POPULATION SIZE AND WINTER DISTRIBUTION OF EASTERN AMERICAN OYSTERCATCHERS

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Abstract: Conservation of the eastern subspecies of the American oystercatcher (*Haematopus palliatus palliatus*) is a high priority in the U.S. Shorebird Conservation Plan, but previous population estimates were unreliable, information on distribution and habitat associations during winter was incomplete, and methods for long-term monitoring had not been developed prior to this survey. We completed the aerial survey proposed in the U.S. Shorebird Conservation Plan to determine population size, winter distribution, and habitat associations. We conducted coastal aerial surveys from New Jersey to Texas during November 2002 to February 2003. This area comprised the entire wintering range of the eastern American oystercatcher within the United States. Surveys covered all suitable habitat in the United States for the subspecies, partitioned into 3 survey strata: known roost sites, high-use habitat, and intercoastal tidal habitat. We determined known roost sites from extensive consultation with biologists and local experts in each state. High-use habitat included sand islands, sand spits at inlets, shell rakes, and oyster reefs. Partner organizations conducted ground counts in most states. We used high resolution still photography to determine detection rates for estimates of the number of birds in particular flocks, and we used ground counts to determine detection rates of flocks. Using a combination of ground and aerial counts, we estimated the population of eastern American oystercatchers to be 10,971 +/– 298. Aerial surveys can serve an important management function for shorebirds and possibly other coastal waterbirds by providing population status and trend information across a wide geographic scale.

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American oystercatchers breed on the east and west coasts of North America. The eastern subspecies, *Haematopus palliatus palliatus*, breeds on the Atlantic coast from Cape Cod south to Florida and east to Louisiana, with a few birds present in Texas, Mexico, Central America, and the Caribbean (Nol and Humphrey 1994). The subspecies is resident in much of its range, but most birds from the Northeast move at least as far south as Virginia for the winter. The distribution of eastern American oystercatchers shrank dramatically during the last century, with the northern extent moving southward from Canada to Virginia, and numbers apparently declining rangewide (Bent 1929, Forbush and May 1939, Nol and Humphrey 1994, Davis et al. 2001). While the subspecies is expanding its breeding range northward into formerly occupied areas of the Northeast (Humphrey 1990, Mawhinney et al. 1999), numbers remain small. The subspecies faces significant threats in the United States from heavy recreational use of coastal breeding habitats, and it is unknown whether reproductive success is adequate to maintain current population size (Davis et al. 2001).

The U.S. Shorebird Plan gave high priority to determining population size and trends for shorebird species thought to be at risk, including the eastern American oystercatcher (Brown et al. 2001). This plan also identified the need to test aerial photography as a population monitoring technique for conspicuous shorebirds. Oystercatchers were counted previously during a coordinated winter survey by boat in the southeastern states along the Atlantic coast, which produced a point estimate of 7,700 birds (E. Nol, Trent University, personal communication). Davis et al. (2001) estimated that 3,248 breeding birds were present on the east coast of North America. There was considerable uncertainty in the Shorebird Plan about the current population size in the United States and about which techniques were most suitable for population monitoring. Winter surveys were proposed in the Shorebird Plan because the birds regularly congregate during this period (Brown et al. 2001).

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Our primary goal was to provide an estimate of the current population size and winter distribution of eastern American oystercatchers. In addition, we provided a field test of the role of aerial surveys and photography in meeting the monitoring goals of the Program for Regional and International Shorebird Monitoring (PRISM), a comprehensive approach to monitoring North American shorebirds under the U.S. Shorebird Plan (http://amap.wr.usgs.gov/). We evaluated the effectiveness of the aerial techniques employed, discussed their potential application to other species, and also addressed the management implications of the population estimate and wintering distribution of the subspecies, including an analysis of roosting site habitats.

METHODS

Our study area included the entire winter range of eastern American oystercatchers in the United States from New Jersey to Texas. We subdivided suitable habitat into 3 categories: high-quality habitat (identified by interviews and inspection of photographs), barrier beaches, and salt marshes. We surveyed all high-quality habitat with aerial surveys. We partitioned barrier beaches and salt marshes into 239 blocks that we delineated on National Land Cover Data maps for each state, and we surveyed a systematic subsample of these blocks in each state from the air. On aerial surveys, we estimated flock sizes, and we photographed flocks whenever possible. We determined flock size from the photographs when pictures covered the entire flock and from visual estimates corrected by detection rate when photographs were incomplete or not available. We compared aerial and ground techniques by conducting both types of counts in high-quality habitat areas in 5 states, including all of the highest density wintering areas. In the final population estimate, we only used ground counts wherever they occurred and only aerial surveys for all other locations.

We conducted survey flights between November of 2002 and February of 2003. The Atlantic coast from Barnaget Inlet, New Jersey to Daytona Beach, Florida was surveyed in November and December, including Delaware Bay, Chesapeake Bay, and Pamlico Sound. The Gulf Coast from Everglades National Park to the Mexico border was surveyed in January and early February.

Aerial surveys were flown at 300 to 500 feet above sea level in single engine Cessna Skyhawk 172s. One observer was trained using a simulation program and conducted all surveys from the front seat of the plane. A photographer in the back seat acted as a second observer and photographed as many flocks as possible with a Canon D10 digital camera on maximum resolution with a 300 mm image stabilized lens. We recorded survey data with tape recorders, and both observers used 10 × 42 binoculars to aid in locating and identifying the birds. We marked the position of every flock, pair, or single American oystercatcher with a GPS receiver. The same observer conducted all flights except the Chesapeake Bay and New Jersey coast surveys.

We conducted surveys on the Atlantic coast between 2 hours before high tide and 2 hours after high tide when oystercatchers were most likely to be roosting. Tidal amplitude in the Gulf of Mexico was much smaller, so water level (and therefore time of roosting) was more dependent on wind. We initially timed surveys in the Gulf of Mexico to coincide with the high tide, and we adjusted daily to high water periods when wind affected the timing of high tide.

We surveyed all known roost sites and all high use winter habitats, including sand spits and sandbars at inlets, shell rakes, and oyster reefs. We also covered a systematic subsample of low use wintering habitat, such as barrier beach and salt marsh. We surveyed areas with extensive marsh systems, such as the Virginia coast and barrier islands in Georgia, by flying along marsh rivers. This allowed for a complete survey of all high use habitats while still surveying 40–80% of the marsh habitat. In areas where the coastal marsh was limited to a narrow strip inside barrier islands, we surveyed the entire marsh complex along with Intracoastal Waterway shell rakes and dredge spoil islands. We timed boat surveys in North Carolina, South Carolina, Georgia, and Florida, and land surveys in New Jersey, to coincide with survey flights. Aerial and ground surveys were planned for the same high tide cycle. Experienced observers from state and local organizations conducted ground surveys.

We measured the extent of major habitat types in the survey area by examining orthographic photos from Microsoft Terraserv imagery (http://terraserver.microsoft.com/). We divided the Atlantic and Gulf coasts into 239 block segments for the aerial survey, and we used these same blocks to partition habitat sample units. We randomly selected one-third of the blocks in each state for habitat measurements. One quadrant of each selected block was then randomly chosen and examined at a scale of 1:28000 (8 meter resolution). We determined the percentage of each habitat type by overlaying a dot grid. Oyster Reef was the only habitat type not included in the analysis since it was not consistently identifiable from the photos.

We viewed flocks as population units and the number of birds in a flock as the response variable. The population was thus all flocks in the study area during the study period, and the parameter of interest was the population total. We assumed the population size was constant during the several days required to conduct surveys in each state because maximum population sizes had been reached in South Carolina at the time we conducted the surveys, suggesting that southward migration was largely complete (Sanders et al. 2004).

Survey Strata

We employed stratified sampling with strata defined by location and survey method. In each state, we defined up to 4 strata:

(1) Flocks in High-quality Habitat Counted on the Ground or in Photographs from the Air.—This stratum included all flocks in areas covered by ground surveys and flocks that we photographed during aerial surveys. The stratum was thus completely surveyed. We assumed that ground-based surveyors detected all flocks and counted them accurately because roosting oystercatchers are highly visible, use open beach habitat, use regular roosting sites, and are relatively sedentary during roosting, and because the stratum was defined to include specific sites that could be completely searched. We also assumed that all birds were detected in flocks that were photographed. The point estimate for this stratum was thus the number recorded, and the variance of the estimate was zero because the stratum was completely surveyed without sampling.

(2) Flocks in High-quality Habitat Estimated Visually Only from the Air.—This stratum included the remainder of the flocks in high-quality habitat. Surveys covered all high quality habitat, but we assumed that flocks might be missed from the air and that the visual estimates of flock size might be biased. We estimated the flock detection rate by comparing the number of flocks detected from the air and from the ground in all areas where both types of surveys occurred. For population size estimates, we used only ground counts for all areas where they occurred, and we used aerial counts for other locations. We estimated the ratio of flock size estimates to the actual number present by comparing visual estimates of flocks and photographs of the same flocks.

(3) Flocks on Barrier Beaches.—These areas were usually, but not always, completely surveyed from the air. Only a few flocks were seen in this stratum. Oystercatchers are conspicuous on barrier beaches, which are generally narrow at high tide, so we assumed that all flocks were detected in surveyed areas. We estimated birds missed in unsurveyed areas by extrapolating from surveyed areas in each state where birds occurred in this stratum. We used results from the flocks that were photographed to estimate bias in the visual estimates from the air.

(4) Flocks in Low-quality Habitat.—We surveyed a systematic subsample of salt-marsh blocks in each state. No birds were seen in these areas, so the point and variance estimates were 0.0.

Detection Rates and Estimators for Strata 2 and 3

We detected 35 flocks during ground surveys in areas also covered by aerial surveys, and aerial surveys detected 31 flocks. We excluded from our analysis areas where birds flushed at >1 mile and areas where aerial and ground counts were >1 day apart. In our sample of flocks with <50 birds, we detected 11 of 15 from the air, for a detection rate of 0.73. For flocks with ≥50, we detected 20 of 20 from the air for a detection rate of 1.0. The sample size was too small to permit estimating the detection rate as a continuous function of flock size. We assumed that the detection rates for all flocks with <50 birds was 0.73 and the detection rate for all flocks with ≥50 birds was 1.0. The estimates were proportions obtained in simple random sampling, so their variances may be estimated as $p(1 - p)/(n - 1)$ where p is the proportion and n is the sample size (Cochran 1977). This yields 0.0141 and 0.0 as the variances of the estimate 0.73 and 1.00, respectively. The detection rate for small flocks, 0.73, is referred to as d_{SF} below.

We obtained photographs for 74 flocks, all of which we estimated visually from the aircraft. The ratio (visual estimate)/(count on the photograph) was 0.91. There was no suggestion of a trend with flock size (Fig. 1) or with location. The variance of this estimate, obtained with the formula for ratios of random variables (Cochran 1977), was 0.00034. We used d_B and $v(d_B)$ for these terms below.

In stratum 2 (within a given state), the estimated number of oystercatchers present was:

$$\hat{X}_2 = (y_{2S}/dSF + y_{2L})/d_B \quad (1)$$

where y_{2S} was the number of birds recorded in small flocks (i.e., <50 birds) and y_{2L} was the number of birds recorded in larger flocks. The numerator was thus the number of birds we estimate would have been recorded if all flocks were detected. The denominator adjusted this number to account for a small bias in the visual estimates. In calculating the variance for $\hat{X}_2$ in similar cases, it is customary (e.g., Cochran 1977) to condition on y_{2S} and y_{2L} because, under the assumption that the detection rates are unbiased, the expected value of eq. (1) for all possible samples with the observed values of y_{2S} and y_{2L} is essentially equal to the true population size. This approach lets us view the detection rates, d_{SF} and d_B, as the only random variables. By a Taylor series expansion, the variance of $\hat{X}_2$ was:

$$\hat{V}(\hat{X}_2) \approx (y_{2S}/d_{SF}{}^2 d_B)^2\, v(d_{SF}) + ((y_{2S}/d_{SF} + y_{2L})/d_B{}^2)^2\, v(d_{SF}) \quad (2)$$

Substituting the estimated detection rates and their variances given above and simplifying yielded:

$$\hat{V}(\hat{X}_2) = 0.06089 y_{2S}^2 + 0.00136 y_{2S} y_{2L} + 0.00050 y_{2L}^2. \quad (3)$$

In stratum 3, the estimated number present was:

$$\hat{X}_3 = y_3/(F_3 d_B) \quad (4)$$

where y_3 was the number of birds recorded in stratum 3, F_3 was the fraction of the stratum surveyed, and d_B adjusted for the small bias in visual estimates. The approximation for the variance of a ratio of random variables gave:

$$V(\hat{X}_3) \approx \hat{X}_3^2\,[(v(y_3)/y_3{}^2) + (v(d_B)/d_B{}^2)]. \quad (5)$$

We calculated $v(y_3)$ using $v(y_3) = v(n) = n^2[(1 - F)s^2(y_i)/n] = (1 - F)ns^2(y_i)$. In most states (NJ, DE, MD, VA, FL, AL, MS, LA, TX) we either surveyed all of the barrier beaches ($F = 1$), or we did not record any birds during surveys [$s^2(y_i) = 0$]. In either case, $v(y_3) = 0.0$. In North Carolina, South Carolina, and Georgia, we found birds on the barrier beach surveys, but we did not survey all of the barrier beach habitat, so we calculated $s^2(y_i) = 57.3$ for these surveys. With these estimates, and with $v(d_B) = 0.00034$, $d_B = 0.91$, the estimated variance for stratum 3 was:

$$V(\hat{X}_3) \approx \hat{X}_3^2\,[(57.3)(1 - F)(n)/y_3^2 + 0.00040]. \quad (6)$$

For these calculations, we used $n = FN$, where N was the number of blocks in the state, as an estimate of the effective sample size.

RESULTS

We observed 10,321 American oystercatchers during the survey along the Atlantic and Gulf coasts from New Jersey to Texas (Fig. 2). This number included all birds we saw during ground counts, plus birds estimated by the primary observer in areas where only aerial surveys occurred, plus birds later added to the aerial estimates by examining the still photographs (Table 1). Our estimates of population size included results for each stratum described above. We calculated estimates and variances for each state in each stratum (Table 2). When we summed values for all strata, the final population size estimate was 10,971 +/– 298. This included all birds counted from the ground, plus birds counted only

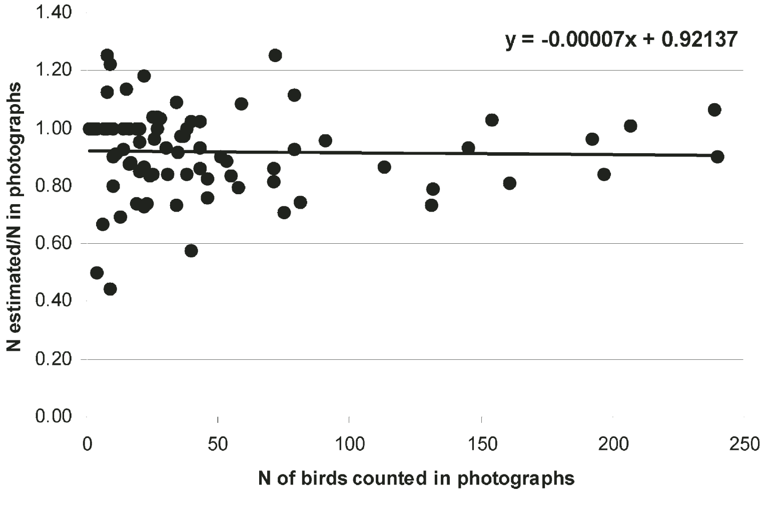

Fig. 1. The ratio of visual estimates of American oystercatcher numbers, in flocks detected during aerial surveys along the Atlantic and Gulf coasts in 2002 and 2003, to number counted in aerial photographs of the same flocks.

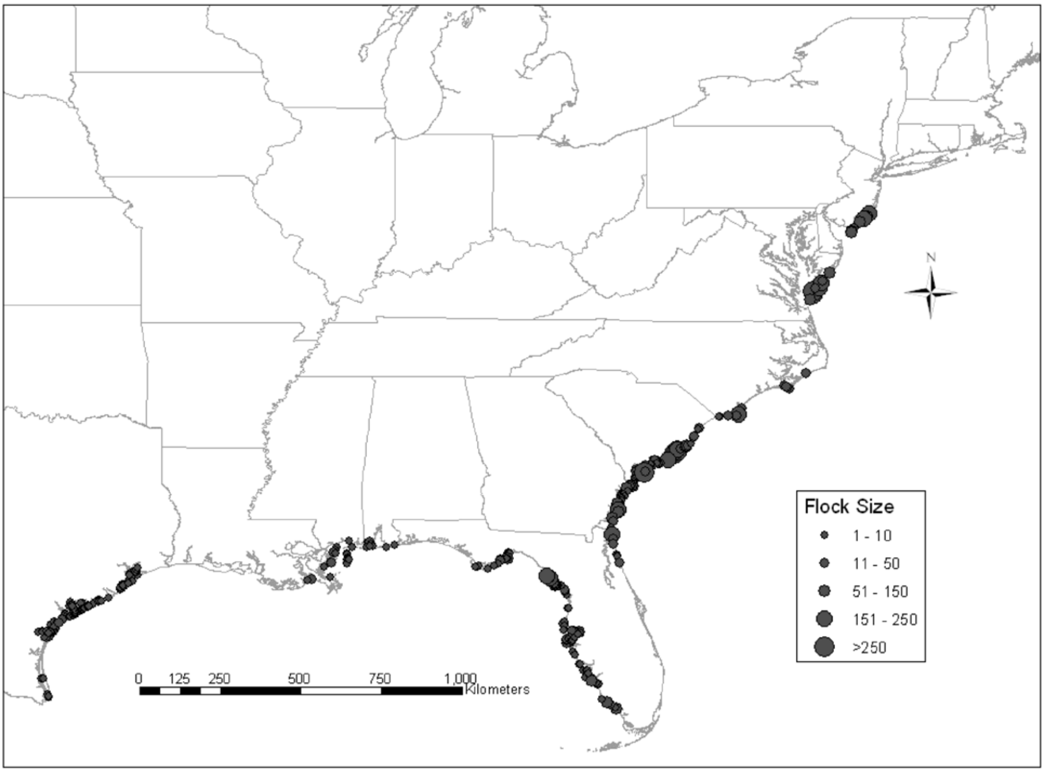

Fig. 2. The locations and relative sizes of American oystercatcher flocks detected in surveys along the Atlantic and Gulf coasts in 2002 and 2003.

from the air, plus our estimates of birds missed from the air.

We observed oystercatchers using 10 distinct habitat types. Shell rakes were by far the most favored roosting habitat. This was particularly true in Georgia and South Carolina. Elsewhere, most oystercatchers used sand islands and sand spits, particularly near inlets. Although we found

Table 1. Proportion of total area covered and numbers of American oystercatchers recorded by state, habitat, and survey method, during Atlantic and Gulf coast surveys in 2002 and 2003.

	High-quality habitat				Barrier beaches		Salt marshes		
		Number of birds							
State	Proportion covered	Ground surveys	Photographed[a]	Visual estimates[a]	Proportion covered[b]	No. of birds[c]	Proportion covered[d]	No. of birds	Total no. recorded
NJ	1.00	595	0	353	1.00	0	1.00	0	948
DE	1.00	0	0	0	1.00	0	1.00	0	0
VA	1.00	1,701	0	0	1.00	0	0.35	0	1,701
NC	1.00	402	38	82	0.70	53	0.25	0	575
SC	1.00	3,704	37	5	1.00	32	0.33	0	3,778
GA	1.00	80	747	128	0.90	26	0.29	0	981
FL	1.00	3	966	883	0.95	0	0.33	0	1,852
AL	1.00	0	14	22	1.00	2	0.33	0	38
MS	1.00	0	4	4	1.00	4	0.33	0	12
LA	1.00	0	63	56	0.80	0	0.22	0	119
TX	1.00	0	0	317	0.45	0	0.33	0	317
All	1.00	6,485	1,869	1,850	0.83	117	0.28	0	10,321

[a] On aerial surveys only.
[b] Based on lengths of beach segments.
[c] All records were visual counts from the air.
[d] Proportion of compartments surveyed.

Table 2. Estimated population sizes of American oystercatchers by state and stratum[a] in Atlantic and Gulf coast surveys during 2002 and 2003.

	Stratum 1		Stratum 2		Stratum 3		Totals			
State	Estimate	Variance	Estimate	Variance	Estimate	Variance	Estimate	Variance	SE	CV
NJ	595	0	396	89	0	0	991	89	9	0.01
DE	0	0	0	0	0	0	0	0	0	-
VA	1,701	0	0	0	0	0	1,701	0	0	0.00
NC	440	0	123	409	83	1,070	647	1,480	38	0.06
SC	3,741	0	8	2	35	0	3,784	2	1	0.00
GA	827	0	164	213	32	131	1,023	344	19	0.02
FL	969	0	1,168	14,782	0	0	2,137	14,782	122	0.06
AL	14	0	33	29	2	0	49	29	5	0.11
MS	4	0	6	1	4	0	14	1	1	0.07
LA	63	0	84	191	0	0	147	191	14	0.09
TX	0	0	477	6,119	0	0	477	6,119	78	0.16
All	8,354	0	2,460	21,835	157	1,202	10,971	23,037	152	0.01
SE	0		148		35		152			
CV	0.00		0.06		0.22		0.01			

[a] Small discrepancies in rows and columns are due to rounding error. Strata are defined in the text.

703 oystercatchers (7.6%) roosting on marsh islands, these comprised only 3 flocks, all on the Eastern Shore of Virginia. Birds roosting on these islands were always at the edge of open water, never in the middle of the marsh. Barrier beach was only rarely used for roosting habitat, and it accounted for only 2% of the population. Enclosed bays and areas with little water flow or tidal action were generally devoid of birds, possibly because these areas do not allow for the formation of shell rakes or other roosting areas. Low-quality habitats, including salt marsh, did not appear to provide any habitat for roosting birds. Even though detection rates may be lower in these habitats, we did not observe any birds, indicating that use of these areas was very low.

We measured the effectiveness and accuracy of the aerial survey technique by directly comparing the results of aerial and ground surveys conducted in the same areas. When conducted simultaneously, the counts from the aerial surveys correlated very closely with the ground surveys ($R^2 = 0.943$, $N = 16$, $p < 0.001$). When we conducted aerial and ground surveys 24 hours apart, the correlation dropped substantially ($R^2 = 0.543$, $N = 23$, $p < 0.001$). We missed counting some flocks from the air when birds flushed, but aerial surveys reached areas where ground surveys were not practical.

The habitats used most frequently were shell rakes and sand islands (Fig. 3). Other habitat types represented smaller proportions of the total number of roosting birds. Preferred habitat types were relatively rare on the Atlantic and Gulf coasts (Table 3), with shell rakes and sand islands comprising only 0.65 and 0.71% of the available habitats in the study area, respectively.

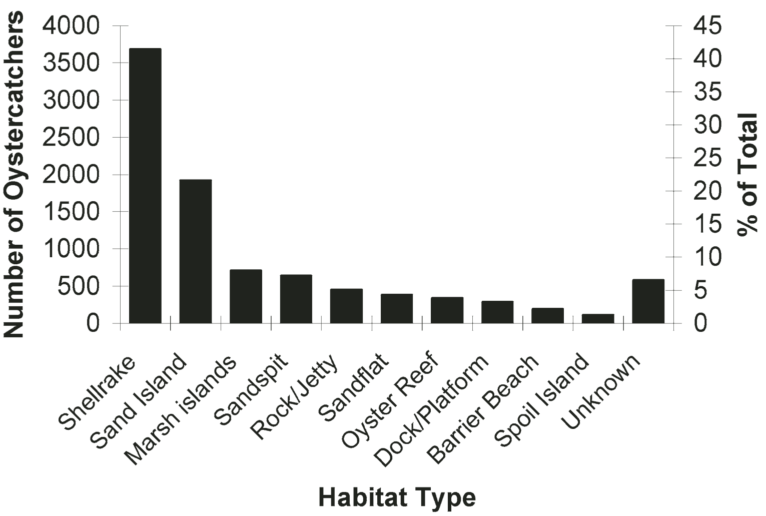

Fig 3. Habitat use by roosting American oystercatchers on the Atlantic and Gulf coasts in surveys conducted in 2002 and 2003. Bars show numbers of birds recorded and percent of total from all flocks identified.

Table 3. Percentage of available habitat for each survey section by state in surveys for American oystercatchers on the Atlantic and Gulf coasts during 2002 and 2003. Percentages are given only for habitat types used by American oystercatchers for roosting, with unsuitable habitats excluded.

	Barrier rake	Shell jetty	Sand rale	Sand-spit	Sand flat	Salt island	Dock marsh	Spoil platform	Rock jetty
NJ	3.79	0.00	0.35	2.91	0.82	91.90	0.23	0.0	0.0
DE, MA,VA	6.85	0.09	0.80	1.07	2.05	88.88	0.27	0.0	0.0
NC	11.30	0.54	1.00	8.94	1.04	74.59	0.23	2.36	0.0
SC	5.34	0.78	0.56	0.26	0.13	92.36	0.48	0.0	0.09
GA	2.26	1.58	0.10	0.55	0.21	95.26	0.03	0.0	0.0
NE Florida	13.18	2.70	0.68	0.51	0.84	78.55	0.51	2.87	0.17
West Florida	27.99	0.00	2.59	13.16	2.13	50.60	0.19	2.87	0.46
AL	0.00	0.90	0.90	2.70	0.00	95.50	0.0	0.0	0.0
MS	31.71	0.00	3.25	2.44	0.81	56.91	4.88	0.0	0.0
LA	0.77	0.27	0.23	0.73	0.34	97.62	0.04	0.0	0.0
TX	10.64	0.29	0.36	15.01	0.58	51.17	0.22	21.72	0.0
Total	7.21	0.65	0.63	4.07	0.71	83.97	0.24	2.46	0.05

DISCUSSION

The population size determined from the combination of aerial and ground surveys was substantially larger than previous estimates, probably because this was the most complete survey to date, and included extensive surveys of habitats that are difficult to access from the ground.

The most significant variation in the effectiveness of the survey among locations resulted from the differing behavior of oystercatcher flocks. Throughout the Gulf coast and the majority of the Atlantic coast, oystercatcher flocks did not react to the presence of the survey plane. However, in Cape Romain National Wildlife Refuge and the Eastern Shore of Virginia, flocks flushed 1 mile or more ahead of the plane and often scattered into small groups. This behavior made detection and accurate flock estimation difficult. Ground and aerial counts from Cape Romain NWR, where birds flushed, differed much more than comparisons along the Intracoastal Waterway at Bull's Bay where oystercatchers remained on the roosts. Of the birds missed by aerial surveys, 49% ($n = 568$) of the 1,161 missed birds came from Cape Romain and Virginia, even though these areas collectively contained only 21% of the total oystercatcher population. One possible explanation is that flock reaction to the plane was a function of habituation to disturbance. The areas where birds flushed readily were remote, and the birds may have been less conditioned to low-flying planes, while disturbance in other areas of the coast was generally higher. It is also possible that many birds in these areas were relatively recently arrived migrants and were therefore more susceptible to disturbance than resident birds. Further work is necessary to understand what causes variation in flushing distance and how this would affect an operational aerial survey.

While flushing behavior made aerial surveys less accurate in some locations, a combination of aerial and ground surveys was necessary because each technique located birds missed by the other. Aerial surveys provide the only practical means to survey oystercatcher populations in extensive areas of the coast not accessible from land and areas where boat access was difficult. Aerial surveys were highly effective in areas where birds did not flush from the plane. When carried out within 1 hour of each other, aerial and ground surveys returned very similar results. When aerial and ground counts were conducted at the same point in the tide cycle, but separated by a full day, the differences were much greater. Numbers of birds at each roost site varied considerably between days, and several roost sites were only used on 1 count day. These differences highlighted the value of aerial surveys, as they allow large sections of coastline to be surveyed on a single high tide, thereby mitigating the effects of day-to-day movement among roost sites.

In our calculations, we assumed ground counts were complete, but it was possible that we missed some birds. During surveys in South Carolina in 2002, double counting by ground observers provided an estimate of the possible effects of error in ground counts. Out of 23 flocks double counted, there was no error for any flocks smaller than 200 individuals, and a detection rate of 0.975 for 5 flocks larger than 200 (F. Sanders, South Carolina Department of Natural Resources, unpublished data). In the ground count data there were 11 flocks >200 individuals, accounting for 2,993 of the birds counted on the ground. If we divide

2,993 by the detection rate of 0.975, it yields 3,070 birds, or 77 birds that may have been missed, a small number relative to the total population estimate of 10,971. This suggests that any small errors made in counting the larger flocks during ground surveys would have very little effect on the overall population size estimate.

Weather conditions can significantly affect aerial surveys. Days with overcast or light rain provided the best survey conditions, as glare off the water was eliminated. On clear days it was important to approach a roost site with the sun behind the plane or on the opposite side of the observer/photographer. If a flock flushed it was easy to lose sight of the birds in the glare off the water, particularly near sunrise or sunset.

MANAGEMENT IMPLICATIONS

Management of most shorebird species is limited by accurate information on population status and trend. Aerial surveys can serve an important management function for shorebirds and possibly other coastal waterbirds by providing population status and trend information across a wide geographic scale. Our population estimate confirms that American oystercatcher should be considered a high priority species. Although our population estimate is larger than previous estimates, the population size estimate is in the lowest category established in the Shorebird Plan (Brown et al. 2001), and the population trend is still unknown. We recommend that the survey should be completed at least every 5 years, in conjunction with ongoing ground surveys, until the population trend can be determined. Combining winter census data with more thorough surveys of populations in breeding areas, along with estimates of survival rates, will result in better estimates of population status and trends. In addition, further work is needed to determine the size of the small populations wintering outside our study area, including Mexico and the Caribbean.

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