COVER UTILIZATION AND FLOCKING BEHAVIOR OF SHOREBIRDS FORAGING IN AGRICULTURAL FIELDS IN NORTHAMPTON COUNTY, VIRGINIA

A thesis submitted for partial fulfillment of the requirements for the Degree of Bachelor of Science with Honors in Biology at the College of William and Mary

by

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April 1992

Williamsburg, Virginia

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ACKNOWLEDGEMENTS

I would particularly like to thank Mrs. Ruth A. Beck, my research advisor, for her enthusiastic help with the setup of the research and preparation of the thesis, and Dr. Bryan D. Watts for his invaluable assistance in giving direction to the research, suggesting solutions to statistical problems, and making helpful criticisms of the thesis. I would also like to thank Dr. Mitchell A. Byrd and Ms. M. Joy Archer for reviewing the thesis and serving on my Honors committee.

I am grateful to Tom Armour for providing transportation on one of the censuses, and to Barry Truitt, Randy Carlson, Fred Diem, and Presley Curling for providing local information regarding shorebirds on the Eastern Shore. Housing was provided by the biology department of the College of William and Mary and the Eastern Shore of Virginia National Wildlife Refuge. Transportation and tolls were paid for in part by the Mary E. Ferguson Award of the Biology Club of the College of William and Mary, and by research grants from the Augusta Bird Club and the Monticello Bird Club. Equipment was provided through a minor research grant from the College of William and Mary.

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ABSTRACT

Cover use and flocking in birds is closely tied to foraging efficiency and risk of predation. Foraging efficiency tends to be higher and risk of predation lower (in some species) in flocks, especially in mixed-species flocks. Birds foraging in the open or on short cover tend to forage more efficiently, but the risk of predation there is generally higher than in tall cover. I studied shorebirds foraging in agricultural fields on Virginia's Eastern Shore to determine cover use and flocking patterns of these birds, and to evaluate whether or not these foraging behaviors were consistent with predictions based on foraging efficiency and predation risk. Shorebirds were common in the study area in spring, fall, and winter. Most species exhibited a positive association with plough and a negative association with >10 cm cover, while the associations with <10 cm cover were varied. In most species, relative cover use remained constant from one season to the next on plough and >10 cm cover, but on <10 cm cover more species exhibited a positive association in spring than in fall or winter, possibly due to crowding effects on plough during spring. Most species preferred plough or short cover, where they may have been able to forage more efficiently than on tall cover. Almost all the individuals observed were foraging in flocks, and most species were positively associated with mixed-species flocks and negatively associated with monospecific flocks. These associations were consistent during all seasons and on all cover types. Foraging in flocks probably reduced the risk of predation, allowing the

shorebirds to forage on plough (where they were more visible to predators). Choice of cover involves a tradeoff between foraging efficiency and predation risk. I concluded that these birds were probably able to forage on plough (where foraging was most efficient) because alternate foraging strategies (e.g. flocking) increased their safety from predators. In addition, flocking probably enhanced not only the birds' safety, but also their foraging efficiency.

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INTRODUCTION

Waders of the suborders Charadrii and Scolopaci, commonly called shorebirds, are often associated with wet open areas such as beaches, mud flats, and lake and river shores. The substrate in these areas consists of homogeneous sand or mud and is usually devoid of vegetation, providing little cover for birds. A few species of shorebirds, however, occur primarily in upland fields and pastures, where cover types are more diverse. In addition, many species that prefer to forage and roost on intertidal areas move to fields when beaches and flats are inundated during daily or seasonal high tides (Goss-Custard 1969, Page & Whitacre 1975, Gerstenberg 1979, Page et al. 1979), or feed in fields during migration through inland areas (Ohmart et al. 1985).

Whereas much work has been done on the foraging and flocking behavior of shorebirds in aquatic and semiaquatic habitats, relatively little research has been conducted on shorebirds in upland habitats. Energetics models developed for shorebirds feeding in intertidal areas predict that the birds forage in such a way that net energy gain is maximized (Evans 1976); the same prediction can be assumed to hold true for shorebirds foraging in agricultural fields as well. On the Eastern Shore of Virginia, where avian predators are fairly common during the seasons in which shorebirds are present in fields (Kain 1987, Sutton 1991, pers. obs.), such maximal net energy gain must reflect a balance of those behavioral and morphological adaptations that promote foraging efficiency and those promoting safety from predators. Two factors that influence this balance in an individual shorebird using fields are the bird's associations with other individuals, both of its own species and of other species, and the cover types on which the bird forages.

A great deal of research has been conducted in an attempt to explain flock formation in birds. Most discussion of flocking has focussed on the costs and benefits of flocking in terms of safety from predators and foraging efficiency (Gaddis 1980, Barnard and Stephens 1983, Sullivan 1984, Barnard & Thompson 1985). Aggregations of shorebirds may be more visible to predators than single birds, especially if the flocks contain larger species (Recher & Recher 1969), and larger flocks may be attacked more often and with greater success than smaller flocks (Page & Whitacre 1975). However, for many species the benefits of flocking, in terms of safety from predators, seem to outweigh the costs. (Page & Whitacre 1975, Stinson 1980, Barnard & Thompson 1985). Although aggregations are more visible than single individuals, flocking allows birds to be concentrated in fewer locations, increasing the area a predator must search to find prey (Barnard & Thompson 1985). The probability of a single individual being attacked decreases asymptotically with increasing flock size, a phenomenon known as the "dilution effect" (Foster & Treherne 1981). Also, the more birds a flock contains, the more individuals there are scanning for predators, and the earlier a predator will be detected. If an individual forages with others, it is able to exploit the vigilance of other members of the flock (Buskirk 1974), so that the time that any individual must spend scanning for predators decreases asymptotically with increasing flock size (Thompson & Barnard 1983), while the flock as a whole maintains adequate vigilance. Thus, a single bird in a flock can spend more time feeding and less time scanning for predators than if it were alone, increasing its foraging efficiency.

The benefits and costs of feeding in flocks, with regard to foraging efficiency, have been well-studied. Individuals may increase their foraging efficiency through "local enhancement" (Hinde 1961), in which birds are able to find good feeding areas quickly by locating birds that are foraging (Murton 1971). Once at a suitable site, individuals in a flock may enhance their foraging efficiency by copying the foraging techniques of successful feeders (Krebs et al. 1972, Barnard & Sibly 1981), by "area copying", in which less successful feeders move to forage in the same area as successful birds (Thompson 1981), or by stealing food from other birds (Barnard & Sibly 1981).

Such copying and kleptoparasitism may benefit the individuals adopting these techniques, but the foraging efficiency of other birds in the flock will suffer as a result. Kleptoparasitism and aggression become more common with increasing flock size (Goss-Custard 1977, Burger et al. 1979), and both interspecific (Byrkjedal & Kalas 1983) and intraspecific (Recher & Recher 1969) aggression decrease foraging time for both individuals involved. Other costs of feeding in flocks include rapid prey depletion by large numbers of birds, especially in mixed-species flocks (Bentson et al. 1976, Byrkjedal & Kalas 1983), and the reduction in prey availability due to disturbance of the substrate (Pienkowski 1983). Visual hunters such as plovers need a larger search area than do tactile foragers, so they must maintain an open space around them (Stinson 1977, Pienkowski 1983). Plovers in flocks maintain this space by avoiding each other (Stinson 1977), but in mixed-species flocks with tactile foragers, the plovers may have their search paths disrupted by other birds (Goss-Custard 1977), which may require them to show more aggression toward the tactile foragers or move to the periphery of the flock.

Despite the potential energetic costs to birds foraging in mixed-species flocks, many birds spend a great deal of their time in such aggregations. Species that tend to occur in close association with other species are "flock-positive", while "flock-negative" species rarely join mixed-species groups (Herrera 1979). One or several species may comprise a flock's nucleus, to which other species are attracted (Buskirk 1974), presumably because the nuclear species increase the safety and/or foraging efficiency of other birds in the flock. Studies of Northern Lapwings (*Vanellus vanellus*), Golden Plovers (*Pluvialis apricaria*), and Dunlin (*Calidris alpina*) in Great Britain give evidence for such species associations. Wintering Golden Plovers occur in mixed flocks with Lapwings much more often than they occur in monospecific flocks (Fuller & Youngman 1979, Barnard & Thompson 1985). The time required for Lapwings to respond to alarm stimuli decreases with increasing numbers of Golden Plovers in a mixed flock (Thompson & Barnard 1983), providing evidence that the plovers aid the lapwings in early detection of potential predators. Both Dunlin and Golden Plovers are more responsive to alarm stimuli when they occur together, although in mixed flocks Golden Plovers are more vigilant than Dunlin, so the Dunlin seems to exploit the plover's vigilance more than the plover relies on the vigilance of the Dunlin (Barnard & Thompson 1985, Thompson & Thompson 1985). The Dunlin also relies on the plover to find good feeding sites, and may compete with the Golden Plover for some prey items (Byrkjedal & Kalas 1983), so apparently the Dunlin benefits from this relationship more than does the plover.

Like flocking behavior, the cover types on which birds feed are also important determinants of foraging efficiency and safety from predators. Song Sparrows (*Melospiza melodia*) and Savannah Sparrows (*Passerculus sandwichensis*) in high, thick vegetation incur less predator-related mortality than birds in more open areas (Watts 1990). As cover increases in height and thickness, avian predators must increase their height above ground in order to maintain a wide search area; while this allows for a higher rate of prey detection, the increased distance between predator and prey results in a longer attack time, giving the prey more time to escape (Watts 1990). Although their prey is generally denser in tall cover, Ferruginous Hawks (*Buteo regalis*) (Wakely 1978, Bechard 1982) and American Kestrels (*Falco sparverius*) (Sparrowe 1972) hunt more frequently and more successfully on short cover, presumably because the prey is easier to locate and capture on shorter cover.

These studies provide evidence that birds feeding in agricultural areas would be safer if they foraged in tall, thick cover than if they foraged in short cover or on plough (bare earth). Thick cover also contains more of the prey sought by shorebirds, such as earthworms, arthropods, and arthropod larvae (Burton 1974). Golden Plovers and Lapwings wintering in Great Britain forage primarily on pastures and winter cereals, where their prey (earthworms) are larger and more abundant than on fresh plough (Barnard & Thompson 1985). In addition, vegetation prevents or slows drying and freezing of the soil, processes that decrease prey availability by killing prey or causing them to burrow deeper (Burton 1974, Murton & Westwood 1974, Evans 1976, Pienkowski 1981, Shrubb 1988).

Tall, thick vegetative cover does, however, present some problems to foraging birds. Thick vegetation reduces the search area of visual hunters, and may make it harder for birds to locate and extract prey (Fuller & Youngman 1979). Locomotion in birds may be impeded in tall grass (Bent 1949), and foraging efficiency has been shown to be lower in tall vegetation than on short cover in American Robins (*Turdus migratorius*) (Eiserer 1980) and Northern Mockingbirds (*Mimus polyglottos*) (Roth 1979). If a bird in a flock is able to see its neighbors, it can assess the vigilance of the other birds and exploit that vigilance, allowing the bird to spend more time feeding and less time scanning for predators. In thick cover, however, a bird may not be able to see its neighbors clearly; under such conditions the bird will be unable to assess the vigilance of other members of the flock, and it will have to increase the time it spends scanning at the expense of foraging time (Metcalfe 1984a,b). Thus, although birds may be safer feeding in tall vegetation, foraging efficiency may be low in such cover.

It might be predicted, then, that shorebirds feeding in agricultural fields would prefer plough or short cover (where they could forage efficiently) if avian predators were scarce or if the birds' flocking behavior reduced the risk of predation. A study of field utilization by migrant shorebirds along the Colorado River may support this prediction, finding that 15 of 17 species recorded were significantly associated with irrigated plowed fields; even in vegetated fields more birds were correlated with short cover than with tall cover (Ohmart et al. 1985), although no mention is made of predator density or flocking behavior.

On the Eastern Shore of Virginia, avian predators are common to abundant during winter, spring, and fall (Kain 1987, Sutton 1991, pers. obs.), when shorebirds are most common there. Therefore, I predicted that if shorebirds were to forage efficiently in fields during this time while remaining safe from predators, they should prefer plough or short vegetative cover and feed in flocks. To test these predictions, I studied shorebirds foraging in agricultural fields on the Eastern Shore to examine the cover utilization and flocking behavior of each species and to try to evaluate whether or not cover use and flocking behavior are consistent with these predictions.

THE STUDY AREA

Geology and Climate

The study was conducted in 400 agricultural fields comprising 6598.8 ha in the southern portion of Northampton County on Virginia's Eastern Shore, between the Eastern Shore of Virginia National Wildlife Refuge (37 21'46" N) and Eastville (37 07'42" N) [see Figure 1]. This area is, for practical purposes, divided into two general regions: the "seaside" refers to the mainland east of State Route 13, while the "bayside" consists of all the land west of Route 13. The mainland is bounded on the seaside by a nearly continuous band of tidal salt marsh (broken only by the inlet at Oyster), beyond which lie the channels, bays, mudflats and marshes separating the mainland from the barrier island chain. These flats and marshes host a large assemblage of foraging shorebirds in spring, fall, and winter, especially during low tide (pers. obs.). The western edge of the study area borders on the Chesapeake Bay, with a thin sandy beach along most of the mainland edge. This beach is broken at three points where tidal creeks (Elliott Creek, Old Plantation Creek, and the Cherrystone Inlet system), all of which have small amounts of tidal flats and marshes, enter the bay. A fourth break occurs at Cape Charles Inlet. Some shorebirds do forage on the bayside beaches and mudflats, though in smaller numbers than the feeding congregations in seaside marshes (pers. obs.).

The Eastern Shore first appeared above the waters of the Atlantic Ocean during the early Pleistocene Epoch; most of the

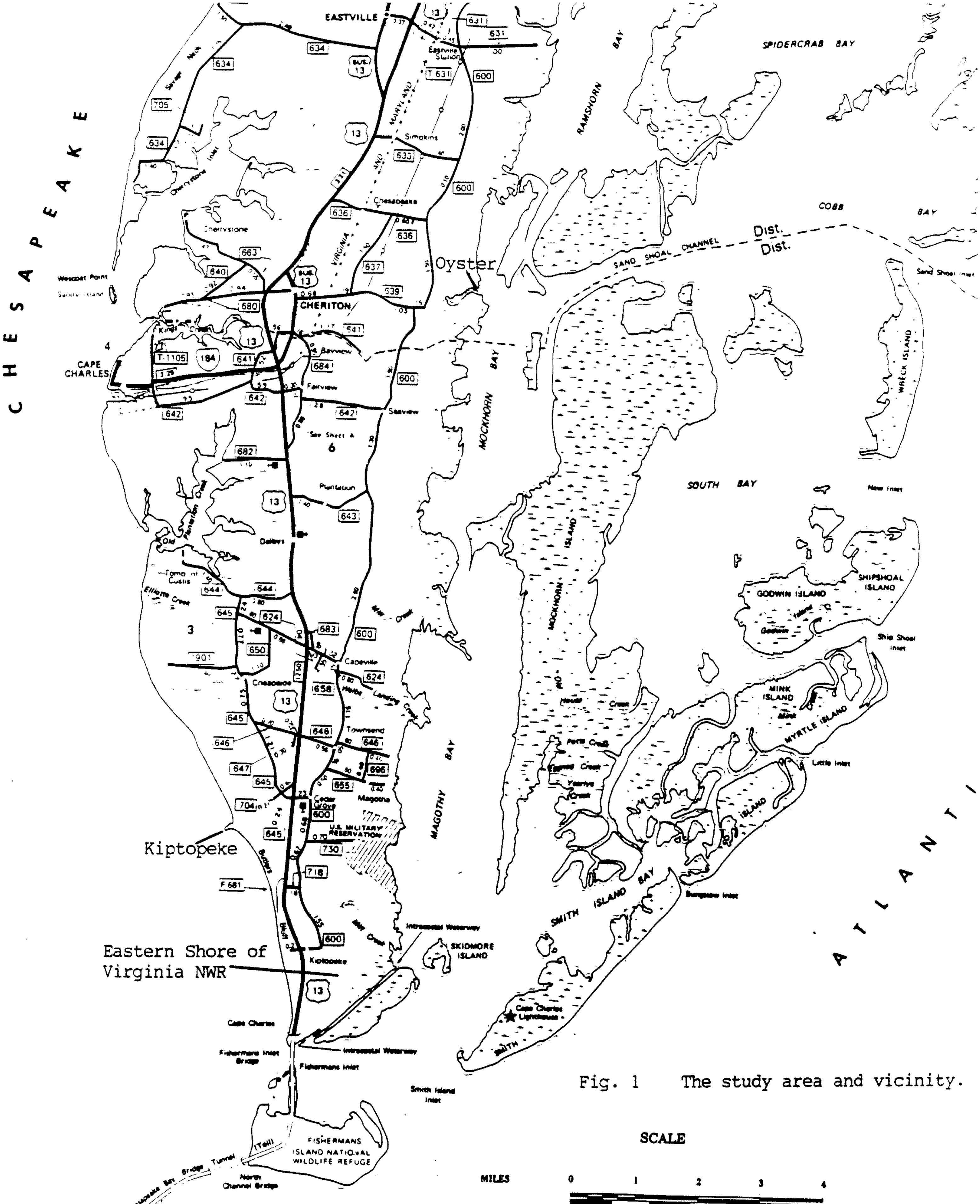


Fig. 1 The study area and vicinity.

sediments comprising the mainland of the Eastern Shore are indeed Pleistocene in origin (Sinnott & Tibbitts 1954). The upper layer of soil in most of the bayside fields north of Kiptopeke consists of fine to medium grain sand of the Occohannock Member (Mixon et al. 1989). This material was deposited in a low-energy bay environment, and is as thick as twenty feet in some areas (Mixon et al. 1989). The bayside south of Kiptopeke and most of the land on the seaside has an upper layer of soil consisting of coarser sand and small gravel from the Butlers Bluff Member, with some silty clay in the topsoil (Sinnott & Tibbitts 1957, Mixon et al. 1989). Molluscan fossils in this soil provide evidence for a shallow shelf-deposition of these sediments (Mixon et al. 1989). A thin band of coarse sand and gravel from the Joynes Neck Sand deposit runs adjacent to the seaside marshes from Oyster south to the Eastern Shore of Virginia National Wildlife Refuge, along with pockets of finer sand from the Wachapreague Formation (Mixon et al. 1989). Beach and mudflat sediments are all Holocene in origin. In most places, this sandy soil allows surface water to percolate fairly quickly into the ground, so that large puddles are usually uncommon and short-lived. As a result, the shorebirds that forage almost exclusively in water, such as the *Tringa* species, are uncommon in fields in the study area, especially during dry periods.

Weather data (U.S. Department of Commerce 1991b) collected at Painter, 18.5 km north of Eastville, show that precipitation during the study period was below normal in all months except March and October, and overall precipitation (85.33 cm) was 22.47 cm below the norm (107.80 cm). The study period was also warmer than normal during all months except September, which had an average temperature equal to the norm.

Agriculture

Most of the mainland is agricultural land, and is ploughed and planted every year; less than one percent of the fields lay fallow during the entire study period. Only 24 of the 400 fields in the study area were irrigated during the study period, and none of these 24 fields was watered for more than 7-8 weeks. Appendix A gives, for each census, the area of land with each of three cover types (plough, vegetation <10 cm, vegetation >10 cm) and the proportion of each cover type in the entire pool of cover types in the study area. Crops planted in the study area during the study period were potato, cotton, string bean, winter cereals, and soybean, with smaller amounts of sorghum, zucchini, yellow squash, butternut squash, peanut, corn, tomato, red pepper, cabbage, watermelon, and cucumber. If a ploughed field was left unplanted, agrestals, weedy grasses and herbs of cultivated fields (Baker 1991), often covered the field; this vegetation was also considered in the analysis of cover types.

METHODS

From March 1991 through February 1992, I conducted thirty censuses of 400 agricultural fields in the study area. For the purposes of this study, a field was defined as a continuous plot of land with homogeneous cover of bare earth or herbaceous vegetation of the same height (<10 cm or >10 cm) not divided by a paved road or continuous woody vegetation. From my observations of shorebirds in these fields, I believe that this definition conforms to the birds' perception of these plots, both from the air and on the ground. From the air (as seen on aerial photographs) plough, fields with cover <10 cm tall, and fields with cover >10 cm in height all appear quite different.

Censuses normally lasted 7-8 hours, an average of slightly more than one minute per field [see Appendix B for the times of and weather during the censuses]. On the Eastern Shore, shorebirds are generally more abundant in fields at high tide, when their intertidal foraging areas are inundated (pers. obs.). For this reason, I made an attempt to start each census 3-4 hours before high tide so that all fields would be censused during the high half of the tidal cycle; Appendix C lists the approximate times and heights of all low and high tides on census dates. To randomize the tide height during my observation of each field, I began each census at a location chosen randomly from a pool of 20 points along the census route, although I always censused the study area in a more or less counterclockwise direction (south to north on the seaside, north to south on the bayside).

During each census I drove from field to field, recording the type and height of cover in each field, as well as the number of individuals of each species of shorebird observed foraging. In an attempt to record every bird, I carefully scanned each field from several vantage points with 10X binoculars and a 22X spotting scope. I also listened for calling birds, as feeding shorebirds are often quite vociferous. For very large or widely dispersed flocks, replicate counts were made and the mean of the original and replicate counts was recorded.

Even the smallest shorebirds could be seen relatively easily on plough and <10 cm cover. I was able to corroborate the accuracy of my counts for these cover types by locating three fields each of plough and <10 cm cover that contained shorebirds, counting the birds from the road, and then walking through the fields to flush and count every bird. In all six cases, the error in these replicate counts was less than two percent. I was unable to corroborate my counts for >10 cm cover, and error may have been slightly higher for these fields. However, on one occasion I visually located 13 Upland Sandpipers (*Bartramia longicauda*) dispersed throughout a 68.2 ha field of agrestals 20-25 cm tall; a nearby disturbance caused all birds in the field to take flight, and indeed the only shorebirds were the 13 sandpipers. Vocalizations were helpful in locating some birds, although I was always able to quickly find each calling bird by sight, even in fields with tall vegetation. Thus, I believe that my counts for fields of >10 cm cover were fairly accurate.

From my observations of shorebirds in agricultural fields, I found that birds rarely flew from one field to another, and when they did they normally did not fly far from the original field. When disturbed, birds often took flight and circled over the field several times, but they usually returned to the same field, although birds disturbed in small fields were less likely to return than birds in larger fields (Thompson & Barnard 1983). During the study I observed 43 incidences of birds flying to or away from fields, and in all of these cases the birds flew in either an easterly or westerly direction (in the direction of seaside or bayside beaches and/or mudflats), presumably to or from tidal feeding areas. Therefore, my counts probably did not over- or under-represent shorebird numbers due to the movement of birds among fields.

Cover Utilization

The area of each field was measured with a planimeter from field-checked (and field-modified) 7.5 minute topographic maps. For each census, the areas of all the fields with a specific cover type were summed to determine the total availability of each cover type, and the number of individuals of each species of shorebird observed on each cover type was determined. The number of individuals expected to occur in each cover type if distribution over the entire study area were random was determined for each census (given in Table 2), and was the product of the total number of individuals of each species and the proportion of each cover type in the entire pool of cover types. I pooled observed and expected values for each cover type by season in order to determine the total number of individuals observed and expected in each cover type during each season. Cover associations were determined with a Chi-squared test, which compared the number of individuals observed and expected, for each species for which 30 or more individuals were observed. Chi-squared values were compared to the Chi-squared distribution, and if the probability of the values occurring due to chance was less than 0.05, then the null hypothesis (that the number of birds in a given area was independent of cover type) was rejected. In cases where the expected frequency of a species in a given cover type was less than 5.0, a G-test, valid in such situations (Zar 1974), was performed in place of the Chi-squared test to test the null hypothesis. The G-statistic was then compared to a Chi-squared distribution, and again the null hypothesis was rejected if $P<0.05$.

Flocking

For the purposes of this study, a "flock" was defined as a group of two or more individuals representing the entire assemblage of shorebirds in a field, and a "subflock" was defined as the total number of individuals of a given species in a field, whether in a monospecific flock or as part of a larger mixed-species flock. In an agricultural field, foraging shorebirds were generally spread over a large portion of the field, with frequent movement of birds (both on foot and in the air) among different locations within the field. No matter how widely dispersed the birds were, however, they all generally reacted to threat stimuli (such as human disturbance) as a group, supporting my definition of a flock.

On 29 of the 30 censuses, a majority of the fields with any given cover type were not occupied by any shorebirds, and on the single exceptional census over 45% of the fields were unoccupied. Therefore, shorebirds foraging in fields had ample opportunity to occur singly (not in a flock) if they chose to do so. Assuming that unoccupied fields were readily available, I compared, for each species, the total number of occurrences of single individuals to the total number of individuals observed in flocks in order to determine whether a species seemed to prefer feeding singly or in flocks. For each species that preferred to forage in flocks, I determined whether the species occurred significantly more often in monospecific flocks or in mixed-species flocks by comparing the number of individuals of the species observed in each flock type to the number expected if distribution of the birds were random; this analysis was conducted separately for the three cover types (plough, <10 cm vegetation, and >10 cm vegetation) to determine whether or not the birds preferred different types of flocks in different cover situations.

The number of individuals of a species expected to occur in monospecific flocks was related to the proportion of the study area (with a given cover type) that was not occupied by any other species. Therefore, the number of birds expected to occur in monospecific flocks was the product of the total number of individuals of that species observed on a given cover type and the proportion of the land area with that cover type that was either unoccupied or was occupied only by the species in question. Likewise, the number of individuals expected to occur in mixed-species flocks was the product of the total number of individuals of a species observed on a given cover type and the proportion of the land area with that cover type that was occupied by other species. The numbers of individuals observed and expected in each flock type during each census were summed by season for covers of plough, <10 cm, and > 10 cm, and a Chi-squared test was used to determine whether each species occurred significantly more or less often in monospecific or mixed-species flocks on each cover type during each season. Again, a G-test was performed on data for species with expected frequencies of less than five in a certain flock type. Finally, the mean subflock size (± standard error), calculated for each species on each cover type, was determined separately for individuals in monospecific and mixed-species flocks to determine the effects of cover and flock composition on subflock size. A t-test was used to compare the means in single-species and mixed flocks for species that occurred at least five times in each flock type on a given cover.

RESULTS

Shorebirds were observed foraging in agricultural fields during 24 of the 30 censuses; no birds were seen on 4/06/91, 6/10/91, 6/28/91, 7/15/91, 12/19/91, and 1/19/92. A total of 21,161 individuals of 21 species were recorded during the study; Table 1 lists these species, and gives the number of censuses on which each species was recorded and the total number of individuals of each species observed during the study. The four species which were recorded on the most censuses, Black-bellied Plover (*Pluvialis squatarola*), Semipalmated Plover (*Charadrius semipalmatus*), Killdeer (*Charadrius vociferus*), and Dunlin (*Calidris alpina*), were also the most abundant species, accounting for 93.9% of all the individuals observed. Black-bellied Plover was the most abundant and most often recorded species (8004 individuals on 20 censuses). Only two other species, Semipalmated Sandpiper (*Calidris pusilla*) and Short-billed Dowitcher (*Limnodromus griseus*), were represented by more than 90 individuals. The seven species represented by 30-90 individuals were Lesser Golden-Plover (*Pluvialis dominica*), Willet (*Catoptrophorus semipalmatus*), Upland Sandpiper (*Bartramia longicauda*), Ruddy Turnstone (*Arenaria interpres*), Western Sandpiper (*Calidris mauri*), Pectoral Sandpiper (*Calidris melanotos*), and Buff-breasted Sandpiper (*Tryngites subruficollis*). The number of individuals of each of the 13 preceding species recorded on each census is given in Table 5a-m. Each of the eight rarer species was represented by 11 or fewer individuals; the occurrences of these birds, which include Greater Yellowlegs

Table 1. Species recorded during study, with number of censuses on which each was recorded and number of individuals of each species observed.

Species	No. of censuses	No. of individuals
Black-bellied Plover	20	8004
Lesser Golden-Plover	9	55
Semipalmated Plover	14	3989
Killdeer	18	1026
Greater Yellowlegs	3	4
Lesser Yellowlegs	1	11
Solitary Sandpiper	1	1
Willet	6	70
Upland Sandpiper	4	30
Whimbrel	2	4
Ruddy Turnstone	6	64
Red Knot	1	1
Semipalmated Sandpiper	8	551
Western Sandpiper	6	34
Least Sandpiper	3	4
Baird's Sandpiper	1	1
Pectoral Sandpiper	6	90
Dunlin	15	6861
Buff-breasted Sandpiper	4	31
Short-billed Dowitcher	9	231
Common Snipe	1	1

Figure 2. Number of censuses on which each species was recorded.

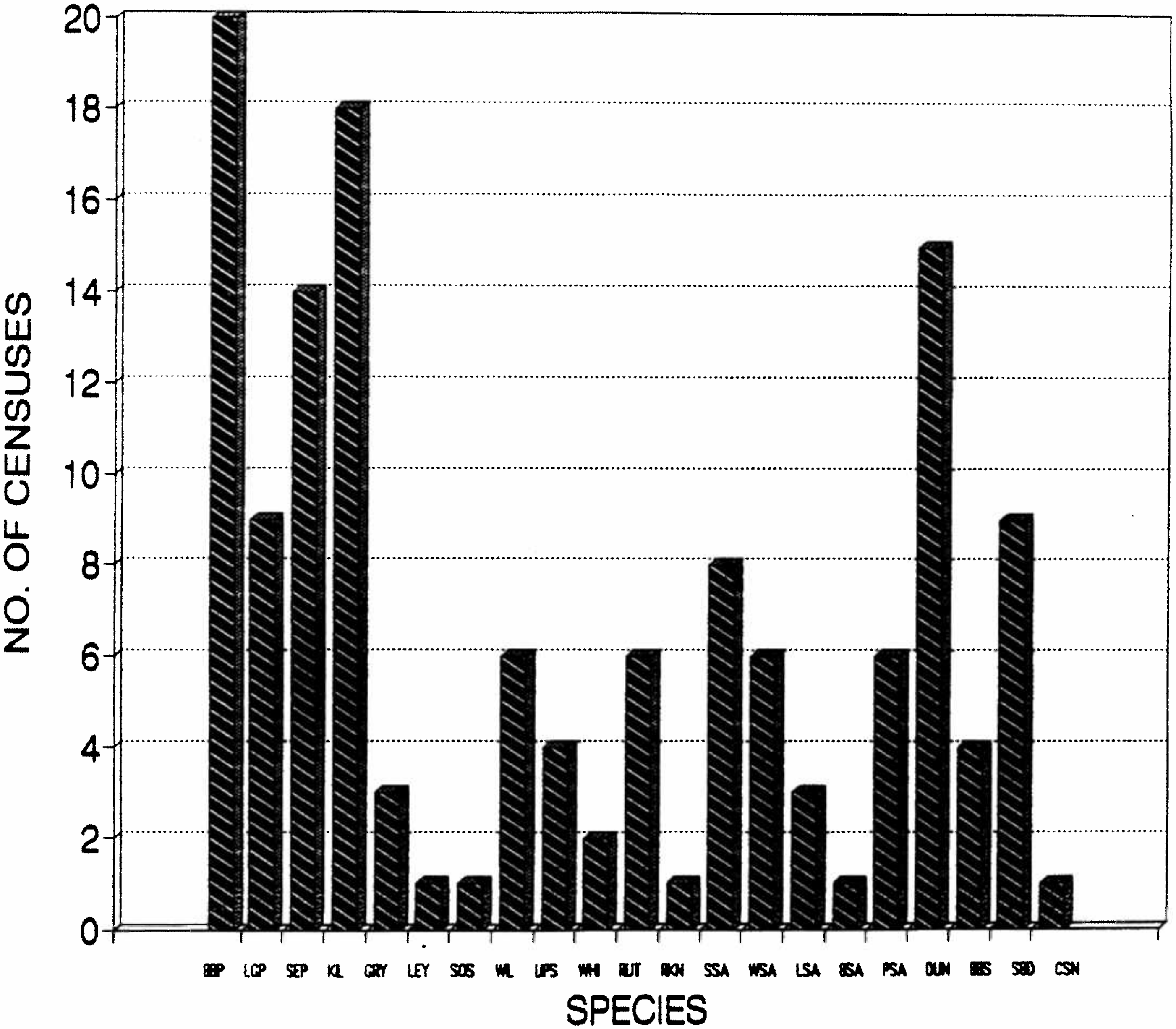
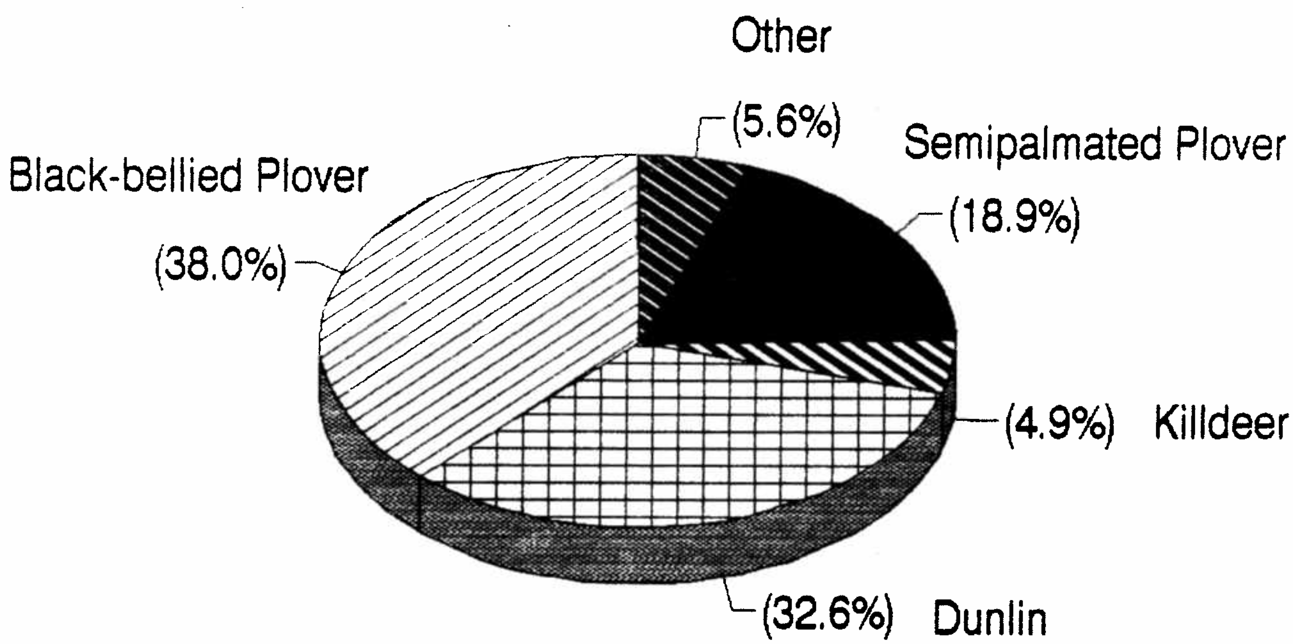


Figure 3. Species composition of shorebirds foraging in agricultural fields.



(*Tringa melanoleuca*), Lesser Yellowlegs (*Tringa flavipes*), Solitary Sandpiper (*Tringa solitaria*), Whimbrel (*Numenius phaeopus*), Red Knot (*Calidris canutus*), Least Sandpiper (*Calidris minutilla*), Baird's Sandpiper (*Calidris bairdii*), and Common Snipe (*Gallinago gallinago*), are listed in Table 4.

Examination of the total numbers of species and individuals recorded on each census (given in Table 2) allowed me to divide the study period into four seasons of shorebird activity. During spring, which lasted from early April until the end of May, 11,323 individuals of 10 species were recorded in the study area, most of the birds northbound migrants. Over half of all the birds observed during the study were recorded in spring, even though the northward migration was compressed into a relatively short span of approximately seven weeks. The most abundant species in spring was Black-bellied Plover (4663 individuals), followed by Dunlin (3199) and Semipalmated Plover (2713). For shorebirds, summer was the short period between the passing of the last northbound migrants in spring and the arrival of the first southbound birds. In these agricultural fields, that period extended from early June until late July. During this time, the only shorebirds recorded were a pair of Willets that attempted to nest in one of the fields. Fall saw a decrease in total numbers of individuals (5581) as compared to spring, but an increase in diversity, with 18 species recorded. Again, Black-bellied Plover was the most numerous species (2009 individuals), while Semipalmated Plover was second (1283) and Dunlin third (963). This period of migration was considerably

Table 2. Number of species and individuals observed on each cover type during each census.

Date	No. of Species N	PL	<10	>10	No. of Individuals N	PL	<10	>10
3/04/91	3	3	0	0	2121	2121	0	0
3/16/91	3	3	0	0	884	884	0	0
4/06/91	0	0	0	0	0	0	0	0
4/14/91	4	4	3	0	3510	2362	1148	0
4/27/91	5	5	1	1	206	187	1	18
5/05/91	7	7	1	0	520	515	5	0
5/16/91	8	8	6	1	5754	5266	486	2
5/27/91	7	4	7	2	1333	540	781	12
6/04/91	1	0	0	1	2	0	0	2
6/10/91	0	0	0	0	0	0	0	0
6/28/91	0	0	0	0	0	0	0	0
7/15/91	0	0	0	0	0	0	0	0
7/26/91	11	11	0	0	273	273	0	0
8/01/91	9	7	2	0	264	262	2	0
8/14/91	13	9	8	1	54~~3~~4	458	72	13
8/20/91	11	10	2	5	693	627	7	59
9/01/91	9	9	0	1	~~399~~ 400	397	0	2
9/14/91	8	8	0	0	203	203	0	0
9/28/91	3	3	0	0	~~127~~ 137	127	0	0
10/13/91	6	6	0	0	27~~7~~8	277	0	0
11/03/91	7	7	0	0	816	816	0	0
11/09/91	8	6	5	0	198~~6~~4	1891	95	0
11/23/91	3	3	0	0	60	60	0	0
12/08/91	1	1	0	0	8	8	0	0
12/19/91	0	0	0	0	0	0	0	0
12/27/91	1	0	1	0	20	0	20	0
1/04/92	4	3	3	0	304	227	77	0
1/19/92	0	0	0	0	0	0	0	0
2/09/92	5	1	5	0	816	52	764	0
2/29/92	2	2	1	0	42	41	1	0

Total number of species and individuals on each cover type

Season	No. of Species N	PL	<10	>10	No. of Individuals N	PL	<10	>10
Spring	10	10	7	2	11323	8870	2421	32
Summer	1	0	0	1	2	0	0	2
Fall	18	17	14	5	5581	5341	176	64
Winter	6	5	5	0	4255	3393	862	0
Total	21	19	17	7	21161	17604	3459	98

Figure 4. Number of species recorded by season.

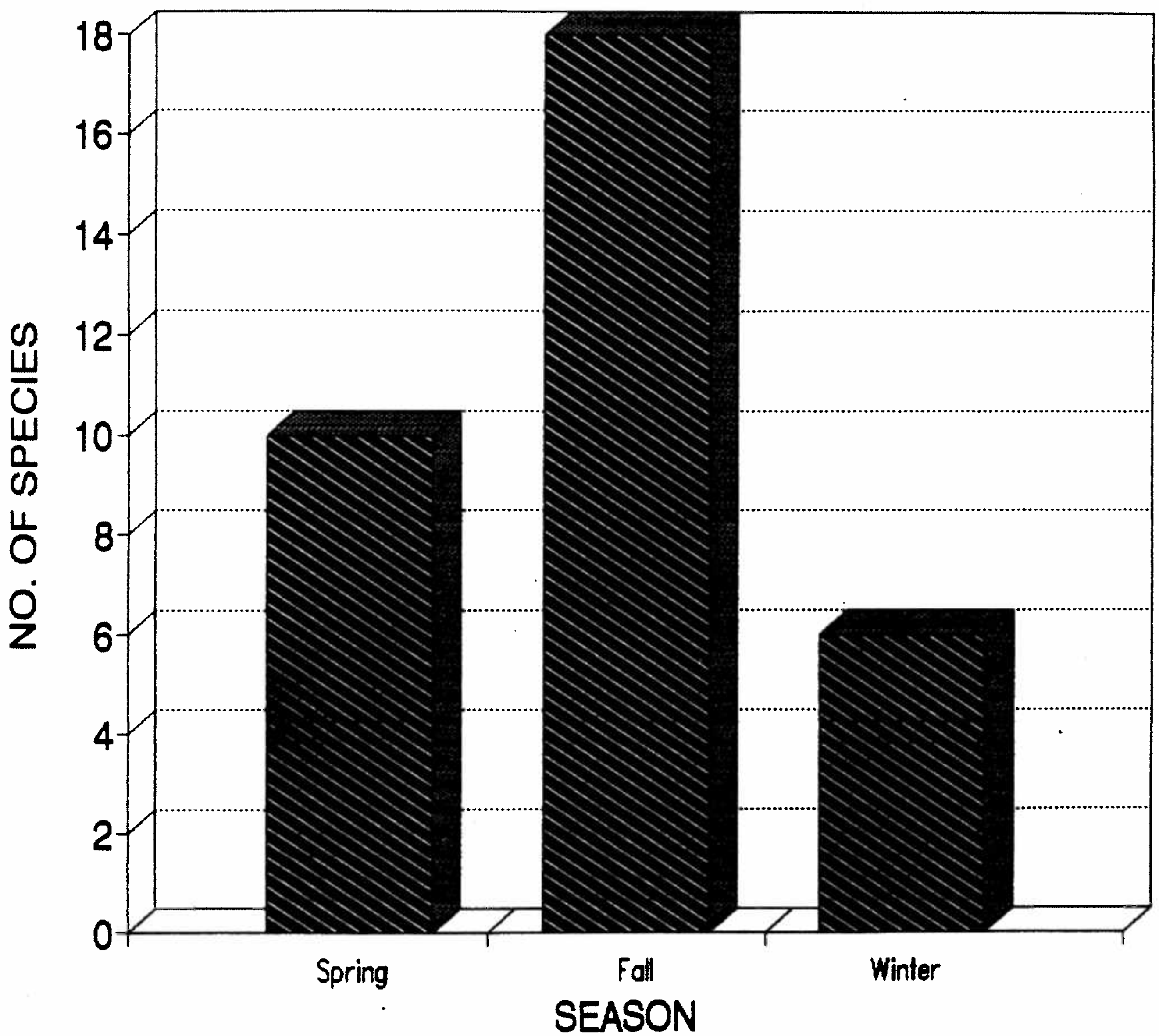
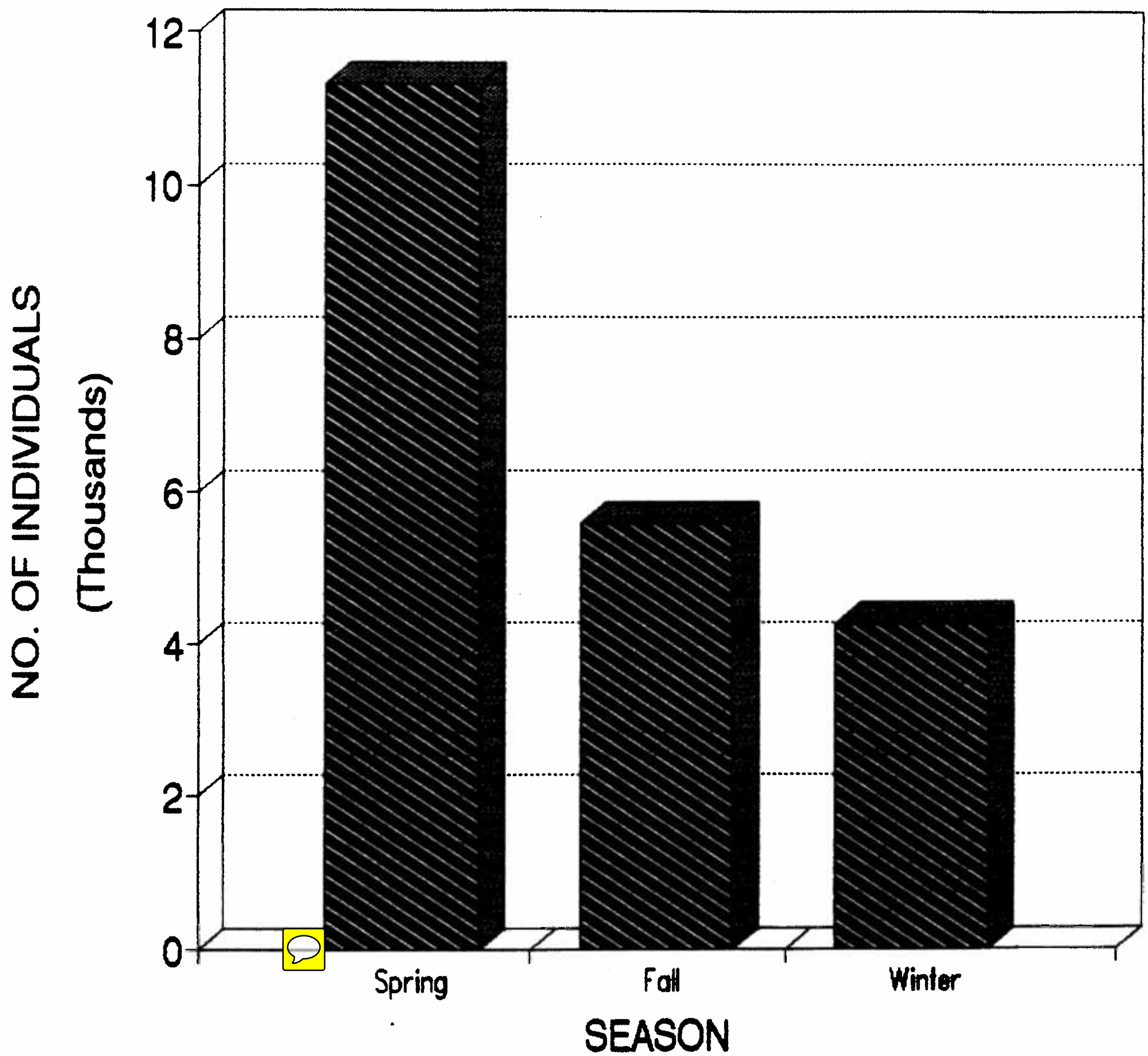


Figure 5. Number of individuals recorded by season.



longer than spring migration, and lasted from the arrival of the first southbound shorebirds in late July until the departure of the last migrants from the study area in mid-November, a period of approximately 3.5 months. During winter, six species and 4255 individuals were recorded. Dunlin was the most abundant species during winter (2703 individuals), followed by Black-bellied Plover (1337) and Killdeer (169). This season began after the departure of the last fall migrants in mid-November and ended with the arrival of the first northbound birds in early April, a period of approximately five months.

Several patterns of occurrence are apparent from the data in Table 3, which provide the seasons in which each species was recorded. Willet was the only species recorded in summer, and it, Red Knot, and Common Snipe were the only species not observed in fall. Semipalmated Plover, Greater Yellowlegs, Ruddy Turnstone, and Semipalmated Sandpiper occurred only as spring and fall transients, and nine species, including Lesser Golden-Plover, Lesser Yellowlegs, Solitary Sandpiper, Upland Sandpiper, Whimbrel, Least Sandpiper, Baird's Sandpiper, Pectoral Sandpiper, and Buff-breasted Sandpiper, were recorded only in fall. Black-bellied Plover, Killdeer, Dunlin, and Short-billed Dowitcher were observed in these fields during spring, fall, and winter. Western Sandpiper was recorded only in fall and winter, while Common Snipe was the one species recorded only in winter.

Cover Utilization

As Table 2 indicates, 19 species were observed foraging on plough, with 17 species on <10 cm cover and only 7 species on >10 cm cover. In spring, slightly more species were recorded on plough (10) than on <10 cm cover (7); the same held true for fall, when 17 species were recorded on plough and 14 on <10 cm cover. In winter, however, diversity was higher for <10 cm cover (5 species) than for plough (4 species). Cover more than 10 cm in height was utilized by far fewer species than the other cover types in spring (2 species), fall (5 species), and winter (0 species), but in summer the only species recorded did occur in >10 cm vegetation.

Although the number of species recorded on plough was only slightly higher than the number on <10 cm cover, far more individuals were observed foraging on plough than on the other cover types. A total of 17,604 individuals, or 82.3% of all birds recorded during the study, were foraging on plough. On cover of <10 cm, 3459 individuals (16.3% of total) were observed, with >10 cm cover hosting only 98 birds (0.5% of total). Overall, shorebirds exhibited a positive significant association with plough (Chi-squared = 25,971.2, P<0.001) and negative significant associations with <10 cm cover (Chi-squared = 3454.7, P<0.001) and >10 cm cover (Chi-squared = 10,723.6, P<0.001).

A record of the cover types on which each of the 21 species occurred during each season appears in Table 3. Additional data concerning the dates seen and numbers recorded for the rarer species appear in Table 4. Due to the small sample sizes of each of

Table 3. The occurrence of each species on plough (P), <10 cm cover (<), and >10 cm cover (>) during each season*. Y = occurrence.

Species	Spring			Fall			Winter		
	P	<	>	P	<	>	P	<	>
Black-bellied Plover	Y	Y	Y	Y	Y	Y	Y	Y	
Lesser Golden-Plover				Y		Y			
Semipalmated Plover	Y	Y		Y	Y	Y			
Killdeer	Y			Y	Y	Y	Y	Y	
Greater Yellowlegs	Y			Y	Y				
Lesser Yellowlegs				Y					
Solitary Sandpiper					Y				
Willet	Y	Y	Y						
Upland Sandpiper				Y	Y	Y			
Whimbrel				Y	Y				
Ruddy Turnstone	Y	Y		Y	Y				
Red Knot	Y								
Semipalmated Sandpiper	Y	Y		Y					
Western Sandpiper				Y	Y		Y		
Least Sandpiper				Y	Y				
Baird's Sandpiper				Y					
Pectoral Sandpiper				Y	Y	Y			
Dunlin	Y	Y		Y	Y		Y	Y	
Buff-breasted Sandpiper				Y	Y				
Short-billed Dowitcher	Y	Y		Y	Y			Y	
Common Snipe								Y	

* Data for summer omitted, as the only species recorded during this season was Willet in >10 cm cover.

Figure 6. Number of species recorded on each cover type.

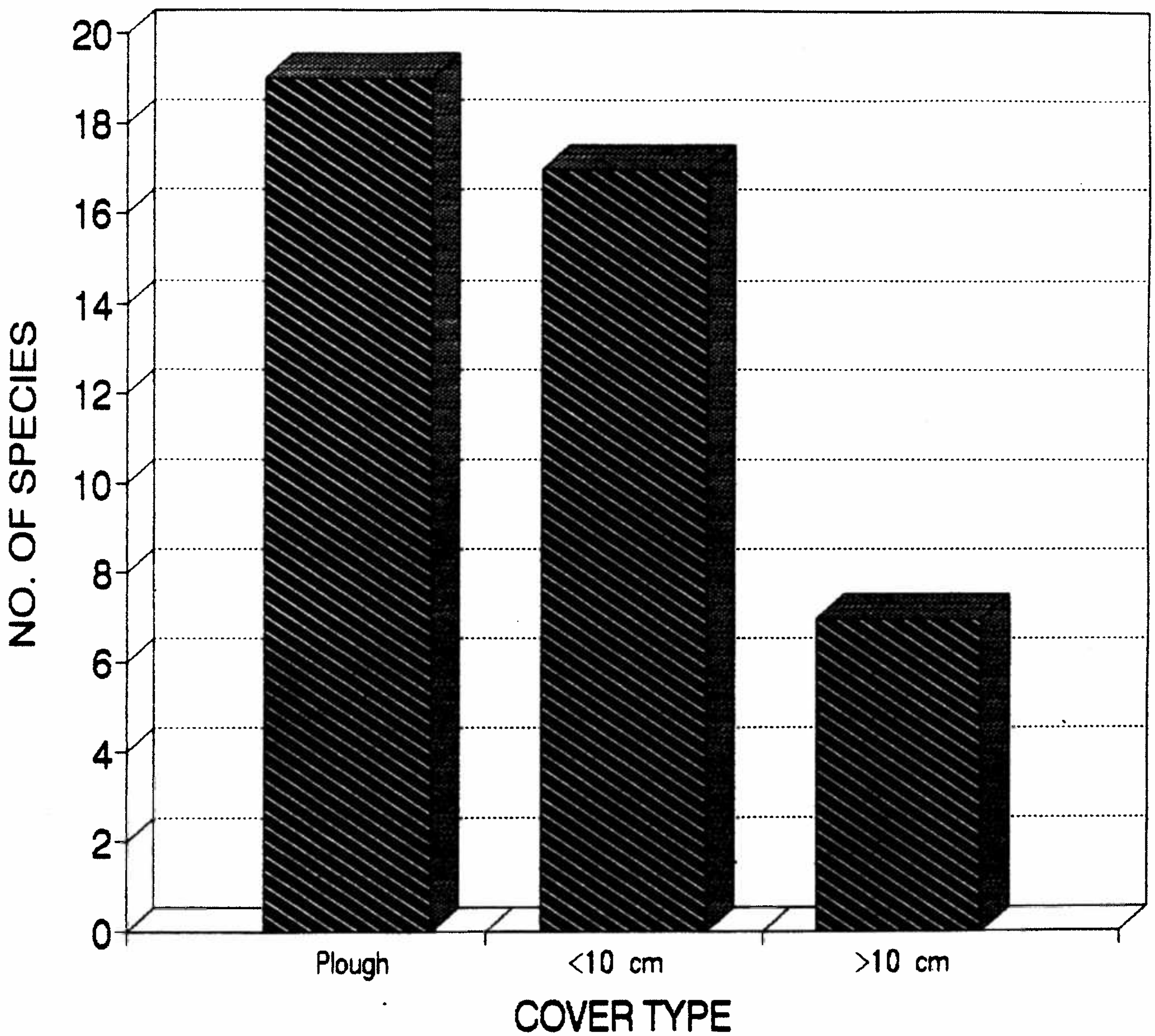


Figure 7. Number of individuals recorded on each cover type.

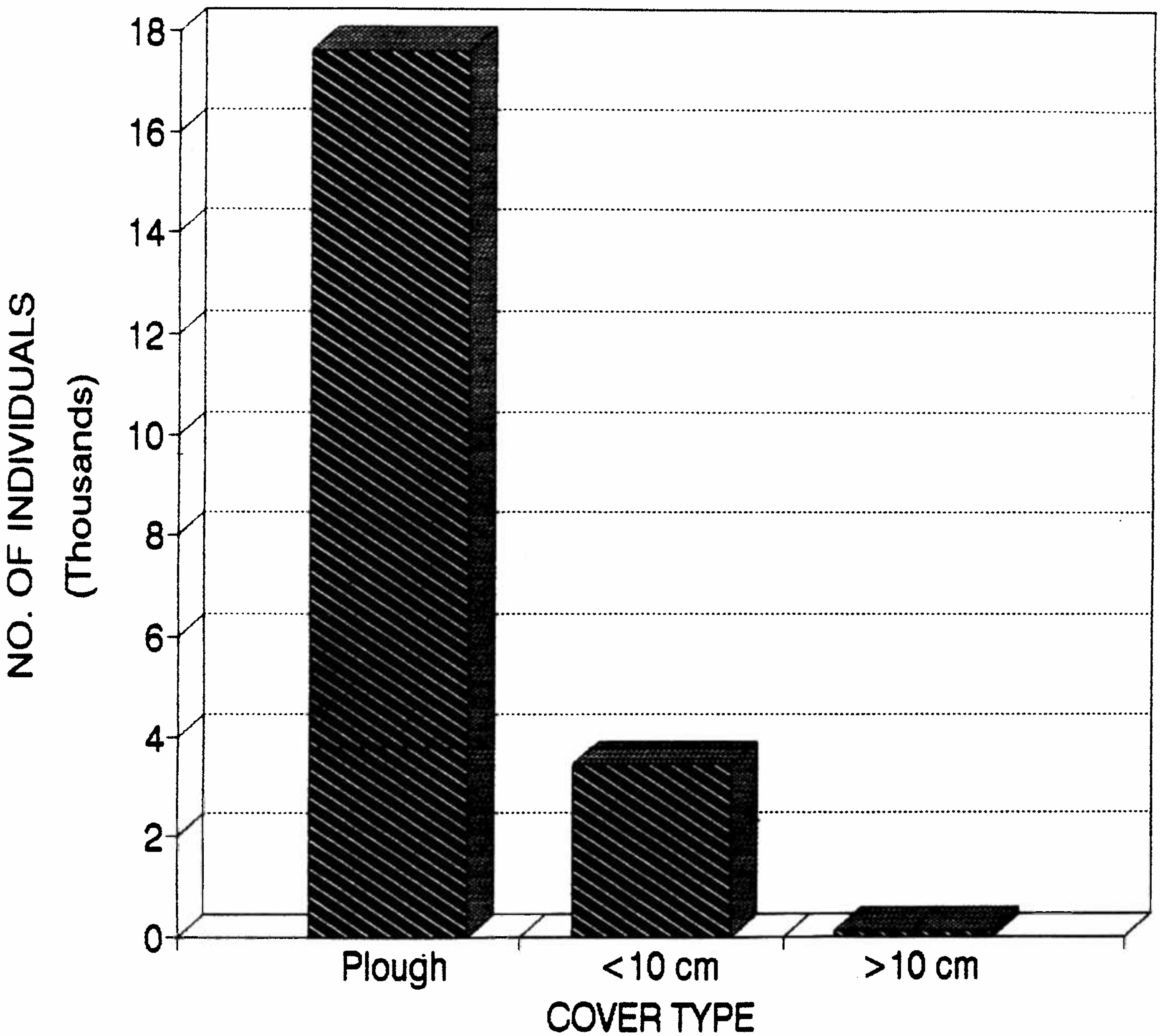


Table 4. Occurrences of rarer species.

Species	Date	Number	Cover Type
Greater Yellowlegs	4/27/91	2	PL
	7/26/91	1	PL
	8/01/91	1	<10 cm
Lesser Yellowlegs	7/26/91	11	PL
Solitary Sandpiper	8/01/91	1	<10 cm
Whimbrel	8/14/91	2	<10 cm
	9/14/91	2	PL
Red Knot	5/16/91	1	PL
Least Sandpiper	7/26/91	1	PL
	8/14/91	1	PL
	9/01/91	2	<10 cm
Baird's Sandpiper	8/20/91	1	PL
Common Snipe	2/09/91	1	<10 cm

these eight species, they were excluded from statistical analysis of cover preference, although examination of this data reveals that all occurrences of these species were on plough or <10 cm cover. The data for those 13 species represented by at least 30 individuals were analyzed to determine cover preference and avoidance. Table 5a-m lists the number of individuals of each species observed during each census, as well as the number of birds expected to occur on each cover (based on the weighting factor of cover type availability) if the birds were randomly distributed over the study area. The Chi-squared and P values are also given in this table for each cover type during each season and for the entire study period.

Table 6a-b provides the P values for association between species and cover type, demonstrating cover preference or avoidance during each season and for the entire study period. Examination of these data reveals several interesting patterns of occurrence and suggests that cover preference varies with the time of year. During spring, five of the seven species abundant enough to be analyzed for cover preference showed a preference for plough and <10 cm cover, while demonstrating an avoidance of >10 cm cover; these species were Black-bellied Plover, Semipalmated Plover, Ruddy Turnstone, Dunlin, and Short-billed Dowitcher. The only exceptions to this pattern were provided by Willet, which was not significantly associated (positively or negatively) with plough but still preferred cover of <10 cm and avoided >10 cm cover, and Semipalmated Sandpiper, which preferred plough but avoided both <10

Table 5a. Number of Black-bellied Plovers (observed / expected) on each cover type.

Date	N	Plough	<10 Cover	>10 Cover
3/04/91	337	337/72.12	0/224.44	0/40.44
3/16/91	520	520/158.60	0/291.72	0/69.88
4/06/91	0			
4/14/91	1322	821/536.73	501/137.49	0/646.46
4/27/91	78	78/27.53	0/12.64	0/37.91
5/05/91	43	38/13.72	5/1.29	0/27.99
5/16/91	2641	2268/665.53	373/200.72	0/1774.75
5/27/91	574	47/78.06	517/63.14	10/432.80
6/04/91	0			
6/10/91	0			
6/28/91	0			
7/15/91	0			
7/26/91	78	78/19.11	0/4.99	0/53.90
8/01/91	54	54/12.15	0/1.84	0/39.96
8/14/91	203	180/41.01	23/15.83	0/146.16
8/20/91	268	268/39.93	0/21.17	0/206.90
9/01/91	91	89/9.97	0/8.83	2/71.89
9/14/91	60	60/8.76	0/0.72	0/50.46
9/28/91	0			
10/13/91	91	91/30.12	0/5.82	0/55.06
11/03/91	285	285/76.38	0/60.71	0/147.92
11/09/91	879	863/286.55	16/267.22	0/324.35
11/23/91	16	16/2.08	0/11.60	0/2.32
12/08/91	0			
12/19/91	0			
12/27/91	20	0/1.48	20/11.42	0/7.10
1/04/92	203	139/16.85	64/118.15	0/68.01
1/19/92	0			
2/09/92	241	52/40.97	189/128.45	0/71.58
2/29/92	0			

		No. Obs.	No. Exp.	Chi-squared	P
Spring	PL	3252	1321.60	2819.8	+<0.001
	<10	1401	415.28	2339.7	+<0.001
	>10	10	2926.12	2906.2	-<0.001
Fall	PL	1968	523.98	3979.5	+<0.001
	<10	39	387.13	313.1	-<0.001
	>10	2	1097.89	1093.9	-<0.001
Winter	PL	1064	292.10	2039.8	+<0.001
	<10	273	785.80	334.6	-<0.001
	>10	0	259.10	259.1	-<0.001
Total	PL	6284	2137.65	8042.6	+<0.001
	<10	1708	1588.19	9.0	+<0.05
	>10	12	4278.16	4254.2	-<0.001

Table 5b. Number of Lesser Golden-Plovers (observed / expected) on each cover type.

Date	N	Plough	<10 Cover	>10 Cover
3/04/91	0			
3/16/91	0			
4/06/91	0			
4/14/91	0			
4/27/91	0			
5/05/91	0			
5/16/91	0			
5/27/91	0			
6/04/91	0			
6/10/91	0			
6/28/91	0			
7/15/91	0			
7/26/91	1	1/0.25	0/0.06	0/0.69
8/01/91	1	1/0.23	0/0.03	0/0.74
8/14/91	1	1/0.20	0/0.08	0/0.72
8/20/91	9	6/1.34	0/0.91	3/6.75
9/01/91	22	22/2.46	0/2.33	0/17.18
9/14/91	16	16/2.34	0/0.49	0/13.06
9/28/91	1	1/0.23	0/0.16	0/0.61
10/13/91	2	2/0.44	0/0.53	0/1.04
11/03/91	2	2/0.65	0/0.61	0/0.74
11/09/91	0			
11/23/91	0			
12/08/91	0			
12/19/91	0			
12/27/91	0			
1/04/92	0			
1/19/92	0			
2/09/92	0			
2/29/92	0			

		No. Obs.	No. Exp.	Chi-squared	P
Fall	PL	52	8.14	228.6	+<0.001
(Total)	<10	0	5.20	5.2	NS
	>10	3	41.66	35.9	-<0.001

Table 5c. Number of Semipalmated Plovers (observed / expected) on each cover type.

Date	N	Plough	<10 Cover	>10 Cover
3/04/91	0			
3/16/91	0			
4/06/91	0			
4/14/91	0			
4/27/91	51	51/18.00	0/8.26	0/24.79
5/05/91	455	455/145.15	0/13.65	0/296.21
5/16/91	1668	1600/420.34	68/126.77	0/1120.90
5/27/91	539	341/73.30	198/59.29	0/406.41
6/04/91	0			
6/10/91	0			
6/28/91	0			
7/15/91	0			
7/26/91	145	145/35.53	0/9.28	0/100.20
8/01/91	172	172/38.70	0/5.85	0/127.28
8/14/91	287	249/57.97	38/22.39	0/206.64
8/20/91	347	296/51.70	6/27.41	45/267.88
9/01/91	178	178/19.94	0/17.27	0/140.62
9/14/91	48	48/7.01	0/0.58	0/40.37
9/28/91	20	20/3.58	0/0.20	0/16.32
10/13/91	53	53/17.54	0/3.39	0/32.07
11/03/91	20	20/5.36	0/4.26	0/10.38
11/09/91	12	12/3.91	0/3.65	0/4.43
11/23/91	0			
12/08/91	0			
12/19/91	0			
12/27/91	0			
1/04/92	0			
1/19/92	0			
2/09/92	0			
2/29/92	0			

		No. Obs.	No. Exp.	Chi-squared	P
Spring	PL	2447	656.79	4879.6	+<0.001
	<10	266	207.97	16.2	+<0.001
	>10	0	1848.31	1848.3	-<0.001
Fall	PL	1194	241.24	3762.9	+<0.001
	<10	44	94.28	26.8	-<0.001
	>10	45	947.48	859.6	-<0.001
Total	PL	3640	898.03	8372.1	+<0.001
	<10	304	302.25	0.0	NS
	>10	45	2794.50	2705.2	-<0.001

Table 5d. Number of Killdeer (observed / expected) on each cover type.

Date	N	Plough	<10 Cover	>10 Cover
3/04/91	11	11/2.35	0/7.33	0/1.32
3/16/91	41	41/12.51	0/23.00	0/5.49
4/06/91	0			
4/14/91	0			
4/27/91	0			
5/05/91	1	1/0.32	0/0.03	0/0.65
5/16/91	0			
5/27/91	0			
6/04/91	0			
6/10/91	0			
6/28/91	0			
7/15/91	0			
7/26/91	2	2/0.49	0/0.13	0/1.38
8/01/91	11	11/2.48	0/0.37	0/8.14
8/14/91	7	5/1.41	2/0.55	0/5.04
8/20/91	8	6/1.19	0/0.63	2/6.18
9/01/91	39	39/4.37	0/3.78	0/30.81
9/14/91	58	58/8.47	0/0.70	0/48.78
9/28/91	10	10/1.79	0/0.10	0/8.16
10/13/91	87	87/28.80	0/5.57	0/52.64
11/03/91	310	310/83.08	0/66.03	0/160.89
11/09/91	324	323/105.62	1/98.50	0/119.56
11/23/91	40	40/5.20	0/29.00	0/5.80
12/08/91	8	8/0.80	0/5.45	0/1.75
12/19/91	0			
12/27/91	0			
1/04/92	45	45/3.74	0/26.19	0/15.08
1/19/92	0			
2/09/92	22	0/3.74	22/11.73	0/6.53
2/29/92	2	1/0.43	0/0.66	0/0.92

		No. Obs.	No. Exp.	Chi-squared	P
Fall	PL	851	237.70	1582.4	+<0.001
	<10	3	176.36	170.4	-<0.001
	>10	2	436.94	432.9	-<0.001
Winter	PL	146	28.77	477.7	+<0.001
	<10	23	103.36	62.5	-<0.001
	>10	0	36.87	36.9	-<0.001
Total	PL	998	266.79	2004.1	+<0.001
	<10	26	279.75	230.2	-<0.001
	>10	2	479.12	475.1	-<0.001

Table 5e. Number of Willets (observed / expected) on each cover type.

Date	N	Plough	<10 Cover	>10 Cover
3/04/91	0			
3/16/91	0			
4/06/91	0			
4/14/91	3	3/1.22	0/0.31	0/1.47
4/27/91	23	4/8.12	1/3.73	18/11.18
5/05/91	3	3/0.96	0/0.09	0/1.95
5/16/91	13	9/3.28	2/0.99	2/8.75
5/27/91	26	0/3.54	24/2.86	2/19.60
6/04/91	2	0/0.19	0/0.11	2/1.70
6/10/91	0			
6/28/91	0			
7/15/91	0			
7/26/91	0			
8/01/91	0			
8/14/91	0			
8/20/91	0			
9/01/91	0			
9/14/91	0			
9/28/91	0			
10/13/91	0			
11/03/91	0			
11/09/91	0			
11/23/91	0			
12/08/91	0			
12/19/91	0			
12/27/91	0			
1/04/92	0			
1/19/92	0			
2/09/92	0			
2/29/92	0			

		No. Obs.	No. Exp.	Chi-squared	P
Spring	PL	19	17.31	0.2	NS
(Total)	<10	27	8.09	44.2	+<0.001
	>10	24	44.64	9.5	-<0.01

Table 5f. Number of Upland Sandpipers (observed / expected) on each cover type.

Date	N	Plough	<10 Cover	>10 Cover
3/04/91	0			
3/16/91	0			
4/06/91	0			
4/14/91	0			
4/27/91	0			
5/05/91	0			
5/16/91	0			
5/27/91	0			
6/04/91	0			
6/10/91	0			
6/28/91	0			
7/15/91	0			
7/26/91	0			
8/01/91	0			
8/14/91	13	0/2.63	0/1.01	13/9.36
8/20/91	9	0/1.34	1/0.71	8/6.95
9/01/91	6	6/0.67	0/0.58	0/4.74
9/14/91	2	2/0.29	0/0.02	0/1.68
9/28/91	0			
10/13/91	0			
11/03/91	0			
11/09/91	0			
11/23/91	0			
12/08/91	0			
12/19/91	0			
12/27/91	0			
1/04/92	0			
1/19/92	0			
2/09/92	0			
2/29/92	0			

		No. Obs.	No. Exp.	G-statistic	P
Fall	PL	8	4.93	7.7	+<0.05
(Total)	<10	1	2.32	1.7	NS
	>10	21	22.73	3.3	NS

Table 5g. Number of Ruddy Turnstones (observed / expected) on each cover type.

Date	N	Plough	<10 Cover	>10 Cover
3/04/91	0			
3/16/91	0			
4/06/91	0			
4/14/91	0			
4/27/91	0			
5/05/91	0			
5/16/91	26	25/6.55	1/1.98	0/17.47
5/27/91	25	13/3.40	12/2.75	0/18.85
6/04/91	0			
6/10/91	0			
6/28/91	0			
7/15/91	0			
7/26/91	0			
8/01/91	0			
8/14/91	3	2/0.61	1/0.23	0/2.16
8/20/91	2	2/0.30	0/0.16	0/1.54
9/01/91	0			
9/14/91	0			
9/28/91	0			
10/13/91	0			
11/03/91	1	1/0.27	0/0.21	0/0.52
11/09/91	7	7/2.28	0/2.13	0/2.58
11/23/91	0			
12/08/91	0			
12/19/91	0			
12/27/91	0			
1/04/92	0			
1/19/92	0			
2/09/92	0			
2/29/92	0			

		No. Obs.	No. Exp.	Chi-squared	P
Spring	PL	38	9.95	79.1	+<0.001
	<10	13	4.73	*26.2	+<0.001
	>10	0	36.32	36.3	-<0.001
Fall	PL	12	3.46	*29.8	+<0.001
	<10	1	2.73	* 2.0	NS
	>10	0	6.80	6.8	-<0.05
Total	Pl	50	13.41	99.8	+<0.001
	<10	14	7.46	5.7	NS
	>10	0	43.12	43.1	-<0.001

*Value from G-test (N=2G).

Table 5h. Number of Semipalmated Sandpipers (observed / expected) on each cover type.

Date	N	Plough	<10 Cover	>10 Cover
3/04/91	0			
3/16/91	0			
4/06/91	0			
4/14/91	0			
4/27/91	0			
5/05/91	8	8/2.55	0/0.24	0/5.21
5/16/91	327	320/82.40	7/24.85	0/219.74
5/27/91	158	139/21.49	19/17.38	0/119.13
6/04/91	0			
6/10/91	0			
6/28/91	0			
7/15/91	0			
7/26/91	1	1/0.25	0/0.06	0/0.69
8/01/91	2	2/0.45	0/0.27	0/1.38
8/14/91	11	11/2.22	0/0.96	0/7.82
8/20/91	11	11/1.64	0/0.49	0/8.49
9/01/91	33	33/3.70	0/3.23	0/26.07
9/14/91	0			
9/28/91	0			
10/13/91	0			
11/03/91	0			
11/09/91	0			
11/23/91	0			
12/08/91	0			
12/19/91	0			
12/27/91	0			
1/04/92	0			
1/19/92	0			
2/09/92	0			
2/29/92	0			

		No. Obs.	No. Exp.	Chi-squared	P
Spring	PL	467	106.44	1221.4	+<0.001
	<10	26	42.47	6.4	-<0.05
	>10	0	344.09	344.1	-<0.001
Fall	PL	58	8.26	299.5	+<0.001
	<10	0	5.01	5.0	NS
	>10	0	44.45	44.5	-<0.001
Total	PL	525	114.70	1467.7	+<0.001
	<10	26	47.11	9.5	-<0.01
	>10	0	389.19	389.2	-<0.001

Table 5i. Number of Western Sandpipers (observed / expected) on each cover type.

Date	N	Plough	<10 Cover	>10 Cover
3/04/91	0			
3/16/91	0			
4/06/91	0			
4/14/91	0			
4/27/91	0			
5/05/91	0			
5/16/91	0			
5/27/91	0			
6/04/91	0			
6/10/91	0			
6/28/91	0			
7/15/91	0			
7/26/91	16	16/3.92	0/1.02	0/11.06
8/01/91	1	1/0.23	0/0.03	0/0.74
8/14/91	4	4/0.81	0/0.31	0/0.28
8/20/91	0			
9/01/91	0			
9/14/91	0			
9/28/91	0			
10/13/91	0			
11/03/91	1	1/0.27	0/0.21	0/0.52
11/09/91	12	0/3.91	12/3.65	0/4.43
11/23/91	0			
12/08/91	0			
12/19/91	0			
12/27/91	0			
1/04/92	3	3/0.25	0/1.75	0/1.01
1/19/92	0			
2/09/92	0			
2/29/92	0			

		No. Obs.	No. Exp.	Chi-squared	P
Fall	PL	22	9.14	18.1	+<0.001
(Total)	<10	12	5.22	8.8	+<0.05
	>10	0	19.63	19.6	-<0.001

Table 5j. Number of Pectoral Sandpipers (observed / expected) on each cover type.

Date	N	Plough	<10 Cover	>10 Cover
3/04/91	0			
3/16/91	0			
4/06/91	0			
4/14/91	0			
4/27/91	0			
5/05/91	0			
5/16/91	0			
5/27/91	0			
6/04/91	0			
6/10/91	0			
6/28/91	0			
7/15/91	0			
7/26/91	5	5/1.23	0/0.32	0/3.46
8/01/91	21	21/4.73	0/0.71	0/15.54
8/14/91	8	5/1.62	3/0.62	0/5.76
8/20/91	36	35/5.36	0/2.84	1/27.79
9/01/91	14	14/1.57	0/1.36	0/11.06
9/14/91	6	6/0.88	0/0.07	0/5.05
9/28/91	0			
10/13/91	0			
11/03/91	0			
11/09/91	0			
11/23/91	0			
12/08/91	0			
12/19/91	0			
12/27/91	0			
1/04/92	0			
1/19/92	0			
2/09/92	0			
2/29/92	0			

		No. Obs.	No. Exp.	Chi-squared	P
Fall (Total)	PL	86	15.39	324.0	+<0.001
	<10	3	5.92	1.4	NS
	>10	1	68.66	66.7	-<0.001

Table 5k. **Number of Dunlin (observed / expected) on each cover type.**

Date	N	Plough	<10 Cover	>10 Cover
3/04/91	1773	1773/379.41	0/1180.80	0/212.76
3/16/91	323	323/98.52	0/181.20	0/43.28
4/06/91	0			
4/14/91	2120	1503/860.72	617/220.48	0/1036.68
4/27/91	52	52/18.36	0/8.42	0/25.27
5/05/91	3	3/0.96	0/0.09	0/1.95
5/16/91	1014	979/255.53	35/77.06	0/681.41
5/27/91	10	0/1.36	10/1.10	0/7.54
6/04/91	0			
6/10/91	0			
6/28/91	0			
7/15/91	0			
7/26/91	0			
8/01/91	0			
8/14/91	0			
8/20/91	0			
9/01/91	0			
9/14/91	0			
9/28/91	6	6/1.07	0/0.06	0/4.90
10/13/91	41	41/13.57	0/2.62	0/24.81
11/03/91	197	197/52.80	0/41.96	0/102.24
11/09/91	715	684/233.09	31/217.36	0/263.84
11/23/91	4	4/0.52	0/2.90	0/0.58
12/08/91	0			
12/19/91	0			
12/27/91	0			
1/04/92	53	40/4.40	13/30.85	0/17.76
1/19/92	0			
2/09/92	510	0/86.70	510/271.83	0/151.47
2/29/92	40	40/8.56	0/13.12	0/18.32

		No. Obs.	No. Exp.	Chi-squared	P
Spring	PL	2537	1136.93	1724.1	+<0.001
	<10	662	307.15	410.0	+<0.001
	>10	0	1754.92	1754.9	-<0.001
Fall	PL	932	301.05	1322.4	+<0.001
	<10	31	264.90	206.5	-<0.001
	>10	0	397.05	397.1	-<0.001
Winter	PL	2180	578.11	4438.7	+<0.001
	<10	523	1680.70	797.4	-<0.001
	>10	0	444.19	444.2	-<0.001
Total	PL	5645	2015.57	6535.5	+<0.001
	<10	1216	2249.85	475.1	-<0.001
	>10	0	2595.58	2595.6	-<0.001

Table 51. Number of Buff-breasted Sandpipers (observed / expected) on each cover type.

Date	N	Plough	<10 Cover	>10 Cover
3/04/91	0			
3/16/91	0			
4/06/91	0			
4/14/91	0			
4/27/91	0			
5/05/91	0			
5/16/91	0			
5/27/91	0			
6/04/91	0			
6/10/91	0			
6/28/91	0			
7/15/91	0			
7/26/91	0			
8/01/91	0			
8/14/91	3	0/0.60	3/0.23	0/2.16
8/20/91	2	2/0.30	0/0.16	0/1.54
9/01/91	15	15/1.68	0/1.46	0/11.85
9/14/91	11	11/1.61	0/0.13	0/9.25
9/28/91	0			
10/13/91	0			
11/03/91	0			
11/09/91	0			
11/23/91	0			
12/08/91	0			
12/19/91	0			
12/27/91	0			
1/04/92	0			
1/19/92	0			
2/09/92	0			
2/29/92	0			

		No. Obs.	No. Exp.	Chi-squared	P
Fall	PL	28	4.19	135.3	+<0.001
(Total)	<10	3	1.98	* 2.5	NS
	>10	0	24.80	24.8	-<0.001

*Value from G-test (N=2G).

Table 5m. Number of Short-billed Dowitchers (observed / expected) on each cover type.

Date	N	Plough	<10 Cover	>10 Cover
3/04/91	0			
3/16/91	0			
4/06/91	0			
4/14/91	65	35/26.39	30/6.76	0/31.79
4/27/91	0			
5/05/91	7	7/2.23	0/0.21	0/4.56
5/16/91	64	64/16.13	0/4.86	0/43.01
5/27/91	1	0/0.14	1/0.11	0/0.75
6/04/91	0			
6/10/91	0			
6/28/91	0			
7/15/91	0			
7/26/91	12	12/2.94	0/0.77	0/8.29
8/01/91	0			
8/14/91	1	1/0.20	0/0.08	0/0.72
8/20/91	0			
9/01/91	0			
9/14/91	0			
9/28/91	0			
10/13/91	4	4/1.32	0/0.26	0/2.42
11/03/91	0			
11/09/91	35	0/11.41	35/10.64	0/12.92
11/23/91	0			
12/08/91	0			
12/19/91	0			
12/27/91	0			
1/04/92	0			
1/19/92	0			
2/09/92	42	0/7.14	42/22.39	0/12.47
2/29/92	0			

		No. Obs.	No. Exp.	Chi-squared	P
Spring	PL	106	44.89	83.2	+<0.001
	<10	31	11.94	30.4	+<0.001
	>10	0	80.17	80.2	-<0.001
Fall	PL	17	15.87	0.1	NS
	<10	35	11.75	46.0	+<0.001
	>10	0	24.38	24.4	-<0.001
Total	PL	123	67.90	44.7	+<0.001
	<10	108	46.08	83.2	+<0.001
	>10	0	116.93	116.9	-<0.001

Table 6a. P values for associations between species and cover types. + = positive association, - = negative association, NS = no significant association.

Species	PL	Spring <10 cm	>10 cm
Black-bellied Plover	+<.001	+<.001	-<.001
Lesser Golden-Plover			
Semipalmated Plover	+<.001	+<.001	-<.001
Killdeer			
Willet	NS	+<.001	-<.01
Upland Sandpiper			
Ruddy Turnstone	+<.001	+<.001	-<.001
Semipalmated Sandpiper	+<.001	-<.05	-<.001
Western Sandpiper			
Pectoral Sandpiper			
Dunlin	+<.001	+<.001	-<.001
Buff-breasted Sandpiper			
Short-billed Dowitcher	+<.001	+<.001	-<.001

Species	PL	Fall <10 cm	>10 cm
Black-bellied Plover	+<.001	-<.001	-<.001
Lesser Golden-Plover	+<.001	NS	-<.001
Semipalmated Plover	+<.001	-<.001	-<.001
Killdeer	+<.001	-<.001	-<.001
Willet			
Upland Sandpiper	+<.05	NS	NS
Ruddy Turnstone	+<.001	NS	-<.05
Semipalmated Sandpiper	+<.001	NS	-<.001
Western Sandpiper	+<.001	+<.05	-<.001
Pectoral Sandpiper	+<.001	NS	-<.001
Dunlin	+<.001	-<.001	-<.001
Buff-breasted Sandpiper	+<.001	NS	-<.001
Short-billed Dowitcher	NS	+<.001	-<.001

Table 6b. P values for associations between species and cover types. + = positive association, - = negative association, NS = no significant associaton.

Species	PL	Winter <10 cm	>10 cm
Black-bellied Plover	+<.001	-<.001	-<.001
Lesser Golden-Plover			
Semipalmated Plover			
Killdeer	+<.001	-<.001	-<.001
Willet			
Upland Sandpiper			
Ruddy Turnstone			
Semipalmated Sandpiper			
Western Sandpiper			
Pectoral Sandpiper			
Dunlin	+<.001	-<.001	-<.001
Buff-breasted Sandpiper			
Short-billed Dowitcher			

Species	PL	Total (Study Period) <10 cm	>10 cm
Black-bellied Plover	+<.001	+<.05	-<.001
Lesser Golden-Plover	+<.001	NS	-<.001
Semipalmated Plover	+<.001	NS	-<.001
Killdeer	+<.001	-<.001	-<.001
Willet	NS	+<.001	-<.01
Upland Sandpiper	+<.05	NS	NS
Ruddy Turnstone	+<.001	NS	-<.001
Semipalmated Sandpiper	+<.001	-<.01	-<.001
Western Sandpiper	+<.001	+<.05	-<.001
Pectoral Sandpiper	+<.001	NS	-<.001
Dunlin	+<.001	-<.001	-<.001
Buff-breasted Sandpiper	+<.001	NS	-<.001
Short-billed Dowitcher	+<.001	+<.001	-<.001

cm and >10 cm cover types. In fall, most of the 12 species analyzed still preferred plough and avoided >10 cm cover (with only one exception in each case), but the variation in preference for or avoidance of <10 cm cover was much greater in fall than in spring. Whereas six of the seven species in spring preferred <10 cm cover, only two of 12 species analyzed for fall (Western Sandpiper and Short-billed Dowitcher) exhibited such a preference. Likewise, the proportion of species avoiding <10 cm vegetation changed also, from one out of six species in spring (Semipalmated Sandpiper) to four of 12 (Black-bellied Plover, Semipalmated Plover, Killdeer, and Dunlin) in fall. In addition, six species (Lesser Golden-Plover, Upland Sandpiper, Ruddy Turnstone, Semipalmated Sandpiper, Pectoral Sandpiper, and Buff-breasted Sandpiper) demonstrated no significant avoidance of or preference for <10 cm cover in fall. In winter, only three species occurred in numbers high enough to merit statistical analysis, and all three species (Black-bellied Plover, Killdeer, and Dunlin) preferred plough while avoiding both types of vegetated cover.

Although these seasonal data suggest that patterns of cover preference and avoidance vary with the time of year, the species-cover associations were also analyzed for the entire study period to demonstrate overall cover preference. These data (Table 7b) are similar to the data for fall in that all but one of the 13 species analyzed exhibited a preference for plough, all but one avoided >10 cm cover, and there was great variation on <10 cm cover. On vegetation shorter than 10 cm, four species were found to be

Table 7. Species diversity on each cover type in terms of total number of species observed and number of species with positive and negative associations.

Spring

Cover	No. of Species Obs.	+Assoc.	-Assoc.
Plough	10	6	0
<10 cm	7	6	1
>10 cm	2	0	7
Total	10		

Fall

Cover	No. of Species Obs.	+Assoc.	-Assoc.
Plough	17	11	0
<10 cm	14	2	4
>10 cm	6	0	11
Total	18		

Winter

Cover	No. of Species Obs.	+Assoc.	-Assoc.
Plough	4	3	0
<10 cm	5	0	3
>10 cm	0	0	3
Total	6		

Total

Cover	No. of Species Obs.	+Assoc.	-Assoc.
Plough	19	12	0
<10 cm	17	4	3
>10 cm	7	0	12
Total	21		

associated positively and three associated negatively, with six species showing neither preference nor avoidance. Table 7, which summarizes the number of species positively and negatively associated with each cover type during each season, clearly indicates the high numbers of positive relationships with plough and negative relationships with >10 cm cover during all seasons. No species actively avoided plough, and none were shown to prefer >10 cm cover. Again, the data for <10 cm cover indicate that some species do preferentially utilize this cover type while others use it only incidentally or actively avoid it.

Flocking

Almost all of the shorebirds encountered in agricultural fields were in flocks (groups of two or more individuals), regardless of the cover type on which they foraged. Only in five species (Black-bellied Plover, Killdeer, Semipalmated Plover, Willet, and Upland Sandpiper) were single birds ever recorded, and as Table 8 indicates, in most species these singly-occurring birds represented only a miniscule proportion of the sample size on a given cover type. The only exception was provided by Upland Sandpipers foraging on <10 cm cover, where two of the seven individuals occurring were singles. All of the eight rarer species (those represented in the study by 11 or fewer individuals) did occur in flocks.

For those birds that did occur in flocks, the number of

Table 8. **Number of individuals of each species foraging singly and in flocks, and number/proportion of total in single-species and mixed-species flocks.**

Plough

Species	Singles	Flocks	Single-Sp.	Mixed-Sp.
Black-bellied Plover	1	6303	193/.031	6110/.969
Lesser Golden-Plover	0	52	0/.000	54/1.00
Semipalmated Plover	0	3640	381/.105	3259/.895
Killdeer	3	995	400/.402	595/.598
Willet	1	18	9/.500	9/.500
Upland Sandpiper	0	2	0/.000	2/1.00
Ruddy Turnstone	0	50	0/.000	50/1.00
Semipalmated Sandpiper	0	531	0/.000	531/1.00
Western Sandpiper	0	25	0/.000	25/1.00
Pectoral Sandpiper	0	86	13/.149	73/.851
Dunlin	0	5645	40/.007	5605/.993
Buff-breasted Sandpiper	0	28	0/.000	28/1.00
Short-billed Dowitcher	0	123	0/.000	123/1.00

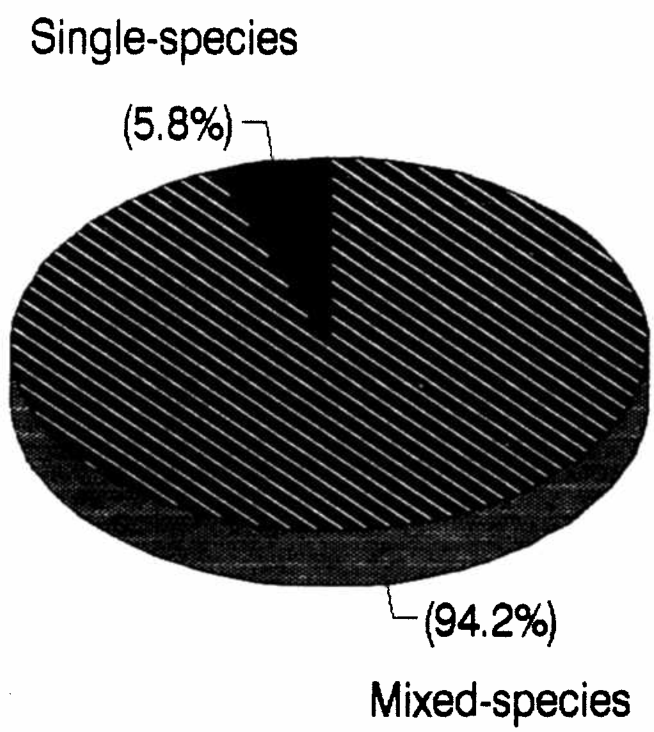
<10 cm

Species	Singles	Flocks	Single-Sp.	Mixed-Sp.
Black-bellied Plover	0	1688	80/.047	1608/.953
Lesser Golden-Plover				
Semipalmated Plover	2	308	63/.205	245/.795
Killdeer	2	24	0/.000	24/1.00
Willet	1	26	2/.077	24/.923
Upland Sandpiper	2	5	5/1.00	0/.000
Ruddy Turnstone	0	14	5/.357	9/.643
Semipalmated Sandpiper	0	20	0/.000	20/1.00
Western Sandpiper	0	12	0/.000	12/1.00
Pectoral Sandpiper	0	3	0/.000	3/1.00
Dunlin	0	1216	0/.000	1216/1.00
Buff-breasted Sandpiper	0	3	0/.000	3/1.00
Short-billed Dowitcher	0	108	0/.000	108/1.00

>10 cm

Species	Singles	Flocks	Single-Sp.	Mixed-Sp.
Willet	2	22	22/1.00	0/.000
Upland Sandpiper	0	21	21/1.00	0/.000

Figure 8. Percentage of individuals in single-species and mixed-species flocks.



individuals and proportion of the total sample that occurred in monospecific flocks and mixed-species flocks are given in Table 8 for each of the species for which 30 or more individuals were recorded. Each of these 13 species was analyzed for plough and <10 cm cover. The only species in which a large proportion of the total sample size occurred on a cover of >10 cm were Willet and Upland Sandpiper, so only these two species were analyzed for flocking behavior on this cover type.

Most of the species foraging on plough occurred proportionately more often in mixed-species flocks than in single-species flocks. Seven species, including Lesser Golden-Plover, Upland Sandpiper, Ruddy Turnstone, Semipalmated Sandpiper, Western Sandpiper, Buff-breasted Sandpiper, and Short-billed Dowitcher, always foraged in mixed-species flocks on plough. In four other species (Black-bellied Plover, Semipalmated Plover, Pectoral Sandpiper, and Dunlin) over 85% of the individuals of each species occurred in mixed flocks on this cover type. The percentage of Killdeers foraging in mixed flocks (59.8%) was slightly higher than the percentage in monospecific flocks (40.2%). Only in the Willet, where the numbers of birds observed on plough in each flock type were equal, was there not a majority of individuals occurring in mixed-species flocks.

This general pattern of occurrence also held true for <10 cm cover. Here there were no individuals occurring in monospecific flocks for Killdeer, Semipalmated Sandpiper, Western Sandpiper, Pectoral Sandpiper, Dunlin, Buff-breasted Sandpiper, and Short-billed Dowitcher. Three other species, Black-bellied Plover, Semipalmated Plover, and Willet, occurred over 75% of the time in mixed-species flocks, and a slightly higher percentage of Ruddy Turnstones occurred in mixed flocks (64.3%) than in monospecific flocks (35.7%) on < 10 cm cover. In Upland Sandpiper, however, all five of the individuals occurring in flocks on this cover type were in single-species flocks. This was the case on >10 cm cover as well, where all the Upland Sandpipers and Willets occurred in monospecific groups. For the eight rarer species, all occurrences except one (two Greater Yellowlegs together on 4/27/91) were in mixed flocks.

Statistical analysis of the flocking behavior of these birds (Table 9a-m) confirmed that most species occurred significantly more often than expected in mixed-species flocks than in monospecific flocks. As Table 10 indicates, 11 of the 13 species analyzed were negatively associated with monospecific flocks and positively associated with mixed flocks on all cover types on which the birds foraged and during all seasons in which they were present in the study area. Furthermore, almost all of these associations were highly significant ($P<0.001$). The two exceptions to this pattern of flocking behavior were provided by Upland Sandpiper and Willet. Willets were not associated significantly with one flock type or the other on plough or >10 cm cover, but on <10 cm cover they did exhibit the general pattern of positive association with mixed flocks and negative association with monospecific flocks. Likewise, Upland Sandpipers were not correlated with either flock

Table 9a. Number of Black-bellied Plovers (observed / expected) in single-species flocks and mixed-species flocks.

Plough

Date	Total Area (ha)	Area Unocc. or with only BBPL (ha / prop. of total area)	Area with other spp. (ha / prop. of total area)	Total N	BBPL in Single (No. obs./No. exp.)	BBPL in Mixed (No. obs./No. exp.)
3/04/91	1408.8	1341.4/.952	67.4/.048	337	0/320.9	337/16.2
3/16/91	2013.1	1773.3/.883	235.8/.117	520	0/459.2	520/60.8
4/14/91	2681.3	2392.8/.892	288.5/.108	821	43/732.3	778/88.7
4/27/91	2329.7	2075.7/.891	254.0/.109	78	4/69.5	68/8.5
5/05/91	2085.5	1570.9/.753	514.6/.247	38	0/28.6	38/9.4
5/16/91	1661.0	752.4/.453	908.6/.547	2268	0/1028.0	2268/1240
5/27/91	898.5	602.7/.671	259.8/.329	47	0/31.5	47/15.5
7/26/91	1622.5	1236.7/.762	385.8/.238	78	0/59.4	78/18.6
8/01/91	1486.8	1201.6/.808	285.2/.192	54	16/43.6	38/10.4
8/14/91	1333.7	1081.3/.811	252.4/.189	180	0/146.0	180/34.0
8/20/91	984.1	750.1/.767	234.0/.238	268	0/204.2	268/63.8
9/01/91	740.6	439.1/.593	301.5/.407	89	0/52.8	89/36.2
9/14/91	965.0	785.4/.814	179.6/.186	60	0/48.8	60/11.4
10/13/91	2184.9	1766.2/.808	418.7/.192	91	0/73.5	91/17.5
11/03/91	1771.0	1558.1/.880	212.9/.120	285	7/250.8	278/34.2
11/09/91	2154.1	1580.7/.734	573.4/.266	863	0/633.4	863/229.6
11/23/91	854.8	785.8/.919	69.0/.081	16	0/14.7	16/1.3
1/04/92	549.4	385.4/.701	164.0/.299	139	52/97.4	87/41.6
2/09/92	1121.5	1121.5/1.00	0/.000	52	52/52.0	0/0.0

		No. Obs.	No. Exp.	Chi-squared	P
Spring	- single	47	1889.3	1796.5	-<0.001
	mixed	3199	1362.7	2474.5	+<0.001
Fall	- single	23	1512.5	1466.8	-<0.001
	mixed	1945	455.7	4867.3	+<0.001
Winter	- single	104	944.2	747.7	-<0.001
	mixed	960	119.9	5886.3	+<0.001

<10 cm

Date	Total Area (ha)	Area Unocc. or with only BBPL (ha / prop. of total area)	Area with other spp. (ha / prop. of total area)	Total N	BBPL in Single (No. obs./No. exp.)	BBPL in Mixed (No. obs./No. exp.)
4/14/91	2681.3	2644.8/.986	36.5/.014	501	0/494.0	501/7.0
5/05/91	2085.5	2064.5/.990	21.0/.010	5	5/4.9	0/0.1
5/16/91	1660.9	1614.1/.972	46.8/.028	373	73/362.6	300/10.4
5/27/91	898.5	571.5/.636	327.0/.364	517	2/328.8	515/188.2
8/14/91	1333.7	1188.1/.891	145.6/.109	23	0/20.5	23/2.5
11/09/91	2154.1	2100.0/.975	54.1/.025	16	0/15.6	16/0.4
12/27/91	3770.5	3770.5/1.00	0/.000	20	20/20.0	0/0.0
1/04/92	549.4	435.8/.793	113.6/.207	64	0/51.0	64/13.0
2/09/92	3520.4	3490.7/.992	29.7/.008	189	0/187.4	189/1.6

		No. Obs.	No. Exp.	Chi-squared	P
Spring	- single	80	1190.3	1035.7	-<0.001
	mixed	1316	205.7	5993.0	+<0.001
Fall	- single	0	36.1	36.1	-<0.001
	mixed	39	2.9	449.4	+<0.001
Winter	- single	20	258.4	219.0	-<0.001
	mixed	253	14.6	3833.7	+<0.001

Table 9b. Number of Lesser Golden-Plovers (observed / expected) in single-species flocks and mixed-species flocks.

Plough

Date	Total Area (ha)	Area Unocc. or with only LGPL (ha / prop. of total area)	Area with other spp. (ha / prop. of total area)	Total N	LGPL in Single (No. obs./No. exp.)	LGPL in Mixed (No. obs./No. exp.)
7/26/91	1622.5	1226.7/.756	395.8/.244	1	0/0.8	1/0.2
8/01/91	1486.8	1180.6/.794	306.2/.206	1	0/0.8	1/0.2
8/14/91	1333.7	1070.7/.803	263.0/.197	1	0/0.8	1/0.2
8/20/91	984.1	716.6/.728	267.5/.272	6	0/4.4	6/1.6
9/01/91	740.6	424.9/.574	315.7/.426	22	0/12.6	22/9.4
9/14/91	965.0	728.0/.754	237.0/.246	16	0/12.1	16/3.9
10/13/91	2184.9	1746.5/.799	438.4/.201	1	0/0.8	1/0.2
11/03/91	1771.0	1498.5/.846	272.5/.154	2	0/1.7	2/0.3
11/09/91	2154.1	1580.7/.734	573.4/.266	2	0/1.5	2/0.5

		No. Obs.	No. Exp.	Chi-squared	P
Fall	- single	0	34.9	34.9	-<0.001
	mixed	52	17.1	71.2	+<0.001

Table 9c. Number of Killdeer (observed / expected) in single-species flocks and mixed-species flocks.

Plough

Date	Total Area (ha)	Area Unocc. or with only KILL (ha / prop. of total area)	Area with other spp. (ha / prop. of total area)	Total N	KILL in Single (No. obs./No. exp.)	KILL in Mixed (No. obs./No. exp.)
3/04/91	1408.8	1356.8/.963	52.0/.037	11	11/10.6	0/0.4
3/16/91	2013.1	1955.9/.972	57.2/.028	41	37/39.9	4/1.1
7/26/91	1622.5	1263.8/.779	358.7/.221	2	0/1.6	2/0.4
8/01/91	1486.8	1255.5/.844	231.3/.156	11	0/9.3	11/1.7
8/14/91	1333.7	1052.9/.789	280.8/.211	5	0/4.0	5/1.0
8/20/91	984.1	713.9/.725	270.2/.275	6	0/4.4	6/1.6
9/01/91	740.6	467.5/.631	273.1/.369	39	0/24.6	39/14.4
9/14/91	965.0	759.5/.787	205.5/.213	58	0/45.7	58/12.3
9/28/91	1182.3	1170.9/.990	11.4/.010	10	0/9.9	10/0.1
10/13/91	2184.9	1827.9/.837	357.0/.163	87	48/72.8	41/14.2
11/03/91	1771.0	1521.7/.859	249.3/.141	310	64/266.4	246/43.6
11/09/91	2154.1	1723.6/.800	439.5/.200	324	197/259.2	127/64.8
11/23/91	854.8	834.2/.976	20.6/.024	40	7/39.0	33/1.0
12/08/91	658.7	658.7/1.00	0/.000	8	8/8.0	0/0.0
1/04/92	549.4	327.2/.596	222.2/.404	45	21/26.8	24/18.2

		No. Obs.	No. Exp.	Chi-squared	P
Fall	- single	309	687.9	208.7	-<0.001
	mixed	545	164.1	884.2	+<0.001
Winter	- single	84	114.3	8.0	-<0.01
	mixed	61	20.7	78.4	+<0.001

Table 9d. Number of Semipalmated Plovers (observed / expected) in single-species flocks and mixed-species flocks.

Plough

Date	Total Area (ha)	Area Unocc. or with only SEPL (ha / prop. of total area)	Area with other spp. (ha / prop. of total area)	Total N	SEPL in Single (No. obs./No. exp.)	SEPL in Mixed (No. obs./No. exp.)
4/27/91	2329.7	2012.5/.864	317.2/.136	51	20/44.1	31/6.9
5/05/91	2085.5	1819.7/.873	265.8/.127	455	46/397.2	409/57.8
5/16/91	1660.9	873.2/.526	787.7/.474	1600	68/841.6	1532/758.4
5/27/91	898.5	685.0/.762	213.5/.238	341	15/259.8	326/81.2
7/26/91	1622.5	1347.8/.831	274.7/.169	145	49/120.5	96/24.5
8/01/91	1486.6	1255.3/.844	231.5/.156	172	7/145.2	165/26.8
8/14/91	1333.7	1196.0/.897	137.7/.103	249	74/223.4	175/25.6
8/20/91	984.1	861.8/.876	122.3/.124	296	49/259.3	247/36.7
9/01/91	740.6	470.5/.635	270.1/.365	178	34/113.0	144/65.0
9/14/91	965.0	759.5/.787	205.5/.213	48	0/37.8	48/10.2
9/28/91	1182.3	1170.9/.990	11.4/.010	20	0/19.8	20/0.2
10/13/91	2184.9	1746.5/.799	438.4/.201	53	8/42.3	45/10.7
11/03/91	1771.0	1498.5/.846	272.5/.154	20	0/16.9	20/3.1
11/09/91	2154.1	1649.3/.766	504.8/.234	12	9/9.2	3/2.8

		No. Obs.	No. Exp.	Chi-squared	P
Spring	- single	149	1542.7	1259.1	-<0.001
	mixed	2298	904.3	2148.0	+<0.001
Fall	- single	203	987.4	581.0	-<0.001
	mixed	963	205.6	2790.1	+<0.001

<10 cm

Date	Total Area (ha)	Area Unocc. or with only SEPL (ha / prop. of total area)	Area with other spp. (ha / prop. of total area)	Total N	SEPL in Single (No. obs./No. exp.)	SEPL in Mixed (No. obs./No. exp.)
5/16/91	500.5	423.5/.846	77.0/.154	68	0/57.5	68/10.5
5/27/91	724.6	376.5/.520	348.1/.480	198	58/103.0	140/95.0
8/14/91	512.6	398.1/.777	114.5/.223	38	1/29.5	37/8.5
8/20/91	519.0	435.3/.839	83.7/.161	6	6/5.0	0/1.0

		No. Obs.	No. Exp.	Chi-squared	P
Spring	- single	58	160.5	65.5	-<0.001
	mixed	208	105.5	99.6	+<0.001
Fall	- single	7	34.5	21.9	-<0.001
	mixed	37	9.5	79.6	+<0.001

Table 9e. Number of Willets (observed / expected) in single-species flocks and mixed-species flocks.

Plough

Date	(ha) Total Area	(ha / prop. of total area) Area Unocc. or with only WILL	Area with other spp.	Total N	(No. obs./No. exp.) WILL in Single	WILL in Mixed
4/14/91	2681.3	2330.2/.869	351.1/.131	3	3/2.6	0/0.4
4/27/91	2329.7	2034.4/.873	295.3/.127	4	4/3.5	0/0.5
5/05/91	2085.5	1689.2/.810	396.3/.190	3	3/2.4	0/0.6
5/16/91	1660.9	799.1/.481	861.8/.519	9	0/4.3	9/4.7

		No. Obs.	No. Exp.	Chi-squared	P
Spring -	single	10	12.8	0.6	NS
	mixed	9	6.2	0.3	NS

<10 cm

Date	(ha) Total Area	(ha / prop. of total area) Area Unocc. or with only WILL	Area with other spp.	Total N	(No. obs./No. exp.) WILL in Single	WILL in Mixed
4/27/91	1068.5	1068.5/1.00	0/.000	1	1/1.0	0/0.0
5/16/91	500.5	489.7/.978	10.8/.022	2	2/2.0	0/0.0
5/27/91	724.6	393.5/.543	331.1/.457	24	0/13.0	24/11.0

		No. Obs.	No. Exp.	Chi-squared	P
Spring -	single	3	16.0	10.6	-<0.01
	mixed	24	11.0	15.4	+<0.001

>10 cm

Date	(ha) Total Area	(ha / prop. of total area) Area Unocc. or with only WILL	Area with other spp.	Total N	(No. obs./No. exp.) WILL in Single	WILL in Mixed
4/27/91	3200.9	3200.9/1.00	0/.000	18	18/18.0	0/0.0
5/16/91	4437.5	4437.5/1.00	0/.000	2	2/2.0	0/0.0
5/27/91	4975.7	4965.7/.998	10.0/.002	2	2/2.0	0/0.0

		No. Obs.	No. Exp.	Chi-squared	P
Spring -	single	22	22.0	0.0	NS
	mixed	0	0.0	0.0	NS

Table 9f. Number of Upland Sandpipers (observed / expected) in single-species flocks and mixed-species flocks.

Plough

Date	Total Area (ha)	Area Unocc. or with only UPSA (ha / prop. of total area)	Area with other spp. (ha / prop. of total area)	Total N	UPSA in Single (No. obs./No. exp.)	UPSA in Mixed (No. obs./No. exp.)
9/01/91	740.6	424.9/.574	315.7/.426	6	4/2.6	2/3.4
9/14/91	965.0	760.3/.788	204.7/.212	2	2/1.6	0/0.4

		No. Obs.	No. Exp.	G-Statistic	P
Fall	- single	6	4.2	4.3	+<0.05
	mixed	2	3.8	2.6	NS

>10 cm

Date	Total Area (ha)	Area Unocc. or with only UPSA (ha / prop. of total area)	Area with other spp. (ha / prop. of total area)	Total N	UPSA in Single (No. obs./No. exp.)	UPSA in Mixed (No. obs./No. exp.)
8/14/91	512.6	512.6/1.00	0/.000	13	13/13.0	0/0.0
8/20/91	519.0	486.5/.937	32.5/.063	8	8/7.5	0/0.5

		No. Obs.	No. Exp.	Chi-squared	P
Fall	- single	21	20.5	*1.0	NS
	mixed	0	0.5	0.5	NS

*Data from G-test (G-Statistic)

Table 9g. Number of Ruddy Turnstones (observed / expected) in single-species flocks and mixed-species flocks.

Plough

	(ha)	(ha / prop. of total area)			(No. obs./No. exp.)	
Date	Total Area	Area Unocc. or with only RUTU	Area with other spp.	Total N	RUTU in Single	RUTU in Mixed
5/16/91	1660.9	799.1/.481	861.8/.519	25	0/12.0	25/13.0
5/27/91	898.5	626.4/.697	272.1/.303	13	0/9.1	13/3.9
8/14/91	1333.7	1070.7/.803	263.0/.197	2	0/1.6	2/0.4
8/20/91	984.1	716.6/.728	267.5/.272	2	0/1.5	2/0.5
11/03/91	1771.0	1498.5/.846	272.5/.154	1	0/0.8	1/0.2
11/09/91	2154.1	1580.7/.734	573.4/.266	7	0/5.1	7/1.9

		No. Obs.	No. Exp.	Chi-squared	P
Spring -	single	0	21.1	21.1	-<0.001
	mixed	38	16.9	26.3	+<0.001
Fall -	single	0	9.0	9.0	-<0.01
	mixed	12	3.0	27.0	+<0.001

<10 cm

	(ha)	(ha / prop. of total area)			(No. obs./No. exp.)	
Date	Total Area	Area Unocc. or with only RUTU	Area with other spp.	Total N	RUTU in Single	RUTU in Mixed
5/16/91	500.5	423.5/.846	77.0/.154	1	0/0.8	1/0.2
5/27/91	724.6	689.4/.951	35.2/.049	12	5/11.4	7/0.6

		No. Obs.	No. Exp.	Chi-squared	P
Spring -	single	5	12.2	4.2	-<0.05
	mixed	8	0.8	64.8	+<0.001

Table 9h. Number of Semipalmated Sandpipers (observed / expected) in single-species flocks and mixed-species flocks.

Plough

Date	Total Area (ha)	Area Unocc. or with only SESA (ha / prop. of total area)	Area with other spp. (ha / prop. of total area)	Total N	SESA in Single (No. obs./No. exp.)	SESA in Mixed (No. obs./No. exp.)
5/05/91	2085.5	1570.9/.753	514.6/.247	8	0/6.0	8/2.0
5/16/91	1660.9	799.1/.481	861.8/.519	320	0/153.9	320/166.7
5/27/91	898.5	626.4/.697	272.1/.303	158	0/110.1	158/47.9
7/26/91	1622.5	1226.7/.756	395.8/.244	1	0/0.8	1/0.2
8/01/91	1486.8	1180.6/.794	306.2/.206	2	0/1.6	2/0.4
8/14/91	1333.7	1070.7/.803	263.0/.197	11	0/8.8	11/2.2
8/20/91	984.1	716.6/.728	267.5/.272	11	0/8.0	11/3.0
9/01/91	740.6	424.9/.574	315.7/.426	33	0/18.9	33/14.1

		No. Obs.	No. Exp.	Chi-squared	P
Spring	- single	0	270.0	270.0	-<0.001
	mixed	486	216.6	335.0	+<0.001
Fall	- single	0	38.1	38.1	-<0.001
	mixed	58	19.9	72.9	+<0.001

<10 cm

Date	Total Area (ha)	Area Unocc. or with only SESA (ha / prop. of total area)	Area with other spp. (ha / prop. of total area)	Total N	SESA in Single (No. obs./No. exp.)	SESA in Mixed (No. obs./No. exp.)
5/16/91	500.5	423.5/.846	77.0/.154	7	0/5.9	7/1.1
5/27/91	724.6	369.5/.510	355.1/.490	19	0/9.7	19/9.3

		No. Obs.	No. Exp.	Chi-squared	P
Spring	- single	0	15.6	15.6	-<0.001
	mixed	58	19.9	72.9	+<0.001

Table 9i. Number of Western Sandpipers (observed / expected) in single-species flocks and mixed-species flocks.

Plough

Date	Total Area (ha)	Area Unocc. or with only WESA (ha / prop. of total area)	Area with other spp. (ha / prop. of total area)	Total N	WESA in Single (No. obs./No. exp.)	WESA in Mixed (No. obs./No. exp.)
7/26/91	1622.5	1226.7/.756	395.8/.244	16	0/12.1	16/3.9
8/01/91	1486.8	1180.6/.794	306.2/.206	1	0/0.8	1/0.2
8/14/91	1333.7	1070.7/.803	263.0/.197	4	0/3.2	4/0.8
11/03/91	1771.0	1498.5/.846	272.5/.154	1	0/0.9	1/0.1

		No. Obs.	No. Exp.	Chi-squared	P
Fall	- single	0	17.0	17.0	-<0.001
	mixed	22	5.0	57.8	+<0.001

Table 9j. Number of Pectoral Sandpipers (observed / expected) in single-species flocks and mixed-species flocks.

	Plough					
	(ha)	(ha / prop. of total area)			(No. obs./No. exp.)	
Date	Total Area	Area Unocc. or with only PESA	Area with other spp.	Total N	PESA in Single	PESA in Mixed
7/26/91	1622.5	1226.7/.756	395.8/.244	5	0/3.8	5/1.2
8/01/91	1486.8	1180.6/.794	306.2/.206	21	0/16.7	21/4.3
8/14/91	1333.7	1070.7/.803	263.0/.197	5	0/4.0	5/1.0
8/20/91	984.1	716.6/.728	267.5/.272	35	0/25.5	35/9.5
9/01/91	740.6	247.5/.333	493.1/.667	14	13/9.3	1/4.7
9/14/91	965.0	728.0/.754	237.0/.246	6	0/4.5	6/1.5

		No. Obs.	No. Exp.	Chi-squared	P
Fall	- single	0	18.4	18.4	-<0.001
	mixed	28	9.6	35.3	+<0.001

Table 9k. Number of Buff-breasted Sandpipers (observed / expected) in single-species flocks and mixed-species flocks.

	Plough					
	(ha)	(ha / prop. of total area)			(No. obs./No. exp.)	
Date	Total Area	Area Unocc. or with only BBSA	Area with other spp.	Total N	BBSA in Single	BBSA in Mixed
8/20/91	984.1	716.6/.728	267.5/.272	2	0/1.5	2/0.5
9/01/91	740.6	424.9/.574	315.7/.426	15	0/8.6	15/6.4
9/14/91	965.0	728.0/.754	237.0/.246	11	0/8.3	11/2.7

		No. Obs.	No. Exp.	Chi-squared	P
Fall	- single	0	18.4	18.4	-<0.001
	mixed	28	9.6	35.3	+<0.001

Table 91. Number of Dunlin (observed / expected) in single-species flocks and mixed-species flocks.

Plough

Date	Total Area (ha)	Area Unocc. or with only DUNL (ha / prop. of total area)	Area with other spp. (ha / prop. of total area)	Total N	DUNL in Single (No. obs./No. exp.)	DUNL in Mixed (No. obs./No. exp.)
3/04/91	1408.8	1341.4/.952	67.4/.048	1773	0/1687.9	1773/85.1
3/16/91	2013.1	1777.3/.883	235.8/.117	323	0/285.2	323/37.8
4/14/91	2681.3	2321.3/.866	360.0/.134	1503	0/1301.6	1503/201.4
4/27/91	2329.7	1977.1/.849	352.6/.151	52	0/44.1	52/7.9
5/05/91	2085.5	1570.9/.753	514.6/.247	3	0/2.3	3/0.7
5/16/91	1660.9	799.1/.481	861.8/.519	979	0/470.9	979/508.1
9/28/91	1182.3	1170.9/.990	11.4/.010	6	0/5.9	6/0.1
10/13/91	2184.9	1746.5/.799	438.4/.201	41	0/32.8	41/8.2
11/03/91	1771.0	1498.6/.846	272.5/.154	197	0/166.7	197/30.3
11/09/91	2154.1	1580.7/.734	573.4/.266	684	0/502.1	684/181.9
11/23/91	854.8	797.2/.933	57.6/.067	4	4/3.7	4/0.3
1/04/92	549.4	332.8/.606	216.6/.394	40	0/24.2	40/15.8
2/29/92	1411.1	1340.6/.950	70.5/.050	40	40/38.0	0/2.0

		No. Obs.	No. Exp.	Chi-squared	P
Spring	- single	0	1818.9	1818.9	-<0.001
	mixed	2537	718.1	4607.2	+<0.001
Fall	- single	0	707.5	707.5	-<0.001
	mixed	928	220.5	2270.1	+<0.001
Winter	- single	40	2039.0	1959.8	-<0.001
	mixed	2140	141.0	28340.4	+<0.001

<10 cm

Date	Total Area (ha)	Area Unocc. or with only DUNL (ha / prop. of total area)	Area with other spp. (ha / prop. of total area)	Total N	DUNL in Single (No. obs./No. exp.)	DUNL in Mixed (No. obs./No. exp.)
4/14/91	689.3	652.8/.947	36.5/.053	617	0/584.3	617/32.7
5/16/91	500.5	423.5/.846	77.0/.154	35	0/29.6	35/5.4
5/27/91	724.6	369.5/.510	355.1/.490	10	0/5.1	10/4.9
11/09/91	2009.3	1955.2/.973	54.1/.027	31	0/30.2	31/0.8
1/04/92	3840.1	3779.1/.984	61.0/.016	13	0/12.8	13/0.2
2/09/92	3520.4	3468.6/.985	51.8/.015	510	0/502.4	510/7.6

		No. Obs.	No. Exp.	Chi-squared	P
Spring	- single	0	619.0	619.0	-<0.001
	mixed	662	43.0	8910.7	+<0.001
Fall	- single	0	30.2	30.2	-<0.001
	mixed	31	0.8	1140.1	+<0.001
Winter	- single	0	515.2	515.2	-<0.001
	mixed	523	7.8	34029.6	+<0.001

Table 9m. Number of Short-billed Dowitchers (observed / expected) in single-species flocks and mixed-species flocks.

Plough

Date	(ha) Total Area	(ha / prop. of total area) Area Unocc. or with only SBDO	Area with other spp.	Total N	(No. obs./No. exp.) SBDO in Single	SBDO in Mixed
4/14/91	2681.3	2321.3/.866	360.0/.134	35	0/30.3	35/4.7
5/05/91	2085.5	1570.9/.753	514.6/.247	7	0/5.3	7/1.7
5/16/91	1660.9	799.1/.481	861.8/.519	64	0/30.8	64/33.2
7/26/91	1622.5	1226.7/.756	395.8/.244	12	0/9.1	12/2.9
8/14/91	1333.7	1070.7/.803	263.0/.197	1	0/0.8	1/0.2
10/13/91	2184.9	1746.5/.799	438.4/.201	4	0/3.2	4/0.8

		No. Obs.	No. Exp.	Chi-squared	P
Spring -	single	0	66.4	66.4	-<0.001
	mixed	106	39.6	111.3	+<0.001
Fall -	single	0	13.1	13.1	-<0.001
	mixed	17	3.9	44.0	+<0.001

<10 cm

Date	(ha) Total Area	(ha / prop. of total area) Area Unocc. or with only SBDO	Area with other spp.	Total N	(No. obs./No. exp.) SBDO in Single	SBDO in Mixed
4/14/91	689.3	652.8/.947	36.5/.053	30	0/28.4	30/1.6
5/27/91	724.6	369.5/.510	355.1/.490	1	0/0.5	1/0.5
11/09/91	2009.3	1955.2/.973	54.1/.027	35	0/34.1	35/0.9
2/09/92	3520.4	3468.6/.985	51.8/.015	42	0/41.4	42/0.6

		No. Obs.	No. Exp.	Chi-squared	P
Spring -	single	0	28.9	28.9	-<0.001
	mixed	31	2.1	397.7	+<0.001
Fall -	single	0	34.1	34.1	-<0.001
	mixed	35	0.9	1292.0	+<0.001
Winter -	single	0	41.4	41.4	-<0.001
	mixed	42	0.6	2856.6	+<0.001

Table 10. P values for associations between species and flock types. + = positive association, - = negative association, NS = no significant association.

Plough

Species	Single-species Spring	Single-species Fall	Single-species Winter	Mixed-species Spring	Mixed-species Fall	Mixed-species Winter
Black-bellied Plover	-<.001	-<.001	-<.001	+<.001	+<.001	+<.001
Lesser Golden-Plover		-<.001			+<.001	
Semipalmated Plover	-<.001	-<.001		+<.001	+<.001	
Killdeer		-<.001	-<.001		+<.001	+<.001
Willet	NS			NS		
Upland Sandpiper		+<.05			NS	
Ruddy Turnstone	-<.001	-<.01		+<.001	+<.001	
Semipalmated Sandpiper	-<.001	-<.001		+<.001	+<.001	
Western Sandpiper		-<.001			+<.001	
Pectoral Sandpiper		-<.001			+<.001	
Buff-breasted Sandpiper		-<.001			+<.001	
Dunlin	-<.001	-<.001	-<.001	+<.001	+<.001	+<.001
Short-billed Dowitcher	-<.001	-<.001		+<.001	+<.001	

<10 cm

Species	Single-species Spring	Single-species Fall	Single-species Winter	Mixed-species Spring	Mixed-species Fall	Mixed-species Winter
Black-bellied Plover	-<.001	-<.001	-<.001	+<.001	+<.001	+<.001
Semipalmated Plover	-<.001	-<.001		+<.001	+<.001	
Willet	-<.001			+<.001		
Ruddy Turnstone	-<.05			+<.001		
Semipalmated Sandpiper	-<.001			+<.001		
Western Sandpiper		-<.001			+<.001	
Pectoral Sandpiper		-<.001			+<.001	
Buff-breasted Sandpiper		-<.001			+<.001	
Dunlin	-<.001	-<.001	-<.001	+<.001	+<.001	+<.001
Short-billed Dowitcher	-<.001	-<.001	-<.001	+<.001	+<.001	+<.001

>10 cm

Species	Single-species Spring	Single-species Fall	Single-species Winter	Mixed-species Spring	Mixed-species Fall	Mixed-species Winter
Willet	NS			NS		
Upland Sandpiper		NS			NS	

Table 11. Mean subflock size (± standard error) in single-species and mixed-species flocks on each cover type.

Plough

Species	Single-Species	Mixed-Species	t	P
Black-bellied Plover	24.1 ± 7.4	63.1 ± 10.7	40.63	.001
Lesser Golden-Plover		2.9 ± 0.8		
Semipalmated Plover	9.3 ± 0.9	37.0 ± 4.8	51.62	.001
Killdeer	15.4 ± 2.5	15.7 ± 3.5	0	NS
Willet	2.3 ± 0.3	2.3 ± 0.8	0	NS
Upland Sandpiper		2*		
Ruddy Turnstone		3.6 ± 0.9		
Semipalmated Sandpiper		16.6 ± 3.9		
Western Sandpiper		4.2 ± 2.4		
Pectoral Sandpiper	13*	7.3 ± 2.4		
Dunlin	20.0 ± 17.0	114.4 ± 46.0		
Buff-breasted Sandpiper		4.7 ± 1.5		
Short-billed Dowitcher		10.3 ± 3.8		

<10 cm

Species	Single-Species	Mixed-Species	t	P
Black-bellied Plover	20.0 ± 13.5	88.9 ± 28.3	69.77	.001
Semipalmated Plover	15.8 ± 5.3	35.0 ± 11.8	19.91	.001
Killdeer		12.0 ± 10.0		
Willet	2*	6.0 ± 2.7		
Upland Sandpiper	2.5 ± 0.5			
Ruddy Turnstone	5*	2.3 ± 1.3		
Semipalmated Sandpiper		6.7 ± 3.5		
Western Sandpiper		4.0 ± 0.6		
Pectoral Sandpiper		3*		
Dunlin		121.6 ± 53.4		
Buff-breasted Sandpiper		3*		
Short-billed Dowitcher		21.6 ± 8.7		

>10 cm

Species	Single-Species	Mixed-Species
Willet	7.3 ± 5.3	
Upland Sandpiper	7.0 ± 3.2	

*Only one subflock recorded in that flock type (not a mean value).

type on >10 cm cover, and on plough they did not exhibit a significant association, either positive or negative, with mixed-species aggregations. However, Upland Sandpipers were found to be positively associated with monospecific flocks on plough. This was the only example of a positive association with single-species flocks; no species were negatively associated with mixed flocks.

Further evidence of the apparent preference of some species for mixed flocks is provided by the comparison of mean subflock size (Table 11) for birds occurring in single-species and mixed-species flocks. On plough, 10 of 13 species occurred in larger subflocks in mixed-species flocks than in monospecific flocks, and in Black-bellied Plover and Semipalmated Plover this difference was significant ($t=40.63$, $P<.001$ and $t=51.62$, $P<.001$ for Black-bellied and Semipalmated Plovers respectively). The exceptions were Willet and Killdeer, for which mean subflock size was nearly equal in the two flocking situations ($t=0$), and Pectoral Sandpiper. The same trend appeared on <10 cm cover, where Black-bellied and Semipalmated Plovers again occurred in significantly larger subflocks in mixed flocks than in monospecific flocks ($t=69.77$, $P<.001$ and $t=19.91$, $P<.001$ respectively). Upland Sandpiper (which did not occur in mixed flocks on this cover type) and Ruddy Turnstone were the only exceptions on <10 cm cover. No comparison was possible for Willet and Upland Sandpiper on >10 cm cover, as these species occurred there only in monospecific flocks.

DISCUSSION

Agricultural fields on Virginia's Eastern Shore are very important as foraging areas for migrant and wintering shorebirds. Although a few "field specialists", such as Killdeer, Lesser Golden-Plover, Upland Sandpiper, and Buff-breasted Sandpiper, generally prefer these fields to intertidal areas (pers. obs., Hayman et al. 1986), most species prefer to forage in intertidal habitats and use fields as an alternative foraging site when mudflats and beaches are inundated by high water (Goss-Custard 1969, Page & Whitacre 1975, Gerstenberg 1979, Page et al. 1979). On most days, shorebirds foraged in intertidal areas during low tide, then flew to fields when the tide rose (pers. obs.). However, on days with strong, sustained east winds, tides were often considerably higher than normal, so that mudflats were not exposed even at low tide. During these events, even the shorebirds that preferred intertidal areas would spend the entire day foraging in fields.

The importance of agricultural fields to shorebirds varied with the time of year. More individuals foraged in fields during the short period of spring migration than in any other season, but during this time there were few or none of the "field specialist" species present. Fewer birds utilized fields in fall, but more species, including the four "field specialists", occurred during fall than at any other time. The periods of spring and fall migration require long-distance migrants to accumulate large energy reserves (Berthold 1975, Evans 1976), so it is crucial that the birds have alternate foraging sites when intertidal areas are inundated, especially when stormy weather keeps mudflats and beaches covered for days at a time. In winter, several species of shorebirds were quite abundant in fields, although species diversity was low. Agricultural fields were used by Willets for nesting in the summer, but very few pairs of these birds (and no other species) were present during this time.

The importance of fields also varied among species. As stated previously, some species fed primarily in fields, rarely moving to tidal areas. Depending on the seasonal distribution of each species, some shorebirds (Black-bellied Plover and Dunlin) foraged in these agricultural fields during three of the four seasons of the year, while the other species were present for only one or two seasons.

To shorebirds on the Eastern Shore, the two major causes of mortality are probably starvation and predation. The long distances that some of these species migrate necessitate a high rate of energy intake during migration, and in winter food intake must be high enough to balance the energy lost as heat. Alternative foraging sites, such as agricultural fields, ensure that the birds will always have available foraging areas, regardless of the tide height. However, the foraging efficiency of shorebirds in agricultural fields may vary depending on several factors. Some of these factors, such as weather (Evans 1976, Pienkowski 1981), human disturbance, and disturbance by predators (Caraco et al. 1979), are beyond the control of shorebirds, and may drastically reduce the rate or efficiency of foraging, making the birds more susceptible to starvation. Other factors, such as foraging strategies (e.g. cover use and flocking), can be actively controlled by the birds in order to enhance foraging efficiency.

Although several species of potential mammalian predators, including domestic dogs and cats, are very common on the Eastern Shore, the main predators of shorebirds in fields are other birds. Raptors such as Sharp-shinned Hawks (*Accipiter striatus*), Cooper's Hawks (*Accipiter cooperii*), Merlins (*Falco columbarius*), Peregrine Falcons (*Falco peregrinus*), American Kestrels (*Falco sparverius*), Northern Harriers (*Circus cyaneus*), Red-tailed Hawks (*Buteo jamaicensis*), Great Horned Owls (*Bubo virginianus*), and Short-eared Owls (*Asio flammeus*), all of which have been known to prey on shorebirds (Page & Whitacre 1975), are all common to abundant on the Eastern Shore in fall, and are present in fair numbers during spring and winter as well (Kain 1987, Sutton 1991, pers. obs.). On several occasions, flocks of shorebirds were observed being attacked by Peregrine Falcons, Red-tailed Hawks, and American Kestrels, but none of these attacks were successful. The only incident of predation on shorebirds that I observed was the attack by three American Crows (*Corvus brachyrhynchos*) on a healthy adult Killdeer. One of the crows captured, killed, and ate the Killdeer on the ground. Although shorebirds foraging in agricultural fields are unable to control predator density, they can preferentially utilize certain cover types or practice certain flocking strategies that might reduce the risk of predation. This study investigated some important shorebird behaviors, namely cover utilization and flocking, that help the birds reduce the risk of mortality due to starvation and predation.

Cover utilization

Most of the species recorded were on plough and <10 cm cover, with far fewer species on >10 cm cover. Despite the fact that diversity on plough and <10 cm cover was almost the same, shorebirds showed almost universal preference for plough, while the utilization of vegetation less than 10 cm tall varied considerably among species. No species preferred >10 cm cover, and most actively avoided it. This suggests that foraging efficiency is highest on plough and lowest on >10 cm cover, while on <10 cm cover certain species may be able to obtain prey efficiently while others may not. These results agree with the prediction that foraging should be easier on plough, where visual hunters are able to maintain a wide search area unobstructed by vegetation and where no moving vegetation is present to distract these shorebirds, so that prey is easier to locate and extract (Fuller & Youngman 1979). Furthermore, thick vegetation inhibits locomotion (Bent 1949), and may cause an increase in the attack time of visual hunters or provide a major impediment to movement in smaller birds. On <10 cm cover, vegetation is apparently not thick enough to inhibit foraging efficiency for some species, as many species do utilize or even show a positive association with this cover type. It appears that the seasonal effects on prey availability of wind, extreme temperatures, and drought, effects which tend to reduce prey availability more on plough than on vegetated cover (Burton 1974, Murton & Westwood 1974, Evans 1976, Pienkowski 1981, Shrubb 1988), may not be great enough or last long enough to cause a shift in cover preferences of the birds, as preference for plough remained fairly consistent throughout the year.

The only broad-scale seasonal difference in cover utilization was on <10 cm cover, where most species exhibited a positive association in spring, but either no association or a negative one in fall. Although the reasons for this are unclear, there are several possible explanations for this phenomenon. Prey availability on <10 cm cover may be higher in spring than in fall, so that birds are able to forage on this cover with a sufficiently high rate of energy intake in spring. Repeated applications of pesticides throughout the summer may reduce the density of prey (Presley Curling, pers. comm.), accounting for the lower prey availability in fall. However, many prey species, especially insects, are known to reproduce through several generations in a summer's time (Borror 1976), potentially increasing the size of the shorebirds' prey base in fall. Therefore, this hypothesis may not fully explain the shift in cover utilization. A more plausible (but still speculative) explanation is that the high density of birds present in spring resulted in detrimental crowding effects, such as prey disturbance (Pienkowski 1981), prey depletion (Bentson et al. 1976, Byrkjedal & Kalas 1983), aggression (Burger et al. 1979, Byrkjedal & Kalas 1983, Recher & Recher 1969), kleptoparisitism

(Goss-Custard 1977), and search-path disruption (Goss-Custard 1977). Shorebirds preferred plough to vegetated cover types, but if a majority of ploughed fields were occupied by large numbers of birds, then it might have been more efficient energetically for some birds to move to <10 cm cover than to remain in crowded fields. In fall, when there were fewer total individuals present and the migration period was protracted, the area of unoccupied plough at any given time was greater, so birds would not have had to move to <10 cm cover.

Studies have indicated that avian predators hunt more often and more successfully on short cover than in tall, thick cover (Sparrowe 1972, Wakely 1978, Bechard 1982), and that predator-related mortality is higher on short cover (Watts 1990). Most of these shorebirds, however, consistently preferred plough to vegetated cover. Although some adaptive coloration, such as dull brown and grey tones, countershading, and disrutive coloration, reduces the shorebirds' visibility to predators (Gill 1990), the behavior of foraging on plough leaves the birds very vulnerable to attack. Furthermore, many species that were positively correlated with <10 cm cover (which may inhibit the location of foraging shorebirds by predators) in spring avoided that cover type and foraged primarily on plough in fall, when avian predators were much more numerous. This seems to indicate that foraging efficiency, rather than risk of predation, was the principle factor governing cover preference in these birds.

In the presence of predators, the choice of cover by foraging birds may represent a tradeoff between foraging efficiency and predation risk, as the cover on which foraging efficiency is highest may not coincide with the cover where the risk of predation is lowest. If a bird is able to employ alternate foraging strategies that increase the efficiency of foraging, then perhaps it can remain on a cover where the risk of predation is fairly low. Likewise, employing alternate strategies that increase a bird's safety might enable it to forage on a cover where foraging efficiency is high. Thus, given an array of cover types that differ in predation risk, the optimal cover may depend on the array of options available that enhance foraging efficiency. In the same manner, the optimal cover among an array of cover types that differ in prey availability may depend on the alternate strategies available that enhance a bird's safety. Given the fact that most shorebirds consistently preferred plough and shorter cover, where foraging efficiency was probably high but where the birds were visible to predators, it appears that the birds were able to employ alternate foraging strategies (e.g. flocking) to reduce the risk of predation.

Flocking

In all species, most individuals occurred in flocks, with very few birds foraging alone. Therefore, the benefits of flocking, in terms of foraging efficiency and safety from predators, seemed to outweigh the costs in these shorebirds. Furthermore, most of these species were positively associated with mixed-species flocks and negatively correlated with monospecific flocks, and mean subflock size was generally larger in mixed aggregations than in single-species flocks. The studies of Lapwings, Golden Plovers, and Dunlin in Great Britain documented the enhanced foraging efficiency and predator detection abilities of birds in mixed flocks (Fuller & Youngman 1979, Byrkjedal & Kalas 1983, Thompson & Barnard 1983, Barnard & Thompson 1985, Thompson & Thompson 1985).Occurrence in mixed-species flocks probably offers the same benefits to shorebirds foraging in agricultural fields on the Eastern Shore as well. Because of these shorebirds' co-occurrence in the same habitats, reliance on the same types of prey, and vulnerability to the same predators, there has been convergence in the evolution of these species (Barnard 1982). Similar adaptations found in different species, such as similar warning calls, white wing-stripes, and white markings in the rectrices, may promote flock cohesiveness or allow all species in a flock to be quickly and simultaneously warned of a threat.

While it is easy to see how small tactile foragers, such as the small Calidris species, benefit from occurrence with visual hunters and larger species, the benefits accrued to the larger species are less evident. Visual hunters, such as plovers, usually adopt an upright posture when searching for prey. In such a stance they would be better able to see predators than a tactile feeder of the same size that had its head bent toward the ground, because there would be fewer obstructions (plant material, clumps of dirt, etc.) to the bird's vision. Larger species may have an even clearer line of sight to a predator, and even in large tactile feeders (Willet and Whimbrel) individuals usually have their heads well above the substrate when foraging. Thus, small tactile hunters may rely on the more effective vigilance of other species, allowing them to spend more time feeding and still remain relatively safe from predators (Byrkjedal & Kalas 1983, Barnard and Thompson 1985, Thompson & Thompson 1985). Conversely, the larger species may hardly benefit at all from the vigilance of the smaller birds. Shorebirds flying over fields may use "local enhancement" (Hinde 1961) to find good feeding sites by locating birds that are already foraging. While such a tactic may be beneficial to all species, the larger species are more visible from the air, allowing the smaller birds to easily locate good feeding areas. Indeed, Dunlin have been shown to rely on Golden Plovers to locate foraging sites (Byrkjedal & Kalas). Smaller species may also benefit more from convergent evolution of plumage and calls, as the white wing and tail markings on larger species are more visible to other birds in the flock than those on smaller birds, and larger shorebirds generally have louder calls than the smaller ones.

Thus, it seems that in mixed flocks, smaller species may benefit more than larger birds, and tactile foragers may benefit more than visual hunters of the same size. Larger species and visual hunters probably benefit from the presence of other individuals if they flock only with birds that use similar feeding methods or are of similar size. Even in flocks with small tactile foragers, these birds may increase their foraging rate somewhat through local enhancement or sharing of vigilance (Barnard & Thompson 1985, Thompson & Thompson 1985). However, their foraging efficiency may also suffer due to the presence of these smaller birds. Larger species require a wide search area, and this area may be easily interrupted, especially in visual hunters, by small tactile foragers (Goss-Custard 1977). When Dunlin and Black-bellied Plovers occurred together, the plovers were often uniformly dispersed to maintain open search areas, while the Dunlin fed among, and often quite close to, the plovers (pers. obs.). Larger birds are usually able to supplant smaller birds at feeding sites (Burger et al. 1979). Alternatively, the larger birds could move to the periphery of the flock in order to minimize interactions with the small tactile hunters. However, the energetic costs of aggression and relocation to the flock's periphery may be high relative to the loss of efficiency due to the presence of the smaller birds. Therefore, overall foraging efficiency in the large visual hunters may be higher if they simply tolerate the presence of the smaller birds.

Because some shorebird species may act as "flock nuclei" and attract other species (Buskirk 1974), possibly at the expense of their own foraging efficiency, it was difficult to determine whether a species that was positively correlated with mixed flocks actually preferred such aggregations or whether it simply attracted other species. Evidence suggests that some species in both categories were present in this shorebird community. Some visual hunters, including Black-bellied Plover, Killdeer, and Semipalmated

Plover, occasionally occurred in monospecific flocks, even when other species were present nearby. In flocks with other plovers, which tend to avoid each other while feeding to maintain a wide search area (Stinson 1977), these birds are probably able to forage efficiently while sharing vigilance fairly equally. It seems that such species would have the most to lose by foraging in flocks with small tactile hunters, yet they were often observed doing so. Because the plovers may have had relatively effective predator detection abilities, these birds probably served as nuclear species that attracted the smaller birds. Such small tactile foragers, including Dunlin and the "peeps" (Semipalmated, Western, Least, and Baird's Sandpipers), almost always occurred in mixed-species flocks with larger visual hunters.

The attraction of one species to another may indeed have been so strong that the choice of cover in the "follower" species depended on the presence or absence of a nuclear species. For instance, a species that preferred to forage on a certain cover when in monospecific flocks may have switched to another cover in the presence of a nuclear species. Black-bellied Plover (a potential nuclear species) was recorded on a majority of censuses; the presence of this species in certain fields may have been more attractive to other shorebirds than the cover type on which the plover was foraging. There was no clear evidence that such a process was operating, as most of the supposed "followers" never occurred in monospecific flocks (so it was not possible to compare cover use in single-species flocks with cover use in the presence of a nuclear species). However, the possibility of an interaction between flocking and cover use does exist, and such an interaction may have confounded results for cover use.

Regardless of whether a species was a nuclear species or a "follower", most species were consistent in their positive association with mixed flocks during all seasons and on both plough and <10 cm cover. Also, mean subflock size, another measure of the number of birds associated with one flock type or the other, was significantly higher in mixed-species aggregations and lower in monospecific flocks in some species. If flocking is closely related to safety from predators, one might expect this behavior to vary as the density of predators varies. Shorebirds foraging in agricultural fields in fall, when predator density is very high, would then be expected to show a greater propensity for mixed-species flocks than at other times of the year. However, these shorebirds remained positively associated with mixed flocks in winter and spring as well, even though predator density was not nearly as high during those seasons. Incidental observations of summering Black-bellied Plovers and Short-billed Dowitchers foraging on mudflats adjacent to the study area showed that these species occurred in mixed-species flocks even during mid-summer, when predator density was extremely low.

It has been hypothesized that the evolutionary basis for flocking in Dunlin is safety from predation (Shanewise & Herman 1979), yet Dunlin foraging in agricultural fields occurred in large flocks even in mid-May, when very few predators were present in the study area (pers. obs.). If my data were to support that hypothesis, given the fact that Dunlin maintained the same flocking behavior in all seasons and on all cover types, then one may assume that the risk of predation need not be very high in order for these birds to congregate into flocks. An alternate hypothesis is that flocking in these shorebirds was selected for because it increased the birds' foraging efficiency and prevented them from starving. However, the most plausible explanation for flocking in the shorebirds that forage in agricultural fields probably reflects a balance between these two hypotheses; in most of these species, flocking and occurrence in mixed-species flocks may reduce the risk of mortality due to both predation and starvation. The relative importance of each of these threats in inducing flock formation varies throughout the year as energetic demands and predator density change, but both factors are probably always operating.

Two exceptional species

While most of the 13 most common species of shorebirds observed foraging in agricultural fields were similar in terms of cover utilization and flocking behavior, two species were exceptional in their lack of agreement with the behavior of the other species. These two species, Willet and Upland Sandpiper, were rather similar in their own habits, although they never co-occurred. Willets were present only in spring and summer, while Upland Sandpipers occurred only in fall. These were the only species in which a large percentage of the individuals recorded (34% in Willet, 70% in Upland Sandpiper) were observed foraging on >10 cm cover, yet both also occurred on plough and <10 cm cover. These species generally did not exhibit a strong preference for plough or avoidance of >10 cm cover as did the others, and they tended to occur more often in monospecific flocks than the other 11 species (probably because of their occurrence on >10 cm cover, where very few individuals of other species foraged). Most individuals of both species did occur in flocks (monospecific) on tall cover, however.

Apparently the problems associated with foraging, vigilance sharing, and predator detection that other species might have experienced in >10 cm cover did not affect these two species to the point where foraging on this cover type became inefficient. Whereas the other species seem to have employed alternate foraging strategies that reduced the risk of predation on plough and short cover (where foraging efficiency was probably high), these two species may have done the opposite, using alternate strategies to enhance foraging efficiency on tall cover (where risk of predation was relatively low). Willets and Upland Sandpipers must be able to forage efficiently and maintain some sort of flock cohesion in tall cover, perhaps because they are relatively tall, long-legged species. The Willet (and the sandpiper to a lesser extent) may use vocalizations more often than most of the other species to attract other individuals of its species or to warn them of a potential threat.

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Appendix A. **Abundance of each cover type during each census (absolute area (ha) / proportion of total study area).**

Date	Plough	<10 cm Cover	>10 cm Cover
3/04/91	1408.8 / 0.214	4396.0 / 0.665	793.3 / 0.121
3/16/91	2013.1 / 0.305	3707.2 / 0.561	878.1 / 0.134
4/06/91	3200.7 / 0.485	103.6 / 0.016	3294.5 / 0.499
4/14/91	2681.3 / 0.406	689.3 / 0.104	3228.1 / 0.489
4/27/91	2329.7 / 0.353	1068.5 / 0.162	3200.9 / 0.486
5/05/91	2085.5 / 0.319	199.2 / 0.030	4314.4 / 0.651
5/16/91	1660.9 / 0.252	500.5 / 0.076	4437.5 / 0.672
5/27/91	898.5 / 0.136	724.6 / 0.110	4975.7 / 0.754
6/04/91	616.8 / 0.093	368.5 / 0.056	5616.4 / 0.851
6/10/91	597.1 / 0.090	0.0 / 0.000	6001.7 / 0.910
6/28/91	1234.5 / 0.187	0.0 / 0.000	5364.3 / 0.813
7/15/91	1599.8 / 0.242	416.8 / 0.063	4582.2 / 0.694
7/26/91	1622.5 / 0.245	420.4 / 0.064	4555.9 / 0.691
8/01/91	1486.8 / 0.225	226.7 / 0.034	4885.3 / 0.740
8/14/91	1333.7 / 0.202	512.6 / 0.078	4752.5 / 0.720
8/20/91	984.1 / 0.149	519.0 / 0.079	5095.7 / 0.772
9/01/91	740.6 / 0.112	643.2 / 0.097	5215.0 / 0.790
9/14/91	965.0 / 0.146	82.0 / 0.012	5551.8 / 0.841
9/28/91	1182.3 / 0.179	2165.3 / 0.328	3022.4 / 0.458
10/13/91	2184.9 / 0.331	423.3 / 0.064	3990.6 / 0.605
11/03/91	1771.0 / 0.268	1403.2 / 0.213	3424.6 / 0.519
11/09/91	2154.1 / 0.326	2009.3 / 0.304	2435.4 / 0.369
11/23/91	854.8 / 0.130	4785.3 / 0.725	958.7 / 0.145
12/08/91	658.7 / 0.100	4494.7 / 0.681	1445.4 / 0.219
12/19/91	548.6 / 0.083	4533.7 / 0.687	1516.5 / 0.230
12/27/91	487.0 / 0.074	3770.5 / 0.571	2341.3 / 0.355
1/04/92	549.4 / 0.083	3840.1 / 0.582	2209.3 / 0.335
1/19/92	462.9 / 0.070	3714.5 / 0.563	2421.4 / 0.367
2/09/92	1121.5 / 0.170	3520.4 / 0.533	1956.9 / 0.297
2/29/92	1411.1 / 0.214	2165.3 / 0.328	5383.5 / 0.816

Appendix B. Times Of and Weather During Censuses

0000 is midnight. 1200 is noon.

3/04/91 - 0645-1500
- 12°C, wind 10-16 m.p.h. from SW, mostly cloudy at 0645; cooling to 9°C at 1200.

3/16/91 - 0715-1545
- 8°C, wind 5-10 m.p.h. from NNW, clear at 0715; becoming cloudy and warming to 12°C, wind shifting to N at 1500.

4/06/91 - 0645-1530
- 14°C, clear but hazy with no wind at 0645; becoming partly cloudy, warming to 20°C at 1200.

4/14/91 - 0500-1300
- 9°C, overcast, light rain at 0630; wind increasing to 10-15 m.p.h. from NNE at 0730.

4/27/91 - 0500-1215
- 15°C, no wind, mostly cloudy; warming to 18°C and clearing by 0800, wind increasing to 5-10 m.p.h. from SW.

5/05/91 - 0830-1630
18°C, wind 5-8 m.p.h. from SE, clear at 0900; becoming mostly cloudy, 20°C, wind shifting to E by 1200.

5/16/91 - 0515-1300
- 16°C, no wind, overcast with fog at 0515; clearing by 0700; warming to 20°C, wind increasing to 6 m.p.h. from E at 1200.

5/27/91 - 0500-1315
- 21°C, no wind, clear at 0510; wind 4-7 m.p.h. from W, 24°C at 1200.

6/04/91 - 0800-1500
- 26°C, wind 12-15 m.p.h. from WNW, mostly cloudy throughout census.

6/10/91 - 1200-1910
- 23°C, wind 2-5 m.p.h. from W, clear throughout census.

6/28/91 - 0500-1320
- 21°C, no wind, clear at 0600; warming to 26°C, wind 3-5 m.p.h. from SSE at 0930.

7/15/91 - 0700-1500
- 29°C, wind 2-4 m.p.h. from E, clear at 0730; becoming cloudy during census.

7/26/91 - 0500-1440
- 23°C, no wind, overcast and foggy at 0545; clearing slightly during census.

8/01/91 - 0700-1500
- 26°C, no wind, partly cloudy at 0800; wind increasing to 4-7 m.p.h. from NNE by 1200.

8/14/91 - 0600-1345
- 23°C, no wind, partly cloudy throughout census.

8/20/91 - 1100-1830
- 21°C, no wind, overcast at 1130; warming to 26°C and clearing by 1530.

9/01/91 - 0800-1630
- 22°C, wind 10-15 m.p.h. from NE, overcast at 0930; clearing slightly during census.

9/14/91 - 0730-1500
- 20°C, no wind, clear at 0800; warming to 24°C at 1500.

9/28/91 - 0630-1500
- 14°C, wind 3-5 m.p.h. from N at 0700; becoming partly cloudy, warming to 16°C by 1100.

10/13/91 - 0630-1400
- 9°C, wind 4-7 m.p.h. from NW, overcast, raining lightly at 0700; warming to 14°C at 1100.

11/03/91 - 0615-1400
- 10°C, wind 3-5 m.p.h. from N, clear at 0630; wind increasing to 10 m.p.h., becoming mostly cloudy by 1130.

11/09/91 - 0600-1515
- 7°C, wind 9-14 m.p.h. from NNW, overcast at 0630; light rain started at 0840 and continued all day, wind gusting to 25 m.p.h. in afternoon.

11/23/91 - 0600-1405
- 10°C, wind 5-8 m.p.h. from NW, partly cloudy at 0630, warming to 13°C at 1200.

12/08/91 - 0615-1500
- 6°C, no wind, clear at 0630; warming to 12°C by 1500.

12/19/91 - 0630-1330
- -4°C, wind 20-35 m.p.h. from N, intermittent light rain, cloudy throughout census.

12/27/91 - 0830-1630
- 6°C, no wind, intermittent light rain and sleet, overcast until 1200; wind 2-6 m.p.h. from NW at 1200.

1/04/92 - 0630-1445
- 7°C, wind 15-25 m.p.h. from NE, light rain, overcast at 0630; wind changing to NW, becoming 5-15 m.p.h. and warming to 12°C at 1445.

1/19/92 - 0630-1500
- -7°C, wind 10-18 m.p.h. from NW, overcast with snow flurries at 0630; warming to -4°C by 1200.

2/09/92 - 0830-1530
- -2°C, no wind, clear at 0830; warming to 1°C, wind 4-7 m.p.h. from WNW at 1130.

2/29/92 - 0830-1530
- 2°C, wind 20-25 m.p.h. from NNW, partly cloudy at 0830; 3°C, clearing by 1200.

Appendix C. Estimated High and Low Tides on Census Dates

0000 is midnight. 1200 is noon.
Data is for Kiptopeke Beach (U.S. Dept. of Commerce 1990, 1991).

Date	Time (EST)	Height (cm)
3/04/91	0530	-6
	1051	79
	1705	-6
	2315	85
3/16/91	0221	-3
	0818	89
	1435	-3
	2035	95
4/06/91	0052	79
	0736	19
	1316	69
	1931	19
4/14/91	0158	-3
	0749	89
	1400	-3
	2008	106
4/27/91	0127	-3
	0718	82
	1326	0
	1937	98
5/05/91	0013	82
	0656	19
	1245	72
	1858	19
5/16/91	0410	-6
	0957	85
	1607	-6
	2222	106
5/27/91	0153	3
	0734	76
	1336	3
	1954	95
6/04/91	0023	79
	0658	13
	1330	76
	1920	19

Date	Time (EST)	Height (cm)
6/10/91	0022	0
	0603	79
	1210	-3
	1832	106
6/28/91	0324	6
	0909	76
	1513	10
	2120	89
7/15/91	0510	-10
	1112	95
	1736	-3
7/26/91	0219	6
	0806	79
	1411	10
	2021	92
8/01/91	0542	6
	1152	92
	1825	16
8/14/91	0521	-3
	1134	98
	1806	6
8/20/91	0428	69
	1034	19
	1703	89
9/01/91	0042	79
	0654	12
	1319	98
	2010	19
9/14/91	0002	79
	0612	16
	1234	95
	1917	23
9/28/91	0452	10
	1107	109
	1752	16
10/13/91	0537	19
	1154	95
	1839	26

Date	Time (EST)	Height (cm)
11/09/91	0343	6
	1000	98
	1641	13
	2218	79
11/03/91	0545	98
	1215	6
	1803	89
11/23/91	0242	-6
	0902	112
	1543	-3
	2125	85
12/08/91	0321	0
	0937	89
	1615	3
	2154	72
12/19/91	0609	95
	1253	-3
	1830	76
12/27/91	0058	82
	0722	-3
	1316	76
	1944	-10
1/04/92	0142	-3
	0803	85
	1440	-3
	2021	67
1/19/92	0123	-21
	0742	101
	1419	-18
	2009	82
2/09/92	0553	3
	1150	67
	1800	-3
2/29/92	0553	76
	1222	6
	1812	67