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DISTRIBUTION AND BIOLOGY OF
SEMIPALMATED SANDPIPERS AND WESTERN SANDPIPERS
IN ALASKA

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INTRODUCTION

The two small shorebirds Semipalmated sandpiper (Calidris pusilla) and Western Sandpiper (C. mauri) comprise a pair of species in which at least one member is among the most common shorebirds during summer at all lowland coastal sites from the southern Bering Sea north and east along the Chukchi and Beaufort Coasts into Canada. They are highly migratory, occurring in other seasons on both coasts and at many interior sites of temperate North America and at coastal locations in Central and South America. They are similar in size, appearance, behavior and ecology, and often occur in the same or similar habitats during breeding, migration and winter seasons. In Alaska these include habitats which are vulnerable to environmental damage associated with coastal oil and gas development; it is therefore of interest to summarize our knowledge of their distribution and natural history. These two species share many characteristics, such as timing of movements, habitats, diets and foraging behavior to varying extent with several other shorebird species, especially Ruddy and Black Turnstones (Arenaria interpres and A. melanocephala), Baird's and Pectoral Sandpipers (Calidris bairdii and C. melanotos), Dunlin (C. alpina), and Long-billed Dowitcher (Limnodromus scolopaceus). In some degree therefore, an analysis of the environmental problems facing semipalmated and western Sandpipers can serve as a partial model for these other species.

This report will explore two themes: that the two species are remarkably similar in many aspects of their ecology, and are probably the most closely related of North American sandpipers; and conversely, that they differ in many respects, as befits two forms which are specifically distinct. Nesting ecology and behavior of each species has been studied in depth by different workers at sites where only one species is common; we report here a more direct comparison of the species arising from studies within the overlap range where both are common.

TAXONOMY

Semipalmated Sandpipers and Western Sandpipers are among the smallest of the shorebirds or waders (Charadriiformes: Charadrii: sandpipers, plovers and their close relatives) and are placed in the family Scolopacidae, tribe Calidridini with many other sandpipers (A.O.U. 1983). The two forms are consistently considered closest relatives by taxonomists, with some Russian authors even questioning their separation as different species (Kuzyakin 1959, Portenko 1981). There seems little doubt, however, of their status as separate species, but their close relationship has been recognized by Larson (1957) as constituting a species pair, by Mayr and Short (1970) as a species group, and by Johnsgard (1981) as a superspecies.

These classifications all suggest a recent **evolution** from a common ancestor.

DESCRIPTIONS

Both species are small, with most Individuals weighing between 20 and 40 grams (Irving 1960; Johnsgard 1981}. Adult Western Sandpipers average slightly heavier than **Semipalmated** sandpipers at the same breeding site (see Table 1)0 wing length is similar in both species (Ouellet et al. 1973, Prater et al. 1977, Johnsgard 1981), but culmen (bill) and tarsus length of Western sandpipers average longer (Table 1). Size comparisons such as these are meaningful only when dealing with local breeding populations, since size of **Semipalmated Sandpipers** varies significantly across the species' range, with maximum sizes measured in birds from eastern Canada. East of Hudson Bay **Semipalmated** sandpiper culmen lengths average 20.46 mm, 13% longer than the average for Alaska (Barrington and Morrison 1979). In addition, both species exhibit sexual variation in size, with females larger than males (Page and Fearis 1971, Prater et al. 1977; Table 2). Sexual size dimorphism is greater in Western Sandpipers, and except for culmen length, size differences between sexes in the same species are comparable to size differences between species in the same sex. Plumage descriptions and drawings of both species can be found in many sources (See Peterson 1980, Stout 1967, Prater et al. 1977, Johnsgard 1981). Adults are easily separated in breeding plumage by the more russet coloration of much of the back of the Western sandpiper and by the more definite and extensive dark streaking on the flanks and sides of the breast of the Western Sandpiper. Juveniles can be distinguished also, but with more difficulty: Western Sandpipers in this plumage also show more reddish coloration on the back and head. However, birds in winter plumage are very difficult to separate on the basis of plumage alone. Bill measurements serve to separate most individuals (Ouellet et al. 1973), but this is less useful as a field mark except for extreme sizes. Especially in eastern North America where longer-billed **Semipalmated** sandpipers are common, separation is difficult and has led to many misidentifications (Phillips 1975).

DISTRIBUTION AND ABUNDANCE

The **Semipalmated** Sandpiper breeding range is more easterly and much more extensive than that of the Western sandpiper, stretching across much of northern Canada as well as Alaska. The ranges overlap across much of northwest Alaska, with both species breeding regularly at least from the Yukon Delta to Barrow (Figure 1). Recent studies have expanded the known breeding ranges and have added significantly to our knowledge of species abundances within the region of sympatry where both species nest.

Table 1. size comparison of adult **Semipalmated** Sandpipers and Western Sandpipers on breeding grounds at cape **Krusenstern, Alaska**. Equally weighted means of both sexes. All birds trapped in pairs at nests or collected between 23 **June** and 3 **July** 1978. From Connors (unpublished).

	<u>88, n=17</u>	<u>WS, n=19</u>	<u>WS:SS</u>
Weight	26.6 gm	28.9 gm	1.088
Tarsus length	22.48 mm	23.59 mm	1.049
Culmen length	18.45 mm	24.63 mm	1.335

Table 2. Sexual dimorphism in **Semipalmated** and Western Sandpipers. Ratios of female:male lengths.

	Semipalmated¹	Western²
Wing	1.022	1.029
Tarsus	1.041	1.061
Culmen	1.089	1.137

1 Means of values from Ouellet et. al. 1973, Prater et. al. 1977, Barrington and Morrison 1979.

2 Means of values from Ouellet et. al. 1973, Prater et. al 1977, Page and Fearis 1971.

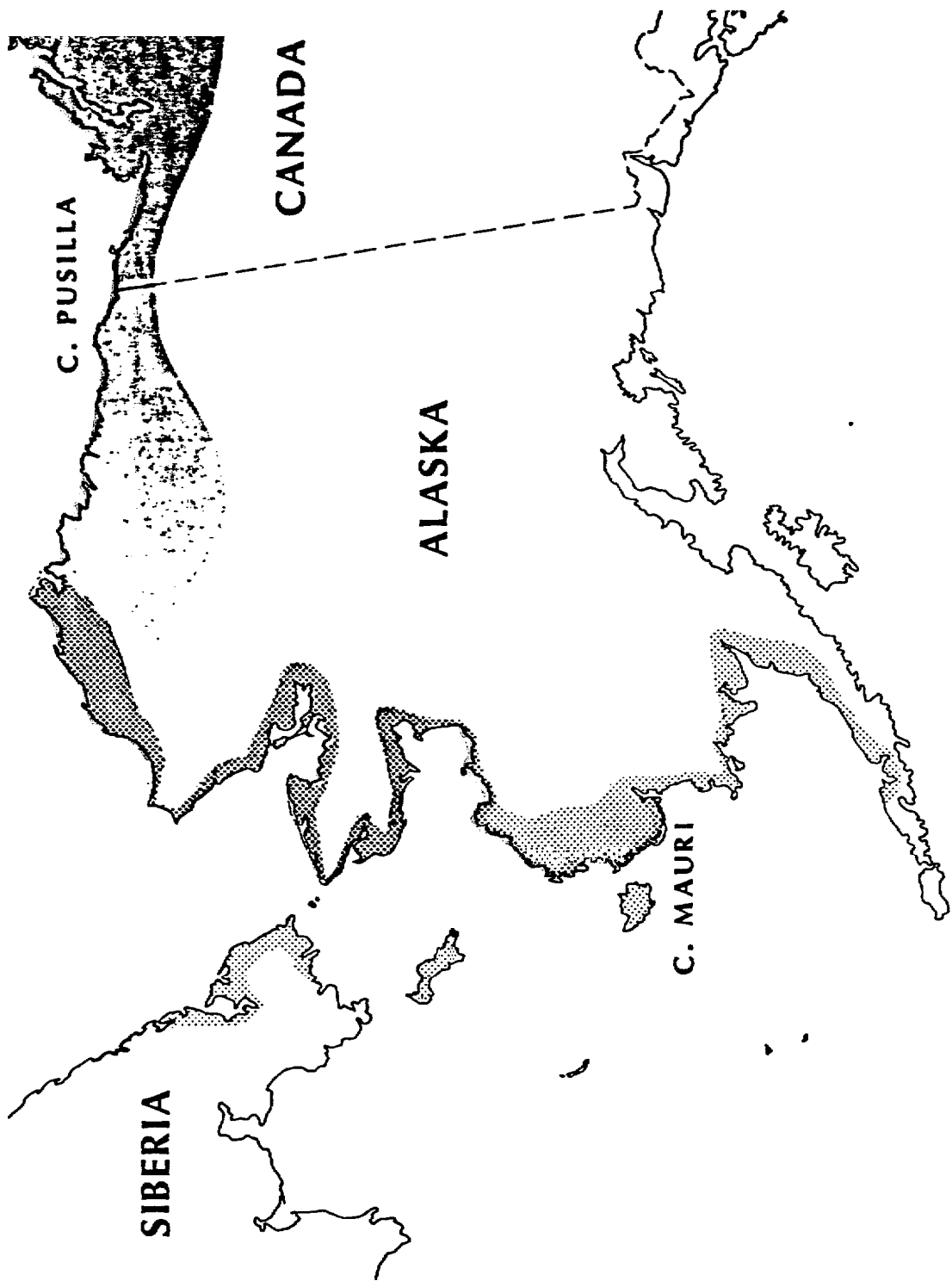


Figure 1. Breeding ranges in Alaska. Western Sandpiper, dotted; Semipalmated Sandpiper, shaded.

Western Sandpipers nest from the Alaska Peninsula at Nelson Lagoon, where they are widespread (Gill et al. 1981), north along the coasts of the Bering and Chukchi Seas to Barrow and Atkasook, 80 km inland on the Meade River, where they are regular breeders (Pitelka 1974, Myers and Pitelka 1980). They nest regularly on the northeastern Chukchi Peninsula of Siberia (Portenko 1981), and on Nunivak, St. Matthew, and St. Lawrence Islands (Gill and Handel 1981). They may also nest occasionally outside of this range, and are listed as having nested at Camden Bay on the Beaufort coast (American ornithologists' union 1983), but this record, although widely reported in numerous publications during the past half century, is probably a mistake. I can find no original report for this observation, but do note that Gabrielson and Lincoln (1959) misinterpreted Anderson (1915) as having collected the species at Camden Bay. Actually, Anderson's specimens were from Teller on the Bering seacoast and were included in a report dealing also with Camden Bay. Furthermore, in recent years field workers at many North Slope sites east of Barrow and Atkasook have always failed to find evidence of Western Sandpiper breeding, although occasional individuals have been sighted, including two birds in June near the Atigun River in the North slope foothills (Sage 1974).

Semipalmated sandpipers nest in Alaska from the mouth of the Kuskokwim River (Gill and Handel 1981) north and east along the Bering, Chukchi and Beaufort coasts, the North slope, and in the Brooks Range (Anaktuvuk Pass: Irving 1960), and widely in the Canadian arctic and subarctic east to northern Labrador (Godfrey 1966). Thus, the two species are sympatric breeders over a large portion of the Western Sandpiper's breeding range, but a much smaller portion of the Semipalmated Sandpiper's range.

Nesting densities of both species at several Alaskan sites are presented in Table 3. Measured densities depend critically on the habitats included in study plots and therefore may not reflect regional averages. I have included ranges of densities measured on different habitat plots at a site when densities vary widely. The highest recorded densities of either species are those measured by Holmes (1971) for Western sandpipers on a study area consisting of islands of heath tundra surrounded by marsh foraging areas in the Yukon Delta. At that site nesting birds did much of their foraging away from the study area, so densities based on total habitat use were undoubtedly less. In a similar habitat situation at Cape Krusenstern, Semipalmated Sandpiper densities approached 'those densities, and total density of both species combined was" even greater.

since the preferred nesting habitat of Western Sandpipers is much more extensive in the Yukon Delta than elsewhere in the species' range, this area represents a major portion of the total breeding population, and in this area Semipalmated Sandpipers are restricted to a coastal strip, which

Table 3. Breeding densities of **Semipalmated(SS)** and western Sandpipers in Alaska. **Nests** per km². **Ranges** indicate **densities** measured in different habitats.

	SS	WS	References
Kolomak River, Yukon-Kuskokwim Delta	0	220-285	Holmes 1971
NE Norton Sound	73	14	Shields and Peyton 1979
Wales	0	68	Hirsch and Woodby 1978
Arctic River, Shismaref	49	29	wright 1979
Cape Espenberg	8-74	4-60	Schamel et. al. 1979
Cape Krusenstern	11-183	9-150	Connors and Connors 1978 Connors et. al. 1979 Connors, unpublished
Cape Thompson	0-23	0-37	Williamson et. al. 1966
Atkasook, Meade River	29	27	Myers and Pitelka 1980
Barrow	1-29	0-1	Myers and Pitelka 1980
Prudhoe Bay	15-40	0	Norton et. al. 1975 TrOy et. al. 1983
Franklin Bluffs	4	0	Jones et. al. 1980 McCaffery et. al. 1982
Ginning River Delta	0-24	0	Martin and Moiteret 1981
Okpilak River Delta	0-6	0	spindler 1978

reduces or eliminates contact between the species. At sites from Norton Sound to Atkasook, densities of both species vary widely depending on habitat, but ranges of density are similar, and surprisingly often, nearly equal. On the coast at Peard Bay near the Western Sandpiper range limit, these species were the 3rd and 4th most common shorebirds in June 1983, and rough estimates of breeding densities at two sites put both species at similar densities in the range of those at Atkasook. The region of roughly equal sympatry thus extends over about six degrees of latitude and almost one-half the range of the Western Sandpiper.

MIGRATION

Semipalmated and Western Sandpipers, like all other arctic shorebirds, are long-distance migrants. Migration routes of these two species are comparatively well known, although difficulties of identification, particularly in winter plumage, have caused confusion to persist concerning wintering areas (Phillips 1975). Ranges of the two species overlap in winter in parts of Central and south America. Western Sandpipers winter on the pacific coast from California south to central south America and along the Atlantic and Caribbean coasts from the southeastern united States to northern South America (Johnsgard 1981). Semipalmated Sandpipers winter primarily on both coasts of South America south to Argentina and Peru, and to a lesser extent on the Pacific coast of Central America north to Guatemala and on some Caribbean islands (Phillips 1975).

Post-breeding migration begins in July and August, with dates depending on species, age class and geographic location. In general, Semipalmated sandpipers leave breeding grounds earlier than Western sandpipers; adults depart before juveniles; and southerly populations begin migration before northerly populations, although migrant densities at southern or "downstream" sites may peak later because of passage of other populations.

Adults of both species leave breeding grounds soon after nesting duties are over, in late June to late July. Their appearance in shoreline habitats at this time is brief and of lower density than the subsequent movements of fledged juveniles to these same migration habitats. At a site, adults of both species appear to begin migration on similar schedules, as expected since their nesting phenologies are similar, but Western sandpiper adults remain at some arctic sites in littoral habitats later than Semipalmated Sandpiper adults, most of whom have departed by about 25 July at Barrow (Connors et al. 1981) or 15 July at cape Krusenstern. Juvenile migration is much more noticeable in arctic and subarctic littoral habitats. Both species move from tundra to mudflats, saltmarshes, lagoon, stream and

slough edges soon after fledging (Connors et al. 1979). The Semipalmated Sandpiper juvenile movement at arctic sites is striking, as juvenile sandpipers suddenly appear in high density (2 to 5 birds/ha) in these habitats overnight. It is short-lived, however, and densities taper off within a few days. Almost the entire movement at Beaufort sites is contained within a period of 10 to 15 days centered around the last week in July or first week in August (Connors et al. 1981). Peak dates vary among years, ranging from 23 July to 5 August over 4 years at Barrow. Within one year, peaks at different sites vary, but this variation may be consistent. In 1978, peaks at Cape Krusenstern, Barrow and Prudhoe Bay progressed in that order at about 5-day intervals. The timing may have been due to differences in breeding season phenology or to sequential passage of this west to east migrant. At the southern limit of Semipalmated Sandpipers range in the Yukon-Kuskokwim Delta, this movement to littoral habitats as the first step in southward migration is not noticeable (Gill and Handel 1981). At this point all Semipalmated Sandpipers must be migrating eastward to the interior or northward, then eastward, along the Alaska coast. North of the Yukon Delta and Norton Sound, Shields and Peyton (1979) recorded a significant movement of Semipalmated Sandpipers on river delta mudflats, peaking at the beginning of August 1977.

The movement of juvenile Western Sandpipers into littoral habitats is an echo of the Semipalmated Sandpiper migration, with peak movements occurring after Semipalmated Sandpiper populations have declined. The interval between peak dates of the two species varied between 10 and 18 days over 4 years at Barrow (Connors et al. 1981), was 10 days in 1977 at Cape Krusenstern (Connors and Risebrough 1978), and was 20 days in 1977 at Norton sound (Shields and Peyton 1979). Western Sandpipers departed from Cape Krusenstern at an early date (population peak about 1 August 1977) probably to forage at more extensive mudflat areas elsewhere, such as Kotzebue sound, Seward Peninsula, or Norton Sound, where Western Sandpipers are common throughout August.

Numbers and timing of juvenile movements of both species vary among years, but variations between species at a site are highly correlated. Over 4 consecutive years at Barrow, cumulative densities of both species varied approximately 7-fold, but the timing and magnitude of the juvenile movements corresponded strikingly between species (Figure 2). Both species apparently respond almost identically to the same environmental variation, again suggesting close similarity in nesting ecology and post-breeding ecology.

From Alaska, main migration routes of the two species differ. Western Sandpipers breeding on the Bering sea coast move southeastward along the Pacific coast of North America, after staging at sites on the Yukon-Kuskokwim Delta and Alaska Peninsula' (Gill et al. 1979). Birds nesting

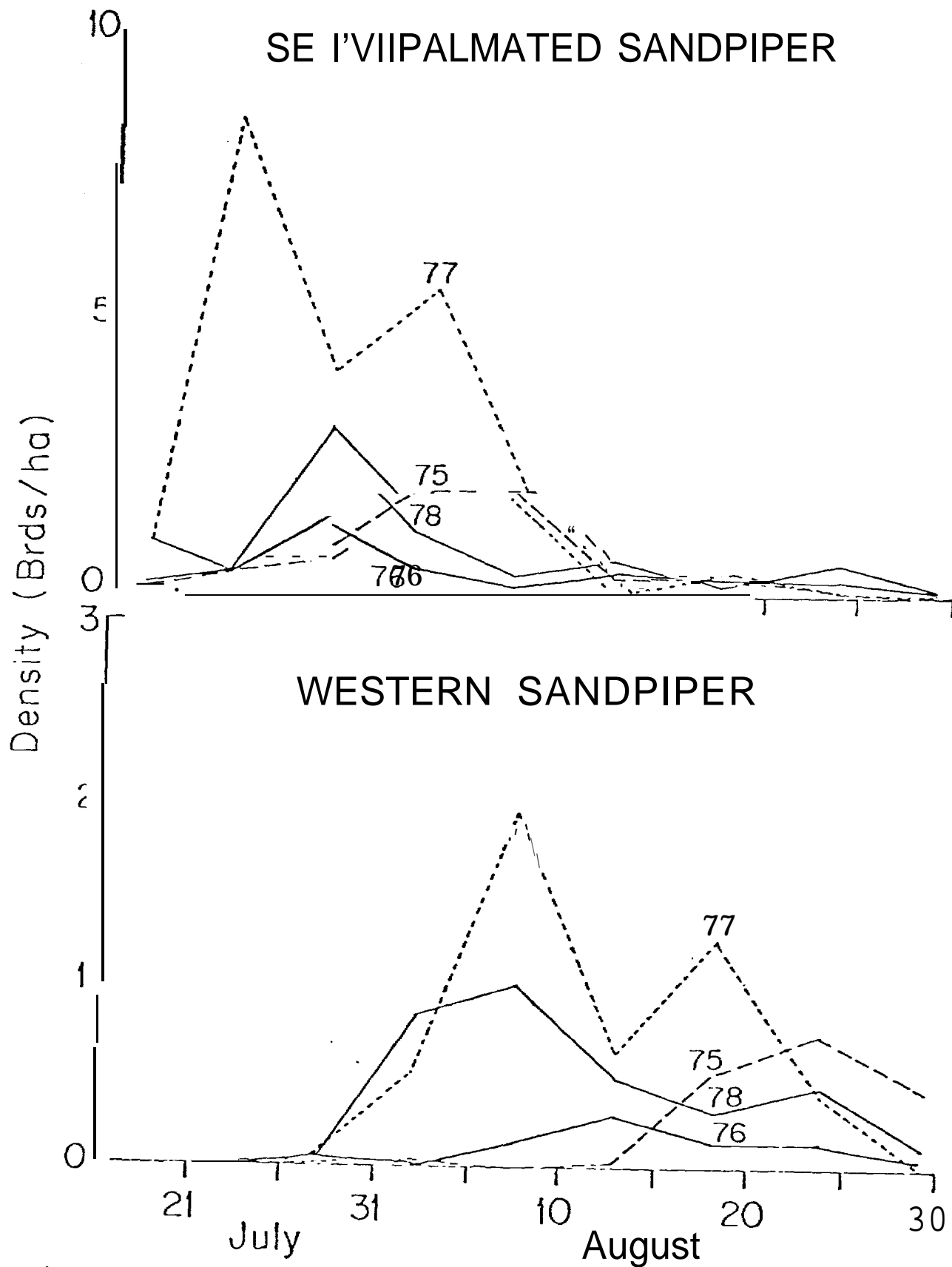


Figure 2. Sandpiper densities in littoral habitats near Barrow, 1975-1978

nesting farther north are believed to move inland from the Chukchi coast and possibly eastward along the Beaufort coast to follow the Mackenzie River drainage south through Canada to the central plains and then to the Gulf of Mexico (Senner and Martinez 1982). Some birds occur on the Atlantic coast of the United States in autumn. In spring, northward migration shifts westward. Western Sandpipers are abundant spring migrants at sites on the Pacific coast of California, Oregon and Washington, and their concentrations on the Copper-Bering River Deltas in May are enormous, with total passing populations estimated at several million birds (Isleib 1979, Senner 1979). Lower Cook Inlet is also a major stopping point (Senner 1979). Some Western sandpipers also migrate northward through the interior, but numbers are less than in autumn (Senner and Martinez 1982).

Semipalmated Sandpipers from Alaska move southeastward in autumn, migrating principally through the interior of North America, with some birds possibly moving farther east to join Canadian migrants on the Atlantic coast. In spring routes of all populations shift somewhat westward, and -- - Alaskan birds are most common on the Great Plains and in the Mississippi Valley, where they are joined by Canadian populations. Routes of different populations are discussed in Barrington and Morrison (1979). Semipalmated sandpipers banded at Barrow were recovered in Kansas, and one banded in Kansas was recovered near Prudhoe Bay, where it bred (Martinez 1974).

MOLT AND MIGRATION ENERGETIC

Migration schedules in both species are similar, but migration distances differ for some populations, since many Western Sandpipers winter much closer to their breeding grounds than do any Semipalmated sandpipers. As a result, the competing energetic demands of migration and post-breeding molt result in somewhat different molt schedules for the two species. Semipalmated Sandpipers begin their post-breeding molt after they leave the arctic breeding grounds (Holmes 1966), although some body molt takes place during early migration, before they depart southward from staging areas in eastern North America (McNeil and Cadieux 1972). During this early migration period, birds traveling different routes across North America stop at various inland or coastal feeding areas before departing on a long trans-oceanic flight to South America. Their different schedules and different routes place different demands on energy needed for migration. At Long Point, Ontario, Semipalmated Sandpipers accumulate fat during their late summer stopover, but many birds depart with moderate or low fat levels, perhaps to continue a short-hop migration (Page and Middleton 1972). Under these circumstances, body molt may be sustainable during migration. At staging areas for long-distance flight, however, such as the Bay of Fundy on the North Atlantic coast, Semipalmated Sandpipers rapidly increase their fat

levels, nearly doubling their weights before they depart (Hicklin 1983). Under the severe energy demands of preparation for the transoceanic flight to South America, molt may be suspended or delayed (Holmes 1966, McNeil and Cadieux 1972) and post-breeding molt then takes place on the breeding grounds from October to February (Prater et al. 1977). Juveniles leave the arctic with low body fat levels while still in juvenal plumage (Connors et al. 1981), and probably migrate in short stops until they reach major staging areas where they increase fat reserves for long distance migration. In late winter, birds again increase their body fat levels to prepare for northward migration and prenuptial body molt, but fat levels remain less than late summer levels on the Canadian east coast, presumably because the northward migration through the North American interior does not involve such a long trans-oceanic flight (McNeil and Cadieux 1972).

Western Sandpipers traveling to the southern portions of the species' winter range face similar demands on migration energetic, and probably do not molt until they arrive on winter grounds, completing it on the same schedule as Semipalmated Sandpipers (Prater et al. 1977}. However, many Western Sandpipers begin their post-breeding body molt in late June and July on the Yukon Delta, and others begin it soon after they reach wintering grounds on the Pacific coast of North America in late summer (Holmes 1972). Birds which begin molting in Alaska may display arrested molt during the period of rapid southward migration. Molt of flight feathers (remiges and rectrices) does not begin until birds have completed their migration. Juvenile Western Sandpipers, which remain in many arctic and subarctic feeding areas much later than adult Western Sandpipers or juvenile Semipalmated Sandpipers, may increase their premigratory fat reserves during this period, but fat levels of juvenile Westerns collected at Cape Thompson on the Chukchi coast showed no pronounced increase in fat during late July and early August, and levels remained below those of departing adults (Johnston 1964). During spring migration along the Pacific coast of North America, Western Sandpiper weights and presumed fat levels do not vary widely from Mexico northward, except that high weights occur in southern British Columbia, just before a relatively long migration to feeding grounds in the copper River Delta of Alaska (Senner 1979). Weights do not appear to increase significantly within this major feeding area, suggesting that subsequent migration to breeding grounds consists of short hops with intermittent foraging, or that birds migrate independently in such a way that all samples within the Copper River Delta area included newly arrived, light weight migrants (Senner 1979).

HABITATS

Breeding habitats of Western Sandpipers and Semipalmated Sandpipers

differ on average in a way which appears consistent from site to site in Alaska, but the difference is often slight, and both species share the same range of habitats at many sites. The primary distinction relates to the presence of dwarf shrubby heath tundra (Western Sandpiper] compared to grass-sedge tundra (Semipalmated Sandpiper). On the Yukon-Kuskokwim Delta, Western sandpipers nest on heath tundra islands, ridges and low elevation slopes (Williamson 1957, Holmes 1971). vegetation is mainly mosses, " lichens, and species of Betula, Salix, Empetrum, Arctostaphylos, Vaccinium, and Rubus, mixed with some grasses, sedges and forbs. Sandpipers forage extensively in nearby marshy areas. Near Norton sound, Western Sandpipers nest in areas dominated by low Salix species (willows] and also upland tussock tundra (Eriophorum) (Shields and Peyton 1979). At Cape Krusenstern, nests are usually in heath tundra areas, often near sedge marsh and mudflat areas.

Semipalmated Sandpipers at Norton Sound nested in Carex (sedge)-dominated areas (Shields and Peyton 1979), and at Cape Krusenstern some nests occurred in areas of *grass* and sedge without heath tundra nearby. Many nests of both species at this latter site encompassed both kinds of habitat however, and both species foraged on heath tundra and in marsh habitats (Figure 3). At Atkasook, breeding season habitats were similar, consisting of tundra with intermediate characteristics in terms of topographic relief, vegetation density, and extent of ponds (Myers and Pitelka 1980). Western Sandpipers, however, tended to nest in slightly more upland situations.

Microhabitats around the nest sites were different at Cape Krusenstern, even when both species included the same areas within their territories "[Connors, unpublished). Nest sites were distinguished primarily by the *more* frequent presence of woody vegetation near or over the nests of Western Sandpipers. The general conclusion, then, seems to be that both species nest near marsh or mudflat feeding areas or on territories containing these habitats, but if only lowland sedge tundra surrounds these areas, only Semipalmated Sandpipers are likely to breed. If nearby nesting sites consist of better drained heath tundra with low woody vegetation, Western sandpipers are more likely. If the tundra is a well-mixed mosaic of these types, within the geographic range of species overlap, both species may nest commonly, as at Cape Krusenstern. In many areas (Sisualik and Seward Peninsula sites) this distinction results in Semipalmated Sandpipers nesting more commonly in low areas near beaches, lagoons, sloughs and mudflats, with Western sandpipers nesting a bit farther from shorelines on more elevated tundra (B. Kessel, pers. comm.). on the Yukon- Kuskokwim Delta, an extreme is reached, with Semipalmated Sandpipers nesting only in a narrow zone (approximately 100-200m) along the shore, and all Western Sandpipers nesting on heath tundra within the delta area (R. Gill and C.

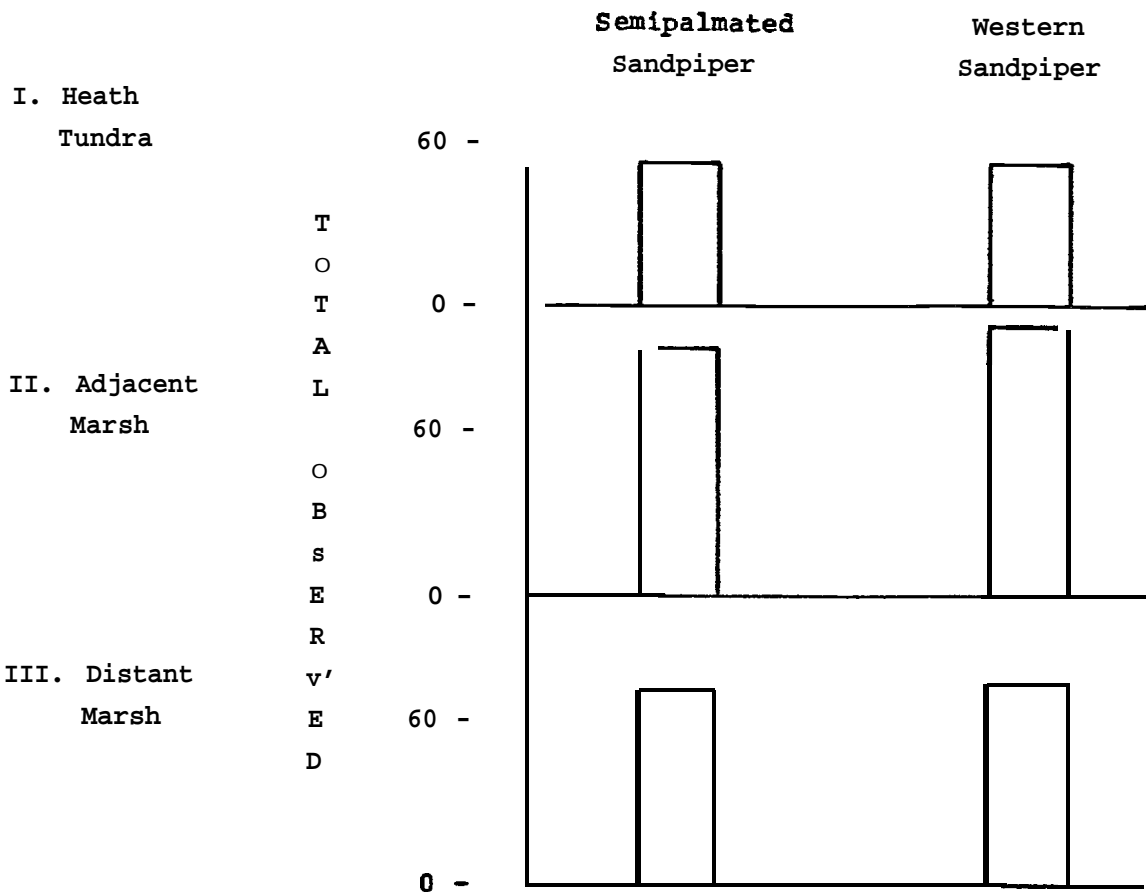


Figure 3. Relative use by 2 species in habitat areas at cape Krusenstern breeding grounds (Connors, unpublished).

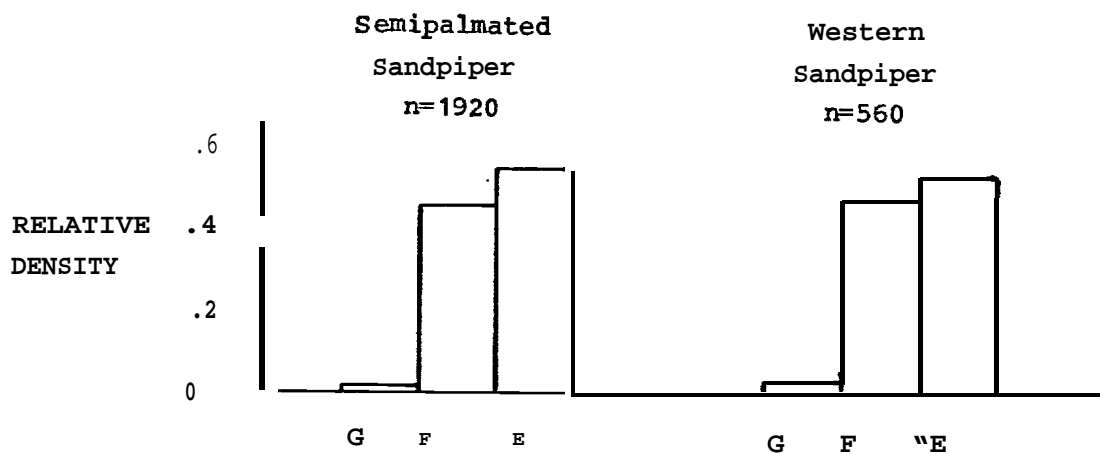


Figure 4. Relative density in littoral habitats near Barrow. G, gravel beach; F, mudflat-saltmarsh; E, lagoon and slough edge (Connors 1984).

Handel, pers. comm.). At other sites, particularly those farther north (Atkasook, Peard Bay), both species are more evenly mixed over the mosaic of tundra habitats.

After breeding activities have been completed, adults and fledged juveniles of both species move from tundra to coastal habitats (Connors et al. 1979). This is apparent for Semipalmated Sandpipers from Norton Sound north and east throughout arctic Alaska, and for Western Sandpipers from the Alaska Peninsula to Barrow, where the species becomes much more common than during the breeding season. At Barrow and elsewhere along the Western Beaufort and northern Chukchi coasts, muddy margins of sloughs and lagoons, and mudflats and muddy pools in saltmarshes attract highest densities, but gravel beaches of seas, lagoons and lakes, as well as some tundra ponds, are also used. Densities in preferred habitats at this time are much higher than tundra nesting densities during the breeding season, because the coastal habitats are more limited in extent. Both species show almost identical habitat use during this period (Figure 4), in marked contrast to the full range of habitat use patterns among Barrow shorebirds (Connors 1984). Foraging microhabitats within these habitats are also similar for the species, but Semipalmated Sandpipers display a tendency to probe in shallower water or farther from the water's edge, in larger grain size sediments, and closer to vegetation (Connors and Risebrough 1977). These differences, however, are slight.

Farther south in Alaska, the extensive mudflat and saltmarsh areas of Kotzebue Sound, Northern Seward Peninsula and Norton sound attract large flocks of both species of adults in July followed by juveniles of both species of adults in July and August, with Western sandpipers consistently later than Semipalmated Sandpipers, as discussed above. South of Norton Sound only Western Sandpipers are conspicuous in post-breeding migration, concentrating on mudflats in the Yukon-Kuskokwim Delta and the Alaska Peninsula (Gill et al. 1981).

Winter and migratory habitats of both species consist primarily of mudflats and beaches, mainly coastal but also in interior wetlands. Here also habitat use is similar, but the longer-billed Western Sandpiper frequently forages in deeper water than the Semipalmated Sandpiper (Ashmole 1970).

REPRODUCTIVE BIOLOGY

Semipalmated sandpiper

Adults arrive unpaired on breeding grounds from mid-May to mid-June, with the earlier arrival dates at southern sites. Males probably arrive before females, and almost immediately after arrival, or as snowmelt exposes tundra breeding areas, they begin territorial advertisement, which consists

primarily of hovering flights accompanied by a monotonous buzzy trill. Territorial birds also engage in ground and aerial chases and occasional fluttering contact fights. At Barrow, pair formation occurred 3 to 6 days after territories were established (Ashkenazie and Safriel 1979a). Semipalmated Sandpipers are monogamous and relatively site-faithful, with adults of both sexes returning to breed on a study site at Prudhoe Bay on which they had previously bred (Norton et. al. 1975). Six of 14 returning birds comprised 3 pairs which had bred together successfully in the previous year, possibly indicating a degree of mate-faithfulness. The nest site is chosen by the female from among several "scrapes" (potential nest sites) established by the male, and the first egg is laid 4 to 6 days after pair formation. Nest sites are typically grass-lined depressions on the ground, surrounded by tundra vegetation which partially covers and conceals the nest and incubating bird. The full clutch consists of 4 eggs (occasionally 3) laid over a 4 day period. Eggs are cryptically colored to aid concealment from predators, and, adults engage in distraction displays involving injury-feigning and a "rodent-run", a rapid, stooped run while squeaking, to draw predators away from the nest.

Incubation is intermittent during the egg-laying period, but becomes steady when the fourth egg is laid, or a few hours before (Norton 1972). Both sexes share incubation duties, alternating for periods of 3-8 hours early in incubation, increasing to 13-14 hours later (Ashkenazie and Safriel 1979a). The off-duty bird spends most of its time feeding, bathing and preening, sometimes as much as 2-3 km away from the nest. Incubation period is 20 days. Incubation schedules become less regular, with more frequent change-overs, during the last two days prior to hatching, apparently in response to chick vocalizations or the appearance of cracks and holes in the eggshell. All four eggs usually hatch within about 24 hours, with the parents incubating early chicks in the nest cup during that period. Within a few hours of the final hatching, adults and chicks leave the nest.

For the first several days, both parents share duties of tending the young, usually within the boundaries of the nesting territory (Ashkenazie and Safriel 1979a). Chicks are brooded intermittently but frequently for the first several days, and less often as they mature. Adults protect the young from predation partially through alarm calls and distraction displays and partially through "mobbing" of mammalian predators. In this activity, birds hover near the potential predator (human or otherwise) while calling insistently. Adults often leave their broods to fly distances up to several hundred meters to mob a predator, and may be joined by parents of several other nearby broods. This species is usually the most energetic and annoying mobber among the Alaskan arctic shorebirds.

After about 2 to 6 days, the female deserts the brood to begin southward migration, and the male assumes all chick-tending duties. Female

desertion may function to reduce competition for the food supply of emerging adult insects on which the young depend (Pitelka et. al. 1974) or to increase survival rates of females through migration to better food sources (Ashkenazie and Safriel 1979b). Female weights decline more sharply than do male weights during the breeding season, so females suffer a greater energy deficit than males after hatching is complete (Ashkenazie and Safriel 1979b). After female desertion, males and broods may move up to 2-3 km from nesting territories, usually into areas of low tundra wetlands and around lakes and streams.

Fledging occurs when chicks are about 16 days old. Males may desert chicks just prior to fledging or remain with them for a few days after fledging (Ashkenazie and Safriel 1979a). At this time {mid and late July near Barrow), adults, including early departing females, failed breeders, and finally, successful males, occur in foraging flocks near ponds, lakes, streams, and lagoons. Coastal densities increase as breeders from inland sites move coastward to begin migration. These are joined and subsequently , replaced by newly-fledged juveniles, whose sudden and striking occurrence in high densities in littoral and near-littoral habitats has been discussed above. Within a few days or weeks of fledging and after most adults have left the arctic, juveniles begin their first southward migration. This ends the brief period of summer residency of Semipalmated Sandpipers in the arctic, a *sojourn* which occupies less than one quarter of each year. The major portion of the annual cycles of both Semipalmated Sandpipers and Western Sandpipers are spent in migration and on winter ranges, and the population dynamics of both species depend in part upon conditions during these periods, as well as on reproductive success during the brief breeding season.

Western Sandpiper

The most intensive studies of Western Sandpiper breeding biology have been done on the Yukon-Kuskokwim River Delta (Holmes 1971, 1972, 1973), and most of the following description derives from that work, supplemented at times by observations at other sites, including cape Krusenstern.

Western sandpipers and Semipalmated Sandpipers are very similar in breeding season social systems and reproductive strategies, considered to be among the most conservative of sandpiper social systems (Pitelka et al. 1974). In both species males establish nesting territories with aerial advertisement displays, and males and females form pair bonds which persist at least throughout incubation, which both sexes share. In the Western Sandpiper, males arrive on the Bering coast breeding grounds in mid-May, coincident with the first appearance of snow-free tundra. Arrival dates are later in northern parts of the breeding range. Birds arrive in flocks which may contain both sexes (Holmes 1972), and gradually disperse over the

tundra. On the Yukon Delta, Western Sandpipers are strongly site-faithful. Among banded birds, 58% of males and 49% of females returned to breed on a study plot in the next year (Holmes 1971). Within the study plot, birds tended to return to specific sites, with many males and females using the same territory and even the same nest cup in subsequent years. Some pairs reunited in subsequent years, probably because of the association with the same territory. Return rates of young sandpipers are much less than for adults, probably deriving both from lower survival rates and from wider returning dispersion patterns.

Males establish territories through chases, fights, and display flights (Holmes 1973). Advertisement display flights are of two kinds: one involves a slow patrol flight at a typical elevation of 4 to 6 m, with intermittent trilling vocalizations; the other begins as a low rapid flight, changing to an abrupt ascent to 3 to 4 m with a trilled song, followed by a gliding descent to the ground. Ground displays involving one or both wings extended upward usually follow this flight, and also occur independently or as an aggressive challenge. Chases take place on the ground and in the air, and may involve *only two* territorial neighbors or several local birds chasing an intruder. Fights begin with two birds facing each other, and involve contact fluttering, using bill, feet, and wings as weapons. These behavioral interactions are described in detail in Holmes (1973) and Brown (1962).

After territories have been established by males, monogamous pairing occurs. Displays include a low guttural trill by the male, enticement flights, wing-up display, tail-up courtship stance by the male, and nest-scraping displays (Holmes 1973). Several nest scrapes are usually prepared by the male before a single scrape is accepted by the female. Copulation occurs several times per day during the pre-nesting and egg-laying periods. Clutch size is almost always 4 eggs, laid at intervals of approximately 24 hours. Peak clutch completion dates on the Yukon-Kuskokwim Delta ranged from 27 May to 5 June over 4 years (Holmes 1972); at Cape Krusenstern in 1978 the median date was about 2 weeks later, on 15 June (Connors, unpublished). However the full laying period differed little between the two areas; at the Yukon Delta site the peak occurred early during the period, followed by small numbers of nests which may have been re-nesting attempts by birds whose first clutch had been lost to predators. At Cape Krusenstern, instead, scattered nests were initiated during the first 3 weeks of the nesting period, followed by a late peak which represented the bulk of the population.

Both sexes share incubation, which averages 21 days in length (Holmes 1972). Adults distract predators from the nest with displays which include injury-feigning and "rodent-runs", and occasionally with aerial attacks (Brown 1962). The young from a single nest usually hatch within 24 hours,

the first chicks remaining in the nest until all have hatched. Chicks leave the nest within a few hours, or the next morning if hatching is completed in late afternoon or evening. Unlike Semipalmated sandpipers, both parents tend the young until fledging (Holmes 1972). The male is more constantly in attendance, while the female sometimes forages elsewhere. Chicks are brooded frequently during the first few days, at night, and in wet weather. They forage for themselves, tended by nearby parents, on tundra and in marshes off the nesting territory. Adults protect the young from predation by giving alarm calls and by distraction displays (Brown 1962) and by mobbing mammalian predators. In response to alarm calls, chicks squat motionless in low vegetation; their cryptically colored downy plumages provide excellent visual concealment. Fledging occurs after 2 1/2 to 3 weeks, and young and adults flock separately prior to southward migration. Flocking birds forage on heath tundra and especially on mudflats and around marshes, sloughs, lakes and rivers. Adult flocks begin to form in late June with failed breeders and are augmented with post-breeding adults during July. These birds move from inland areas to littoral mudflat and saltmarsh habitats near the coast during July, and begin southward migration during the same month. Most juveniles remain in these habitats until mid or late August.

INTERSPECIFIC INTERACTIONS

Aggressive interactions between individuals of different species are infrequent in most nesting shorebird communities, permitting all aggressive energies to be funneled into interactions with nonspecific individuals, who present the greatest competition for potentially limited resources. On the Yukon Delta, Western sandpipers, Semipalmated Sandpipers and Dunlin are separated by nesting habitat, although they share some foraging habitats. Interactions in these foraging habitats occur, but they are infrequent (Brown 1962). At Barrow, Western Sandpipers are uncommon, but aggressive interactions among Semipalmated Sandpipers and 3 other Calidris sandpipers are rare (Holmes and Pitelka 1968). At Cape Krusenstern, however, a very different situation exists. With both Western Sandpipers and Semipalmated Sandpipers nesting in nearly equal, high densities in the same habitat areas, opportunities for interactions are frequent, and the two species are often interspecifically aggressive. From observations of 223 aggressive interactions on a 12 ha study area, I calculated that aggressive interactions arose from interspecific encounters at 45% of the rate at which they arose from intraspecific encounters (Connors, unpublished). The interspecific interactions included all intraspecific forms and intensities of aggression, from ground and aerial chases to boundary displays and contact fights. In spite of all this aggression, however, territories of the two species appeared to overlap broadly in most cases. The significance

of this unusual interspecific relationship is unclear, but it gives further testimony to the close evolutionary relationship and similar breeding ecology of the two species,

FORAGING ECOLOGY

These two sandpiper species have generally similar diets and foraging behaviors in all seasons, corresponding to their similarity in size, morphology and habitat use. Breeding season diets have been studied with large series of stomach samples at Barrow and on the Yukon Delta (Tables 4 and 5). During the early breeding season, Western Sandpipers (Holmes 1972) feed on larval insects, especially chironomids (midges) and muscid flies, by probing in the wet soil and muddy margins of ponds, marshes and sloughs. They also capture spiders and beetles, especially before snow melt has exposed the wetter habitats. Later, adult flies of these same families become important during the period of peak insect emergence. In July, as chironomid larvae around tundra pools become scarcer, birds shift more to edges of sloughs and rivers, where they prey heavily on muscid larvae. Chicks follow a similar seasonal pattern, utilizing emerging adult insects soon after chicks hatch, then shifting to greater dependence on larval insects. When they move coastward in flocks on the Yukon Delta, they continue to forage in habitats providing chironomid and muscid fly larvae, rather than shifting to more marine organisms. Along the-southern Chukchi coast, juveniles in late summer flocks feed mainly on chironomid larvae on mudflats and saltmarshes (Connors and Connors 1982) but also take adult chironomids and oligochaetes, and some birds foraging on beaches also take amphipods and marine zooplankton (Connors and Risebrough 1978).

In similar fashion, Semipalmated Sandpipers at Barrow (Holmes and Pitelka 1968) rely heavily on dipteran larvae during the early breeding season, supplemented with spiders and beetles. Muscid flies are unimportant at Barrow, however, and chironomid and tipulid larvae constitute larger portions of this species' diet (Table 4). Most foraging during June is on chironomid larvae in the muddy margins of pools, lakes and streams. During the period of peak insect emergence in early July at Barrow, Semipalmated Sandpipers shift more strongly to adult chironomids than do Yukon Delta Westerns, but they also shift back to larval diptera before they leave the breeding grounds. Again, muscid larvae are absent from semipalmated Sandpiper diets, and chironomid larvae are more prevalent than in Western Sandpiper diets. The Barrow data agree with diet information for Semipalmated Sandpipers breeding in the eastern Canadian arctic (Baker 1977) where stomachs of 33 birds collected mainly during June contained 60% chironomid larvae, 23% spiders, and small amounts of several other categories of prey.

Table 4. Diets of adult sandpipers on breeding grounds. Per cent composition by number of items in stomachs. Western Sandpiper, Yukon Delta, n=137 (Holmes 1972). Semipalmated Sandpiper, Barrow, n=60 (Holmes and Pitelka 1968).

	Early Breeding Season		Late Breeding Season	
	western	Semipalmated	Western	Semipalmated
	18 May-20 June	1-30 June	21 June-20 July	1-31 July
Larval Diptera				
Tipulidae	4	.13	<1	1
Muscidae	22	0	48	0
Chironomidae	49	62	24	46
Adult and pupal Diptera (mainly emerging Chironomidae and Muscidae)				
	5	2	17	44
Adult and larval				
Coleoptera	12	11	10	5
Arachnida	7	12	<1	4
Other	<1	<1	<1	<1

Table 5. Diets of immature sandpipers. Same collection sites as in Table 4. Western Sandpiper, n=59 (Holmes 1972). Semipalmated Sandpiper, n=39 (Holmes and Pitelka 1968).

	Chick Period		Juvenile Period	
	Western	Semipalmated	Western	Semipalmated
	21 Jun-10 July	1-20 July	11 July-10 Aug	21 July-14 Aug
Larval Diptera				
Tipulidae	0	1	15	2
Muscidae	29	1	38	0
Chironomidae	0	2	5	85
Adult and pupal Diptera (mainly emerging Chironomidae and Muscidae)				
	34	70	31	4
Coleoptera	23	12	9	4
Arachnida	3	10	0	3
Other	11	4	2	2

Semipalmated Sandpiper chicks also depend on emerging adult insects, mainly chironomid midges, for most of the period from hatching to fledging, and this dependence is numerically even greater than for Western Sandpipers (Table 5). The seasonal availability of this food supply of easily captured prey for chicks is probably the most important factor influencing the schedule of breeding of both these species, and of other arctic shorebirds as well (Holmes and Pitelka 1968, MacLean and Pitelka 1971). As insect emergence diminishes in mid to late July, young Semipalmated Sandpipers switch to chironomid larvae much more heavily than do Yukon Delta Western Sandpipers, where some adult dipterans remain available. Semipalmated Sandpiper juveniles also move to coastal areas after fledging, where they forage on mudflats, saltmarshes, and edges of sloughs and lagoons prior to southward migration (Figure 4). Stomachs of late summer juveniles collected in these habitats along the Beaufort coast contained primarily chironomid larvae (78%) and oligochaetes (17%) (Connors and Risebrough 1977).

These data demonstrate that the seasonality of diets of these two species in Alaska is remarkably similar, with the major differences probably resulting from differences in insect populations at different sites. At Cape Krusenstern, where both species nest in nearly equal densities in same areas, diets appear to be even more similar. In a sample of 7 adults of each species collected in species pairs foraging in a range of habitats from heath tundra to muddy marsh margins, stomachs of both species contained dipteran pupae, coleopterans, chironomid larvae and adults, and seeds, in similar proportions (Connors, unpublished).

During migration and in winter quarters, diets of both species vary widely depending upon local availability of invertebrate prey, mainly in wet mud and sand habitats, both coastal and inland. They include a variety of insect larvae, worms, crustaceans and molluscs. Where the species winter together on coastal mudflats of South America, some habitat separation is evident, with Semipalmated Sandpipers usually foraging with pecking motions on wet and dry substrates, while Western Sandpipers, possessing a longer bill, forage more frequently by probing in shallow water areas (Ashmole 1970). This winter habitat separation is likely to produce much greater differences in winter diets than in summer diets. Indeed, the difference in bill size between the species is probably the evolutionary result of competition for food on wintering grounds or in migration, rather than on breeding tundra. A similar habitat differentiation is evident between Western and Least Sandpipers (*C. minutilla*) wintering sympatrically on the Pacific coast of North America, with the shorter-billed Least Sandpiper frequently foraging farther above the water's edge (Recher 1966, Couch 1966). In this case, dietary differences between these two similar species are evident in tidal habitats in Washington (Couch 1966), Bolinas Lagoon, California (Page and Stenzel 1975), and Palo Alto, California (Recher 1966),

although **all** three areas show considerable overlap in prey taken. **To** a great extent the diets of both species indicate an opportunistic response to the local availability of prey; diets **change** abruptly as birds change foraging locations. Some abundant potential prey such as the small clams Gemma gemma and Transennella tantilla, however, are apparently avoided (Page and Stenzel, 1975). At **all** three sites the diets of wintering Western Sandpipers consist principally of a variety of small crustaceans (amphipods, ostracods, isopods, tanaidaceans) supplemented by small clams, snails, worms, and in some areas, insect larvae (Couch 1966, Recher 1966, Page and Stenzel 1975). On the Copper River Delta, Alaska, where vast numbers of northward migrating Western sandpipers feed during May, important prey species are mainly small molluscs (Macoma, Mytilus, and Mya), copepods, and chironomid larvae (Senner 1979).

Semipalmated Sandpipers during migration and in winter occur on coastal mudflats and beaches and on muddy margins of lakes, ponds, estuaries and flooded fields, from eastern and central Canada to South America. Invertebrate foods available over this extensive range vary widely, and Semipalmated Sandpiper diets must vary accordingly. Important prey include small crustaceans (especially amphipods; Hicklin 1983), worms, and insect larvae and adults.

MANAGEMENT

Worldwide populations of both Semipalmated sandpipers and western Sandpipers are large (both in excess of one million individuals) and, as far as is known, relatively stable at present. Several potential threats loom, however, primarily because of population dependence on limited habitats or areas during parts of the life cycle. With such highly migratory species, we must consider all phases of the annual cycle, since population numbers might be affected by conditions at sites encountered only during breeding, migration, or winter periods.

For these and most tundra-nesting shorebirds, present threats to populations while on the breeding grounds are mainly local and limited, arising from loss of nesting or foraging habitat, as from construction and oil development activities (gravel roads, impoundments, etc). such construction is usually accompanied by other effects such as noise disturbance or attraction of predators which may extend the area affected, but at present these do not seem likely to have serious impacts on regional population sizes.

After breeding, birds concentrate in coastal habitats which are both more limited in extent and more susceptible to certain potential development impacts, such as oil spills. For example, an oil spill during the open water period in arctic saltmarshes near Harrison Bay, Kotzebue Sound or the

Yukon Delta might eliminate or greatly reduce the insect larvae populations upon which **large** numbers of sandpipers depend for energy reserves to begin southward migration. Furthermore, such a loss of prey populations might last for several seasons, continuing to affect **bird** populations. **The** net effect on sandpipers might be much greater than the **initial** effects of direct contact **with** the spilled oil, since these species do not wade consistently enough to result in loss of large numbers of birds through direct oiling. Except for **phalaropes, which** swim on the **water's** surface, shorebirds have seldom suffered oil spill mortality matching, for example, that of diving **seabirds**.

population threats from large oil spills become even **greater** at a few key sites during migration, such as the copper River Delta for Western Sandpipers during May, when almost the entire population is present (Senner 1979, Islieb 1979) or the Bay of Fundy for Semipalmated Sandpipers during July and August, when several hundred thousand individuals of this species occur *on tidal flats* (Morrison and Barrington 1979). These and other sites of concentrations on migration routes and winter grounds **also** provide situations in which segments of the population might be affected by any impacts which reduce prey densities or available foraging habitat. These might include draining, filling, or **diking** of wetlands, coastal construction which includes dredging or covering tidal flats, or damming of estuaries for **tidal power** projects. In fact, the gradual but continuing loss of many **small** examples of prime winter and migratory habitat may "have a cumulative population effect of considerable impact, even if the effect of each individual example can not be determined. This process may represent the greatest threat to sandpiper populations, and a management problem difficult to attack because of the multitude of governmental agencies (including several countries) involved and the difficulty of proving a connection between a potential cause and the suspected effect. Within Alaska, however, population management must include attempts to preserve saltmarsh and mudflat habitats used by these species.

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