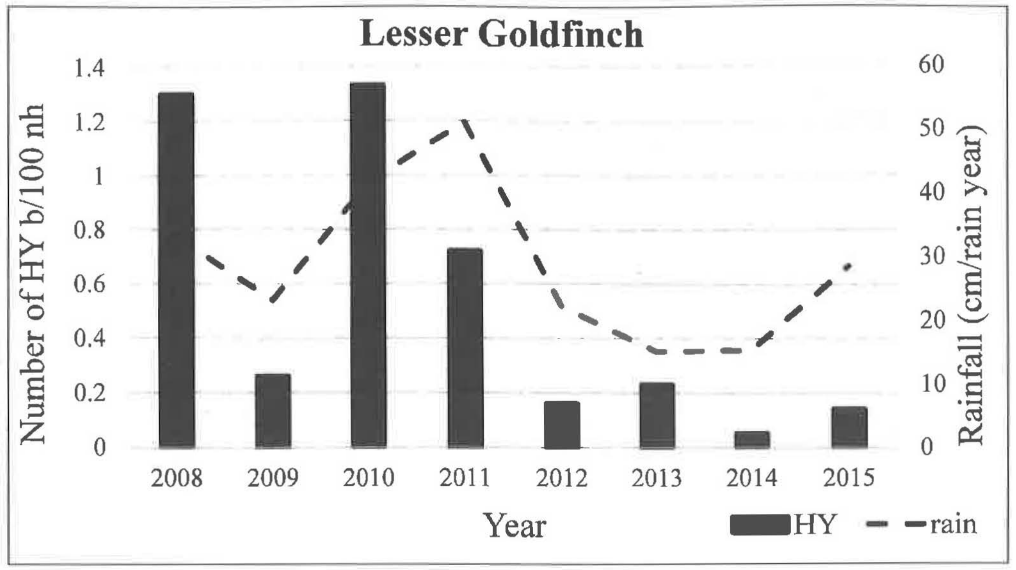

Fig. 7. Number of HY Lesser Goldfinch captured (bars) and rianfall (dashed line) by year from 2008- 2015. Average = 0.52 HY LEGO/100 nh/year.

There was an average of 0.52 HY LEGO/100nh/year captured from 2008-2015 (Fig. 7). There was an average of 0.10 b/100 nh captured in 2014-2015, representing an 80.8% decline in HY birds. Captures of HY birds were low throughout the drought years.

Table 2. Number of HY b/100 nh per year encountered by year from 2008-2015

Year	2008	2009	2010	2011	2012	2013	2014	2015
Species					D	D	D	D
SPTO	1.53	0.61	0.94	0.54	0.99	0.97	0.05	0.48
CALT	0.15	0.17	0.20	0.23	0.05	0.14	0.00	0.00
SOSP	0.38	0.26	0.54	0.18	0.42	0.33	0.14	0.19
BEWR	0.46	0.22	0.94	0.54	0.21	0.00	0.05	0.14
COYE	1.61	0.74	1.33	0.91	0.16	0.41	0.00	0.38
BHGR	0.38	0.26	0.10	0.14	0.05	0.14	0.00	0.00
LEGO	1.30	0.26	1.33	0.72	0.16	0.23	0.05	0.14
sum	5.81	2.52	5.38	3.26	2.04	2.22	0.29	1.33
% average	203.15%	88.11%	188.11%	113.99%	71.33%	77.62%	10.14%	45.50%

D = drought year
Average annual number of HY birds encountered per year from 2008-2015 = 2.86 b/100 nh.
% average = % of HY birds encountered each year compared to 2008-2015 average.

Table 2 is a composite of Figures 1-7 for HY birds for 2008-2105. The decline in HY birds between pre-drought (2008-2011) and drought (2012-2015) years was statistically significant (pair-wise t-test, p=0.0179). The decline was more statistically significant when a comparison was made between 2008-2013 and 2014-2015 (pair-wise t-test, p=0.0053). The percentage decline of HY birds for the seven species dropped 25.5% in the first two years of the drought. For the second two years of the drought, this decline was 71.7%. Four species produced no young birds (Figs. 2, 4-6, Table 2) during at least one of the four years of the drought; two species produced no young birds in two years of the drought (Figs. 2,6). Five species (Figs. 1,2,4,6,7, Table 2) produced only one young bird during one of the four years of the drought. The slight recovery in 2015 overall was likely due to a modest increase in rainfall (Table 1), although the number of HY birds was still 54.5% below average.

Table 3. Number of AHY b/100 bh per year encountered by species from 2008-2015.

Year	2008	2009	2010	2011	2012	2013	2014	2015
Species					D	D	D	D
SPTO	1.30	0.65	0.78	1.49	2.30	1.20	1.54	0.82
CALT	0.54	0.74	0.94	0.41	1.20	0.46	0.59	0.34
SOSP	1.30	0.52	0.79	1.20	1.46	1.11	0.82	0.48
BEWR	0.61	1.22	0.79	0.72	0.89	1.20	0.59	0.58
COYE	1.23	1.26	2.27	1.88	2.35	1.52	1.04	1.64
BHGR	1.07	0.61	0.34	0.32	0.52	0.32	0.23	0.43
LEGO	0.69	0.70	0.84	1.04	0.73	0.55	0.54	0.58
sum	6.74	5.70	6.76	6.36	9.45	6.36	5.35	4.87
% average	101.40%	85.70%	101.70%	95.60%	142.10%	95.60%	80.50%	73.20%

D = drought year.
Average number of AHY bird encountered per year from 2008-2015 = 6.45 b/100 nh.
% average = % of AHY bird/encountered each year compared to 2008-2015 average.

Table 3 shows the number of AHY birds captured by species from 2008-2015. The average number of AHY birds captured for all seven species per year for 2008-2015 was 6.45 b/100nh. The decline in AHY birds between pre-drought (2008-2011) and drought (2012-2015) years was not statistically significant (pair-wise t-test, p=0.854). There was a gradual decline in the number of AHY birds during the four years of the drought. The total decline for the second two years of the drought was 20.8% of the eight year average.

Table 4. Number of breeding b/100 nh encountered by species from 2008-2015.

Year	2008	2009	2010	2011	2012	2013	2014	2015
Species					D	D	D	D
SPTO	0.46	0.17	0.49	0.77	0.89	0.46	0.27	0.24
CALT	0.15	0.17	0.30	0.32	0.57	0.14	0.18	0.05
SOSP	0.61	0.00	0.49	0.32	0.78	0.78	0.41	0.10
BEWR	0.00	0.39	0.44	0.36	0.31	0.41	0.00	0.00
COYE	0.92	0.91	1.43	0.68	0.68	1.03	0.50	1.01
BHGR	0.69	0.39	0.30	0.32	0.47	0.23	0.14	0.19
LEGO	0.31	0.09	0.20	0.59	0.42	0.28	0.20	0.53
sum	3.14	2.12	3.65	3.36	4.12	3.36	1.59	2.12
% average	107.20%	72.40%	124.60%	114.30%	140.60%	114.70%	54.30%	72.40%

D = drought year.
Average number of breeding birds encountered per year from 2008-2015 = 2.93 b/100 nh.
% average = % of breeding birds/encountered each year compared to 2008-2015 average.

Table 4 shows the number of AHY birds in breeding condition captured as determined by presence of a CP or a BP, by species, from 2008-2015. A paired t-test indicated there was no difference in breeding condition pre-drought and during the drought (p=0.45). A statistically significant decline (p=0.0068) in breeding did not occur until the third and fourth years of the drought (36.5%). BEWR seems most affected by the drought, as there were no breeding birds captured in the second two years of the drought.

DISCUSSION

In this study I found that all of the seven species examined showed marked declines in the total number of birds captured during the years of the present drought (Table 1) and HY birds (Figs. 1-7, Table 2). These findings, although significant and apparently alarming, have been observed in other studies (e.g., Morrison and Bolger 2002, Bolger et al. 2005).

In other studies comparing results between wet and drought years, the comparisons have typically been single year drought events, when a drought year was followed by a wet year, or vice versa. For example, such was the case reported by Errington and Hamerstrom (1938) for a 1934 drought's effect on Grey (Hungarian) Partridge [*Perdix perdix*] in Iowa, Lindsey et al (1997) for an El Niño Southern Oscillation drought in Hawaii in 1991-92, Christman (2002) for a 1999 drought in southeastern Arizona, and Bolger et al. (2005) for the 2001 drought in California. Some studies were able to compare a drought year with pre- and post-drought years. Smith (1982) looked at the 1977 drought compared to 1976 and 1978 in the montane habitat in Utah. George et al. (1992) looked at the impact of a severe 1988 drought in North Dakota on the grassland bird community as compared to 1987 and 1989. Morrison and Bolger (2002) and Bolger et. al (2005) reported on the impact of a severe La Niña drought in1999 in the coastal sage scrub habitat in southern California. The underlying theme of these studies is that bird populations declined during the drought. Yet Bennett et. al (2014), looking at a long drought in Australia, found mixed results with some species recovering quickly, others did not recover after two years, and others yet continuing to decline.In most all cases, the population declined during the year of the drought but recovered to previous numbers following the drought.

The fact that there was no decline in the number of birds during the first two years of the drought (Table 1) illustrates that drought does not necessarily lead to an immediate decline in bird populations, although the severity of the drought is an issue (see Table 1). As the California drought persisted into the third and fourth years (2014 and 2015), impacts were seen with an overall 25% decline in the bird population numbers (Tables 1, 3). This delay in declines may be due to the nature of the chaparral habitat studied. First, the scrub-land habitat (locally called chaparral) is semiarid. The average rainfall is 37.46 cm /yr (14.75 in/yr) and unpredictable. Second, this community is in a normal, annual drought from April through November (Felton 1965), essentially nine months of every year. Approximately 80% of normal annual precipitation falls from December through March. Third, below-average annual rainfall seems to have become the norm for the past two decades, with 14 of the last 20 years having rainfall below the long-term average of 37.46 cm/year, and four of the last 20 years having less than 50% of average [2002, 2007, 2013, and 2014] (http://www.laalmanac.com/weather/we13.htm). Fourth, the entire community is adapted to this weather regime, including birds, food sources, and predators. Last, six of the seven species presented here are year-round resident birds. By definition, these birds remain regardless of the conditions, rain or drought, and have adapted to survive these rigorous conditions.

The mechanism for population declines and reduced reproductive success during or following droughts has been attributed to reduced food resources (Cody 1981, Smith 1982), while Preston and Rottenberry (2006) have studied the impact of supplemental food.Although food may be the proximal cause, the direct impact of a drought on food sources is the lack of water. Some researchers suggest drought or the lack of surface water may directly affect some species (Verner and Purcell 1999), but it seems less likely in highly mobile birds.

Predation and Parasitism - Drought has been shown to increase incidences of West Nile Virus (WNV) and St. Louis encephalitis (Shaman et al. 2003, 2005; Johnson and Sukhdeo 2013). The California Department of Public Heath reports a three-fold increase in the number of birds infected with WNV in California from pre-drought years (http://www.westnile.ca.gov).However, the seven species discussed here represent only 59/10,859 (0.0045%) cases over the last eight years, indicating that WNV has had a minimal impact on the decline on these seven species.

Although I saw no evidence of predation in Zuma Canyon, the impact of this present extended drought can be inferred from the vegetation. Numerous dead and dying drought-deciduous shrubs losing most of their leaves, sparse annuals in open fields, and dieback in large shrubs and trees were common by 2014. The loss of foliage was important as cover not only for adult birds but also for nests and nestlings (Albright et al. 2010), given the effect plant cover has on avifauna predation and heat deaths. McCreedy et. al (2015) reported higher degree of nest depredation and brood parasitism following low winter precipitation. Although in a completely different habitat, Alberico (1993) reported drought increased predation in American Avocets [*Recurvirostra americana*] and Black-necked Stilts [*Himantopus mexicanus*] as ponds where these birds breed dried up due to drought creating land bridges for coyotes to predate young.

Hatching-Year Birds - The reduced number or absence of HY birds caught in Zuma Canyon during the recent drought years (Table 2) was similar to what others have found (DeSante and Geupel 1987, George et. al 1992, Christman 2002). The overall decline in productivity began in the first year of the drought when the number of HY birds dropped by 28.7%. By the third year of the drought (2014), productivity dropped to 89.9% of average. In 2015, the birds rebounded to 55.5% of average, probably due to a higher and more timely rainfall (see Table 1) which was still below average (76.2% of average).

If we look at individual species, there were differences in responses to the drought. SPTO, SOSP, and BHGR had numbers of HY birds during the first two years of the drought (2012 and 2013) similar to those prior to the drought (Table 2, Figs. 1,3,6) not showing any declines in productivity until the third and fourth years of the drought (2014 and 2015) (Figs. 1-3,6).

BEWR. COYE, and LEGO showed declines in productivity from the onset of the drought (Figs. 4,5). This difference in the response to the long-term drought and the lag in response by some birds is expected (Albright et. al 2010). Although BEWR and COYE are common in chaparral ecosystems, they tend to be found in, and select, moister microhabitats. Kennedy and White (2013) noted that BEWR is found in riparian woodlands as well as brushy habitat. Guzy and Ritchison (1999) note that the COYE prefers thick vegetation in moister habitats. Watts and Willoughby (2014) note that LEGO inhabit a variety of habitats as long as water is available. The COYE is much more common in the nearby willow and marsh habitat at the mouth of Zuma Creek (Sakai, unpubl. field notes). BEWR and COYE are also carnivores feeding on insects and spiders (Guzy and Ritchison 1999, Kennedy and White 2013).The other four species will feed on terrestrial invertebrates but are much more omnivorous, mainly feeding on seeds and berries (Bartos Smith and Greenlaw 2015, Benedict et. al 2011, Arcese et. al 2002, Ortega and Hill 2010, Watt and Willoughby 2014).This interpretation should be taken with some caution as Verner and Purcell (1999) found BEWR did not seem to be affected by drought years in a study from 1987-1990 in the foothills of the Sierra Nevada.

The BHGR has a strategy altogether different, compared to the other six species, since it is a summer migrant. Maybe it is able to recharge during the winter months in more tropical areas, yet the species returned each year but did not produce any offspring in the second two years of the drought. Sufficient resources may not have been present to successfully produce offspring.

What is troubling is the fact that there were no CALT and BHGR hatching-year birds caught in 2014 and 2015, no COYE HY birds in 2014, and no BEWR HY birds in 2013. Compound this with the fact that we captured no BEWR in breeding condition in 2013 and 2014. Although Zuma Canyon is not an island without immigration or emigration, this four-year drought extended over the entire Santa Monica Mountains as well as essentially all of California. The reduced recruitment of young individuals and in some species the complete absence of HY birds will result in lower population sizes for those species in ensuing years (DeSante et. al 1993) even if precipitation returns to normal. Massey et al. (1992) found that colonial nest failure in one year impacted the Least Tern [*Sterna antillarum*] colony as much as five years down the road. Verner and Purcell (1999) noted that precipitation can exert its influence for more than one year. Essentially, the loss of one year class can result in a decline in a population for the entire projected life-time of an individual.In passerines, this can amount to as many as 10 years (Lutmerding and Love 2015). For CALT and BHGR, this was an absence of birds for two successive year classes. Surviving individuals may compensate by producing more individuals, but the success of that scenario depends on suitable conditions and enough time to eventually create a population-level increase in productivity.

The number of HY birds (productivity) was found to be correlated with the total adult population in the previous year for Swainson's Thrush [*Catharus ustulatus*] (Johnson and Geupel 1996), Wilson's Warbler [*Wilsonia pusilla*] (Chase et. al. 1997), and Least Terns [*Sterna antillarum*] (Massey et al. 1992). I anticipate that avifaunal numbers will remain lower than pre-drought averages for several years.

With modest rainfall in 2015 (75% of normal), SPTO and COYE showed a rise in the numbers of HY birds captured in 2015 (Figs. 1, 5), while CALT and BHGR apparently continued to produce no HY birds in 2015 (Table 2, Figs. 2, 6). It is likely that even though there was below-average rainfall in 2015, there was a sufficient amount of rainfall for some species to breed successfully, but still not in the numbers prior to the drought. Patten and Rotenberry (1999) showed that rainfall during egg formation was a good predictor of clutch size in the California Gnatcatcher [*Polioptila californica*], while seasonal rainfall was not. Although precipitation is a primary factor in breeding success, the key may be sufficient rainfall at the right time, which affects the presence and timing of available food resources. Other authors have noted that rainfall is correlated with food availability (Morrison and Bolger 2002). The reproductive success of Gambel's Quail [*Callipepla gambelii*] in the deserts of California is based on sufficient winter rains to trigger enough green vegetation growth that the quail consumes to trigger reproduction (Alcock 1985). Greenlaw (1978) found that food for laying females is the key factor in determining the timing of nesting, studying Rufous-sided Towhees [*Pipilo erythrophthalmus*]. Jaksic (2001) found herbs and ephemerals tended to recover quickly after a drought while perennials took several years, and small rodents tended to recover quickly compared to larger rodents. This would affect the recovery of particular species of birds that feed on these food items. Although 2015 was not a wet year by any means and was considered a drought year, there seemed to be sufficient rainfall at the right time that led to seed germination. These plants provide food for insects as well as seed production (Laurance and Yensen 1985); the insects provide food for predators such as spiders, etc., on up the food chain. Some of the differences between drought-related studies may come down to the definition of a drought and the hyperbole associated with the event.

A good example of how the timing of rains and the amount of rains interrelated is the 6.07 cm (21% for the water year) of precipitation that fell in September 2015. This amount was most likely not helpful in the spring 2016 breeding season, as most of the germinating annuals had already died by October. Annual grasses seem to respond quickly to even a modest amount of rain, often sprouting within a week or two after rains (Jaksic 2001). Good annual rainfall with a substantial amount of mid-summer thunderstorms but no/little winter rain will not help spring annuals and birds that are breeding in the spring.

After-Hatching-Year Birds

The highest number of AHY birds captured was in 2012, following two above-average rainfall years (Tables 1,3). Although the number of AHY birds then declined throughout the four-year drought, the decline during the last two years of the drought was 25.5% of the 2008-2015 average. The AHY bird decline was much less than the decline for HY birds (see Tables 2,3).

Breeding Adult Birds

Christman (2002) found a reduced number of Bridled Titmouse (*Baeolophus wollweberi*) breeding during the drought. Other researchers have noted that declines occurred during the actual drought year (Bolger et. al. 2005; Chan 1999, DeSante and Geupel 1987, George et. al 1992). In this present study, the number of breeding birds did not drop (20.8%) until the third and

fourth years of the drought. The number of breeding birds was reduced by almost double (36.5%) during that same period. The decline was not uniform, as there were no breeding Bewick's Wrens captured in 2014 and 2015, indicating reproductive failure. On the other hand, the numbers of breeding adult COYE and LEGO were near or above their respective eight-year average.

The presence of CPs and BPs indicates birds are in breeding condition but does not equate to successful breeding. Although there were no CALT and BHGR HY birds captured in 2014 and 2015, this study found five CALT and seven BHGR with a CP or BP (Table 4). I interpret this to indicate that birds tried to breed but appeared to be unsuccessful. Conversely, no BEWR were found with a CP or BP in 2014 and 2015, yet four HY BEWR were captured. Of course, one never captures all of the birds in an area. It is more likely that numbers of birds truly were depressed during these drought-affected years.

Other factors have been noted by researchers to further reduce reproductive success. For example, Christman (2002) noted that among those breeding birds that did establish territories during a drought, there was a reduced amount of nest building, survival of young in nests, number of fledglings, and juvenile (fledgling) survivorship.Other impacts include fewer nesting attempts (Bolger et al 2005), reduced hatching success (George et al. 1992, Bolger et al. 2005), reduced number of fledglings/nest (George et al. 2002, Morrison and Bolger 2002, Bolger et al. 2005), reduced number of fledgling/successful nest (George et al. 1992), increased nest abandonment (George et al. 1992), increased nest predation (McCreedy et. al. 2015), and increased parasitism (McCreedy et al. 2015, Johnson and Sukdheo 2013).

Researchers have found mixed results in looking at survivorship of AHY birds vs HY birds. Sillett and Holmes (2002) found no difference in survivorship looking at Black-throated Blue Warblers (*Setophaga caerulescens*) Doherty and Grubb (2002) found higher adult survivorship in Carolina Chickadees (*Poecile carolinensis*) , White-breasted Nuthatches (*Sitta carolinensis*), and Downy Woodpeckers (*Picoides pubescens*). Again the definition of a drought and the severity of the event are issues.

Looking at Tables 2,3, and 4, we see that the decline in HY birds during the drought was greater than the decline of AHY birds and breeding birds, probably indicating that although adult birds were surviving and breeding, reproductive success was significantly reduce, often to zero.Table 3 indicates that AHY bird populations gradually declined as the drought progressed but this was not statistically significant comparing 2008-2012 to 2013-2015 or 2008-2013 to 2014-2015. The same can be said for the number of breeding birds, yet productivity (HY birds) decline was statistically significant. Adult birds seemed to have tried to breed but were generally unsuccessful. The exact cause could not be determined from this study. Thus, the primary cause of the population decline is the general failure to produce young birds.

Most studies have found that bird populations returned to their pre-drought numbers in the year following the drought. By continuing our banding work for this present project, we hope to be able to see which species quickly return to pre-drought numbers, or see if the protracted/extended drought causes long-term effects and a slower recovery for some or all species.

CONCLUSIONS

The overall avian population in my study area declined by approximately 25% during the extended four-year drought in CA. In comparing the second two years of the drought against the average of 2008-2015, although the AHY bird population only declined 23.2%, the number of breeding birds declined by 36.6%, indicating a large number of birds did not attempt breeding. The number of HY birds, or productivity, declined by 72.2% during the same period of time, indicating that many birds that attempted to breed were unsuccessful, leading to reproductive failure.

This study shows that simple comparing a drought year to a pre- or post-drought year can be misleading, as some birds are not noticeably affected unless the drought is more extensive.

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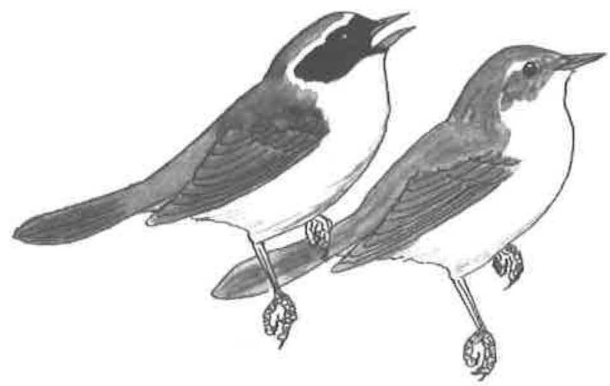

Common Yellowthroat by George West

The Accuracy of Wing Chord Ranges in Pyle (1997) as Indicators of Sex in North-Central Alberta Populations of Least Flycatcher, Myrtle Warbler, and Clay-colored Sparrow

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ABSTRACT

Wing chord ranges for several species and sexes in Pyle (1997) are primarily based upon measurements of museum study skins.Intended to encompass North America, these ranges provide the sole means of non-invasively sexing monomorphic birds outside of the breeding season. The validity of such ranges for live, individual populations has been little explored.

Beaverhill Bird Observatory and Boreal Monitoring Avian Productivity and Survivorship (MAPS) data for sexed, After-Second-Year Least Flycatcher (Empidonax minimus), *Myrtle Warbler* (Setophaga coronata coronata), *and Clay-colored Sparrow* (Spizella pallida) *individuals were used to determine the accuracy of sexing through wing chord ranges provided in Pyle (1997). Wing chord ranges developed from Alberta data varied by up to 3 mm from those in Pyle (1997). Despite this, wing chord ranges in Pyle (1997) correctly sexed 81.4% of Least Flycatchers, 95.8% of Myrtle Warblers, and 90.2% of Clay-colored Sparrows. Fisher's exact test found a significant relationship between sex classifications based upon wing chord ranges in Pyle (1997) and those based upon breeding or feather characteristics for all three*