

THE USE OF COASTAL AGRICULTURAL FIELDS IN VIRGINIA AS FORAGING HABITAT BY SHOREBIRDS

STEPHEN C. ROTTENBORN

ABSTRACT.—I studied temporal abundance patterns and use of cover types by shorebirds foraging in coastal croplands on the eastern shore of Virginia from March 1991 through February 1992. A total of 21,254 shorebirds of 21 species was observed foraging in agricultural croplands. Shorebird abundance reached a peak during spring migration and was lower during fall and winter. Shorebird species richness was highest in fall and lower in spring and winter. Some species appeared to use fields primarily as alternate foraging habitat when preferred intertidal habitats were covered by high tides, whereas other species foraged in fields regardless of tidal height. Most species showed highly significant positive associations with plowed fields (bare earth) and negative associations with herbaceous vegetation >10 cm tall. Associations with vegetated cover of <10 cm varied seasonally, tending to be positive in spring and negative (or with no association) in fall and winter for most species. Because most shorebirds foraged on the cover type providing the least cover from predators (plowed fields), the observed cover associations may reflect differences in predator detection or foraging efficiency among the cover types. *Received 20 Nov. 1995, accepted 13 April 1996.*

Most research on habitat use and foraging strategies of shorebirds has focused on the use of intertidal habitats, where they may choose different foraging sites and strategies depending on tidal conditions (cf Burger et al. 1977, Connors et al. 1981). When preferred intertidal habitats are inundated by high tides, shorebirds may forage temporarily in alternate areas, including agricultural fields (Atkinson 1976, Gerstenberg 1979, Page et al. 1979). Previous studies of the use of agricultural croplands by shorebirds have dealt primarily with species that prefer upland habitats and rarely move to intertidal areas (Fuller and Youngman 1979, Barnard and Thompson 1985, Milsom et al. 1985) or were conducted in inland regions where tidal regime had no influence on shorebird distribution and behavior (Ohmart et al. 1985). In California, a number of shorebird species move from intertidal areas to pastures during high tides (Gerstenberg 1979, Page et al. 1979), and some of the habitat features associated with the birds' use of coastal pastures have been described (Colwell and Dodd 1995). Despite the potential importance of cropland as alternate foraging habitat for shorebirds (Ohmart et al. 1985), the use of coastal cropland by foraging shorebirds has not been described. The objectives of this study were (1) to determine the species composition and temporal abundance patterns of shorebirds foraging in coastal cropland on the Eastern

Shore of Virginia, and (2) to determine patterns of cover use by these shorebirds.

STUDY AREA AND METHODS

I conducted this study on the southern tip of the Eastern Shore of Virginia, within an area of approximately of 170 km². The study area is bounded to the east by extensive tidal salt marsh, mud flats, and barrier islands and to the west by narrow sandy beaches (with several tidal creeks) along Chesapeake Bay. Large numbers of shorebirds forage in these tidal areas, especially at low tide when beaches and mudflats are exposed. Previous observations indicated that individuals of some shorebird species moved from these intertidal habitats to agricultural croplands to forage during high tide.

In order to determine the relationship between tidal height and the abundance of certain shorebird species in agricultural fields, I conducted four surveys of a small number of fields in the study area (6–8 fields/survey). The days on which these censuses were conducted, 29 May, 12 and 31 August, and 2 November 1991, were chosen so that the timing of high and low tides varied among surveys. Such variation in the timing of high and low tides allowed me to distinguish possible relationships between shorebird abundance and time of day from relationships between shorebird abundance and tidal height. During these surveys, I visited each field at one- to two-h intervals between dawn and dusk, recording the number of individuals of each species in each field during each round of censuses. All fields were visited the same number of times on a given date, but the number of census rounds varied from seven to nine among different survey dates. I divided the species observed in fields into two groups based on my previous experience with shorebirds in intertidal habitats around the study area and life history information (Stout 1967, Hayman et al. 1986): field specialists, thought to forage primarily in fields and rarely visiting intertidal habitats, and field exploiters, species that regularly forage in intertidal habitats during low tide but occasionally forage in fields during high tide. For each field, the abundance of shorebirds in each of these groups was determined for the censuses conducted closest to the times corresponding to high and low tide at Cape Charles, Virginia (U.S. Department of Commerce 1990). Paired comparisons *t*-tests were used to test the null hypothesis that the abundance of shorebirds in these fields did not differ between high tide and low tide (Sokal and Rohlf 1981).

In order to determine seasonal patterns of shorebird abundance and the use of various cover types by shorebirds foraging in coastal croplands, I conducted thirty censuses of croplands (comprising 4598.8 ha) in the study area from March 1991 through February 1992. For the purpose of determining the relative availability of cover types, I defined a field as a continuous plot with homogeneous cover of bare earth or herbaceous vegetation of the same height class (<10 cm or >10 cm) not divided by a paved road or by woody vegetation. Because high and low tides were separated by approximately 6.0–6.5 h, I began each census 4 h before high tide so that all fields would be surveyed during the highest 2/3 of the tidal cycle. Each census lasted approximately 8 h. To randomize the tide height during my observation of any particular field, I began each census at a location chosen randomly from a pool of 20 points along the census route. Censuses were not conducted if visibility was hampered by fog or precipitation.

During each census, I drove along the census route, stopping at each field to scan for shorebirds. I counted shorebirds from one or more points at the edge of each field using 8.5× binoculars. For larger fields and for fields with taller vegetation, I scanned from several points along the edge of each field, using a 22× spotting scope as necessary. Scanning along rows of vegetation and listening for the birds' calls (given frequently by foraging flocks)

aided in the detection of shorebirds. For large or widely dispersed flocks, I made replicate counts of shorebirds and recorded the mean of the original and replicate counts. Most of the shorebirds observed on croplands were actively foraging, with only a small proportion roosting. Observations made during the four dawn-to-dusk surveys and at other times suggested that very few shorebirds, if any, used these fields for roosting without spending some time foraging. Therefore, all shorebirds recorded during censuses were assumed to be foraging in the fields.

I was able to corroborate the accuracy of counts for cover types of <10 cm vegetation and plowed fields by locating three fields with each of these cover types that contained large flocks of foraging shorebirds, counting the birds from the edge of each field, 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 directly my counts for >10 cm cover, but on one occasion a disturbance in a field of tall vegetation flushed the shorebirds within the field, confirming my previous count.

During each census, I recorded the type and height of cover in each field. I recognized three cover types in these croplands: plowed (bare earth with no vegetation), herbaceous vegetation <10 cm tall, and herbaceous vegetation >10 cm tall. No distinction was made between row crops (which included cotton, soybeans, potatoes, string beans, and several other crops) and mat crops (mostly cereals). Fields with weedy herbaceous vegetation allowed to grow in the interval between the harvest of one crop and seeding of another were also included in this study, although I excluded fields that lay fallow for the entire study period. All crop types reached heights exceeding 10 cm, so vegetation height (<10 cm or >10 cm) was not dependent on crop type. I did not include any pastureland in this study, as very little was present within the study area.

The area of each field was measured with a planimeter from field-checked 7.5-min topographic maps. For each census, I summed the areas of all fields with a particular cover type to determine the total availability of each cover type in the study area. I then determined, for each census, the number of individuals of each shorebird species expected to occur in fields with each cover type if shorebird distribution over the study area were independent of cover type. These numbers were the products of the total number of observed individuals of each species and the proportion of fields having each of the three cover types. I summed the numbers of shorebirds observed and expected on each cover type over all censuses in each season in order to determine the total number of individuals of each species that were observed and expected on each cover type by season. In pooling these numbers by season, I assumed that patterns of cover use did not differ significantly among different censuses within the same season.

For the purposes of this study, I delimited seasons *a posteriori* by examining abundance patterns of species known to occur in coastal Virginia as summer or winter residents or as northbound (spring) or southbound (fall) migrants (Kain 1987). I defined summer as the period from early June until mid-July, during which the only species observed in the study area was a local breeder. Fall lasted from the arrival of the first southbound migrants in late July until the departure of the last southbound transients (i.e., species that do not overwinter in Virginia) from the study area in mid-November. Winter extended from mid-November until late March. Spring began with the first arrival of northbound migrants in early April and ended in late May. Because I observed only two individuals of one locally breeding species during summer, analyses presented here are restricted to fall, winter, and spring. Sampling intensity differed among seasons due to differences in season length; four censuses were conducted during summer, 10 during fall, 11 during winter, and five during spring.

For the species represented by at least 30 individuals during a given season, I used a χ^2 test to test the null hypothesis that shorebird distribution was independent of cover type. I

performed these χ^2 tests separately for each season. In a few cases, the expected number of individuals on both plowed and <10 cm vegetation was less than five; in such cases, the numbers of shorebirds observed and expected were pooled for these cover types, allowing for a valid test (Sokal and Rohlf 1981). Each total χ^2 value was the sum of three "component χ^2 " values, one for each of the three cover types. If the total χ^2 exceeded the critical value (rejecting the null hypothesis), then each "component χ^2 " was examined individually to determine which of the shorebird-cover associations were significant. If a "component χ^2 " for a single cover type was so high that it exceeded the critical χ^2 value required for significance for the entire test, then the association between the species and the cover type in question was deemed significant. This method provided a conservative approach to assessing individual species-cover associations. The nature of each significant association was identified by determining whether the number of individuals observed on a cover type was greater than or less than the number expected on that cover type (indicating a positive or negative association, respectively).

Standard χ^2 tests assume independence of individuals, an assumption that may be violated in species, such as shorebirds, that frequently move in flocks. In this study, I was rarely able to determine the number of independent groups of shorebirds that selected a field for foraging. However, to treat the entire shorebird assemblage in each field as a single unit composed of interdependent individuals may unnecessarily reduce the number of observations available for analysis if, indeed, the shorebirds individually display their own cover preferences. In order to determine whether cover use may have been affected by social interactions, I examined the results of the χ^2 tests a posteriori. If flocking, rather than selection of a desired cover type, had been the primary influence on the birds' choice of fields, I would have expected a preponderance of insignificant, weak, or inconsistent shorebird-cover associations. However, the consistent, strong cover associations observed in this study indicate that social interactions did not mask actual patterns of cover preference or avoidance, supporting the validity of the χ^2 tests as they were conducted. I conducted an analysis of variance (in SYSTAT, Wilkinson 1990) to test the null hypotheses that mean species richness and shorebird abundance per census did not differ among the seasons.

RESULTS

Relationship between shorebird abundance and tidal height.—During the four dawn-to-dusk surveys, those species thought to prefer foraging in intertidal habitats (field exploiters) were most abundant on croplands during the higher portion of the tidal cycle and were scarce or absent during the lower portion (Fig. 1). During these surveys, such species included Semipalmated Plover, Black-bellied Plover, Whimbrel, Willet, Ruddy Turnstone, Semipalmated Sandpiper, Least Sandpiper, and Dunlin (scientific names in Table 1). Abundance of these shorebirds in fields at high tide and low was significantly higher during censuses conducted near high tide on 29 May ($t = 2.670$, $df = 5$, $P < 0.05$), 12 August ($t = 3.940$, $df = 6$, $P < 0.01$), 31 August ($t = 4.255$, $df = 7$, $P < 0.01$), and 2 November ($t = 2.449$, $df = 6$, $P < 0.05$). According to Fig. 1, relatively few field exploiters were present on censuses conducted more than two hours preceding or following high tide, although peak abundance did not always coincide with the census conducted nearest high tide (e.g., 29 May). Peak shorebird abundance occurred at different times during the

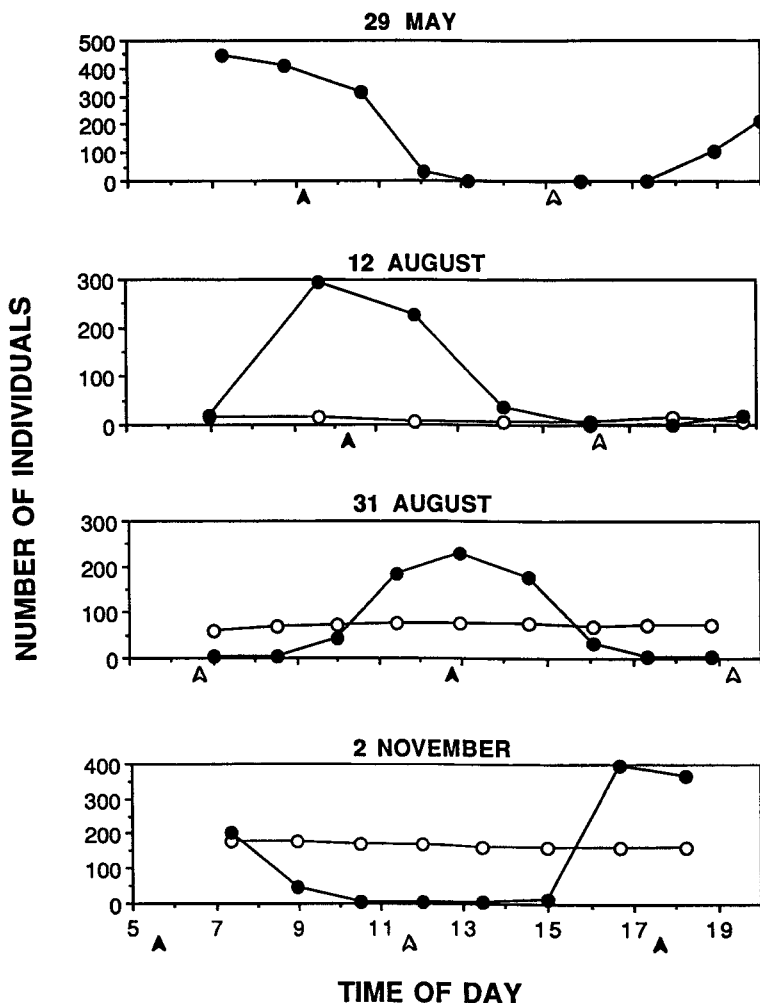


FIG. 1. Plots of shorebird abundance vs time of day. Solid circles represent individuals of "field exploiter" species, while open circles represent "field specialist" species (see "Methods" for descriptions of these two groups). Labels on the lower axis indicate hours after midnight. Solid and open arrows along the lower axis signify the times of high and low tides, respectively.

different surveys, indicating that these dynamics were related to tidal height and not time of day.

In contrast, the abundance of species thought to forage almost exclusively in fields (field specialists), including Killdeer, American Golden-

TABLE 1
ABUNDANCE OF SHOREBIRDS FORAGING IN AGRICULTURAL FIELDS BY SPECIES AND SEASON

Species	No. of censuses	No. of individuals	Percent of total	No. of individuals/season		
				Spring (N = 5) ^a	Fall (N = 10)	Winter (N = 11)
Black-bellied Plover (<i>Pluvialis squatarola</i>)	20	7982	37.6	4664	2033	1285
Dunlin (<i>Calidris alpina</i>)	15	6911	32.5	3252	959	2700
Semipalmated Plover (<i>Charadrius semipalmatus</i>)	14	4121	19.5	2822	1299	0
Killdeer (<i>C. vociferus</i>)	18	1039	4.9	1	869	169
Semipalmated Sandpiper (<i>Calidris pusilla</i>)	8	560	2.6	502	58	0
Short-billed Dowitcher (<i>Limnodromus griseus</i>)	9	233	1.1	138	53	42
Pectoral Sandpiper (<i>Calidris melanotos</i>)	6	90	0.4	0	90	0
Willet (<i>Catoptrophorus semipalmatus</i>)	6	68	0.3	68	0	0
Ruddy Turnstone (<i>Arenaria interpres</i>)	6	64	0.3	51	13	0
American Golden-Plover (<i>Pluvialis dominica</i>)	9	57	0.3	0	57	0
Western Sandpiper (<i>Calidris mauri</i>)	6	37	0.2	0	34	3
Buff-breasted Sandpiper (<i>Tryngites subruficollis</i>)	4	31	0.1	0	31	0
Upland Sandpiper (<i>Barramania longicauda</i>)	4	32	0.1	0	32	0
Lesser Yellowlegs (<i>Tringa flavipes</i>)	1	11	0.1	0	11	0
Greater Yellowlegs (<i>T. melanoleuca</i>)	3	4	0.0	2	2	0
Whimbrel (<i>Numenius phaeopus</i>)	2	4	0.0	0	4	0
Least Sandpiper (<i>Calidris minutilla</i>)	3	4	0.0	0	4	0
Solitary Sandpiper (<i>T. solitaria</i>)	1	1	0.0	0	1	0
Red Knot (<i>C. canutus</i>)	1	1	0.0	1	0	0
Baird's Sandpiper (<i>C. bairdii</i>)	1	1	0.0	0	1	0
Common Snipe (<i>Gallinago gallinago</i>)	1	1	0.0	0	0	1
TOTAL	N = 30	21,252	100.0	11,501	5551	4200

^a N values following season names indicate the number of censuses conducted during each season.

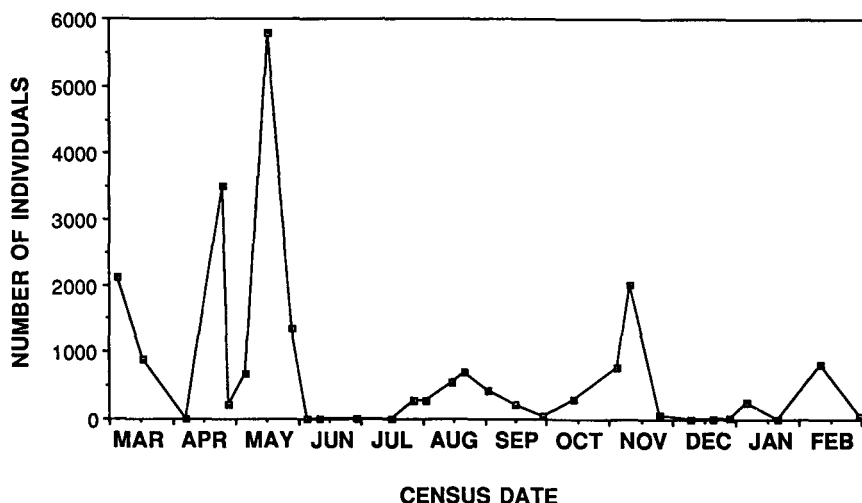


FIG. 2. Number of individual shorebirds foraging in agricultural fields during each census (Mar. 1991–Feb. 1992).

Plover, Upland Sandpiper, and Buff-breasted Sandpiper, fluctuated little during each of the four dawn-to-dusk surveys (Fig. 1). There were no significant differences in the abundance of these species in fields between high and low tides on 12 August ($t = 1.016$, $df = 6$, $P > 0.05$), 31 August ($t = 0.429$, $df = 7$, $P > 0.05$), and 2 November ($t = 1.000$, $df = 6$, $P > 0.05$). None of these species was observed during the 29 May survey.

Species composition and seasonal abundance patterns.—During the study of seasonal abundance patterns and cover use, I recorded a total of 21,254 individuals of 21 species of shorebirds foraging on croplands (Table 1). Shorebirds were observed foraging in agricultural fields on 24 of 30 censuses; no shorebirds were observed on two censuses in June and one each in April, July, January, and February. Only two individuals of one species (Willet) were observed during the four censuses in summer. Total shorebird species richness reached a peak of 18 species in fall, compared to 10 in spring and six in winter. This pattern also held for the mean number of species/census, being highest in fall ($\bar{x} = 8.4 \pm 6.9$ [SD]), intermediate in spring ($\bar{x} = 6.2 \pm 2.7$), and lowest in winter ($\bar{x} = 2.0 \pm 3.0$). In contrast, mean abundance/census was highest during spring ($\bar{x} = 2300.2 \pm 2320.8$ individuals/census) and lower in fall ($\bar{x} = 555.1 \pm 536.1$) and winter ($\bar{x} = 381.8 \pm 663.7$). ANOVAs confirmed that mean species richness/census ($F = 24.5$, $P < 0.001$) and mean shorebird abundance/census ($F = 4.83$, $P < 0.02$) did differ among seasons. In addition,

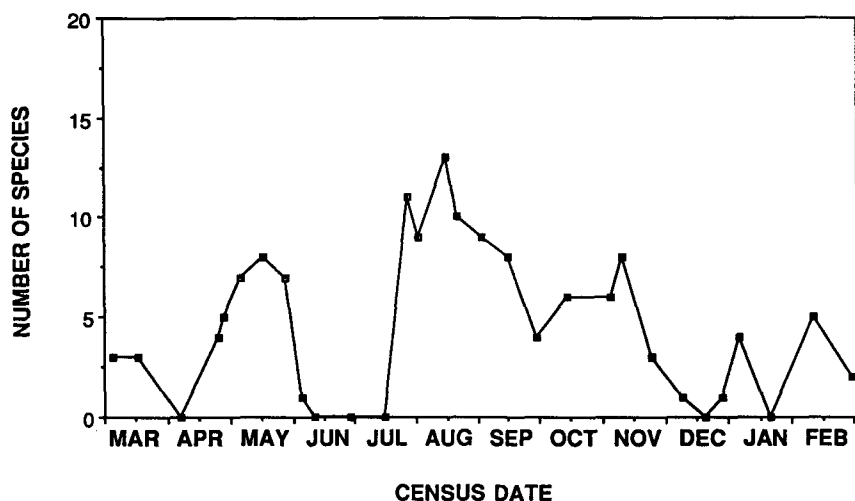


FIG. 3. Number of shorebird species foraging in agricultural fields during each census (Mar. 1991–Feb. 1992).

there was substantial variation in shorebird species richness and abundance within seasons as well.

The four species which were recorded on the most censuses (Black-bellied Plover, Killdeer, Semipalmated Plover, and Dunlin) were also the most abundant species, accounting for 94.3% of all the individuals observed. Most species were represented by relatively few individuals. Only 11 species were observed on more than four censuses, and only six species were represented by more than 90 individuals.

Whereas most species foraged in agricultural fields in only one or two seasons, Black-bellied Plover, Killdeer, Dunlin, and Short-billed Dowitcher were present during spring, fall, and winter. There were no species recorded year-round, as the only species present during summer (Willet) was not recorded in fall or winter. Of the remaining eight species represented by at least 30 individuals, four occurred strictly as fall transients (Pectoral Sandpiper, American Golden-Plover, Buff-breasted Sandpiper, and Upland Sandpiper), three were present only as spring and fall transients (Semipalmated Plover, Semipalmated Sandpiper, and Ruddy Turnstone), and one was present only during fall and winter (Western Sandpiper).

Because few of the fields were irrigated and rainfall was generally lower than average during the study period (U.S. Dept. of Commerce 1991), standing water was rarely present in the fields. As a result, species that require open water, such as Greater Yellowlegs, Lesser Yellowlegs,

and Solitary Sandpiper, were poorly represented on surveys. All other shorebirds usually foraged on relatively dry substrates, quite different from the saturated intertidal habitats with which the "field exploiter" species are more commonly associated.

Cover use.—A total of 19 species foraged on plowed fields, 17 species on fields with <10 cm cover, and seven species on fields with >10 cm cover. Although the number of species recorded on plowed fields was only slightly higher than the number on fields with <10 cm cover, far more individuals were observed foraging on plowed fields than on the other cover types. A total of 17,714 shorebirds, or 83.3% of all birds recorded during the study, foraged on plowed fields. In contrast, 3432 individuals (16.2% of total) foraged on fields with <10 cm vegetation and 108 birds (0.5% of total) on fields with >10 cm vegetation.

Of the species sufficiently numerous for analysis, all consistently showed highly significant positive associations with plowed fields and negative associations with fields with >10 cm cover except for Willet in spring and Upland Sandpiper in fall (Table 2). No species seemed actively to avoid plowed fields, and none was shown to prefer fields with >10 cm cover. The data for fields with <10 cm cover suggest that use of this cover type varied not only among species but also among seasons within a species. The proportion of species analyzed for cover use that showed positive associations with fields of <10 cm cover decreased from 0.71 in spring to 0.09 in fall and to 0.00 in winter. Conversely, the proportion of species negatively associated with fields of <10 cm cover increased from 0.14 in spring to 0.45 in fall and 1.00 in winter. For no species was the association with fields of <10 cm cover consistent among all seasons.

DISCUSSION

Agricultural fields on Virginia's Eastern Shore seem to be important foraging areas for migrating and overwintering shorebirds. A few species, such as Killdeer, American Golden-Plover, Upland Sandpiper, and Buff-breasted Sandpiper, are known to prefer such habitats to intertidal areas (Stout 1967, Hayman et al. 1986). These field specialists were never seen moving from fields to intertidal areas, and their numbers did not seem to vary with tidal height. Most of the species observed in this study, however, are known to prefer intertidal habitats when they are available. These field exploiters use fields as alternate foraging sites when mudflats and beaches are inundated by high water (Goss-Custard 1969, Page and Whittacre 1975, Gerstenberg 1979, Page et al. 1979).

Data from the four dawn-to-dusk surveys indicated that the abundance of field exploiters on cropland was high only within approximately two hours of high tide. Therefore, the surveys conducted to determine sea-

TABLE 2
COVER ASSOCIATIONS OF SHOREBIRDS FORAGING IN AGRICULTURAL FIELDS

Species	Total ob- served	No. observed/expected on each cover type ^a					
		Plowed	<10 cm		>10 cm		
Spring							
Black-bellied Plover	4664	3271/1323.1	++	1383/ 415.7	++	10/2925.2	--
Semipalmated Plover	2822	2439/ 694.2	++	233/ 209.4	ns	0/1918.4	--
Willet	68	19/ 16.8	ns	27/ 7.9	++	22/ 43.3	-
Ruddy Turnstone	51	38/ 10.0	++	13/ 4.7	++	0/ 36.3	--
Semipalmated Sandpiper	502	483/ 108.7	++	19/ 43.2	--	0/ 350.1	--
Dunlin	3252	2596/1150.3	++	656/ 313.2	++	0/1788.5	--
Short-billed Dowitcher	138	108/ 45.1	++	30/ 12.1	++	0/ 80.8	--
Fall							
Black-bellied Plover	2033	1970/ 527.2	++	61/ 388.6	--	2/1117.2	--
American Golden-Plover	57	50/ 8.7	++	4/ 4.3	ns	3/ 44.0	--
Semipalmated Plover	1299	1122/ 246.1	++	132/ 97.4	+	45/ 955.2	--
Killdeer	869	829/ 242.8	++	38/ 177.7	--	2/ 448.5	--
Upland Sandpiper ^b	32	7/ 5.2	ns	4/ 2.5		21/ 24.3	ns
Semipalmated Sandpiper	58	58/ 8.3	++	0/ 4.6	ns	0/ 37.2	--
Western Sandpiper	34	33/ 9.1	++	1/ 5.2	ns	0/ 19.6	--
Pectoral Sandpiper	90	89/ 15.4	++	0/ 5.9	-	1/ 68.7	--
Dunlin	959	959/ 300.8	++	0/ 262.6	--	0/ 395.6	--
Short-billed Dowitcher	53	53/ 16.1	++	0/ 11.8	-	0/ 24.1	--
Buff-breasted Sandpiper ^b	31	28/ 4.2	++	3/ 2.0		0/ 24.8	--
Winter							
Black-bellied Plover	1285	1012/ 287.8	++	273/ 755.5	--	0/ 241.7	--
Killdeer	169	145/ 28.8	++	24/ 103.4	--	0/ 36.8	--
Dunlin	2700	2177/ 577.5	++	523/1679.7	--	0/ 442.8	--
Short-billed Dowitcher	42	42/ 7.1	++	0/ 22.4	--	0/ 12.5	--

^a ns, $P > 0.05$; + and ++, significant positive associations ($P < 0.05$, $P < 0.001$ respectively), - and --, significant negative associations ($P < 0.05$, $P < 0.001$ respectively).

^b For these species, observed and expected numbers were pooled for plowed fields and fields with <10 cm to achieve expected values sufficiently high for testing.

sonal abundance and cover use patterns probably underestimated the use of croplands by field exploiters, as roughly half of the fields in each survey were visited 2–4 h preceding or following high tide. Because there was no apparent relationship between the times at which fields were visited and the cover types present in fields, this observation should have no effect on analyses of cover use.

Shorebird abundance in agricultural fields showed substantial variation among censuses. Fluctuations in abundance within (rather than among) seasons may have reflected differences in tidal height during the census periods. More shorebirds may have foraged in fields during higher peak

tides, when intertidal habitats were inundated for long periods, than during periods when high tide levels failed to inundate intertidal flats completely. In addition, variation in shorebird abundance within seasons may have been magnified by pulses of migration or regional movements that augmented or reduced shorebird abundance within the study area.

More individuals foraged in fields during spring migration than in any other season. This result may simply reflect larger numbers of birds passing through the study area in the shorter period of spring migration than during the more protracted fall migration. The compressed spring movement may also increase the shorebirds' need for rapid energy intake at staging areas (Pitelka 1979). If shorebirds benefit energetically from agricultural fields during high tide, then they should forage in fields during those periods when rapid energy intake is most critical (e.g., spring migration).

Agricultural fields were used by few species during winter, but of those present, most foraged in fields in high numbers. Because the threat of starvation to shorebirds may be quite high during winter (Goss-Custard 1979), alternate foraging areas such as coastal agricultural fields may enhance the chances of survival of overwintering shorebirds.

The type and structure of cover on which shorebirds forage may influence both predation risk and foraging efficiency. Despite the abundance of avian predators in the study area during winter, spring, and especially fall (pers. obs., Sutton 1992), most of the shorebird species in this study showed an overwhelming preference for plowed fields while avoiding dense vegetation.

Nearly all of the shorebirds observed were foraging in flocks, reducing the risk of depredation for any one individual during a predation attempt (Page and Whitacre 1975). Thus, flocking may have allowed the birds to forage relatively safely on plowed fields as they do on open mudflats and beaches. Flocking may also enhance foraging efficiency by allowing birds to share vigilance (Powell 1974, Metcalfe 1989). Sharing vigilance reduces the time that any one individual must spend looking for predators, thus increasing foraging time. Because vigilance sharing requires close contact among individuals and is inhibited in tall cover (Metcalfe 1984), vigilance sharing may not have been as profitable on vegetated fields as on plowed fields.

Foraging in plowed fields may also have been more efficient than on fields with >10 cm vegetation due to problems associated with foraging in dense vegetation. Because taller or more dense vegetation is thought to reduce the search area available to visual hunters, such as plovers (Fuller and Youngman 1979), or to inhibit locomotion and prey extraction, foraging on plowed fields may have been more efficient than on

fields with >10 cm vegetation. On fields with <10 cm cover, vegetation may not have been thick enough to impede efficient foraging in those species exhibiting positive associations with this cover type. Wind, extreme temperatures, and drought have been shown to reduce prey availability to a greater extent on bare earth than on vegetated cover (Burton 1974, Murton and Westwood 1974, Evans 1976, Shrubbs 1988). However, given the year-round preference for plowed fields shown by most of the species in this study, these factors (and their seasonal variation) seem to have had little effect on the birds' preference for this cover type.

Although associations between most shorebird species and fields of bare earth or >10 cm vegetation were consistent among seasons, the use of fields with <10 cm cover showed substantial seasonal variation. Most significant associations with this cover type were positive in spring but negative in fall and winter. It is possible that the large numbers of shorebirds present in spring and the need to obtain energy rapidly during that season forced some shorebirds to forage on non-preferred cover types (e.g., <10 cm vegetation). Alternately, prey densities on these agricultural croplands may have been higher in spring than in other seasons, allowing efficient foraging on both plowed fields and fields with <10 cm cover during spring.

Because the periods of spring and fall migration require long-distance migrants to accumulate large energy reserves (Davidson 1984, Myers et al. 1987), and the threat of starvation to wintering shorebirds may be high (Goss-Custard 1979), coastal agricultural croplands may be important foraging areas for shorebirds during these periods. Where croplands are present near important shorebird staging areas, field management for foraging shorebirds may increase the value of the overall staging areas to these birds. Based on the results of this study, management regimes that provide an ample supply of plowed fields during periods of peak shorebird abundance might be most beneficial to shorebirds. Further research on the effects of field size, shape, or proximity to intertidal areas and of agricultural practices (e.g., plowing vs no-till farming, pesticide use, and timing of plowing and crop rotation) on shorebird abundance may facilitate the management of coastal agricultural lands for use by nonbreeding shorebirds.

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LITERATURE CITED

- ATKINSON, J. M. S. 1976. Inland wintering and urban roosting by redshanks. *Bird Study* 23:51-55.
- BARNARD, C. J. AND D. B. A. THOMPSON. 1985. *Gulls and plovers*. Columbia Univ. Press, New York, New York.
- BURGER, J., M. A. HOWE, D. C. HAHN, AND J. CHASE. 1977. Effects of tide cycles on habitat selection and habitat partitioning by migrating shorebirds. *Auk* 94:743-758.
- BURTON, P. J. K. 1974. Feeding and the feeding apparatus in waders. *British Museum of Natural History, London, U.K.*
- COLWELL, M. A. AND S. L. DODD. 1995. Waterbird communities and habitat relationships in coastal pastures of northern California. *Cons. Biol.* 9:827-834.
- CONNORS, P. G., J. P. MYERS, C. S. W. CONNORS, AND F. A. PITELKA. 1981. Interhabitat movements by Sanderlings in relation to foraging profitability and the tidal cycle. *Auk* 98:49-64.
- DAVIDSON, N. C. 1984. Identification of refueling sites by studies of weight changes and fat deposition. Pp. 68-78 in *Shorebirds and large waterbirds conservation* (P. R. Evans, H. Hafner, and P. L'Hermite, eds.). Commission of the European Communities.
- EVANS, P. R. 1976. Energy balance and optimal foraging strategies in shorebirds: some implications for their distributions and movements in the non-breeding season. *Ardea* 64:117-39.
- FULLER, R. J. AND R. E. YOUNGMAN. 1979. The utilisation of farmland by golden plovers wintering in southern England. *Bird Study* 26:37-46.
- GERSTENBERG, R. H. 1979. Habitat utilization by wintering and migrating shorebirds on Humboldt Bay, California. Pp. 33-40 in *Shorebirds in marine environments* (F. A. Pitelka, ed.). Allen Press Inc., Lawrence, Kansas.
- GOSS-CUSTARD, J. D. 1969. The winter feeding ecology of the redshank *Tringa totanus*. *Ibis* 111:338-356.
- . 1979. Effect of habitat loss on the numbers of overwintering shorebirds. Pp. 167-177 in *Shorebirds in marine environments* (F. A. Pitelka, ed.). Allen Press Inc., Lawrence, Kansas.
- HAYMAN, P., J. MARCHANT, AND T. PRATER. 1986. *Shorebirds: an identification guide to the waders of the world*. Houghton-Mifflin Company, Boston, Massachusetts.
- KAIN, T. 1987. Virginia's birdlife. Virginia Society of Ornithology, Virginia Avifauna No. 3.
- METCALFE, N. B. 1984. The effects of habitat on the vigilance of shorebirds: is visibility important? *Anim. Behav.* 32:981-985.
- . 1989. Flocking preferences in relation to vigilance benefits and aggression costs in mixed-species shorebird flocks. *Oikos* 56:91-98.
- MILSON, T. P., R. S. HOLDITCH, AND J. B. A. ROCHARD. 1985. Diurnal use of an airfield and adjacent agricultural habitats by Lapwings *Vanellus vanellus*. *J. Appl. Ecol.* 22:313-326.
- MURTON, R. K. AND N. J. WESTWOOD. 1974. Some effects of agricultural change on the English avifauna. *Brit. Birds* 67:41-67.
- MYERS, J. P., R. I. G. MORRISON, P. Z. ANTAS, B. A. HARRINGTON, T. E. LOVEJOY, M. SALLABERRY, S. E. SENNER, AND A. TARAK. 1987. Conservation strategy for migratory species. *Am. Sci.* 75:19-26.
- OHMART, R. D., B. W. ANDERSON, AND W. C. HUNTER. 1985. The influence of agriculture on waterbird, wader, and shorebird use along the lower Colorado River. Pp. 117-122 in *Riparian ecosystem and their management: reconciling conflicting uses* (R. R. John-

- son, C. D. Ziebell, D. R. Patton, B. F. Ffolliott, and R. H. Hamre, eds.). USDA For. Serv. Gen. Tech. Rep. RM-120.
- PAGE, G., L. E. STENZEL, AND C. M. WOLFE. 1979. Aspects of the occurrence of shorebirds on a central California estuary. Pp. 15–32 in *Shorebirds in marine environments* (F. A. Pitelka, ed.). Allen Press Inc., Lawrence, Kansas.
- AND D. F. WHITACRE. 1975. Raptor predation on wintering shorebirds. *Condor* 77: 73–83.
- PITELKA, F. A. 1979. Introduction: the Pacific Coast shorebird scene. Pp. 1–11 in *Shorebirds in marine environments* (F. A. Pitelka, ed.). Allen Press Inc., Lawrence, Kansas.
- POWELL, G. V. N. 1974. Experimental analysis of the social value of flocking by starlings (*Sturnus vulgaris*) in relation to predation and foraging. *Anim. Behav.* 22:501–505.
- SHRUBB, M. 1988. The influence of crop rotations and field size on a wintering lapwing *V. vanellus* population in an area of mixed farmland in West Sussex. *Bird Study* 35:123–31.
- SOKAL, R. R. AND F. J. ROHLF. 1981. *Biometry* (second edition). W. H. Freeman and Company, New York.
- STOUT, G. D. 1967. *The shorebirds of North America*. Viking Press, New York.
- U.S. DEPT. OF COMMERCE. 1990. Tide tables 1991—high and low water predictions, east coast of North and South America. National Oceanic and Atmospheric Administration, Washington, D.C.
- . 1991. Climatological data: Virginia. National Oceanic and Atmospheric Administration, Washington, D.C.
- WILKINSON, L. 1990. SYSTAT: the system for statistics. SYSTAT, Inc., Evanston, Illinois.