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MIGRATION CHRONOLOGY, LENGTH OF STAY, SEX RATIO, AND WEIGHT OF WESTERN SANDPIPERS, (*CALIDRIS MAURI*) ON THE SOUTH COAST OF BRITISH COLUMBIA

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Abstract.—In 1978–1980 and 1985–1986, we banded, weighed, and measured 2660 Western Sandpipers (*Calidris mauri*) at 2 sites in south coastal British Columbia. Adults migrated north between mid-April and mid-May, and south between late June and late July. Most juveniles migrated south after the adults, between late July and early October. Adult males mostly migrated ahead of females in spring and after them in fall, whereas juveniles showed no sexual segregation. Migrants of both sexes were heavier in spring than fall and females outweighed males regardless of time of year, age, or standardized body size. Body weights of adults tended to increase as migration proceeded. We estimated the length-of-stay during migration at about 1–3 d for adults in autumn.

CRONOLOGÍA DE LA MIGRACIÓN, PERIODO DE ESTADÍA, PROPORCIÓN DE SEXOS Y PESO DE *CALIDRIS MAURI*, EN LA COSTA SUR DE LA COLUMBIA BRITÁNICA, CANADA

Sinopsis.—Durante 1978–1980 y 1985–1986, anillamos, pesamos, y medimos 2660 playeros (*Calidris mauri*) en dos localidades de la costa sur de Columbia Británica. Los adultos migraron al norte desde mediados de abril hasta mediados de mayo, y al sur desde finales de junio hasta finales de julio. La mayoría de los juveniles migraron al sur entre finales de julio y principios de diciembre, después de los adultos. Por su parte los machos adultos comenzaron sus movimientos migratorios previo a las hembras en la primavera y después de estas en el otoño. Los juveniles no mostraron segregación por sexo.

El peso de las aves resultó ser mayor en la primavera que en el otoño. Las hembras pesaron mas que los machos en cualquiera de las épocas, aún considerandose edad de estas y tamaño normalizado del cuerpo. Se encontró en los adultos, la tendencia de aumentar en peso segun procedió la época de migración. El periodo de estadía de los adultos durante la migración resultó ser de 1 a 3 dias.

Migrating Western Sandpipers (*Calidris mauri*) gather in the hundreds of thousands in the Fraser River delta in southwestern British Columbia and along the Gulf of Alaska (Senner et al. 1981). Between those two areas lie nearly 1200 km of fjords where no concentrations of Western Sandpipers have been discovered. Senner et al. (1981) reported on the number, timing of migration, and sex ratio of spring migrants in Alaska but the importance of the Fraser River delta has yet to be realized. Most of the human population in British Columbia is located around the Fraser River delta where their activities threaten the remnant wetlands. Recently important parts of the delta have been recommended as a 'Hemispheric Site' in the Sister Reserves Program (Morrison 1984), so it is particularly important to document the use and significance of the area to the Western Sandpiper.

This paper seeks to: (1) describe the timing of migration, sex and

weight ratios of adult and juvenile Western Sandpipers in the Fraser River delta, and (2) determine the length of stay of adult fall migrants in south, coastal British Columbia.

STUDY AREAS AND METHODS

We studied Western Sandpipers in British Columbia at the Fraser River delta (49°05'N, 123°00'W) from 1 April to 15 October 1978–1980 and 1–31 July 1985, and at a lagoon on Sidney Island (48°40'N, 123°20'W) from 23 July–15 August 1985 and 1–9 July 1986 (Fig. 1). The Fraser River delta has 20,000 ha of mudflat and sandflat extending between Iona Island and Boundary Bay and 1500 ha of marsh (Fig. 1).

We caught 2660 sandpipers mostly (96.8%) in Boundary Bay in mist nests strung across the beach. We weighed each bird within 0.5 h of capture with a Pesola spring balance and measured its culmen and wing length with a ruler. Adult (AHY) and juvenile (HY) birds with bill lengths $\leq$24 mm were considered to be males and $\geq$25 mm as females; those with intermediate bill lengths (n = 22) were excluded because they could not be confidently sexed (Page and Fearis 1971, Prater et al. 1977). Adults and juveniles can be separated by plumage marking and coloration (Prater et al. 1977). Adults have conspicuous chestnut-colored edges along the feathers of the posterior crown and ear-coverts as well as prominent streaks on the white breast and flanks. In contrast, juveniles have gray-brown colored crowns and coverts with fine streaks on a buff-colored breast.

To estimate the length-of-stay, defined here as the average number of days that any given Western Sandpiper spent in the study area, requires that marked birds have a high probability of being resighted. The probability of resighting a marked sandpiper on the vast Fraser River delta was low so we chose Sidney Island about 30 km southwest of the Fraser River delta. On the north end of the island a 2.3 km long sandy spit extends northwest from a 96 ha lagoon (Fig. 1). The lagoon is made up of eelgrass (*Zostera marina*) beds (30 ha), mudflat (4 ha), and saltmarsh (mostly *Distichlis spicata, Salicornia virginica* 25 ha); similar to Boundary Bay on the Fraser River delta. At Sidney Island, we attached unique combinations of color bands to the legs of adult sandpipers on 6–7 July (n = 14) and on 23–24 July (n = 72) to determine the length of stay of adult migrants. We searched on foot using binoculars and 15–60× telescopes all flocks of sandpipers for marked birds each morning, afternoon, and evening beginning on 7 and 25 July. Large numbers of sandpipers were seen in the lagoon and on the spit so search efforts were concentrated at those feeding and roosting sites. We examined all flocks of sandpipers until 24 h after the last marked bird had departed.

RESULTS

Spring migration occurred from mid-April to late May and autumn migration from the third week of June to early October. The prolonged autumn migration was due to age-segregated movement first by adults

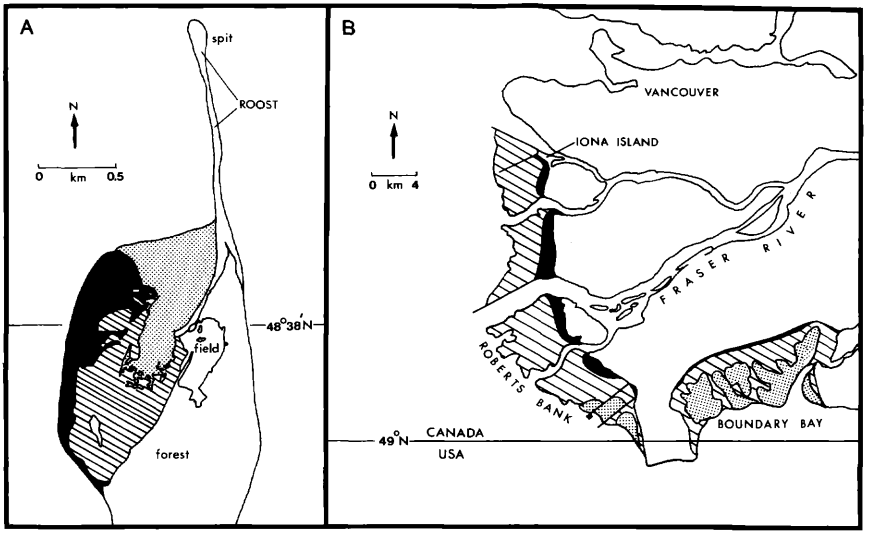

FIGURE 1. Study areas at Sidney Island (A) and Fraser River delta (B) in southwestern British Columbia. Shaded area = marsh, cross hatch = mudflat, and stipple = eelgrass.

followed by juveniles. Catches in 21 June–21 July were exclusively of adults (n = 653). They predominated (90.3%, n = 186) between 22–31 July but were replaced by juveniles (n = 1062) after 31 July. Adult males and females appeared to migrate at slightly different times in spring and autumn (Fig. 2). Males were proportionately more abundant than females in early spring whereas females predominated in late spring. The opposite occurred in autumn.

In contrast, the sex ratio of juveniles remained fairly constant during their southward migration in August and September (Fig. 3). More data on early arriving juveniles are needed to conclude whether females predominate in late July (Fig. 3).

Males and females were significantly heavier in spring than in autumn and females were significantly heavier than males in spring and autumn (Table 1). However, the sexes are dimorphic in body size. For example, females' wings were 1.04 times longer than those of males and that difference is significant (female: $\bar{x}$ = 100.1 mm, SD = 2.8, n = 100; male: $\bar{x}$ = 96.2 mm, SD = 3.2, n = 100, t = 15.9, $P < 0.01$). Nevertheless, male body weights remained significantly (t = 15.9, df = 198, $P < 0.01$) lighter than female weights when male weights were standardized by multiplying them by that difference (1.04). In addition, juvenile females outweighed juvenile males (Table 2) but did not differ significantly from adult females and males in autumn, respectively.

Of 86 color-marked adults at Sidney Island, 35 (40.7%) disappeared following banding, 25 (29.1%) were seen one day after banding, 8 (9.3%) were seen 2 d later, 6 (7.0%) 3 d later, 11 (12.8%) 4 d afterwards, and

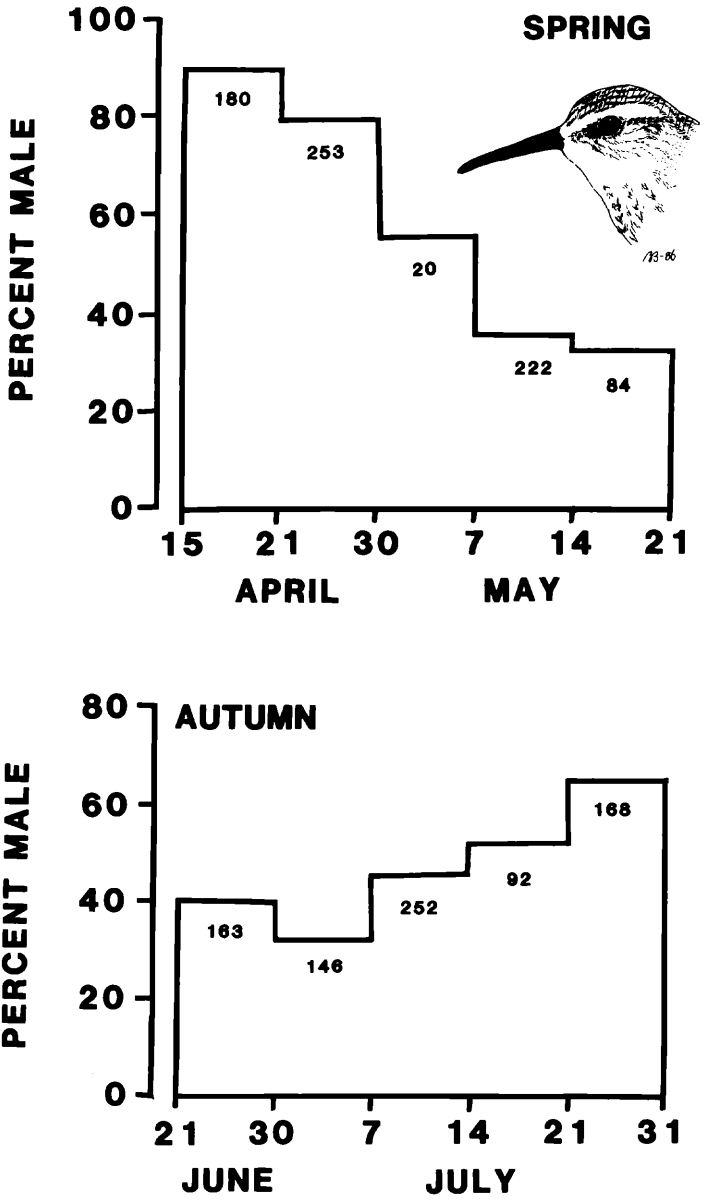

FIGURE 2. Sex ratio of adult Western Sandpipers during spring and autumn migrations on the southeast coast of British Columbia. Numbers in the bars are sample sizes.

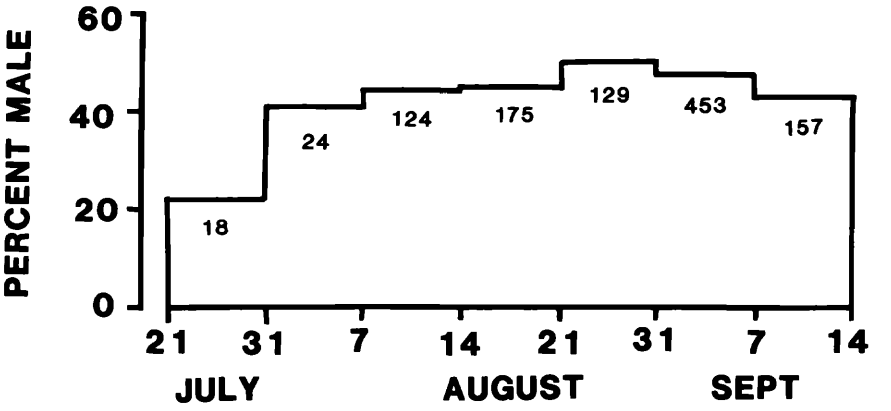

FIGURE 3. Sex ratio of juvenile Western Sandpipers on the south coast of British Columbia. Numbers in the bars are sample sizes.

1 (1.1%) 5 d later. Using the method of maximum likelihood (Seber 1974) we derived (Appendix A), estimators for p, the probability that a bird present the current day will be present the next, and L, the expected length of stay. Our results are $p = 0.410$ (SE = 0.022) and $L = 1.17$ (approximate 95% confidence interval is [1.04, 1.34]). The above analysis assumes that p is constant regardless how long the bird was already on the island or what date it arrived and that all banded birds present in

TABLE 1. Weights of adult Western Sandpipers during spring and autumn migration on the south coast of British Columbia.

Period	Male			Female		
	$\bar{x}$	SD	n	$\bar{x}$	SD	n
Spring						
April 17–26	27.0	1.1	235	30.2	2.5	34
April 27–May 10	27.9	1.2	138	29.6	1.3	74
May 12–16	28.1	1.4	81	31.6	1.7	175
Mean	27.5[a]	1.2	454	30.9[b]	1.7	283
Autumn						
June 25–30	23.9	1.3	65	25.7	1.5	98
July 1–7	24.2	1.0	47	27.9	1.3	99
8–14	24.3	1.5	114	26.6	1.7	138
15–21	25.8	1.6	48	28.0	1.2	44
22–31	24.3	0.7	108	26.9	0.5	60
Mean	24.4[a]	1.2	382	26.9[c]	1.4	439

[a] Males and females were significantly ($P < 0.01$) heavier in spring than in autumn ($t = 38.8$, df = 834).

[b] Females were significantly ($P < 0.01$) heavier than males ($t = 18.6$, df = 735).

[c] Females were significantly ($P < 0.01$) heavier than males ($t = 16.7$, df = 819).

TABLE 2. Weights of juvenile Western Sandpipers on the south coast of British Columbia.

Period	Male			Female		
	$\bar{x}$	SD	n	$\bar{x}$	SD	n
July 21–31	27.0	1.3	4	26.6	0.8	14
August 1–7	25.3	1.4	10	27.4	2.0	14
8–14	24.7	2.1	51	29.1	2.0	63
15–21	25.7	1.6	79	27.3	1.8	96
22–31	25.7	2.0	66	28.1	1.9	63
September 1–7	26.1	1.6	218	28.3	1.8	235
8–14	26.8	1.7	68	29.8	1.8	89
Overall mean	25.6[a]	1.7	497	28.2[a]	1.8	574

[a] Females significantly ($P < 0.01$) heavier than males ($t = 32.5$, df = 1068).

the study area will be seen and counted. Our sample included birds captured throughout the period of adult migration. The birds were generally quite visible. However, we may have missed some because they were temporarily absent from the lagoon and spit. Thus our estimate of L may be conservative. Since we saw no marked birds 5 d after banding the actual length of stay lies between 1 and 5 d, probably about 3 d.

DISCUSSION

Males of many species of birds winter at higher latitudes than females (Ketterson and Nolan 1976, 1983; Myers 1981a; Nice 1937) and the Western Sandpiper appears to be no exception (Page et al. 1972). Segregation by sex on the wintering grounds may explain why males arrived ahead of females in southern British Columbia during spring migration. Myers (1981b) showed that among shorebirds the sex that migrated the farthest, usually the female, departed earliest from the breeding grounds. That probably explains why we caught mostly adult females early in autumn migration followed by males late in migration.

There are at least two possible explanations why males and females were heavier in spring than autumn. First, when Western Sandpipers arrived at the Fraser River delta in spring, they had passed several extensive mudflats in the United States where they could feed. However, following their autumn departure from the Copper River delta in Alaska, Western Sandpipers pass very few mudflats along the British Columbia coast before arriving at the Fraser River delta. That flight through poor habitat might deplete their reserves more than on their northward journey. Although several studies have shown that several shorebird species accumulate fat in relation to the distance of the subsequent flight (McNeil and Burton 1973, McNeil and Cadieux 1972) others have concluded that the amount of fat carried by a bird is a poor predictor of the subsequent length of flights (Lank 1983, Page and Middleton 1972).

A second explanation for weight differences between spring and autumn might result from the energy requirement for breeding and molting.

Many birds lose weight through the breeding season (e.g., Askenmo 1977, Freed 1981, Hussell 1972). In this study, post-breeding female Western Sandpipers lost more weight than males (8.4% vs. 6.5% of spring weight, respectively) some of which might have been due to changes in the ovary, oviduct (Ricklefs 1974) and degeneration of the vascularized portion of the incubation patch (Peterson 1955).

Although the average body weight of all Western Sandpipers, regardless of age, sex, or season, increased as migration proceeded, lighter weight birds might not have migrated ahead of heavier individuals. Early in migration, there is a higher probability of catching a recently arrived sandpiper, with depleted reserves and thus lighter in weight, than toward the end. The difference in weight of early versus late migrants might therefore, represent the average weight gained during the stay on the south coast of British Columbia. McEwan and Whitehead (1984) found that Dunlin (*Calidris alpina*) gained about 11.9% body weight at the Fraser River delta before migrating to Alaska. The 6.5–8.4% increase we found appears reasonable for the smaller Western Sandpiper that makes shorter flights than the Dunlin (Senner 1979). In addition, Morrison (1984) found that the similar-sized Semipalmated Sandpiper gained an average of 0.35 g/d during autumn migration in James Bay. Assuming a similar gain of weight gain in the Western Sandpiper would mean that the average male stayed about 1 d and the average female about 3 d. Our estimate of length of stay was 1–3 d, but we don't have enough data to conclude whether females stayed longer than males.

Adult Western Sandpipers arrived at Sidney Island and the Fraser River delta in late June and departed in late July which suggests that they spent similar amounts of time at the two sites. Furthermore, adult Western Sandpipers are seen on the Fraser River delta for about the same number of days in spring and autumn. That suggests that Western Sandpipers migrate in a wave along the south coast of British Columbia at a similar rate in spring and autumn.

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APPENDIX: Estimation of average length of stay

Let

X_o = number of birds banded (all are banded during a single day),
X_i = number of banded birds present i days after banding ($i = 1, 2, \ldots, k$),
p = probability that a bird present one day will be present the next.

Using the method of maximum likelihood (Seber 1974) with the assumptions that

1) p is constant over the season,
2) p does not depend on the time the bird has already been on the colony,
3) all the birds can be seen during observation, and
4) once a bird leaves the spit, it does not return;

then an estimator for p is

$$\hat{p} = \frac{S_k}{S_k + X_o - X_k}$$

and for the variance of p is

$$\text{var } \hat{p} = \frac{S_k(X_o - X_k)}{(S_k + X_o - X_k)^3}$$

where

$$S_k = \sum_{i=1}^{k} X_k$$

The expected length of stay, L, is estimated by

$$\hat{L} = \frac{\hat{p}}{(1 - \hat{p})^2}$$

If assumptions 3 and 4 are true then we must have $X_i \geq X_{i+1}$ for all i. If either is violated, then $\hat{p}$ and $\hat{L}$ will be biased and tend to underestimate p and L respectively. If $X_i < X_{i+1}$ for some i, we may set $X_i = X_{i+1}$. This will reduce the bias but will produce an underestimate of the standard error. Approximate 95% confidence limits for L are obtained by calculating the 95% confidence limits for $\hat{p}$ ($\hat{p} \pm 2$ SE) and substituting these into the equation for L. The assumption that p is constant will allow us to combine two or more sets of banding and sighting data.