

AN EVALUATION OF THE COPPER RIVER DELTA AS CRITICAL HABITAT FOR MIGRATING SHOREBIRDS

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ABSTRACT.—The migration strategies of the northwest Pacific Coast populations of the Dunlin and Western Sandpiper are compared with reference to their use of the Copper-Bering River deltas in the northern Gulf of Alaska as a stopover and staging area in spring. Dunlin arrive with depleted fat reserves and use the area to replenish these not only to fuel migration to breeding grounds, but to provide energy for the initiation of reproductive activity. Migrating Western Sandpipers show less variation in weight along the Pacific Coast, and no significant gain in mean weight occurs across the delta system. This suggests less within-population coordination of migratory movement and/or shorter flight range than is seen in the Dunlin, but at the level of the individual, the delta system is critical for replenishment of fat reserves for migration and reproduction in the Western Sandpiper, also. It appears that the completion of the annual cycle in these two and probably other shorebird populations depends significantly on access to and use of the Copper-Bering River delta system during spring migration.

Each year in April and May, more than 20 million waterfowl and shorebirds pass through the Copper River Delta in south-central Alaska. Species which are trans-Gulf or trans-Pacific migrants may make their first landfall in Alaska in this area (Isleib and Kessel 1973). More than half of these 20 million migrants are either Dunlins (*Calidris alpina pacifica*) or Western Sandpipers (*Calidris mauri*). For both species, the Copper River Delta is a stopping point for great percentages of their respective breeding populations (Isleib and Kessel 1973).

Collectively, the Copper and Bering River deltas (hereafter referred to as the C-BRD system) constitute an isolated break or habitat island in this north Pacific region otherwise dominated by steep fjord-like coastal topography with limited intertidal habitats. The Copper River alone, with $\frac{1}{6}$ the discharge, transports $\frac{1}{4}$ the sediment and a greater amount of sand than the Mississippi River (Galloway 1976). The vast sandy and muddy intertidal zone (about 500 km²) and associated supratidal wetlands of the C-BRD system attract an assemblage of migrating and breeding birds distinct from those of the heavily forested, steep, and rocky coastal areas stretching almost uninterrupted from the Puget Sound and southern British Columbia to Bristol Bay and the Yukon-Kuskokwim Delta in western Alaska. Contributing to the C-BRD system's intriguing qualities are its relatively wide tidal range (about 3.5 m at Cordova) and long history of seismic activity (Committee on the Alaska Earthquake 1971).

Because ice and snow cover much of the supratidal wetlands in late April and May, migrant shorebirds are largely obligate users of the intertidal zone, though some feeding and loafing occurs at the thawing margins of freshwater ponds. In May, densities up to 250,000 shorebirds per mile² of mudflats have been recorded in Orca Inlet at the western fringe of the Copper River Delta (Isleib and Kessel 1973). Isleib describes the phenomenon of migration elsewhere in this volume.

Within the tidal flats the shorebirds follow a typical and well described behavioral pattern (e.g., Holmes 1966, Recher 1966). The shorebirds feed with both the rising and falling tides; the most intensive activity is associated with the receding

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tide line. At high tides dense aggregations of loafing birds form above high tide line. Aerial displays among mixed-species flocks are frequent.

Petroleum- and natural gas-related activities in the Prince William Sound and northern Gulf of Alaska will include oil tanker traffic to and from Valdez (scheduled to begin in mid-1977) and the exploration and possible development of outer continental shelf lease tracts in the northern Gulf. One lease sale has been held in the northeastern Gulf, and a second is scheduled. Additionally, a natural gas liquifaction and tanker facility is proposed for Point Gravina, about 25 km northwest of Cordova. If this facility is constructed there will be a large thermal discharge into the Sound's cold waters, with unknown consequences for intertidal and marine organisms (F. P. C. Staff 1976).

There is no doubt that oil will be spilled in the region as a result of these petroleum-related activities, and that some of it will come ashore (USDI 1976). When and in what amounts oil will be spilled, and with what ultimate destinations, are unanswered questions.

In view of the several energy-related developments in store for Prince William Sound and the northern Gulf, can the C-BRD system be considered a critical habitat in the annual cycle of Dunlins, Western Sandpipers, and possibly other shorebird species? My purpose in this paper is to establish the significance of the C-BRD system to shorebirds by considering 1) the vulnerability of their food resources with respect to oil spills, and 2) the energy reserves of individuals in migration along the Pacific Coast and within the C-BRD system. Some of the results presented here are from research in progress. However, considering the developments described above it is timely to present our current state of knowledge with respect to the potential relationship between oil and shorebirds in the C-BRD system.

STUDY AREAS

The physiography and climate of the northern Gulf of Alaska and Prince William Sound region, including the intertidal zone, have been described by Rosenberg (1972) and Isleib and Kessel (1973). The Copper and Bering River deltas—the C-BRD system—are prominent features of this region. The present study focused on tidal flats at 3 sites within the system: Controller Bay, the mouth of the Eyak River, and Hartney Bay in Orca Inlet (Fig. 1).

Controller Bay is a sheltered indentation in the Gulf of Alaska coast. At low tides much of Controller Bay is a flat plain of mud and sand. Martin (1908) described the Controller Bay region in considerable detail. Activity in the present study focused on the eastern shore of the low-lying Kanak Island and the Bering River Delta.

The second study site was located on the plain between the intertidal portions of the Eyak River and Government Slough to the east of the Eyak River. At low tides this triangle-shaped, silty plain is part of the Copper River flats extending across the mouth of the Copper River west into Orca Inlet (Galloway 1976). The Copper River Delta was uplifted an average of 1.89 m by the 1964 earthquake (Reimnitz and Marshall 1965) and the upper portion of what was formerly intertidal zone is now a sedge (*Carex* spp.) flat. Above this "old" intertidal zone is a region of wetlands and marshes extending inland, in some cases as far as 13 km, to the base of the Chugach Mountains (Isleib and Kessel 1973). The plant communities of the wetlands consist primarily of sedges, grasses, and some shrubs (Potyondy et al. 1975).

Orca Inlet, including Hartney Bay, the third study site, represents a transition into the fjord-type environment of Prince William Sound. Orca Inlet is bordered by the rocky shore typical of Prince William Sound, yet it is very shallow because of sediments transported westward from the Copper River. At low tides much of Orca Inlet is an exposed mud and sand flat. Hartney Bay itself is nested against the west side of the Heney Mountain Range where it is sheltered from the prevailing southeasterly winds. Several freshwater streams feed into Hartney Bay, and again because of earthquake

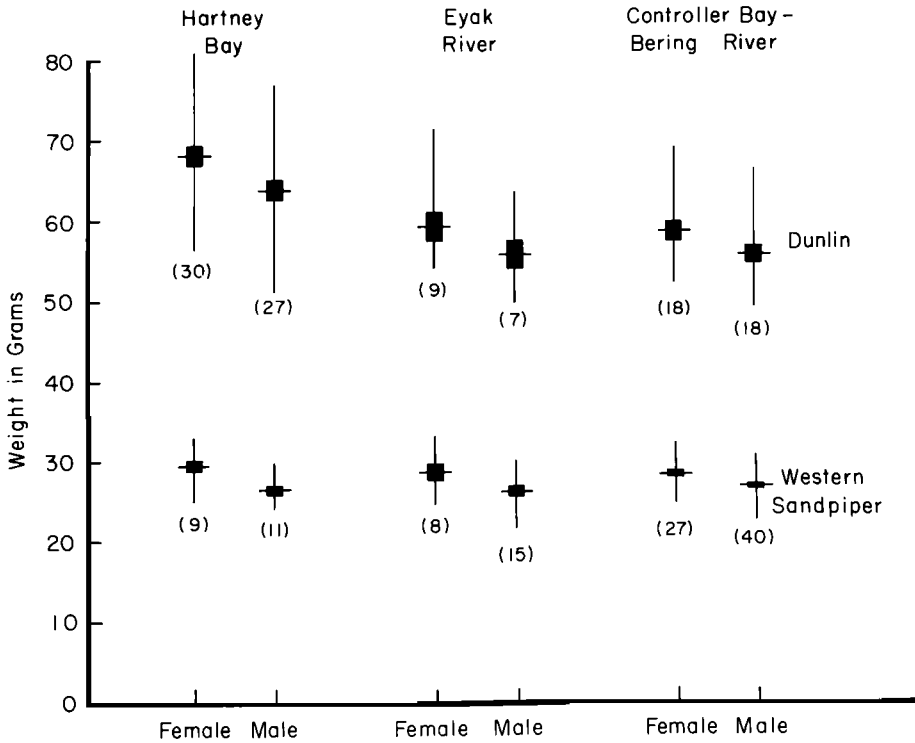
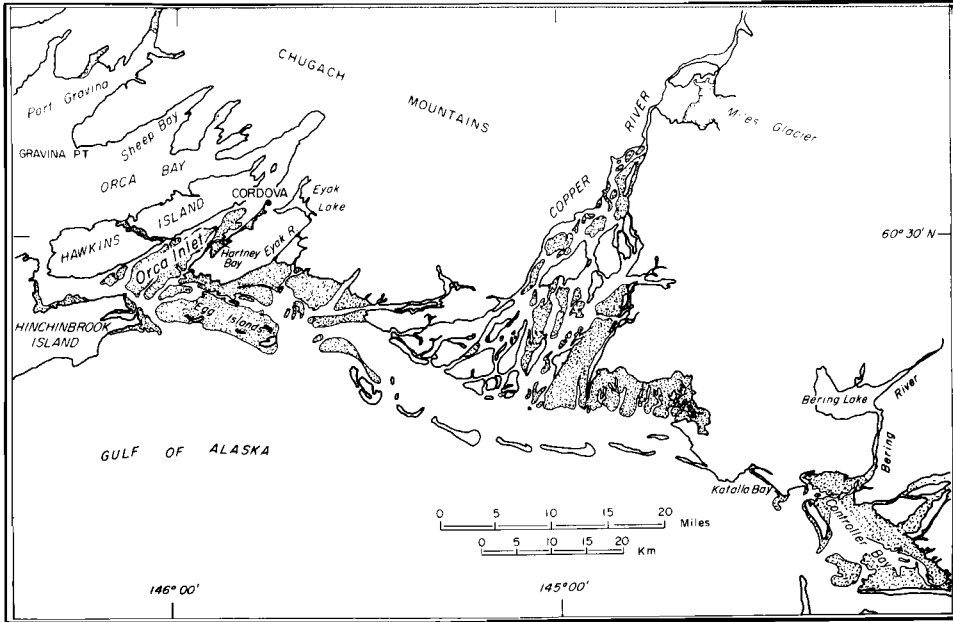


FIGURE 1. Map (top) showing Copper-Bering River delta system and study sites. Stippled areas are tidal flats. Weights (bottom) of *Calidris alpina* and *Calidris mauri* collected concurrently at three locations in the C-BRD system. The horizontal line is the mean, the solid rectangle is the standard error of the mean, and the vertical line is the range. Sample sizes are in parentheses.

uplift, there is an extensive sedge zone between the present high tide line and the "pre-earthquake" rocky shore. A road crosses the flats at the northeastern end of the bay.

Tides in the region are semi-diurnal, with a marked inequality between successive low waters (Rosenberg 1972). During the study period, 30 April to 27 May 1976, the mean tidal range was about 3 m at Cordova. Weather data are gathered at the Cordova FAA station on the Copper River Delta. During the study period the average maximum and minimum temperatures were, respectively, 9.3°C and 1.2°C, with a mean of 5.2°C. Precipitation totaled 17.9 cm (NOAA 1976).

BREEDING AND WINTERING RANGES

The prime breeding range for Western Sandpipers and Dunlins in western Alaska is the Yukon-Kuskokwim Delta and the Seward Peninsula (AOU 1957). Western Sandpipers, less commonly, nest as far north as Barrow and as far east as Camden Bay (Holmes 1972). The Dunlins nesting abundantly at Barrow are *C. alpina sakhalina*, a subspecies which migrates and winters along the Pacific Coast of Asia (MacLean and Holmes 1971, Norton 1971). *C. alpina pacifica* (the Dunlins referred to throughout this paper unless otherwise indicated) nest only as far north as Cape Thompson (MacLean and Holmes 1971), while they winter from the northern Gulf of Alaska to Baja California (AOU 1957, Isleib and Kessel 1973). Western Sandpipers winter along the Pacific Coast from California to Peru and along the southern Atlantic Coast and the Gulf of Mexico, south to Central America and northern South America (AOU 1957).

PHENOLOGY OF SPRING MIGRATION

Spring migration in California begins in late March and April for Western Sandpipers and Dunlins, respectively, and ends in early May for both species (Jurek 1973). Many Dunlins apparently shift from a coastal to an interior route during spring migration in California (Page 1974). Peak numbers of *alpina* in interior western Oregon were reported between mid-March and mid-April (Strauch 1967). At Cultus Bay, Puget Sound, Van Zelzen (1973) reported the largest numbers of *alpina* in March and April and peak numbers of *mauri* in mid-May. Richardson (in Van Zelzen 1973), at the northern end of Vancouver Island, found that *mauri* were abundant as early as 23 April and peaked in the first week in May. At the same location *alpina* were first recorded on 28 April. In the Vancouver area in 1970, large numbers of *mauri* passed through from 26 April to 15 May (Campbell et al. 1972).

Holmes (1966) suggested that Dunlins move north to British Columbia and then fly directly across the Gulf of Alaska to Alaska. Munro and Cowan (1947) classify *alpina* as abundant transients along the British Columbia coast, while *mauri* are considered common. Both species are common at Glacier Bay National Monument, Alaska, according to Wik and Streveler (1967).

During the second and third weeks in May, Dunlins and Western Sandpipers combined outnumber all other shorebird species on the Copper River Delta (Isleib and Kessel 1973). So far as is known, virtually all Dunlins of the *pacifica* subspecies pass through the C-BRD system in spring. Western Sandpipers migrating through the C-BRD system include most of their entire population, though at least a small number migrate through interior continental United States (Parmelee et al. 1969).

Little is known about migration between the C-BRD system and the Yukon-Kuskokwim Delta. On 11 May 1976, 1 to 2 million "small" sandpipers, an estimated 80% of which were *mauri*, were sighted on the Fox River flats at the head of Kachemak Bay in lower Cook Inlet (D. Erikson, unpubl. data). Arrival dates in the Yukon-Kuskokwim Delta reported by both Conover (1926) and Holmes (1971, 1972) for *mauri* and *alpina* were between 10 and 20 May, inclusive.

TABLE 1
ORIGINS OF WEIGHT RECORDS

Location	Record type ^a	Species	
		<i>C. mauri</i>	<i>C. alpina</i>
San Quintin Bay	S	Museum Vert. Zoology	Museum Vert. Zoology
Salton Sea	S	San Diego Mus. Nat. Hist.	San Diego Mus. Nat. Hist.
San Francisco Bay	S	Museum Vert. Zoology	Holmes 1966
Bolinas Lagoon	C	Point Reyes Bird Obs.	Point Reyes Bird Obs.
Humboldt Bay	C	R. Gerstenberg, unpubl. data	Gerstenberg 1972
Puget Sound	C	—	S. Shanewise, unpubl. data
Vancouver Island	C	Brit. Columb. Prov. Mus.	Brit. Columb. Prov. Mus.
Controller Bay	S	This study	This study
Eyak River	S	This study	This study
Hartney Bay	S	This study	This study
Hooper Bay	S	R. Holmes, unpubl. data	R. Holmes, unpubl. data
Cape Thompson	S	Museum Vert. Zoology	—

^a Key to symbols: S, collected specimen; C, live-captured bird.

METHODS

Between 30 April and 27 May 1976, *alpina* and *mauri* specimens were collected, while they were feeding, at the 3 sites in the C-BRD system. The shorebirds were collected at various times of day, stages of the tide, and levels within the intertidal habitat. Two transects were established normal to the tide line at Hartney Bay to provide a basis for collecting the shorebird specimens and sampling invertebrate prey species in the mudflats. We weighed shorebird specimens to the nearest 0.5 g in the field using Pesola spring balances. Their stomach contents were removed and placed in buffered formalin as soon as possible after collection. Carcasses were frozen, and all samples were transported to the University of Alaska, Fairbanks, for analysis.

In Fairbanks the stomach contents have been sorted, their key parts counted, and the whole items weighed. Data analysis, however, is not yet complete. Dr. George West, Institute of Arctic Biology, University of Alaska, is presently determining lipid levels in the bird carcasses (the technique is described in West and Meng 1968).

Whole body weights of *alpina* and *mauri* specimens from museum collections, the literature, and unpublished records of various investigators were assembled to provide a perspective from which to view the weights of specimens secured in the C-BRD system. Table 1 shows the sources for weight data by species and location. Because the specimens from a given site were often collected on widely scattered dates, it was necessary to lump these data into 2 broad categories. The first interval, 2 March–15 April, roughly corresponds to the first half of spring migration (depending on the specific site), while the second 16 April–31 May, corresponds to the latter half of migration and early breeding (at Hooper Bay). Mean body weights are reported only for those sites and intervals for which I found at least 5 specimen records.

Potential flight ranges were estimated for a sample ($N = 10$ for each species, with equal sex ratios) of specimens on which lipid extractions are complete. The formula developed by McNeil and Cadieux (1972) was used.

RESULTS

Most prey taken by Western Sandpipers and Dunlins (Tables 2 and 3) in the C-BRD system are intertidal invertebrates. Note that several species of bivalve molluscs are preyed on by both *mauri* and *alpina*. A small sample of both shorebird species from Hartney Bay in May 1975, showed that many molluscs, and amphipods, also, were taken (Senner 1976).

Dunlins of both sexes show substantial weight gains when comparing the mean body weights from samples at either Controller Bay or the Eyak River to Hartney

TABLE 2
STOMACH CONTENTS OF *Calidris mauri* AND *Calidris alpina*^a

Items	Bird species			
	<i>Calidris mauri</i>		<i>Calidris alpina</i>	
	A ^b	B ^b	A	B
Pelecypoda				
<i>Macoma balthica</i>	60	4.1	95	27.9
<i>Mytilus edulis</i>	40	2.7	13	13.0
<i>Mya</i> spp.	20	24.0	13	1.0
<i>Astarte</i> spp.	6	1.0	—	—
Unidentified	6	2.0	—	—
Copepoda				
Harpacticoida	20	13.7	—	—
Amphipoda				
<i>Corophium</i> spp.	—	—	4	1.0
Unidentified	6	1.0	23	+
Insecta				
Diptera	6	1.0	—	—
Chironomidae	47	48.7	4	1.0
Acarina				
Unidentified	6	1.0	—	—
Animal				
Unidentified frag.	6	2.0	4	1.0
Plant				
Unidentified seeds	27	3.5	9	21.5
Unidentified debris	73	+	54	+
Grit				
<1 mm	60	299.2	90	10.7
≥1 mm	60	43.3	23	7.6

^a For *C. mauri*, $N = 15$; for *C. alpina*, $N = 22$; collected while feeding on the Hartney mudflats, May 1976.

^b A = frequency (percent of stomachs with item), B = average number of items per stomach. Items which could not be quantified are indicated by "+".

Bay (Fig. 1). Female *alpina*, for example, show a 16.2 percent gain in mean weight when comparing the samples from Hartney and Controller Bays. Male and female *mauri*, on the other hand, show nearly constant mean weights across the C-BRD system (Fig. 1).

During migration along the Pacific Coast Dunlin females show a general increase in mean body weight (Fig. 2). Male *alpina* have a similar pattern, though they average several grams lighter. Western Sandpiper males show a small but significant ($P < 0.05$) increase in mean weights between the two intervals at Humboldt Bay (Fig. 3). With the exception of the Vancouver Island sample, however, the mean weights remain relatively constant when compared to those of the Dunlins. The pattern for females is similar, though they average several grams heavier. Individual *mauri* weights range from 17 to 35 g in males and up to 42 g (at Bolinas Lagoon) in females. The respective coefficients of variation for *mauri* males vary from 2.79 to 13.28 percent, while those for *alpina* females vary from 1.73 to 14.05 percent.

Comparing the mean fat indices (g fat/g fat-free dry weight) for *mauri* and

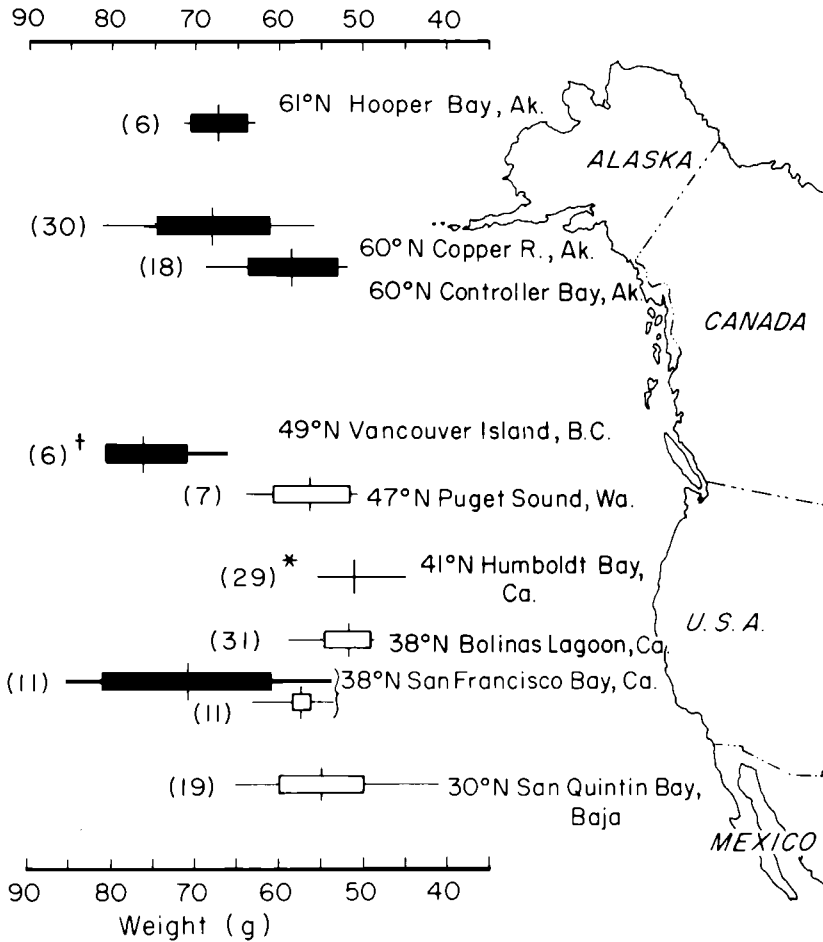


FIGURE 2. Weights of female *Calidris alpina* during spring migration along the Pacific Coast. The vertical line is the mean, the rectangle is the standard deviation, and the horizontal line is the range. Open rectangles indicate samples from 2 March to 15 April, and dark rectangles indicate samples from 16 April to 31 May. Sample sizes are in parentheses. * Unable to calculate standard deviation from this source. The sample is from the earlier interval. † The upper limit of the range = 79.5 g.

alpina at Hartney Bay shows that *alpina* are significantly fatter than *mauri* (0.46 ± 0.03 , $N = 17$, and 0.17 ± 0.02 , $N = 18$, respectively; $P < 0.05$) as they leave the C-BRD system. These different fat levels are reflected in the shorebirds' estimated flight range capabilities (Fig. 4). Western Sandpipers have about half the mean estimated range of Dunlin: 600 ± 77 km ($R = 177-1081$) compared to 1260 ± 89 km ($R = 744-1791$).

DISCUSSION

FOOD RESOURCES

Interpreting the contents of stomach samples is difficult because of differing digestion rates for different types of prey items (e.g., molluscs vs. polychaetes)

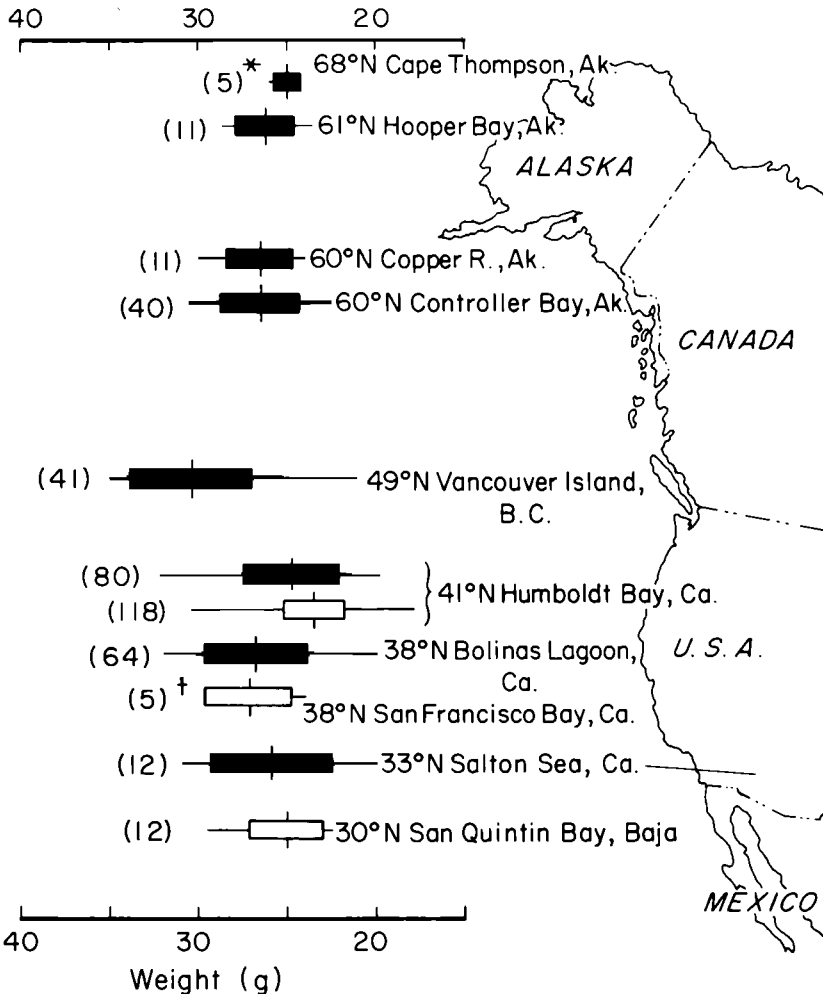


FIGURE 3. Weights of male *Calidris mauri* during spring migration along the Pacific Coast. The symbols are the same as in Fig. 2. † The upper limit of the range = 29.0 g. * The lower limit of the range = 24.3 g.

(e.g., Goss-Custard and Jones 1976). There is no doubt here, however, that both *mauri* and *alpina*, but especially *alpina*, are preying on many bivalve molluscs. *Macoma balthica*, by far the most frequently taken mollusc (Tables 2 and 3), is an abundant pelecypod with a circum-arctic distribution (Coan, 1971). It is a frequent prey of many shorebird species (e.g., Wolff 1969, Goss-Custard and Jones 1976). My own sampling of *M. balthica* showed densities up to about 2600 per m² on the Hartney Bay mudflats, and Myren (in press and pers. comm.) has recorded densities up to 3200 per m² (not including individuals able to pass through a screen with square openings 3.2 mm per side) in the Dayville mudflats at Port Valdez.

Shaw et al. (1976) suggested that *M. balthica* has good potential as an "indicator" of oil pollution in sediment habitats. He simulated stranding of an oil slick

TABLE 3
STOMACH CONTENTS OF *Calidris mauri*^a

Items	A ^b	B ^b
Nematoda		
Unidentified	5	1.0
Pelecypoda		
<i>Macoma balthica</i>	60	7.6
<i>Mytilus edulis</i>	5	1.0
<i>Mya</i> spp.	20	1.8
Insecta		
Diptera	55	3.7
Chironomidae	65	8.1
Tipulidae	5	1.0
Staphylinidae	5	1.0
Plants		
Unidentified seeds	25	1.8
Unidentified debris	55	+
Grit		
<1 mm	100	186.6
≥1 mm	100	40.5

^a N = 20, collected while feeding on the mudflats at the mouth of the Eyak River, May 1976.

^b A = frequency (percent of stomachs with item); B = average number of items per stomach. Items which could not be quantified are indicated by "+".

on a mudflat at Valdez Arm and found that mortality in a naturally occurring *M. balthica* population increased significantly with increasing duration of exposure. Laboratory studies by Taylor et al. (1976) showed *M. balthica* responded to the presence of oil by coming to the sediment surface, a response which would, in a natural environment, make them susceptible to tidal action, exposure (freezing and desiccation), and predation.

Studies elsewhere have considered the effects of accidental oil spills on invertebrate life. Oil may smother, foul, or directly poison intertidal organisms. Single spills may be relatively short-term in their effects, while chronic pollution is more likely to have long-term effects (Boesch et al. 1974, Crapp et al. 1971). Given the petroleum-related developments projected for the northern Gulf of Alaska, it is not unreasonable to conclude that the intertidal invertebrates of the C-BRD system are in a vulnerable position.

In light of the shorebirds' dependence on vulnerable intertidal organisms, how will the shorebirds be affected if their food resources should greatly diminish in availability and/or quality? I have approached this question by examining the energy reserves of *alpina* and *mauri* as they move through the C-BRD system.

ENERGY RESERVES

Fat is the primary source of energy for birds in long-distance migratory flights (Odum et al. 1961), and birds making long migrations deposit fat before leaving the wintering grounds (Kendeigh et al. 1960; Nisbet et al. 1960). Fat deposits may also be replenished en route, since original reserves may be depleted before a final destination is reached (Odum et al. 1961). Hanson (1962) noted that Canada Geese (*Branta canadensis*) increase in body fat during their northbound migra-

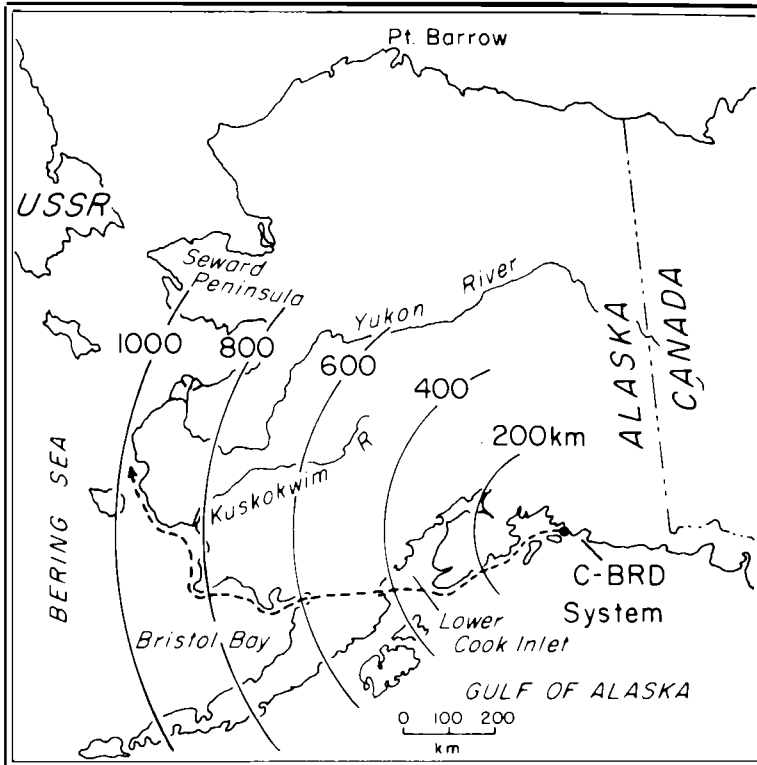


FIGURE 4. Flight distances from Hartney Bay in the C-BRD system to western Alaska. The dashed line shows a probable migratory pathway through lower Cook Inlet.

tion, and MacLean (1969) found that fat was used to support early season breeding activities in sandpipers in arctic Alaska.

Many investigators have reported the fat-free weight of a bird remains relatively constant while the lipid weight is highly variable; thus, changes in whole body weights reflect changes in fat reserves (e.g., Page and Middleton 1972). This generalization does not always hold (MacLean 1969), but in the present study lipid levels have been determined in enough specimens to show that whole weights do reflect fat reserves.

To best understand the weights recorded in the C-BRD system, it is useful to consider them in context with weights throughout spring migration.

Mean body weights in Dunlins increase during migration (Fig. 2). The fact that the mean of the Vancouver Island sample is the highest of the entire migration and that its range does not overlap with the range of the Puget Sound sample suggests two hypotheses. First, the absence of overlap with the range of the earlier Puget Sound sample suggests that individuals in Dunlin flocks migrate collectively (i.e., there is a communal response among members of a flock) rather than independently of each other (Recher 1966 contrasts the two approaches). Recher (1966) attributed a wave-like character to the migration of individual shorebird species in California, while Holmes (1966) noted that *alpina* populations at several locations in central California did not increase during spring migration.

He suggested the entire population shifted northward gradually in a slow-moving migration. Page (1974) pointed out that there are spring peaks for Dunlins at some locations in some years in coastal California and presented evidence that Dunlins shift to an inland rather than coastal route in spring migration in California.

Second, the high mean value at Vancouver Island compared to the much lower values at Controller Bay and the Eyak River is evidence supporting Holmes' (1966) suggestion that in spring Dunlins fly across the Gulf of Alaska from British Columbia to Alaska. Though *alpina* are reported along the British Columbia coast and at Glacier Bay (see "Phenology" section), so far as is known, there are no concentration points—spatially or temporally—between southern British Columbia and the C-BRD system which approach the magnitude of the C-BRD system.

Dunlins, then, at Controller Bay are light because they have depleted their fat reserves in making long, probably over-water flights. Since the mean body weights (Fig. 1) at the Eyak River site are essentially the same as the Controller Bay values (within the respective sexes), it is possible that arriving *alpina* first land at any number of sites across the C-BRD system.

Once within the system, however, *alpina* move from east to west, probably stopping repeatedly to feed as tides and weather permit. From field observations and comparisons of morphometric measurements such as culmen lengths (Senner, in progress), there is no evidence suggesting that distinct populations are making single stops in the C-BRD system and then leaving the region entirely. It is my impression that the richest feeding opportunities are at the western fringe of the system. For example, my limited sampling of intertidal organisms shows few *Macoma balthica* at the Eyak River site relative to the rich Hartney Bay mudflats. If the Orca Inlet area is the final staging/feeding opportunity before *alpina* depart on another flight to their breeding grounds in the Yukon-Kuskokwim Delta (and points north), then one would expect to find the heaviest birds there. This is indeed the case (Fig. 1).

It is not presently known what lengths of time transient shorebirds, including *alpina*, spend within the C-BRD system, though Isleib (pers. comm.) believes that at individual sites they may remain for only a few tide cycles. In terms of the rate at which fat can be deposited, it may be pertinent to note that juvenile *C. a. alpina* gained about 1 g (extreme of 3 g) daily after the third day in pauses in their autumnal migration in Sweden (Mascher 1966). Curlew Sandpipers (*C. ferruginea*) in Britain gained 2 to 4.5 g weight per day during pauses in their fall migration (Minton 1969). Lapland Longspurs (*Calcarius lapponicus alascensis*), in spring migration in the Yukon Territory, showed an average gain in fat of 0.76 g daily (West et al. 1968).

The pattern of weight change in Western Sandpipers is much less clear than in Dunlins, but there are indications that the two species use different migratory strategies. Lumping the weights from a given site into extended intervals as was necessary here may obscure patterns which require a more sensitive approach. But it is conceivable that mean body weights for Western Sandpipers at a given site could remain relatively constant (Fig. 3) because the continuing influx and departure of individuals with different weights and thus, fat reserves, could balance each other out. If true, this suggests that individual *mauri*, to a greater extent than with *alpina*, migrate independently of each other (i.e., each pursues its own schedule), and that the flocks seen in migration may be relatively tem-

porary and haphazard associations resulting from factors such as the limited availability of prime intertidal feeding habitats. West et al. (1968), West and Peyton (1972), and DeWolfe et al. (1973) document this migration pattern in three species of overland-migrating fringillids. One argument against the hypothesis of individual *mauri* pursuing their own schedules is that with this strategy one would expect much greater variability among the *mauri* at a given site when compared to the *alpina*. The similar coefficients of variation for the two species (see "Results") show this not to be true. Good series of birds captured or collected on a regular basis at specific sites would shed much light on the nature of the *mauri* migration.

Regardless of whether Western Sandpipers migrate as independent individuals or collectively, the fact that their mean body weight at Vancouver Island is the highest for any site (Fig. 3) again suggests a general readying for a demanding flight to Alaska. If not an over-water flight, it is at least a flight along a long, rocky coast with few extensive feeding opportunities. As was true with *alpina*, the *mauri* mean body weight at Controller Bay is substantially lower than the mean for the Vancouver Island sample.

Western Sandpipers show no gain in mean weights across the C-BRD system, nor are they as fat as Dunlin at Hartney Bay. A single non-stop flight from Hartney Bay to Bristol Bay should fully deplete the fat reserves for *mauri*, while *alpina* could fly well beyond that distance. It is misleading to assume, however, that the only value of fat reserves is to propel these birds to their breeding grounds. MacLean (1969) and Norton (1973) argue strongly that for calidridine sandpipers fat reserves play a critical role in the early phase of reproductive activity—a period of highest energy demands when weather conditions may reduce feeding opportunities. In Pectoral Sandpipers (*C. melanotos*), particularly, MacLean (1969) suggested breeding success is related to the fat reserves of individual males as they arrive in Barrow, Alaska, breeding grounds. Many arctic breeding species arrive on their breeding grounds with fat reserves that are not depleted until courtship, territorial activity, or egg-laying occur (Irving 1960).

In this context the observation of 1 to 2 million small shorebirds in lower Cook Inlet takes on new significance. It may well be that for *mauri*, particularly, intermediate stops between the C-BRD system and the Yukon-Kuskokwim Delta are a necessity. Note that the lower extreme of the *mauri* flight range (177 km) is not even sufficient to take them as far as lower Cook Inlet (Fig. 4). Comparisons of fat indices and estimated flight ranges for *mauri* and *alpina* could show that through the entire spring migration *mauri* tend to move in relatively short "hops" as opposed to long, sustained flights.

SUMMARY AND CONCLUSIONS

MIGRATION STRATEGIES

To contrast the migration strategies of Dunlin and Western Sandpipers, the former, as a population, shows weight gains as a result of fat deposition during spring migration. Dunlin may migrate collectively rather than as independent individuals. Dunlin appear to make long, over-water flights from southern British Columbia to Alaska and arrive in the C-BRD system with depleted fat reserves. The C-BRD system provides an opportunity to replenish depleted fat reserves

not only to fuel migration to their breeding grounds, but to provide energy reserves for the early phase of reproductive activity.

Individual Western Sandpipers undoubtedly deposit and then use fat reserves during migration, but as a population they show less variation than Dunlins in mean body weights through spring migration. One possible explanation for these observations is that individual *mauri* migrate independently of each other. Western Sandpipers at Vancouver Island do show a gain in mean weight, indicating a readying for a strenuous flight to Alaska. The fact that their mean body weights do not change across the C-BRD system does not diminish the value of the system as a habitat in which individual *mauri* can replenish fat reserves needed for migration and reproduction. The shorter estimated flight range of *mauri* relative to *alpina* suggests a need for intermediate stops between the C-BRD system and the Yukon-Kuskokwim Delta. Further research is needed to determine whether a pattern of short hops typifies *mauri* migration in general.

COPPER-BERING RIVER DELTA SYSTEM

The C-BRD system is a unique habitat island in the northern Gulf of Alaska serving as a focal point in the spring migration of more than 20 million waterfowl and shorebirds. Oil- and natural gas-related developments in the northern Gulf region pose serious threats to intertidal invertebrate resources upon which many shorebirds depend.

Evidence is presented that the C-BRD system is a critical habitat in the annual cycle of the Dunlin and Western Sandpiper. If adequate feeding opportunities are denied them in the C-BRD system, it could seriously affect reproductive success in significant fractions of the entire populations of Western Sandpipers and the western Alaska subspecies of Dunlin.

The C-BRD system may be a critical habitat to shorebird species other than *mauri* and *alpina*. The Red Knot (*C. canutus*), for example, is a prime candidate, since a large portion of North America's Pacific Coast migrants apparently use the Copper River Delta's tidal flats during a brief interval in May (Isleib and Kessel 1973).

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