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NON-MIGRATORY MOVEMENTS OF DUNLINS ON THEIR CALIFORNIA WINTERING GROUNDS

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ABSTRACT.—In 1991–1992, we tracked 150 marked Dunlins (*Calidris alpina*) from two central California coastal sites to ascertain if they made winter-time movements to inland areas and examined census data from these and other coastal sites to document the possible extent and frequency of these movements. Between December 1991 and January 1992, Dunlin numbers at four central California coastal sites decreased by 44–84% during periods of heavy rain. Subsequently, six or seven of the marked Dunlins from one of these sites were located inland, up to 140 km away. The sudden disappearance of more than 40% of the wintering Dunlins from this coastal area in 10 of 21 years suggests that such movements may be fairly frequent. Median (October–March) numbers of Dunlins at this site during the 21 years were negatively correlated with local rainfall, suggesting a relationship between winter storm activity and the level of use of coastal sites. It remains to be determined whether deteriorating conditions in coastal wetlands or the increased availability of inland habitats related to winter storms is responsible for reducing Dunlin winter-time use of coastal sites. *Received 28 March 1994, accepted 6 Sept. 1994.*

Although much has been learned about the distribution and abundance of shorebirds in the Pacific Flyway in recent years (Page et al. 1992), how different sectors of the flyway are linked together remains poorly understood, particularly for wintering shorebirds. Small scale movements of shorebirds are known to occur in winter, often in response to specific weather conditions. Eurasian Curlews (*Numenius arquata*) move between coastal mudflats and agricultural fields up to 30 km away, depending on weather (Bainbridge and Minton 1978, Townshend 1981) and perhaps moon phase (Hale 1980). Freezing weather in Europe forces Lapwings (*Vanellus vanellus*) and Greater Golden-Plovers (*Pluvialis apricaria*) from inland fields to coastal estuaries (Hale 1980). Local movements of 2–10 km between estuaries and fields in response to rain, snow, or ice have been documented for Redshanks (*Tringa totanus*), Dunlins (*Calidris alpina*), Black-bellied Plovers (*Pluvialis squatarola*), Killdeers (*Charadrius vociferus*), Marbled Godwits (*Limosa fedoa*), Least Sandpipers (*Calidris minutilla*), Western Sandpipers (*C. mauri*), Greater Yellowlegs (*Tringa melanoleuca*), and dowitchers (*Limnodromus* spp.) (Goss-Custard 1969, Hoff 1979, Page et al. 1979, Shuford et al. 1989, Ruiz et al. 1989).

Movements of greater distances have also been reported for some shore-

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birds. Wintering Red-necked Stints (*Calidris ruficollis*) respond to newly-flooded inland habitat by moving from the coast to the interior of eastern Australia; in contrast, droughts force Red-kneed Dotterels (*Erythrogonys cinctus*), Black-winged Stilts (*Himantopus himantopus*), Banded Stilts (*Cladorhynchus leucocephalus*) and Red-necked Avocets (*Recurvirostra novaehollandiae*) from interior breeding sites to coastal wetlands (Lane 1987). In South Africa, Greenshanks (*Tringa nebularia*) move to the coast after summer rains inundate their interior sites (Tree 1979).

It has been speculated that wintering Dunlins in California move inland from coastal sites in response to storms and high tides (Strauch 1967, Page 1974, Page et al. 1979, Ruiz et al. 1989, Shuford et al. 1989), but this has not been confirmed through direct observations. From December 1991 to March 1992, we tracked marked Dunlins from two central California coastal sites for evidence of movements inland during winter. We also examined census data from four coastal sites to document the possible extent and frequency of these movements.

STUDY AREAS AND METHODS

Each year, between October and March, up to 5000 Dunlins reside at the 587-ha Bolinas Lagoon, Marin County (Shuford et al. 1989), and up to 6000 at the 320-ha Bodega Harbor, Sonoma County, California (Ruiz et al. 1989), about 50 km away (Fig. 1). From 12 December 1991 to 27 January 1992, we trapped 150 Dunlins in mist nets at Bolinas Lagoon and Bodega Harbor. Twenty-five birds were captured at Bodega between 8–16 January, marked ventrally with a solution of picric acid and a green plastic color band was applied on the upper leg. At Bolinas, 51 Dunlins captured from 12 December to 7 January were marked similarly, except for red color bands; 64 additional Dunlin were marked individually with four color bands but not dyed. Another 10 birds, captured at Bolinas from 7–27 January were fitted with 1-g radio transmitters, having a range of approximately 2 km from the ground and 4–7 km from the air. Radio battery life was about seven weeks (Warnock and Warnock 1993).

Bolinas Lagoon was checked for marked birds almost daily from 12 December 1991 to 28 February 1992. We searched Richardson Bay, within central San Francisco Bay (Fig. 1), on 29 dates between 17 January and 25 February after we received reports of dyed birds being present there. Other accessible regions of north and central San Francisco Bay were also checked four times during this period. On 28 February, we searched for the radio signals of marked birds from an aircraft throughout north San Francisco and Suisun bays. On four dates from 13 February to 6 March, parts of the Sacramento Valley were monitored for radio-tagged birds by an observer in an automobile and, on 20 and 26 February, aerial searches for radio-tagged birds were conducted in the Sacramento-San Joaquin River Delta and the Sacramento Valley north to the Sutter Buttes (Fig. 1). On 27 February, we checked for dyed and radio-tagged Dunlins in many of the wetlands accessible by road in the northern San Joaquin Valley (Fig. 1) and scanned for radio-tagged birds from a 20-m tower located near the center of the upper San Joaquin Valley. Newsletter notices were also used to alert bird watchers and duck hunters to look for dyed Dunlins.

To examine the extent and frequency of large scale departures of Dunlins from the coast, we examined shorebird censuses taken weekly to monthly from October through March at

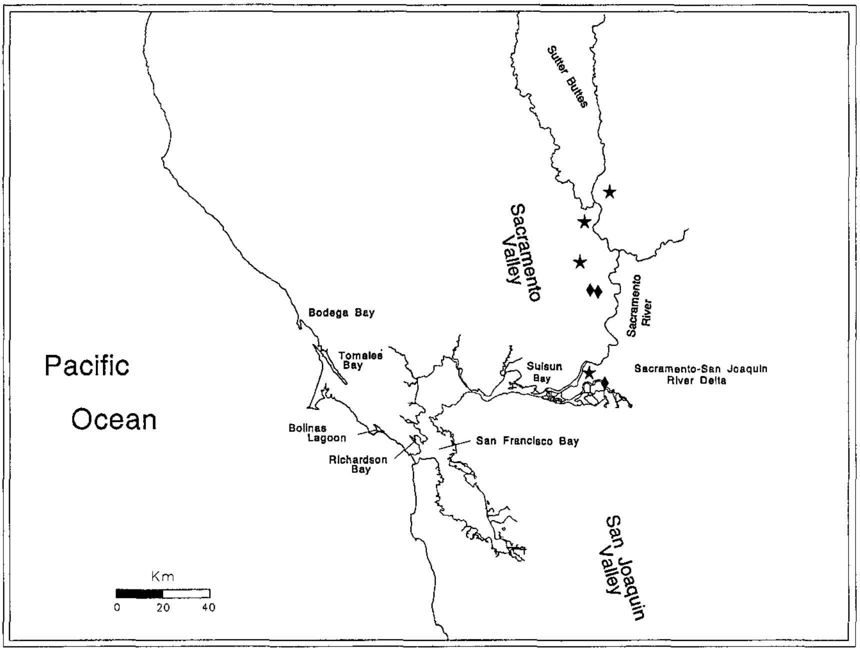

FIG. 1. Map showing study sites as well as resighting locations away from Bolinas Lagoon of radio-tagged (★) and dyed/color-banded (♦) Dunlin.

Bolinas Lagoon between 1971 and 1992, and monthly at Bodega Harbor, Tomales Bay, and San Francisco Bay (16 sites) between October 1991 and March 1992. All counts at Bolinas Lagoon were accomplished by three teams of observers covering their respective areas simultaneously; censuses were generally timed so that the rising tide would be about 1.4 m above mean low water by mid-count. Marked departures of Dunlins at Bolinas Lagoon were defined as any decline of 40% or more between mean monthly numbers that was not counteracted by a notable increase in the following months.

We also examined the residency patterns of 75 individually marked Dunlins that were present at Bolinas Lagoon in at least three of the four years from 1984–1987. The length of stay of these individuals was available from extensive observations ($\bar{x}$ = 89.5 days of sightings, range 73–111 days from 30 Sept.–15 April) during four consecutive seasons. Other years could not be used because we lacked complete coverage over the period that Dunlins were present.

To test whether Dunlin numbers at Bolinas Lagoon varied with amount of local rainfall, we regressed the natural log-transformed median number of Dunlins at Bolinas Lagoon between 24 Oct. and 31 Dec. against the mean amount of rainfall at Bolinas from October through December for the 21 year period from 1971 to 1991.

RESULTS

Dunlins dyed at Bolinas Lagoon in 1991 were first located 14 km away in San Francisco Bay (at Richardson Bay) on 28 December 1991. Subsequently, up to five dyed Dunlins were seen in Richardson Bay through January. Nine of the 10 radio-tagged Dunlins also travelled at least once to Richardson Bay then back to Bolinas (median number of moves = 3, range = 1–8 moves). Seven moved from Bolinas to Richardson Bay and then back to Bolinas within one 12-hr period. On three occasions, birds were recorded at Bolinas and then in Richardson Bay less than one hour later (range = 38–57 min.). No dyed Dunlins from Bodega were sighted in San Francisco Bay or elsewhere.

Four radio-tagged Dunlins were located in the Sacramento-San Joaquin River Delta or the Sacramento Valley, up to 140 km from Bolinas (Fig. 1). One, last seen in Bolinas on 10 February, was found in the delta on three dates between 18–26 February. The other three, last seen at Bolinas or Richardson Bay between 10–14 February, were located in the Sacramento Valley on both 20 and 26 February. None of the four birds was recorded at Bolinas Lagoon or Richardson Bay later in the spring of 1992, but two returned to Bolinas in the fall of 1992. One color-banded Dunlin from Bolinas was sighted in the delta on 25 February, and two dyed Dunlins (one positively from Bolinas) were seen in the Sacramento Valley on 22 and 25 February (Fig. 1). No marked Dunlins were found in the San Joaquin Valley.

Dunlin numbers at Bolinas Lagoon and three other central California coastal sites fell steeply between December 1991 and January 1992 (Fig. 2). Numbers declined by 66% at Bolinas Lagoon, 84% at Bodega Harbor, 64% at Tomales Bay, and 44% at San Francisco Bay. Numbers at Bolinas declined by a further 89% from January to February 1992 (Table 1).

Winter-time departures of 40% or more of the Dunlin from Bolinas Lagoon were noted on 13 occasions in 10 of 21 seasons between 1971–1991 (Table 1). The declines occurred from November to December once, December to January five times, and January to February seven times (Table 1). There were no marked departures during 10 years, and in 1984, numbers fell by over 50% between November and December but subsequently rose again. The average number of Dunlin in the month prior to departures ranged from 1100 to 4821 birds ($\bar{x}$ = 2693, SD = 2693, N = 10). The mean November–February numbers (each month given equal weighting) during the 10 years without marked departures ranged from 1041 to 4306 birds ($\bar{x}$ = 2327, SD = 989).

Individually-marked Dunlins differed in their residency patterns at Bolinas Lagoon through the four years that were examined. Thirty-nine percent (N = 75) that consistently arrived in the fall and departed in the spring did not abandon their coastal wintering site during any of three periods of large scale departures at Bolinas Lagoon. In contrast, 26% consistently disappeared during departure periods and 9% left during two

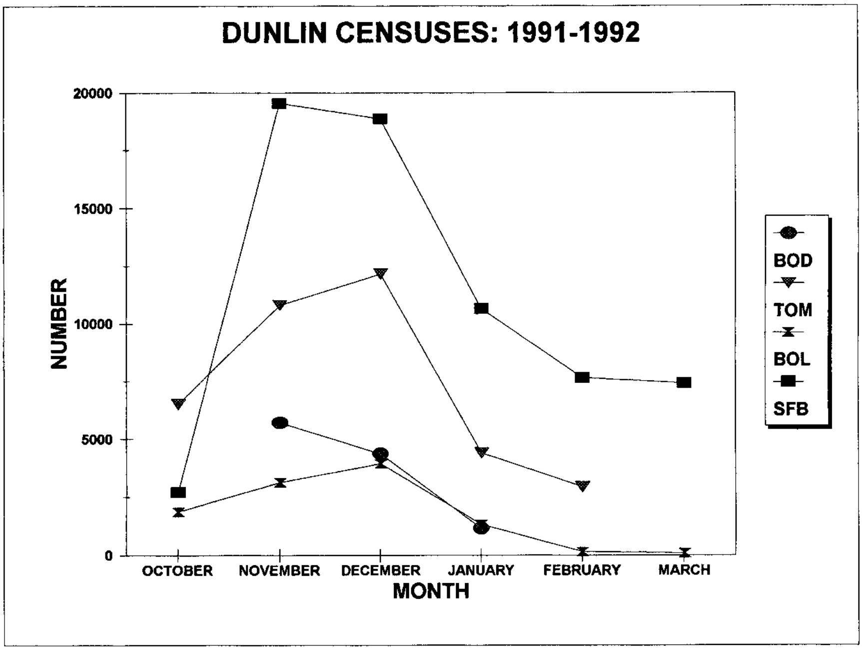

FIG. 2. Numbers of Dunlins counted in monthly censuses at Bodega Bay (BOD), Tomales Bay (TOM), Bolinas Lagoon (BOL), and San Francisco Bay (SFB) in 1991–1992.

but remained through one departure period. Of the remaining birds, 7% consistently arrived and departed prior to departure periods and 19% had patterns that were ambiguous with regard to the departures.

Over 21 years, median yearly (October–March) numbers of Dunlins at Bolinas Lagoon were significantly negatively correlated with local fall rainfall ($r^2 = 0.66$, $P < 0.001$).

DISCUSSION

This study confirms that some Dunlins in central California move inland from the coast during some winters. The rapid disappearance of more than 40% of the wintering Dunlins from Bolinas Lagoon in 10 of 21 years suggests that such movements may be fairly frequent. Abandonment of coastal wetlands for inland habitats is probably not restricted to Bolinas Lagoon or the central California coast, since there was a winter decline in the numbers of Dunlins at three other wetlands on the central coast in 1991–1992; Mark Colwell (pers. comm.) reported the departure of Dunlins from Humboldt Bay on the north coast of California during the same period.

TABLE 1
MEAN MONTHLY NUMBERS OF DUNLIN AT BOLINAS LAGOON DURING 21 SEASONS

	October	November	December	January	February	March
1971	2502	3666	3124	1718 (45%)[a]	1339	1089
1972	2092	1912	1705	887 (48%)	243 (83%)	289
1973	1327	1353	1004	879	926	862
1974	2019	3837	3092	2513	2019	2035
1975	2763	4581	4295	4237	4110	4060
1976	1812	2394	3058	3795	3446	5084
1977	2236	2211	2067	1455	2186	2614
1978	1092	2641	2148	1974	2724	1816
1979	487	1915	1969	2439	2390	1931
1980	34	2391	3028	2623	2598	1253
1981	278	1797	1388	1246	1581	37
1982	1940	2144	343 (84%)	960	940	725
1983	1892	1185	—	1285	1109	992
1984	1000	900	245	600	1032	1048
1985	1985	1576	1202	1100	587 (47%)	520
1986	2356	1775	2853	2917	1356 (54%)	691
1987	1669	3115	2092	1184 (54%)	987	539
1988	3276	1897	2469	1132 (54%)	680 (40%)	60
1989	2275	3020	2951	3021	1713 (43%)	1823
1990	4338	3734	5845	4821	755 (84%)	34
1991	1869	3131	3931	1321 (66%)	151 (89%)	95

[a] (% N) = Percent decline of Dunlin population from previous month; only declines ≥40% shown.

The first documented winter exodus of large numbers of Dunlins from Bolinas Lagoon in 1972–1973 coincided with a period of heavy rainfall (Page 1974, Page et al. 1979, Shuford et al. 1989). The 1991–1992 departure, which involved radio-tagged and dyed birds, also occurred during a period of heavy rainfall. Observations such as these and a negative correlation between winter numbers at Bolinas and amount of local rainfall suggest movement inland from the coast may be related to winter storms, but the nature of this relationship is not clear. The negative correlation between rainfall and numbers of wintering Dunlin could also reflect, in part, differences in the number of birds settling at Bolinas Lagoon relative to amount of rainfall.

Winter storms may cause feeding conditions for Dunlins to deteriorate in coastal wetlands. Winter months can be harsh for shorebirds at Bolinas Lagoon due to a general decrease in invertebrate prey items, increased numbers of potential competitors, and decreased daylight exposure of tidal flats (Stenzel et al. 1983). Winter storms cause a further deterioration of feeding conditions. Associated with the storms are increased runoff, strong southerly winds, and low air pressure, all of which cause water levels to remain higher than normal and result in less feeding time for Dunlins. Rain is also known to affect negatively feeding and capture rates of some shorebirds in tidal areas (Goss-Custard 1970, 1984; Pienkowski 1981). At Bolinas Lagoon, Dunlins have been observed to switch from feeding on invertebrates to small fish (*Clevelandia ios*) during heavy rainfall (Warnock 1989), but the cost or benefit of this change is unknown.

Dunlins may also abandon the coast in response to increased availability of inland habitat in the Sacramento Valley where 162,000 ha of agricultural lands are subject to flooding from river overflows and local runoff during wet winters and 32,000 ha of harvested rice fields are intentionally flooded for waterfowl hunting during fall and winter (Heitmeyer et al. 1989). In the San Joaquin Valley, about 50,000 ha of wetlands are seasonally flooded during winter rains (Heitmeyer et al. 1989). Thus several interacting factors may cause wintering Dunlins to abandon Bolinas Lagoon for the interior or cause them not to settle there at all.

The function of the local Dunlin movements between Bolinas Lagoon and San Francisco Bay is unclear. The 50-min difference in high tides seems too short to provide much opportunity for Dunlin to exploit the tidal time lag between sites. Differences in food resources could account for the local movements as has been suggested for Dunlins within San Francisco Bay (Holway 1990). Return movements back to Bolinas Lagoon could be prompted by heavy human disturbances of the limited roost sites in Richardson Bay (Warnock, pers. obs.). The flights could also be scouting trips to assess conditions outside of Bolinas Lagoon. All four radio-tagged Dunlins, found in the Sacramento Valley, made at least one trip to San Francisco Bay within five days of departing from the Bay area.

Currently, little is known about why some shorebirds remain at one wintering site throughout a season while others depart. Most Grey (Black-bellied) Plovers in England spend the entire winter at one site every year, but a smaller number show up each year and then move on (Townshend 1985). The predominate pattern for Dunlins at Bolinas was to stay all winter, although some consistently participated in large scale departures. Townshend (1981) found that short-billed, male Eurasian Curlews were more likely to leave the coast and feed in fields than longer-billed females. He suggested that during cold weather these males were unable to reach marine invertebrates that burrowed deeper to escape the cold. An analogous situation might occur with Dunlins, since all of the known-sex birds participating in large scale movements in 1985, 1986 and 1987 were males, which average shorter bill lengths than females.

We have demonstrated that Dunlins in California will move from coastal to inland sites in winter. We have also shown that individual Dunlins have differing but often consistent patterns of seasonal movements. Research elucidating the mechanisms controlling these movements should lead to a better understanding of the interplay of coastal and interior wetlands in providing habitat for wintering shorebirds and lead to a more comprehensive conservation strategy for west coast shorebirds.

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