Monthly Abundance and Seasonal Spatial Distribution of Shorebirds in Cape Romain National Wildlife Refuge, South Carolina

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Introduction

Shorebirds are declining globally, including in the western hemisphere (Brown 2001, Morrison et al. 2001, Morrison et al. 2006, Bart et al. 2007, Andres 2009). Knowing shorebird numbers and trends is essential to identifying high priority species, identifying important conservation areas, and designing management programs (Brown et al. 2001). However, there is a paucity of shorebird abundance data, which is an obstacle to prioritizing conservation efforts (Brown et al. 2001, Andres 2009, Clay et al. 2010). Specifically, more information is needed on shorebird numbers at staging, migration, and wintering areas. At these nonbreeding sites shorebirds gather in dense groups during high tides, which provide easier surveying opportunity and thus more accurate population estimates than breeding surveys (Howe 1989).

Repeated surveys of shorebirds at nonbreeding sites also provide temporal and spatial data which can be used to identify habitat characteristics of roost sites such as proximity to foraging grounds and predation risks (Catlin et al. 2005, Rogers et al. 2006). These data can also guide management and restoration of habitats for the shorebird assemblage or for individual high priority species (Weber and Haig 1996, Farmer and Parent 1997, Saalfeld et al. 2011, Meager et al. 2012). For example, changes in distribution over time may indicate a change in habitat that warrants attention from managers (Ledee et al. 2008, Muir and Colwell 2010).

Previous studies by Marsh and Wilkinson (1991) and Dodd and Spinks (2001) identified the entire Cape Romain Region, which includes the Cape Romain National Wildlife Refuge (CRNWR) and adjacent private and state properties, as an important area for migrating and wintering shorebirds. Marsh and Wilkinson (1991) found that, at the time, the Cape Romain Region had 30% of the estimated American Oystercatcher (*Haematopus palliatus*) and Marbled Godwit (*Limosa fedoa*) populations during both spring and fall migrations. In addition, the site had 15% of migrating Short-billed Dowitcher (*Limnodromus griseus*), Dunlin (*Calidris alpina*), Willet (*Tringa semipalmata*), Whimbrel (*Numenius phaeopus*), Wilson's Plover

(*Charadrius wilsonia*), and Semipalmated Plover (*Charadrius semipalmatus*) populations, which led to the designation as a site of Hemispheric Importance in the Western Hemisphere Shorebird Reserve Network, a network of critical shorebird habitats in the Western Hemisphere (Myers et al. 1987 and Bildstein et al. 1991).

Although the importance of CRNWR has been established in previous studies, shorebird abundance for most of CRNWR has not been published since 2001, and previous studies did not include thorough surveys of the barrier island beaches. Additionally, this project is the first time high density areas have been identified, which is important to local conservation efforts.

Methods

Study Area

CRNWR encompasses 26,817 ha along 35 km of the South Carolina coast, centered at (33° 00' N, 79° 30' W). It is bordered by but does not include the Atlantic Intracoastal Waterway (AICW) to the west, and to the north and south by undeveloped islands managed by the South Carolina Department of Natural Resources (Fig. 1). CRNWR is composed of 75% tidal wetlands dominated by Smooth Cordgrass (*Spartina alterniflora*, USFWS 2010). These wetlands have numerous shallow bays and creeks, with Eastern Oyster (*Crassostrea virginica*) reefs. The majority of these creeks empty into Bulls Bay and Cape Romain Harbor.

Bulls Bay is a shallow, sandy and muddy expanse which opens directly to the Atlantic Ocean. The bay is fringed in many areas adjacent to marsh by shell rakes, exposed deposits of washed oyster shells. Bulls Bay contains two main land masses, White Banks, a collection of three shell rake islands, and Marsh Island, a small horseshoe shaped beach with interior marsh. Cape Romain Harbor, also has fringing oyster rakes along marsh edges, and is protected from the ocean by two long, sandy islands: Cape and Lighthouse Islands. South of Lighthouse Island and north of Bulls Bay is Raccoon Key, which is currently cut by two small creeks. A small island Sandy Point, which was once the southern tip of Raccoon Key, was isolated from Raccoon Key by Five Fathom Creek. To the south of Bulls Bay, Bulls Island extends to the southern boundary of CRNWR Refuge at Price Inlet, and is the largest island in CRNWR. Although Bulls Island has 12 km of beach, the majority of the shoreline has eroded into the maritime forest, leaving standing oak, cedar, pines and palms on the beach, preventing shorebird roosting except on the ends of the island.

Survey sites included all habitat described above but did not include all shorebird roosting sites in CRNWR. Some shell rakes along bays and creeks and most of Bulls Island, including ideal roosting habitat on the north end

and all of the south end, were not included. Only the north tip of Bulls Island was surveyed. Larger islands were divided into regions. Raccoon Key was divided into three sites: south, middle, and north. These were delineated at 33° 00' 59" N, 79° 25' 21" W and 33° 00' 44" N, 79° 27' 33"W. Sandy Point was delineated from Raccoon Key at 33° 00' 27" N, 79° 28' 23" W. Lighthouse Island was divided into four sites: south, a washover area, middle, and north. These were delineated at 33° 00' 28" N, 79° 24' 57" W, 33° 00' 27" N, 79° 24' 37" W and 33° 00' 33" N, 79° 22' 18" W. Cape Island was divided into three sites: south, middle, and north. These were separated at 33° 01' 00" N, 79° 21' 35" W and 33° 04' 11" N, 79° 20' 09" W.

Censuses

Monthly censuses of all shorebirds were completed by a single observer, Mary-Catherine Martin, between November 2007 and October 2010 along the islands and bays of CRNWR (Fig. 1). Because of the extent of the survey area, censuses were completed over 3 consecutive days coinciding with spring high tides (see Marsh and Wilkinson 1991 for additional methods). All censuses were completed within 2 hours before and after high tide when birds were concentrated in roosting areas and less likely to be foraging (Prater 1981). Censuses of Cape and Lighthouse Islands were done from an ATV and by walking. Raccoon Key, Marsh Island, White Banks, and north end of Bulls Island were done by walking and all other areas were censused from a boat. Shorebirds were observed and counted ahead of the observer using a spotting scope unless the survey was from a boat when binoculars were used. Attempts were made not to recount flushed birds. It was assumed that birds were not recounted on consecutive days within the same month. A handheld GPS unit was used to record locations of all shorebirds.

Data analysis

Data collected in surveys were used to determine monthly abundance and seasonal spatial distribution for the most abundant species and Wilson's Plover and Piping Plover (*Charadrius melodus*), which are high priority species. Seasonal spatial analysis was completed using the Kernel Density Estimation (KDE) tool in ArcGIS version 9.3 (ERSI, Redlands, California). The KDE tool was used to determine seasonal hotspots, or where highest shorebird densities occurred during spring migration (March through July), fall migration (August through October) and winter (November through February) for each year and for all years combined. All search radii were set to 600m, and density outputs were set as individuals per square km. For each dataset KDE 1° and 2° hotspots were identified if the location had a density value in the top 20th % or 40th to 21st % respectively. To assess seasonal

distribution across years, 3 KDE outputs for each of the 3 seasons (years 1, 2 and 3) were normalized and summed using raster math available in ArcGIS version 9.3 (ERSI, Redlands, California). Each input season was reclassified into 10 equal interval categories within each dataset; each category was then scored 10 through 1in descending order. Summing the 3 KDE outputs for each season required a 2 step application of the Plus tool available in the Spatial Analyst Extension of ArcGIS 9.3.

Results

A total of 109 surveys were conducted and 216,418 shorebirds and 23 species were counted. The highest yearly total shorebird count was 93,177 during year 3 from November 2009 to October 2010 (Table 1). February had the most shorebirds (Fig. 2) with the highest monthly count in February 2009 of 18,262 birds (Table 2).

For each of the 9 survey seasons, between 1 and 3 locations were identified as 1° hotspots for the total shorebird assemblage (Tables 3-5). South Raccoon Key was a 1° hotspot for the total assemblage for 2 fall and spring seasons, and 1 winter season.

Dunlin was the most abundant species comprising 52.0% of yearly total counts (Table 1), and a maximum monthly count in February 2009 of 15,842 (Table 2). Dunlin were absent from CRNWR from June to September (Fig 2). South Raccoon Key was the only 1° hotspot for Dunlin during all spring seasons; 1° hotspots in fall and winter seasons were different each year (Tables 3-5). Short-billed Dowitcher was the second most observed species, accounting for 9.0% of total shorebird abundance. The highest density of Dowitchers were observed during winter seasons at Middle Raccoon Key each year, with additional 1° hotspots at North Bulls Island and the Washover area of Lighthouse Island during winters 1 and 3 respectively (Table 5). Spring and fall densities were highest at Marsh Island (Tables 3 and 4). American Oystercatcher was the third most common species and averaged 5233 per year (Table 1), the peak monthly abundance of 776 was in September of year 3 (Table 2). Mean highest counts were in September and lowest in July (Fig. 2). Densities were highest each season on 1 or more White Banks islands, additional 1° hotspots included South Lighthouse Island during winter seasons, and Marsh Island in spring (Tables 3-5).

Red Knots (*Calidris canutus*) were the nineth most common species observed and the highest counts occurred during May and August (Fig. 3). The peak count of 1185 individuals was observed in August of year 2, with a high spring migration count of 1156 occurring in May of year 3 (Fig. 2). The highest density for spring was observed at Marsh Island and fall at South Raccoon Key and (Tables 3 and 4).

Discussion

In South Carolina, no monthly shorebird censuses have been published from areas outside of the Cape Romain Region and few in adjacent states. Surveys of the North Carolina Outer Banks found Sanderling (*Calidris alba*), Red Knot, and Willet to be the most abundant species, with no species overwintering in large numbers (Dinsmore 1998). It is difficult to compare this study to other surveys in the Cape Romain Region because the survey area was different. Cubie et al. (2012) focused on the impoundments on Bulls Island and the beach front on the north end of Bulls Island. Marsh and Wilkinson (1991) and Dodd and Spinks (2001) surveyed limited beachfront, and included areas outside CRNWR, including the adjacent AICW. The AICW is an important shorebird roosting site. For example, Dodd and Spinks (2001 unpublished data) found similar numbers of shorebirds on the AICW as were on beachfronts; as many as 20,000 shorebirds on the AICW in Cape Romain Region in the winter. Sanders et al. (2004) and Brown et al. (2005) found approximately 2000 oystercatchers in the Cape Romain Region, of which 1400 were on the AICW. High tide surveys of CRNWR under represent shorebird use of CRNWR because many shorebirds roosting on the AICW forage in CRNWR (Hand 2010). If possible the AICW adjacent to CRNWR should be surveyed for a more thorough understanding of shorebird use of the area and for better comparisons with previous studies.

Dunlin accounted for over half of all shorebirds counted with a peak count of nearly 16,000, representing 7% of the estimated population of C. a. *hudsonia* of 225,000 (Morrison et al. 2006). Similarly Dunlin was the most abundant species in other studies in Cape Romain Region (Marsh and Wilkinson 1991, Dodd and Spinks 2001, Cubie et al. 2012). Wetlands in the Southern Atlantic Coast have substantial wintering numbers, however there is a lack of published data (Fernandez et al. 2010). Fernandez et al. (2010) examined International Shorebird Survey data and identified only 3 locations which had over 2000 wintering Dunlin in the United States. Only Laguna Madre, along the Texas/Mexico border had more wintering birds (52,000) than this study (Fernandez et al. 2010). Although not included in Fernandez et al. (2010), Georgia Midwinter Waterbird Surveys conducted in mid-January in 1999, 2002, 2004 and 2005 found flocks of nearly 6,000 birds distributed across the state's barrier islands, with statewide counts as high as 32,016 in 2002, 26,455 in 2004, and 16,051 in 2005 (Georgia Department of Natural Resources 2005). In the 1990s, Dinsmore et al. (1998) reported few Dunlin on the Outer Banks of North Carolina during migration and wintering months, with a high count of only 196 in November. The Florida Game and Freshwater Fish Commission estimated less than 7,000 Dunlin wintering in the state (Sprandel et al. 2000, Sprandel et al. 1997). Although widespread surveys are needed to understand wintering Dunlin distribution, it appears South Carolina

and Georgia are more important than other states in the Southeast United States.

Little is known about the status of many North American shorebirds and for those species which trend data is available, 88% are declining (Andres 2009, Brown et al. 2001). Seven of the ten most abundance species observed in this study are thought to be declining ((Dunlin, Short-billed Dowitcher, Western Sandpiper (*Calidris mauri*) Sanderling, Black-bellied Plover (*Pluvialis squatarola*) Red Knot, and Willet, Morrison et al. 2006)). CRNWR is also important for federally listed species and includes two critical habitat units for Piping Plover (SC-7 and SC-8) (US Fish and Wildlife Service 2001). Units include the beaches of Lighthouse Island, and North and Middle Raccoon Key, as well as the south end of Bulls Island, which was not included in these surveys. The areas identified as critical habitat and included in these surveys contained all Piping Plover hotspots identified in this study, with the exception of an additional 1° hotspot site at north Bulls Island during spring years one and two. This area had 37% (13) of Piping Plovers seen during those two seasons combined and should be included in future critical habitat designation. The population of the Red Knot subspecies C. c. *rufa* is estimated to be 20,000 and was listed as a threatened species on December 5, 2014 (US Fish and Wildlife Service 2014). Although low numbers winter in CRNWR, the Refuge is used by Red Knots on south and north bound migrations.

Shorebird numbers in this study may under represent the number of migrating birds which utilize the CRNWR as a stopover area. Residency times at stopover sites may be less than 30 days for individuals and flocks (Battley et al. 2005). Lyons and Haig (1995) found most Semipalmated Sandpipers (*Calidris pusilla*) stayed less than 11 days in South Carolina. Western Sandpipers at stopover sites along the Pacific Flyway stayed less than 10 days (Warnock and Bishop 1998). Because censuses were only conducted once a month, it is likely surveys missed flocks passing through CRNWR between counts and counts represent minimum numbers within the survey area.

The kernel density estimation method identified the spatial variability of each species during each season at a resolution not previously available. In doing so, important areas were identified for individual species, such as the South Lighthouse Island which had high American oystercatcher winter density or for supporting large numbers of the entire shorebird assemblage, such as Middle Raccoon Key. This distribution information creates opportunity for species oriented seasonal management. Numerous initiatives (e.g. Brown et al. 2001, USFWS 2010) highlight the need to identify roost sites as a primary step towards conservation, followed by management actions designed to limit disturbance. The effects of boat, human and pet disturbances at roosting and foraging sites are well documented and have been found to cause increased parental vigilance, increased flushing from nests, and decreased chick survival (Burger 1991, Lafferty 2001, Rodgers and Schwikert 2002).

Management actions may include total restriction of human activities, a method currently employed at the CRNWR, or conditional restrictions, such as tide based closures as suggested by Harrington (2003) and the Cape Romain Comprehensive Conservation Plan (USFWS 2010). Sandy Point was lost in the summer of 2009 after at least 10 years of erosion. The loss of Sandy Point exemplifies the dynamic nature of the CRNWR barrier island system. This site had high numbers of Red Knots. Because coastal systems are dynamic and shorebirds may move roost sites due to environmental conditions and disturbance pressure (Peters and Otis 2007), implementing flexible closures is optimal for shorebird conservation.

Currently, there are closures at White Banks and Marsh Island from February 15 to September 15 but no protection for late fall migrant or wintering shorebirds. The need for habitat protection is increasing in the CRNWR. Recreational use of the CRNWR will increase in the coming years because Charleston, located approximately 32 km south, is projected to triple its geographic size by 2030 and expand into adjacent rural and natural areas (Allen and Lu 2003). Because of the dynamic nature of CRNWR and use by shorebirds, continuing surveys will provide useful information that can guide protection of shorebirds.

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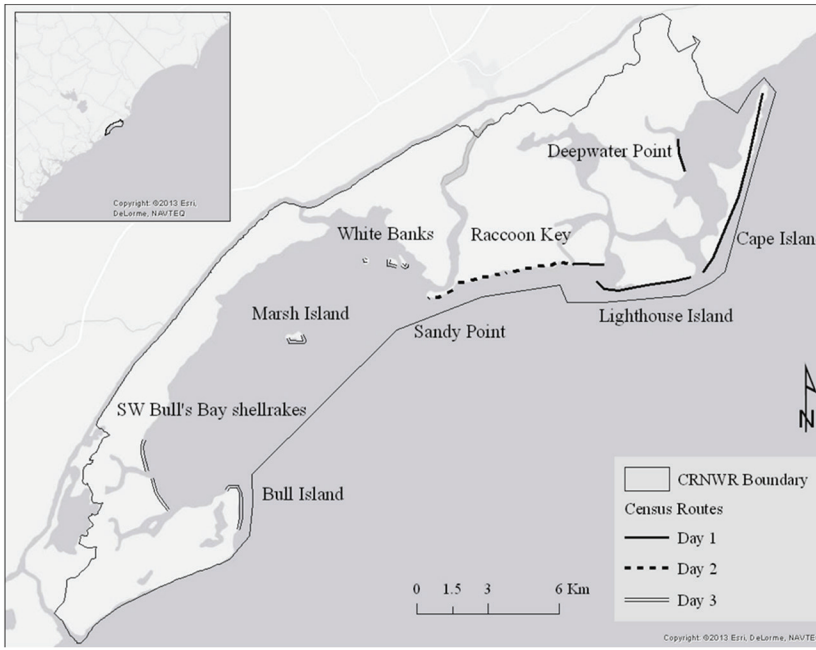


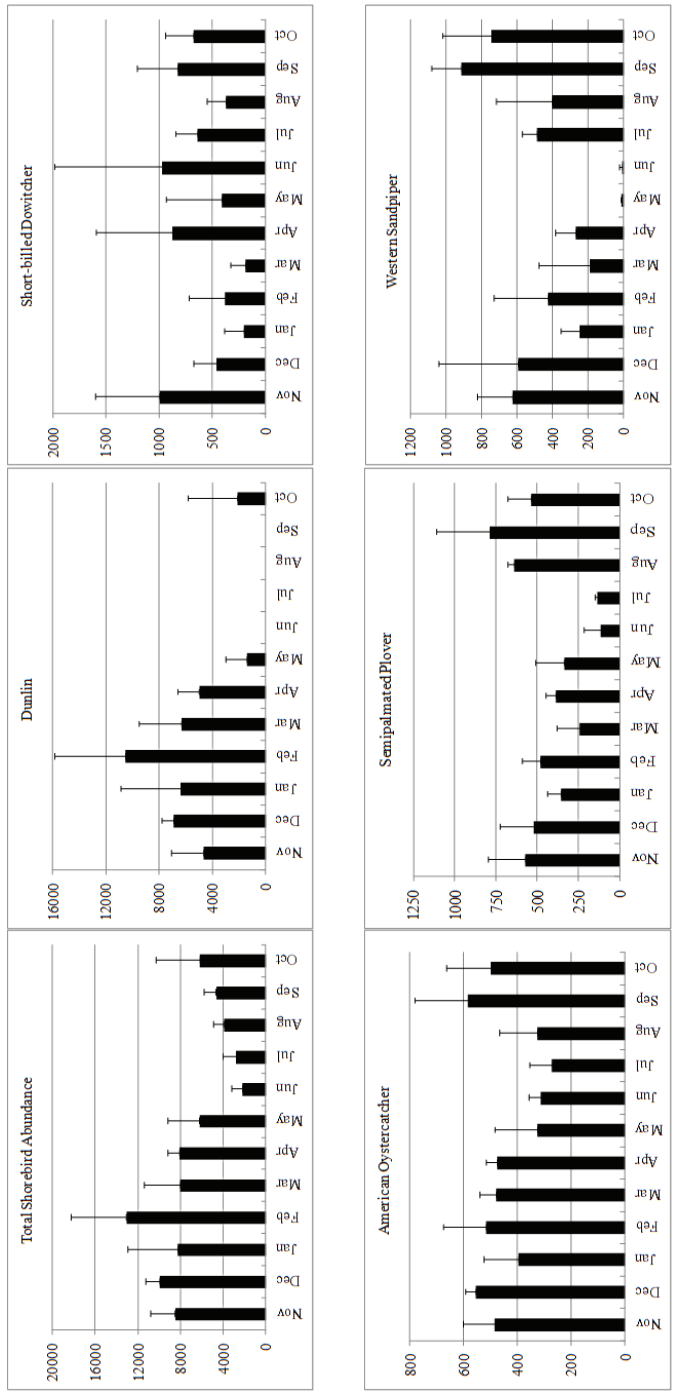
Figure 1. Routes and locations surveyed for shorebirds between November 2007 and October 2010 in Cape Romain National Wildlife Refuge (CRNWR), South Carolina.

Table 1. Relative yearly and mean abundance of shorebirds censused monthly November 2007 - October 2010 in Cape Romain NWR, South Carolina.

	Year 1		Year 2		Year 3		Mean	
Species	%	Abundance	%	Abudance	%	Abundance	%	Abundance
Dunlin, *Calidris alpina*	42.90	27998	58.86	51787	54.26	50557	52.01	43447
Short-billed Dowitcher, *Limnodromus griseus*	13.81	9010	7.44	6544	5.81	5413	9.02	6989
American Oystercatcher, *Haematopus palliatus*	7.33	4782	5.87	5166	6.17	5751	6.46	5233
Semipalmated Plover, *Charadrius semipalmatus*	7.64	4984	5.46	4804	5.88	5481	6.33	5090
Western Sandpiper, *Calidris mauri*	6.01	3924	5.66	4978	6.26	5837	5.98	4913
Sanderling, *Calidris alba*	6.35	4143	4.48	3938	5.52	5147	5.45	4409
Black-bellied Plover, *Pluvialis squatarola*	4.18	2727	2.90	2552	2.82	2625	3.30	2635
Ruddy Turnstone, *Arenaria interpres*	3.01	1967	2.46	2167	3.05	2842	2.84	2325
Red Knot, *Calidris canutus*	2.83	1849	2.86	2515	2.55	2379	2.75	2248
Willet, *Catoptrophorus semipalmatus*	3.40	2221	2.03	1782	1.52	1416	2.00	1806
Semipalmated sandpiper, *Calidris pusilla*	0.39	255	0.01	10	4.33	4036	2.00	1434
Marbled Godwit, *Limosa fedoa*	0.63	411	0.82	725	0.40	371	0.61	502
Least Sandpiper, *Calidris minutilla*	0.39	256	0.45	395	0.65	605	0.00	419
Wilson's Plover, *Charadrius wilsonia*	0.67	439	0.38	336	0.36	335	0.45	370
Whimbrel, *Numenius phaeopus*	0.23	147	0.17	148	0.24	227	0.21	174
Piping Plover, *Charadrius melodus*	0.11	73	0.05	48	0.08	75	0.08	65
Long-billed Curlew, *Numenius americanus*	0.03	22	0.03	26	0.04	38	0.03	29
Spotted Sandpiper, *Actitis macularia*	0.04	24	0.03	22	0.02	16	0.03	21
Greater Yellowlegs, *Tringa melanoleuca*	0.03	18	0.02	15	0.01	5	0.02	13
Killdeer, *Charadrius vociferus*	0.00	0	0.00	2	0.02	20	0.01	7
Unknown	0.02	10	0.01	12	0.00	0	0.01	7
Lesser Yellowlegs, *Tringa flavipes*	0.01	5	0.00	1	0.00	1	0.00	2
Pectoral Sandpiper, *Calidris melanotos*	0.00	0	0.00	2	0.00	0	0.00	1
Stilt Sandpiper, *Calidris himantopus*	0.00	0	0.00	1	0.00	0	0.00	0
Total		65265		87976		93177		82139

	Spring		Fall		Winter	
	Count	Date	Count	Date	Count	Date
All Shorebirds	11,150	Mar 10	10,401	Oct 10	18,262	Feb 09
Dunlin	9209	Mar 10	5929	Oct 10	15842	Feb 09
Semipalmated Sandpiper	3468	May 10	402	Aug 10	0	
Sanderling	2510	May 10	743	Oct 08	524	Nov 07
Short-billed Dowitcher	1917	Jun 08	1176	Sep 10	1517	Nov 07
Red Knot	1156	May 10	1185	Aug 09	139	Nov 09
Willet	1021	Jul 08	258	Aug 09	89	Nov 08
Ruddy Turnstone	886	May 10	296	Oct 08	267	Nov 09
Western Sandpipers	569	Jul 08	1076	Sep 08	1049	Dec 09
American Oystercatcher	531	Mar 09	776	Sep 10	678	Feb 10
Semipalmated Plover	513	May 08	1106	Sep 10	731	Nov 09
Black-bellied Plover	410	Apr 09	663	Sept 10	330	Dec 07
Marbled Godwit	286	Jul 08	386	Aug 09	12	Dec 09
Wilson's Plover	221	Jul 08	84	Aug 09	11	Dec 09
Whimbrel	163	May 10	55	Aug 09	2	Nov 07
Least Sandpiper	31	Mar 08	113	Sep 10	152	Dec 09
Piping Plover	10	Mar 08	15	Sep 10	12	Feb 09

Table 2. Maximum monthly counts of shorebirds and date of survey for each season. Surveys were conducted monthly for three years from November 2007 to October 2010 in Cape Romain National Wildlife Refuge, South Carolina. Spring is March through July, Fall is August through October, and Winter is November through February.


Total Shorebird Abundance
Dunlin
Short-billed Dowitcher
American Oystercatcher
Semipalmated Plover
Western Sandpiper
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct

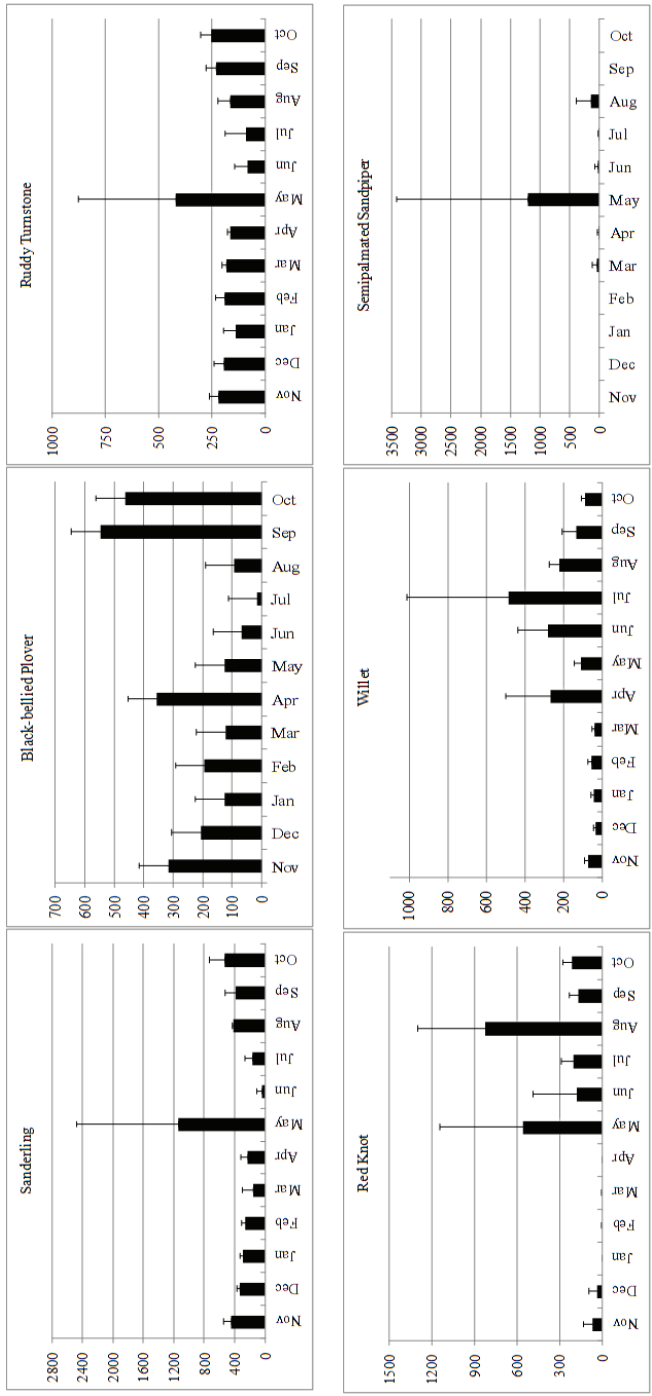


Figure 2. Mean monthly abundance and 95% confidence intervals of shorebirds censused monthly in Cape Romain National Wildlife Refuge, South Carolina, for three years from November 2007 to October 2010. Data presented for the 11 most abundant species and total assemblage of shorebirds.

		Spring Year 1		Spring Year 2		Spring Year 3		Spring Combined
		Site(s)	Density Range	Site(s)	Density Range	Site(s)	Density Range	Site(s)
All Shorebirds	1°	MI	5344-6681	SRK	12765-15957	MI, SRK (2)	12072-15090	MI, SRK, MRK
	2°	NBI, SRK (2)	4008-5344	SRK	9574-12765	NBI	9054-12072	-
Dunlin	1°	NBI, MI, SRK, MRK, SCI	696-870	SRK	5434-6793	SRK	3347-4184	SRK (2)
	2°	-	522-696	SRK	4056-5434	SRK	2510-2929	MI
Short-billed Dowitcher	1°	NBI	634-793	MI	522-652	MRK	153-191	MI
	2°	-	476-634	-	391-522	-	114-153	MRK
American Oystercatcher	1°	EWB	113-142	MWB	107-133	EWB	102-128	MI, MWB, EWB
	2°	MI	85-113	MI	80-107	MI	77-102	WWB
Semipalmated Plover	1°	SCI	111-138	SRK	118-147	SRK	146-183	SRK
	2°	SRK, MRK (2)	83-111	MRK	88-118	MRK	109-146	MRK
Western Sandpiper	1°	NBI, MRK	88-111	SRK	109-136	SRK	230-288	SRK
	2°	SRK	66-88	-	81-109	MRK	173-230	MRK
Sanderling	1°	NBI	126-142	MI, NBI	106-132	NBI	141-177	NBI
	2°	-	94-126	-	79-106	-	106-141	-
Black-bellied Plover	1°	MRK	58-73	MRK	128-160	MRK	105-132	MRK
	2°	-	44-58	-	96-128	-	79-105	MRK
Red Knot	1°	NBI	64-80	SRK	164-205	MI	401-501	MI
	2°	SP	48-64	-	123-164	-	301-401	SRK, SP
Ruddy Turnstone	1°	MWB, EWB	35-44	MI	79-99	MI	204-229	MI
	2°	MRK	26-35	MWB	59-59	NBI	153-204	MWB
Willet	1°	MI	278-348	DWP	119-149	EWB, DWP, NBI	37-47	MI, DWP
	2°	-	209-278	MI	89-119	MI	28-37	-
Wilson's Plover	1°	MRK	42-53	MRK	14-17	NLI, MRK, NCI	17-21	MRK
	2°	-	32-42	-	10-14	-	12-17	NLI
Piping Plover	1°	MRK	3-4	NBI	2-3	NBI	2-3	MRK
	2°	WLI	2-3	MRK	1-2	MRK	1-2	-

See page 79 for Table Key.

Table 3. Results of kernal density estimation (KDE) of monthly shorebird census data in the Cape Romain National Wildlife Refuge, South Carolina for Spring seasons (March through July) 2008-2010.

		Winter Year 1		Winter Year 2		Winter Year 3		Winter Combined
		Site(s)	Density Range	Site(s)	Density Range	Site(s)	Density Range	Site(s)
All Shorebirds	1°	NBI	14739-18424	MI	19093-23867	SRK	19643-24553	NBI, MI,SRK, MRK
	2°	-	11054-14739	SRK (2)	14320-19093	-	14732-19643	NRK
Dunlin	1°	NBI	3211-4013	MI	4515-5644	SRK	4530-5663	NBI, MI, SRK, NRK
	2°	-	2408-3211	-	3386-4515	-	3397-4530	MRK, WLI
Short-billed Dowitcher	1°	NBI, MRK (2)	280-351	MRK (2)	217-272	MRK, WLI	187-234	SRK
	2°	SBB	210-280	SBBSR	163-217	-	140-187	MRK, WLI
American Oystercatcher	1°	EWB, SP, NLI	150-188	WLI	195-243	EWB, WLI	330-412	EWB, WLI
	2°	WLI	113-150	MWB	146-195	-	247-330	-
Semipalmated Plover	1°	MRK (2)	286-357	MRK	315-394	MRK	252-316	MRK
	2°	-	214-286	-	236-315	SRK	189-252	-
Western Sandpiper	1°	MRK	126-157	SRK, MRK	207-259	NBI	351-439	NBI, MRK
	2°	NBI, MRK, NLI	94-126	-	155-207	-	263-351	SRK (2)
Sanderling	1°	NBI	227-284	NBI	228-285	NBI	175-218	NBI
	2°	-	170-227	-	171-228	-	131-175	-
Black-bellied Plover	1°	MRK	52-65	MRK (2)	65-81	MRK	120-150	SRK, MRK
	2°	SRK	39-52	-	49-65	MRK	90-120	MRK
Red Knot	1°	-	0-0	NBI	20-25	MRK	64-81	MRK, NBI
	2°	-	0-0	-	15-20	-	48-64	-
Ruddy Turnstone	1°	MI	66-82	MI	77-97	MI	135-168	MI
	2°	MWB	49-66	MWB	58-77	-	101-135	-
Willet	1°	SBB, NLI	18-23	DWP	44-55	DWP, NRK	34-43	DWP
	2°	NCI	14-18	-	33-44	-	26-34	-
Wilson's Plover	1°	MRK	4-5	MRK	4-5	MRK	4-5	MRK
	2°	NBI	3-4	-	3-4	-	3-4	-
Piping Plover	1°	NLI	3-4	WLI	2-2	WLI	4-5	NLI, WLI
	2°	-	2-3	-	1-2	NLI	3-4	-

See page 79 for Table Key.

Table 4. Results of kernal density estimation (KDE) of monthly shorebird census data in the Cape Romain National Wildlife Refuge, South Carolina for Winter seasons (Nov. through Feb.) 2007-2009.

		Fall Year 1		Fall Year 2		Fall Year 3		Fall Combined
		Site(s)	Density Range	Site(s)	Density Range	Site(s)	Density Range	Site(s)
All Shorebirds	1°	NBI, SRK, MRK	2273-2842	SRK	3377-4222	MI	11656-14570	NBI, MI, SRK
	2°	MRK (2)	1705-2273	NBI, MI, MRK	2533-3377	-	8742-11656	MRK, NRK
Dunlin	1°	MLI	3-3	SRK	274-342	MI	3453-4317	MI, SRK, MLI
	2°	-	2-3	-	205-274	-	2590-3453	MRK
Short-billed Dowitcher	1°	SBB, MRK (2)	127-159	MI	210-263	MI	645-806	MI
	2°	EWB	95-127	SBB	157-210	-	483-645	MRK
American Oystercatcher	1°	MWB	202-253	MWB	351-438	WWB, MWB	355-444	MWB
	2°	-	152-202	EWB, WLI	263-351	WLI	266-355	WLI
Semipalmated Plover	1°	MRK	316-395	MRK (2)	261-326	WLI, MRK	287-359	MRK
	2°	MRK	240-316	SRK, NLI	195-261	-	215-287	-
Western Sandpiper	1°	MRK (2)	250-312	SRK, MRK	333-416	MI	616-771	MRK
	2°	NBI, MRK	187-250	NBI	249-333	-	462-616	MI, SRK
Sanderling	1°	NBI, MI	360-451	NBI, MI	214-268	NBI	236-295	NBI, MI
	2°	-	270-360	-	160-214	-	177-236	-
Black-bellied Plover	1°	EWB, MLI, MRK (2)	70-87	MRK (2)	87-109	MI, MRK (2)	160-200	SRK MRK
	2°	-	52-70	MRK, NCI	65-87	WLI	120-160	MRK
Red Knot	1°	SRK	545-682	SRK	442-553	MRK	134-168	SRK
	2°	-	409-545	-	331-442	MI	100-134	-
Ruddy Turnstone	1°	MI	78-98	MI	98-123	MWB, MI	115-144	MI
	2°	MWB	59-78	MWB	74-98	-	86-115	MWB
Willet	1°	NBI	47-59	NBI, WWB, NRK (2)	28-35	MWB, DWP	56-63	DWP, NBI
	2°	-	35-47	MI	21-28	-	42-56	MI, MWB, NRK (2)
Wilson's Plover	1°	MRK	25-31	MRK	17-22	MRK	18-22	MRK
	2°	MRK	18-25	-	13-17	-	13-18	-
Piping Plover	1°	WLI	7-9	NLI	4-5	WLI	11-14	WLI
	2°	-	5-7	MRK	3-4	-	8-11	-

See page 79 for Table Key.

Table 5. Results of kernal density estimation (KDE) of monthly shorebird census data in the Cape Romain National Wildlife Refuge, South Carolina for Fall seasons (Aug. through Oct.) 2008-2010.

KEY TO TABLES 3 - 5: All search radii were set to 600 meters and density outputs were set as individuals per square kilometer. For each dataset KDE 1° and 2° hotspots were identified if the location had a density value in the top 20th % or 40th to 21st % respectively. Sites are abbreviated as: NBI = North Bull Island, SBB = Southwestern Bull's Bay shell rakes, MI = Marsh Island, WWB = West White Banks, MWB = Middle White Banks, EWB = East White Banks, SP = Sandy Point, SRK = South Raccoon Key, MRK = Middle Raccoon Key, NRK = North Raccoon Key, SLI = South Lighthouse Island, WLI = Washover area of Lighthouse Island, MLI = Middle Lighthouse Island, NLI = North Lighthouse Island, SCI = South Cape Island, MCI = Middle Cape Island, NCI = North Cape Island, and DWP = Deepwater Point.

Fifty Years Ago in *The Chat*—June 1965

Theodore A. Beckett III provided an account of the 1964 nesting season of colonial waterbirds on Drum Island, located directly below the Cooper River bridge in Charleston, SC. For many years, the birds in this colony had been regularly killed for use as crab bait in bait pots run by local commercial crabbers. New "rigid" enforcement of bird protection laws had put an end to this practice and the colony had begun to recover.

Beckett visited the island weekly. Parts of the island were being raised by deposits of dredge spoil but the highest point was only about five feet above sea level. It was covered in marsh grasses, rushes, yaupon holly, wax myrtle and salt myrtle, and the interior had a mix of wild mulberry and palmetto trees. He documented ten species of waterbirds nesting there between March and August. It was the only known nesting site for Glossy Ibis in the state. As part of his ongoing study, Beckett captured and banded a total of 5,600 birds. Field conditions were harsh and he noted "mosquito nets were necessary as well as heavy jackets when the population built up in late June".

Many of the young birds did not survive due to both natural and man-induced causes. Black-crowned Night-Herons preyed on the nestlings of White Ibis and Cattle Egrets. "Frequently", nestlings that had fallen from nests were found impaled on the stiff spines of yucca leaves. However, the most serious impact to the survival of the chicks was caused by the application of a pesticide called "granular BHC", used in mosquito control. The chemical was broadcast from an airplane directly over the island nests and marsh areas. Beckett documented several hundred young "in all stages of paralization for about three weeks after the application". Later, he found between two and three thousand nestlings had disappeared when they should have been the right size for banding, but he remained unsure as to the exact cause of death. Beckett concluded that "if this colony can be protected from human exploitation, there is every indication that it will expand in numbers". Today, wading birds still nest on small parts of the island. However, about three-quarters of the island is used by the S.C. State Ports Authority for drying dredge material.