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WINTERING SHOREBIRDS INCREASE AFTER KELP (*MACROCYSTIS*) RECOVERY[1]

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Abstract. We censused shorebirds along 4 km of southern California rocky shoreline in 1969–1973 when kelp was absent, and in 1985–1986 after kelp had been restored. Nonparametric regression was combined with a multi-level bootstrap to show that the recent counts were substantially higher than the previous years for those wintering species most specifically associated with rocky shorelines. Black and Ruddy Turnstones, two species frequently seen feeding on algal windthrow in 1984–1986, displayed the most dramatic increases. Kelp restoration has apparently enhanced wintering shorebird numbers along the Palos Verdes Peninsula of California.

Key words: Shorebirds; pollution; kelp; restoration ecology; rocky shoreline; winter distribution; Arenaria.

INTRODUCTION

There are few data characterizing the status and density of intertidal rocky shoreline birds. A variety of shorebirds, primarily sandpipers and plovers, winter along the rocky shorelines of southern California (Jurek 1974). Some are territorial, defending portions of the shore from conspecifics (Whimbrel, Wandering Tattler, Spotted Sandpiper). Others occur in irregular numbers, often forming small flocks (Black-bellied Plover, Sanderling, Black Turnstone, Ruddy Turnstone, Willet). These shorebirds feed on the marine invertebrates abundant in the intertidal zone. At high tide, most of these species loaf on exposed rocky areas above the high tide line, but some species visit other habitats (e.g., Sanderlings congregate on sand or cobble beaches).

The Palos Verdes Peninsula lies between Santa Monica Bay and Los Angeles harbor. The avifauna of this peninsula has affinities to that of the Santa Barbara Channel Islands (Bradley 1980). Most of the coastline (26 km) is rocky surmounted by steep cliffs of 30–65 m. There are a few isolated sandy and cobble beaches (Finke 1966, Gales 1974). Prior to 1940 there were extensive offshore kelp (*Macrocystis pyrifera*) forests (Wilson and North 1983). These kelp forests gradually declined, until the essential extirpation of kelp in 1958. The causes of this decline undoubtedly include pollution (Wilson et al. 1980, Wilson and North 1983). Kelp restoration efforts beginning in the late 1960s re-established a small but growing population by the mid-1970s (Wilson et al. 1977, Wilson and North 1983).

Shorebird censuses were conducted in four successive winters during the later portion of the period of kelp absence (1969–1973) in conjunction with a state-wide shorebird survey (Jurek 1974). Censuses along the same route were repeated for two winters after kelp recovery (1984–1986). Here we compare the results of these censuses by constructing a statistical model based on the initial four years of data; we then examine the recent data in the context of that model.

METHODS

Complete counts of all shorebirds encountered between the cliff and the ocean were made by two or three observers walking along the rocky shoreline. Care was taken to account for the fact that some birds flew ahead of the census team; they were not counted until they had either doubled back or until the end of the route was reached, at which time these birds were included. The 4.0 km census route extended between Lunada Bay and Bluff Cove on the Palos Verdes Peninsula, Los Angeles County, California (33°25′N, 118°46′W). Bradley et al. (1972) describe the characteristics of the route, including a survey of intertidal algal cover during spring 1971. For early years, nearly complete counts were possible. During later years, some shorebirds foraged on

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the floating kelp mats offshore and may have been missed. No such habitat was available during the early census period. Thus, recent data probably underestimates the true number of birds present.

The raw data, with irregularly spaced counts, blend short-term fluctuations with seasonal and annual variation, greatly complicating comparative analysis. We combined two flexible statistical techniques, nonparametric smoothing (Gasser and Muller 1979), and the bootstrap (Efron and Tibshirani 1986) to overcome these difficulties with a readily interpretable graphical basis for comparison between the early set of surveys and those from recent years. This method smooths the raw time series of counts per species with a specially constructed heavy-tailed finite-span kernel (Bradley and Bradley 1987). Smoothed curves were then bootstrapped by a complex process that simulated typical census series and applied the kernel-smoother to the resulting pseudo-samples. Pointwise confidence bands covering 95% and 50% of the simulated smoothed curves provide the basis for comparative evaluation.

The bootstrap used here was specially designed to preserve the separate variance components in these data, adding yearly deviations and short term residuals to the grand average over the early years to produce simulated censuses. Annual variation was simulated by sampling a normalized sequence of residuals taken from the differences between the yearly smooths and the grand average in a manner that preserved the high autocorrelation of these residuals. Seasonal variation was simulated by resampling deviations of the raw data from the yearly smooths with locally weighted sampling windows. One thousand of these simulated data sets (based strictly on 1969–1973 data) were filtered through the kernel-smoother and accumulated to obtain the confidence bands. This method generates confidence bands that vary in width and value based on the variance patterns in the data. For example, the bands are generally wider during the highly variable migration periods.

This procedure was applied to data from each of nine species (Spotted Sandpiper *Actitus macularia,* Wandering Tattler *Heteroscelus incanus,* Whimbrel *Numenius phaeopus,* Black Turnstone *Arenaria melanocephala,* Ruddy Turnstone *Arenaria interpres,* Surfbird *Aphriza virgata,* Willet *Catoptrophorus semipalmatus,* Black-bellied Plover *Pluvialis squatarola,* and Sanderling *Calidris alba*). The resulting plots superimpose individual smoothed curves based on the recent census data on regions marking the pointwise 50% and 95% confidence bands for the early years data. About half the span of the recent curves would fall within the inner bounds, with the outer bounds covering about 95% of the span, if the recent data is typical of that found in the early years. The pointwise bands provide a context for comparison, rather than a global significance test.

RESULTS

In general, the number of shorebirds counted during winter in the recent census years was greater than the number counted during earlier censuses (Table 1). Counts during all years for most species showed increased numbers during the end of the fall migration and the beginning of the spring migration. This was especially obvious for territorial species (Spotted Sandpiper, Wandering Tattler, and Whimbrel, Fig. 1) and undoubtedly reflected the passage of migrant flocks. The data for territorial species present the greatest contrast because of their regular spacing behavior that results in lower variance among samples. The migrant pulses provide a stronger contrast for these species than for the more variable, non-territorial flocking species. Numbers of spring migrants were higher for Wandering Tattlers and Whimbrels during both 1985 and 1986. Large numbers of Spotted Sandpipers, Whimbrels, Black Turnstones, and Ruddy Turnstones seen during October and November during both recent census years may represent late migration or increased migrant abundance (Figs. 1, 2). The peak of Sanderling numbers during December of 1985 was much higher than the earlier census period (Fig. 2). Surfbirds were found along the study route mainly during spring migration. There was no indication that Surfbird numbers occurring along this coastline have changed between census periods.

Territorial species. All three of the territorial species were more abundant (often twice as many birds) in 1984–1985 as compared to 1969–1973 (Fig. 1). Spotted Sandpiper numbers exceeded the upper confidence limit throughout the period from November to March. Numbers in 1985–1986 were more variable than in previous years and may indicate visitation by non-resident birds. Wandering Tattlers occurred in stable numbers throughout the winter. Tattler counts were clear-

TABLE 1. A comparison of the mean number of shorebirds counted per census for each census winter. The winter period was defined as beginning on 15 November and ending on 15 March. All values have been rounded to the nearest integer. For a treatment of the complex patterns of variation in these data, consult Figures 1–3.

	Census year					
	1969–1970	1970–1971	1971–1972	1972–1973	1984–1985	1985–1986
Number of censuses:	11	4	8	4	8	6
Spotted Sandpiper	11	11	18	14	26	28
Wandering Tattler	3	5	4	3	8	6
Whimbrel	4	3	5	4	10	12
Black Turnstone	9	2	3	18	38	45
Ruddy Turnstone	0	0	0	0	3	12
Sanderling	3	22	32	22	32	46
Black-bellied Plover	23	46	46	46	40	44
Surfbird	0	0	0	0	0	0
Willet	12	27	30	18	31	34
Total	55	116	138	125	188	227

ly higher in 1984–1986, although a brief dip in late February and early March 1986 brought numbers down near the earlier averages. Whimbrel numbers also increased, with 1985–1986 counts showing about a three-fold increase over the early years.

Kelp associated non-territorial species (Fig. 2). Black Turnstone numbers increased dramatically, four to eight fold in recent years. These birds were frequently observed foraging on and around the dead windthrow of kelp along the shore. This micro-habitat preference was also noted by Shuford et al. (1989). Such mats of decomposing algae are a rich source of food such as shoreflies (Ephydridae), isopods (especially *Ligia* sp.) and other invertebrates. Only a few Ruddy Turnstones were encountered during the earlier census period. Substantial numbers were found in both 1984–1985 and 1985–1986. Ruddy Turnstones were more strongly associated with algal windthrow than Black Turnstones, and this may explain their greater numbers during recent censuses. Sanderlings were also attracted to algal windthrow and sometimes occurred in large numbers during 1984–1986. However, with the exception of late November and December 1985, Sanderling numbers were similar to the model generated from the earlier census period and generally fell within the confidence bounds.

Other non-territorial species (Fig. 3). Black-bellied Plovers occurred in relatively large flocks. Such behavior probably explains the high vari-

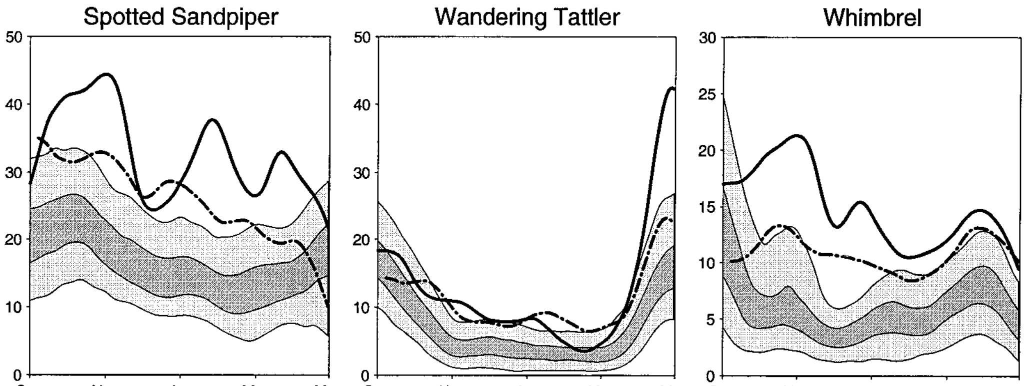

FIGURE 1. *Territorial species:* Numbers of birds (vertical axis) during the census period (horizontal axis). Plots show recent smoothed abundance curves and 50% and 95% confidence bands for 1969–1973. The light shaded areas symbolize the 95% confidence band, the dark shaded areas symbolize the 50% confidence band. The dashed line covers 1984–1985, while the solid line displays 1985–1986.

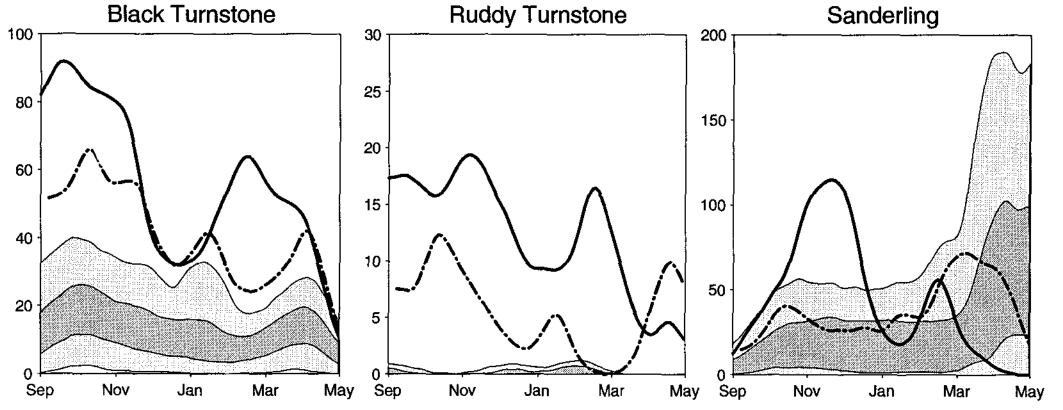

FIGURE 2. *Kelp associated flocking species:* Numbers of birds (vertical axis) during the census period (horizontal axis). Plots show recent smoothed abundance curves and 50% and 95% confidence bands for 1969–1973. The light shaded areas symbolize the 95% confidence band, the dark shaded areas symbolize the 50% confidence band. The dashed line covers 1984–1985, while the solid line displays 1985–1986.

ability in the counts from all years and the lack of any consistent trends in abundance. Surfbirds were seldom found along the census route during winter. The model predicts a low number of wintering birds, and there is no indication that this situation has changed. Willet numbers were fairly constant during the two recent census years. Despite values that centered around the upper 50% limit, there is no convincing evidence of a change in Willet abundance.

DISCUSSION

Among nine species of shorebirds, the counts of five (Spotted Sandpiper, Wandering Tattler, Whimbrel, Black Turnstone and Ruddy Turnstone) increased dramatically during the recent census period. These five are typically restricted to rocky shorelines. At least three of these five species (Spotted Sandpiper and the turnstones) forage by gleaning small active invertebrate prey. Turnstones concentrate their foraging on the kelp windthrow that is more abundant in recent years since the recovery of the kelp forests offshore. These two species appear to depend upon algal mats and associated food resources in winter (Shuford et al. 1989). Secondary production is significantly higher in areas where detritus from kelp forests exists (Duggins et al. 1989). Other studies have shown that wintering shorebirds concentrate in areas where prey are most avail-

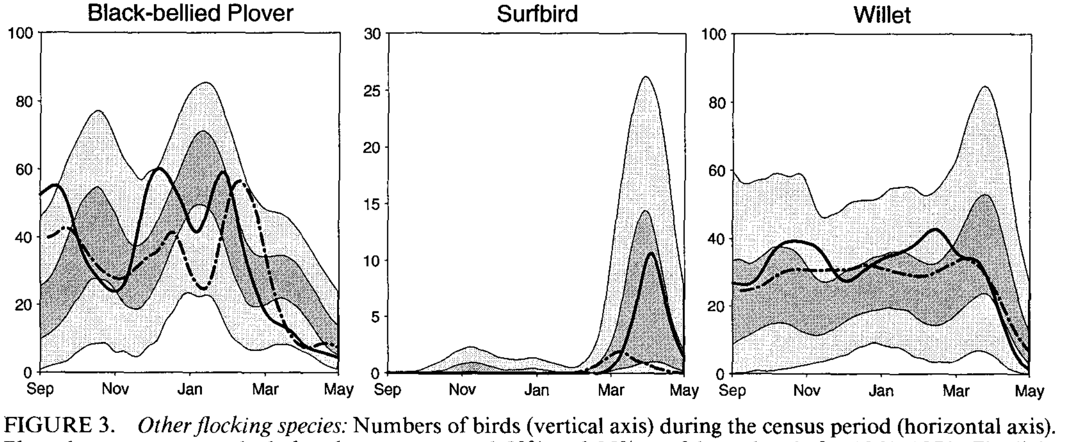

FIGURE 3. *Other flocking species:* Numbers of birds (vertical axis) during the census period (horizontal axis). Plots show recent smoothed abundance curves and 50% and 95% confidence bands for 1969–1973. The light shaded areas symbolize the 95% confidence band, the dark shaded areas symbolize the 50% confidence band. The dashed line covers 1984–1985, while the solid line displays 1985–1986.

able (Goss-Custard 1970, 1979, 1981; Zwarts and Drent 1981). It is possible that the return of kelp beds off the coast of Palos Verdes caused an increase in prey available to foraging shorebirds there. Black-bellied Plovers which do not utilize the algal windthrow did not increase significantly. It is reasonable to suppose that winter shorebird densities are primarily determined by resource abundance along this coastline. We hypothesize that the return of kelp has significantly increased the resource base on adjacent rocky shores. Testing this hypothesis will require sampling of food abundance, potential food availability and the winter diets of these birds. Such a study might include experimental manipulation of algal mats.

With only a single study site and one time period with kelp and one without kelp, generalization beyond this specific situation is impossible. Statistical inference from our model allows us to judge whether recent smoothed curves are typical of the range of variation observed in the early years. However, normal variation on a 15-year time span may well exceed variation in a four-year span. To assess observed differences in this context would require many additional samples at 15-year intervals. As an alternative to this unlikely prospect, expansion to other similar locations might be feasible. Another possible explanation for the patterns observed in this study is that there have been overall increases in the populations of certain species. This hypothesis might be tested by examination of data collected over a continental scale.

We conclude that kelp restoration along the Palos Verdes Peninsula has significant beneficial effects for local wintering shorebirds. This suggests that systems with long histories of habitat degradation are capable of recovery.

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