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Nutritional Significance of Copper-Bering
Intertidal System to Spring-Migrating
Shorebirds Breeding in Western Alaska

By

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I. Summary

In the year ending 1 April 1978, significant new dimensions were added to an appraisal of the Copper River Delta system as critical habitat for Dunlins and Western Sandpipers in spring migration. Selective field work was conducted at other sites in Alaska along the migratory-to-breeding continuum of localities between the Copper Delta and north-western Alaska. Predictions made last year about the differing physiological/behavioral/ migration dynamics of the two species have been borne out by the documentation of predicted major stopovers by westerns in Kachemak Bay, Lower Cook Inlet and the virtual absence of Dunlins from that region, as predicted. Close cooperation with Arneson (RU 3) and Gill (RU 341, Nelson Lagoon) has proven to be mutually advantageous in both putting the Copper Delta into context, and verifying that postulated different migration strategies characterize the two species in fall as well as in spring movements.

Both species appear to be highly susceptible to any intertidal habitat degradation in the C-BRD system, although of the two, the Dunlin shows a higher degree of obligate habitat dependency on the C-BRD system itself. By contrast, current understanding leads us to regard habitat degradation in Lower Cook Inlet as at least as serious a threat to westerns as similar events in the Copper-Bering system. A final report of this phase of work is expected to be ready on 1 October 1978. Perturbation experiments (small plot oiling, exclosure pens) are under consideration for possible renewal proposals in 1979.

II. Introduction

Expanding on the work of Senner (1977), the purpose of the present study is to evaluate the importance of the Copper-Bering River Delta system (C-BRD system, Fig. 1) in the context of the annual cycle of two abundant shorebirds - Western Sandpiper (Calidris mauri) and Dunlins (C. alpina pacifica). Additionally, we may gain new insight into the way northern-breeding birds secure and expend the energy and nutrients necessary for migration and reproduction.

Specific project objectives have been articulated as a set of questions:

A. How much nutritional and energetic gain is made by birds between Controller and Hartney Bay, and how does this gain relate to spring migratory and breeding physiological status?

B. What are present-day conditions, e.g., trophic dynamics in this supposedly sensitive region, against which future status (following energy developments) can be compared?

C. If denied any feeding opportunities in the C-BRD system (as a result of cataclysmic or chronic disturbance) would the breeding success of the two species-populations be seriously jeopardized?

D. Can evidence for past fluctuations in breeding ranges or success be correlated with events on the delta intertidal system (such as the 1964 earthquake)?

E. At what rate do Dunlins and Western Sandpipers move through the Copper-Bering system? Are differing consumptive strategies during migration reflected in differing rates of passage? How much time do individual birds spend in the C-BRD system in which they are susceptible to the direct effects of oil or other pollution? Must individual birds achieve a certain level of fat reserves before they leave the system?

F. To what extent do shorebirds enroute between the Copper River delta and the Yukon-Kuskokwim delta stop to feed in the Lower Cook Inlet (Fig. 2)? What route do they follow between C-BRD system and Cook Inlet?

G. What is their physiologic state when they arrive at breeding grounds such as Hooper Bay in the Yukon-Kuskokwim delta?

Applications of the information obtained in this study will primarily be used in documenting or refuting the suggested importance of this unique, heavily used geomorphic feature and habitat. The results may be useful in specifically indicating protective measures (legislation, leasing stipulations, regulation and permitting) by state and federal resource management agencies.

Several potentially damaging petroleum-related developments underway or proposed in the northern Gulf of Alaska make these objectives pertinent. Marine tankers travel to and from Valdez daily, transporting oil from the terminus of the trans-Alaska pipeline. The tankers pass through Hinchinbrook Entrance west of the C-BRD system. One OCS lease sale has been held and exploration initiated east of Kayak Island. A second sale is scheduled offshore of the C-BRD system in June, 1980.

III. Current State of Knowledge

The C-BRD system is strategically located in the spring migratory routes of at least two shorebird species-populations bound for western Alaska breeding grounds. Dunlins and Western Sandpipers enter the north Gulf coast region in vast numbers during the first two weeks of May. Isleib and Kessel (1973) report that they constitute more than half the 20 million waterfowl and shorebirds using the system during spring migration.

The following is a summary of pertinent background information:

1. Virtually all adults of the two sympatric, congeneric species, which migrate up the Pacific coast, stop and feed in this region. No other geographically restricted zone, nor temporally restricted phenomenon elsewhere between Baja California and western Alaska, has been identified as a site of concentration and feeding for comparable percentages of these breeding populations.

2. Nearby terrestrial and aquatic habitats in early May of most years are largely unavailable for feeding because of persistent heavy snow and ice cover. Hence, the sandpipers are largely obligate users of the intertidal system.

3. Dunlins prey heavily on the bivalve Macoma balthica, while Western Sandpipers take a variety of intertidal invertebrates including molluscs, amphipods, and larval insects (Senner, 1977). Intertidal invertebrates are vulnerable to the damaging effects of oil pollution, especially chronic discharges. Shaw et al. (1976) and Taylor et al. (1976) have studied the effects of oil on M. balthica in Prince William Sound and believe that M. balthica is a good "indicator" of oil pollution in a sediment environment.

4. Besides having different food habits, Western Sandpipers and Dunlins have a different "strategy" for using the intertidal habitat. Dunlins have a strong tendency to feed at the falling tide line and "loaf" through high tide periods. Westerns, on the other hand, feed both at water's edge and away from the tide line, and continue to feed through the high tide period (Senner, 1977).

5. The occurrence of many bivalve molluscs in the diet of both sandpiper species raises the possibility that the mollusc shells are a source of calcium for pre-breeding adults. MacLean (1974) showed the use by several Calidris spp. of lemming teeth as a calcium source on arctic breeding grounds.

6. Individual birds may spend as few as 30 hours on the Copper-Bering deltas, before essentially being "impelled from behind" by the influx of new arrivals (Isleib, pers. comm.). Therefore, individual birds may have as few as two or three tide periods in which there are exposed mudflats on which to feed.

7. Fat is the primary source of energy for long-distance migratory flights in birds (Odum et al., 1961), and variations in whole body weight can usually be attributed to variations in fat reserves (Page and Middleton, 1972). Probably having flown non-stop from the Puget Sound region, both Dunlins and Western Sandpipers arrive in the eastern C-BRD system with depleted fat reserves (Senner, in prep.). Based on whole body weights of specimens collected in 1976, Dunlins leaving the western end of the C-BRD system have replenished their fat reserves. In 1976, however, Western Sandpipers showed no weight increase as they moved across the C-BRD system (Senner and Norton, 1977; Senner, in prep.).

8. In May 1976 there was a report of one to two million small shorebirds, probably Western Sandpipers, at Kachemak Bay, Lower Cook Inlet (Erikson, 1977). Based on estimations of the potential flight ranges of Western Sandpipers and Dunlins leaving the C-BRD system, Senner (in prep.) predicted that many Western Sandpipers needed an

intermediate stop at suitable sites in Lower Cook Inlet while enroute between the C-BRD system and western Alaska. Such a feeding stop was not believed necessary for Dunlins following the same migration route.

IV. Study area

Within the C-BRD system, Kanak Island and Hartney Bay were the primary study sites (Fig. 1). Specific sites are described in Senner (1977); the region and intertidal system are characterized in Isleib and Kessel (1973) and Rosenberg (1972).

The second major study area was Kachemak Bay, lower Cook Inlet; specifically, the Fox River flats at the head of the bay and the Mud Bay flats inside the Homer Spit (Fig. 3). These sites are described in Erickson (1977); the Kachemak Bay as a whole is characterized in Wennekens *et al.* (1975).

Secondary study sites were Hooper Bay in the Yukon-Kuskokwim Delta and Capes Espenberg and Krusenstern in the Kotzebue Sound area (Fig. 2); the latter are described in Schamel and Tracy (1977) and Connors (1977, respectively).

V. Methods

A. Study Period

Senner, Norton, and two field assistants were in the C-BRD system for purposes of banding, collecting, and observing shorebirds from 26 April to 24 May, 1977. Aerial surveys, ground observations, and specimen collection were performed at Kachemak Bay by a field assistant from 30 April to 21 May. Norton and West made a brief excursion plagued by foul weather and an airline strike to Hooper Bay, 13-19 May, to collect specimens arriving on the breeding grounds. Senner was at Cape Espenberg and Norton at Cape Krusenstern from 28-30 May to collect sandpiper specimens.

B. Banding and Marking

For the purpose of determining turnover rates at individual sites in the C-BRD system, and at sites across the system, sandpipers at Kanak Island were captured with mist nets or walk-in traps, banded with an aluminum U.S. Fish and Wildlife Service leg band, marked with a colored feather glued to a central rectrix (after West *et al.*, 1968), and released. Live weight, culmen length, and flattened wing length of each captured bird were recorded for use in analyses of fat levels, flight ranges, and morphometric comparisons with other populations.

C. Aerial and Ground Observations

Kanak Island: Throughout daylight hours shorebird activities were observed. Numbers, species composition, behavior, etc. were noted. A special effort was made to spot marked birds and record the color of the feather attached to individual birds. Using charter aircraft three roundtrips were flown between Kanak Island and Cordova, usually flying low over the water's edge in the intertidal zone for the purpose of spotting marked birds. Numbers, species composition (so far as possible), and locations of concentrations were noted.

Hartney Bay: One hundred and twenty-two censuses were conducted (by D. Matkin) on an hourly basis through half tide cycles (i.e., high to low or low to high) on two transects established as part of an earlier study (full methodology described in Senner, 1977). Additionally, sandpiper flocks on the mudflats were continually scanned for the presence of marked birds; total number and species composition were estimated and noted.

Kachemak Bay: Six aerial surveys, one hour before high tides, were flown over the Fox River flats in a Cessna 172 (including pilot plus one observer). Survey techniques replicated those described in Erickson (1977); see Figure 3 for survey areas. Three trips were made on foot to the Fox River flats, in part for the purpose of verifying the species composition of shorebirds flocks seen from the air. Additionally, a 500 m transect was censused as it was exposed following a high tide on 12 days at Mud Bay.

D. Specimen Collection and Analysis

Calidis sandpipers were collected in the C-BRD system (Kanak Island, mouth of Eyak River, and Hartney Bay), at Kachemak Bay (Mud Bay, Fox River flats), Hooper Bay, Cape Espenberg, and Cape Krusenstern. Table 1 shows the numbers and species at each location.

From each specimen the following was recorded in the field: 1) fresh weight, 2) culmen length, 3) flattened wing length, and 4) sex. Stomach contents were removed as soon as possible and placed in buffered formalin.

Stomach samples were processed at the University of Alaska to determine: 1) identity of food items, 2) numbers of food items, 3) size and weight of whole food items, 4) total weight, and 5) numbers and weights of non-food items such as grit (see Senner, 1977).

Frozen bird carcasses were transported to the University of Alaska where they are being processed to obtain fat-free dry weight, lipid and water weights (West and Meng, 1968; Johnson and West, 1973), fatty acid "signatures" (West and Meng, 1968; West and Peyton, 1972), and total calcium (MacLean, 1974).

VI. Results

A. Censuses, Surveys, and Observations

General observations at Kanak Island showed that in 1977, unlike 1976, Western Sandpipers, Dunlins, and other shorebirds were able to make extensive use of supratidal brackish and freshwater wetlands for feeding purposes. In most years, during late April and early May, this habitat is largely unavailable because of snow and ice cover.

Some 6,961 shorebirds (Charadrii) were recorded on censuses of the two Hartney Bay transects. Species composition by percentages is shown in Figure 4. Estimated peak daily numbers of all shorebird species at Hartney Bay are shown in Figure 5.

Figure 6 shows the numbers of Western Sandpipers and Dunlins recorded on the Mud Bay transect (in Kachemak Bay). These numbers are believed to include 80 percent of all sandpipers in Mud Bay at the time of each census. Note that peak numbers were recorded on 6 May, the same day the peak number of "small sandpipers" were recorded in Fox River aerial surveys (Fig. 7). Results of aerial surveys at three sites in western Cook Inlet are shown in Figure 3.

B. Banding and Marking

On Kanak Island 279 Western Sandpipers were captured, banded, and marked. Only two Dunlins were captured and processed; about 25 additional sandpipers of miscellaneous species were captured and banded (not color-marked).

Color-marked Western Sandpipers which were resighted after their release on Kanak Island are listed, along with the interval between release and resighting, in Table 2. No color-marked Western Sandpipers were resighted off of Kanak Island in the C-BRD system or elsewhere. No banded westerns were recaptured live on Kanak Island, although two were shot.

These two Western Sandpipers had been on Kanak Island 3 and 4 days, respectively, and showed -0.5 g and +6.0 g weight changes, respectively. Additionally, a single banded Least Sandpiper (*Calidris minutilla*) was recaptured 3 days after its initial capture and release. It showed a weight loss of 0.5 g.

C. Food Habits

Stomach contents from all specimens, with the exception of those from Capes Espenberg and Krusenstern, have been sorted, and most identifications are complete. Final identifications and data analysis are underway.

Figure 8 shows the percent composition on a numeric basis of food items in the stomachs of Western Sandpipers and Dunlins from Hartney Bay and the Fox River flats at Kachemak Bay. Macoma balthica predominates in the Dunlin stomachs at both locations, while Western Sandpipers, particularly at Hartney Bay, show considerable diversity in prey selection (at least as represented by remains in stomach).

D. Analyses of Specimens

Fresh, whole weights

Fresh, whole weights of Dunlins and Western Sandpipers collected in the C-BRD system and at Kachemak Bay are shown in Table 3. Weights of 1976 specimens were reported in Senner and Norton (1977).

Between Kanak Island and Hartney Bay, both female Dunlins and Western Sandpipers showed significant weight gains. Males of both species showed weight gains too, although in both cases the differences were not significant (small sample sizes were a problem here).

Mensural characters

Analyses of culmen and wing lengths for 1976 and 1977 are not yet complete. Table 4 presents the mean culmen lengths of 1976 and 1977 specimens collected at Bodega Bay, CA (Fig. 2) and in the C-BRD system. The Bodega Bay specimens were collected by P. G. Connors in 1976.

Comparisons of values within years indicates two "anomalous" values. Culmen lengths for Dunlin males at the Eyak River in 1976 are significantly ($P < .05$) longer than samples from Bodega and Hartney Bays. Male Western Sandpipers at Hartney Bay in 1976 have significantly shorter ($P < .05$) culmen lengths than males at the three other locations.

Also of interest are changes in mean culmen lengths over time through the migration period. As an example, Table 5 presents mean culmen lengths for Dunlin males before and after 10 May 1976 at three locations in the C-BRD system. Although sample sizes are small, note the longer culmen lengths in the later period and that there are no significant differences in the mean values between the three sites, within the respective periods. Note also the narrow ranges of the values in the later period.

Total calcium

Calcium digests are complete on all 1976 specimens from the C-BRD system. The data are not yet summarized and analyzed. Percent Ca values ranged from 2.147 to 5.510 percent of dry carcass weight for both Western Sandpipers and Dunlins (both sexes), more than a twofold difference. However, a cursory inspection of the data does not reveal any obvious trends or differences between species, sexes, or among locations.

Lipid levels

Lipid extractions are complete on all 1976 specimens from Bodega Bay and the C-BRD system. Calculations of fat indices (g fat/g fat-free dry wt) allows comparison between populations and species. Mean fat indices for all completed specimens are shown in Table 6.

Within the C-BRD system, lipid levels as reflected in the mean fat indices do not differ significantly among Western Sandpipers of either sex. Values for westerns at Bodega Bay are about the same in males and lower in females.

For Dunlins, Bodega Bay values are higher than those at Kanak Island, significantly so ($P < .05$) for female Dunlins. Mean fat indices for both sexes are higher at Hartney Bay than at either Kanak Island or the Eyak River.

Comparing the species at the western end of the C-BRD system, Hartney Bay, Dunlins of both sexes are significantly ($P < .05$) more fat than westerns of the respective sexes.

Fatty acid signatures

Thin layer chromatographic separations of total extracted lipids to obtain triglycerides for fatty acid analysis are partially complete. Only a few fatty acid signatures have been obtained and no trends are yet evident.

VII. Discussion

Trophic relationships

Trophic relationships of Western Sandpiper and Dunlins are considered in detail in Senner (1977). Data presented in Figure 8 are consistent with those in Senner (1977). Dunlins in the C-BRD system prey most heavily on Macoma balthica, an abundant intertidal mollusc which is susceptible to the effects of oil pollution (Shaw et al., 1975; Taylor et al., 1976). Western Sandpipers take some molluscs, including M. balthica, but also a variety of other intertidal invertebrates.

No previous food habits study had been conducted for these sandpiper species at Kachemak Bay, and the results there are similar to those reported for the C-BRD system. Note that two-thirds of the Western Sandpipers collected at the Fox River flats had eaten M. balthica, and on a numeric basis, they accounted for 30(+) percent of the western's diet. Analysis of the stomach contents of Mud Bay sandpipers will provide a more complete picture of Kachemak Bay trophic relationships.

Migration dynamics

Reports by Senner (1977; in prep.) and Senner and Norton (1977) have begun to complete a "picture" of spring migration in which the C-BRD system is placed in the context of an entire annual cycle. Gill (1978) has contributed greatly to our understanding of fall migration for Western Sandpipers and Dunlins. Following is a brief discussion of the results reported above as they contribute to our understanding of the dynamics of migration.

Based on museum and other specimens, Senner (in prep.) showed that mean body weights of Dunlins increased with time during migration along the Pacific Coast, while weights of Western Sandpiper showed little change. Dunlins, and probably Western Sandpipers too, are believed to make overwater flights from the Vancouver area to the C-BRD system (Senner, in prep.). However, Senner (in prep.), hypothesized that in general, Western Sandpiper migration was characterized by short "hops" relative to the longer flights of Dunlins. Gill's (1978) recoveries of marked birds showed these generalizations to be true for Dunlins and Western Sandpipers during fall migration.

The fact that the mean fat indices for Western Sandpipers at Bodega Bay are the same as, or lower than, values from within the C-BRD system (Table 6) suggests that Bodega westerns are not making long overwater flights originating at Bodega Bay. They probably continue at least as far as Vancouver, where their high mean whole weights (Senner, in prep.) suggest greater fat reserves. Dunlins, on the other hand, having high fat reserves (Table 6) at Bodega Bay, may well be able to leave directly for the Alaskan coast. This is apparently what some do, in reverse, during fall migration (Gill, 1978). Further work with flight range estimates based on known or estimated fat reserves (after McNeil and Cadieux, 1972) will be useful in clarifying this matter further.

Senner (in prep.) and Senner and Norton (1977) proposed that Dunlins enter the C-BRD system with depleted fat reserves, move from east to west across the system, and leave the west end of the system with replenished fat reserves (based on changes in whole weights). Western Sandpipers were also believed to enter the system with depleted reserves, but in 1976 they showed no gain in weight across the C-BRD system.

Lipid analysis of 1976 specimens showed that lipid levels generally paralleled changes in whole weights. Assuming this relationship holds for 1977 specimens, Western Sandpipers in 1977 will show an increase in fat reserves across the C-BRD system. To what the difference between 1976 and 1977 weight patterns can be attributed is not known. One environmental factor which differed, however, is the amount of snow and ice cover. As noted in the results, there were extensive fresh and brackish water sites available for feeding purposes, thus enabling Western Sandpipers to feed regardless of the tide cycle (cf. Senner, 1977).

Fundamental to our hypothesized pattern of movement and weight deposition across the C-BRD system is that we are sampling members of the same population at each site. For this reason morphometric measurements such as culmen lengths may be important (cf. Evans, 1964). Culmen measurements for female Dunlins and Western Sandpipers are essentially the same at Bodega Bay and within the C-BRD system (Table 4). In the males of both species, these are some anomalous values (mauri bills are short at Hartney Bay and alpina bills are long at the Eyak River). A combination of small sample sizes and the timing of specimen collections may account for these deviations. Note in Table 5 that mean culmen lengths in Dunlin males were longer after 10 May, the period when the 7 males were collected at the Eyak River. Furthermore, within the later time period, the mean values at the three sites do not differ significantly ($P > .05$).

Although these considerations may explain the anomalous values, at present it is prudent to conclude that the culmen length data neither support nor refute the assumption that the same populations are being sampled at different sites. The data in Table 5 do, however, raise the intriguing possibility that within the Dunlin subspecies pacifica there are populations with different culmen lengths passing through the C-BRD system at different times. This is not implausible as work in progress by Senner and Schamel (IAB, Univ. of Alaska) suggest that different breeding populations of pacifica have different culmen lengths. This prospect will be examined in more detail as data analysis proceeds.

The fact that of the two Western Sandpipers marked and later collected at Kanak Island, one had gained 6 g, indicates the potential for remaining at a single site and replenishing fat reserves. Turnover rates at Kanak Island ranged from 0 or 1 to 4 days, with 4 days likely being a maximum stop caused, in part, by trauma associated with the capture and handling of the individual birds (cf. Thompson, 1974).

Since no marked sandpipers were seen after leaving Kanak Island, we, again, cannot say whether these same birds stopped elsewhere in the C-BRD system. That no marked birds were seen again is not particularly surprising considering the probability of spotting one of 279 marked birds among millions of birds scattered through the vast C-BRD system. However, it is certainly possible that some birds make only a single stop in the system. A "decision" to stop once, or several times, might well hinge on a variety of variables - e.g., physiologic status, weather, and feeding conditions.

Based on estimated flight range potentials of sandpipers at Hartney Bay (birds believed to be ready to leave the system) Senner (in prep.) predicted that Western Sandpipers would need an intermediate stop(s) at sites such as are found in lower Cook Inlet before reaching breeding grounds in western Alaska. It was predicted that Dunlins, on the other hand, had no need of intermediate stops and, thus, would be poorly

represented among the small sandpipers surveyed at Kachemak Bay. Our 1977 surveys in Kachemak Bay indicate that the sandpiper flocks overwhelmingly consisted of westerns (Fig. 6). For example, at Mud Bay on 6 May there were an estimated 25,000 westerns compared to only 600 Dunlins (6 May was the peak day in Kachemak Bay).

Whether the Western Sandpipers stopping in lower Cook Inlet can account for the millions using the C-BRD system is unknown. With the exception of limited survey work in 1976 (Erikson, 1977) and 1977 (this study), Lower Cook Inlet is essentially unstudied so far as shorebird migrations are concerned. This may change as Paul Arneson, Alaska Dept. of Fish and Game, is planning a survey program on lower Cook Inlet's west side during early May 1978.

VIII. Conclusions

Western Sandpipers and Dunlins arrive in the C-BRD system with depleted fat reserves, having made long, probably nonstop, overwater flights from the Puget Sound-Vancouver area (perhaps from points farther south for some Dunlins). In "normal" years, when snow and ice cover the supratidal wetlands, the sandpipers are largely confined, for feeding, to the intertidal zone of the C-BRD system. Both Westerns Sandpipers and Dunlins prey on a variety of intertidal invertebrates, with Dunlins relying most heavily on Macoma balthica.

Within the C-BRD system, movements are generally from east to west across the system. Many birds probably stop several times to feed before leaving the western end of the system, although some birds may only stop at a single site before leaving the area entirely. Turnover rates at Kanak Island for Western Sandpipers are a maximum of four days, and general observations suggest this is true elsewhere in the C-BRD system.

Western Sandpipers at the western extreme of the C-BRD system are less fat than are Dunlins and appear to make use of intermediate stopping points such as Kachemak Bay. Most Dunlins probably fly directly, non-stop, from the C-BRD system to the Bering Sea coast.

Although there are still many unanswered questions regarding the spring migrations of those two, congeneric sandpiper species, application of the critical habitat criteria proposed by Senner (1977) leads to a conclusion that the C-BRD system is a critical habitat in the annual cycle of both Dunlins and Western Sandpipers.

IX. 4th Quarter Operations

Laboratory work in the fourth quarter included the processing of all stomach contents samples (1977), with the exception of those from specimens collected at Capes Espenberg and Krusenstern. Lipid and calcium extractions on all 1976 specimens were completed; analyses of 1977 specimens were initiated.

Laboratory work remaining includes final identification of some organisms found as stomach contents and processing samples from Espenberg-Krusenstern specimens (about 25 total). Lipid extractions on all 1977 specimens will be completed. Calcium and fatty acid analyses will be performed on a subsample of specimens.

A few days of field work are planned for spring migration, 1978. Personnel will be located at Hartney Bay, southwest of Cordova, during the first 10 days of May, to band and color-mark Western Sandpiper and Dunlins. We hope to gain further insights into turnover rates at the western extreme of the C-BRD system.

Project completion, including submission of final reports, is targeted for 30 September 1978. A milestone chart is shown in Figure 9.

As of March 1978, approximately \$22,900 out of \$26,000 had been spent.

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Table 1. Specimens collected in 1977 field season.

	<u>C-BRD System</u>		<u>Kachemak Bay</u>		<u>Y-K</u> <u>Delta</u>	<u>Northwest Ak</u>	
	<u>Kanak Island</u>	<u>Hartney Bay</u>	<u>Fox River</u>	<u>Mud Bay</u>	<u>Hooper Bay</u>	<u>Cape Espenburg</u>	<u>Cape Krusenstern</u>
Dunlin	23	34	3	4	2	14	6
Western Sandpiper	20	32	15	14	1	4	12

Table 2. Summary of color-marking activity and results on Western Sandpipers on Kanak Island, May 1977.

Date/Time [†] (May 1977)	Number Color-Marked w/Feather	Feather Color	Number Resighted (feather color)	Number Dif- ferent Indiv- iduals Resighted	Days Elapsed Since Capture - Initial Release (min-max)
1/12:00	28	white	-	-	-
2	10	white	4-5 (white)	at least 2	0-1
4/04:15	9	yellow	-	-	-
5	2	yellow	-	-	-
7	12	yellow	-	-	-
9	19	yellow	-	-	-
10/09:00	15	red	1 (red)	1	0
11	60	red	-	-	-
12	30	red	1 (red)	1	0-2
13/09:15	39	orange	2 (red)	2	1-3
14	20	orange	1 (orange)	1	0-1
			1 (red or orange)	1	0-4
/12:00	11	turquoise	2* (red)	2	4 and 3
15	24	turquoise	-	-	-
16	-	-	1 (turquoise)	1	1-2

[†]Time at which a "new" feather color was first used.

*Collected

Table 3. Fresh, whole weights of Dunlins and Western Sandpipers collected in the C-BRD system and Kachemak Bay in 1977.

Sex	Location:	C-BRD System			Kachemak Bay
		Kanak	Hartney		(both sites lumped)
Western Sandpiper					
M		25.4 ± 1.90 ¹ (7)	27.4 ± 1.92 (9)	*	30.0 ± 2.95 (11)
F		27.0 ± 1.37 * (13)	28.8 ± 2.81 (20)	*	31.5 ± 2.21 (18)
Dunlins					
M		53.8 ± 5.67 (7)	56.6 ± 5.63 (14)		56.3 ± 5.07 (4)
F		56.5 ± 4.51 * (14)	64.8 ± 7.27 (18)		64.0 ± 2.65 (3)
<hr/>					
¹ $\bar{x}$ SD (N)					

* Respective pairs of values significantly different ($P < .05$) as determined by t-test.

Table 4. Mean culmen lengths of Dunlins and Western Sandpipers collected in 1976 and 1977 at Bodega Bay, CA, and in C-BRD system.

	Bodega Bay	Kanak		Eyak	Hartney	
Sex	1976	1976	1977	1976 only	1976	1977
Dunlin						
		*				
M	37.1 ± 1.28 ¹ (7)	37.3 ± 1.91 (18)	37.2 ± 1.76 (8)	38.7 ± 0.89 (7)	* 36.8 ± 1.32 (25)	36.7 ± 0.95 (14)
F	40.4 ± 1.14 (4)	41.2 ± 1.73 (18)	39.7 ± 1.29 (14)	40.5 ± 1.40 (7)	40.9 ± 1.50 (31)	40.6 ± 1.72 (17)
Western Sandpiper						
		*				
M	23.2 ± 0.91 (12)	23.3 ± 0.94 (41)	23.3 ± 0.55 (6)	23.3 ± 1.39 (16)	* 22.2 ± 0.83 (11)	22.5 ± 1.10 (11)
F	27.0 ± 1.10 (9)	27.2 ± 1.10 (27)	26.4 ± 1.00 (14)	27.1 ± 0.97 (11)	27.4 ± 1.38 (7)	26.0 ± 1.20 (20)

¹ $\bar{x}$ (mm) ± SD
(N)

*Respective pairs of values significantly different ($P < .05$) as determined by t-test.

Table 5. Mean culmen lengths of male Dunlins in the C-BRD system in 1976. The migration period is divided into two intervals for comparative purposes.

Date	Location	N	$\bar{x}$	SD	Range (mm)
1-10 May	Kanak Island	15	37.0 ± 1.93		33.0 - 40.1
11-22 May		3	38.9 ± 0.78		38.0 - 39.5
1-10 May	Eyak River	-	-		-
11-22 May		7	38.7 ± 0.88		37.7 - 40.0
1-10 May	Hartney Bay	18	36.3 ± 1.25		32.7 - 38.2
11-22 May		9	37.6 ± 1.13		36.0 - 39.7

*Pair of values significantly different ($P < .05$)

Table 6. Mean fat indices (g fat/g fat-free dry wt) of Dunlins and Western Sandpipers at Bodega Bay, CA and in C-BRD system (1976 specimens).

Sex	Bodega	Kanak	Eyak	Hartney
Western Sandpiper				
M	0.30 ± 0.222^1 (12)	0.39 ± 0.166 (41)	0.33 ± 0.115 (16)	0.24 ± 0.085 (11)
F	0.13 ± 0.067 (9)	* 0.29 ± 0.158 (27)	0.33 ± 0.161 (11)	0.32 ± 0.111 (7)
Dunlin				
M	0.48 ± 0.266 (7)	0.35 ± 0.121 (18)	0.31 ± 0.062 (7)	* 0.54 ± 0.222 (25)
F	0.64 ± 0.082 (4)	* 0.31 ± 0.112 (18)	0.33 ± 0.154 (7)	* $0.53 \pm 0.197^*$ (31)

$\bar{x} \pm SD$
(N)

*Respective pairs of values significantly different
($P < .05$) as determined by t-test.

Fig. 1. Map of Copper-Bering River Delta system. Primary study sites were located at (from east to west) Kanak Island, the mouth of the Eyak River, and Hartney Bay.

Fig. 2. Map of the western coast of North America.

Fig. 3. Map of Lower Cook Inlet showing areas surveyed in 1977 and number of small shorebirds seen on three surveys on the west side of the inlet.

Fig. 4. Relative abundance of different shorebird species at Hartney Bay. Includes all censuses of two transects between 1 and 16 May 1977. N = 6,961 birds. "Other" category includes Semipalmated Plover (Charadrius hiaticula), Ruddy Turnstone (Arenaria interpres), Sanderling (Calidris alba), and Whimbrel (Numenius phaeopus).

Fig. 5. Estimated peak daily numbers of all shorebird species at Hartney Bay during spring migration, 1976.

Fig. 6. Number of Western Sandpipers and Dunlins recorded on censuses of intertidal transect at Mud Bay, Kachemak Bay, 1977.

Fig. 7. Number of small shorebirds estimated on aerial surveys of the Fox River flats, Kachemak Bay, 1977.

Fig. 8. Stomach contents of Dunlins and Western Sandpipers collected at Hartney Bay and the Fox River flats during spring migration, 1977. Contents are expressed as percent composition of total food on a numeric basis. Slashed bars show the sum of food items which, individually, comprise less than 5 percent of total food items. Numbers within the bars indicate stomachs in which the respective taxa were present.

Fig. 9. Milestone chart for work remaining in FY78.