Seasonal abundance of migrant shorebirds in Baja California Peninsula, Mexico, and California, USA

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Nearctic shorebirds use three main flyways (Pacific, Central and Atlantic) and the largest numbers are found in the Pacific Flyway, which includes the Baja California Peninsula. There, at various different sites, the following patterns of abundance have been observed: very low numbers in summer; large numbers in autumn; low and stable numbers in winter; and moderate numbers in spring. In contrast, further north in California, numbers during spring migration are as high as or even higher than those in autumn. We contrast the differential utilization by shorebirds of Baja California during spring and autumn. In autumn, southbound migrants arrive at sites in southern California and the upper Gulf of California, and then either continue along the mainland coast of Mexico or along the Baja California Peninsula. Some continue migrating further south while others stay for the winter. During the return migration in spring, modest numbers occur throughout the peninsula, with rather greater numbers in the north-west, probably associated with the northward migration through the extensive wetlands of Sonora and Sinaloa on the mainland coast.

INTRODUCTION

Of the 49 shorebird species that breed in the Nearctic, 40 migrate to temperate and tropical areas of Mexico, Central and South America for the northern winter (Myers *et al.* 1987).

At typical shorebird stopover and wintering sites throughout the Pacific Flyway, there are distinct patterns of seasonal abundance. In summer, numbers are very low because most are breeding in the north. In autumn, most sites record the largest numbers as first adults and later juveniles migrate south. Lower numbers are present in winter, but they remain relatively stable because little movement takes place. In spring, northward migration leads to increased numbers as birds return to their breeding areas (Page *et al.* 1979).

Of the three major shorebird flyways in North America (Pacific, Atlantic and Central), the most important in terms of numbers is the Pacific Flyway (Myers *et al.* 1987) and midway along the Pacific Flyway lies the 1,100-km Baja California peninsula (Fig. 1). There, during the past decade, systematic data on shorebird abundance have been collected for several different coastal localities (e.g. Palacios *et al.* 1991, González 1996, Carmona & Danemann, 1998). These studies have shown that the peninsula is particularly important during autumn migration and of less importance during spring migration (Carmona 1997, Fernández *et al.* 1998, Carmona & Danemann 1998). In this paper, we present a general hypothesis to explain the patterns of seasonal abundance of migrant shorebirds along the Baja California peninsula.

STUDY AREA AND METHODS

We have analysed shorebird abundance data for five sites along the south-west coast of the United States and in north-west Mexico that have been previously identified as supporting important populations. These are Humboldt Bay (north California), the Central Valley of California and three sites in the Baja California peninsula: Punta Banda, Guerrero Negro and Ensenada de La Paz (Fig. 1).

Although there are many sites with extensive intertidal mudflats along the Pacific Flyway in California, we selected just two (Humboldt Bay and Central Valley) to represent those that are typical – in terms of both habitat and shorebird abundance – of the ones used by migrant shorebirds in that area (Colwell 1994, Shuford *et al.* 1998).

All five sites are influenced by a fairly stable, tropical, high-pressure belt that brings dry winds (Coria 1997). California and north-west Baja California have a Mediterranean-type climate, while the southern part of the peninsula (around 30°N) has an arid climate, except for its southern tip (the Cape region) which is subtropical (García 1981).

The largest areas of intertidal mudflats in California are found in Humboldt, San Francisco and San Diego bays (Peinado *et al.* 1995), while on the west coast of Baja California there are mudflats in the bays of Todos Santos, San Quintín, Ojo de Liebre-Guerrero Negro, San Ignacio and Magdalena. On the east coast the largest mudflats are at Ensenada de La Paz in Bahía de La Paz (Carmona *et al.* 1994).

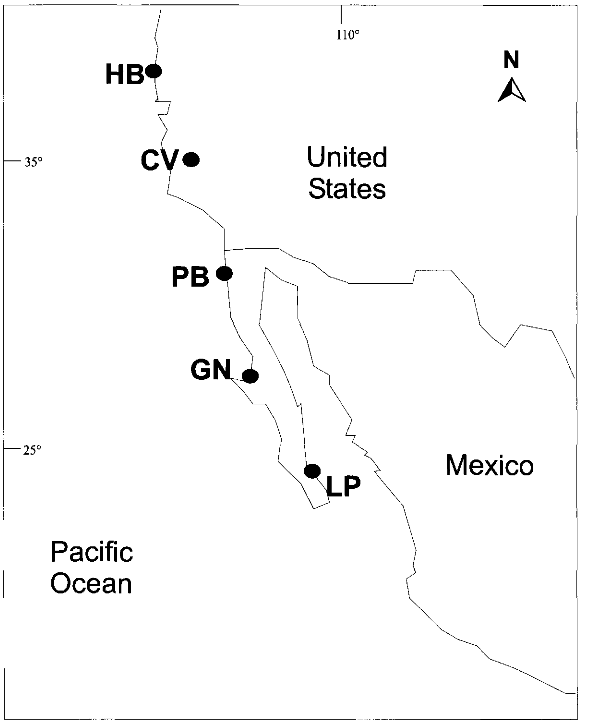

Fig. 1. Study area and shorebird census sites. (HB = Humboldt Bay (north California); CV = Central Valley of California; PB = Punta Banda (north-west Baja California); GN = Guerrero Negro (mid-west Baja California); and LP = Ensenada de La Paz (south Baja California.))

Our analysis relates to data from six studies during 1991–1998. Two were carried out at Estero Punta Banda (north-west Baja California) by Palacios *et al.* (1991) and González (1996) and covered sampling periods of seven months and one year, respectively.

The study sites (Fig. 1) were: (1) Humboldt Bay, north California (38°N, Colwell 1994); (2) Central Valley of California (35°N, Shuford *et al.* 1998); (3) Punta Banda, north-west Baja California (31°N, Palacios *et al.* 1991, González 1996); (4) Guerrero Negro (28°N, Carmona & Danemann 1998); and (5) Ensenada de La Paz (24°N, Carmona 1997).

The frequency of sampling at each site was rather variable and depended on the particular objectives of each study (see Appendix). Therefore, to facilitate comparisons on both spatial and temporal scales (i.e. sites and seasons) we calculated the monthly average abundance of each species and then converted to percentages on the basis that the aggregate of the monthly averages for each site was 100%.

The data for Humboldt Bay include a number of separate counts for sites within the bay (Colwell 1994), so for each month these were aggregated. For two sites, Humboldt Bay and the Central Valley of California, there were no data for several months. Therefore, for these, the data were analysed on a seasonal rather than monthly basis as follows: winter (December–February), spring (March–April), summer (May–June) and autumn (July–November). Even on this basis, there were no data for Humboldt Bay or Central Valley for summer (see Appendix).

An independence χ^2 test ($\alpha = 0.05$; Zar, 1999) was used to compare the abundances of shorebirds at Punta Banda as reported by Palacios *et al.* (1991) and González (1996). Likewise, two types of comparisons of shorebird abundance among sites were made using χ^2 tests: (1) seasonal abundance of the species among the five sites (except for summer because no data are available for Central Valley and Humboldt Bay), and (2) seasonal abundance of the species among the three sites having data for all four seasons. In both cases, when the independence hypothesis was rejected in the first test, we determined which site contributed the most to this rejection, and then removed it from the analysis. This process was repeated until the hypothesis was accepted (and therefore a homogeneous group was formed). In addition, the excluded sites from the initial analysis were compared mutually, restarting the procedure ($\alpha = 0.05$ in all the cases; Zar 1999).

RESULTS

In our monthly analysis, Humboldt Bay, California, had the greatest abundance of shorebirds in autumn (November) and spring (April), with lower numbers in winter (February) (Fig. 2a). In the Central Valley of California, abundance increased gradually from autumn (November) to winter (January) to spring (April) (Fig. 2b). At Punta Banda, Baja California, there was greater evenness in seasonal abundances, with only small increases in autumn (October & November) and spring (March) and a notable decrease in summer (May & June; Fig. 2c). At Guerrero Negro, highest abundance occurred in autumn (August & September) with much lower but more stable numbers in winter (December–February) and a small increase in spring (April; Fig. 2d). At Ensenada de La Paz, the highest abundance occurred in autumn (September & October) and winter (January), with no increase in spring (March & April; Fig. 2e).

In our analysis by season (Fig. 3), Humboldt Bay, California, had the largest numbers during spring and autumn migration, with only a small decrease in winter (Fig. 3a). In contrast, numbers in the Central Valley of California were

Fig. 2. Mean monthly relative abundance (%) for the five study sites.

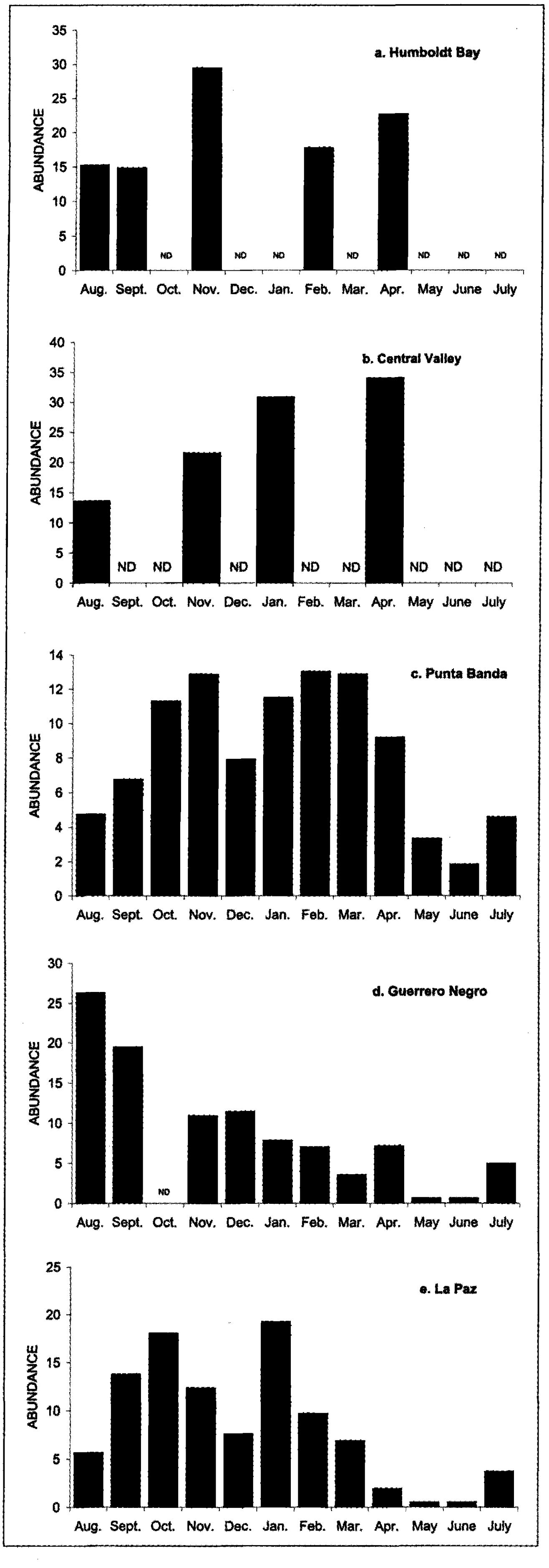

Fig. 3. Mean seasonal relative abundance (%) for the five study sites.

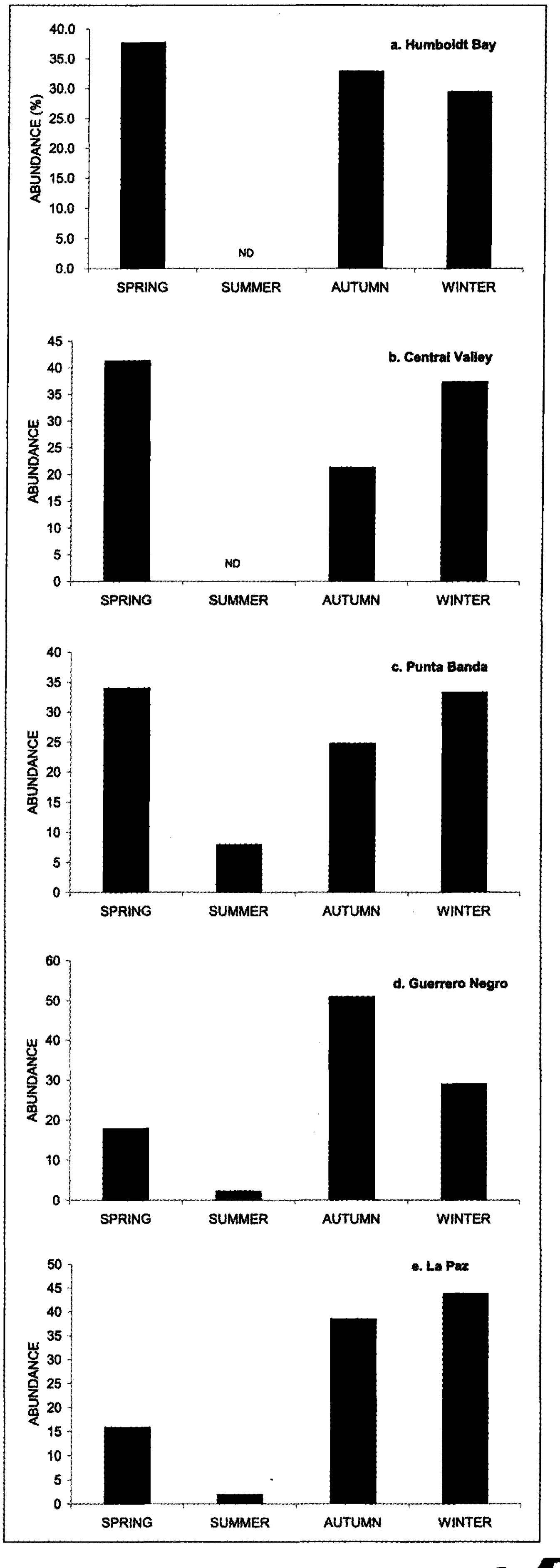

Table 1. Results of χ^2 tests on the relative seasonal abundance of shorebirds at five sites along the Pacific shorebird flyway (excluding summer) (HB = Humboldt Bay, CV = Central Valley, PB = Punta Banda, GN = Guerrero Negro, LP = Ensenada de La Paz).

Group compared	χ^2	P	d.f.	Site contributing most to the rejection of the null hypothesis	% of the site more heterogeneous
HB-CV-PB-GN-LP	61.9	<0.001	8	LP	48
HB-CV-PB-GN	29.7	<0.001	6	GN	57
HB-CV-PB	8.2	0.085	4	–	–
GN-LP	5.0	0.083	2	–	–

Table 2. Results of χ^2 tests on the relative seasonal relative abundance of shorebirds at three sites in the peninsula of Baja California, Mexico (including summer) (PB = Punta Banda, GN = Guerrero Negro, LP = Ensenada de La Paz).

Group compared	χ^2	P	d.f.	Site contributing most to the rejection of the null hypothesis	% of the site more heterogeneous
PB-GN-LP	42.8	<0.001	6	PB	58
GN-LP	4.9	0.18	3	–	–

Table 3. Seasonal peak counts of shorebirds at the five study sites (ND = no data available).

	Humbolt Bay	Central Valley	Punta Banda	Guerrero Negro	Ensenada De La Paz
Winter (Dec.–Feb.)	66,000	374,000	1,100	33,000	12,000
Spring (March–Apr.)	83,000	393,000	800	10,000	1,700
Summer (May–June)	ND	ND	600	1,900	470
Autumn (July–Nov.)	36,000	177,000	1,300	76,000	13,000

greatest in spring, and there were more in winter than in autumn (Fig. 3b). In Baja California, Punta Panda held the largest numbers in winter and spring, fewer in autumn and only small numbers in summer (Fig. 3c). At Guerrero Negro, highest numbers occurred in autumn, relatively small numbers in spring, but the wintering population was fairly high; only tiny numbers occurred in summer (Fig. 3d). The pattern was similar at Ensenada de La Paz with higher numbers in autumn than in spring and only small numbers in summer. However, wintering numbers were greater than at any other time of year (Fig. 3e).

Comparing the numbers reported for Punta Banda by Palacios *et al.* (1991) and González (1996), we found that there were no significant differences ($\chi^2 = 3.87$, d.f. = 5, $p = 0.43$). However, we decided to use the data of González (1996) only because it covered a full year rather than just seven months.

Comparing seasonal numbers across all five study sites except summer (Table 1), it is evident that Ensenada de La Paz and Guerrero Negro contributed the most heterogeneity. Once these two sites are removed from the analysis, those remaining (Humboldt Bay, Central Valley and Punta Banda) can be considered homogeneous. Similarly, comparison between Guerrero Negro and Ensenada de La Paz indicates these sites are similar (Table 1). In summary, the statistical tests indicate that there are two homogeneous groups: the three northern sites (Humboldt Bay, Central Valley and Punta Banda) and the two peninsular sites (Guerrero Negro and Ensenada de La Paz).

The same result emerges when the data for the three sites in Baja California (including summer) are analysed together: the pattern at Punta Banda is shown to be significantly different from the other two, Guerrero Negro and Ensenada de La Paz, which are similar (Table 2).

DISCUSSION

Our study focuses on patterns of spatial and temporal abundance, not absolute numbers. It is important to remember this because absolute numbers using a site may be much greater than those counted at any one time because of turnover, especially during spring and autumn migration. However, to give an indication of the scale of shorebird migration through the five study sites we present data on the peak counts for each season (Table 3).

As expected, the lowest numbers at the three Peninsula sites were recorded in summer when most nearctic migrants are breeding in the far north (Page *et al.* 1979, Rappole *et al.* 1993). However, relatively more were recorded at Punta Banda in the north of the peninsula than at the two sites in the south. This might reflect a tendency for non-breeding birds (mainly one-year-olds) to over-summer close to the nesting areas (McNeil *et al.* 1994).

It is noteworthy that at all sites (except Guerrero Negro) the wintering population was very similar to the peak population in the rest of the year. This may mean that in winter each site is used to carrying capacity (though detailed feeding studies would be needed to confirm this).

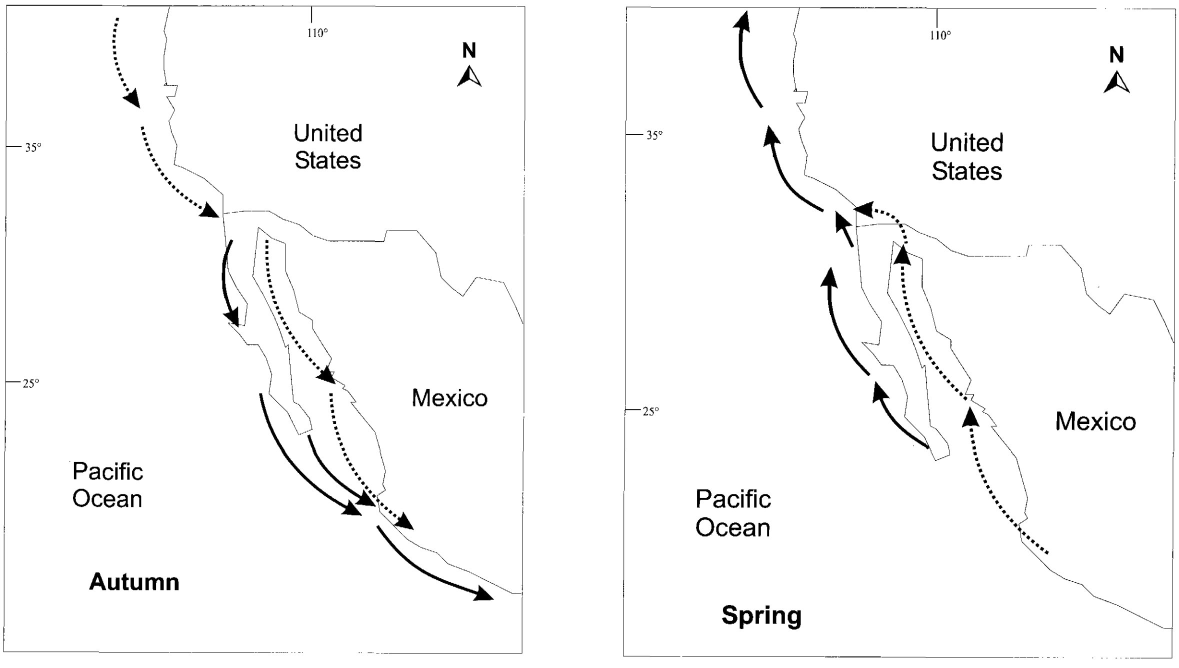

Fig. 4. Model of migratory movements of shorebirds in autumn and spring along the coasts of the south-west of the United States of America and north-west Mexico.

In spring, relatively fewer birds used the two sites in the south of Baja California than Punta Banda or the sites in California, but in autumn the pattern was almost reversed with large numbers passing through Guerrero Negro and La Paz (a pattern confirmed by our statistical analysis). Our hypothesis is that this indicates differential use of the Baja California peninsula in spring and autumn with many passage birds moving southwards down the peninsula in autumn (and then onwards along the southern Mexican coast towards South America) but mostly following the mainland coast of Mexico in spring (Fig. 4).

Thus we suggest that in autumn migrants coming from the north travel along the Pacific coast until they arrive at the base – the northern end – of the Baja California peninsula. There they have two options: to follow the mainland coast of Mexico through Sonora and Sinaloa or to follow the peninsula of Baja California. Some take one route, some the other. Those that follow the peninsula pass through to wintering areas further south while others stay for the winter. In spring, the northward movement of birds that have wintered in the Baja California peninsula leads to only a modest passage through La Paz and Guerrero Negro and few birds, if any, pass through from wintering sites to the south. At this time, most passage migrants follow the mainland coast of Mexico. There are probably two main reasons why they do this. First, following the coast may be safer than making the 250 km sea-crossing to the southern tip of the peninsula. Second, there are some large wetlands along the coasts of Sinaloa and southern Sonora (Engilis *et al.* 1998) that probably afford good feeding opportunities for shorebirds using this route.

We hope our results will provide a focus for future studies of the phenology of shorebirds passing through the Baja California peninsula as well as for the targeting of conservation action. Future studies should test our hypothesis for several of the commoner species, using a variety of methods including systematic counts, banding etc. Conservation efforts in the southern parts of the peninsula should be focussed on the seasons of autumn and winter; while in the north more effort should be put into winter and spring.

The Baja California peninsula is an important part of the Pacific shorebird flyway, especially in autumn. Moreover numerically large groups of shorebirds winter there. However, it remains rather isolated during the spring migration.

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APPENDIX

Number of monthly counts carried out in the shorebird studies along the Pacific Flyway on which our analyses are based. The year is given in parentheses: ( ), followed in the case of Colwell[b] by the number of sites visited in braces: { }. (BC = Baja California, CA = California, ND = No data available)

	Punta Banda[a] BC	Humboldt Bay[b] CA	Punta Banda[c] BC	Ensenada de La Paz[d] BC	Guerrero Negro[e] BC	Central Valley[f] CA
January	2(89)	ND	3(90)	2(97)	1(96)	1(93); 1(94); 1(95)
February	2(89)	1(91){37};1(92){32};1(93){30}	3(90)	2(97)	1(96)	ND
March	2(89)	ND	3(90)	2(97)	1(96)	ND
April	3(89)	1(91){30};1(92){26};1(93){27}	4(90)	2(97)	1(96)	1(92);1(93);1(94)
May	ND	ND	3(90)	2(97)	1(96)	ND
June	ND	ND	3(90)	2(97)	1(96)	ND
July	ND	ND	3(90)	2(97)	1(96)	ND
August	ND	1(91){22};1(92){29}	3(90)	2(97)	1(96)	1(92);1(93);1(94)
September	ND	1(90){32}	3(89)	2(97)	1(96)	ND
October	ND	ND	4(89)	2(97)	ND	ND
November	3(88)	1(90){33};1(91){31};1(92){27}	4(89)	2(96)	1(96)	1(93);1(94)
December	2(88)	ND	3(89)	2(96)	1(95);1(96)	ND

[a] Palacios *et al.* 1991; [b] Colwell 1994; [c] González 1996; [d] Carmona 1997; [e] Carmona & Danemann 1998; [f] Shuford *et al.* 1998.