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Food Habits of Charadriiform Birds During Peak Migration Through Eastern South Dakota

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FOOD HABITS OF CHARADRIIFORM BIRDS DURING PEAK MIGRATION THROUGH EASTERN SOUTH DAKOTA

BY

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FOOD HABITS OF CHARADRIIFORM BIRDS DURING

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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INTRODUCTION

The shorebirds, Order Charadriiformes, are very important organisms as they make up a great proportion of the summer biomass in arctic regions. Spring migration routes of many species of shorebirds carry them through eastern South Dakota where lakeshores and temporary ponds are crucial stopover points. At these stopover points, the birds feed on various organisms which will supply them with the energy needed for completion of migration and for breeding.

This is a study of the migratory schedules and feeding ecology of shorebirds migrating through eastern South Dakota during the spring migrations of 1985 and 1986. It is a part of the ongoing shorebird banding project conducted by Dr. John Haertel of the Biology Department at South Dakota State University.

The major objectives of this study are: 1) to determine the peaks of shorebird migration through eastern South Dakota; 2) to determine the food items taken on migration stopover; and 3) to determine if the birds are selecting for specific food items. Information from studies based in South Dakota will add to the overall picture of migration across the United States.

LITERATURE SURVEY

A classification of the shorebirds sampled in this study is shown in Table 1. The literature review of their seasonal schedules will follow this taxonomic arrangement.

SEMIPALMATED PLOVER (Charadrius semipalmatus)

This plover winters in southern North America (California east to Bermuda), Central America, and South America. It leaves its wintering grounds in mid-April and passes through South Dakota in May (earliest - April 20; latest - June 5). It breeds in Alaska, Newfoundland, northern Canada, and Nova Scotia, arriving in May to June (Bent, 1929; Harrell, 1978).

KILLDEER (Charadrius vociferus)

The killdeer winters from British Columbia and Utah south to Panama and Puerto Rico. It leaves its wintering grounds in February to March and occurs in South Dakota whenever open water is found. It winters in South Dakota rarely. It nests in South Dakota in late May to September. The killdeer breeds in almost all of North America; north into Canada, south to southern California and northern Bahamas. This bird arrives on its breeding grounds in mid-March to early July (Bent, 1929; Harrell, 1978; Johnsgard, 1977).

TABLE 1. TAXA OF SHOREBIRDS CAPTURED IN THIS STUDY

From Burger and Olla (1984a)

- Order: Charadriiformes
  - Suborder: Charadrii
    - Superfamily: Charadrioidea
      - Family: Charadriidae
        - Tribe: Vanellini
          - *Charadrius semipalmatus* (semipalmated plover)
          - *Charadrius vociferus* (killdeer)
  - Suborder: Scolopaci
    - Superfamily: Scolopacoidea
      - Family: Scolopacidae
        - Tribe: Tringini
          - *Actitis macularia* (spotted sandpiper)
        - Tribe: Phalaropodini
          - *Phalaropus tricolor* (Wilson's phalarope)
        - Tribe: Limnodromini
          - *Limnodromus griseus* (short-billed dowitcher)
          - *Limnodromus scolopaceus* (long-billed dowitcher)
        - Tribe: Calidridini
          - *Calidris bairdii* (Baird's sandpiper)
          - *Calidris pusilla* (semipalmated sandpiper)
          - *Calidris minutilla* (least sandpiper)
          - *Calidris fuscicollis* (white-rumped sandpiper)
          - *Calidris melanotos* (pectoral sandpiper)
          - *Calidris alpina* (dunlin)
          - *Calidris himantopus* (stilt sandpiper)

SPOTTED SANDPIPER (Actitis macularia)

The spotted sandpiper winters in Arizona, Texas, New Mexico, Florida, and Alabama south to mid-South America. It migrates north in early April and passes through South Dakota in mid-May (earliest - April 10) It nests in South Dakota in June and July. It breeds from northern Alaska south to New Mexico, Texas and South Carolina, arriving at its breeding grounds in mid-May to June (Bent, 1929; Harrell,1978).

WILSON'S PHALAROPE (Phalaropus tricolor)

This bird winters on the west coast of South America and migrates northward in April. It passes through and nests in South Dakota in late May to June (earliest nest - May 23; latest nest - June 8). It breeds in inland North America; north to mid-Canada, south to California in the west, Kansas and Indiana in the east, arriving at the breeding grounds in mid-May to late June (Bent, 1929; Harrell, 1978).

DOWITCHERS (Limnodromus sp.)

There are two species of dowitchers, with one of those species divided into several subspecies (Pitelka, 1950; Jehl, 1963). These birds are:

1) Limnodromus scolopaceus, the long-billed dowitcher.

2) Limnodromus griseus griseus, the "eastern" short-billed dowitcher.

3) Limnodromus griseus hendersoni, the "interior" short-billed dowitcher.

4) Limnodromus griseus caurinus, a race of short-billed dowitcher found on Alaskan breeding grounds.

L. scolopaceus, the long-billed dowitcher is considered the western race. It is the most abundant dowitcher on the west coast of the United States during migration. However, it is also found eastward to the east coast (where it is the least common dowitcher) during migration. It has the longest bill (usually) of the dowitchers and its breast is barred, rather than spotted.

L. griseus griseus is the eastern dowitcher. It is the most common dowitcher on the east coast of the United States during migration. It has a shorter bill (usually) and has a heavily spotted, reddish breast.

L. griseus hendersoni is the interior race, being the most abundant dowitcher migrating through the central United States. This dowitcher has a bill of similar length to that of the eastern dowitcher, but it has a redder, less spotted breast (Jehl, 1963).

It is possible to observe any of the three races of dowitchers during the spring migration in South Dakota. The literature suggests that the dominant race migrating through the area is *L. scolopaceus*. This generalization may be in error for two reasons. First, many shorebirds, dowitchers especially, are known to migrate in long hops (Pitelka, 1950; Jehl, 1963) thus many of the birds will not be observed or captured as they pass through any given area. Secondly, until Pitelka's work in 1950, all dowitchers were listed as belonging to a single species, therefore much of the early literature regarding dowitchers does not give information about the individual races.

L. scolopaceus migrates through South Dakota in early May (earliest - March 25; latest - May 24). *L. griseus* has been observed in South Dakota between April 25 and May 22 (Harrell, 1978).

BAIRD'S SANDPIPER (*Calidris bairdi*)

Baird's sandpiper winters in South America from Chile to Argentina and migrates northward through the Mississippi valley in April and May. It passes through South Dakota in mid-April (earliest - March 18; latest - June 11) and breeds from arctic Alaska through the Canadian arctic islands into greenland. It arrives on the breeding grounds in mid-to-late May (Bent, 1927; Harrell, 1978; Burger and Olla, 1984b).

SEMIPALMATED SANDPIPER (*Calidris pusilla*)

This small sandpiper winters in South America, the

West Indies, Texas, And Louisiana. It migrates north in mid-April and passes through South Dakota April to June (earliest - April 18; latest - June 14). It breeds from northern Alaska eastward across the Canadian arctic to northern Quebec, Central Baffin Island, and northern Labrador. It arrives at the breeding grounds in mid-June (Bent, 1927; Harrell, 1978; Burger and Olla, 1984b).

LEAST SANDPIPER (Calidris minutilla)

The least sandpiper winters in California, Arizona Texas, Louisiana, Alabama, and North Carolina. It migrates north in late March to early April and passes through South Dakota in mid-May (earliest - April 21; latest - June 9). It breeds from northern Alaska south to Nova Scotia and Quebec. It arrives on its breeding grounds in May to June (Bent, 1927; Harrell, 1978).

WHITE-RUMPED SANDPIPER (Calidris fuscicollis)

The white-rumped sandpiper winters in extreme southern South America and migrates north in early March. It migrates northward along the Atlantic coast of South America, then north through the interior of the United States. It usually passes through South Dakota in mid-May (earliest - April 17; latest - June 6). It breeds in northern Alaska east to Hudson Bay, Baffin Island, arriving there in late May to mid-June (Bent, 1927; Harrell, 1978).

PECTORAL SANDPIPER (Calidris melanotos)

The pectoral sandpiper winters in Argentina and migrates northward in February and March. It passes through South Dakota in late April to early May (earliest - April 1; latest - June 8), and breeds from Alaska east to Southhampton Island and James Bay. It reaches its breeding grounds in late May (Bent, 1927; Harrell, 1978, Burger and Olla, 1984b).

DUNLIN (Calidris alpina ssp.)

Prater, et al. (1977) recognize six races of dunlin. These birds and their breeding areas are:

1) Calidris alpina arctica --------- N.E. Greenland.
2) Calidris alpina schinzii ------- Iceland, Europe.
* 3) Calidris alpina alpina --------- N.W. Palearctic.
* 4) Calidris alpina pacifica ------------- S. Alaska.
* 5) Calidris alpina hudsonia ---------------- Canada.
* 6) Calidris alpina sakhalina ------ N.E. Palearctic, N. Alaska.

* Dunlin races recorded from the United States. Differences between races are very slight; usually minute size or color variations are involved.

The races that pass through the United States during migration will winter in Florida, North Carolina, and Texas. These birds begin their northward migration in mid-April to early May.

The dunlins passing through South Dakota are mostly C. alpina hudsonia. They pass through the area in late May (earliest - April 24; latest - June 6). This race breeds in north central Canada (Bent, 1927; Prater, et al., 1977; Harrell, 1978; Burger and Olla, 1984b).

STILT SANDPIPER (Calidris himantopus)

The stilt sandpiper winters in extreme southern South America. It migrates northward in March and April, moving up the Mississippi Valley as it passes through the United States. It passes through South Dakota in mid-to-late May (earliest - April 18; latest - June 14). It breeds in the northeast regions of Alaska and in Arctic Canada. It reaches its breeding grounds in late May to early June (Bent, 1927, Harrell, 1978).

MIGRATION OF SHOREBIRDS CAPTURED IN THIS STUDY

Great amounts of energy are spent each time a bird migrates to and from its breeding grounds. However, this expenditure is not without its benefits. Welty (1982) lists some of the advantages of migration as: 1) decreasing competition by dispersion of birds; 2) moving to areas with a greater abundance of the bird's preferred food or to areas with nutrients essential to the bird's dietary needs; 3) moving to latitudes with more daylight hours, thus more "working hours"; 4) predator swamping by raising large numbers of young in an area with a short breeding season; 5) moving to latitudes with less parasites and infectious microbes; 6) more space for each breeding pair; 7) avoidance of extremes in environmental conditions; 8) natural selection (only the strongest and most adaptive will survive migration to breed); and 9) geographic dispersion and mixing of the gene pool.

Welty (1982) notes that shorebirds migrate along coasts (or over areas with many small bodies of water offering appropriate shoreline for feeding) or migrate non-stop from wintering to breeding grounds. Migration routes of individual species seem to reflect this concept.

The white-rumped sandpiper (Calidris fuscicollis) is the long distance traveller of the group. Bent (1929), states that the white-rumped sandpiper winters in Patagonia, in extreme southern South America. Its migration takes it northward along the Atlantic coast of South America, through the interior of the United States and Canada, to its breeding grounds in the arctic. The spring migration route can be seen in Figure 1.

The southward migration in the fall takes the birds by another route. First, the birds move southeast to the Atlantic coast. Then, from Maine and Nova Scotia, they migrate mostly over ocean to South America or the West Indies.

The migration of the least sandpiper (Calidris

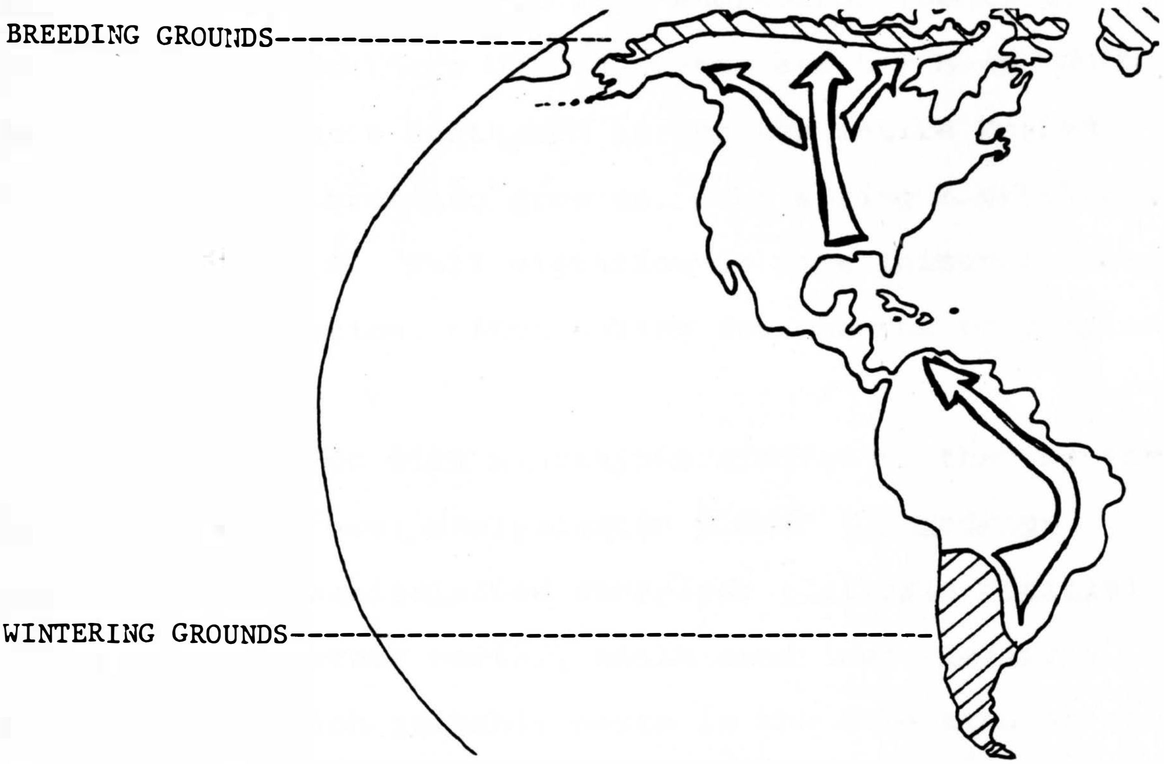

Figure 1. Wintering grounds, spring migration route, and breeding grounds of the white-rumped sandpiper. Modified from Bent (1927).

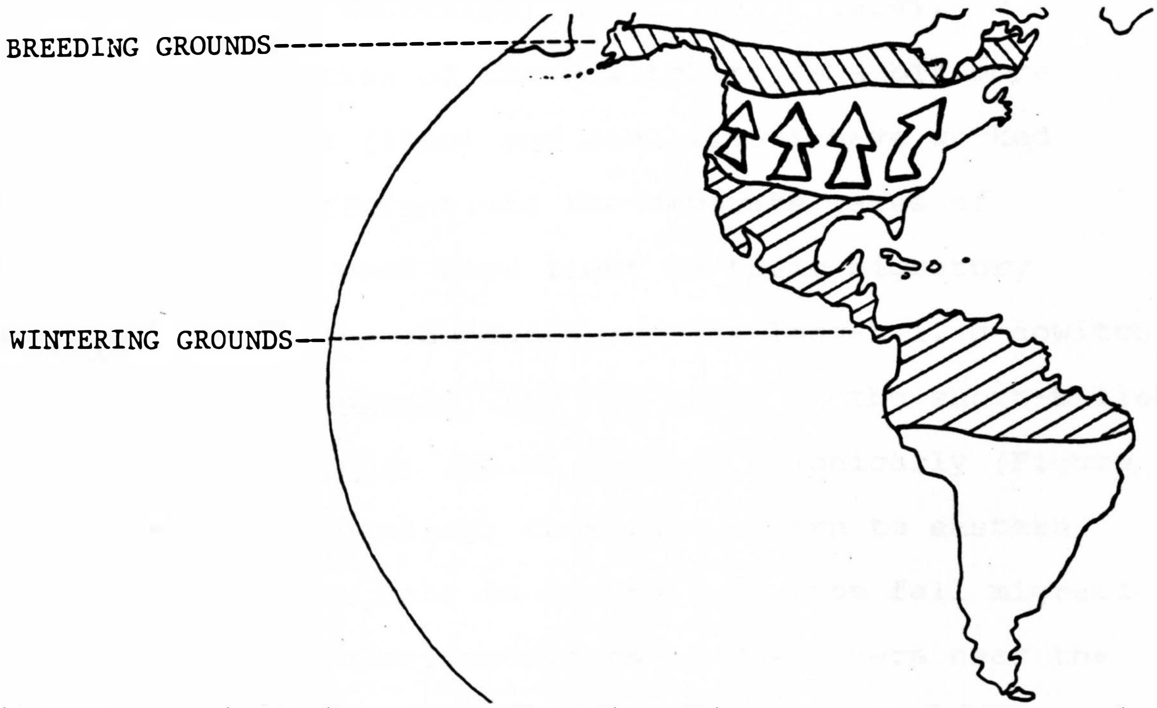

Figure 2. Wintering grounds, migration route, and breeding grounds of the least sandpiper. Modified from Bent (1927).

minutilla) typifies that of most shorebirds (Bent, 1929). They winter in southern United States and northern South America and migrate northward across the entire United States to their breeding grounds. The spring migration is shown in Figure 2. Fall migration is more leisurely than the spring migration, often taking four months to complete.

Shorebirds with migrations similar to that of the least sandpiper are: semipalmated plover (Charadrius semipalmatus), semipalmated sandpiper (Calidris pusilla) (which nests farther north), stilt sandpiper (Calidris himantopus) (which probably nests in the same area as the least sandpiper), and pectoral sandpiper (Calidris melanotos) (which nests farther north and migrates mostly east of the Rocky Mountains) (Bent, 1927, 1929).

The migration of the dowitchers is a bit more puzzling. Pitelka (1950) and Jehl (1963) have worked extensively to differentiate the separate races of dowitchers and to shed some light on their migratory movements. Relative abundances of the long-billed dowitcher (Limnodromus scolopaceus) and the races of the short-billed dowitcher (L. griseus) can be plotted graphically (Figure 3) as one observes migration, from the western to eastern United States. The data in Figure 3 is from fall migration, as the spring migratory movements of dowitchers near the east and west coasts take the birds over the oceans and the inland birds most likely make a non-stop migration. The capture rates of dowitchers by South Dakota bird banders do not reflect this data because of the non-stop migration of the "interior" short-billed dowitcher (Limnodromus griseus hendersoni). Banders in this region thus capture mostly long-billed dowitchers (Limnodromus scolopaceus).

It has also been noted by Jehl (1963) that the different races of dowitchers migrate at different times. The fall migration of dowitchers along the east coast of the United States is shown graphically, plotting time in months

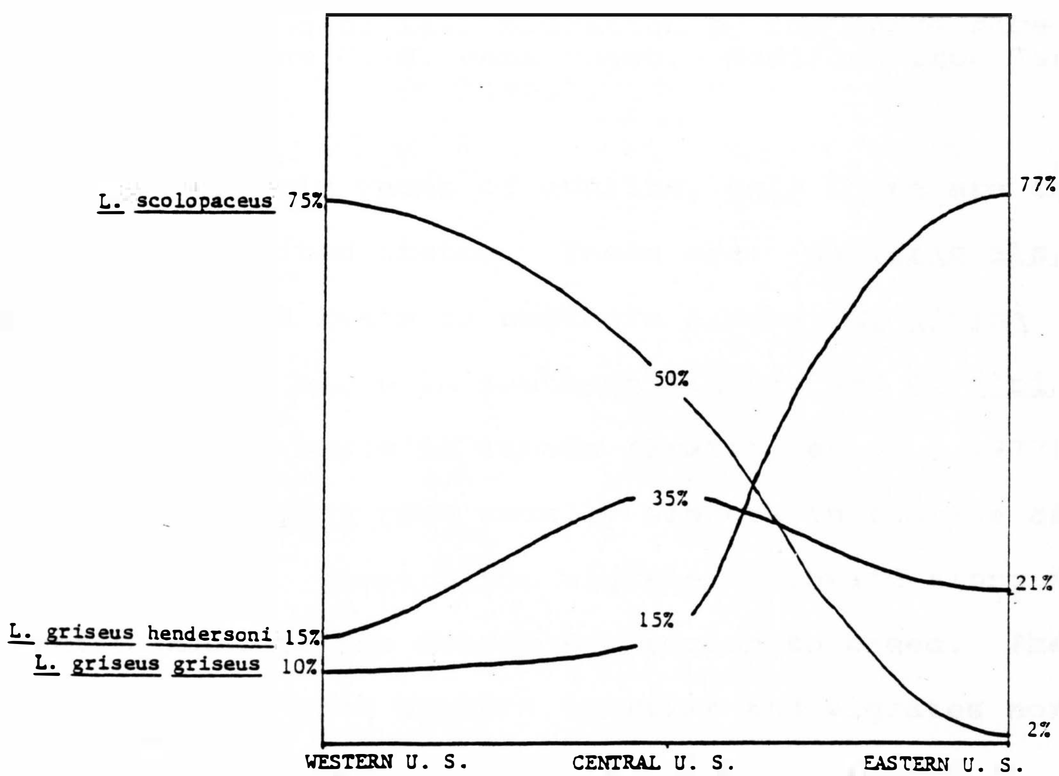

Figure 3. Relative abundances (%) of the three races of dowitchers in western, central, and eastern U. S. during fall migration. Modified from Jehl (1963) and Harrell (1978).

versus. relative abundance of each race of dowitcher, in Figure 4.

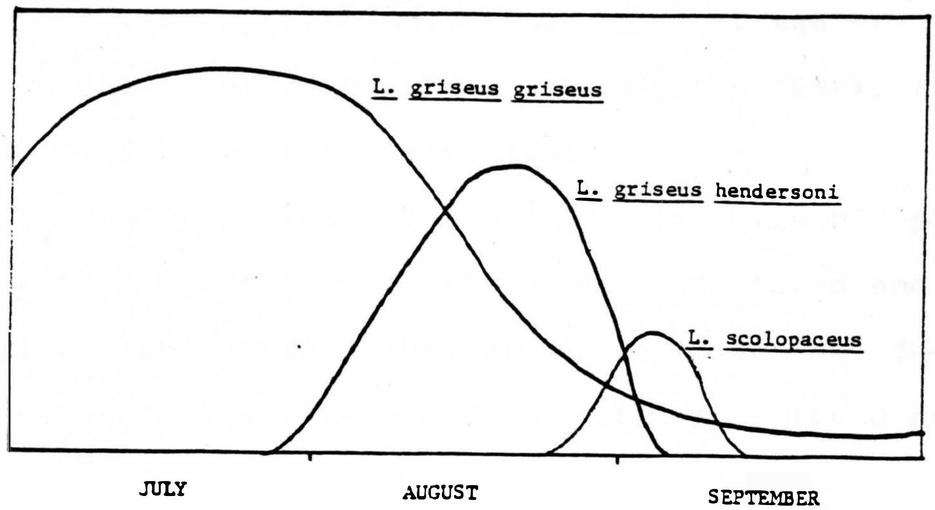

Figure 4. Timing of fall migration by the three races of dowitchers on the U. S. east coast. Modified from Jehl (1963).

Of the six races of dunlins, only three are commonly found in the United States. These are: Calidris alpina sakhalina, which nests in northern Alaska; C. alpina pacifica, which nests in southern Alaska; and C. alpina hudsonia, which nests in Canada (Prater, et al., 1977). The C. alpina sakhalina race usually winters in Florida and South Carolina. These birds migrate northward along the Atlantic coast to the Hudson Bay region to breed. The C. alpina pacifica race winters in Texas and migrates northward along the Pacific coast to their breeding grounds in southern Alaska. Finally, The C. alpina hudsonia race of dunlins winters mostly in Louisiana and migrates northward through the interior of the United States to Canadian breeding grounds. The spring migration of these three races of dunlins is shown in Figure 5.

Southward (fall) migration seems to occur mostly along the coasts, with only occasional stragglers migrating through the interior of the United States (Bent, 1927; South Dakota Ornithologists Union, 1978).

The migrations of the killdeer, Wilson's phalarope and spotted sandpiper are the least structured and "laziest" of all the shorebirds. Unlike most shorebirds, these species are not arctic breeders and may be found nesting throughout Canada and the United States (Bent, 1927).

The killdeer winters from British Columbia to Panama, often moving south just far enough to avoid extreme winter weather. Occasionally, the killdeer has been observed wintering in South Dakota (South Dakota Ornithologists Union, 1978).

Wilson's phalarope breeds in about the same area as the killdeer; mid-Canada to southern United States. This bird winters from Texas and California south to southern South America, so its migration is somewhat longer than that of the killdeer (Bent, 1927).

The migration of the spotted sandpiper is similar to those of the killdeer and Wilson's phalarope. It breeds from Alaska to California and Texas and winters from British Columbia to Bolivia and Brazil (Bent, 1927).

In all three of these birds, it should be noted

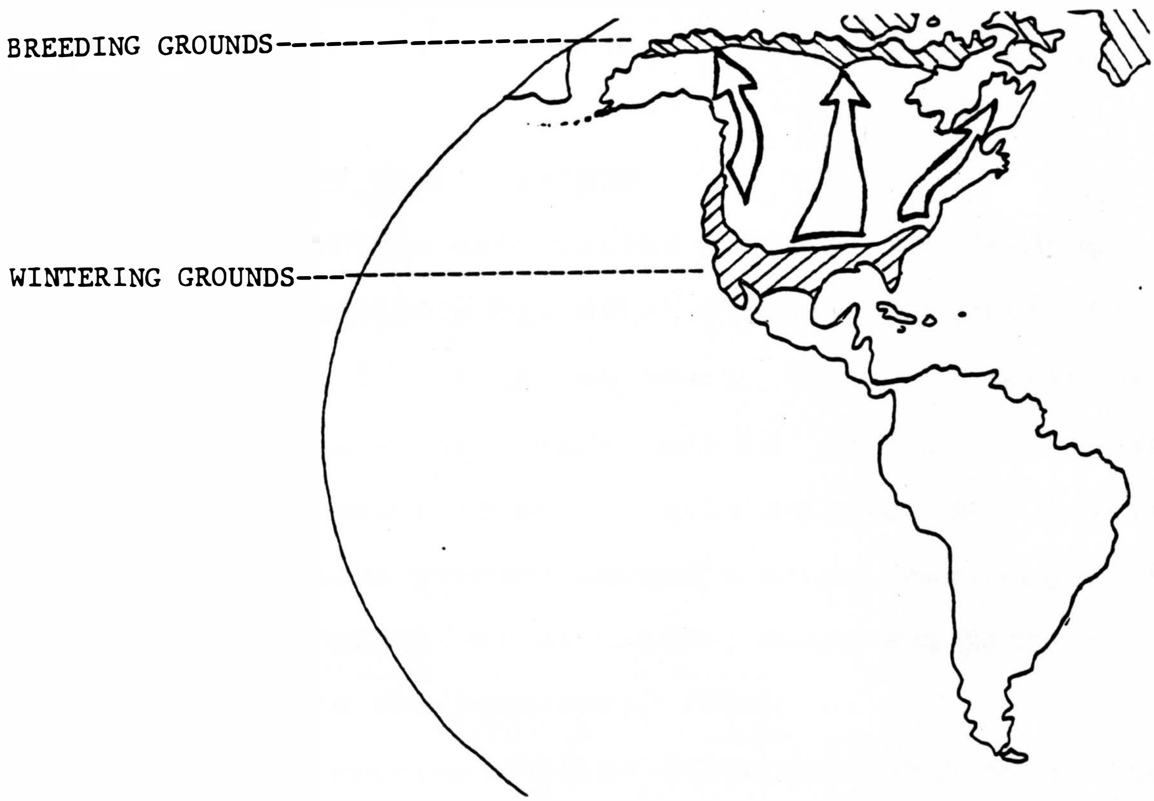

Figure 5. Wintering grounds, migration route, and breeding grounds of the dunlin. Modified from Bent (1927).

that the breeding and wintering grounds overlap. The wintering grounds of the Wilson's phalarope and spotted sandpiper are much larger than their breeding grounds, thus they are more condensed during breeding than during the winter.

HABITAT PREFERENCES OF SHOREBIRDS

Most shorebirds use similar habitats for feeding purposes. These habitats are often divided into separate categories: beach fronts (outer beach, facing an ocean or other large body of water); inner beaches (sandy beaches on smaller bodies of water or on the mainland side of a barrier island); and mudflats (including muddy areas near temporary pools of water) (Burger, et al., 1977; Baker and Baker, 1973; Duffy, Atkins and Schneider, 1981).

Different species utilize different portions of the habitat. The outer beach area is utilized mostly by plovers, such as the semipalmated plover. The inner beach area supports dowitchers, semipalmated sandpipers, and many other species not covered in this paper. The mudflat area supports the greatest number and variety of shorebirds, including all species covered in this paper (Burger, et al, 1977). The distribution of birds across a range of habitat types may be used to reduce competition between species (Recher, 1966).

As shorebirds migrate northward during the spring migration, they usually follow close behind the receding snows. This supplies even the inland migrators with plenty of mudflat feeding habitat in the form of temporary pools.

Nesting habitat is also similar for most species of shorebirds. The nest is usually built on a dry hummock of ground near suitable feeding grounds. One species, the killdeer, does not limit its feeding/nesting habitat to the above parameters. This species quite often nests and feeds on open prairie, sometimes miles from a body of water (Bent, 1927).

FACTORS INFLUENCING HABITAT USE

Factors such as weather, time of day, tidal cycle, and individual characteristics (such as bill length) can alter the use of certain habitats. Most shorebirds show a diurnal pattern when feeding. Hamilton (1959) found that pectoral sandpipers left their feeding habitats in an abrupt exodus approximately 20 minutes after sunset during fair weather. When the amount of light diminished to a set point, the birds simply ceased feeding and left. During times of cloudiness, departure was much earlier and the birds did not all leave as one bunch. When the morning light again reached the threshold intensity, the birds returned to the feeding area and once again began feeding. Burger and Olla (1984b) found that tidal factors, wind factors, and cloud cover are the factors that most affect small shorebirds along marine coasts. Burger et al (1977) worked with birds on the New Jersey coast. They found that tidal cycles directly influenced habitat use. Habitat partitioning was such that different species used a particular habitat during different tidal conditions during the course of the day. One could predict which species would be feeding in an area at any time by knowing the tidal cycle for that area.

There is evidence that seasonal changes lead to changes in habitat use. Shorebirds use a greater diversity of habitats during the summer months than during the winter (Baker and Baker, 1973). Strong competition caused by compressing so many birds into the wintering grounds leads to greater partitioning of available habitats. In contrast to this, Duffy, Atkins, and Schneider (1981) found no evidence of strong competition among shorebirds on wintering grounds. In fact, the birds observed in this study utilized a wide diversity of habitats. This 1981 study, however, was done in an area of coastal upwelling of nutrients, so that even large numbers of shorebirds did not reduce food supplies.

FOOD AND FEEDING HABITS

Manner of feeding

Feeding activities of shorebirds can be divided into two categories (Baker and Baker, 1973). The first is pecking, where less than one-quarter of the bill penetrates the substrate as the bird feeds. The second category is probing, where more than one-quarter of the bill penetrates the substrate. Visual stimuli guide the birds while pecking. Stimuli to the many tactile receptors on the end of the bill guide the birds while probing. Burger and Olla (1984b) found data showing that birds that feed more often by probing (such as dunlin) are less affected by crowding than birds that feed mostly by pecking (such as plovers).

Other criteria, such as locomotion (steady or halting), speed of locomotion while feeding, and number of pecks/probes per site (single or multiple) are used in classifying shorebird feeding behavior.

Data from Baker and Baker (1973) show that the least sandpiper, a short-billed bird, usually moves at a fast pace (about .35 ft/sec) and feeds by pecking. The dunlin, a medium-billed bird, moves slower (.25 ft/sec) and feeds by pecking and probing. The dowitchers, long-billed birds, move at a very slow pace (about .08 ft/sec) and feed by pecking and probing. Often dowitchers will probe several times in quick succession while covering only a very small area. Burger and Olla (1984b) cite data suggesting that young shorebirds feed at slower rates than adults.

Environmental variables such as temperature and bird density in a given area have no effect on feeding or locomotion rates (Baker and Baker, 1973). The effect of bill length on habitat use can even be intraspecific. Harrington (1982) found that female semipalmated sandpipers, which have an average bill length of 20.7 mm (± 1.3 mm), feed in the muddier habitat while males, with an average bill length of 18.68 mm (± 1.0 mm), feed in the sandier portions of the habitat. The difference in bill length has no effect when the birds are feeding by pecking.

Food preferences

Food preferences are controlled by what is available in the environment. However, when a large variety of foods is present each species shows definite preferences for specific types and sizes of food. Baldassarre and Fischer (1984) studied feeding habits of several shorebirds on the Texas High Plains. They found that least sandpipers and stilt sandpipers fed mainly on chironomid larvae, but that seeds and adult Coleoptera were also important. Wilson's phalaropes feed mainly on adult Diptera, but also ate small amounts of almost everything available. Long-billed dowitchers ate mostly chironomids, but seeds were also important. Killdeers fed mostly on larval Diptera, but also ate any other available insects. Baker (1977) found that least sandpipers fed mostly on chironomid and other Diptera larvae (mostly Psychodidae and Ceratopogonidae). Semipalmated sandpipers fed mostly on chironomids and small spiders. Stilt sandpipers fed mostly on larvae of the families Chironomidae and Tipulidae and plant seeds.

Dunlins were found to feed on plant seeds and larvae of the families Chironomidae, Tipulidae, and Dolichopodidae. Short-billed dowitchers fed mostly on plant seeds, but also ate some larvae of the family Tipulidae. Semipalmated plovers ate a variety of larval Diptera.

Baker (1977) studied preferences for different sizes of food particles. If particles of 0 mm to 30 mm are considered small, 31 mm to 89 mm are considered medium, and 90 mm + are considered large, the birds can be categorized by the size of food particles they prefer. Least sandpipers, semipalmated sandpipers, and semipalmated plovers all prefer small food particles. Dunlin choose medium to large sized food particles, stilt sandpipers prefer both small and large food particles, and dowitchers prefer large food particles.

METHODS FOR ANALYSIS OF SHOREBIRD FOOD PREFERENCES

One can determine food preferences by sacrificing the bird and examining the gastrointestinal tract. Baldassarre and Fischer (1984) used this method to study feeding of migrating shorebirds in Texas. Both species diversity of organisms eaten and quantitative data were obtained. An advantage of this method is that samples from the buccal cavity and proventriculus are not ground to pieces by the gizzard. The major disadvantage of this method is the necessity of killing the birds. Non-destructive methods of determining food preferences are described by Ford et al (1982). Methods they propose include observation (simply watching the birds while they feed), examination of feces, use of emetics (solutions such as 1% Antimony Potassium Tartrate which makes the birds regurgitate), and stomach flushing (causing the bird to regurgitate by forcing small amounts of warm water into the bird's gut). It is not possible to observe prey snatched from beneath the surface of the mud by a shorebird. Examination of feces works relatively well on shorebird food studies, but often, nothing remains of soft bodied organisms. Emetics do not always cause regurgitation and often result in death of the bird sampled. The stomach flushing method works well on shorebirds. It yields food items from the buccal cavity to the gizzard. Large numbers of birds can be sampled with little fear of harming them. Ford et al (1982) flushed the stomachs of 144 birds without a casualty. The major disadvantages of this method are 1) larger food items may not be flushed as readily as smaller items, thus biasing the samples toward smaller items; 2) many of the items flushed have been ground by the gizzard; and 3) it is difficult to derive quantitative data.

Using decoy/mist netting techniques and the stomach flushing method, we attempted to determine the migration peaks and food habits of shorebirds at migration stopover points in eastern South Dakota.

STUDY AREAS

Birds for the study were captured at three sites: 1) a flooded pasture of approximately 80 acres at range 52 W, township 106, section 1, Lake County, South Dakota. This area was sampled on April 17, April 24, and May 1 in 1985 and then discontinued. Drainage tiles were unplugged by the landowner and the area dried up; 2) a small area of approximately 3 acres at range 50, township 110, section 20, Brookings County, South Dakota; and 3) an area of 6 acres 1 kilometer west of site 2.

All sites had a soft mud substrate with shallow water cover which was suitable for shorebird feeding and growth of suitable food species. Vegetation at these sites was sparse or nonexistent in areas where birds were captured.

METHODS AND MATERIALS

In 1985, sites 2 and 3 were sampled on May 9, 13, 17, 18, 20, 21, 22, and 23. Sampling periods were determined by weather conditions favorable to the capture of birds. If it is too windy, birds will not "pocket" in the mist net. After May 23, shorebirds were scarce as the migration through eastern South Dakota was essentially completed.

In 1986 all samples were taken from site 3 on the following dates: May 22, 23, 24, 25, 26, 27, 28, and 29. Severe weather in eastern South Dakota delayed migration and sampling attempts until May 22. Migration through this area then proceeded at an accelerated rate, leaving very few birds at the sampling site after May 29.

Birds were captured with a 42 ft. X 7 ft. four tier mist net with one and one half inch 50/2 ply mesh. Decoys of semipalmated sandpipers, western sandpipers, least sandpipers, short-billed dowitchers, common snipe, stilt sandpipers, dunlin, Wilson's phalarope. red-necked phalarope, pectoral sandpipers, spotted sandpipers, white-rumped sandpipers, killdeer, ruddy turnstones, semipalmated plover, lesser golden plover, lesser yellowlegs, greater yellowlegs, american avocet, willet, and hudsonian godwits were used to lure the birds to the mist net. These decoys were hand carved and painted by Harold Haertel. The decoys were placed around the net in water of suitable depth for the birds they represented (shallow water for small birds, deeper water for larger birds and phalaropes).

Captured birds were weighed to the nearest gram with a Pesola spring scale, the wing cord was measured to the nearest millimeter with a ruler, and the culmen length was measured to the nearest tenth of a millimeter with dial calipers. Birds were banded under U.S. Fish and Wildlife Service bird marking and salvage permit number 20722. The gastrointestinal tract was flushed with warm water by a method modified from that described by Ford et al (1982): 1) two 6.5 cm plastic funnels were fitted with 12.5 cm filter paper; 2) the filters were marked with pencil to indicate the date of capture, species, band number, and a "B" or an "F". The "B" indicated "back side" filter which collected feces or flush water that passed through the entire gastrointestinal tract, the "F" indicated "front side", which collected food regurgitated from the stomach; 3) a ten ml syringe was fitted with an 18 gauge needle forced into a 16.5 cm long, 2.5 mm diameter (inside diameter 1.5 mm), flexible plastic tube; 4) the syringe was filled with tap water warmed to a temperature between 80 and 90 degrees Fahrenheit; 5) the bill of the bird was gently pried open and held that way with one hand while the other hand slowly pushed the plastic tube into the oral cavity, past the glottis, and down the esophagus to the proventriculus.

A slight resistance is felt when the tube reaches the proventriculus; 6) the plunger of the syringe was slowly pushed forward, forcing warm water into the proventriculus and gizzard of the bird until the bird began shaking its head or attempted to regurgitate; 7) the tube was quickly withdrawn and the bird's head was held gently over the "F" funnel to catch the regurgitated flush water and stomach contents; 8) the bird was held for a few minutes to make sure it had not been injured by the technique and then released.

The filter papers were then removed from the funnels and folded to fit into a 150 ml jar. Samples from five birds were placed in each jar. The jars were filled one third full with 70% ethanol.

When the flushing technique yielded no stomach contents (only flush water), the sample was discarded. Often, birds captured prior to 8:00 AM yielded no stomach contents. Stomach flushing prior to that time was discontinued.

Samples were taken back to the lab and kept in a refrigerator until they could be examined microscopically. To examine a sample, the filter paper was spread out on the back of a petri dish and examined with a Wild binocular dissecting scope at magnifications from 120X to 1000X. Due to the grinding action of the gizzard, very few samples contained whole organisms. Therefore, identification had to be made from parts of organisms. For this reason, an extensive collection of the fauna of the feeding areas was necessary and individual organisms from this collection had to be "torn apart" so that their parts could be examined and compared to the parts in the samples. Keys by Pennak (1955) and Edmondson (1959) were very useful in identification. A thesis by German (1978) was used to identify Chironomidae larvae. The expertise of South Dakota State University entomologist/acarologist Dr, Burruss McDaniel was utilized.

In 1985 samples of the visible surface insects, water column, and bottom mud were taken periodically. In 1986, these samples were taken daily. These samples were necessary to determine if birds were selecting for specific food items from the "menu" available to them. The surface insects were collected with an insect net from a 30 cm by 30 cm area and were preserved in 70% ethanol. Water column samples were collected in a 150 ml jar that was submerged and then capped. The mud samples were collected with a 12.5 cm^2 collector which was pushed into the mud to a depth of 35 cm and yielded a 437.5 cm^3 sample of mud. Water column and mud samples were preserved with a mixture of Rose Bengal and 70% ethanol. The rose bengal stained animal matter bright red and achieved some contrast between the organisms and the mud.

RESULTS AND DISCUSSION

A. Results of 1985 Mist Netting

In 1985 242 birds of 11 species were captured (see Table 2). Figures 6, 7, 8, 9, 10, and 11 graphically show the timing of migration in 1985 for the least sandpiper, semipalmated sandpiper, white-rumped sandpiper, pectoral sandpiper, dunlin, and short-billed dowitcher respectively. The highest bars in each graph represent the peak of migration through eastern South Dakota for the species shown.

All birds captured in 1985 were captured on dates that fell within the norm listed by the South Dakota Ornithologists Union (1978). The 1985 migration thus appeared to be typical of that seen in other years.

Migration curves for the least sandpiper, semipalmated sandpiper, white-rumped sandpiper, pectoral sandpiper, dunlin, and short-billed dowitcher (Figures 6, 7, 8, and 9 are bell shaped. A general trend showing few birds captured at the beginning of migration followed by a peak during the middle and then another period of few birds captured near the end of migration seemed to be typical. The graphs showing migration of dunlin and short-billed dowitcher are not bell shaped. This may be due to their small sample sizes. The number of least sandpipers captured peaked on May 13. The number of pectoral sandpipers peaked

Table 2. Sampling dates and birds captured, 1985.

Date	Species Captured	Number Captured
April 17	Baird's sandpiper	1
April 24	killdeer	1
May 1	least sandpiper	3
	white-rumped sandpiper	1
May 9	Wilson's phalarope	4
	white-rumped sandpiper	3
	pectoral sandpiper	2
May 13	least sandpiper	19
	semipalmated sandpiper	1
	white-rumped sandpiper	3
	pectoral sandpiper	4
May 17	least sandpiper	13
	semipalmated sandpiper	4
	white-rumped sandpiper	20
	pectoral sandpiper	4
	dunlin	1
May 18	least sandpiper	6
	semipalmated sandpiper	10
	white-rumped sandpiper	8
	pectoral sandpiper	3
	dunlin	7
	short-billed dowitcher	5
May 20	least sandpiper	4
	semipalmated sandpiper	7
	white-rumped sandpiper	10
	pectoral sandpiper	3
	Wilson's phalarope	1
	stilt sandpiper	1
May 21	least sandpiper	4
	semipalmated sandpiper	10
	white-rumped sandpiper	21
	pectoral sandpiper	1
	short-billed dowitcher	1
May 22	semipalmated sandpiper	6
	white-rumped sandpiper	29
	pectoral sandpiper	2
	killdeer	1

Table 2. continued

Date	Species Captured	Number Captured
May 23	least sandpiper	1
	semipalmated sandpiper	1
	white-rumped sandpiper	13
	pectoral sandpiper	1
	Wilson's phalarope	1
	spotted sandpiper	1

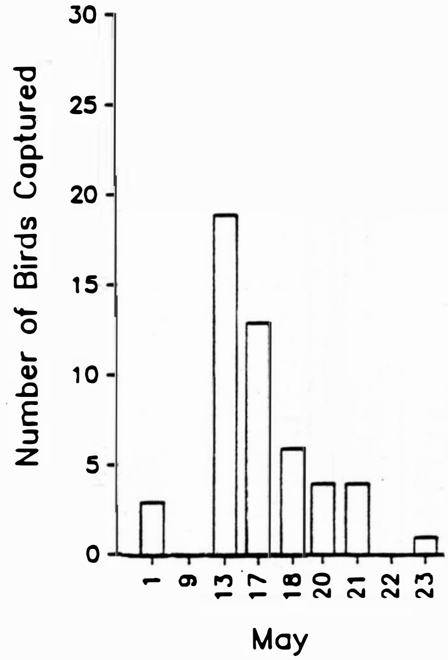

Figure 6. Timing of migration of least sandpipers in 1985.

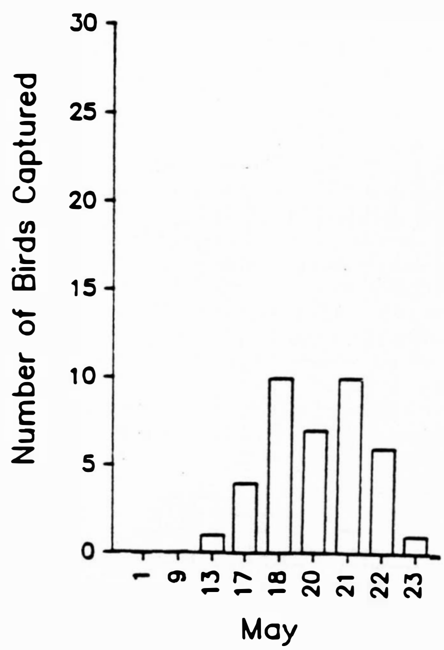

Figure 7. Timing of migration of semipalmated sandpipers in 1985.

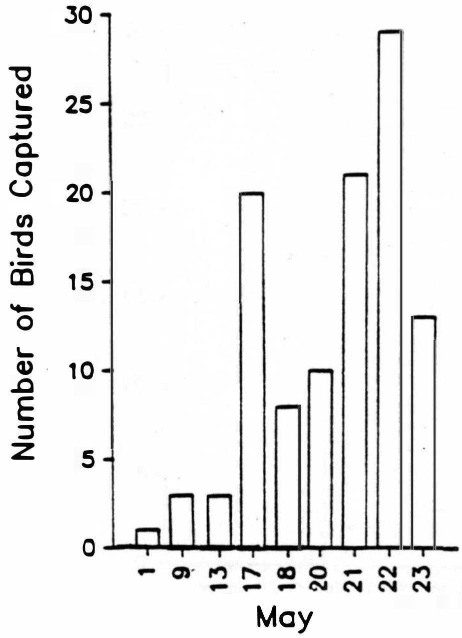

Figure 8. Timing of migration of white-rumped sandpipers in 1985.

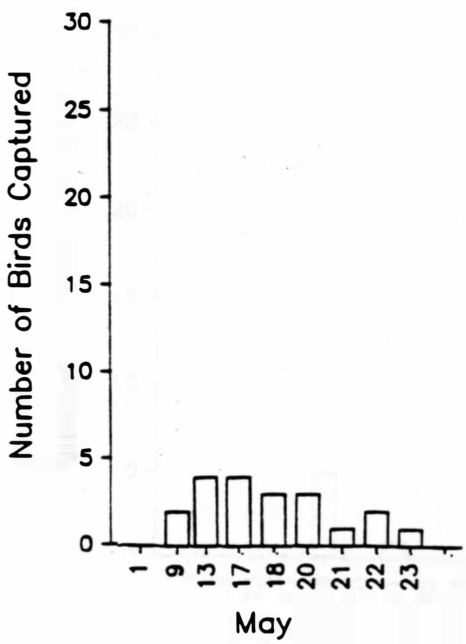

Figure 9. Timing of migration of pectoral sandpipers in 1985.

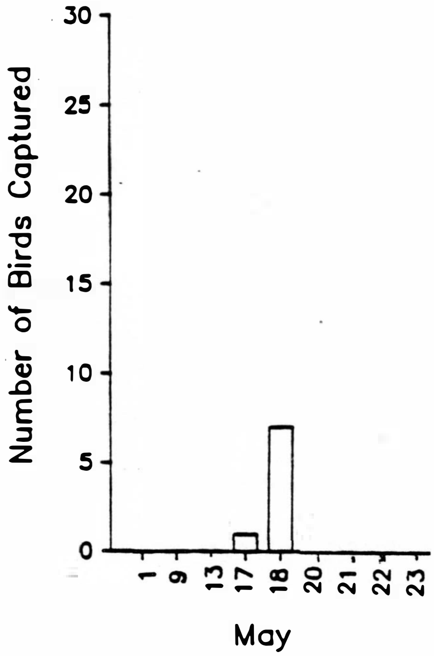

Figure 10. Timing of migration of dunlin in 1985.

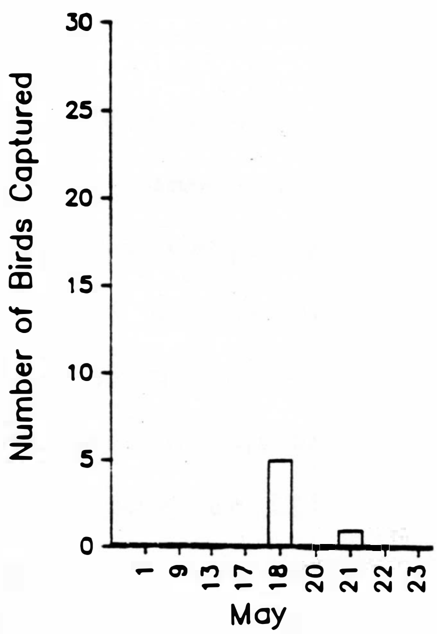

Figure 11. Timing of migration of short-billed dowitchers in 1985.

on May 15, the number of semipalmated sandpipers peaked on May 19, and the number of white-rumped sandpipers peaked on May 22. The spacing of these peaks could be a method by which shorebirds reduce interspecies competition while on migration (Recher, 1966).

B. Results of 1986 mist netting

In 1986, 184 birds of five species were captured (see Table 3). As mentioned earlier, severe weather in the Eastern South Dakota area delayed migration and any attempts to capture birds during the early part of the migration. Consequently, early migrators, such as the least sandpiper were not captured in 1986. The migration that followed this severe weather occurred at an accelerated pace (lasting only 8 days) and yielded fewer birds and less diversity than the 1985 migration.

Graphs showing migration numbers of the semipalmated sandpiper and the white-rumped sandpiper are seen in Figures 12 and 13 respectively. Other birds that were captured during the 1986 migration were the dunlin, pectoral sandpiper, and semipalmated plover. Each of these species appeared on only one day and in small numbers. Like the 1985 samples, the 1986 samples fit into the appropriate ranges listed by the South Dakota Ornithologists Union (1978). Therefore, even though the migration was delayed, it was still within the proper ranges to be considered

Table 3. Sampling dates and birds captured, 1986.

Date	Species Captured	Number Captured
May 22	semipalmated sandpiper	1
	white-rumped sandpiper	8
May 23	semipalmated sandpiper	11
	white-rumped sandpiper	16
	dunlin	2
May 24	semipalmated sandpiper	13
	white-rumped sandpiper	12
	pectoral sandpiper	1
	semipalmated plover	1
May 25	semipalmated sandpiper	24
	white-rumped sandpiper	10
May 26	semipalmated sandpiper	20
	white-rumped sandpiper	9
May 27	semipalmated sandpiper	28
	white-rumped sandpiper	16
May 28	semipalmated sandpiper	5
	white-rumped sandpiper	5
May 29	semipalmated sandpiper	2

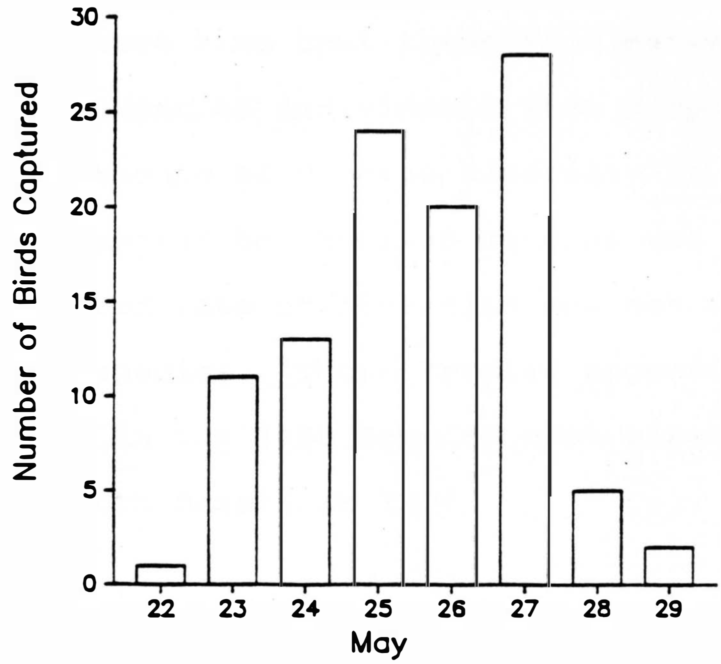

Figure 12. Timing of migration of semipalmated sandpipers in 1986.

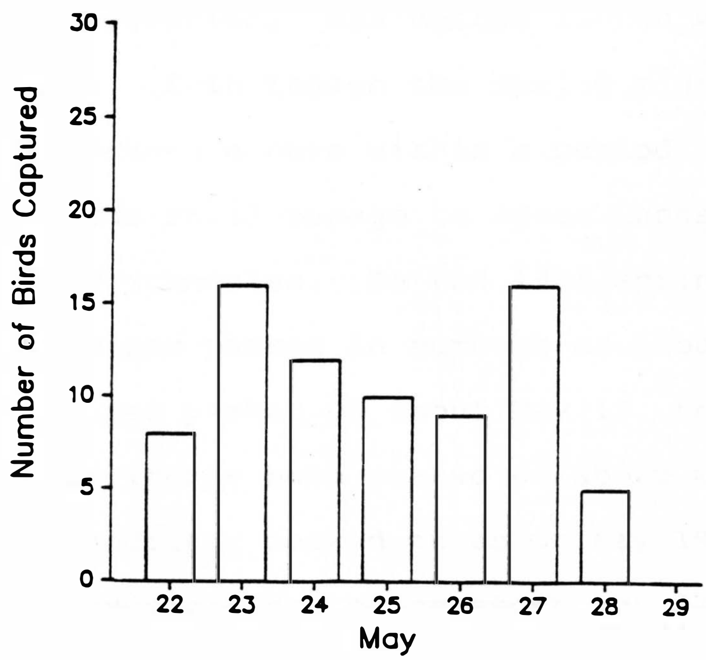

Figure 13. Timing of migration of white-rumped sandpipers in 1986.

typical for South Dakota. The small samples taken of dunlin, pectoral sandpiper, and semipalmated plover reflected the short time that these species were in the area and the small number of individuals when compared to other species. The absence of species diversity in the 1986 samples when compared to the 1985 samples was probably due to the accelerated rate of migration and not to complete absence of the species. Those species appearing in the 1985 samples but not in the 1986 samples most likely passed non-stop through South Dakota in 1986.

C. <u>Summary of migration samples</u>

Recher (1966) listed several methods by which morphologically similar shorebirds avoid competition for food while on migration. One method listed was migrating at different times. Even though the spring migration through eastern South Dakota occurs within a period of only a few weeks, shorebirds still manage to space themselves out in their migratory schedules. In the 1985 spring migration, the least sandpiper peaked in numbers on about May 13. The pectoral sandpiper peaked on about May 15, the dunlin and short-billed dowitcher both peaked on about May 18, the semipalmated sandpiper peaked on about May 19, and the white-rumped sandpiper peaked on about May 22.

The compressed migration in 1986 did not yield similar trends.

D. Results of stomach flushing in 1985

During the 1985 migration, 144 birds were successfully stomach flushed (success meaning that an identifiable sample was obtained). No birds died or suffered any noticeable harm from the stomach flushing technique. A wide variety of organisms was collected and identified during the two years of sampling (see Table 4). Raw data tables showing what each bird sampled consumed are presented in Appendix 1. To determine which food type each species relied most heavily upon, a table was set up showing what percentage of each species had consumed each food type and how many particles each species consumed on the average. This information is presented in Tables 5 through 13. In 1985, most of the shorebirds relied heavily on larval Diptera (especially the family Chironomidae). Most species also utilized adult Coleoptera to some extent. It should be noted that there is a distinct size difference between the different types of food. Adult Coleoptera (beetle) or Diptera larvae (fly) are large when compared to an ephippia (overwintering egg-like structure, Order Cladocera), and therefore would be of more value to the bird where energy is concerned.

Diptera larvae are the most important food in terms of percentage of birds eating them and numbers eaten. These larvae are generally quite large when compared to other food items. Some shorebirds, such as the killdeer and spotted

Table 4. Taxa of organisms collected by stomach flushing.

- Kingdom: Plantae
  - unidentified plant seeds
- Kingdom: Animalia
  - Phylum: Mollusca
    - Class: Pelecypoda
      - unidentified clam
  - Phylum: Arthropoda
    - Subphylum: Chelicerata
      - Class: Arachnida
        - Order: Acari
          - unidentified mite
        - Order: Araneae
          - unidentified spider
    - Subphylum: Crustacea
      - Class: Branchiopoda
        - Order: Cladocera
    - Subphylum: Uniramia
      - Class: Hexapoda
        - Subclass: Apterygota
          - Order: Collembola
        - Subclass: Pterygota
          - Order: Hemiptera
            - Family: Nabidae
            - Family: unidentified
          - Order: Coleoptera
            - Family: Dytiscidae
            - Family: Hydrophilidae
            - Family: unidentified
          - Order: Diptera
            - Family: Ceratopogonidae
            - Family: Chironomidae
            - Family: Simuliidae
            - Family: Empididae
            - Family: Dolichopodidae
            - Family: Ephydridae
            - Family: unidentified

Table 5. Food items taken by least sandpipers in 1985.

(n = 39)

Food Item	% of birds utilizing item	Average number of this item eaten
Diptera larvae	74.4%	5.1
adult Coleoptera	48.7%	1.1
adult Diptera	25.6%	0.5
Cladocera ephippia	25.6%	0.6
Coleoptera larvae	7.6%	0.1
Hemiptera	2.5%	0.03
Collembola	2.5%	0.03

Table 6. Food items taken by semipalmated sandpipers in 1985.

(n = 28)

Food Item	% of birds utilizing item	Average number of this item eaten
Diptera larvae	85.7%	10.3
adult Coleoptera	57.1%	0.9
adult Diptera	14.3%	0.1
Coleoptera larvae	14.3%	0.1
Cladocera ephippia	14.3%	0.3

Table 7. Food items taken by white-rumped sandpipers in 1985.

(n = 52)

Food Item	% of birds utilizing item	Average number of this item eaten
Diptera larvae	86.5%	7.4
adult Coleoptera	59.6%	0.7
Cladocera ephippia	21.2%	0.5
adult Diptera	5.7%	0.1
Collembola	1.9%	0.02
Hemiptera	1.9%	0.02
seeds	1.9%	0.02

Table 8. Food items taken by pectoral sandpipers in 1985.

(n = 12)

Food Item	% of birds utilizing item	Average number of this item eaten
Diptera larvae	75.0%	12.1
adult Coleoptera	83.0%	0.7
adult Diptera	8.0%	0.1
Cladocera ephippia	25.0%	0.4
Arachnida	8.0%	0.1

Table 9. Food items taken by dunlin in 1985.

(n = 6)

Food Item	% of birds utilizing item	Average number of this item eaten
Diptera larvae	83.3%	14.0
adult Coleoptera	66.7%	1.0

Table 10. Food items taken by Wilson's phalaropes in 1985.

(n = 3)

Food Item	% of birds utilizing item	Average number of this item eaten
Diptera larvae	100.0%	23.0
adult Coleoptera	66.7%	1.3
adult Diptera	33.3%	0.3
Coleoptera larvae	33.3%	0.3
Cladocera ephippia	33.3%	0.3

Table 11. Food items taken by killdeer in 1985.

(n = 2)

Food Item	% of birds utilizing item	Average number of this item eaten
adult Coleoptera	100.0%	1.0
Diptera larvae	50.0%	0.5

Table 12. Food items taken by stilt sandpipers in 1985.

(n = 1)

Food Item	% of birds utilizing item	Average number of this item eaten
Diptera larvae	100.0%	30.0
adult Diptera	100.0%	2.0
adult Coleoptera	100.0%	1.0

Table 13. Food items taken by spotted sandpipers in 1985.

(n = 1)

Food Item	% of birds utilizing item	Average number of this item eaten
adult Coleoptera	100.0%	5.0

sandpiper feed in areas with less water and thus will eat more adult Coleoptera than Diptera larvae. This fact is reflected in the data, but the sample sizes are so small that they are not statistically valid.

E. <u>Results of stomach flushing in 1986</u>

Only 36 of the 184 birds captured during the 1986 migration were successfully flushed. This low number is probably due to the fact that most birds were captured early in the morning, before they had fed. A wide variety of organisms were collected and analyzed. Tables 14, 15, and 16 show food items taken by each species sampled. A raw data table showing what each bird captured had consumed is presented in Appendix 2.

The most important food item to shorebirds in 1986 was Diptera larvae. This coincides with data from the 1985 season. Again, adult coleoptera were also important to all species. In the 1986 samples, Coleoptera larvae were found to be important to the white-rumped sandpiper (73.3% of the white-rumped sandpipers flushed had eaten Coleoptera larvae) and to the dunlin (the single dunlin sampled had consumed three Coleoptera larvae). This differs from the 1985 data where no Coleoptera larvae were found in the white-rumped sandpiper or dunlin samples. Other than this difference and the appearance of a few rarely found items (such as spiders, mites, and clams) in samples from only one year or the

Table 14. Food items taken by semipalmated sandpipers in 1986.

(n = 20)

Food Item	% of birds utilizing item	Average number of this item eaten
Diptera larvae	90.0%	5.9
adult Coleoptera	35.0%	0.4
Coleoptera larvae	25.0%	0.4
adult Diptera	20.0%	0.2
Cladocera ephippia	20.0%	0.4
Acarina	5.0%	0.05

Table 15. Food items taken by white-rumped sandpipers in 1986.

(n = 15)

Food Item	% of birds utilizing item	Average number of this item eaten
Diptera larvae	93.3%	7.0
Coleoptera larvae	73.3%	1.3
adult Coleoptera	53.3%	0.6
adult Diptera	6.7%	0.1
Cladocera ephippia	33.3%	3.5
Pelecypoda (clam)	6.7%	0.07

Table 16. Food items taken by dunlin in 1986.

(n = 1)

Food Item	% of birds utilizing item	Average number of this item eaten
Diptera larvae	100.0%	11.0
Coleoptera larvae	100.0%	3.0

other, the results from 1985 and 1986 were very similar.

F. <u>Surface insects, water column, and mud samples</u>

Surface insects (those visible on the substrate or seen flying slightly above) were collected periodically during the 1985 season and daily during the 1986 season. The results of this sampling are given in the appendix. The most common surface insects were adult Diptera. Most of these belonged to the family Simuliidae (black flies). Also present were members of the family Chironomidae (midges). Other insects found were adult Coleoptera (beetles) which were far fewer in number. On one occasion, a spider (Arachnida) was found.

Water column samples yielded organisms that did not appear in the stomach flush samples. The results of this sampling are given in the appendix. The appearance of Chironomidae larvae and Oligochaeta in the water column may have been the result of the water being stirred up during the process of sampling as these organisms are generally found only in the benthos layer.

The most common organisms found in the mud samples were Chironomidae larvae. Members of the family Ceratopogonidae were found rarely. Most of the samples contained Oligochaeta. Three of the samples contained Coleoptera larvae (families Dytiscidae and Hydrophilidae). The results of this sampling are given in the appendix.

G. Comparison of stomach samples to environment samples

Many of the organisms found in the environment samples did not appear in the stomach samples. Two possible reasons for this are: 1) the birds did not eat these organisms; or 2) the organisms were digested before the stomach samples were taken. Organisms such as Oligochaeta, adult Cladocera, and adult copepoda are very soft bodied. The time between feeding (including the time taken to weigh, measure, and band the birds) and flushing may be long enough to allow digestion of these organisms. Because these organisms did not appear in the stomach samples, the water column samples were not included in the statistical analyses. The Oligochaeta were not used in the statistical analyses because they appeared only rarely in the mud samples and never in the stomach samples.

Chi-square tests were used to compare the environment samples to the stomach samples. These tests were run only for species of birds which were sampled in numbers of 12 or greater. Data from these tests is seen in Tables 17 through 22. Results of these tests show that the probability that the birds are selecting for specific food types is highly significant ($P < .01$). All birds sampled appeared to be selecting for adult Coleoptera while feeding on surface insects. In 1985, all species appeared to be selecting for Diptera larvae when feeding beneath the surface of the mud. In 1986, all species appeared to be

Table 17. Chi-square test, environment samples versus stomach samples, least sandpiper, 1985.

	Environment	Stomach	
Diptera larvae	198	202	
Coleoptera larvae	22	6	X^2 2df =
Cladocera ephippia	94	27	35.65 **
adult Coleoptera	22	43	
adult Diptera	170	22	X^2 1df =
			76.88 **

Table 18. Chi-square test, environment samples versus stomach samples, semipalmated sandpiper, 1985.

	Environment	Stomach	
Diptera larvae	198	284	
Coleoptera larvae	22	4	X^2 2df =
Cladocera ephippia	94	7	102.25 **
adult Coleoptera	22	25	
adult Diptera	170	3	X^2 1df =
			88.11 **

Table 19. Chi-square test, environment samples versus stomach samples, pectoral sandpiper, 1985.

	Environment	Stomach	
Diptera larvae	198	134	
Coleoptera larvae	22	0	X^2 2df =
Cladocera ephippia	94	5	54.94 **
adult Coleoptera	22	8	
adult Diptera	170	1	X^2 1df =
			40.59 **

Table 20. Chi-square test, Environment samples versus stomach samples, white-rumped sandpiper, 1985.

	Environment	Stomach	
Diptera larvae	198	395	
Coleoptera larvae	22	0	X^2 2df =
Cladocera ephippia	94	24	116.32 **
adult Coleoptera	22	36	
adult Diptera	170	7	X^2 1df =
			98.69 **

Table 21. Chi-square test, environment samples versus stomach samples, semipalmated sandpiper, 1986.

	Environment	Stomach	
Diptera larvae	738	118	
Coleoptera larvae	12	10	X^2 2df =
Cladocera ephippia	309	8	54.89 **
adult Coleoptera	13	6	
adult Diptera	495	5	X^2 1df =
			82.50 **

Table 22. Chi-square test, Environment samples versus stomach samples, white-rumped sandpiper, 1986.

	Environment	Stomach	
Diptera larvae	738	105	
Coleoptera larvae	12	20	X^2 2df =
Cladocera ephippia	309	52	62.93 **
adult Coleoptera	13	9	
adult Diptera	495	2	X^2 1df =
			166.63 **

selecting for Coleoptera larvae when feeding beneath the surface of the mud.

H. Comparison of food consumed by different species

A Chi-square test was run to determine if each species was ingesting different proportions of available food items. Data from these tests is given in Tables 23 and 24. In 1985, the different species appeared to be ingesting different proportions of food items ($P < .01$) while feeding below the surface of the mud and while feeding on surface insects ($P < .05$). In 1986, The different species of birds appeared to be ingesting different proportions of food items while feeding below the surface of the mud ($P < .01$). The surface insect test showed no significance ($P = 1.89$). This "not significant" test result was due to very small sample sizes rather than to similar selections by the birds.

It appears that different species of shorebirds are ingesting different proportions of the available food items. This could be an adaptation to reduce interspecies competition.

Table 23. Chi-square test to determine if different species of shorebirds selected for different proportions of available food items in 1985.

	larval Diptera	Cladocera ephippia	
least sp.	202	27	
semipalmated sp.	284	7	X^2 3df =
white-rumped sp.	395	24	22.25 **
pectoral sp.	134	5	

	adult Diptera	adult Coleoptera	
least sp.	22	43	
semipalmated sp.	3	25	X^2 3df = 8.58 *
white-rumped sp.	7	36	
pectoral sp.	1	8	

Table 24. Chi-square test to determine if different species of shorebirds selected for different proportions of available food items in 1986.

	larval Diptera	larval Coleoptera	Cladocera ephippia	
semipalmated sp.	105	20	52	X^2 2df =
white-rumped sp.	118	10	8	31.53 **

	adult Diptera	adult Coleoptera	
semipalmated sp.	2	9	X^2 1df = 1.89
white-rumped sp.	5	6	

SUMMARY AND CONCLUSIONS

Shorebirds on spring migration through eastern South Dakota in 1985 and 1986 were captured in mist nets at three feeding sites. In 1985, migration peaked for the least sandpiper on May 13, the pectoral sandpiper on May 15, the semipalmated sandpiper on May 19, and the white-rumped sandpiper on May 22. Three other birds captured, Wilson's phalarope, killdeer, and spotted sandpiper, are not included in this list because they commonly nest in the study area. The numbers of dunlin, short-billed dowitchers, and stilt sandpipers captured were too small to determine their migration peaks. In 1986, severe weather conditions compressed migration and the trends seen in 1985 were not evident.

Analysis of stomach contents showed Diptera larvae were the most important food item for all birds except the killdeer and spotted sandpiper. These birds normally feed in areas with less water and therefore consume more adult Coleoptera. In most species, the second most important food item is adult Coleoptera. Exceptions to this in 1985 were the killdeer and spotted sandpiper which chose adult Coleoptera as their most important food item. In 1986, The white-rumped sandpiper and the dunlin chose Coleoptera larvae as their second most important food item. This is of interest, as Coleoptera larvae did not appear in the 1985 samples taken from these species.

Data from this study shows that shorebirds migrating through eastern South Dakota may reduce interspecies competition by two methods: 1) by migrating through the area at slightly different times; and 2) by ingesting slightly different proportions of the available food items. The data also show that all species of shorebirds select for specific food items found in the environment. Observation while on the study sites found all birds feeding in the same area, but this does not exclude the possibility that some of the birds captured had fed in completely different areas. Comparison of food items from stomach samples and the environment suggests that the birds captured were feeding in the capture area. Also, birds captured prior to 8:00 AM had little food in their stomachs. This suggests that birds were not arriving at the study site after feeding elsewhere.

Birds captured appeared to be characteristic of the populations observed in the area. Only a few of the less abundant species observed were not captured.

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APPENDIX

Appendix 1. Organisms collected by stomach flushing in 1985 (L = larvae, A = adult, U = unidentified family)

Date	Bird	Organism Collected	Number
April 24	killdeer	Coleoptera (UA)	1
May 1	least sp.	Chironomidae (L)	1
	"	Coleoptera (UA)	2
	white-rumped sp.	Chironomidae (L)	1
		Coleoptera (UA)	1
May 9	Wilson's phalarope	Chironomidae (L)	1
		Coleoptera (UA)	2
	"	Chironomidae (L)	1
		Coleoptera (UA)	2
	white-rumped sp.	Chironomidae (L)	7
		Coleoptera (UA)	1
	"	Chironomidae (L)	1
		Coleoptera (UA)	1
	pectoral sp.	Cladocera ephippia	2
		Chironomidae (L)	48
May 13	least sp.	Cladocera ephippia	2
		Chironomidae (L)	4
		Empididae (A)	2
	"	Chironomidae (L)	15
		Coleoptera (UA)	1
	"	Cladocera ephippia	6
		Dolichopodidae (A)	1
		Chironomidae (L)	5
		Chironomidae (A)	2
		Coleoptera (UA)	1
	"	Chironomidae (L)	6
	"	Coleoptera (L)	1

Appendix 1. continued

Date	Bird	Organism Collected	Number
May 13	least sp.	Chironomidae (L)	18
		Coleoptera (UA)	1
	"	Chironomidae (L)	1
	"	Chironomidae (L)	3
	"	Chironomidae (L)	12
		Coleoptera (UA)	2
	"	Cladocera ephippia	2
		Chironomidae (L)	31
	"	Chironomidae (L)	1
	"	Chironomidae (L)	4
	"	Chironomidae (L)	5
	"	Cladocera ephippia	4
		Chironomidae (L)	18
		Coleoptera (UA)	2
	"	Chironomidae (L)	25
		Coleoptera (UA)	1
	"	Collembola (U)	1
	"	Chironomidae (L)	14
	semipalmated sp.	Chironomidae (L)	31
		Coleoptera (UA)	1
	white-rumped sp.	Chironomidae (L)	8
	"	Cladocera ephippia	1
		Chironomidae (L)	2
		Chironomidae (A)	3
	pectoral sp.	Chironomidae (L)	5
	"	Chironomidae (L)	1
	"	Cladocera ephippia	2
		Chironomidae (L)	13

Appendix 1. continued

Date	Bird	Organism Collected	Number
May 13	pectoral sp.	Chironomidae (L)	26
May 17	least sp.	Chironomidae (L)	1
		Ceratopogonidae (A)	1
		Coleoptera (UA)	1
	"	Cladocera ephippia	3
		Chironomidae (L)	1
		Diptera (UA)	2
		Coleoptera (UA)	2
	"	Cladocera ephippia	2
		Chironomidae (L)	2
		Diptera (UA)	2
	"	Chironomidae (L)	3
	"	Coleoptera (UA)	1
	"	Coleoptera (UA)	1
	"	Cladocera ephippia	2
		Chironomidae (L)	3
		Coleoptera (UA)	1
	"	Cladocera ephippia	2
		Chironomidae (L)	2
		Simuliidae (A)	1
		Coleoptera (UA)	2
	"	Coleoptera (UA)	1
	"	Chironomidae (L)	5
		Hydrophilidae (L)	1
	"	Cladocera ephippia	1
		Chironomidae (L)	1
		Hydrophilidae (L)	3
		Coleoptera (UA)	1
May 18	least sp.	Coleoptera (UA)	7

Appendix 1. continued

Date	Bird	Organism Collected	Number
May 18	least sp.	Diptera (UA)	1
	"	Coleoptera (UA)	12
	"	Chironomidae (L)	3
		Ceratopogonidae (L)	1
		Ceratopogonidae (A)	1
		Simuliidae (A)	1
	"	Cladocera ephippia	2
		Ceratopogonidae (A)	1
		Simuliidae (A)	3
		Coleoptera (UA)	4
	"	Chironomidae (L)	3
		Ceratopogonidae (A)	1
		Simuliidae (A)	3
		Hemiptera (UA)	1
	semipalmated sp.	Hydrophilidae (L)	1
		Coleoptera (UA)	3
	"	Chironomidae (L)	1
		Coleoptera (UA)	1
	"	Chironomidae (L)	8
		Coleoptera (UA)	1
	"	Chironomidae (L)	26
	"	Chironomidae (L)	3
		Simuliidae (A)	1
		Coleoptera (UA)	3
	"	Chironomidae (L)	2
		Coleoptera (UA)	2
	"	Cladocera ephippia	1
		Chironomidae (L)	2
		Hydrophilidae (L)	1
		Coleoptera (UA)	2
	"	Chironomidae (L)	4
		Coleoptera (UA)	1

Appendix 1. continued

Date	Bird	Organism Collected	Number
May 18	white-rumped sp.	Diptera (UA)	2
		Coleoptera (UA)	1
	"	Chironomidae (L)	2
		Coleoptera (UA)	1
	white-rumped sp.	Cladocera ephippia	3
		Chironomidae (L)	9
	"	Coleoptera (UA)	1
	"	Chironomidae (L)	1
		Coleoptera (UA)	1
	"	Chironomidae (L)	4
		Chironomidae (A)	2
		Coleoptera (UA)	1
		Hemiptera (UA)	1
	dunlin	Chironomidae (L)	8
		Coleoptera (UA)	1
	"	Chironomidae (L)	16
	"	Chironomidae (L)	23
	"	Chironomidae (L)	26
		Coleoptera (UA)	2
	"	Chironomidae (L)	11
		Coleoptera (UA)	2
	"	Coleoptera (UA)	1
	pectoral sp.	Coleoptera (UA)	2
	"	Chironomidae (L)	7
May 20	least sp.	Cladocera ephippia	1
		Chironomidae (L)	2

Appendix 1. continued

Date	Bird	Organism Collected	Number
May 20	semipalmated sp.	Chironomidae (L)	12
		Hydrophilidae (L)	1
		Coleoptera (UA)	3
	"	Cladocera ephippia	2
		Chironomidae (L)	3
	"	Simuliidae (A)	1
	semipalmated sp	Cladocera ephippia	3
		Chironomidae (L)	1
	white-rumped sp.	Coleoptera (UA)	1
	"	Chironomidae (L)	15
	"	Coleoptera (UA)	1
	"	Chironomidae (L)	3
		Coleoptera (UA)	1
	"	Cladocera ephippia	1
		Chironomidae (L)	4
		Coleoptera (UA)	1
	"	Chironomidae (L)	10
		Coleoptera (UA)	2
	pectoral sp.	Coleoptera (UA)	2
		Arachnida (UA)	1
	"	Chironomidae (L)	1
		Coleoptera (UA)	2
	"	Cladocera ephippia	1
		Ceratopogonidae (A)	1
		Coleoptera (UA)	1
	stilt sp.	Chironomidae (L)	30
		Chironomidae (A)	2
		Coleoptera (UA)	1

Appendix 1. continued

Date	Bird	Organism Collected	Number
May 21	least sp.	Chironomidae (L)	9
		Hydrophilidae (L)	1
	semipalmated sp.	Chironomidae (L)	6
	"	Coleoptera (UA)	1
	"	Coleoptera (UA)	1
	"	Coleoptera (UA)	2
	"	Chironomidae (L)	1
	semipalmated sp.	Chironomidae (L)	32
		Simuliidae (A)	1
		Coleoptera (UA)	1
	"	Chironomidae (L)	1
		Coleoptera (UA)	1
	"	Chironomidae (L)	1
	white-rumped sp.	Coleoptera (UA)	2
	"	Coleoptera (UA)	1
	"	Chironomidae (L)	3
	"	Cladocera ephippia	3
		Chironomidae (L)	5
	"	Cladocera ephippia	1
		Chironomidae (L)	20
		Coleoptera (UA)	1
	"	Chironomidae (L)	4
	"	Chironomidae (L)	64
	"	Cladocera ephippia	3
		Chironomidae (L)	2
		Coleoptera (UA)	1
	"	Chironomidae (L)	9

Appendix 1. continued

Date	Bird	Organism Collected	Number
May 21	white-rumped sp.	Chironomidae (L)	4
	"	Chironomidae (L)	21
	"	Chironomidae (L)	2
		Coleoptera (UA)	1
May 22	semipalmated sp.	Chironomidae (L)	27
	"	Chironomidae (L)	30
		Coleoptera (UA)	1
	"	Chironomidae (L)	6
	semipalmated sp.	Chironomidae (L)	21
	"	Chironomidae (L)	41
		Chironomidae (A)	1
	"	Cladocera ephippia	1
		Chironomidae (L)	24
		Hydrophilidae (L)	1
		Coleoptera (UA)	1
	white-rumped sp.	Chironomidae (L)	11
		Coleoptera (UA)	1
	"	Chironomidae (L)	5
		Coleoptera (UA)	1
	"	plant seed	1
		Chironomidae (L)	7
	"	Collembola (UA)	1
		Chironomidae (A)	1
	"	Cladocera ephippia	2
		Chironomidae (L)	4
	"	Chironomidae (L)	19
	"	Cladocera ephippia	1
		Chironomidae (L)	26
		Coleoptera (UA)	1

Appendix 1. continued

Date	Bird	Organism Collected	Number
May 22	white-rumped sp.	Cladocera ephippia	2
		Chironomidae (L)	6
	"	Chironomidae (L)	2
		Coleoptera (UA)	1
	"	Chironomidae (L)	21
	"	Chironomidae (L)	18
		Coleoptera (UA)	1
	"	Chironomidae (L)	2
	"	Coleoptera (UA)	1
	white-rumped sp.	Chironomidae (L)	11
		Coleoptera (UA)	3
	"	Chironomidae (L)	6
		Coleoptera (UA)	2
	"	Chironomidae (L)	4
		Coleoptera (UA)	1
	"	Chironomidae (L)	2
		Coleoptera (UA)	1
	"	Chironomidae (L)	1
		Coleoptera (UA)	1
	"	Cladocera ephippia	2
		Chironomidae (L)	5
	"	Chironomidae (L)	14
		Coleoptera (UA)	1
	"	Chironomidae (L)	4
	"	Chironomidae (L)	3
	"	Cladocera ephippia	5
		Chironomidae (L)	22
		Coleoptera (UA)	1

Appendix 1. continued

Date	Bird	Organism Collected	Number
May 22	pectoral sp.	Chironomidae (L)	1
		Coleoptera (UA)	1
	"	Chironomidae (L)	33
	killdeer	Chironomidae (L)	1
		Coleoptera (UA)	1
May 23	least sp.	Chironomidae (L)	3
	semipalmated sp.	plant seed	1
		Chironomidae (L)	1
May 23	Wilson's phalarope	Cladocera ephippia	1
		Chironomidae (L)	67
		Ceratopogonidae (A)	1
		Hydrophilidae (L)	1
	spotted sp.	Coleoptera (UA)	5

Appendix 2. Organisms collected by stomach flushing in 1986 (L = larvae, A = adult, U = unidentified family)

Date	Bird	Organism Collected	Number
May 22	semipalmated sp.	Cladocera ephippia	4
		Chironomidae (A)	1
		Coleoptera (UA)	1
	white-rumped sp.	Chironomidae (L)	1
May 23	semipalmated sp.	Chironomidae (L)	1
		Hydrophilidae (L)	1
	"	Chironomidae (L)	2
	"	Chironomidae (L)	5
		Hydrophilidae (L)	2
	"	Chironomidae (L)	20
		Hydrophilidae (L)	4
	white-rumped sp.	Chironomidae (L)	5
		Ephydridae (A)	2
	dunlin	Chironomidae (L)	11
		Hydrophilidae (L)	3
May 24	semipalmated sp.	Chironomidae (L)	1
		Acarina (U)	1
May 25	semipalmated sp.	Cladocera ephippia	2
		Chironomidae (L)	2
	"	Cladocera ephippia	1
		Chironomidae (L)	7
		Coleoptera (UA)	1
	"	Cladocera ephippia	1
		Chironomidae (L)	1
	white-rumped sp.	Chironomidae (L)	10
		Dytiscidae (L)	1
		Coleoptera (UA)	1
May 26	semipalmated sp.	Chironomidae (L)	8

Appendix 2. continued

Date	Bird	Organism Collected	Number
May 26	semipalmated sp.	Chironomidae (L)	2
	white-rumped sp.	Chironomidae (L)	4
		Dytiscidae (L)	1
		Coleoptera (UA)	1
	"	Chironomidae (L)	5
		hydrophilidae (L)	1
		Dytiscidae (L)	1
		Coleoptera (UA)	2
	"	Chironomidae (L)	21
	"	Cladocera ephippia	8
		Chironomidae (L)	11
		Dytiscidae (L)	2
May 27	semipalmated sp.	Chironomidae (L)	27
		Simuliidae (A)	1
		Coleoptera (UA)	1
	"	Simuliidae (A)	1
	"	Chironomidae (L)	6
		Hydrophilidae (L)	1
	"	Chironomidae (L)	4
		Chironomidae (A)	1
		Simuliidae (A)	1
		Coleoptera (UA)	1
	"	Chironomidae (L)	8
		Hydrophilidae (L)	2
	"	Chironomidae (L)	10
	white-rumped sp.	Cladocera ephippia	1
		Chironomidae (L)	8
		Dytiscidae (L)	2
		Hydrophilidae (L)	1
		Coleoptera (UA)	1
	"	Chironomidae (L)	1
		Hydrophilidae (L)	1
		Coleoptera (UA)	1

Appendix 2. continued

Date	Bird	Organism Collected	Number
May 27	white-rumped sp.	Cladocera ephippia	39
		Chironomidae (L)	13
		Dytiscidae, (L)	1
	"	Cladocera ephippia	2
		Chironomidae (L)	8
		Coleoptera (UA)	1
	"	Chironomidae (L)	7
		Hydrophilidae (L)	2
		Coleoptera (UA)	1
	"	Chironomidae (L)	1
		Hydrophilidae (L)	1
	"	Cladocera ephippia	2
		Chironomidae (L)	10
		Dytiscidae (L)	4
		Hydrophilidae (L)	1
		Coleoptera (UA)	1
		Pelecypoda (U)	1
	"	Dytiscidae (L)	1
May 28	semipalmated sp.	Chironomidae (L)	9
		Coleoptera (UA)	1
	"	Chironomidae (L)	1
		Coleoptera (UA)	1
May 29	semipalmated sp.	Chironomidae (L)	4
		Coleoptera (UA)	2

Appendix 3. Surface insects at the study site in 1985

(Numbers equal totals from three samples)

Date	Organism	Number
May 17	Simuliidae	38
	Coleoptera	6
May 20	Simuliidae	67
	Chironomidae	5
	Coleoptera	8
	Hemiptera	2
May 23	Chironomidae	60
	Coleoptera	8

Appendix 4. Surface insects at the study site in 1986

(Numbers equal totals from three samples)

Date	Organism	Number
May 22	Simuliidae	36
	Chironomidae	15
	Coleoptera	3
May 23	Simuliidae	33
	Chironomidae	6
	Coleoptera	3
	Arachnida	3
May 24	Simuliidae	69
	Coleoptera	6
May 25	Simuliidae	63
May 26	Simuliidae	39
	Coleoptera	3
May 27	Simuliidae	72
	Chironomidae	12
May 28	Simuliidae	54
	Chironomidae	15
	Coleoptera	3
May 29	Simuliidae	51
	Coleoptera	3

Appendix 5. Water column samples from the study area in 1985

Date	Organism	Number
May 17	Cladocera	28
	Copepoda	9
	Chironomidae	1
May 20	Cladocera	34
	Copepoda	11
	Chironomidae	1
May 23	Cladocera	46
	Copepoda	26

Appendix 6. Water column samples from the study area in 1986

Date	Organism	Number
May 22	Cladocera	25
	Copepoda	16
	Chironomidae	3
May 23	Cladocera	26
	Copepoda	11
May 24	Cladocera	21
	Copepoda	6
	Chironomidae	4
	Oligochaeta	1
	Ostracoda	1
May 25	Cladocera	38
	Copepoda	21
	Ostracoda	10
May 26	Cladocera	41
	Copepoda	30
	Chironomidae	3
May 27	Cladocera	51
	Copepoda	47
	Chironomidae	5
	Oligochaeta	3
May 28	Cladocera	187
	Copepoda	61
	Chironomidae	3
May 29	Cladocera	209
	Copepoda	62
	Chironomidae	18
	Oligochaeta	1

Appendix 7. Mud samples from the study area in 1985

Date	Organism	Number
May 17	Chironomidae	67
	Ceratopogonidae	1
	Hydrophilidae	6
	Oligochaeta	6
	Cladocera ephippia	6
May 20	Chironomidae	72
	Hydrophilidae	8
	Dytiscidae	1
	Oligochaeta	3
	Cladocera ephippia	55
May 23	Chironomidae	58
	Hydrophilidae	7
	Oligochaeta	3
	Cladocera ephippia	33

Appendix 8. Mud samples from the study area in 1986

Date	Organism	Number
May 22	Chironomidae	23
	Cladocera ephippia	4
May 23	Chironomidae	14
	Oligochaeta	6
	Cladocera ephippia	2
May 24	Chironomidae	34
	Ceratopogonidae	1
	Dytiscidae	1
	Oligochaeta	1
	Cladocera ephippia	6
May 25	Chironomidae	21
	Dytiscidae	2
	Cladocera ephippia	12
May 26	Chironomidae	35
	Oligochaeta	1
	Hydrophilidae	1
	Cladocera ephippia	18
May 27	Chironomidae	32
	Oligochaeta	3
	Cladocera ephippia	23
May 28	Chironomidae	45
	Ceratopogonidae	3
	Oligochaeta	1
	Cladocera ephippia	27
May 29	Chironomidae	38
	Oligochaeta	1
	Cladocera ephippia	11