



Trends in Landbird Abundance at Channel Islands National Park, 1993-2015

Natural Resource Report NPS/MEDN/NRR—2016/1335



ON THE COVER

Orange-crowned warbler (*Vermivora celata*), San Miguel Island
Photograph by: Brad Sillasen

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Abstract

The park's landbird monitoring program, one of the longest-running landbird population monitoring programs in the U.S., provided trend data for 29 of the park's 48 known breeding landbird species. Density estimates from distance sampling were constructed for 19 species. Distance estimates were not available for the legacy point count sites on Santa Cruz, but we used point count data to determine trends for 26 species on that island. Similarly, count data were also used to derive trends for 7 species on other islands. The methods were incapable of detecting trends for relatively rare species such as swifts and swallows, owls, and some large raptors such as bald and golden eagles and peregrine falcons. Distance sampling methods allow estimation of density and are robust to observer variability, due to incorporation of covariates in the model. Problems with confidence intervals and annual variability are lessened over time, as the number of detections for each species accrues.

Trend analysis revealed various rates of change in landbird populations on the five park islands. While small sample sizes made conclusions about change on Anacapa tenuous, there was less change, overall, on Santa Barbara and San Miguel, the other two smaller islands. Some trends on the latter seemed related to the decline and recovery of the island fox, an effective nest predator. The relatively low amount of change on those islands echoes concerns that recovery of vegetation from past land use practices, such as grazing, has slowed or stalled (Davidson et al. *in review*). There was much greater change on the two larger islands of Santa Cruz and Santa Rosa, where recent removal of nonnative ungulates has allowed incipient recovery of shrub and woodland communities. The removal of domestic sheep and feral pigs from Santa Cruz Island, in the 1980s and 2000s, respectively, has apparently resulted in the increase of landbird species which prefer shrub and woodland habitat, and a decrease in those that prefer grassland. There was less change on Santa Rosa, where cattle were removed in 1998, elk and most deer by December 2011. Still, increases in some shrub and woodland bird species on that island suggest that Santa Rosa may eventually follow a similar recovery track as Santa Cruz, where almost all landbird species experienced change over time.

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Introduction

Although landbirds are among the most conspicuous and diurnal of vertebrates, reported trends from longterm datasets are rare, perhaps due to the high variability produced by traditional monitoring methods, such as point counts, and differences in detectability among observers. Recent advances in distance-based sampling methods (Buckland et al. 2001) allow the development of density estimates with reasonable confidence intervals, by incorporating species and observer-specific detectability curves. We used such methods to analyze long-term trends in landbird populations at Channel Islands National Park (Figure 1), where landbird monitoring has been conducted since 1993 as part of the National Park Service's Inventory and Monitoring Program.



Figure 1. Channel Islands National Park comprises San Miguel, Santa Rosa, Santa Cruz, Anacapa, and Santa Barbara islands.

The avifauna of California's Channel Islands has long been of interest to both conservationists and researchers. Early investigations focused on classic island biogeographic theory and questions such as the rate of species turnover on nearshore islands (Diamond 1969, Lynch and Johnson 1974). Also, the islands' isolation from the adjacent mainland has resulted in an overall depauperate avifauna and the evolution of endemic forms. Forty-nine landbird species are known to breed on the park islands

(Table 1). Johnson (1972) reported that 13 breeding landbird taxa were endemic to the Channel Islands, and 11 endemic bird taxa occur on the five park islands (Table 2). Several endemic taxa are currently of management concern. For example, the island scrub jay (see Table 1 for scientific names) is the only full landbird species designated as endemic on the Channel Islands. The species occurs only on Santa Cruz Island, and recent questions about its population status have focused attention on current and future threats to the species. Of greatest concern is potential vectoring of West Nile virus (WNV) to the island, which may occur if warming temperatures allow WNV-host mosquito species to establish on the islands (Morrison et al. 2011). West Nile Virus causes high mortality in the jay's mainland relative, the western scrub jay. Another species, the island loggerhead shrike, is an endemic subspecies found on Santa Cruz and Santa Rosa Islands. It may currently be in decline on those islands, where it exists at very low numbers, and has recently been the object of intensive survey efforts (Stanley et al. 2012).

Table 1. Island-specific breeding status of landbirds known to breed at Channel Islands National Park. Data from Collins and Jones (2015).

Common Name	Latin Name	SM ¹	SR	SC	AN	SB
Great blue heron	<i>Ardea herodias</i>		B ²			
Golden eagle	<i>Aquila chrysaetos</i>		O	O		
Red-tailed hawk	<i>Buteo jamaicensis</i>	B	B	B	B	
Northern harrier	<i>Circus cyaneus</i>	O	O			
Bald eagle	<i>Haliaeetus leucocephalus</i>		B	B	B	
Peregrine falcon	<i>Falco peregrinus</i>	B	B	B	B	B
American kestrel	<i>Falco sparverius</i>	B	B	B	B	B
California quail	<i>Callipepla californica</i>		B	B		
Rock pigeon	<i>Columba livia</i>		O			
Mourning dove	<i>Zenaida macroura</i>		B	B		O
Barn owl	<i>Tyto alba</i>	B	B	B	B	B
Northern saw-whet owl	<i>Aegolius acadicus</i>			B		
Short-eared owl	<i>Asio flammeus</i>					B
Burrowing owl	<i>Athene cunicularia</i>					B
White-throated swift	<i>Aeronautes saxatalis</i>		B	B	B	
Anna's hummingbird	<i>Calypte anna</i>	O	O	B		
Allen's hummingbird	<i>Selasphorus sasin</i>	B	B	B	B	
Northern flicker	<i>Colaptes auratus</i>			B		
Acorn woodpecker	<i>Melanerpes formicivorus</i>		B	B		
Pacific-slope flycatcher	<i>Empidonax difficilis</i>		B	B	B	
Black phoebe	<i>Sayornis nigricans</i>	O	B	B	O	
Ash-throated flycatcher	<i>Myiarchus cinerascens</i>			B		
Horned lark	<i>Eremophila alpestris</i>	B	B	B		B
Barn swallow	<i>Hirundo rustica</i>	B	B	B	B	B

Table 1. Island-specific breeding status of landbirds known to breed at Channel Islands National Park. Data from Collins and Jones (2015) (continued).

Common Name	Latin Name	SM ¹	SR	SC	AN	SB
Island scrub-Jay	<i>Aphelocoma insularis</i>			B		
Bushtit	<i>Psaltiriparus minimus</i>		B	B		
Common raven	<i>Corvus corax</i>	B	B	B		
Red-breasted nuthatch	<i>Sitta canadensis</i>			B		
Canyon wren	<i>Catherpes mexicanus</i>			O		
Rock wren	<i>Salpinctes obsoletus</i>	B	B	B	B	B
Bewick's wren	<i>Thryomanes bewickii</i>		B	B	B	
Blue-gray gnatcatcher	<i>Poliophtila caerulea</i>			B		
American robin	<i>Turdus migratorius</i>			O		
Northern mockingbird	<i>Mimus polyglottos</i>		B	B		
Loggerhead shrike	<i>Lanius ludovicianus</i>		B	B		
European starling	<i>Sturnus vulgaris</i>	B	B	B	B	B
Hutton's vireo	<i>Vireo huttoni</i>		B	B	O	
Orange-crowned warbler	<i>Vermivora celata</i>	B	B	B	B	B
Black-headed grosbeak	<i>Pheucticus melanocephalus</i>			B		
Red-winged blackbird	<i>Agelaius phoeniceus</i>			O		
Rufous-crowned sparrow	<i>Aimophila ruficeps</i>			B	B	
Grasshopper sparrow	<i>Ammodramus savannarum</i>			B		
Song sparrow	<i>Melospiza melodia</i>	B	B	B		
Spotted towhee	<i>Pipilo maculatus</i>		B	B		
Chipping sparrow	<i>Spizella passerina</i>		B	B	B	
Western meadowlark	<i>Sturnella neglecta</i>	B	B	B	B	B
Lesser goldfinch	<i>Carduelis psaltria</i>	B	B	B		
House finch	<i>Carpodacus mexicanus</i>	B	B	B	B	
Total		18	34	43	18	11

² B = regular breeder, O = occasional breeder

Table 2. Endemic landbird taxa at Channel Islands National Park (San Miguel, Santa Rosa, Santa Cruz, Anacapa and Santa Barbara Islands).

Species	Island form	Mainland form	Reference	Notes
Non-migratory Allen's hummingbird	<i>S. s. sedentarius</i>	<i>S. s. sasin</i>	Mitchell (2000)	<i>S. s. sedentarius</i> known also from Palos Verdes peninsula
Island flycatcher	<i>E. d. insulicola</i>	<i>E. d. difficilis</i>	Lowther (2000)	
Island horned lark	<i>E. a. insularis</i>	<i>E. a. actia</i>	Beason (1995)	21 subspecies recognized
Island scrub-jay	<i>A. insularis</i>	<i>A. californica</i>	Delaney and Wayne (2005)	Only island endemic which is full species; mainland form is western scrub-jay
Santa Cruz Island Bewick's wren	<i>T. b. nesophilus</i>	<i>T. b. charienturus</i>	Kennedy and White (1997)	<i>T. b. catalinae</i> occurs on Santa Catalina Island
Island loggerhead shrike	<i>L. l. anthonyi</i>	<i>L. l. gambeli</i>	Eggert et al. (2004)	<i>L. l. mearnsi</i> occurs on San Clemente Island
Dusky orange-crowned warbler	<i>V. c. sordida</i>	<i>V. c. lutescens</i>	Gilbert et al. (2010)	<i>V. c. sordida</i> also occurs on s. California coast
San Clemente spotted towhee	<i>P. m. clementae</i>	<i>P. m. megalonyx</i>	Greenlaw 1996	Occurs on Santa Rosa; mainland form occurs on Santa Cruz
San Clemente house finch	<i>C. m. clementis</i>	<i>C. m. frontalis</i>	Hill (1993)	<i>C. m. clementis</i> occurs on southern islands, including Santa Barbara; house finches on northern islands are the mainland subspecies, <i>frontalis</i>
Santa Cruz rufous-crowned sparrow	<i>A. r. obscura</i>	<i>A. r. ruficeps</i>	Collins (1999)	
Channel Island song sparrow	<i>M. m. graminea</i>	<i>M. m. heermanni</i>	Arcese et al. (2002)	Song sparrows on Santa Cruz are likely hybrids between <i>M. m. graminea</i> and <i>M. m. heermanni</i>

Two introduced species currently breed or recently bred on the park islands. California quail were introduced to Santa Rosa Island during the historic ranching period. European starlings were not intentionally introduced, but were recently common or abundant residents on all islands (van Riper III et al. 1988, Collins and Jones 2015).

In this report we analyze 23 years (1993-2015) of transect and point count data for trends. The National Park Service established a monitoring program for landbirds at CHIS in 1988 as part of its long-term ecological monitoring program (Davis et al. 1994). The objective of the landbird monitoring program was to be able to detect change in abundance and/or distribution of breeding landbirds in the park (van Riper III et al. 1988). The park's landbird monitoring program was originally established for San Miguel, Anacapa and Santa Barbara Islands, and a separate protocol was developed for the larger Santa Rosa Island in 1992 (Super et al. 1991). On Santa Cruz Island, of which two-thirds of which is owned and managed by The Nature Conservancy (TNC), TNC established 100 point count sites on Santa Cruz Island in the 1990s. The NPS began re-monitoring at those sites in 2013, and added sites on East Santa Cruz Island and at or near the recently restored wetland at Prisoner's Harbor. The existence of legacy data for the Santa Cruz point counts allowed us to evaluate trends over time on that island.

Methods

Channel Islands National Park comprises 5 of the 8 Channel Islands which lie off the coast of southern California (Figure 1). The park islands range in size from $<3 \text{ km}^2$ (Anacapa and Santa Barbara Islands) to $>200 \text{ km}^2$ (Santa Rosa and Santa Cruz Islands). The smaller islands are generally low in elevation and have little topographical relief; they are dominated by grass and shrub communities such as non-native annual grasslands, *Isocoma* scrub, *Baccharis* scrub, giant coreopsis, lupine scrub, coastal bluff scrub and coastal sage scrub. The larger islands are topographically diverse and have either deep canyons draining a central massif (Santa Rosa Island) or a large central valley between two mountain ranges, the product of an east-west trending fault line (Santa Cruz Island). In addition to the previously mentioned grass and shrub communities, the larger islands also have extensive areas of chaparral, as well as several types of woodland (i.e., closed-cone pine, Torrey pine, oak, and ironwood).

The islands have a Mediterranean-type climate, characterized by warm, dry summers and cool winters, during which most precipitation occurs. Some precipitation also comes in the form of fog moisture in spring and summer, when a marine layer is pushed onshore by northwest winds. Consequently, islands at the western end of the chain, such as San Miguel, are cooler and moister than those to the southeast (Santa Barbara).

From 1993 through 2015 landbirds were surveyed on line transects and at point count sites (Figures 2-6). The original (legacy) landbird monitoring protocol developed for the park's long-term ecological monitoring program (van Riper et al. 1988) comprised line transects along island trails which crossed multiple habitat types, on the three smaller park islands (Santa Barbara, Anacapa and San Miguel). Each transect was monitored once annually, in the spring (March – April). An observer walked each transect between dawn and 10:00 a.m. and recorded the perpendicular distance from the transect midline to each bird or group of birds detected visually or aurally (i.e., by call or song). Transects were not surveyed if wind was greater than 10 knots or if it was raining at the time. The transects, which had been established on the three smallest park islands (San Miguel, Anacapa and Santa Barbara) were surveyed annually from 1993 through 2015, with some exceptions (see Appendix A).

The legacy program included point count transects on Santa Rosa (Super et al. 1991), which were surveyed sporadically beginning in 1994. We do not report those data here; they have been reported elsewhere (Coonan et al. 2011b) and the different mix of habitat types in that sampling scheme makes the data less comparable to more recent point count data from that island.

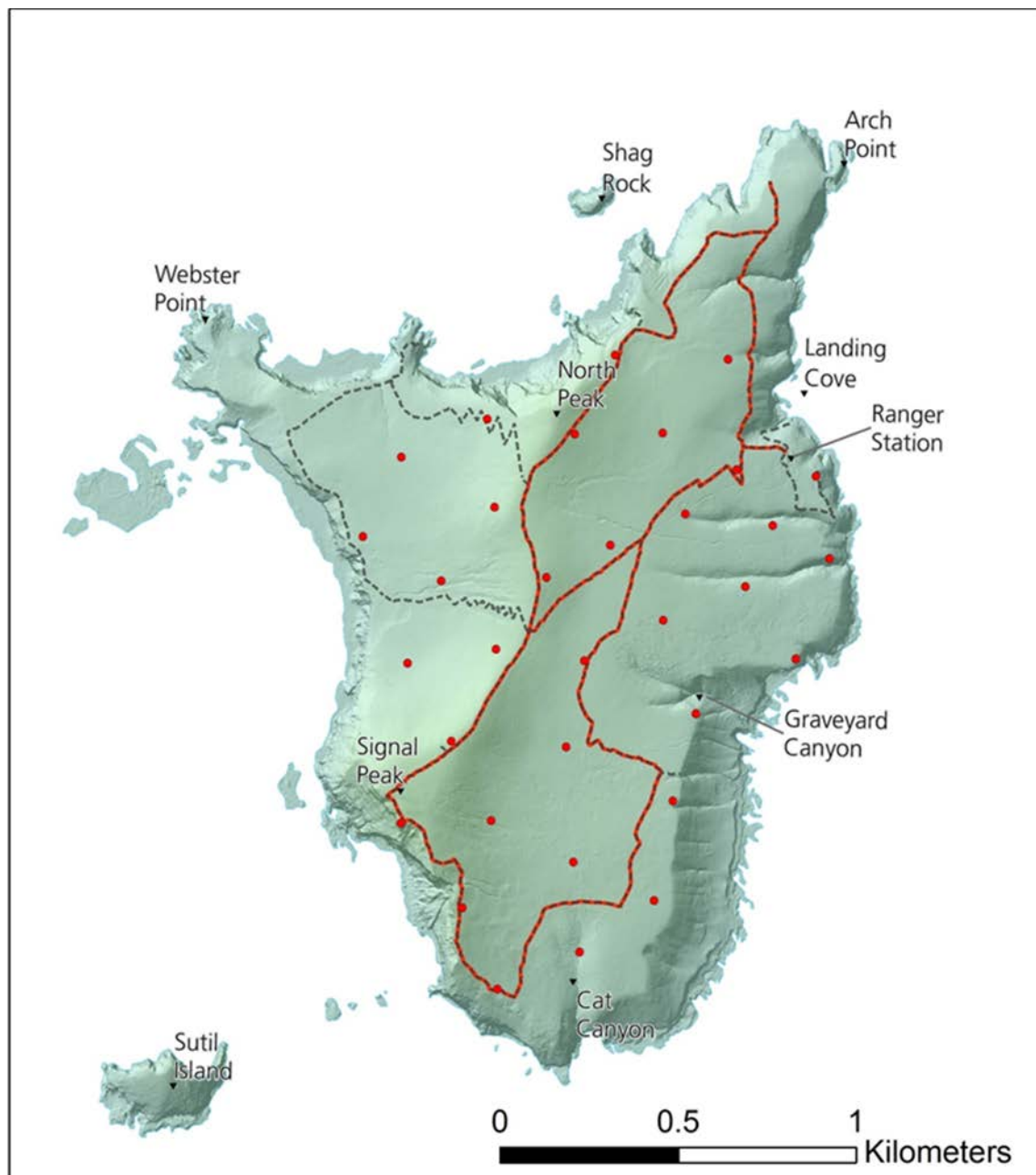


Figure 2. Locations of line transects from the original park landbird monitoring protocol (van Riper et al. 1988) and point count sites (on Santa Barbara Island, Channel Islands National Park)

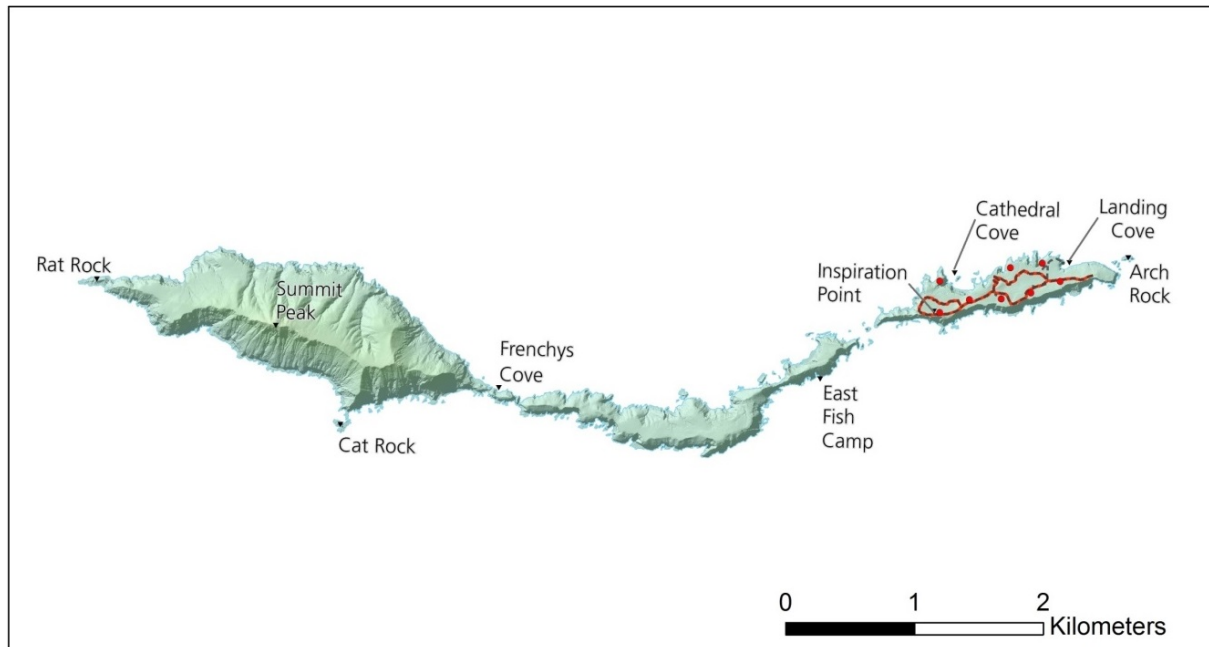


Figure 3. Locations of line transects from the original park landbird monitoring protocol (van Riper et al. 1988) and point count sites on Anacapa Island, Channel Islands National Park.

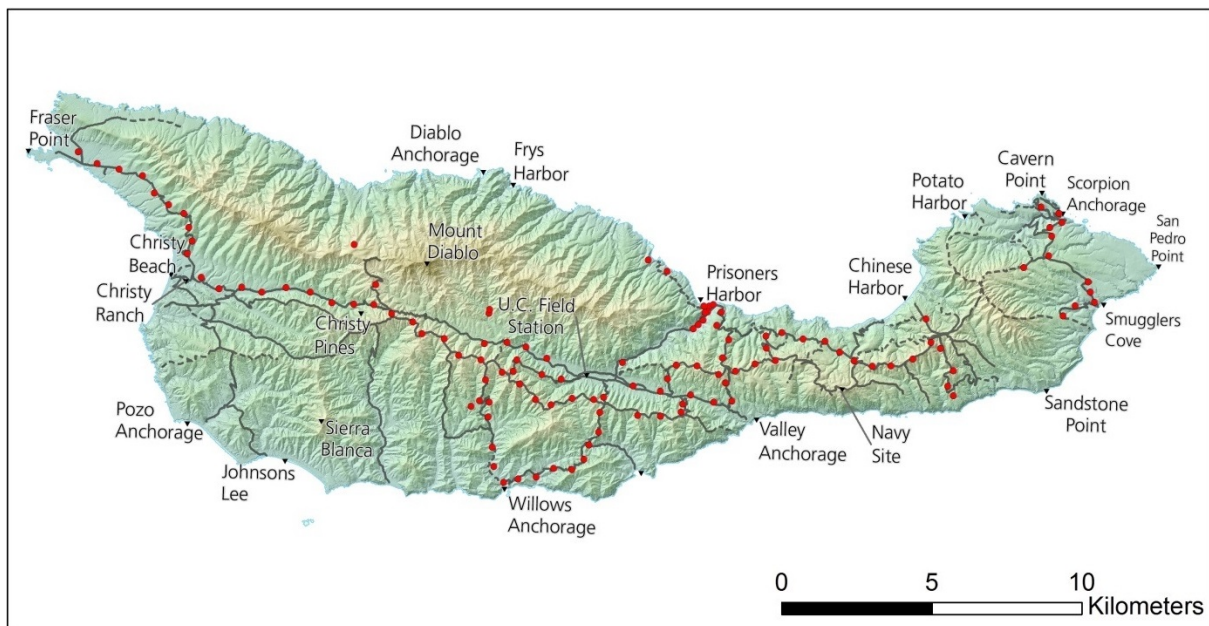


Figure 4. Location of landbird point count monitoring sites on Santa Cruz Island, Channel Islands National Park.

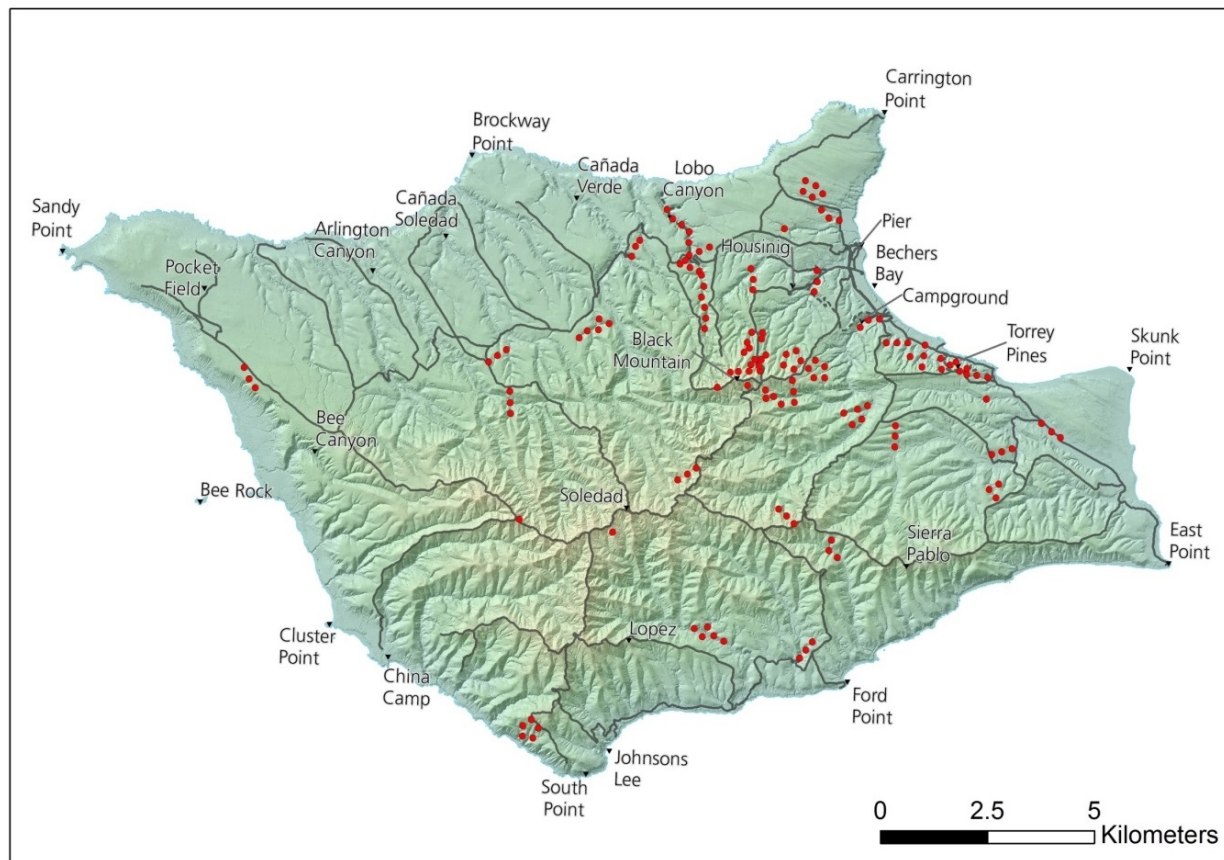


Figure 5. Locations of point count sites on Santa Rosa Island, Channel Islands National Park.

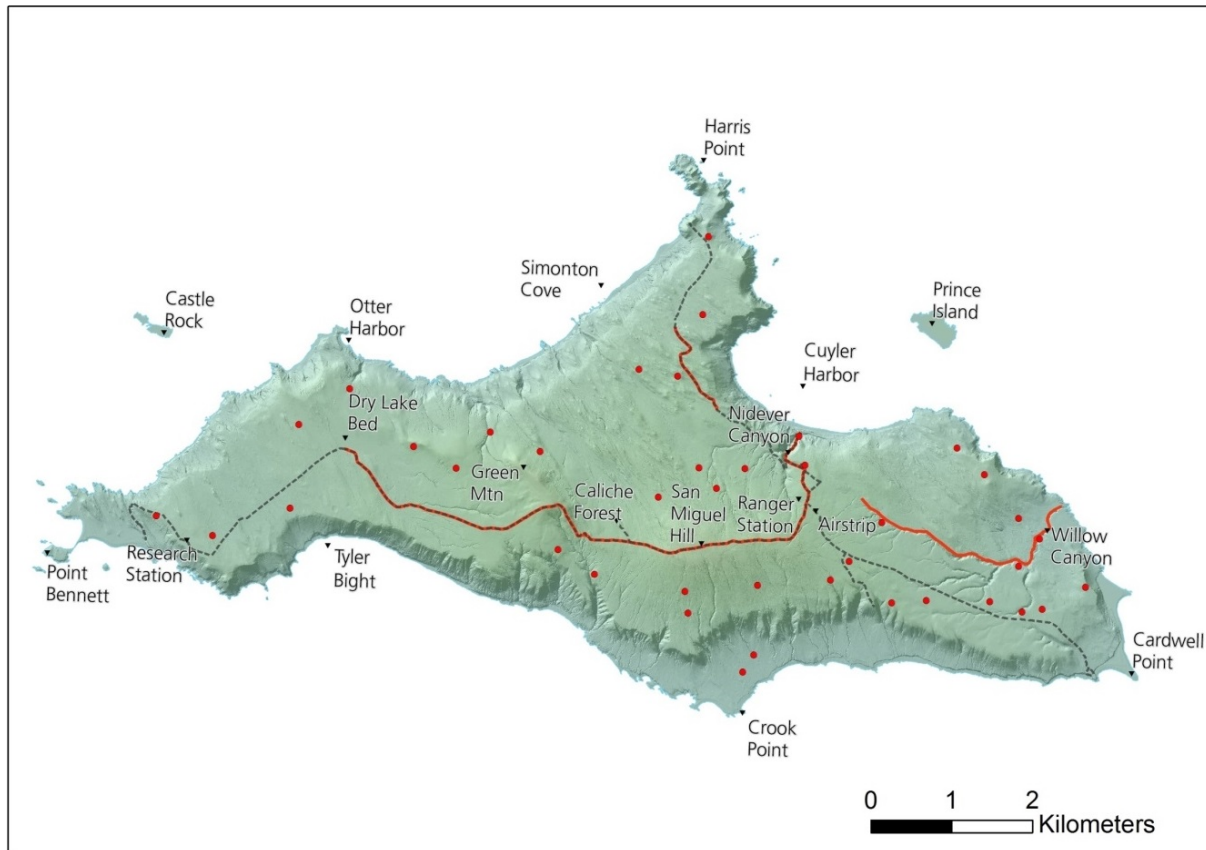


Figure 6. Locations of line transects from the original park landbird monitoring protocol (van Riper et al. 1988), and point count sites on San Miguel Island, Channel Islands National Park.

A program review conducted by the USGS Biological Resources Division (McEachern 2000) recommended shifting to point count sampling with randomly located sites, stratified by habitat type, on Santa Barbara, Anacapa, Santa Rosa and San Miguel Islands. Consequently, a total of 226 point count sites were established: 8 on Anacapa, 33 on Santa Barbara, 40 on San Miguel, and 145 on Santa Rosa (for detailed information about point count sampling and sites, see Coonan et al 2011b). Sampling at each point count site was conducted for 10 minutes, with perpendicular distance to each bird estimated. Details on sampling methods are available in Coonan et al. (2011a). For a plot of 50 m radius at each site the percent cover of different vegetation types was visually estimated, and the dominant type was identified as habitat type for that point. On the smaller islands (Anacapa and Santa Barbara), the number of point count sites was determined by the maximum number that could be randomly located with spacing of at least 250 m. Due to the small size of Santa Barbara Island, its point count sites (Figure 2) were randomly selected from a grid of potential point count sites so that a sufficient number of sites could be located while maintaining adequate space between sites. On Santa Rosa (216 km²), many point count sites were located on transects of 3-5 sites to reduce travel time. Monitoring at the new point count sites began in 2002-2003.

In 2013 we began monitoring on Santa Cruz Island, at 100 point count sites established by Robert C. Klinger of The Nature Conservancy in 1992, and at 12 point count sites we established on East Santa

Cruz Island (Figure 6). The TNC sites, as well as the 12 on East Santa Cruz Island, were spaced $\frac{1}{2}$ mile apart on the island's major roads and trails, with a random compass bearing to the plot (within 150 m of the road or trail) (Klinger 1988).

Habitat Types

One advantage of point count sampling over line transect sampling is that habitat type can be determined for point count sites, and thus habitat type can be considered in analyses. For point count sites established by NPS, dominant habitat type at each site was determined visually at each site, and later confirmed by vegetation mapping (Table 3; see Coonan et al 2011a, 2011b). For the 100 point count sites established by TNC in the early 1990s, we used the habitat type identified when those sites were established (Klinger 1988). Many of those sites have likely changed over time, to the point where the original habitat type may no longer be representative of current vegetation.

Table 3. Number of point count sites in different habitat types on each island, Channel Islands National Park.

Habitat type	SB	AN	SC-TNC	SC-NPS	SR	SM
Shrub Habitats						
Baccharis scrub						1
Boxthorn scrub	1					
Cactus scrub	2					
Caliche scrub						2
Coastal bluff scrub						1
Island chaparral			34		30	
Coreopsis scrub	5	5				8
Coastal sage scrub			8	2	37	2
Coastal scrub (non-spec)						5
Disturbed shrub-savannah				2		
Lupine scrub					5	8
Seablite scrub	4					
Sea cliff scrub	1					
Riparian					16	2
Non-native Habitats						
Fennel			12			
Grassland	17	2	32	10	30	11
Perennial iceplant	3	1				
Woodland Habitats						
Mixed woodland			11	7	9	
Oak woodland					6	
Closed Cone Pine			3		6	
Torrey pine					6	
Total	33	8	100	21	145	40

Data Analysis

We investigated trends over time for island species in two ways. The first, which we preferred if there were adequate data, was to estimate annual island-specific density for a species, and evaluate those annual densities for trend via linear regression. If there were not enough data (detections) to estimate density, we were able, in some cases, to use count data at consistently sampled sites (transects or point counts) to evaluate trend via Poisson regression, which is appropriate for count data.

For both line transect and point count sampling, recording perpendicular distance to all birds detected allowed estimation of density by program Distance (ver. 6.0; Thomas et al. 2009). Twenty of the park's 44 breeding species of landbirds had a sufficient number of detections (>50; Buckland et al. 2001) on either line transects or point counts to allow construction of detectability curves by program Distance (Table 5). For those species we estimated density from either line transect or point-count data using global detectability with models pooling data over all observers and with models using observer as a covariate, to account for the multiple observers who conducted monitoring over the 23-year period. We tested the half-normal estimator with both the cosine and Hermite modifiers, and the hazard estimator with the simple polynomial modifier. We also tested models with observations truncated at 50, 75 and 100 m, as well as a model with observations grouped in intervals between 0 and the maximum distance. To select among estimators, we chose the one which produced a detectability at or close to 1.0 for distance = 0 (Buckland et al. 2001). We used program R (R Core Team 2013) to conduct linear regression of density on year, and so test for trends in density over time, for each species/year combination.

We also used linear regression to examine the relationship between bird density and that of island foxes, which declined in the late 1990s and were completely absent from the wild from 1999-2004, when all remaining foxes were in captivity (Coonan et al. 2010).

For species which had inadequate number of detections over time to construct detectability curves, or for those species for which program Distance failed to run, we used count data to estimate trend over time. We performed such evaluations for data collected at the 100 point counts sites on Santa Cruz Island, initially sampled by The Nature Conservancy in the early 1990s, subsequently resampled by University of California Santa Cruz Island Reserve staff in the mid-2000s, and then added to our monitoring program in 2013. We analyzed count data for trend if annual observations were ≥ 10 in any year of the surveys, and if the species was present in over half the survey years. We identify species which disappeared or appeared in samples over time.

We used point count data from 1992-1995 to identify habitat affinities for landbirds on Santa Cruz Island, and then to determine patterns in habitat affinity among increasing and declining species. Dominant habitat type had been identified for each of the 100 landbird points on Santa Cruz (R.C. Klinger, The Nature Conservancy, unpubl. data). For each species, we determined the proportion of detections in each of the native habitats (those excluding fennel), and compared those to the relative availability of each habitat type to obtain a habitat selection value for each habitat type. Selection values >1.0 indicated preference of that type, whereas values <1.0 indicated avoidance. Because we were interested in the relative use of general habitat types, we combined detections in chaparral and

coastal sage scrub into a general shrub category, and combined mixed woodland and Santa Cruz Island pine into a woodland category. This gave us the three general categories of grassland, shrub, and woodland. For each species, habitat selection values were compared to determine habitat affinities.

Island-specific habitat-type use was previously determined for landbirds on Santa Barbara, Anacapa, Santa Rosa and San Miguel Islands from point count data collected from 2002-2009 (Coonan et al. 2011b). In order to evaluate habitat affinity trends among increasing and declining species, we combined habitat categories into the more general ones of grassland, shrub and woodland.

Observer Bias

Observer bias can be an almost unavoidable source of error in avian count surveys (Ralph et al. 1993, Farmer et al. 2012). We minimized the effect of observer bias in several ways. First, we used relatively few observers over the 23-year sampling period (Figure 7), which provided for more consistency in count quality. A total of 16 observers conducted transect surveys (Figure 7a), and 80% of transect surveys were conducted by just five observers. Similarly, 54 observers conducted point count surveys, and almost 70% of point count surveys were conducted by six observers (Figure 7b). Second, we conducted informal landbird monitoring training from 1993-2011 and formal landbird monitoring training annually beginning in 2012. Participants were trained to recognize island bird species by both sound and sight, and were instructed in proper estimation of distance to birds. Last, when we could we used multiple-observer models to construct detectability curves for island species (see Data Analysis, p. 8). Such models account for differences in detection ability among observers.

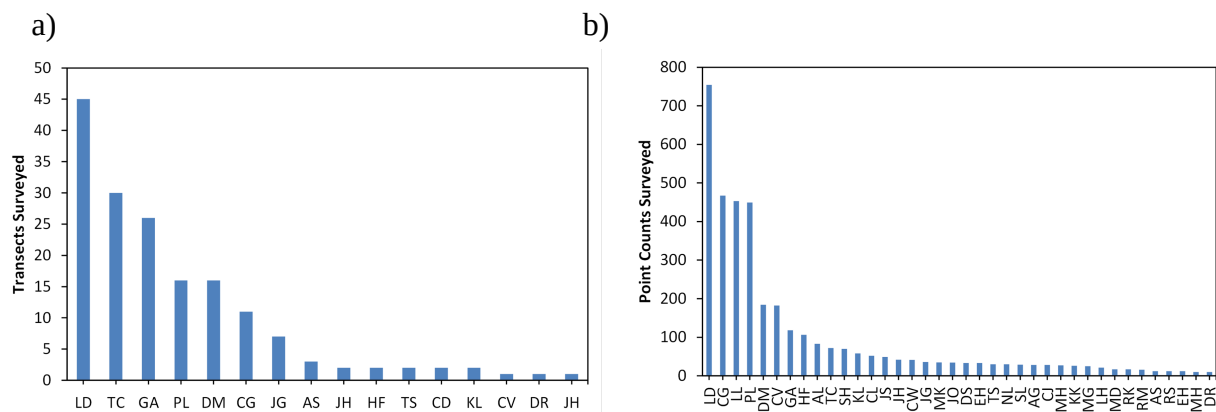


Figure 7. Number of observers for a) line transect and b) point count landbird monitoring surveys, Channel Islands National Park, 1993-2015.

Results

A total of 137 species were observed across all islands, including 47 of the 48 species that breed on the park islands (Table 4; northern saw-whet owls, which breed on Santa Cruz Island, were not observed during monitoring). A total of 9 species had sufficient detections on line transects to estimate density, while 17 had sufficient detections on point count transects to do so (Table 5). The density estimators chosen differed among species. The coefficient of variation for the probability detection function (PDF) was similar for both methods. The highest values for coefficient of variation were for mourning doves and northern mockingbirds on point counts, but those were still below the limit for acceptable (or desirable) coefficient of variation (<20%).

Table 4. Number of individuals observed on each island for species detected during landbird monitoring at Channel Islands National Park, 1992-2015.

Common Name	Scientific Name	SB	AN	SC	SR	SM
Great blue heron	<i>Ardea herodias</i>			7	1	
Mallard	<i>Anas platyrhynchos</i>			128	67	
Green-winged teal	<i>Anas crecca</i>				2	
American wigeon	<i>Anas americana</i>				5	
Ruddy duck	<i>Oxyura jamaicensis</i>				6	
Turkey vulture	<i>Cathartes aura</i>				1	1
White-tailed kite	<i>Elanus leucurus</i>	1		2	1	
Sharp-shinned hawk	<i>Accipiter striatus</i>	1		14	2	2
Cooper's hawk	<i>Accipiter cooperii</i>		1	9		1
Red-tailed hawk	<i>Buteo jamaicensis</i>	1	9	90	134	69
Red-shouldered hawk	<i>Buteo lineatus</i>	1				
Rough-legged hawk	<i>Buteo lagopus</i>					1
Golden eagle	<i>Aquila chrysaetos</i>			1	1	
Bald eagle	<i>Haliaeetus leucocephalus</i>			3	8	1
Northern harrier	<i>Circus cyaneus</i>	58		5	18	126
Osprey	<i>Pandion haliaetus</i>			5	1	
Prairie falcon	<i>Falco mexicanus</i>					1
Peregrine falcon	<i>Falco peregrinus</i>	48	17	12	16	17
Merlin	<i>Falco columbarius</i>	6			1	2
American kestrel	<i>Falco sparverius</i>	179	10	198	105	21
California quail	<i>Callipepla californica</i>			1983	236	
Wild turkey	<i>Meleagris gallopavo</i>			51		
Virginia rail	<i>Rallus limicola</i>				7	
American coot	<i>Fulica americana</i>			19		
Mountain plover	<i>Charadrius montanus</i>					1
Black-bellied plover	<i>Pluvialis squatarola</i>					140
Band-tailed pigeon	<i>Columba fasciata</i>			345		

Table 4. Number of individuals observed on each island for species detected during landbird monitoring at Channel Islands National Park, 1992-2015 (continued).

Common Name	Scientific Name	SB	AN	SC	SR	SM
Rock dove	<i>Columba livia</i>	1				
Mourning dove	<i>Zenaida macroura</i>	1		1107	73	5
Spotted dove	<i>Streptopelia chinensis</i>				1	
Eurasian collared dove	<i>Streptopelia decaocto</i>				6	1
Barn owl	<i>Tyto alba</i>	29			1	8
Long-eared owl	<i>Asio otus</i>	1				
Short-eared owl	<i>Asio flammeus</i>	32				
Burrowing owl	<i>Athene cunicularia</i>	7	2	2		7
Black swift	<i>Cypseloides niger</i>			1		
Vaux's swift	<i>Chaetura vauxi</i>			5		1
White-throated swift	<i>Aeronautes saxatalis</i>			49	33	
Costa's hummingbird	<i>Calypte costae</i>			1		
Anna's hummingbird	<i>Calypte anna</i>	1	1	490	141	67
Rufous hummingbird	<i>Selasphorus rufus</i>				9	
Allen's hummingbird	<i>Selasphorus sasin</i>	4		296	688	496
Belted kingfisher	<i>Ceryle alcyon</i>			11		
Northern flicker	<i>Colaptes auratus</i>	1		1081	29	12
Acorn woodpecker	<i>Melanerpes formicivorus</i>			500	45	
Yellow-bellied sapsucker	<i>Sphyrapicus varius</i>					1
Red-breasted sapsucker	<i>Sphyrapicus ruber</i>			12		
Nuttall's woodpecker	<i>Picoides nuttallii</i>			1		
Hairy woodpecker	<i>Picoides villosus</i>			2		
Western kingbird	<i>Tyrannus verticalis</i>	1	2	3	2	2
Cassin's kingbird	<i>Tyrannus vociferans</i>			1		
Ash-throated flycatcher	<i>Myiarchus cinerascens</i>			334		1
Black phoebe	<i>Sayornis nigricans</i>	5	14	156	131	14
Say's phoebe	<i>Sayornis saya</i>	107	31	210	28	44
Pacific-slope flycatcher	<i>Empidonax difficilis</i>			96	1301	8
Western wood-pewee	<i>Contopus sordidulus</i>			1		
Olive-sided Flycatcher	<i>Contopus borealis</i>					2
Violet-green Swallow	<i>Tachycineta thalassina</i>			3		3
Northern rough-winged swallow	<i>Stelgidopteryx serripennis</i>			13		
Barn swallow	<i>Hirundo rustica</i>	1	49	632	321	46
Cliff swallow	<i>Petrochelidon pyrrhonota</i>	8	1	14		5
Loggerhead shrike	<i>Lanius ludovicianus</i>	1		88	100	2
Cedar waxwing	<i>Bombycilla cedrorum</i>				26	
House wren	<i>Troglodytes aedon</i>	12	12	27	11	15
Winter wren	<i>Troglodytes troglodytes</i>			1		

Table 4. Number of individuals observed on each island for species detected during landbird monitoring at Channel Islands National Park, 1992-2015 (continued).

Common Name	Scientific Name	SB	AN	SC	SR	SM
Bewick's wren	<i>Thryomanes bewickii</i>	7	165	2548	2620	78
Rock wren	<i>Salpinctes obsoletus</i>	60	25	30	121	88
Northern mockingbird	<i>Mimus polyglottos</i>	2		107	115	6
California thrasher	<i>Toxostoma redivivum</i>			2		
Bushtit	<i>Psaltirparus minimus</i>			462	68	13
Red-breasted nuthatch	<i>Sitta canadensis</i>	3		7	12	
Orange-crowned warbler	<i>Vermivora celata</i>	624	423	1032	2316	3111
Nashville warbler	<i>Vermivora ruficapilla</i>				1	1
Yellow warbler	<i>Dendroica petechia</i>			3	2	6
Magnolia warbler	<i>Dendroica magnolia</i>			1		
Yellow-rumped warbler	<i>Dendroica coronata</i>	162	149	257	42	123
Black-throated gray warbler	<i>Dendroica nigrescens</i>	6				
Townsend's warbler	<i>Dendroica townsendi</i>	1		15	10	14
Hermit warbler	<i>Dendroica occidentalis</i>				1	
Palm warbler	<i>Dendroica palmarum</i>		1			
Macgillivray's warbler	<i>Oporornis tolmiei</i>				1	
Common yellowthroat	<i>Geothlypis trichas</i>	1	2	18	16	12
Wilson's warbler	<i>Wilsonia pusilla</i>	3		3	12	20
Hutton's Vvreo	<i>Vireo huttoni</i>		1	239	66	1
Bell's vireo	<i>Vireo bellii</i>			1		
Warbling vireo	<i>Vireo gilvus</i>			1	4	6
Western meadowlark	<i>Sturnella neglecta</i>	2260	349	2340	2718	2226
Yellow-headed blackbird	<i>Xanthocephalus xanthocephalus</i>		1			
Red-winged blackbird	<i>Agelaius phoeniceus</i>			134	5	
Hooded oriole	<i>Icterus cucullatus</i>			5		10
Brewer's blackbird	<i>Euphagus cyanocephalus</i>	8	5	45		7
Brown-headed cowbird	<i>Molothrus ater</i>			2		1
Black-headed grosbeak	<i>Pheucticus melanocephalus</i>			119	6	11
Indigo bunting	<i>Passerina cyanea</i>			1		
Lazuli bunting	<i>Passerina amoena</i>				1	
House finch	<i>Carpodacus mexicanus</i>	21	147	3063	2548	548
Lawrence's goldfinch	<i>Carduelis lawrencei</i>					1
Pine siskin	<i>Carduelis pinus</i>			1		
Lesser goldfinch	<i>Carduelis psaltria</i>	1		725	1035	12
American goldfinch	<i>Carduelis tristis</i>	1		3	2	3
Red crossbill	<i>Loxia curvirostra</i>				8	
Green-tailed towhee	<i>Pipilo chlorurus</i>			2		
Lark bunting	<i>Calamospiza melanocorys</i>			20		3

Table 4. Number of individuals observed on each island for species detected during landbird monitoring at Channel Islands National Park, 1992-2015 (continued).

Common Name	Scientific Name	SB	AN	SC	SR	SM
Savannah sparrow	<i>Passerculus sandwichensis</i>	243	53	23	4	10
Grasshopper sparrow	<i>Ammodramus savannarum</i>	5		81	34	14
Lark sparrow	<i>Chondestes grammacus</i>	2		29		
Rufous-crowned sparrow	<i>Aimophila ruficeps</i>		3	965		2
Dark-eyed junco	<i>Junco hyemalis</i>	16		183	10	5
Chipping sparrow	<i>Spizella passerina</i>	6	1	1090	1782	6
Brewer's sparrow	<i>Spizella breweri</i>			7		
Black-chinned sparrow	<i>Spizella atrogularis</i>			1		
White-crowned sparrow	<i>Zonotrichia leucophrys</i>	1727	570	835	49	189
Golden-crowned sparrow	<i>Zonotrichia atricapilla</i>	42	12	310	14	41
White-throated sparrow	<i>Zonotrichia albicollis</i>			2		
Fox sparrow	<i>Passerella iliaca</i>			60		3
Lincoln's sparrow	<i>Melospiza lincolni</i>			1		2
Song sparrow	<i>Melospiza melodia</i>	1	103	1546	2827	6191
House sparrow	<i>Passer domesticus</i>					10
European starling	<i>Sturnus vulgaris</i>	54	75	320	59	139
Common raven	<i>Corvus corax</i>		9	1042	1063	1556
American crow	<i>Corvus brachyrhynchos</i>			5		
American robin	<i>Turdus migratorius</i>			100	12	1
Hermit thrush	<i>Catharus guttatus</i>	12		217	36	9
Western bluebird	<i>Sialia mexicana</i>			1	1	1
Mountain bluebird	<i>Sialia currucoides</i>	2		3		
Townsend's solitaire	<i>Myadestes townsendi</i>	1		1	1	
Blue-gray gnatcatcher	<i>Poliophtila caerulea</i>	4		81	7	
Ruby-crowned kinglet	<i>Regulus calendula</i>	19		258	86	8
Western tanager	<i>Piranga ludoviciana</i>			7	1	1
Oak titmouse	<i>Baeolophus inornatus</i>			4		
American pipit	<i>Anthus rubescens</i>			1		
Island scrub-jay	<i>Aphelocoma insularis</i>			2697		
Great egret	<i>Ardea alba</i>	1				
Horned lark	<i>Eremophila alpestris</i>	2366	1	790	516	1708
Bullock's oriole	<i>Icterus bullockii</i>			1		
Spotted towhee	<i>Pipilo maculatus</i>	4	2	3464	3347	6
Varied thrush	<i>Zoothera naevia</i>	3		24	16	4

Table 5. Results of analysis with program Distance for both line transect and point count data. n = number of detections; PDF (SE) = value of probability density function at zero distance, with standard error; %CV = coefficient of variation for PDF; %CV = coefficient of variation for PDF; p = probability of detection; ESW = effective strip width, for line transects; ERD = effective radial distance, for point counts; I = intervals.

Species	n	PDF (SE)	%CV	ESW/ERD	Model	T/I
Line Transects						
Northern harrier	99	0.20835 (0.01918)	9.2	104.2	Half-normal	
Allen's hummingbird	343	0.16471 (0.00802)	4.9	16.5	Hazard rate	
Horned lark	1227	0.10698 (0.00398)	3.7	32.1	Hazard rate	I15
Common raven	250	0.19655 (0.00963)	4.9	80.2	Half-normal	
Bewick's wren	131	0.31776 (0.02862)	9.0	47.7	Hazard rate	I25
Orange-crowned warbler	2190	0.1066 (0.0011)	2.0	30.8	Half-normal	I15
Song sparrow	3112	0.01635 (0.00045)	2.4	39.4	Hazard rate	I10
Western meadowlark	2039	0.17434 (0.00281)	1.6	62.8	Half-normal	I30
House finch	93	0.0274 (0.0016)	6.0	36.5	Hazard rate	I20
Point Counts						
California quail	278	0.05300 (0.00156)	2.9	67.5	Hazard rate	
Mourning dove	88	0.0478 (0.00576)	12.0	92.1	Half-normal	
Anna's hummingbird	323	0.03484 ((0.00240)	6.9	22.4	Half-normal	
Pacific-slope flycatcher	1277	0.06549 (0.00412)	6.3	30.7	Half-normal	I10
Black phoebe	223	0.0198 (0.00060)	3.0	54.9	Half-normal	
Hutton's vireo	172	0.03289 (0.00295)	9.0	45.3	Half-normal	
Horned lark	1684	0.02351 (0.00063)	2.7	49.1	Half-normal	I20
Common raven	1535	0.00920 (0.00050)	5.4	96.0	Hazard rate	
Bewick's wren	3496	0.0432 (0.00092)	2.1	37.5	Half-normal	I15
Northern mockingbird	125	0.04378 (0.00725)	16.6	83.7	Hazard rate	
Orange-crowned warbler	4137	0.01393 (0.00048)	3.5	34.2	Hazard rate	I20
Song sparrow	5648	0.01635 (0.00045)	2.7	39.4	Hazard rate	I22
Spotted towhee	4251	0.0123 (0.00032)	1.7	38.8	Half-normal	
Chipping sparrow	1797	0.0097 (0.00002)	2.8	52.7	Hazard rate	
Western meadowlark	4165	0.06797 (0.00241)	3.6	83.4	Half-normal	I40
Lesser goldfinch	814	0.02657 (0.00146)	5.5	39.5	Hazard rate	I20
House finch	1919	0.04174 (0.00191)	4.6	40.9	Hazard rate	I10

There were few problems with probability detection functions (see Appendix A for probability detection curves for each species). Point counts did not perform as well as line transects for species such as western meadowlarks, which flush readily from low grassland or shrub habitat types, and may not return to the point count area

We found no inconsistencies between densities derived for individual species from line transect data and those derived from point count data. Line transect data encompass a longer time period (1993-2015) than do point count data (2002 – 2015), and so the two methods evaluate trends in different

time periods. Our previous work found point count densities to be higher than, but correlated with, line transect densities (Coonan et al. 2011b), and previous studies have also found point count densities to be higher than those from line transects (Wilson et al. 2000). Because we were interested in trends and not the relative value of densities from the different methods, we evaluated trend independently in line transect and point count data.

Trends in Density by Island

Linear regressions of density values (birds/ha; generated by program DISTANCE) versus time revealed varying rates of change on each island (Tables 6-9; see section “Trends at Legacy Point Count Sites on Santa Cruz Island” for change over time in abundance [individuals observed] on point counts for that island). On Santa Barbara, which has the fewest breeding species of any of the islands, the sole trend over time was a decline in western meadowlarks on line transects (Table 6). Anacapa had relatively more change: declines in western meadowlarks and house finches on line transects, and declines in Bewick’s wrens and orange-crowned warblers on point counts (Table 7). However, landbird monitoring on Anacapa is limited to East Anacapa and includes only one transect and 8 point count sites, and so may not be representative of the island as a whole.

Table 6. Results of linear regression for line transect and point count data, Santa Barbara Island, 1993-2015. Habitat affinity is from Coonan et al. 2011a.

Species	n	Slope/coefficient	t	p	Trend	Habitat Affinity
Line transects						
Horned lark	17	-0.008134	-0.558	0.585		GRS
Orange-crowned warbler	17	0.03127	1.914	0.0717		SHR
Western meadowlark	17	-0.055772	-6.699	<0.001	↓	GRS
Point counts						
Horned lark	13	0.1809	1.511	0.159		GRS
Orange-crowned warbler	12	-0.01092	-0.222	0.829		SHR
Western meadowlark	13	-0.02125	-0.971	0.353		GRS

Table 7. Results of linear regression for line transect and point count data, Anacapa Island, 1993-2015.

Species	n	Slope/coefficient	t	p	Trend
Line transects					
Bewick’s wren	17	-0.00131	-0.314	0.758	
Orange-crowned warbler	16	-0.02523	-1.873	0.082	
Western meadowlark	17	-0.03101	-2.155	0.048	↓
House finch	17	-0.05799	-3.671	0.003	↓
Point counts					
Bewick’s wren	11	-0.20902	-2.790	0.021	↓
Orange-crowned warbler	11	-0.2806	-2.394	0.040	↓
Western meadowlark	11	-0.00215	-0.191	0.853	

On Santa Rosa, for which we only have point count data (from 2003 – present), there were significant increases for 4 of the 16 species with sufficient data to evaluate trend in density (Table 8). Hutton’s vireos, orange-crowned warblers, spotted towhees and western meadowlarks all increased over time, and, unlike on the other islands, there were no decreases over time on Santa Rosa.

Table 8. Results of linear regression for point count data, Santa Rosa Island, 2003-2015.

Species	n	Slope/coefficient	t	p	Trend
California quail	10	0.00242	0.672	0.521	
Mourning dove	10	-0.00086	-0.639	0.541	
Pacific-slope flycatcher	10	0.06452	1.245	0.248	
Black phoebe	10	-0.10053	-1.503	0.167	
Horned lark	10	0.00376	0.416	0.688	
Common raven	10	0.00527	1.777	0.114	
Bewick’s wren	10	0.10053	1.503	0.167	
Northern mockingbird	10	0.00176	1.107	0.300	
Hutton’s vireo	10	0.01232	2.843	0.0217	↑
Orange-crowned warbler	10	0.08874	1.175	0.270	
Song sparrow	10	0.21406	2.839	0.0218	↑
Spotted towhee	10	0.29512	5.213	<0.001	↑
Chipping sparrow	10	-0.01258	-0.739	0.479	
Western meadowlark	10	0.04435	3.380	0.0096	↑
Lesser goldfinch	10	-0.05829	-1.504	0.171	
House finch	10	-0.03536	-0.671	0.521	

For San Miguel, we had sufficient data to evaluate trend in density for 7 of the island’s breeding species (Table 9). Three of those species showed trends over time. Horned larks increased on point counts (2002-2015) but had a longer term decline on line transects (1993-2015). Western meadowlarks and house finches increased on point counts.

Table 9. Results of linear regressions for line transect and point count data, San Miguel Island, 1993-2015.

Species	n	Slope/coefficient	t	p	Trend
Line transects					
Allen's hummingbird	20	0.00936	0.924	0.367	
Horned lark	20	-0.02780	-2.274	0.035	↓
Common raven	20	0.00311	1.382	0.184	
Orange-crowned warbler	20	0.03127	1.914	0.072	
Song sparrow	20	-0.06317	-1.385	0.183	
Western meadowlark	20	-0.00572	-1.322	0.203	
House finch	20	-0.00475	-1.168	0.258	
Point counts					
Horned lark	14	0.10080	3.470	0.005	↑
Common raven	14	0.00663	0.936	0.368	
Orange-crowned warbler	13	0.17339	2.007	0.070	
Song sparrow	14	0.13180	1.231	0.242	
Western meadowlark	14	0.02896	2.219	0.047	↑
House finch	14	0.10496	5.854	<0.001	↑

Trends for Individual Species

In this section we present trend over time for individual species, by island, except for trends at legacy point sites on Santa Cruz Island, which are presented in the section following this one.

Red-tailed Hawk

With the exception of point counts on Santa Rosa (Figure 8), there were too few annual observations of red-tailed hawks on line transects and point counts (0-4 per year on any island) to conduct trend analyses. On Santa Rosa, the number of red-tailed hawks recorded on point counts increased over time ($n = 11$, coefficient = 0.05873, $z = 3.131$, $p = 0.002$).

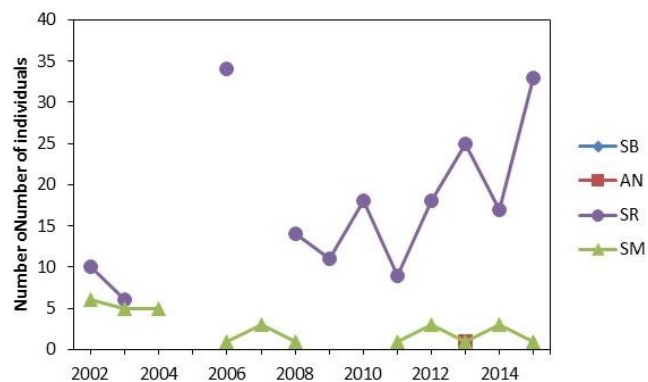


Figure 8. Number of individual red-tailed hawks recorded on point counts, 2002-2015, Channel Islands National Park.

Northern Harrier

Density data from line transects indicated that northern harriers largely fluctuated in a similar manner on Santa Barbara and San Miguel transects (Figure 9) but disappeared from San Miguel in 2012-2015.

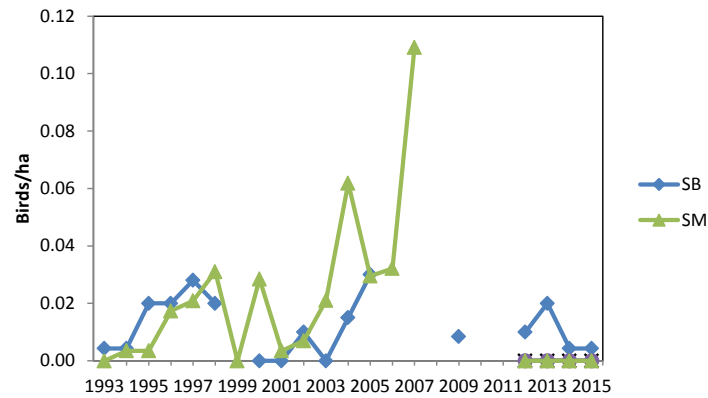


Figure 9. Density of northern harriers on line transects, 1993-2015.

American Kestrel

American kestrels were not recorded in sufficient numbers on either line transects or point counts to estimate density. Counts of kestrels on line transects and at point counts show general decreases (Figure 10), with American kestrels disappearing from Anacapa and San Miguel line transects by 2002-2004 (Figure 10a). Kestrels showed substantial fluctuation on Santa Barbara Island line transects, with an overall decreasing trend ($n = 16$, coefficient = -0.05716 , $z = -3.603$, $p < 0.001$).

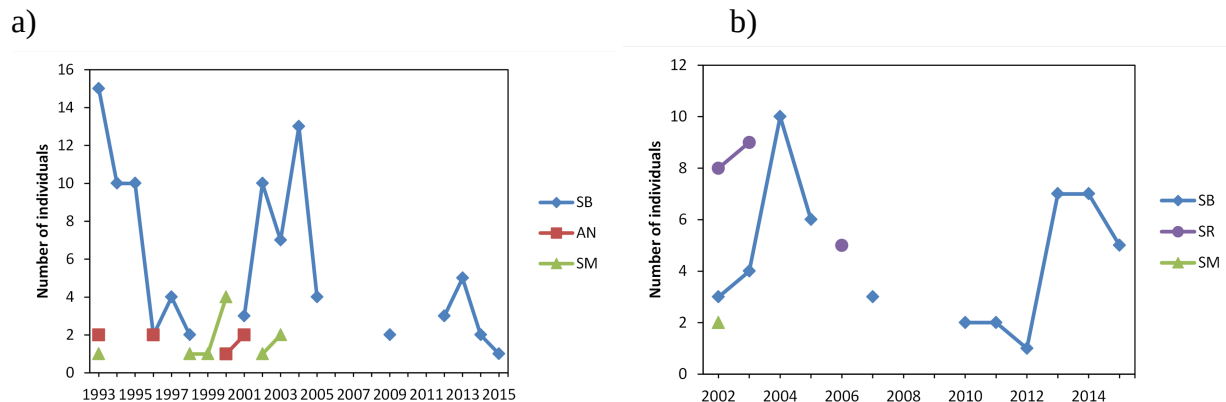


Figure 10. Number of American kestrels recorded on a) line transects and b) point counts, Channel Islands National Park.

American kestrels disappeared from Santa Rosa point counts by 2007 and were only seen on San Miguel point counts in 2002. As on line transects, Santa Barbara Island point counts showed substantial fluctuation in kestrel numbers.

California Quail

California quail occurred at higher overall densities on Santa Cruz than on Santa Rosa Island (Figure 11), and densities on the latter island did not increase or decrease over time (Table 8).

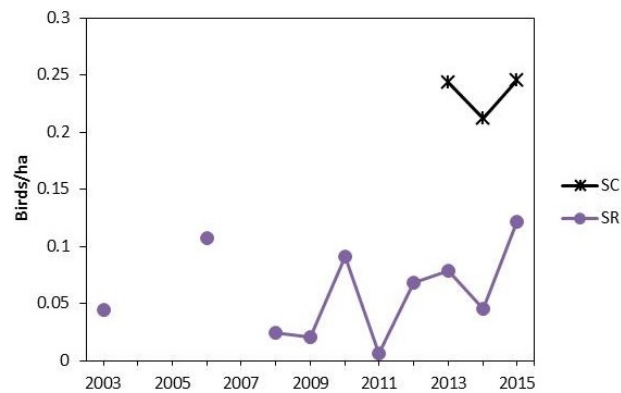


Figure 11. Density of California quail on point counts, Santa Cruz and Santa Rosa Islands, Channel Islands National Park.

Mourning Dove

Mourning doves also occurred at higher densities on Santa Cruz Island (Figure 12). Mourning dove densities appeared to be cyclic on Santa Rosa Island, and did not increase or decrease over time (Table 8).

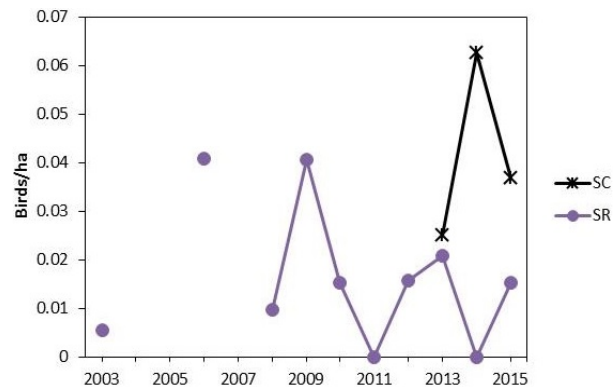


Figure 12. Density of mourning doves on Santa Cruz and Santa Rosa Islands, Channel Islands National Park.

Allen's Hummingbird

Line transect data (Figure 13a) indicate much interannual variation in density of Allen's hummingbirds on San Miguel Island. Detectability curves could not be constructed for point count data, precluding estimation of density, but count data from point counts suggest less annual variation on San Miguel, and an initial decline on Santa Rosa followed by a more recent increase (Figure 13b). In contrast, counts on Santa Cruz decreased recently.

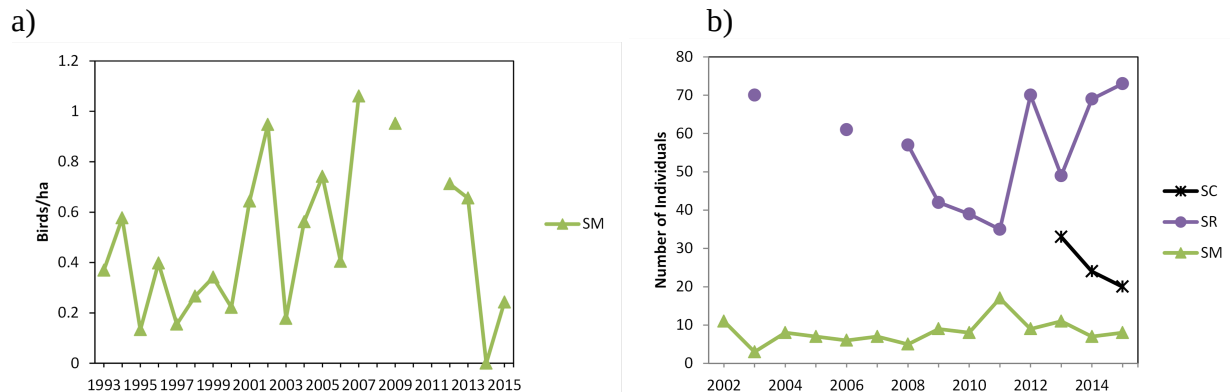


Figure 13. Landbird monitoring results for Allen's hummingbirds: a) density on line transects, and b) number of birds observed each year on point counts.

Pacific-slope Flycatcher

Density of Pacific-slope flycatchers on Santa Rosa was variable over time, with an apparent recent increase (2011-2015) (Figure 14); though there was no statistically significant trend over the entire time period (Table 8).

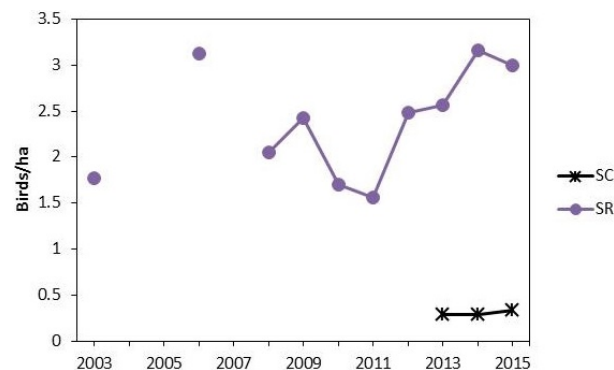


Figure 14. Density of Pacific-slope flycatchers on point counts, Santa Cruz and Santa Rosa Islands.

Black Phoebe

Black phoebe density on Santa Rosa point counts was variable over time (Figure 15), with no statistically significant trend over time (Table 8).

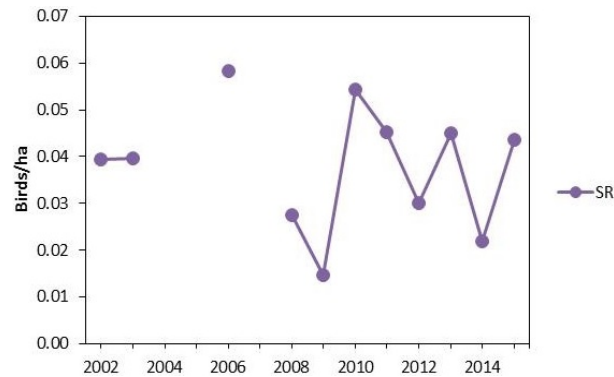


Figure 15. Density of black phoebes on point counts, Santa Rosa Island.

Horned Lark

Density of horned larks on line transects was highly variable on Santa Barbara Island, while horned larks on San Miguel declined over time (Figure 16a, Table 9). Point count densities also showed horned larks on Santa Barbara to exhibit high interannual variation, while horned larks increased on San Miguel over the time period covered by point counts, 2002-2015 (Figure 16b, Table 9).

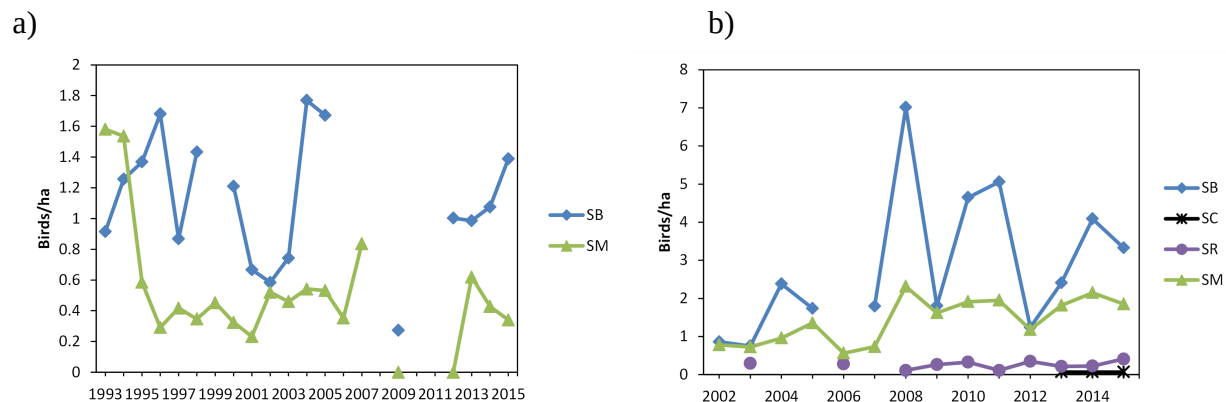


Figure 16. Density of horned larks on a) line transects and b) point counts, Channel Islands National Park.

Common Raven

Density of common ravens did not increase or decrease over the time period bracketed by line transects (1993-2015) or point counts (2002-2015) (Figure 17, Tables 8 and 9), but appeared to increase, without much interannual variability, from 1999 through 2008. Common raven density was less variable on Santa Rosa point counts (Figure 17b) and had no statistically significant increase or decrease over time (Table 8).

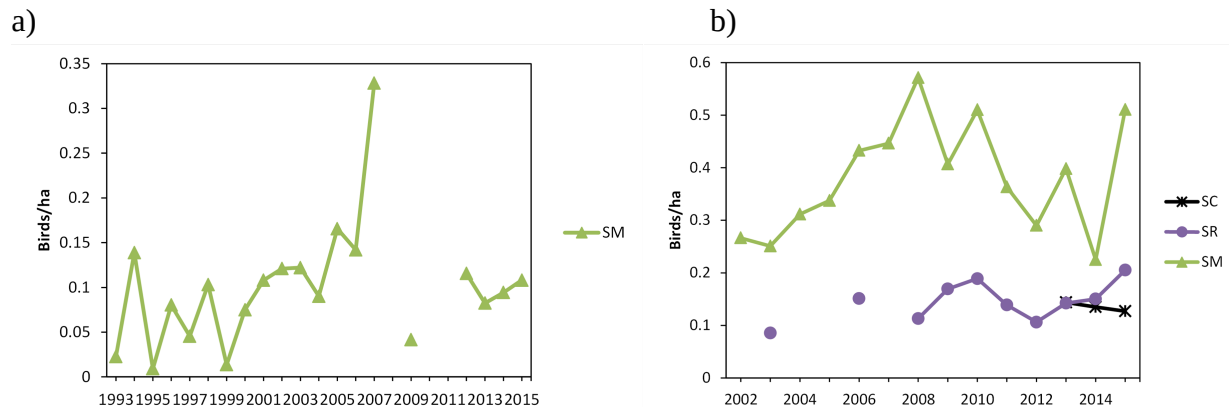


Figure 17. Density of common ravens on a) line transects and b) point counts, Channel Islands National Park.

Bewick's Wren

Bewick's wren density on Anacapa line transects was highly variable (Figure 18a). Point counts (Figure 18b) showed less interannual variability, and a longterm decline on Anacapa (Table 7), and what appears to be an increase on Santa Rosa from 2008 through 2015.

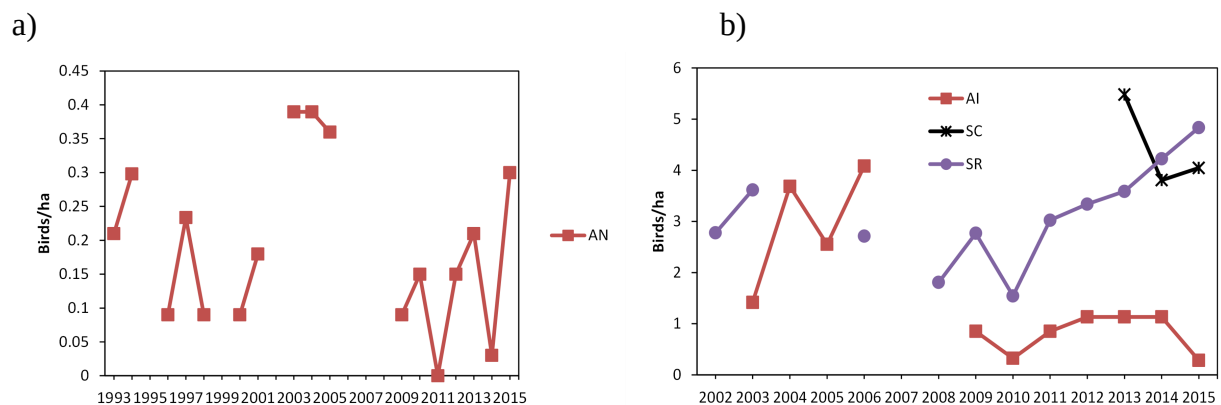


Figure 18. Density of Bewick's wrens on a) line transects and b) point counts, Channel Islands National Park.

Northern Mockingbird

Northern mockingbird density on Santa Rosa was highly variable, with no discernible trend over time (Figure 19, Table 8). Density on Santa Cruz was lower, and appeared to increase in the three years for which we had data.

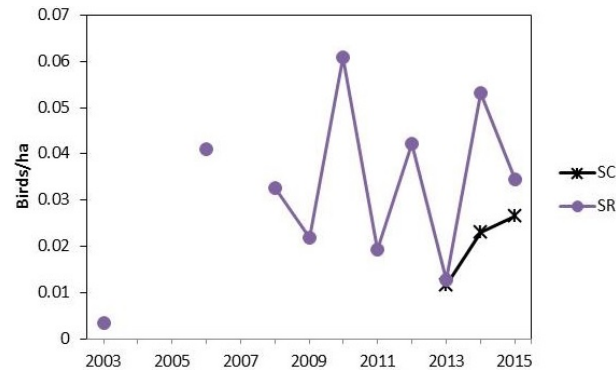


Figure 19. Density of northern mockingbirds on point counts, Santa Cruz and Santa Rosa Islands, Channel Islands National Park.

Hutton's Vireo

Hutton's vireos increased on Santa Rosa point counts (Figure 20, Table 8), and showed some interannual variation on Santa Cruz, for the few years for which we had data.

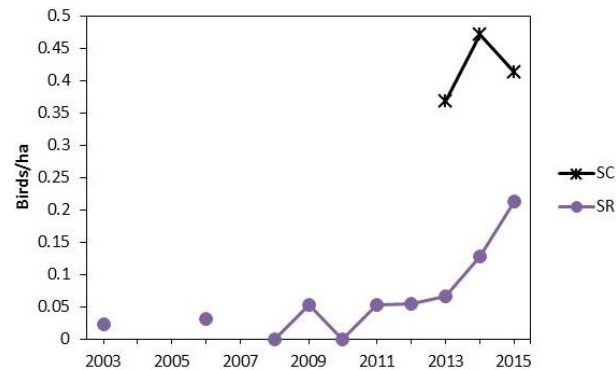


Figure 20. Density of Hutton's vireos on point counts, Santa Cruz and Santa Rosa Islands, Channel Islands National Park.

Orange-crowned Warbler

Orange-crowned warbler densities from line transects suggest some similar fluctuations among populations on Santa Barbara, Anacapa and San Miguel, in that minima and maxima occurred with similar timing (Figure 21a). Over the time period for line transects (1993-2015), there were no statistically significant increases or decreases in orange-crowned warblers (Tables 6, 7 and 9), although orange-crowned warblers on San Miguel appeared to increase from 1993 to 2006, and then subsequently decrease. Orange-crowned warblers decreased on Anacapa point counts (Figure 21b, Table 7), but otherwise there were no statistically significant trends in island populations.

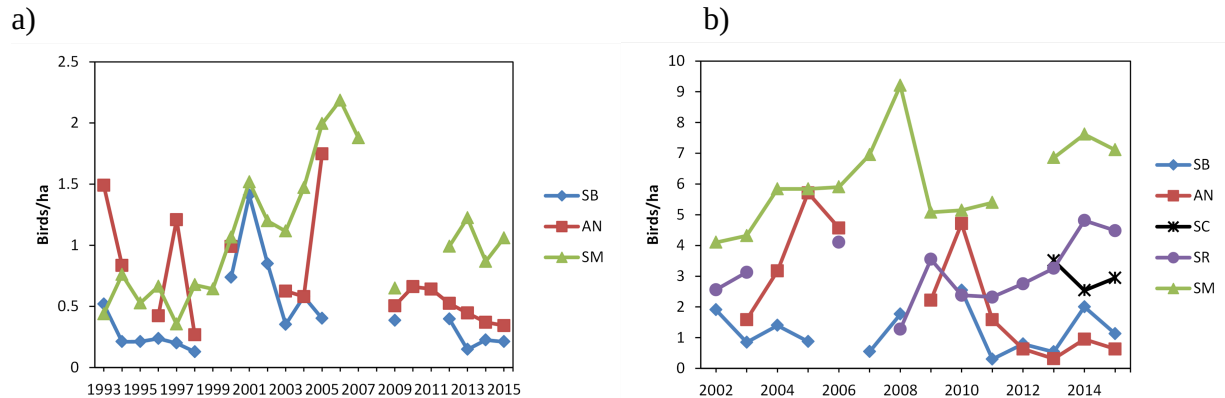


Figure 21. Density of orange-crowned warblers on a) line transects and b) point counts, Channel Islands National Park.

Song Sparrow

There were no significant trends in song sparrow density on line transects (Figure 22a, Tables 7 and 9), although song sparrows increased on San Miguel, with marked interannual variation, from 1993 to 1998. Song sparrows were absent from Anacapa from 1993-2005, and have been recorded there consistently since 2009. Song sparrows increased on Santa Rosa point counts (Table 8) and displayed the most interannual variation on San Miguel (Figure 22b).

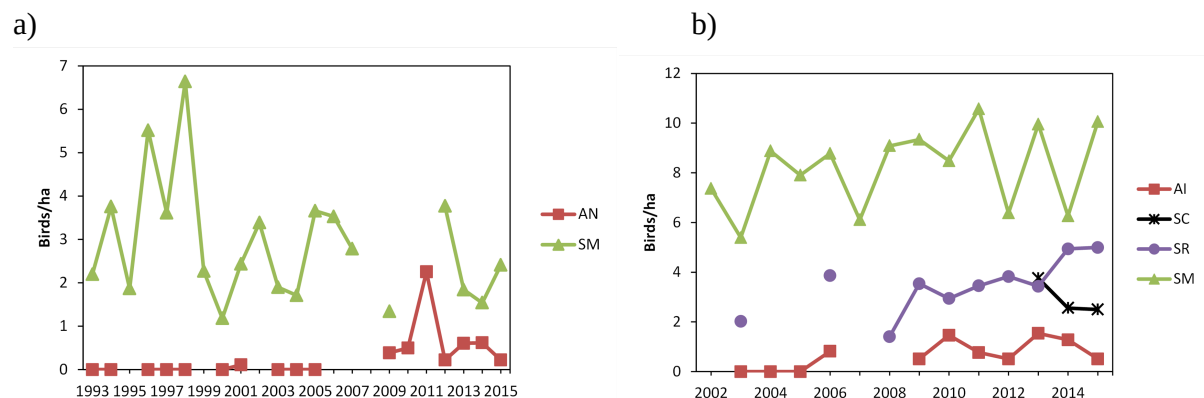


Figure 22. Density of song sparrows on a) line transects and b) point counts, Channel Islands National Park.

Spotted Towhee

Spotted towhees occurred at higher densities (4-7 birds/ha) than any other species, and increased over time on Santa Rosa Island (Figure 23, Table 8).

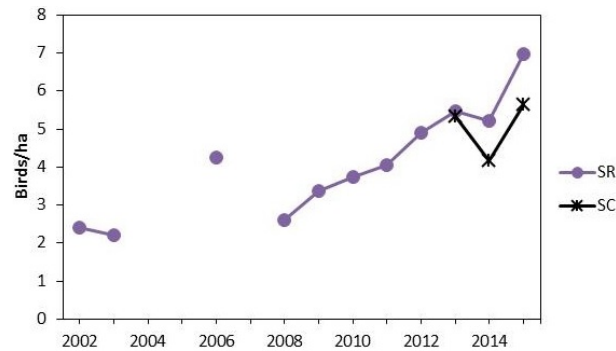


Figure 23. Density of spotted towhees on point counts, Santa Cruz and Santa Rosa Islands, Channel Islands National Park.

Chipping Sparrow

Density of chipping sparrows on Santa Rosa point counts was variable (Figure 24) and did not increase or decrease over time (Table 8).

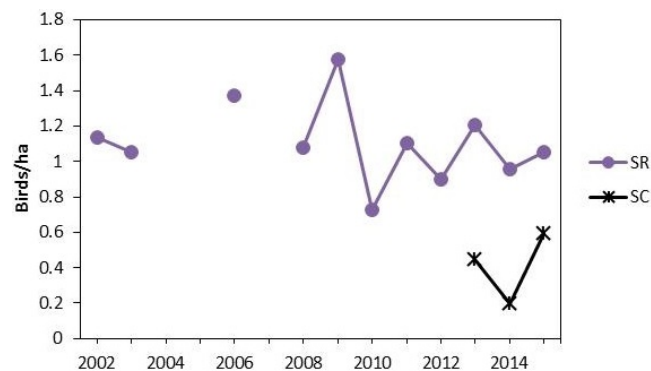


Figure 24. Density of chipping sparrows on point counts, Santa Cruz and Santa Rosa Islands, Channel Islands National Park.

Western Meadowlark

Western meadowlarks declined on both Santa Barbara and Anacapa line transects (Figure 25a, Tables 6 and 7) and declined on Anacapa point counts, while increasing on Santa Rosa and San Miguel point counts (Figure 25b, Tables 7, 8 and 9).

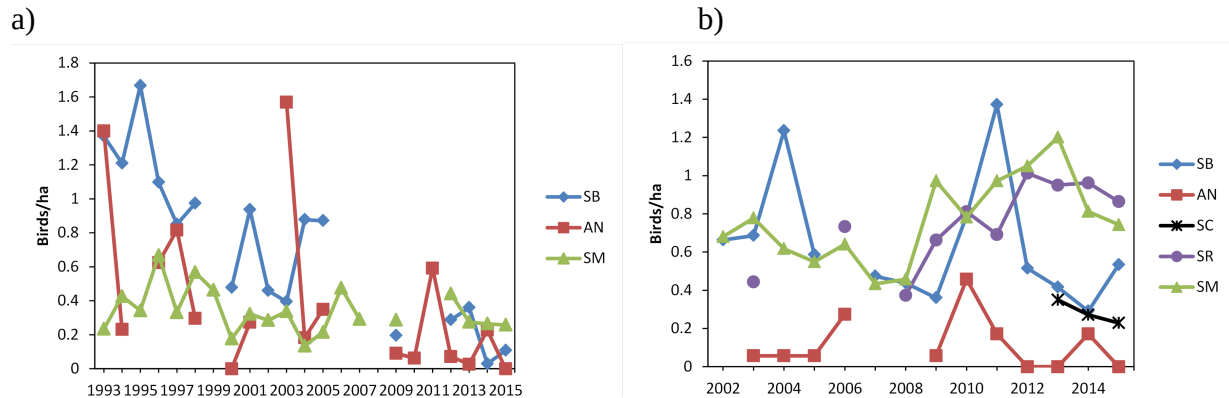


Figure 25. Density of western meadowlarks on a) line transects and b) point counts, Channel Islands National Park.

Lesser Goldfinch

Annual lesser goldfinch density on Santa Cruz and Santa Rosa islands was variable, with no discernible trend (Figure 26, Table 8).

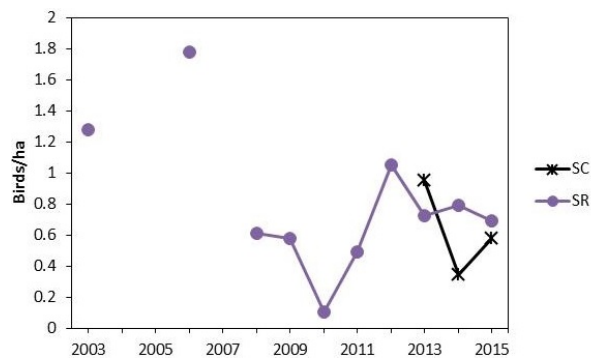


Figure 26. Density of lesser goldfinches on point counts, Santa Cruz and Santa Rosa Islands, Channel Islands National Park.

House Finch

House finch density on both line transects and point counts was highly variable (Figure 27). House finches disappeared for several years during the study period on Santa Barbara, Anacapa and San Miguel Islands, and then reappeared, mainly in low numbers. House finches increased on San Miguel point counts from 2002-2015 (Figure 27b, Table 9). House finch density was highest on Santa Rosa Island, but showed no clear trend (Figure 27b).

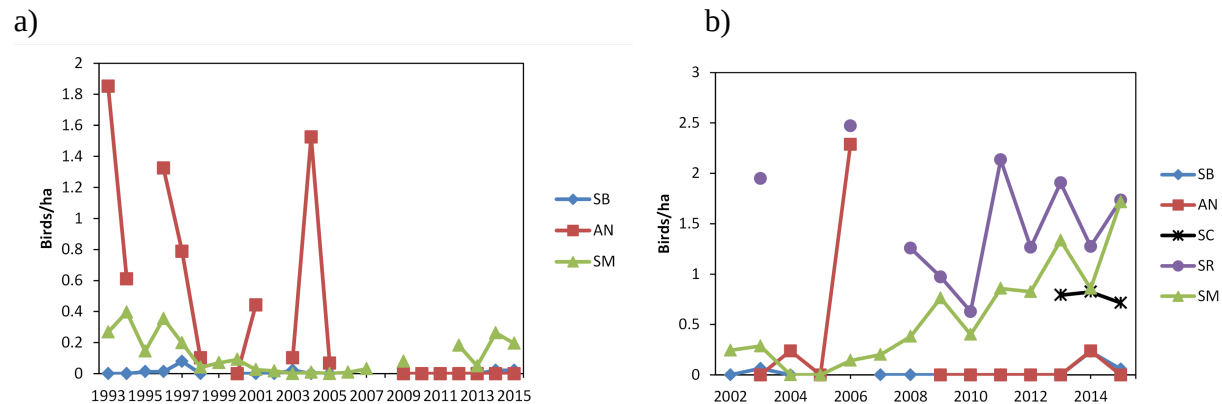


Figure 27. Density of house finches on a) line transects and b) point counts, Channel Islands National Park.

Rare Species on Santa Rosa Island

Several species were not present on Santa Rosa when we began monitoring point counts in 2003, but appeared on Santa Rosa and subsequently increased in number (Figure 28). Some of these species likely have begun breeding on Santa Rosa during this time period. Observations of acorn woodpecker granaries and nest holes have confirmed breeding for this species on Santa Rosa Island. Bushtits also may have begun breeding on Santa Rosa in recent years. It is not known if northern flickers or blue-gray gnatcatchers now breed on Santa Rosa; both breed on neighboring Santa Cruz Island and were observed in small numbers on Santa Rosa point counts. Island loggerhead shrikes are known breeders on Santa Rosa, and their increased occurrence on point counts suggests a population increase.

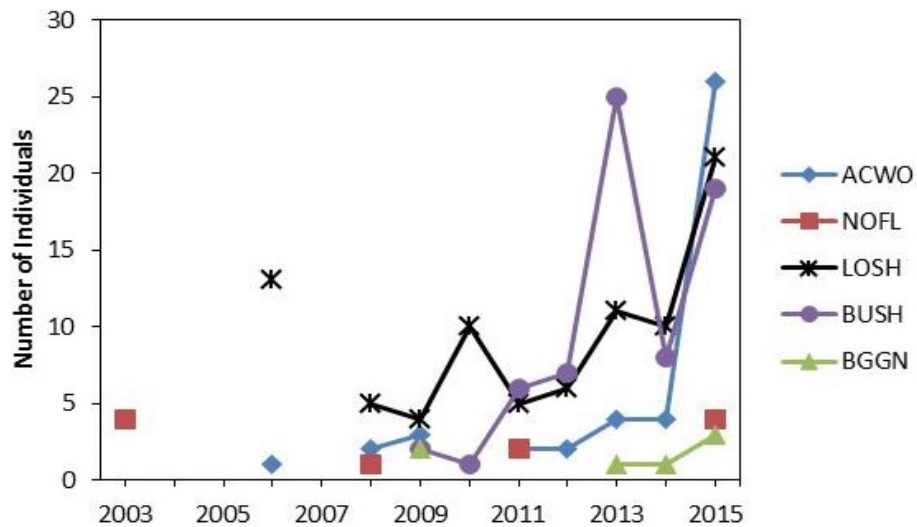


Figure 28. Number of individuals of rare species observed on Santa Rosa point counts, 2003-2015 (ACWO = acorn woodpecker, NOFL = northern flicker, LOSH = loggerhead shrike, BUSH = bushtit, BGGN = blue-gray gnatcatcher).

Landbirds and Island Foxes

Density of two land bird species on San Miguel Island (orange-crowned warblers and song sparrows) appeared to fluctuate inversely with island fox density (Figure 29), increasing when foxes were declining or in captivity, and decreasing when recovering fox population increased to substantial density. Linear regression of bird density on fox density revealed negative slopes for those two species as well as two others (Allen's hummingbirds and western meadowlarks), but the regressions were not significant (Table 10).

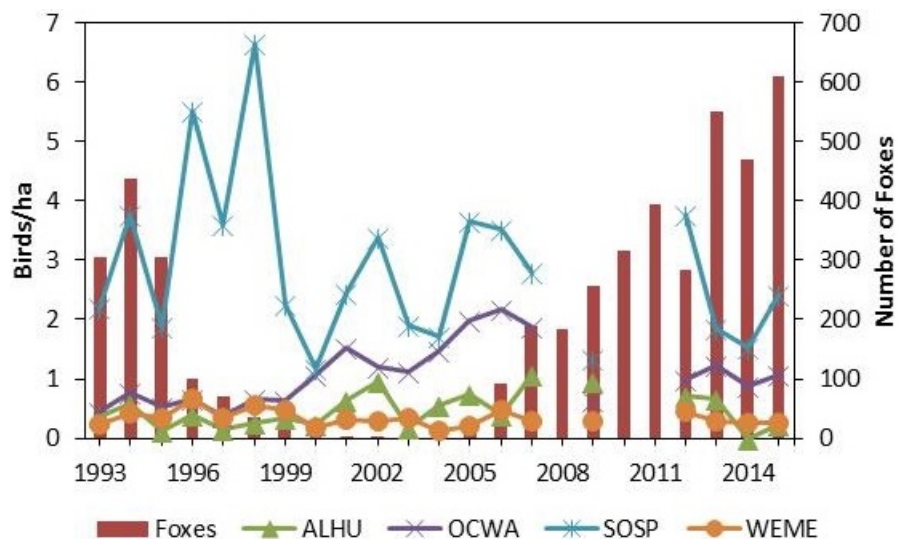


Figure 29. Density of landbird species and the estimated islandwide population of island foxes, San Miguel Island, 1993-2015.

Table 10. Results of linear regressions of line transect bird density and density of island foxes, 1993-2015, San Miguel Island.

Species	n	Slope/coefficient	t	p
Allen's hummingbird	20	-0.00536	-0.396	0.697
Orange-crowned warbler	20	-0.02229	-0.973	0.344
Song sparrow	20	-0.06086	-0.993	0.334
Western meadowlark	20	-0.00289	-0.489	0.631

Trends at Legacy Point Count Sites on Santa Cruz Island

Poisson regression on data from legacy point count sites on Santa Cruz Island documented substantial change in landbird populations over the 20+ year time period covered by that sampling (Table 11, Figure 30). Twenty-eight of the 34 breeding landbird species on Santa Cruz Island had sufficient data (≥ 10 detections in any one of the 8 survey years) to estimate trend. Of those 28 species, all but two (Anna's hummingbird and island scrub-jay) showed a statistically significant trend. Thirteen species had positive trends, and 15 trends were negative.

Table 11. Results of Poisson regression for count data from 100 point count sites on Santa Cruz Island, 1992-2015.

Species	n	Slope/coefficient	z-value	p	Trend
California quail	8	-0.04371	-9.965	<0.001	↓
Mourning dove	8	-0.21734	-11.160	<0.001	↓
Anna's hummingbird	8	-0.01493	-1.547	0.1218	
Allen's hummingbird	8	0.05999	4.555	<0.001	↑
Acorn woodpecker	8	0.08459	6.121	<0.001	↑
Northern flicker	8	0.03930	8.216	<0.001	↑
American kestrel	8	-0.13130	-5.250	<0.001	↓
Pacific-slope flycatcher	8	0.03498	1.987	0.047	↑
Ash-throated flycatcher	8	-0.17643	-7.734	<0.001	↓
Loggerhead shrike	8	-0.17006	-2.910	0.004	↓
Hutton's vireo	8	0.05409	5.760	<0.001	↑
Island scrub-jay	8	-0.00236	-0.696	0.487	
Common raven	8	0.01854	3.101	0.002	↑
Horned lark	8	-0.14831	-10.110	<0.001	↓
Bushtit	8	-0.03103	-4.014	<0.001	↓
Bewick's wren	8	0.02979	9.634	<0.001	↑
Blue-gray gnatcatcher	8	0.08688	5.567	<0.001	↑

Table 11. Results of Poisson regression for count data from 100 point count sites on Santa Cruz Island, 1992-2015 (continued).

Species	n	Slope/coefficient	z-value	p	Trend
Northern mockingbird	8	-0.08742	-3.572	<0.001	↓
European starling	8	-0.16770	-7.764	<0.001	↓
Orange-crowned warbler	8	0.00585	12.420	<0.001	↑
Spotted towhee	8	0.01381	5.518	<0.001	↑
Rufous-crowned sparrow	8	-0.03557	-6.379	<0.001	↓
Chipping sparrow	8	-0.07214	-13.210	<0.001	↓
Song sparrow	8	0.02732	6.693	<0.001	↑
Black-headed grosbeak	8	-0.13631	-4.4795	<0.001	↓
Western meadowlark	8	-0.04499	-9.944	<0.001	↓
House finch	8	0.09195	-18.950	<0.001	↓
Lesser goldfinch	8	0.03023	3.671	<0.001	↑

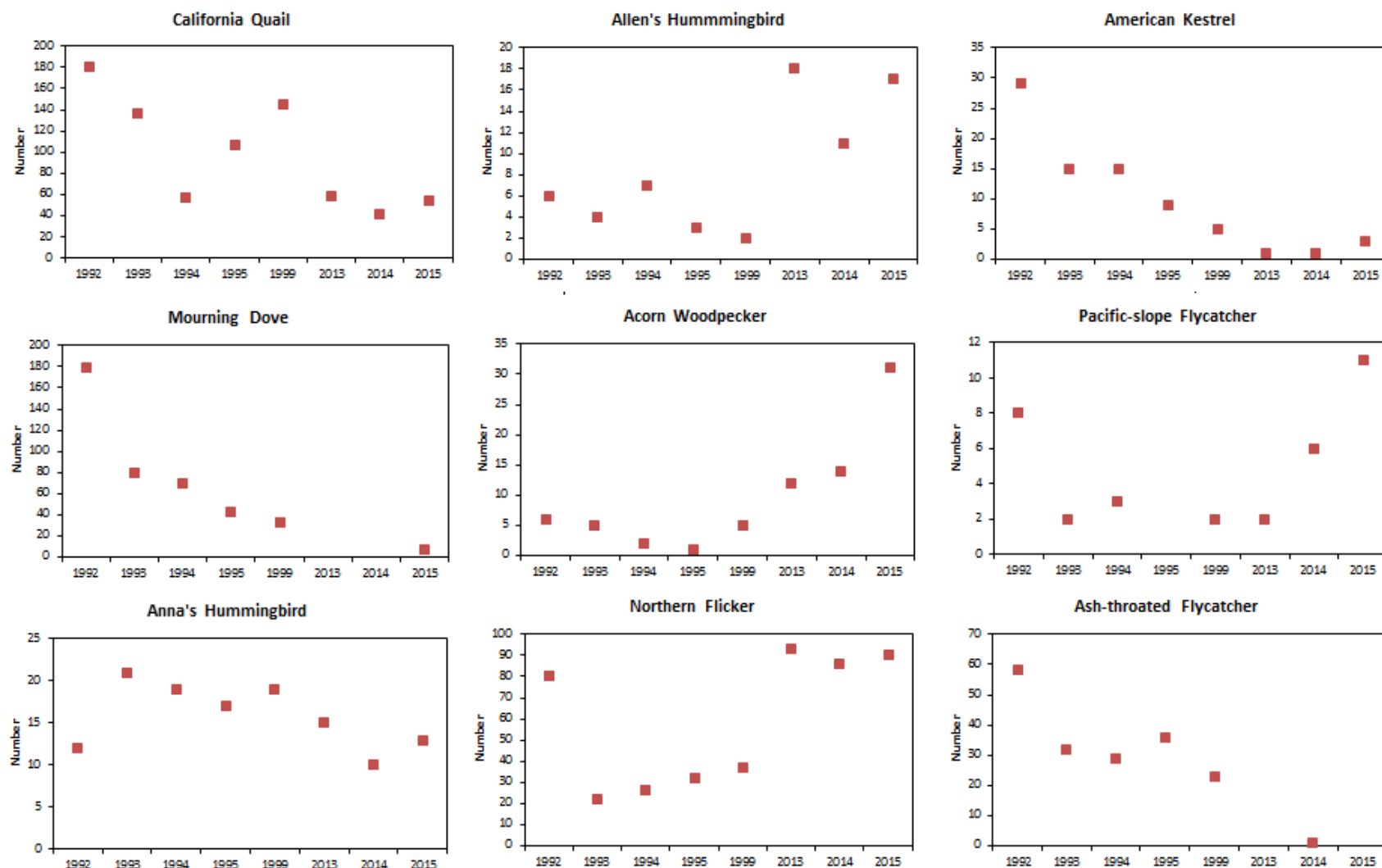


Figure 30. Number of individuals recorded at 100 legacy point count stations, Santa Cruz Island, 1992-2015.

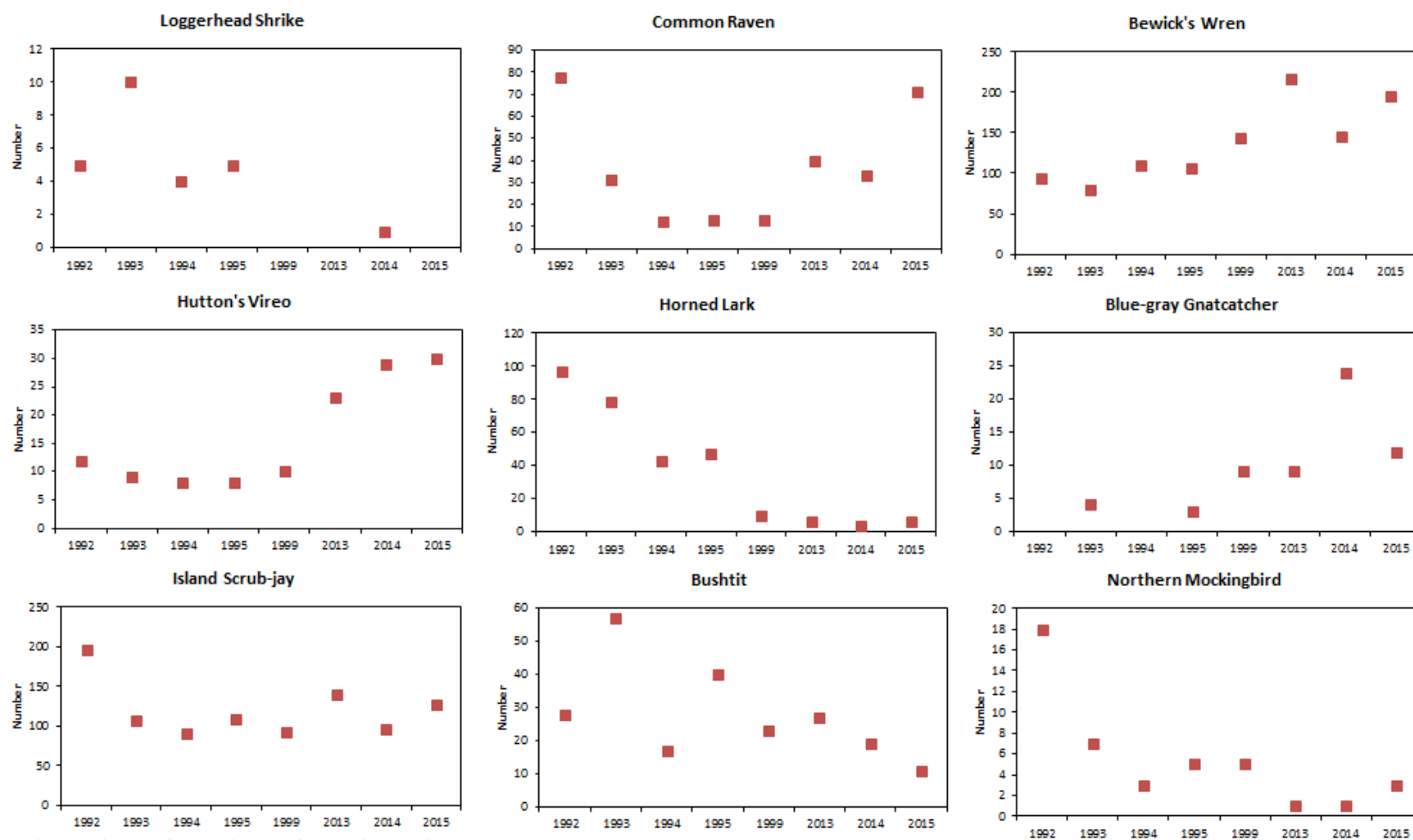


Figure 30. Number of individuals recorded at 100 legacy point count stations, Santa Cruz Island, 1992-2015 (continued).

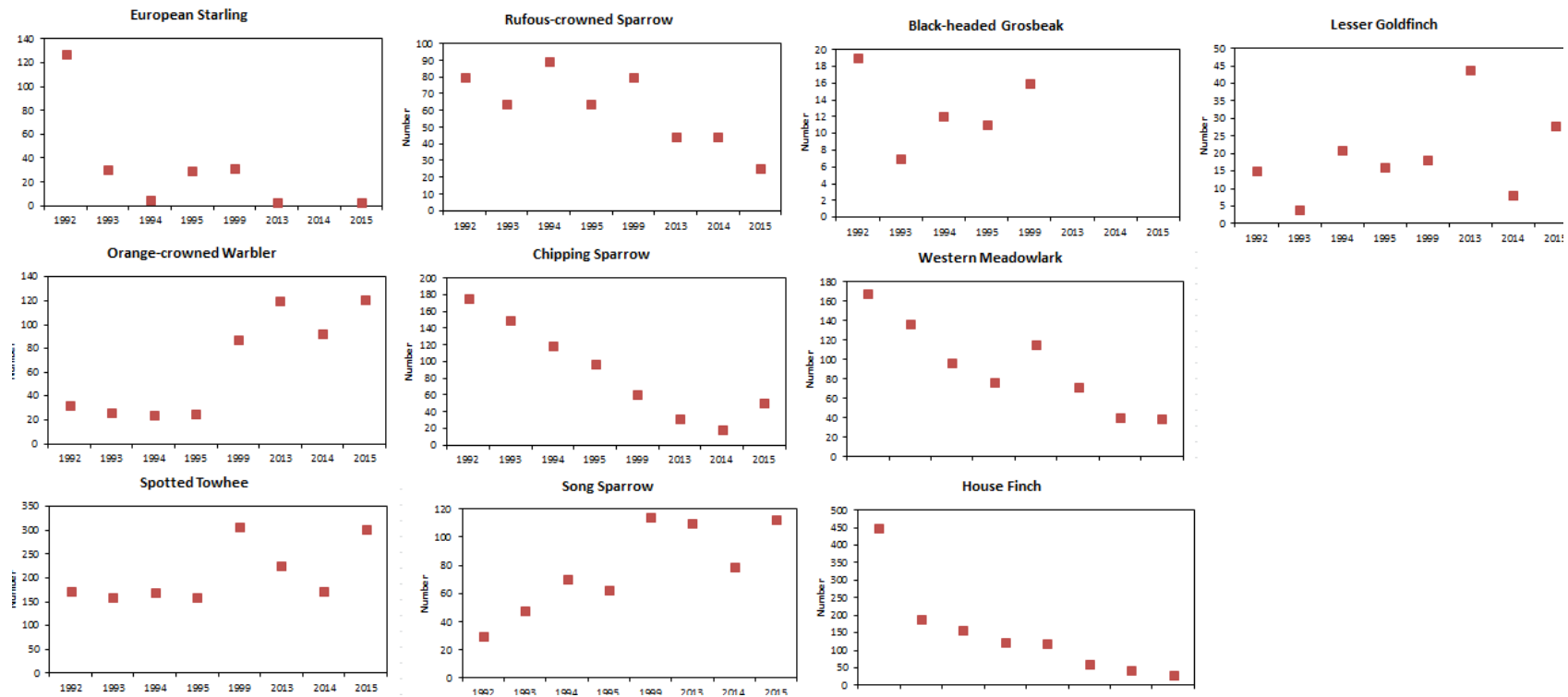


Figure 30. Number of individuals recorded at 100 legacy point count stations, Santa Cruz Island, 1992-2015 (continued).

Most Santa Cruz landbird species showed habitat affinities for one or more of the three general habitat classes (grasslands, shrub and woodland vegetation) (Table 12), although house finches showed little preference, with selection values ranging between 0.93 and 1.08.

Table 12. Habitat selection values for Santa Cruz Island landbirds, based on point count data from 1992-1995. Values >1.0 indicate preference, values <1.0 indicate avoidance.

Species	Grassland	Shrub	Woodland
California quail	0.84	1.25	0.60
Mourning dove	1.29	0.78	1.01
Anna's hummingbird	0.42	1.35	1.29
Allen's hummingbird	0.46	1.33	1.26
Acorn woodpecker	0.29	0.75	3.37
Northern flicker	0.44	1.21	1.66
American kestrel	1.30	0.76	1.04
Pacific-slope flycatcher	0.17	0.52	4.32
Ash-throated flycatcher	0.38	1.25	1.68
Loggerhead shrike	2.20	0.34	0.25
Hutton's vireo	0.14	1.03	2.86
Island scrub-jay	0.43	1.31	1.38
Common raven	1.51	0.73	0.64
Horned lark	2.73	0.01	0.01
Bushtit	0.32	1.53	0.97
Bewick's wren	0.25	1.40	1.53
Blue-gray gnatcatcher	0.00	1.82	0.84
Northern mockingbird	0.65	1.40	0.61
European starling	2.36	0.30	0.00
Orange-crowned warbler	0.12	1.41	1.78
Spotted towhee	0.46	1.39	1.07
Rufous-crowned sparrow	0.66	1.35	0.72
Chipping sparrow	1.61	0.60	0.81
Song sparrow	2.30	0.28	0.20
Black-headed grosbeak	0.34	1.65	0.55
Western meadowlark	2.43	0.18	0.17
House finch	1.06	0.93	1.08
Lesser goldfinch	1.38	0.81	0.70

We were able to evaluate change over time, across the park islands, for species associated with the general habitat types of grassland, shrub and woodland (Table 13). One anomalous species was the house finch, the only species associated with both grassland and woodland, and which had considerable fluctuation on each island; they are not considered in the following discussion.

Table 13. Trends for landbird species at Channel Islands National Park, 1992-2015. Up and down arrows denote significant linear regressions for data from line transects, point counts, or counts over the time period. Habitat affinities are from Table 11 and Coonan et. al. 2001b.

Common Name	SB	AN	SC	SR	SM	Habitat Affinity*
Red-tailed hawk				↑		GRS
Northern harrier					↓	GRS
American kestrel	↓	↓	↓	↓	↓	GRS
California quail			↓	↔		SHR
Mourning dove			↓	↔		GRS
Allen's hummingbird			↑	↔	↔	SHR, WDL
Northern flicker			↑			SHR, WDL
Acorn woodpecker			↑	↑		WDL
Pacific-slope flycatcher			↑	↔		WDL
Black phoebe				↔		WDL
Ash-throated flycatcher			↑			SHR, WDL
Horned lark	↔		↓	↔	↓↑	GRS
Island scrub-Jay			↔			SHR, WDL
Bushtit			↓	↑		SHR
Common raven			↑	↔	↔	GRS
Bewick's wren		↓	↑	↔		SHR, WDL
Blue-gray gnatcatcher			↑			SHR
Northern mockingbird			↓	↔		SHR
Loggerhead shrike			↓	↑		GRS
Hutton's vireo			↑	↑		WDL
Orange-crowned warbler	↔	↓	↑	↔	↔	SHR
Black-headed grosbeak			↓			SHR
Rufous-crowned sparrow			↓			SHR
Song sparrow			↑	↑	↔	GRS, SHR
Spotted towhee			↑	↑		SHR
Chipping sparrow			↓	↔		GRS
Western meadowlark	↓	↓	↓	↑	↑	GRS
House finch	↑	↓	↓	↔	↑	GRS, WDL
Lesser goldfinch			↑	↔		GRS

↓ = significant trend from line transect data

↑ = significant trend from point count data

↑ = significant trend from count data

↔ = no significant trend

* GRS = grassland, SHR = shrub, WDL = woodland

On Santa Barbara Island, one grassland species, the western meadowlark, decreased. There was no change over time for orange-crowned warblers, which prefer shrub habitat. On the other of the two smallest islands, Anacapa, all three species decreased; one grassland, one shrub, and one shrub/woodland.

Santa Cruz is the largest island in the park, has the most topographic and vegetative diversity, and the greatest number of breeding landbird species, and count data from recently-sampled legacy point count site showed that Santa Cruz landbird species had more change over time than did species on any other island. Of the 26 species for which we could evaluate change, only one, the island scrub-jay, showed no change over time. Fourteen species increased over time, and 11 decreased. Two-thirds of shrub/woodland species increased, whereas 6 of 9 grassland species decreased. All three species associated exclusively with woodland increased, as did 4 of the 5 associated with shrub and woodland. The 8 species associated exclusively with shrub habitat were divided equally between increasers and decreasers.

On Santa Rosa, the second largest island in the park, no species decreased over time, and 8 increased. All but two of the species that increased preferred shrub or woodland or both. The two pure grassland species that increased were loggerhead shrikes and lesser goldfinches. On San Miguel, one grassland species, the horned lark, decreased over time, while one, the western meadowlark, increased. Three species associated with shrub or woodland (Allen's hummingbird, orange-crowned warbler and song sparrow) showed no change over time.

Discussion

The 23-year (and counting) tenure of Channel Island National Park's landbird monitoring program makes it one of the longest running bird population monitoring programs in existence. Few other programs have gathered annual data from point count or line transect sampling sites for equivalent or longer time periods (Linder and Buehler 2005, Chace et al. 2009).

The methods, which produced density and count data from line transects and point count sites, were capable of detecting trends for 29 of the park's 48 breeding landbird species. Previous analysis (Coonan et al. 2011b) was unable to detect trend in some less common species, such as Hutton's vireo; but additional years of data and extension of monitoring to Santa Cruz Island expanded the number of species for which trend was capable of being detected.

Other methods, such as constant-effort mist-netting, may provide more detailed demographic information on park landbird species than do point counts and line transects, but would be very difficult to implement on the park islands. Such methods are best implemented in specific habitats, and the number of habitat types and the number of islands would make operation of multiple mist-net sites very expensive. Moreover, the high winds occasionally experienced on the islands in springtime would likely prevent mist-netting from being implemented successfully.

Entire guilds of species are not monitored effectively by point counts and line transects. Nocturnal species, such as owls, are obviously not picked up on diurnal sampling. And although they are diurnal, hawks, eagles and falcons are rarer than other species because they occur at high trophic levels, are wide-ranging, and are seen more often in flight than perched. These qualities reduce the number of observations and render distance methods unusable. Swifts and swallows are also observed almost exclusively in flight, precluding use of distance methods. Finally, colony-breeding species such as great blue herons are not picked up on point counts (moreover, they only breed in one location on Santa Rosa Island).

As mentioned previously, point counts are less effective in low-vegetation habitats such as grassland and coastal bluff scrub, because birds are easily flushed from the point count area during approach, and may not return to near the center of the point count. This affects the assumption that detectability is 100% at the center of the point count, and can result in detectability curves that are problematic (see detectability curve for western meadowlarks on point counts, Appendix B). For this reason, and because our line transects extend further back in time and thus provide a longer look at bird population dynamics, we retained the line transects on the three smaller park islands; those islands have predominantly low vegetation types.

The construction of density estimates allows comparisons among species and islands, to a considerable degree. Comparisons are certainly valid among species on an island, because the mix of habitat types is consistent on an island; comparison among islands is a little more tenuous, since the habitat types sampled on each island differ. However, density estimates derived from line transects and those derived from point counts are less comparable than one would hope. Density estimates

from point counts are correlated with those from line transects, but are consistently higher (see Appendix B in Coonan et al. 2011b).

Despite the limits imposed by the sampling methods, and the considerable interannual variation inherent in landbird population monitoring, we were able to document some significant and predictable changes in the islands' landbird fauna over time. The most significant trend involved the relationship of bird abundance and distribution to vegetation recovery on the islands.

All of the Channel Islands have a history of grazing, and some of browsing, by non-native ungulates brought to the islands during the ranching era. Most of the islands were grazed extensively by domestic sheep, and several by cattle; introduced deer and elk were present on Santa Rosa until recently (Table 14). All introduced ungulates have been removed from the park islands, but the time since removal differs by island and species. Consequently, each island is in a different stage of recovery from grazing/browsing, and this is reflected in the recent changes (or lack of change) in the landbird fauna on each island.

Table 14. Time frames of non-native ungulate presence on the five islands in Channel Islands National Park (adapted from Davidson et al. in review).

Ungulate species	SB	AI	SC	SR	SM
Domestic sheep (<i>Ovis aries</i>)	Pre 1900 - 1946	Pre 1869 - 1937	1851 - 2000	1844 - 1903 ¹	≈1850 - 1966
Cattle (<i>Bos taurus</i>)			1830 - 1989	1842 - 1998	
European hogs (<i>Sus scrofa</i>)			1853 - 2007	1852 - 1993	
Horses (<i>Equus caballus</i>)			1830 - 2000	≈1850 - present	
Feral asses (<i>Equus asinus</i>)					Pre 1917 - 1976
Mule deer (<i>Odocoileus hemionus</i>)				1929 - 2011	
Elk (<i>Cervus elephas</i>)				1905 - 2011	
Rabbits (<i>Oryctolagus cuniculus</i> and <i>Lepus europaeus</i>)	1914 - 1982				

¹The removal of sheep began in 1903 but the last sheep were not eliminated until the 1930s.

The most change by far was seen on Santa Cruz Island, where 26 of 28 species showed a significant trend over time. Increases were observed in shrub and woodland species, and decreases were observed primarily in species who favor grasslands. Substantial vegetation change has taken place on Santa Cruz Island in the past 20 years (Morrison et al. 2011, Davidson et al. *in review*), due to the removal of >45,000 sheep in 1981-2000, and the removal of >5,000 feral pigs in 2005-2007. In their analysis of vegetation condition on the island Davidson et al. (*in review*) concluded that the most

rapid recovery had been in coastal sage scrub and riparian vegetation, and pine and oak woodland had recovered in some places. Increases in such species as Allen's hummingbird, acorn woodpecker, northern flicker, Pacific-slope flycatcher, Hutton's vireo, Bewick's wren, blue-gray gnatcatcher, orange-crowned warbler, spotted towhee and song sparrow attest to the general recovery of shrub and woodland vegetation on Santa Cruz Island. There was a coincident decrease in many grassland species (mourning dove, horned lark, rufous-crowned sparrow, chipping sparrow, and western meadowlark), though lesser goldfinches increased, for reasons that are not apparent, and shrub-loving bushtits declined. There was no detectable change in island scrub-jays, a species of management concern which may not be picked up adequately on point counts, due to its social nature. Another species of management concern, the loggerhead shrike, declined; recent thorough surveys for this species estimated its population size on Santa Cruz to be less than 40 individuals (Stanley et al. 2012). Non-native European starlings declined, perhaps due to the increase of peregrine falcons on the islands (P. Collins, Santa Barbara Museum of Natural History, pers. comm.), and removal of buildings on Santa Rosa Island (Kathryn Faulkner, NPS, pers. comm.).

Davidson et al. (*in review*) suggest that more recovery is yet to come for Santa Cruz Island. Feral pigs were removed rather recently (2007) and colonization of woody species into areas dominated by non-native grasses or other weedy species (such as fennel, *Foeniculum vulgare*) may take time. This augurs more change in the landbird fauna of Santa Cruz, and suggests that similar change may eventually be seen in the landbird faunas of other islands, if comparable vegetation recovery occurs.

Santa Rosa Island, which has a more recent history of ungulate removal than Santa Cruz, saw less change in landbird population dynamics. Sheep have been largely absent from Santa Rosa since the 1930s, when the grazing operation shifted from sheep to cattle. The addition of mule deer and elk in the early 20th century produced a landscape which for the better part of a century was grazed heavily by cattle and elk, with heavy browsing in woodland and riparian areas by mule deer (Davidson et al. *in review*). By the late 20th century the island was two-thirds alien grassland (Clark et al. 1990), and 7 plant taxa had been listed as endangered or threatened due to impacts of ranching activities. The NPS removed feral pigs from the island in 1993, and was sued in the 1990s by the Environmental Defense Center over its management of ranching activities on Santa Rosa. A settlement of that lawsuit in 1997 resulted in the removal of cattle by 1998, and a phased removal of deer and elk, which were nearly completely gone by 2011.

The removal of herbivores on Santa Rosa did not produce as much change in landbird species as on Santa Cruz, because the impacts of mule deer browsing, especially in riparian areas, continued until 2011 or so, when mule deer populations were reduced to a handful of individuals. Eight of 22 species increased over time, and none decreased. Shrub and woodland species such as acorn woodpeckers, bushtits, Hutton's vireo, song sparrow, and spotted towhee increased, but so did the grassland specialist Western meadowlark. There was no increase (or decrease) in shrub-loving orange-crowned warblers or grassland specialist horned larks and chipping sparrows. Davidson et al. concluded that Santa Rosa was in the early stages of vegetation recovery, and this certainly is consistent with what we see in the landbird population trend data. Recovery may continue, but may be limited by competition from alien grasses, lack of precipitation, and lack of soil in some areas (Davidson et al.

in review). Interestingly, the one landbird species of concern on Santa Rosa, the island loggerhead shrike, increased over time. Native grasslands have begun recovering on the island (D. Rodriguez, NPS, pers. comm.) and that may improve foraging opportunities for the shrike.

The appearance of several species on Santa Rosa, with documented breeding in at least one case, may constitute colonization of that island, as post-grazing conditions improve in woodland habitat. Acorn woodpeckers first appeared on Santa Rosa point counts in 2006, and records steadily increased. Granaries and nest cavities have been documented, providing evidence that this cavity-nester now breeds on the island. Bushtits first appeared in 2009, and although no breeding has been documented, it is likely to be occurring. Increased sightings of northern flickers and blue-gray gnatcatchers suggest that those species, which breed on nearby Santa Cruz Island, will eventually breed on Santa Rosa.

Reasons for apparent change, or lack thereof, in landbird populations on the other three islands are less clear. Evaluating change on Anacapa is made difficult by small sample sizes; one line transect and 8 point count stations, all restricted to tiny East Anacapa Islet, limit conclusions, and species that breed on the other two islets, such as rufous-crowned sparrows, are not picked up on East Anacapa. Certainly East Anacapa has seen considerable ecological change in the past few decades. Native deer mice were absent from the islet from the early 1980s until sometime before 1998, when they were rediscovered by park staff. The non-native black rat (*Rattus rattus*) (like the deer mouse, a formidable nest predator), was eradicated from the islet in 2001. Non-native red-flowered iceplant (*Malephora crocea*) blanketed much of East Anacapa Island until recently, when it was removed over a period of years, and native plant restoration began in areas of former iceplant dominance. Are these changes reflected in landbird population dynamics? All five East Anacapa species for which we could evaluate change declined over time. This included a shrub specialist (orange-crowned warbler), shrub/woodland specialist (Bewick's wren) grassland specialist (Western meadowlark), the American kestrel, and the house finch. The latter exhibited great fluctuation on all islands where it occurred, appearing and disappearing over time. Kestrels declined on all islands, perhaps because of the rise in fortune for peregrine falcons.

One would expect the ecological changes of rat and iceplant removal to have resulted in general increases in land bird populations, but that was not evident in the data. Perhaps the apparent decreases in Anacapa orange-crowned warblers, Western meadowlarks and Bewick's wrens are artifacts of the small sample size on that island. The other possibility is increased nest predation by deer mice, which have increased in recent years on East Anacapa, even throughout the current deep four-year drought (Coonan 2015).

When we began monitoring in 1993, we expected to see positive changes in landbird populations over time, as the islands all ostensibly recovered from previous land-use practices, including grazing by non-native herbivores. While small sample size perhaps prevents us from seeing those changes on Anacapa, such changes are evident in landbird population dynamics on Santa Cruz and Santa Rosa Islands. On Santa Barbara and San Miguel, however, such changes are not evident, perhaps because, despite our expectations, significant vegetation recovery has not taken place on those islands during

the time frame of our landbird monitoring. In fact, both islands may have plateaued in their recovery, requiring different ecological conditions or active restoration to effect further change.

Tiny Santa Barbara Island, at 2.6 km² one of the two smallest of the Channel Islands, has the least number of breeding landbird species (11) in the park. Of the five species for which we could determine trend, one (the house finch) increased over time, and two decreased (American kestrels and Western meadowlarks). As mentioned previously, house finch abundance was spotty on all islands, and kestrels declined on all islands. We expected shrub-loving orange-crowned warblers to increase on Santa Barbara Island, because we expected to see recovery of shrubby vegetation communities, such as coreopsis scrub and boxthorn scrub. At the same time, we expected to see decreases in horned larks, which prefer short grasslands and even bare ground, if shrub recovery was taking place. That we saw neither of those changes suggests that native shrub recovery is not occurring on Santa Barbara Island, despite removal of large herbivores by the early 20th century and removal of rabbits by 1982.

In their assessment of vegetation trend on Santa Barbara Island, Davidson et al. (2015) concluded that Santa Barbara Island was in a new stable state of domination by nonnative annual vegetation, even 30 years or so after removal of rabbits. They identified aridity, lack of native seed banks, and an extensive seed bank of nonnative iceplant as factors contributing to the ecological stasis on the island. They determined the potential for further natural recovery to be low, with active restoration needed to move the island toward a state dominated by native shrubs instead of nonnative annuals. Thus, there will likely be little change in landbird populations over time until such restoration is implemented.

The strong, long-term decline in western meadowlarks on Santa Barbara Island is curious, and relatively unexplained. Meadowlarks declined 80% on line transects over the 20+ years, perhaps due to a decline in habitat quality. They prefer tall grasses, which perhaps are being replaced by bare ground or nonnative annuals shorter in stature.

Like Santa Barbara Island, San Miguel is currently well short of full ecological recovery to a shrub-dominated system. Davidson et al. (*in review*) conclude that San Miguel is slowly stabilizing through colonization of sand dunes and erosion pavement by both native and nonnative species. Alien annual grasslands persist in areas, however, and may require active restoration; moreover, hard chaparral is missing and lack of seed sources may prevent this community from reestablishing. This stasis is reflected in landbird population dynamics, wherein the shrub-loving orange-crowned warbler did not increase over time, and the grassland specialist western meadowlark did (on point counts). Horned larks, which favor short grasses and bare ground, decreased on the longer time-frame line transects, but increased on point counts (2002-2015).

Landbird populations are well-known for exhibiting substantial interannual variability (Taylor et al. 1994), in part due to annual differences in the effect of climate on demographic variables such as individual survival and reproductive success. The islands' Mediterranean climate is relatively mild compared to other North American locales, but the periodic occurrence of the El Niño – Southern Oscillation produces considerable variability in annual precipitation (Figure 31).

We began monitoring landbirds in 1993, at the end of a 6-year drought, and had not seen a drought of comparable magnitude until the current 4-year drought (2011-2015). During the 23-year study period, significant El Niño events occurred in 1995, 1997 and 2005. Despite this variation in annual precipitation, there was little evidence of climate effects in the landbird data. Many species increased during the current drought. Species that increased included red-tailed hawks, horned larks on Santa Barbara Island, California quail, Allen’s hummingbirds, Pacific-slope flycatchers, Bewick’s wrens, Hutton’s vireos, spotted towhees, song sparrows, acorn woodpeckers, and loggerhead shrikes on Santa Rosa. On the other hand, a few species did appear to be affected by the drought, with declines during the drought period that were not related to longer term declines. These included orange-crowned warblers on Anacapa and western meadowlarks on Santa Rosa.

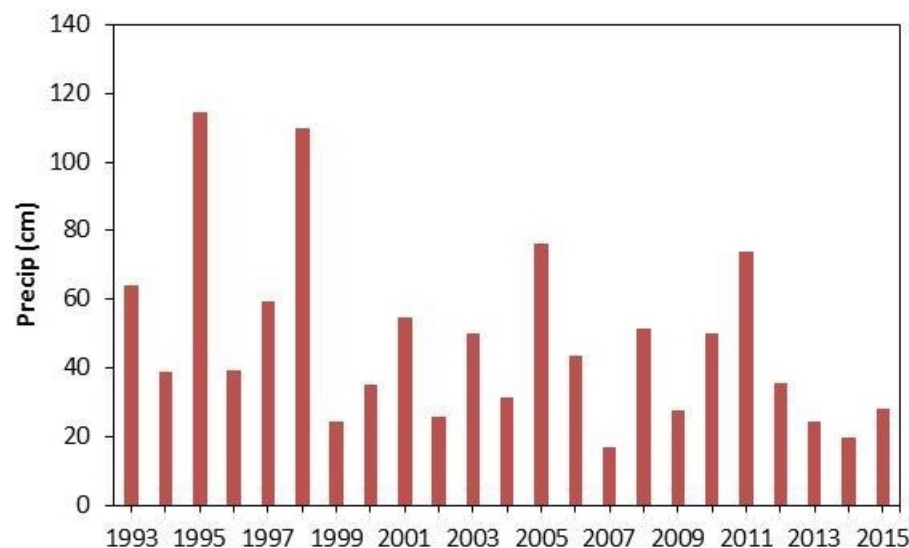


Figure 31. Annual precipitation for the water year (July 1 - June 30), Central Valley Remote Area Weather Station, Santa Cruz Island.

Inter-island climatic variability could also account for some differences in landbird densities between islands. For example, Santa Barbara Island, in the southeast portion of the archipelago, is warmer and drier than the islands in the northwest. The latter are more subject to the cool maritime fog layer driven onshore by prevailing northwest winds, and the fog layer is also a source of moisture in the form of fog drip, as captured by vegetation. Horned larks and western meadowlarks showed higher variability on Santa Barbara Island than on San Miguel, perhaps because of greater climatic variability on Santa Barbara.

One of the most noteworthy factors affecting landbird populations was the apparent effect of island fox densities on landbird populations. That predators on islands exert top-down effects on prey is to be expected, and predators have been removed from islands for the sake of breeding birds (Smith et al. 2010). It is rare, in the first place, to have a native carnivore on a small island, and thus the removal of island foxes for captive breeding provided an unprecedented experiment in temporary removal of a native predator from an ecosystem. Island foxes existed at high population levels on San Miguel (>400) and Santa Rosa (>1000) in the early 1990s. Golden eagle predation caused a rapid and

deep decline in those populations, as well as in Santa Cruz Island foxes, in the mid-1990s, and the remaining foxes were captured and brought into captive breeding facilities in 1999-2000 (Coonan et al. 2010). Foxes were released back into the wild from 2003-2008 on Santa Rosa and 2004-2007 on San Miguel, and those wild populations subsequently increased.

Density of Allen's hummingbirds, song sparrows and orange-crowned warblers on San Miguel Island seemed to be related to changes in density of island foxes, one of the few nest predators on the islands (Figure 29). Line transect landbird density data from San Miguel (1993-2007) bracket the period of fox decline, removal for captive breeding, and release back to the wild. Three landbird species that were stable or slightly declining prior to removal of foxes from the wild subsequently increased, with greater interannual variation, in a multi-year cycle (Figure 29). There are no trees on San Miguel, and foxes are likely very effective nest predators. Collins and Laughrin (1979) found that birds occurred in 22% of San Miguel island fox fecal samples during spring, and comprised 13% of fox diet during that time period. Cypher et al. (2014) found birds to be important island fox diet items on all six islands. Island fox predation can destroy up to ¼ of island song sparrow nestlings on San Miguel (Sogge and van Riper 1988), and consequently song sparrows on that island locate their nests deep within shrubs (Kern et al. 1993).

Removal of island foxes from the wild 1999-2004 may have released these particular bird species from predation pressure. Their populations were no longer limited by predation, but may have fluctuated instead according to climatic and food variability. The effect of fox predation on birds may be more pronounced on San Miguel, where there are no other predators, such as spotted skunks or Santa Cruz Island jays, and where there is less shrub cover and no trees. In contrast, Santa Cruz Island has both island skunks (*Spilogale gracilis amphiala*) and jays, and greater tree and shrub cover than San Miguel. Occurrence of birds in island fox scat on that island was less (3-4%; Crooks and Van Vuren 1995) than on San Miguel.

That orange-crowned warblers on San Miguel experienced release from predation during fox removal is supported by recent work indicating that orange-crowned warblers on the Channel Islands adjust nest height according to perceived predation threat (Peluc et al 2008). During our study, densities of orange-crowned warblers increased on San Miguel but also initially increased on Santa Barbara (Figure 21a), perhaps in response to climatic variability and food resources, although the increase was not sustained throughout the study period as it was on San Miguel.

On San Miguel, song sparrows and Allen's hummingbirds both showed much higher amplitude in interannual variation and a shift to multi-year cycles in the absence of foxes. Such shifts can occur when generalist predators, like the island fox, are removed from systems. Deer mice (*Peromyscus maniculatus*) on San Miguel showed a similar trend after foxes were brought into captivity (Coonan 2012). Deer mice themselves can be effective predators of bird eggs on the Channel Islands. On Santa Barbara Island, deer mouse predation can account for up to 30% annual egg loss in a crevice-nesting alcid, the Xantus's murrelet (*Synthliboranthus hypoleucus*) (Schwemm and Martin 2005). Deer mouse numbers increased considerably on San Miguel following loss of foxes before falling to record lows (Coonan 2012), and some of the fluctuation in bird numbers may have been due to egg predation by mice (Coonan et al. 2010).

Two ground-nesting species, horned larks and western meadowlarks, did not increase after foxes were removed. The two species differ in their nesting requirements, with horned larks using relatively dry areas with sparse grass or forbs, and western meadowlarks nesting in thick grass (Shuford 1993). Because these two species did not increase following fox removal, predation may not have been a limiting factor for them.

Removal of foxes may have allowed one raptor species to begin breeding on the northern Channel Islands. During the period when island foxes were in captivity and absent from the wild, ground-nesting northern harriers began nesting on San Miguel and Santa Rosa Islands (C. Drost, USGS Biological Resources Division, unpubl. data); they had not been previously known to nest on the islands. Monitoring data indicate that northern harriers declined, and perhaps disappeared, on San Miguel after foxes recovered to pre-decline levels (Figure 9).

Conclusion

The park's landbird monitoring program, one of the longest-running landbird population monitoring programs in the U.S., provided trend data for 29 of the park's 48 known breeding landbird species. Density estimates from distance sampling could be constructed for 19 species. Distance estimates were not available for the legacy point count sites on Santa Cruz, but we were able to use count data to determine trend for 26 species on that island. Similarly, count data were also used to derive trends for 7 species on other islands. The methods were incapable of detecting trends for swifts and swallows, for owls, and some large raptors such as bald and golden eagles and peregrine falcons. Distance sampling methods allow estimation of density and are robust to observer variability, due to incorporation of covariates in the model; problems with confidence intervals and annual variability are lessened over time, as the number of detections for each species accrues. The shift to point counts after a 2001 program review allowed evaluation of landbird use of habitat, though line transect monitoring on the three smaller islands, which have less topographical and vegetation diversity, returned interesting trends related to ecological change, with acceptably low coefficients of variation in probability density function.

Trend analysis revealed various rates of change in landbird populations on the five park islands. While a small sample size made conclusions about change on Anacapa tenuous, there was less change, overall, on the smaller islands of Santa Barbara, and San Miguel. Some trends on the latter seemed related to the decline and recovery of the island fox, an effective nest predator. The relatively low amount of change on those islands echoes concerns that recovery of vegetation from past land use practices, such as grazing, has slowed or stalled on those islands (Davidson et al. *in review*). There was much greater change on the two larger islands of Santa Cruz and Santa Rosa, where recent removal of nonnative ungulates has allowed incipient recovery of shrub and woodland communities. The removal of domestic sheep and feral pigs from Santa Cruz Island, in the 1980s and 2000s, respectively, has apparently resulted in the increase of landbird species which prefer shrub and woodland habitat, and a decrease in those that prefer grassland. There was less change on Santa Rosa, where cattle were removed in 1998 and deer and elk were completely eliminated by 2015. Still, increases in some shrub and woodland bird species on that island suggest that Santa Rosa may

eventually follow a similar recovery track as Santa Cruz, where almost all landbird species experienced change over time.

These results underscore the importance and utility of ecological monitoring, a programmatic investment begun by the NPS at Channel Islands National Park in the late 1980s, and which has since paid handsome dividends. Monitoring implemented under the auspices of the program detected the decline of island foxes in the mid-1990s, and had that catastrophic decline not been detected, island foxes would likely be extinct on several of the northern Channel Islands. Beyond such dramatic benefits, longterm monitoring has also allowed the park to track ecological change over a decades-long period of time, as evident in the landbird data. Those data detected shorter-term changes due to island fox decline and capture for captive breeding, and the longer-term changes brought about by nonnative ungulate removal on Santa Cruz and Santa Rosa islands. The recent history of the park has been marked by large-scale ecological recovery actions, and it is gratifying to see positive changes due to those actions writ in the landbird data. Given the specter of global climate change, the NPS would be wise to keep longterm ecological monitoring, including landbird monitoring, intact at Channel Islands National Park, or risk missing possible impairment of the natural resources for which the park was established.

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Appendix A. Survey Years

Table 15. Years (1993-2015) during which complete line transect and point count sampling were conducted at Channel Islands National Park.

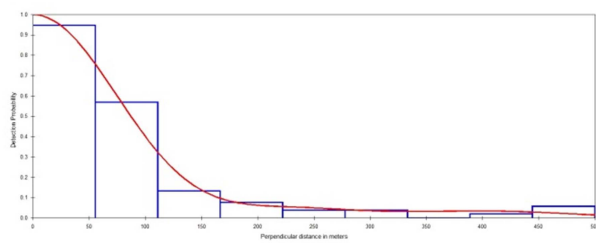
Island	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
Line transects																							
Santa Barbara																							
Anacapa																							
San Miguel																							
Point counts																							
Santa Barbara																							
Anacapa																							
Santa Cruz																							
Santa Rosa																							
San Miguel																							

Appendix B. Detection Probability Plots

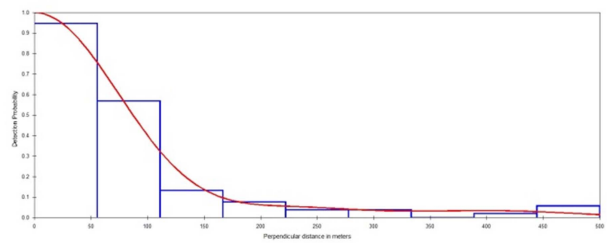
The following detection probability plots depict the attenuation of detectability as distance increases from the observer, for each species. Data are derived from the model selected in program Distance for either line transect or point count analyses (see Table 5). For line transects the x-axis represents perpendicular distance from transect midline, and the y-axis is detection probability. For point counts, x-axis represents distance from center of plot.

Line Transects

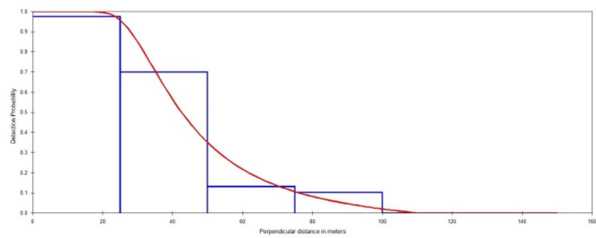
Northern harrier



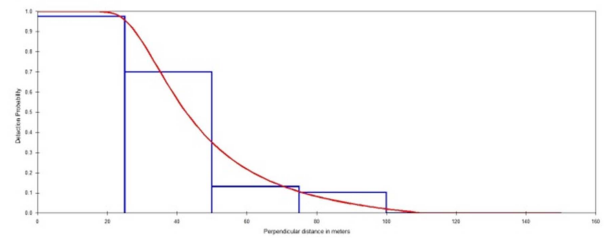
Allen's hummingbird



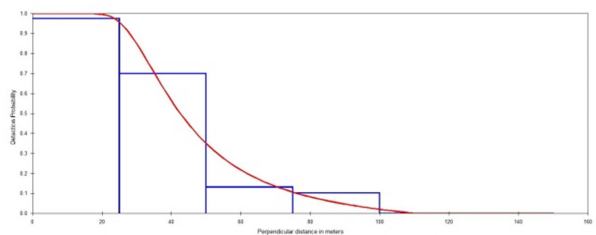
Horned lark



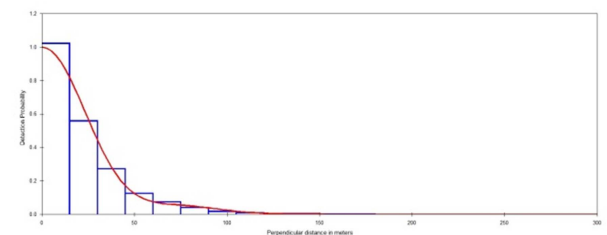
Common raven



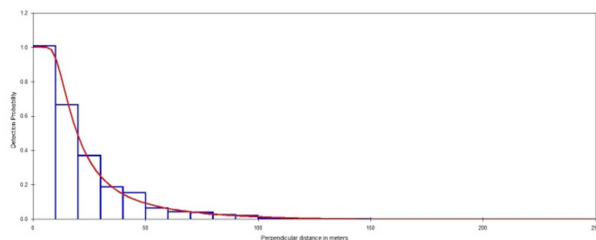
Bewick's wren



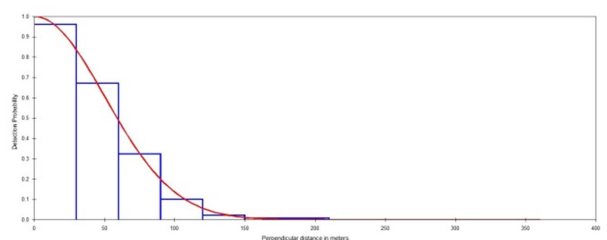
Orange-crowned warbler



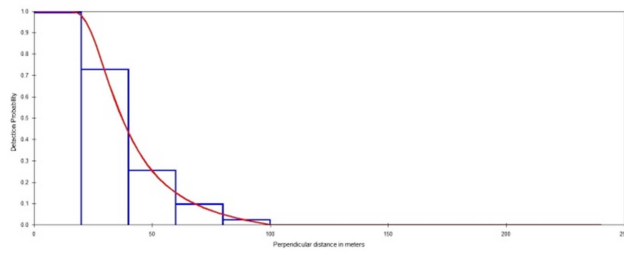
Song sparrow



Western meadowlark

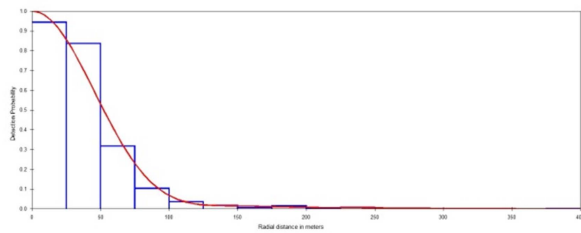


House finch

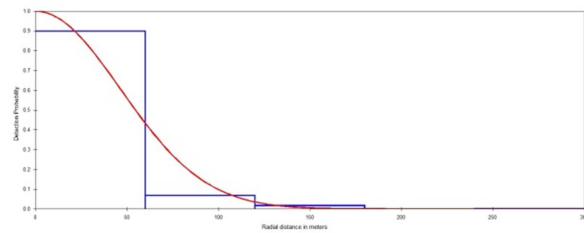


Point Counts

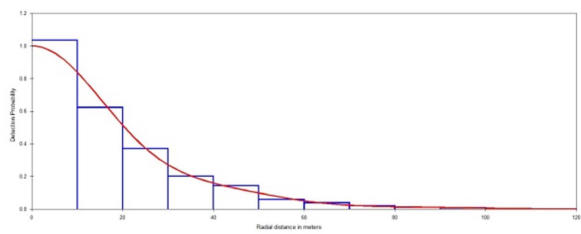
California quail



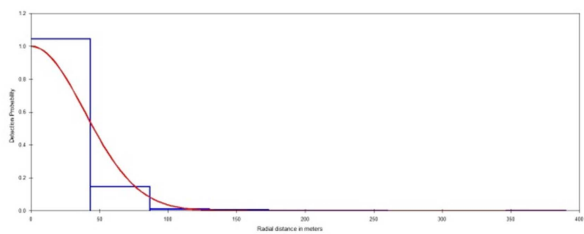
Mourning dove



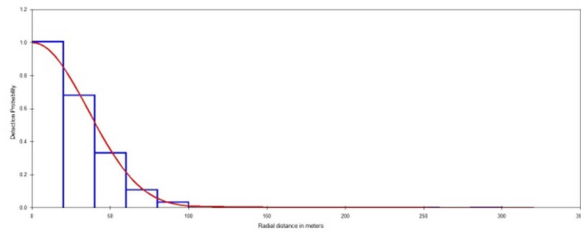
Pacific-slope flycatcher



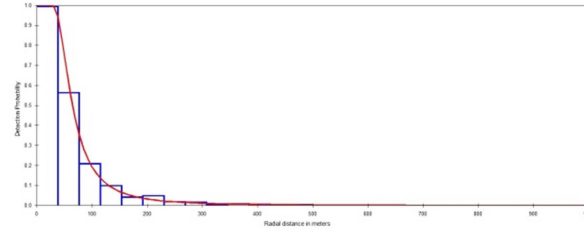
Black phoebe



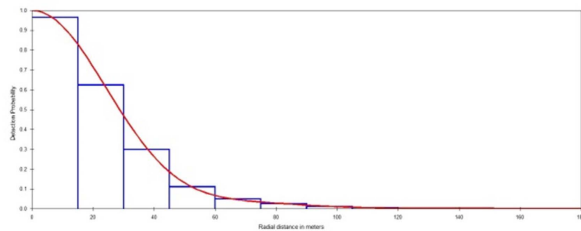
Horned lark



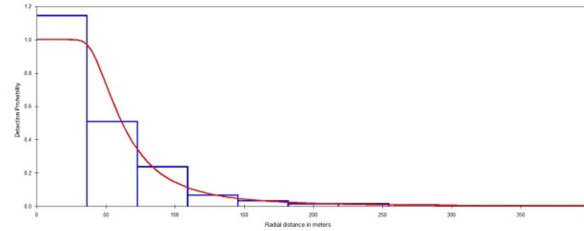
Common raven



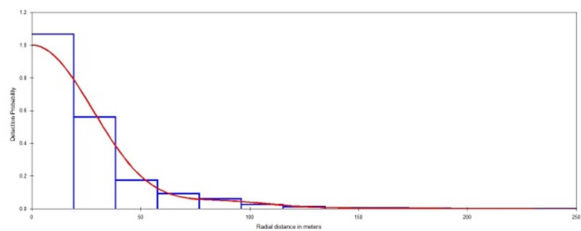
Bewick's wren



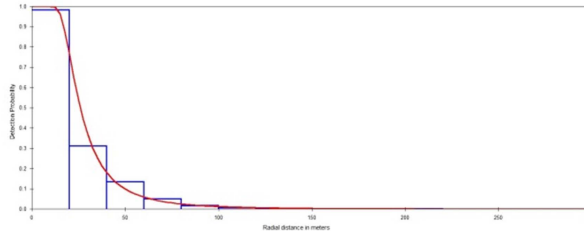
Northern mockingbird



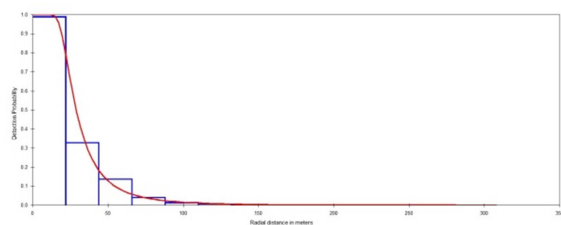
Hutton's vireo



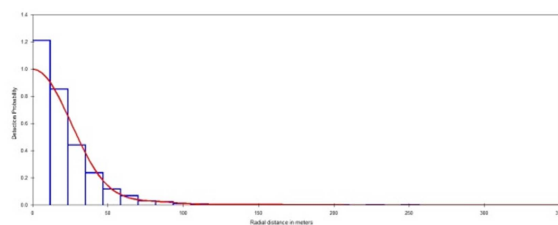
Orange-crowned warbler



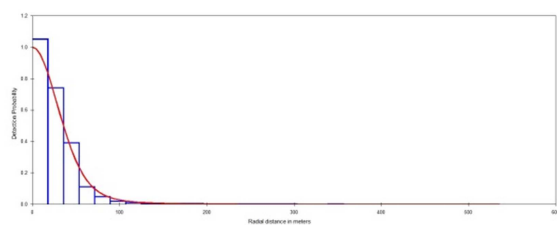
Song sparrow



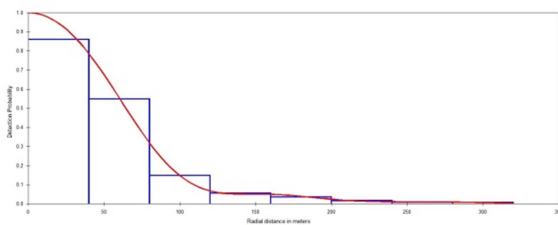
Spotted towhee



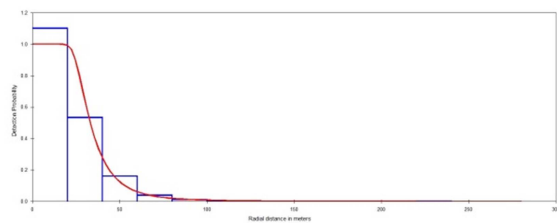
Chipping sparrow



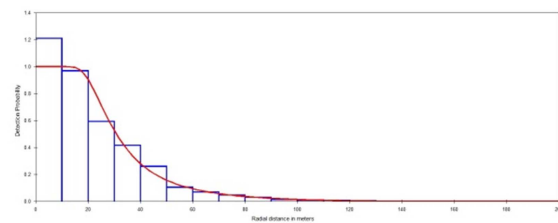
Western meadowlark



Lesser goldfinch



House finch



The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 159/135092, November 2016

National Park Service
U.S. Department of the Interior



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