# Spring Migration of Dunlin and Dowitchers Along the Pacific Flyway 2001

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## Final Report: 2001

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**ABSTRACT**

We successfully tracked migrating individuals of Dunlin, Long-billed and Short-billed Dowitcher on the Pacific Coast from San Francisco Bay to the Yukon-Kuskokwim Delta in western Alaska. We radiotagged 91 shorebirds including 52 at San Francisco Bay (all 3 species), and 39 at Grays Harbor (Dunlin and Short-billed Dowitcher only). Nine birds were excluded from our analyses due to predation (2 birds), lost and malfunctioning radios (2 birds) and overlap with moose or goose radios at monitoring sites (5 birds). Of the 82 remaining birds, our detection rate of birds past their banding site was 88%, and comparable to our previous work on Western Sandpipers. We recorded 120 relocations of radiomarked birds past their banding sites. Birds were detected at 10 of the 11 sites north of San Francisco that conducted monitoring efforts on a regular basis. The Copper River Delta was the single most important stopover site for Dunlin and dowitchers where we located 76% of the 82 possible marked birds. Our next most important site was the Willipa Bay/Grays Harbor complex of wetlands in Washington. Our recoveries past the Copper River Delta are sporadic. We located 7 Dunlin at the Yukon-Kuskokwim Delta. Along the western Alaska Peninsula and the north side of Bristol Bay, AK, another breeding area for shorebirds, we recovered 12 birds of which 10 were dowitchers, 90% Short-billed Dowitchers. Dunlin and dowitcher mean length of stays past banding sites ranged from 1-5 days. Length of stay by Dunlin and dowitchers at the Copper River Delta was negatively related to arrival date. This study, combined with our previous work on Western Sandpipers, reveals the complexity of migration strategies used within and among shorebird species along the Pacific Flyway. Our project was showcased on the list serve and web site of the Sister Shorebird Schools, an environmental education program sponsored by the US Fish and Wildlife Service.

## INTRODUCTION

As a group, shorebirds of North America have experienced declines in populations (Morrison 2001, Morrison and Hicklin 2001). Reasons for the declines are unknown but habitat modification has figured prominently as a potential cause. As increasing amounts of habitats have been altered and destroyed, it is becoming critical for wildlife managers to understand how birds use habitats throughout their range. At present, we have little information on how individual birds use migration areas, especially during migration periods. Understanding the stopover ecology of shorebirds is also a critical component of understanding the complete life cycle of these birds (Skagen 1997). Conservation of migratory stopover sites relies not only on knowing how and when different areas of their migration landscape are used, but also on knowing what influences the use of and time spent at different areas of that landscape (Warnock and Bishop 1998).

The migration strategies used by one of the best-studied shorebird species in North America, the Western Sandpiper (*Calidris mauri*), have been well described for the stretch between San Francisco and western Alaska (Iverson et al. 1996, Bishop and Warnock 1998, Warnock and Bishop 1998). Those studies, applying radio telemetry to follow birds, demonstrated that individual Western Sandpipers typically make short flights during their northward migration and use a variety of stopover sites.

Research on shorebird migration is identified as a priority in the United States Shorebird Conservation Plan (Brown et al. 2001). Three-medium sized shorebirds that migrate along Pacific coastal waters are Dunlin (*Calidris alpina*), Long- billed Dowitcher (*Limnodromus scolopaceus*), and Short-billed Dowitcher (*Limnodromus griseus caurinus*). Dunlin are the second most numerous sandpiper on the Pacific Flyway with a population estimated at 450,000-600,000 birds (Page and Gill 1994). Long-billed Dowitcher are common along the Pacific Flyway, although little is known about their population status (Takekawa and Warnock 2000). Shuford et al. (1998) recorded greater than 115,000 dowitchers (most being Long-billed Dowitcher) during winter and spring counts in California's Central Valley. The Short-billed Dowitcher *caurinus* subspecies population is estimated at 150,000 birds and has been rated nationally of high concern because of suspected population declines (Brown et al. 2001). At present, little is known about the northward migration strategy used by Pacific Coast Dunlin (Warnock and Gill 1996), and nothing is known about how individual dowitchers migrate along the Pacific Flyway (Takekawa and Warnock 2000). In light of this, we set out to learn more about the migration strategies of these three shorebird species along the Pacific Flyway.

We had the following objectives:

1. Determine the spring, coastal migration routes of Dunlin and dowitchers between San Francisco Bay, California and western Alaska.
2. Estimate length of stay of these birds at banding and stopover areas.
3. Evaluate the interrelationships of stopover sites during spring.
4. Compare these results with what is known about Western Sandpiper migration along the Pacific coast.
5. Improve public awareness of shorebird conservation by featuring the project on the USFWS Sister Shorebird School web site.

## METHODS

We captured shorebirds at two coastal areas: San Francisco Bay, California and Grays Harbor, Washington. Between 18 -25 April, shorebirds were trapped at San Francisco Bay on the north side of the Bay at the American Canyon Landfill in Vallejo. Birds were trapped during the day in a diked, muted-tidal wetland using rocket-nets. At Grays Harbor, we trapped birds during daylight hours using mist nets set on tidal flats with shorebird decoys placed nearby. We weighed each bird captured to the nearest 1-g. Other measurements (mm) taken included exposed culmen, flattened wing, and tarsus. All birds were marked with a metal U. S. Fish and Wildlife Service (USFWS) band on the upper right leg. A total of 91 shorebirds (Table 1) had 1.25 g radio transmitters (Holohil Systems Ltd., Woodlawn, Ontario, Canada) glued to their lower backs using methods described by Warnock and Warnock (1993). The radio transmitter weight represented approximately 2% of a Dunlin's and less than 1% of a dowitcher's body mass.

Table 1. Number of shorebirds captured and marked with radio transmitters at San Francisco Bay, CA and Grays Harbor, WA, spring 2001. Banding dates are included.

| | San Francisco Bay | Grays Harbor |
|---|---|---|
| Dunlin | 12 | 18 |
| Short-billed Dowitcher | 21 | 21 |
| Long-billed Dowitcher | 19 | 0 |
| Banding Dates | 17-22 Apr, 25 Apr | 23-25 Apr, 5 May |

We compared two brands of glues for attaching radio transmitters, because the bird epoxy we have used for the past 10 years (Epoxy #332, Titan Corporation) is being discontinued. We alternated affixing transmitters to the birds using Titan Corporation epoxy or cyanoacrylate glue (QuickTite™super glue, Loctite Corp.©, Rocky Hill CT) in the order birds were caught. Radios were designed to 56 days. Maximum retention time of a glued radio was previously found to be ≥49 days before dropping off (Warnock and Takekawa 1996).

Detectability of radios varied by method: range was < 2 km from the ground using a hand-held antenna, 2-4 km from the ground using a truck mounted antenna (3-7 km from a 120 m hill), and sometimes >10 km from an airplane. We placed radio transmitters at all major stopover areas to test aerial telemetry equipment.

From San Francisco Bay up to and including the Copper River Delta, we regularly (>10 d monitoring) monitored 10 potential stopover sites for our radio-marked birds (Table 2, Fig. 1). We also had single day surveys of the Summer Lake area in south-central Oregon, and the coastal section between Newport Bay, OR and the Columbia River. West and north of the Copper River Delta, at potential breeding areas of Dunlin and dowitchers, we flew transects for radio-marked birds in six areas from the Alaska Peninsula north to the Brooks Range (Table 2, Fig. 1). On surveys of the Seward Peninsula and north, we only listened for Long-billed Dowitchers. Trucks equipped with dual-Yagi, null-peak telemetry systems were used at San Francisco Bay. Hand-held, 3-element Yagi antennas were used at remaining ground monitoring sites. Aerial monitoring was conducted from planes equipped with exterior, dual-mounted antennas. Daily flights occurred at Stikine River Delta, Yakutat

Forelands, and Copper River Delta, Alaska with flights conducted less often at banding and other monitoring sites (Table 2).

Table 2. Telemetry methods (A = aerial, G = ground) and field effort (days) for monitoring migratory movements of Dunlin and Dowitchers, April-May 2001. Surveys = number of surveys conducted.

| Location | Method | Surveys | Monitoring Dates |
|---|---|---|---|
| California | | | |
| San Francisco Bay | G | 13 | Apr 20-24, 26,29 May 1,2,4,8,11-12 |
| | A | 7 | Apr 25, 27,30, May 3,5,7,9 |
| Humboldt Bay | G | 24 | Apr 21-May 14 |
| | A | 5 | Apr 29, May 1,3,6,9 |
| Oregon | | | |
| Coos Bay | G | 17 | Apr 22-28, 30, May 1-6,8,10,12 |
| Newport-lower Columbia River | A | 1 | Apr 25 |
| Summer Lake Wildlife Area | G | 1 | May 3 |
| Washington | | | |
| Grays Harbor | G | 12 | Apr 24-26,28-29, May 1,10,12,14-16,18 |
| | A | 11 | Apr 25, May 1, 3-9,11,13 |
| Willapa Bay | G | 2 | Apr 27, May 2 |
| | A | 10 | Apr 25, May 1, 4-9, 11,13 |
| British Columbia | | | |
| Tofino Beach | G | 16 | May 5-6,9-22 |
| Alaska | | | |
| Stikine River Delta | G | 1 | May 1 |
| | A | 23 | Apr 23-30, May 2, 4-12,14-18 |
| Juneau Wetlands | G | 32 | Apr 23-26, 28-30, May 1-25 |
| Yakutat Forelands | G | 3 | May 2,5,21 |
| (Dry Bay-Yakutat) | A | 22 | Apr 26, 28-30, May 1, 3,6-20, 22 |
| Copper River Delta | A | 27 | Apr 27-30, May 1, 3-4, 6-20, 22-26 |
| Bristol Bay | | | |
| Kvichak Bay & E. Nushagak Bay (Egegik- Clarks Point) | A | 13 | Apr 26,30, May 1, 4,6,8, 15, 16, 18, 20, 23, 25, 29 |
| W. Alaska Peninsula | | | |
| Egegik-Pt. Heiden/Ilnik | A | 12 | Apr 26,30, May 1,4,6,8,11,15-16,18,20,23,25,29 |
| Cold Bay/Izembek Lagoon | A | 3 | May 1,2,4 |
| E. Alaska Peninsula | | | |
| Puale Bay-Cold Bay | A | 1 | May 4 |
| Yukon-Kuskokwim Delta | A | 5 | May 16, 17, 21, 24, Jun 1 |
| Seward Penin./Brooks Range | A | 5 | May 27, 29-31 |

Monitoring began north of banding sites as soon as radio-marked birds were suspected of departing. Flights were conducted at altitudes of 300-1500m, with timing of flights varying by area. When a bird was located at a site, we monitored its presence until it had not been detected for at least 2 days, or the bird had been relocated at another site. All monitoring at a site ceased when either all radio-marked birds had departed, or when minimal migratory activity was observed.

We assumed there was no difference in the probability of detection by method (ground or air), and that all radio-marked birds at a banding or monitoring site were detected on a given day. We defined relocations as the number of monitoring sites a bird was detected and migration time as the interval (full day increments) between successive sites that a bird remained undetected. Length of stay (LOS) for each site was the number of days from first to the last detection. We assumed a detected bird remained on a site the entire day, (i.e. LOS $\geq$ 1 day), and it remained on site from the first to last detection day. For birds arriving or departing on days we were unable to monitor (usually because of weather, Table 2), we estimated the arrival or departure date by taking the midpoint between dates we monitored.

Of the 91 radio-marked birds, we excluded 4 birds from all analyses. Two birds were Long-billed Dowitcher banded at San Francisco Bay including one depredated by a Red-tailed Hawk (*Buteo jamaicensis*), and one whose transmitter was found with feathers attached on a mudflat about a week after being banded. At Grays Harbor, one transmitter on a Short-billed Dowitcher appears to have malfunctioned and one Dunlin either was depredated or lost its transmitter. In addition, four radio frequencies coincided with radio-collared moose at the Copper River Delta, and one radio frequency coincided with a Greater White-fronted Goose (*Anser albifrons*) causing premature cessation of monitoring for four Short-billed Dowitchers banded at Grays Harbor and one Long-billed Dowitcher banded at San Francisco Bay. We excluded these 5 birds from all analyses except length of stay and timing of departure from banding sites, unless otherwise noted.

Except where indicated otherwise, we combined monitoring sites into 11 areas for our analyses. We used the following abbreviations for banding and monitoring areas: *California* - SF = San Francisco Bay, HB = Humboldt Bay; *Washington* - WB = Willipa Bay, GH = Grays Harbor; *British Columbia* – TB = Tofino Beach; *Alaska* - SR = Stikine River Delta, JU = Juneau wetlands, YF = Yakutat Forelands, CR = Copper River Delta, BB = Bristol Bay Clark's Point to Egegik, and W. Alaska Peninsula from Egegik-Pt. Heiden/Ilnik, and YK = Yukon-Kuskokwim Delta (Scammon Bay to w. Kuskokwim Bay, east to Bethel).

For analyses, dates were converted into Julian dates (JD) so that 1 January = JD 1, 2 January = JD 2, etc. Statistical analyses were performed using STATA (Computing Resource Center, Santa Monica CA 1999). We tested for normality using the Shapiro-Wilk test and used a square-root transformation for length of stay at banding and stopover sites. Significance was determined if $P \leq 0.05$.

## RESULTS

*Banding*

Culmen measurements of Dunlin did not vary significantly by banding site ($F_{1,28}$ = 1.56, $P$ = 0.22), but mass of birds did vary significantly ($F_{1,28}$ = 5.56, $P$ = 0.03). Dunlin banded at Grays Harbor were heavier than Dunlin banded at San Francisco (Table 3). A similar pattern of significance was found for Short-billed Dowitchers (culmen, $F_{1,40}$ = 1.76,

$P = 0.19$; mass, $F_{1,40} = 6.22$, $P = 0.02$). However, contrary to the Dunlin, Short-billed Dowitchers banded at San Francisco Bay were heavier than those banded at Grays Harbor (Table 3).

Table 3. Measurements of culmen length (mm) and body mass (g) of Dunlin and dowitchers captured for spring 2001 migration study. Banding sites include San Francisco Bay, CA and Grays Harbor, WA.

| | San Francisco | | Grays Harbor | |
|---|---|---|---|---|
| | Culmen | Mass | Culmen | Mass |
| Dunlin | 38.2 ± 2.5 | 47.3 ± 9.9 | 37.2 ± 1.5 | 54.3 ± 3.4 |
| *N* | 18 | 18 | 12 | 12 |
| Short-billed Dowitcher | 58.1 ± 3.6 | 125.2 ± 11.9 | 59.5 ± 3.2 | 117.2 ± 8.7 |
| *n* | 21 | 21 | 21 | 21 |
| Long-billed Dowitcher | 58.9 ± 2.6 | 124.7 ± 10.6 | | |
| *n* | 19 | 19 | | |

*Relocations*

Of the 82 radio-marked birds that we could have detected, we detected 88% ($n = 72$) of them at least one site past their banding site (Table 4). Of the 11 sites that we monitored regularly, radio-marked birds were detected at least once at all sites except Coos Bay Oregon. The Copper River Delta, Alaska was the single most important recovery site with 76% of our 82 radio-marked birds being detected there. If we combine the Willipa Bay and Grays Harbor areas, this was our most important recovery site south of the Copper River Delta, (Table 4). There we detected 50% of San Francisco's radio-marked Dunlin, 43% of the marked Short-billed Dowitchers and 25% of the marked Long-billed Dowitchers. No radio-marked birds were detected during single surveys at Summer Lake, the coast of Oregon, the east side of the Alaska Peninsula, or on the Seward Peninsula.

Table 4. Number of birds radio-marked in Spring 2001 and recovered away from banding site, by species of bird. [*n*] equals the number of birds of a particular shorebird species radio-marked at that site. Subsequent numbers in row are the numbers of birds from that species and banding sites seen in other locations. SF = San Francisco Bay, CA; HB = Humboldt Bay, CA; CB = Coos Bay region, OR; WB = Willipa Bay; GH = Grays Harbor, WA; TO = Tofino Beach, BC; SR = Stikine River, AK; JU = Juneau, AK; YF = Yakutat Forelands, AK; CR = Copper River Delta, AK; BB = Bristol Bay region, AK; YK = Yukon-Kuskokwim Delta region, AK.

| | SF | HB | CB | WB | GH | TO | SR | JU | YF | CR | BB | YK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dunlin | [18] | 0 | 0 | 4 | 5 | 1 | 0 | 0 | 2 | 15 | 2 | 4 |
| | | | | | [11] | 1 | 2 | 0 | 2 | 8 | 0 | 3 |
| Short-billed Dowitcher | [21] | 2 | 0 | 5 | 4 | 0 | 0 | 0 | 1 | 14 | 7 | 0 |
| | | | | | [20][1] | 0 | 0 | 1 | 2 | 12 | 2 | 0 |
| Long-billed Dowitcher | [17][2] | 0 | 0 | 2 | 2 | 0 | 3 | 0 | 0 | 13 | 1 | 0 |

[1]Four birds not included in relocations past banding site due to radio-overlap with animals at other locations.
[2]One bird not included in relocations past banding site due to radio-overlap with animals at other locations.

*Effect of Glue Type*

For radio-marked birds that we were able to track, we found no difference in the mean number of days birds were detected that had transmitters attached with the Titan Corporation epoxy versus the QuickTite superglue ($F_{1,80} = 0.55$, $P = 0.46$; Epoxy, $\bar{x} = 20.1 \pm 7.0$ days, range = 1-39 days, $n = 38$; Superglue, $\bar{x} = 18.9 \pm 6.7$ days, range = 6-34 days, $n = 44$).

*Length of stay at banding sites*

Controlling for the day a bird was banded, length of stay at banding sites varied by species ($F_{1,82} = 3.52$, $P = 0.03$) , but not location ($F_{1,82} = 1.22$, $P = 0.27$), although there was a significant species by location interaction ($F_{1,82} = 9.04$, $P = 0.004$). The model was able to explain significant ($F_{4,82} = 3.66$, $P = 0.009$) but not substantial amounts of variation (adjusted $r^2 = 0.11$) in length of stay at banding sites. Shortest mean length of stays at banding sites were exhibited by Short-billed Dowitchers at Grays Harbor and longest mean length of stays at the banding sites were exhibited by Dunlin at Grays Harbor (Table 5).

Table 5. Mean length of stay (days ± SD, number birds marked) of radio-marked shorebirds at banding sites.

| | San Francisco Bay, CA | | Grays Harbor, WA | |
|---|---|---|---|---|
| | $\bar{x} \pm$ SD | *n* | $\bar{x} \pm$ SD | *N* |
| Dunlin | 8.9 ± 3.5 | 18 | 11.0 ± 3.9 | 11 |
| Short-billed Dowitcher | 10.8 ± 5.6 | 21 | 6.2 ± 4.6 | 20 |
| Long-billed Dowitcher | 7.7 ± 4.3 | 17 | - | |

*Length of stay past the banding site*

We had 120 relocations of radio-marked birds past their banding sites. Due to unexplained radio interference at Humboldt Bay, CA and the Stikine River, AK we were unable to calculate length of stays for birds detected at those sites. Due to incomplete search efforts, we also did not calculate length of stays for birds detected at Tofino Beach, BC, or any sites west and north of the Copper River Delta. Mean length of stays at five other sites we monitored ranged from 1-5 days, depending on the species and banding location (Table 6).

Table 6. Mean length of stays for shorebirds at stopover sites along the Pacific Flyway. WB = Willipa Bay, WA; GH = Grays Harbor, WA; JU = Juneau, AK; YF = Yakutat Forelands, AK; CR = Copper River Delta, AK. Length of stay reported in days ($\bar{x}$ days ± SD, *n*)

| | WB | GH | JU | YF | CR |
|---|---|---|---|---|---|
| Banded at San Francisco | | | | | |
| Dunlin | 1.1 ± 0.3, *4* | 2.2 ± 1.8, *5* | | 1.0 ± 0.0, *2* | 3.8 ± 1.3, *15* |
| Short-billed Dowitcher | 5.1 ± 4.4, *5* | 1.3 ± 0.3, *4* | | 1.0 ± 0.0, *1* | 3.2 ± 2.0, *14* |
| Long-billed Dowitcher | 5.0 ± 0, *2* | 3.0 ± 2.8, *2* | | | 3.1 ± 1.8, *13* |
| Banded at Grays Harbor | | | | | |
| Dunlin | | | | 1.8 ± 0.4, *2* | 2.8 ± 0.9, *8* |
| Short-billed Dowitcher | | | 1.0 ± 0.0, *1* | 2.0 ± 1.4, *2* | 3.8 ± 1.4, *12* |

The mean length of stays for dowitchers stopping at Willipa Bay and Grays Harbor suggests that the sites are used differently. Low sample sizes preclude analyses. For the one site where we had sufficient sample sizes, the Copper River Delta, we did detect significant differences in length of stays for Dunlin banded at San Francisco vs. Dunlin banded at Grays Harbor (ANOVA, $F_{1,22} = 4.54$, $P = 0.045$), but not for Short-billed Dowitcher ($F_{1,25} = 0.82$, $P = 0.37$). Modeling length of stay of all birds detected at the Copper ($n = 62$, Table 7), looking at the effects of banding location, species, a location by species interaction, and controlling for arrival day at the Copper, explained significant amounts of variation (adjusted $r^2 = 0.27$, Table 7). For birds radio-marked at San Francisco Bay and Grays Harbor, length of stay at the Copper River Delta was negatively related to arrival date (SF, adjusted $r^2 = 0.15$, $P = 0.006$, $n = 42$; GH, adjusted $r^2 = 0.62$, $P = 0.0000$, $n = 20$).

Table 7. Linear model of the effects of banding location, and species on the length of stay at the Copper River, AK in May 2001. Species = Dunlin, Short-billed Dowitcher and Long-billed Dowitcher; Banding locations = San Francisco Bay and Grays Harbor. Length of stay was square root transformed.

| Effects | Df | *F* | *P* |
|---|---|---|---|
| Model | 5 | 5.59 | 0.0003 |
| Location | 1 | 0.54 | 0.47 |
| Species | 2 | 1.97 | 0.15 |
| Species * location | 1 | 0.16 | 0.69 |
| Arrival date at Copper | 1 | 21.00 | 0.0000 |

*Public outreach and education*

Our project was featured both on the Sister Shorebird Schools list serve and web site. Sister Shorebird Schools (SSS) is an environmental education program sponsored by the US Fish and Wildlife Service. An overview of our project was provided to SSS list-serve subscribers on 16 April. Subsequently, 6 list-serve updates described the movements of selected Dunlin and dowitchers. List-serve subscribers were able to access a web page that provided more information on the migration progress of our selected radio-marked birds. The Sister Shorebird web site also posted the project under the “What’s New” section. Detailed information on the project including study objectives, methods, schedule, cooperators, study site map, photos, and where and how to contact the principal investigators were provided. As of August 2001, the project continues to be posted on the web site, and all list-serve messages are archived under “Where are they today“.

We estimate that information on our project reached several thousand people. Over 850 users from 36 US states, and 23 countries subscribe to the site, including many school classes. While the list-serve is in English, the web site is featured in English, Spanish, Russian, Japanese, and Portuguese. During May 2001 when our study was being conducted, the web site received over 125,000 hits.

## DISCUSSION

*Sites used in migration*

For the first time, we have been able to successfully track migrating individuals of Dunlin, Long-billed and Short-billed Dowitchers. Our detection rate of birds past their banding site was extremely high (88%), and comparable to our previous work on Western Sandpipers (1995 - 84% recovered, 1996 - 91% recovered; Warnock and Bishop 1998). As with the Western Sandpiper, the Copper River Delta, AK was the single most important stopover site for Dunlin and dowitchers, with 76% of the 82 possible marked birds being located there.

Our next most important site was the Willipa Bay/Grays Harbor complex of wetlands in Washington. Half of the Dunlin we marked at San Francisco Bay and almost half (43%) of the Short-billed Dowitchers were detected there while only 23% of the Long-billed Dowitchers were detected there. With the exception of the Long-billed Dowitcher, these detection rates were higher than what we found for Western Sandpipers in previous years. In 1996, the year of our best survey effort at Grays Harbor and Willipa Bay, we relocated 37% of Western Sandpipers banded at San Francisco Bay (Warnock and Bishop unpubl. data). The low recovery rate of Long-billed Dowitchers at the Willipa Bay/Grays Harbor complex in light of the high recovery rate of those birds at the Copper River Delta (76%) and their low recovery rates elsewhere suggest that these birds are either stopping at smaller sites than what we monitored or are migrating longer distances and bypassing many sites.

It is difficult to evaluate the low recovery rates of birds (< 6%) at Humboldt Bay and the Stikine River Delta, since we had numerous erroneous radio signals at these sites. Part of this problem appeared to be due to interference from airplanes affecting the receivers which we used to listen for birds at those sites; however, at Humboldt Bay we may have also had overlap with other radio-marked animals, in particular, waterfowl. Of interest, is that we had no recoveries from the Oregon Coast despite intensive ground effort in the Bandon Marsh/Coos Bay area where significant concentrations of Dunlin and dowitchers can occur (Nehls 1994, Warnock in press), and a flight up the coast from Newport Bay to the border of Washington. Numbers of shorebirds along the Oregon coast fluctuate greatly among years (PRBO unpubl. data), and 2001 might have been a low use year. We undoubtedly would have had recoveries from the Fraser River Delta, BC, particularly Dunlin (Butler 1994), but unfortunately we did not have coverage there. Additionally, at Tofino, BC we undoubtedly missed birds since we had limited ground efforts there and we began surveying past the peak of migration.

At Juneau, AK, for one day, we detected one Short-billed Dowitcher banded at Grays Harbor. Search efforts there were ground-based and covered a small area, but the site was monitored 30 days. This suggests that relatively few Dunlin and dowitchers used the site in 2001 and stopped only briefly. At the Yakutat Forelands, AK, we relocated 14% of Dunlin we marked, and 5% of the dowitchers, compared to about 18% of the Western Sandpipers banded during our 1995 and 1996 migration study. Andres and Browne (1998) documented a substantial spring migration of Dunlin and Western Sandpipers at Yakutat Forelands.

Our recoveries past the Copper River Delta are sporadic, but they suggest several patterns. Of 82 possible birds, we located 7 of them at the Yukon-Kuskokwim Delta, a site where many shorebirds breed (Gabrielson and Lincoln 1959), including Western Sandpipers from San Francisco and Grays Harbor (Bishop and Warnock 1998). All of the detected birds were Dunlin. Along the western Alaska Peninsula and the north side of Bristol Bay, another major breeding region for shorebirds (Gill et al. 1981), we recovered 12 birds of which 10 were dowitchers, 9 being Short-billed Dowitchers. One of the Dunlin heard in the Bristol Bay region on 15 May was subsequently detected on the Yukon-Kuskokwim Delta on 21 May. Only one Long-billed Dowitcher was detected past the Copper River Delta, at Bristol Bay. It is possible that bird was actually a misidentified Short-billed Dowitcher since these birds are notoriously difficult to separate, but it may have been a Long-billed Dowitcher stopping on its way to more northerly breeding grounds beginning at about Hooper Bay, AK (Takekawa and Warnock 2000). Short-billed Dowitchers have been reported to breed near Goodnews Bay, sympatric with the more northerly breeding range of Long-billed Dowitchers (Pitelka 1950).

*Length of stay at banding sites*

We found significant variation in length of stay of Dunlin and dowitchers among species and between banding sites, but the range of length of stay of these birds was similar to the length of stay observed for Western Sandpipers banded at San Francisco Bay and Grays Harbor (9.1 ± 4.6 days for San Francisco, 8.5 ± 3.7 days for Grays Harbor; Warnock and Bishop 1998). It is intriguing that the length of stay of Dunlin at San Francisco Bay were 20% shorter than their length of stay at Grays Harbor, while for Short-billed Dowitchers, length of stay at San Francisco Bay were 42% longer than their length of stay at Grays Harbor. It is not clear why we see these differences among species between sites but further years of comparisons are warranted to see if these differences are consistent among years.

*Length of stay past banding sites*

Past banding sites, length of stay for Dunlin and dowitchers ranged from 1-5 days. Our greatest length of stay was exhibited by dowitchers stopping at Willapa Bay, and their length of stay was on average 2-4 days longer than for nearby Grays Harbor, suggesting that for dowitchers, these adjacent sites are used differently during the spring migration. Leadbetter Point, and the outer beaches of Willipa Bay are important areas for Dunlin and dowitchers, in particular Short-billed Dowitchers (Widrig 1979). Even though sample sizes are small, length of stay of dowitchers at Willapa Bay suggest that this site serves more as a staging vs. stopover site for dowitchers, where they stop for longer periods of time to accumulate significant amounts of fat and other fuel for migration (Warnock and Bishop 1998). However, this may be a function of small sample size there since two of the Long-billed Dowitchers stayed >8 days while the rest stayed ≤3 days.

For Dunlin on the other hand, as was the case with Western Sandpipers (Warnock and Bishop 1998), turnover was rapid at both areas. Length of stay at Yakutat Forelands was generally less than 2 days, similar to what we observed in Western Sandpipers, indicating birds are resting briefly, foraging quickly, and then departing.

Upon arrival at the Copper River Delta, length of stay for Dunlin and dowitchers increase. On average, Dunlin and dowitchers spend about a day longer at the Copper River Delta than do Western Sandpipers ($\bar{x}$ length of stay = 2.2 ± 1.1 days, Warnock and Bishop 1998). Dunlin banded at San Francisco Bay stayed about one day longer than Dunlin banded at Grays Harbor, but no significant difference by banding location was detected in the Short-billed Dowitcher. For Western Sandpipers, banding location did not significantly affect length of stay at the Copper (Warnock and Bishop 1998).

As with Western Sandpipers, length of stay by Dunlin and dowitchers at the Copper River Delta was negatively related to arrival date, especially for birds radio-marked at Grays Harbor. Farmer and Wiens (1999) in a study of Pectoral Sandpipers (*Calidris melanotos*) migrating through the Central Flyway in the spring showed a similar relationship with birds banded at more northerly sites having shorter lengths of stay the later they were banded in the season. Undoubtedly, this is related to the need for late- arriving shorebirds to get to the breeding grounds in time to breed. Shorebirds migrating towards breeding grounds in the subarctic and Arctic face time constraints, and males probably face tighter constraints than females the closer they get to the breeding grounds, as has been suggested for Western Sandpipers (Warnock and Bishop 1998) and Pectoral Sandpipers (Farmer and Wiens 1999). Eggs laid too early in the season face freezing (Green et al. 1977), while for chicks hatching too late in the short breeding season there is an increased probability of food shortages (Holmes 1972) and, in some years, greater predation (Oring and Lank 1986, Jönsson 1991). However, energetic costs for females may be equally or more important than time considerations because egg production is energetically expensive (MacLean 1969, Blem 1990). Unfortunately, we were unable to look at sex differences in migration strategies because we could not reliably sex our Dunlin and dowitchers due to the great deal of overlap in morphology (Warnock and Gill 1996, Takekawa and Warnock 2000).

*Banding effects on length of stay*

As we demonstrated with Western Sandpipers (Warnock and Bishop 1998), there appears to be a temporary banding effect on length of stay of Dunlin and dowitchers at the site where they are banded. Dunlin radio-marked at Grays Harbor stayed about 5 times longer there than Dunlin that passed through Grays Harbor after being radio-marked at San Francisco Bay (11.0 vs 2.2 days). For Short-billed Dowitchers there was also about a five fold difference (6.2 vs. 1.3 days). These results reiterate the need to factor in banding and handling effects in length of stay studies that are conducted exclusively at the site where the birds are banded.

*Summary*

This study, combined with our previous work on Western Sandpipers, reveals the complexity of migration strategies used within and among shorebird species along the Pacific Flyway. As with Western Sandpipers, Dunlin, Long-billed and Short-billed Dowitchers rely on an interconnected web of wetlands along the Flyway. Different sites serve different functions among shorebirds, although the Copper River Delta in Alaska consistently comes out as an extremely important migration stopover site for shorebirds. Exactly how individual sites are used by these migrating birds especially in terms of what types of prey are consumed, how birds accumulate fat for migration at these sites, and what specific habitats within sites are important remain largely unknown. Research in these areas is especially desirable. Our length of stay estimates will allow for more accurate estimates of numbers of shorebird passing through particular sites to be estimated, as has been done for Western Sandpipers (Bishop et al. 2000). We found evidence for a banding effect on length of stay estimates at the site where birds were marked, as found for Western Sandpiper (Warnock and Bishop 1998). This confirms the need to mark shorebirds south of San Francisco Bay to get accurate length of stay estimates for that extremely important shorebird site (Page et al. 1999).

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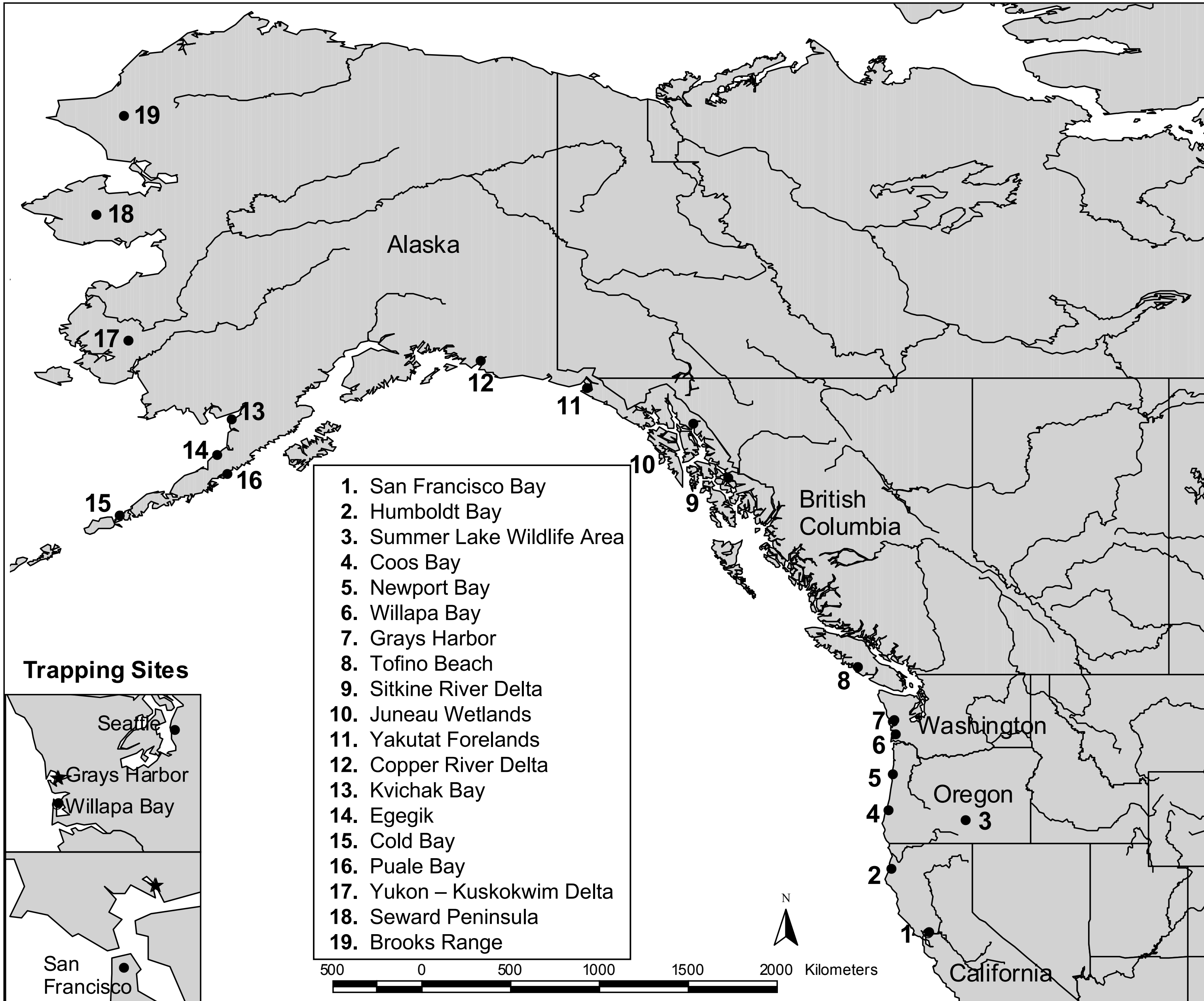


**Figure 1.** Dunlin and dowitcher monitoring sites used during Spring 2001 study.