Winter Shorebird Survey

FINAL PERFORMANCE REPORT

November 1, 1993–March 1, 1994

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February 1997

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WINTER SHOREBIRD SURVEY

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Abstract: We surveyed the coast of Florida in winter 1993–94 to identify important sites for wintering shorebirds. From November to mid-December 1993, we identified 273 sites from the ground and 217 sites from aircraft. Indices of biological importance and potential for adverse impacts were developed and applied to these initial sites. The 60 sites with the highest biological ranking were visited at least 4 more times between mid-December 1993 and 1 March 1994 and we counted 134,442 shorebirds of 20 species during these visits. Of the top 60 sites, 53 were on Florida's west coast. Nine sites had very high biological scores: 6 near Tampa Bay, 2 in Florida Bay, and 1 near Apalachicola Bay. Eighteen sites had a moderate or high potential for large numbers of shorebirds to be impacted by human activities. Most were in Tampa Bay or on nearby barrier islands. The number of birds counted at each of the 60 study sites varied widely among visits (mean coefficient of variation [CV] for all shorebirds counted on a site visit was 0.86; when counts were grouped by species, the mean CV of all counts was 1.5). Increasing the number of visits at a site did not reduce the CV for total shorebirds counted. Only for a few sites could the CV be reduced by using just counts made during specific tidal conditions. We prepared power analysis procedures to predict the number of visits required to detect a population trend. Simulations indicated that with a CV of 0.6 at least 5 visits per year for 10 years would be required to detect a 10% annual decline in shorebird numbers at an Alpha of 0.05. At that rate, monitoring any but the most important sites would likely be impractical. We recommend monitoring, at a minimum, the 9 most important sites plus at least 2 sites in each coastal region 4 times each winter. Monitoring other locally important or easily accessible sites would be valuable. Additional surveys, with at least 2 visits per site, would provide a more accurate view of important sites for wintering shorebirds in Florida, particularly in Tampa Bay, Florida Bay, and Northeast Florida. In addition to monitoring bird numbers, conservation actions such as educating visitors about shorebirds, posting areas against disturbance, monitoring contaminants, managing water levels, and seeking acquisition or other formal protection should be initiated. We identify general conservation needs for the 29 most important winter shorebird sites.

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INTRODUCTION

Shorebirds comprise a diverse group of short-legged wading birds that inhabit the margins of inland or coastal waters (Hayman et al. 1986). Most shorebird species breed in interior locations, often at high latitudes, and move to coastal areas in the nonbreeding season (Burger 1984*a)*. Many species that breed in arctic regions of North America migrate along the Atlantic and Gulf coasts on their way to more distant wintering grounds. Florida serves as a feeding and resting stop each spring and fall for many of these migrating shorebirds, but for others, Florida is the winter destination. At least 25 species reside in the state during winter and the conservation of these wintering species is the focus of this report.

The current and future status of Florida's shorebird populations is of concern because much of the coast has been developed for human use and is vulnerable to further development, pollution, or disturbance (Fernald and Purdum 1992). Because of these threats and the lack of knowledge of shorebird population sizes or trends, the Bureau of Nongame Wildlife of the Florida Game and Fresh Water Fish Commission (FGFWFC) identified shorebirds as a group of coastal wildlife species needing conservation attention and, especially, surveys of their distribution and abundance (Millsap et al. 1990, 1991).

The current assessment of shorebird abundance and distribution in Florida focused on wintering birds rather than breeding or migrating birds. Because few species breed in the state, surveys of breeding shorebirds would have addressed few species or individuals. Migrating shorebirds are more common, but reliable estimates of migrating shorebirds are difficult to obtain because of the high daily variation and turnover in bird numbers (Thompson 1993). Wintering shorebirds are more common than breeding shorebirds in Florida and more easily counted than migrants. More importantly, they may be most in need of attention. Impacts from habitat degradation, pollution, and human disturbance may affect shorebirds most severely on their winter range because most species spend considerable time on the wintering grounds and the energy stress due to severe weather and scarce food is often greatest in winter (Baker and Baker 1973, Senner and Howe 1984). For these reasons, we decided that conservation efforts directed toward populations of wintering shorebirds offered the greatest benefits to the greatest number of shorebirds in Florida. We focused on coastal habitats because we assumed that coastal sites supported more shorebirds and presented more potential impacts than interior sites and because access to many interior sites was limited.

The objectives of this study were to:

(1) identify, by species, the relative distribution and abundance of wintering shorebirds along Florida's coast,

(2) rank shorebird roosting and foraging sites based upon biological importance and vulnerability,

(3) describe the variation in estimates of the number of wintering shorebirds and discuss its effects upon monitoring trends in wintering populations, and

(4) suggest needs and means for conserving the most important sites.

STUDY AREA

The coast of Florida is not ecologically homogeneous (Livingston 1984); therefore, we divided the coast into 6 distinct regions based upon ecological conditions that we suspected would differentially influence shorebird abundance (Fig. 1). The factors we evaluated included tidal variation, water depth, abundance of aquatic vegetation, influx of fresh water, presence of protected waters, and availability of sandflats or mudflats. These factors are not independent and they affect not only the physical features shorebirds require for roosting and feeding but also the conditions necessary for their invertebrate prey to be abundant.

The Panhandle coast (Fig. 1) has moderate-energy waves, diurnal tides, and a broad salinity gradient (Fernald and Purdum 1992). This coastal region is also distinguished by the abundance of largely undeveloped barrier islands, broad bays, and large rivers (Wolfe et al. 1988). In contrast to the Panhandle coast, the Big Bend coast (Fig. 1) represents a very low-energy wave system with broad shallow waters, expansive salt marsh, and freshwater influx from smaller rivers and streams (Livingston 1984).

The southwest coast (Fig. 1), like the Panhandle, has many barrier islands, large bays, and features moderate-energy waves. Winter temperatures, however, are warmer than in the Panhandle, and mangroves, which are absent to the north, line much of the shoreline of bays and inlets (Fernald and Purdum 1992). Most of the southwest coast, particularly along the sandy beaches, has been highly developed for human use.

The Everglades coast, at the southern tip of the Florida peninsula (Fig. 1), is characterized by narrow mangrove-lined shores, sediments with relatively high organic content and shell or coral fragments, and low-energy waves (Fernald and Purdum 1992). We included the Florida Keys in this region, even though the outer coast of the Keys represents a high-energy wave system more typical of the coast to the north.

We defined 2 survey regions along the Atlantic coast (Fig. 1) and both regions have high-energy waves and semidiurnal tides. The southeast coast (Fig. 1), extending from northern Biscayne Bay (Dade County) to Sebastian Inlet (Indian River County), is characterized by narrow shorelines that have been intensively developed. The northeast coast (Fig. 1) has colder winter temperatures, greater tidal fluctuations, and more bays or lagoons than the southeast coast (Fernald and Purdum 1992). The linear shallow-water lagoons and salt marsh that occur sporadically from Cape Canaveral north to Jacksonville are a significant feature of the northeast coast.

Fig. 1. Six coastal regions identified for the survey of wintering shorebirds in Florida, 1 November 1993 through 1 March 1994.

METHODS

Pilot Study Surveys

In the winter of 1992–1993, we conducted a pilot study in the Florida Panhandle to develop field techniques applicable to a statewide survey of wintering shorebirds. We identified potential sampling sites using information provided by local birders and from aerial surveys of the coast. We then selected 14 sites to be sampled regularly to test our survey methods (Fig. 2). Sites were selected primarily based upon the number of shorebird species and individuals present, but ease of access to a site was also a consideration.

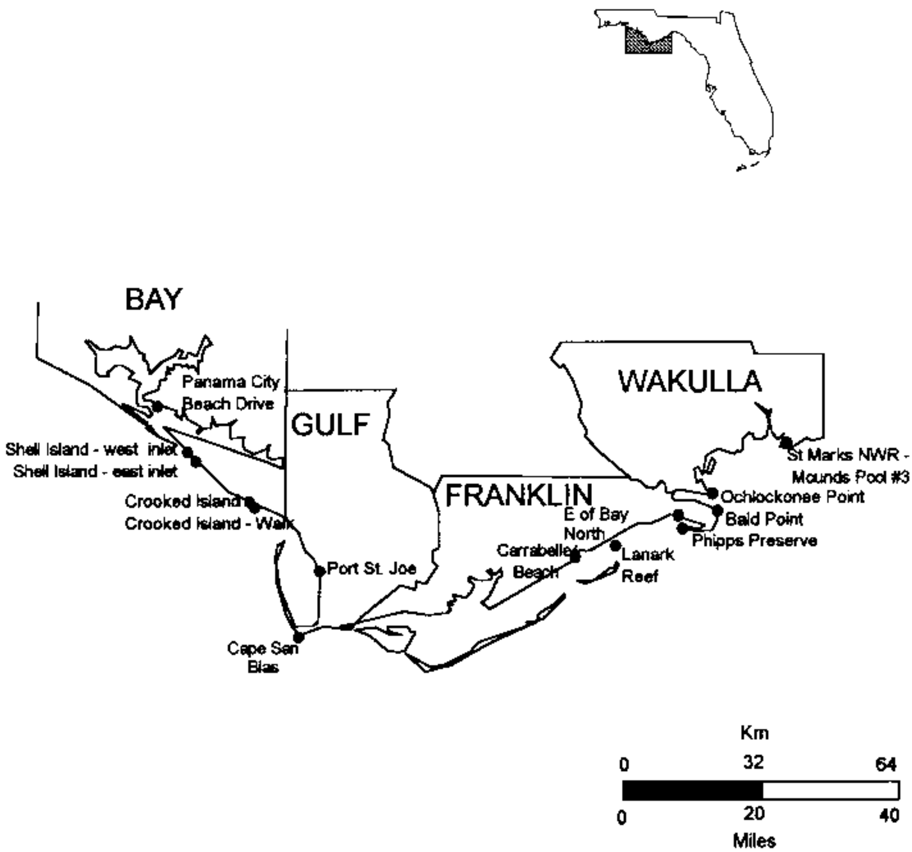

Fig. 2. Fourteen sites surveyed for a pilot study of wintering shorebirds in the Florida Panhandle, 10 January through 8 March 1993.

We visited each of the 14 sites initially during late December 1992 to confirm the presence of shorebirds and to address problems in conducting censuses at the site. We counted shorebirds at each site at least 3 times between January and early March 1993; most sites were visited more frequently, some as often as 14 times. Differences in sampling intensity were due to difficulties in reaching some sites and the infrequent diurnal tides in Bay and Gulf counties. In addition to refining survey techniques, data from the pilot survey were used to assess the affects of tide levels on shorebird numbers and to evaluate variation between seasons and years.

Statewide Surveys

Preliminary Surveys.—We reviewed 6 primary sources of data on the local distribution of shorebirds in Florida (Table 1) and identified 217 potential survey sites. Because the scope of each of the 6 primary sources was limited, we also conducted aerial surveys along the entire Florida coast from 1 November 1993 to 9 December 1993 to locate concentrations of wintering shorebirds. Aerial surveys were conducted in fixed-wing aircraft or helicopters flying primarily at an altitude of 30 to 45 m. Altitude varied with local landforms, structures, wind conditions, and military air space restrictions. Coincidentally, we found the same number of potential sites on the aerial surveys (Fig. 3) as was found from the other sources. However, only 88 of the 217 sites noted from air were sites reported by the other sources.

Only coarse estimates of the number of shorebirds were possible from the air, and we categorized numbers observed as either: <100, 100–1,000, or >1,000 birds. We did not differentiate individuals by species during the aerial surveys. We deleted from further consideration all aerial sites where we saw <100 birds, unless the site was also noted by another source. Some large sites were subdivided into smaller ones; some sites were dropped from consideration due to problems in accessing the site or scheduling visits before winter.

Table 1. The number of potential survey sites identified by each of 6 sources of data on shorebird locations in Florida.

Source	Number	Reference
Coastal Mail Survey	140	Runde and Reynolds (1990)
Christmas Bird Count [a]	36	Anon. (1993)
Piping Plover Survey	35	Haig and Plissner (1992)
International Shorebird Survey	21	Howe et al. (1989)
Pilot Survey	13	
Wildlife Occurrence Database	8	Runde and Reynolds (1990)

[a] CBC circles with an average of ≥100 shorebirds were used as indicators of local shorebird abundance, but these 24-km-wide areas were not sources for specific sites.

After filtering the potential sites in this manner, we visited 273 preliminary sites on the ground between 1 November and 12 December 1993 (Fig. 4). Of these sites, 221 were visited once and 52 were visited twice, once at low and once at high tide. At each site, we counted the number of individual shorebirds by species and recorded observations on behavior and disturbance (Sprandel 1993). Forms for recording site and count data were designed to be compatible with both the Florida Wildlife Occurrence Database System (Runde and Reynolds 1990) and the International Shorebird Survey (ISS) (Anon. 1992). To minimize observer error, observers attended a November 1993 training session to review shorebird identification and learn survey protocol.

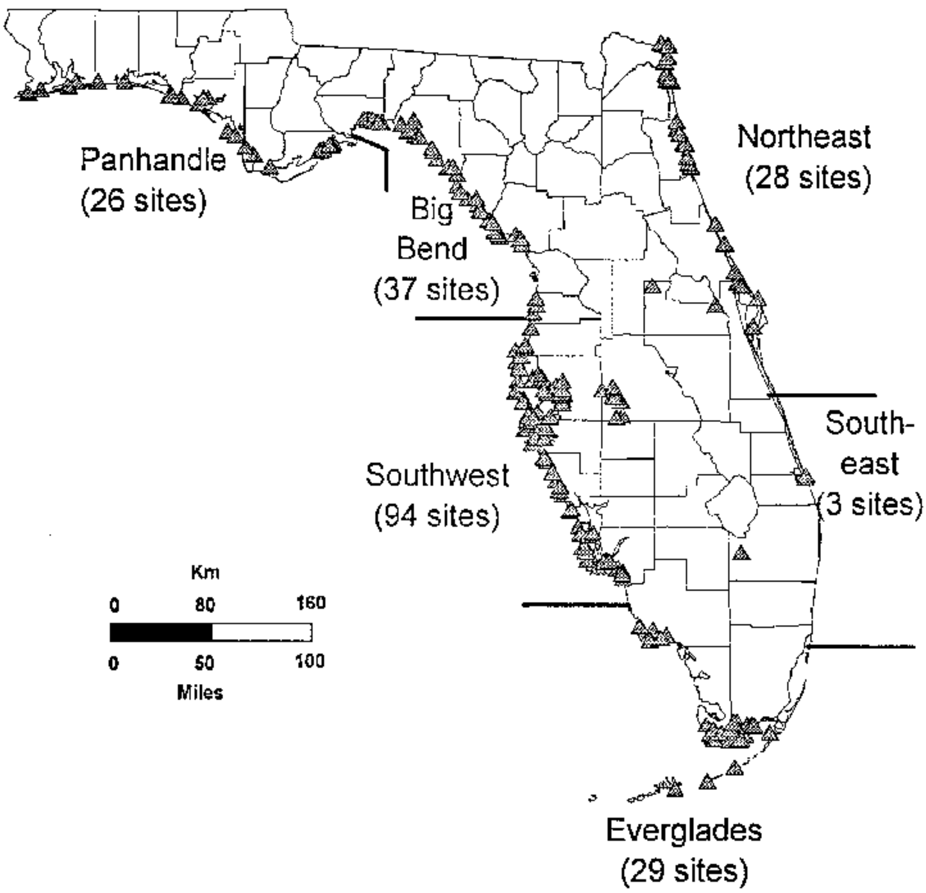

Fig. 3. Preliminary 217 sites surveyed from airplane for wintering shorebirds in Florida, 1 November through 9 December 1993.

Ranking Sites for Biological Importance.—The 273 preliminary sites were ranked according to their relative biological importance based on the sum of 5 variables: shorebird abundance, species richness, site importance for the Atlantic flyway, site importance for Florida in winter, and relative species vulnerability (Table 2). For each variable, we created categories to describe a range of variation and assigned a numerical score to each category.

The shorebird abundance and species richness variables assigned importance to sites with more individual shorebirds and more shorebird species, respectively. The Atlantic flyway and Florida variables indicated a site's proportionate importance, based on numbers of birds, to estimated shorebird populations in the

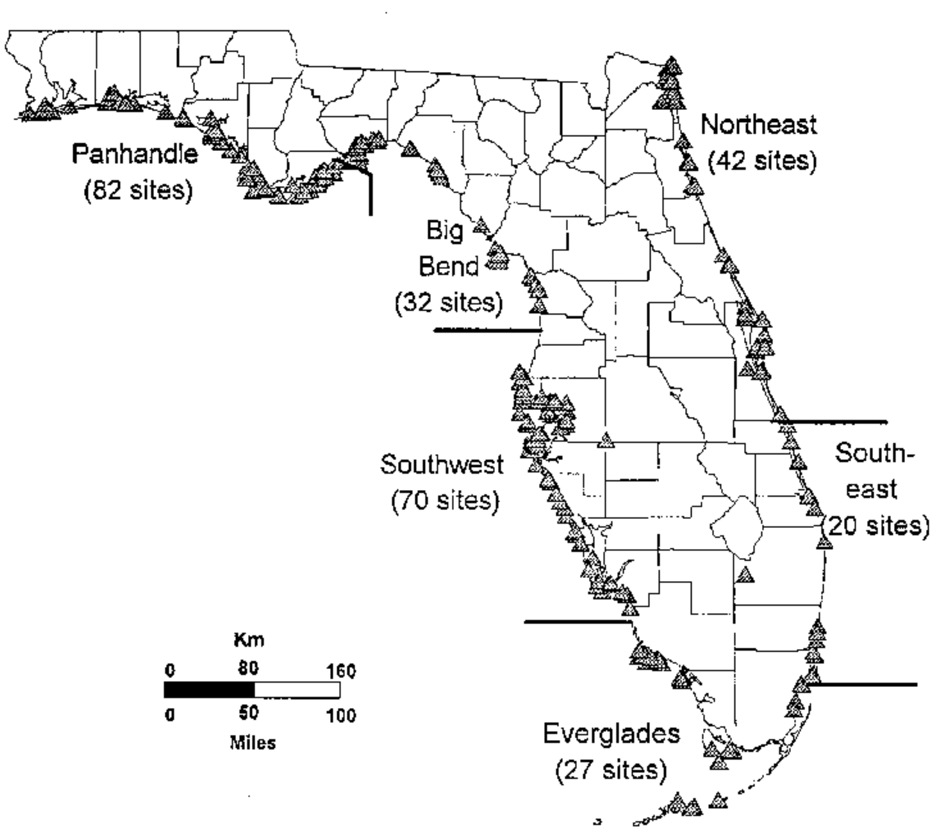

Fig. 4. Preliminary 273 sites surveyed from ground for wintering shorebirds in Florida, 1 November through 12 December 1993.

Table 2. Variables and scores used to rank Winter Shorebird Survey sites in Florida according to relative biological importance.

Biological variables and categories within variables			Score
1.	Shorebird abundance[a]		
	(a)	0–50 individuals	0
	(b)	>50–100 individuals	1
	(c)	>100–200 individuals	2
	(d)	>200–300 individuals	4
	(e)	>300–500 individuals	5
	(f)	>500–800 individuals	6
	(g)	>800–1,000 individuals	8
	(h)	>1,000 individuals	10
2.	Species richness[b]		
	(a)	0–3 species	0
	(b)	4–5 species	2
	(c)	6–7 species	4
	(d)	8–9 species	6
	(e)	10–11 species	8
	(f)	≥12 species	10
3.	Site importance index for the Atlantic flyway[c]		
	(a)	Sum of % of Atlantic flyway populations is < 1	0
	(b)	Sum of % of Atlantic flyway populations is ≥1–5	2
	(c)	Sum of % of Atlantic flyway populations is >5–10	4
	(d)	Sum of % of Atlantic flyway populations is >10–20	6
	(e)	Sum of % of Atlantic flyway populations is >20–30	8
	(f)	Sum of % of Atlantic flyway populations is > 30	10
4.	Site importance index for Florida[d]		
	(a)	Sum of % of Florida winter populations is 0–20	0
	(b)	Sum of % of Florida winter populations is >20–40	4
	(c)	Sum of % of Florida winter populations is >40–70	6
	(d)	Sum of % of Florida winter populations is >70–100	8
	(e)	Sum of % of Florida winter populations is > 100	10
5.	Relative species vulnerability[e]		
	(a)	0–23	0
	(b)	24–28	1
	(c)	29–32	2
	(d)	≥33	3

[a] Mean number of shorebirds of all species counted on all visits.

[b] Mean number of species observed on all visits. Unidentified birds or "peep" are not included in species' counts.

[c] The mean number of shorebirds observed at a site was expressed as a percentage of the species' Atlantic flyway population, based upon International Shorebird Survey data. This index is the sum of percentages for all species at a site. If the flyway population is unknown for a species, counts for that species are not used.

[d] The mean number of shorebirds observed at a site was expressed as a percentage of the species' wintering population in Florida based on 1980–1989 Christmas Bird Count data. This index is the sum of percentages for all species at a site. If the flyway population is unknown for a species, counts for that species are not used.

[e] Sum of points for each species present on a visit based on their vulnerability to extirpation from Florida (Millsap et al. 1990, Appendix E). The mean of vulnerability on all visits is multiplied by 0.6 to have maximum value of 10.

Atlantic flyway (Harrington et al. 1989) and wintering in Florida (Appendix D). The relative species vulnerability index was used to suggest the importance of a site to species most vulnerable to extirpation from Florida, as rated by Millsap et al. (1990, Appendix E). Sites were rated based on the number of shorebird species present that had the median biological scores for endangered, threatened, and special concern species in Florida (Millsap et al. 1990).

After reviewing the range of biological importance scores from the preliminary visits, we decided that sites with a rating score ≥ 10 likely represented significant roosting or foraging sites for wintering shorebirds. Sixty sites met this criterion and were selected for final surveys. These sites were distributed around the state, except along the southeast coast; no site in that region met our minimum rating score.

Systematic Survey Techniques.—With 1 exception, we visited each of the 60 sites at least 4 times from 16 December 1993 through 1 March 1994. The exception was an offshore site—Three Rooker Bar, north end—that we were able to visit only 3 times. Sixteen readily accessible sites were visited >4 times to further assess the value of more survey replicates. We tried to visit each site at least once within an hour of the low- and high-tide times listed in the tide table (National Oceanic and Atmospheric Administration 1993). When possible, we observed important feeding areas at the twice-monthly low spring tide and known roosting sites at the twice-monthly high spring tide. All observations were during daylight hours.

During the initial visit to a site, we recorded detailed information on location, habitat types, human activity, peak disturbance rates, and management activities (Appendix A). On each visit, we noted current site conditions, including weather, tide level, and the type and number of disturbances (Appendix B, Appendix C). We started each survey by estimating the total number of shorebirds present, in case birds flushed before the count was complete. We then counted the number of individuals of each species and subjectively described their spacing as clumped, scattered, or both. Observers were instructed to count at least 30 minutes per visit, regardless of how many birds were present. We also noted whether birds were roosting, feeding, flying, or responding to human disturbance.

At a few Panhandle sites, counts were continued throughout the year from December 1992 to September 1995. These counts allowed analysis of seasonal and interyear variation, and some measure of the efficiency of continued searching for shorebird sites.

Shorebird Distribution and Abundance.—To determine the distribution of sites with the most shorebirds, we first arbitrarily defined small, moderate, and large sites as those with an average of <250 birds, ≥250 but <1,000, and ≥1,000 birds, respectively. We then compared the distribution of sites within each size class among the 6 coastal regions.

To evaluate the distribution of shorebird species, we plotted the mean counts of individuals by species on a map of Florida using thematic categories for different abundance levels. To make mapping more efficient, we arbitrarily grouped species into 2 abundance classes: species with an average of ≤100 birds per site and species with >100 birds per site. For computing means, we included all counts for visits from 16 December 1993 to 1 March 1994, regardless of whether any shorebirds were seen on that visit. We qualitatively compared the distributions for species between the different coastal regions and compared our distributions with historical observations for selected species (Bent 1929; Howell 1932; Anon. 1949, 1950, 1951, 1952, 1953; Proby 1974).

Water Levels and Disturbance.—We attempted to classify sites based upon the predominant behavior of the birds and upon tide level. We segregated the count data, by site and by species, according to the tide level at the beginning of the visit and used *t*-tests to determine whether tide levels had a statistically significant effect on the number of birds observed. To further evaluate the effects of tide levels on shorebird abundance at a site, we also evaluated shorebird abundance by tide level for sites visited during the pilot survey of 1993. We also ordered, by species, the number of birds observed feeding, roosting, or in other behavior. We used *t*-tests to identify species that were observed more commonly either feeding or roosting. We compared dispersal patterns of clumped or scattered birds with tide levels and behavior and used χ^2 tests to identify significant relations.

For each site, we estimated the daily maximum number of human-caused disturbances and computed an hourly disturbance rate based on disturbances seen during our visits. These values were used to determine potential human impact to the site. The activity code for disturbance was recorded for each species disturbed.

Accuracy of Survey Results

Bias may have been introduced into our survey by failure to visit sites, by survey techniques, or by observer error. In order to understand potential biases in our study by missing sites, we evaluated our effectiveness at finding and getting to sites. We compared the number of sites visited on the ground with the number found by aerial surveys. We used the pilot survey in the Panhandle as a measure of the efficiency of continued searches by trained observers over multiple years. By analyzing the preliminary number of sites visited just once, the percentage of sites with clear tidal differentials, and the average variability of all sites, we evaluated the possibility that our single preliminary visit inaccurately portrayed shorebird abundance at a site.

To assess potential biases caused by our survey techniques, we compared our results with ISS and Christmas Bird Count (CBC) results. Because techniques for both the ISS (Anon. 1992) and our survey (Sprandel 1993) were similar, we used *t*-tests to compare shorebird abundance between sites visited on both surveys. Because our survey methods differed greatly from CBC counts (Sprandel 1993), we qualitatively compared the relative abundance of species in each survey over broad local areas, entire coastal regions, and throughout the state.

We evaluated traits of observers to understand potential bias introduced by observers. We used *t*-tests to identify significant differences among observers (and between first- and second-year observers) in the time spent per visit and in the percentage of unidentified birds recorded. We used analysis of variance to identify relationships between the percent of unidentified birds recorded and the total number of birds observed, the activity of the birds, and their distance from the observer.

In order to evaluate the efficiency of guessing group size rather than counting individuals, we determined if the number of shorebirds guessed at the start of each visit was correlated with the actual number of individuals counted during the visit. We computed accuracy as the initial guess' percentage of the counted birds.

Ranking the Final Sites

Biological Importance Ranking.—The 60 final statewide sites were ranked according to their relative biological importance following the same techniques used to rank the preliminary sites (Table 2), but using data from all visits. To understand correlations among the ranking variables, we computed Spearman's rank correlation coefficient among all biological variables. We used principal component analysis (SAS PRINCOMP, SAS Institute, Inc. 1990) to extract components of variation in the importance scores and to rank the sites based upon the values of the most significant components. We used the range of total biological importance scores to determine whether the scores could discriminate among subtle differences in our study sites.

We evaluated the sensitivity of the categories and weightings used for the variables to learn the relative importance of the variables. We replaced the categorical classes used with a linear scale to determine if there was bias due to our selected categories. For example, instead of having 8 categories for the shorebird abundance variables, we used a linear scale from 0 to 10. To evaluate the sensitivity of the abundance variable, we evaluated the impact of using the highest counts at a site versus the average counts. To evaluate the sensitivity of the flyway variables, we evaluated using just 1 versus 2 flyway values. Finally, to understand how the variables related, we evaluated the impact of using a sum of squares of the variables rather than just a sum (Manley and Davidson 1993).

We used CBC data from 1980 through 1989 to estimate the consistency of our biological ranking scores. We ranked the CBC counts from each year using our biological importance scoring and then tested the significance of shifts in ranks using the Spearman's rank correlation coefficient.

Ranking Sites for Potential Impacts.—In addition to ranking the final sites by their biological importance to shorebirds, we ranked them according to their potential to be adversely impacted by human activities. Three variables were used to measure a site's potential for degradation: human disturbance potential, contaminant potential, and development potential (Table 3). Human disturbance potential reflected both the estimated peak daily rate and the average hourly rate observed during our visits. Contaminant potential was an index of the vulnerability of a site to pollutants as measured by the volume of pollutants and petroleum products shipped to ports within 24 km (Department of Natural Resources 1988). The 24-km limit was based on observations from the August 1993 oil spill in Tampa Bay, Florida (Department of Environmental Protection 1993), and spills in Washington (Larsen and Richardson 1990). If multiple ports were within 24 km of a site, their combined volume was used to determine potential impact. Development potential was used to predict the chance that shorebird habitat at a site might be modified or developed for other uses. This variable was estimated as the potential increase in human population density for the county in which the survey site was located as determined by Kiplinger (1992) (Table 4). We ranked the sites according to their overall potential impact score, which was the sum of the scores for disturbance, contaminant, and development potential.

Sensitivity Analysis of Impact Scores.—To analyze the sensitivity of the impact scores we doubled the relative weight of the disturbance variable, evaluated the effect of misidentification of site ownership on the development potential, and analyzed the distance from the port on the pollutant variable. Spearman's rank correlation coefficient was used to measure the degree of association among impact variables.

Important and Vulnerable Wintering Shorebird Sites.—Overlaying the list of sites that are biologically important with the list of sites that have potential impacts will produce a set of biologically important sites with high potential risk (Fig. 5). To identify these sites, we first ordered the sites by biological importance and then grouped them into high, medium, or low importance. The grouping was done by Atlas-Pro software using the Fisher/Jenks iterative method, which maximizes goodness-of-variance fit (Strategic Mapping 1992). This method forms categories that are similar by minimizing differences within each category and maximizing differences between categories. Each of the 3 categories will always have some entries. Next, we used the same process to order the sites into high, medium, or low categories according to the impact scores. Combining the 3 categories for biological importance and the 3 categories for impact produced 9 combinations that we grouped into high, medium, and low risk to reflect the potential loss to wintering shorebird populations (Table 5).

Table 3. Variables and scores used to rank Winter Shorebird Survey sites in Florida according to their potential to be impacted by humans.

Impact variables and categories within variables			Score
1.	Disturbance potential		
	A)	Peak disturbance per day[a]	
		Less than once per day	0
		1–5 times a day	1
		5–10 times a day	3
		More than 20 times a day	5
	B)	Average disturbance per hour[b]	
		0–0.5	0
		>0.5–1.9	1
		2–4	2
		5–9	3
		≥10	5
2.	Contaminant potential[c]		
		No port within 24 km	0
		<0.2 million m^3 shipped annually within 24 km	1
		>0.2–0.8 million m^3 shipped annually within 24 km	2
		>0.8–1.6 million m^3 shipped annually within 24 km	3
		>1.6–6.4 million m^3 shipped annually within 24 km	5
		>6.4 million m^3 shipped annually within 24 km	10
3.	Development potential[d]		
		Public land	0
		≤50 additional people/2.6 km^2/decade	3
		>50–100 additional people/2.6 km^2/decade	6
		>100–200 additional people/2.6 km^2/decade	8
		>200 additional people/2.6 km^2/decade	10

[a] Subjective estimate of observer based upon disturbance rates or evidence recorded during site surveys.

[b] Average number of disturbances observed per visit divided by time spent at the site.

[c] Potential based upon volume of pollutants shipped annually from ports within 24 km. One m^3 equals 6.29 barrels and the categories' equivalent values in millions of barrels are ≤ 1, 1–5, >5–10, >10–40, and >40.

[d] Estimated from projected per capita growth per decade per 2.6 km^2 (multiplication of current human population density in county and projected population growth percentage for the county). Only applicable for privately owned lands.

Table 4. Estimated increase in human population density (people per 2.6 km^2) from 1992 through 2002 and associated development score for Florida counties surveyed for winter shorebirds.

Region and county	% increase[a]	Development score
Panhandle Coast		
Bay	24	3
Escambia	24	3
Franklin	2	3
Gulf	1	3
Big Bend Coast		
Levy	5	3
Taylor	1	3
Wakulla	4	3
Southwest Coast		
Charlotte	52	6
Hillsborough	126	8
Lee	100	8
Manatee	26	3
Pasco	87	6
Pinellas	276	10
Sarasota	104	8
Everglades Coast		
Collier	27	3
Monroe	8	3
Northeast Coast		
Brevard	73	6
Duval	88	6
Volusia	74	6

[a] Derived from estimates by Kiplinger (1992)

Table 5. Logical overlay of biologically impacted sites to determine risk.

	High impact score	Medium impact score	Low impact score
High biological importance	High risk	Medium risk	Low risk
Medium biological importance	Medium risk	Medium risk	Low risk
Low biological importance	Low risk	Low risk	Low risk

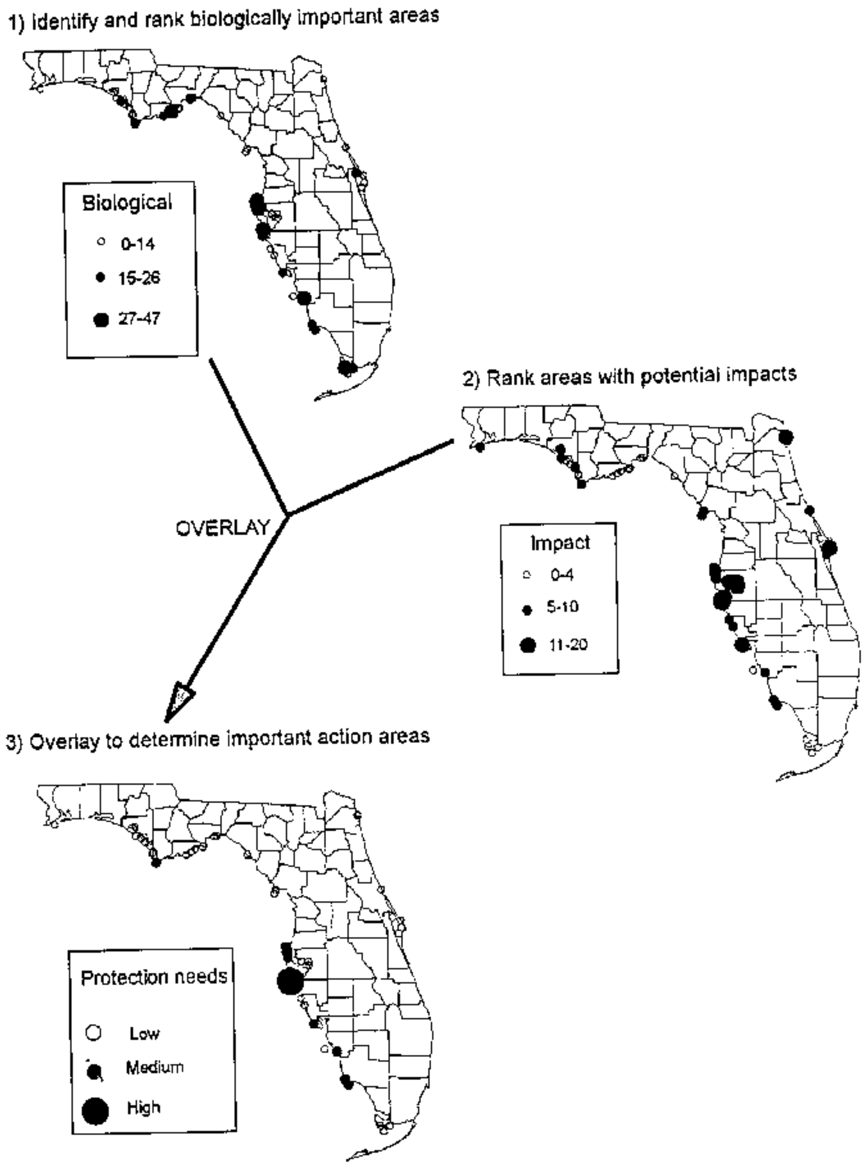

Fig. 5. Conceptual overview of process to determine important shorebird wintering areas in Florida.

Monitoring Winter Shorebird Numbers

One of our objectives was to determine the feasibility of detecting changes in the number of wintering shorebirds (overall and by species) at individual sites and statewide. We evaluated variance in shorebird count data and methods of detecting population trends, and we used power analysis to estimate the effort required to detect trends in shorebird population counts. We evaluated data for each species and for all species combined.

Variance in Shorebird Count Data.—Variation existed in our data for counts both within and between years. We used the coefficient of variation (CV)—standard deviation divided by the mean—as a measure of the variability of the counts. We believe that this variation was related to changes in the population, variation in the sampling effort, and sampling error.

To evaluate variability in shorebird counts by season (i.e., winter, spring, fall), we analyzed ISS data for Marco River, Romano, and Mayport. We continued counts throughout the years of 1994 and 1995 at 4 sites in the Panhandle (Bald Point; Yent Bayou; Carrabelle Beach; and St. Marks National Wildlife Refuge [NWR], Mounds Pool #3) to provide additional data for analyses of seasonal variation.

Reducing Variation within Years.—In an attempt to decrease variability and increase our ability to detect trends, we evaluated transforming the data with logarithmic transformation (Chatfield 1989), square-root transformation (Sokal and Rohlf 1981), and using only the 3 highest counts at each site.

We used 2 simulation modeling approaches to evaluate the effect of increasing sample size on count variability. First, starting with a subset of 7 winter counts for a particular species at a site from the pilot study, the model randomly picked combinations of numbers from the 7 possible visits (e.g., for 2 visits, all combinations of 2 numbers were picked from the 7 data points). The CVs from the resulting combinations were then compared to determine the effect of increasing sample size on data variability. We assumed the existence of a naturally occurring standard deviation that was independent of sample size and that all counts were independent.

We then ran the model with a generated data set of 1,000 normally distributed numbers with a known mean (100) and known standard deviation (33.3). From this set of 1,000 potential visits, 100 sets of data were generated randomly for each of 1 through 10 visits. CVs for each combination were then compared to determine the effect of increasing sample size on data variability.

Because some sites may be more frequently used at high tide for roosting and other sites used at low tide for feeding, we evaluated the effect on variability of grouping data by tide level. Because we had more visits to some sites during the pilot survey, pilot survey data were used in this analysis. We grouped the visits for high tides at St. Marks NWR, Mounds Pool #3 and at low tides at Carrabelle Beach. We performed similar analyses on ISS sites at Marco River and Mayport.

Variation by Species.—In addition to evaluating the CV of the total number of shorebirds at a site, we computed the CV for each species at each site and across all sites. We used the average CV of all species as an indication of how easily individual species could be monitored.

Trend Detection

As an example of techniques that might be applied in trend estimation with continued monitoring, we used linear regression and nonparametric methods to estimate population trends (i.e., long-term changes in the mean population levels) in snowy plover (see Appendix D for scientific names of all shorebird species) CBC data for Bay County, Florida, 1976 through 1989. We assumed (1) that the snowy plover data typify the kind of data that would be acquired from continual winter shorebird monitoring, (2) that changes in counts represented population changes, (3) that total count (rather than individuals per party hour) was a good index to population level, (4) that total count was not affected by sampling intensity, and (5) that the winter shorebird population was closed. We ran the nonparametric method described by Titus et al. (1990) and Theil's test (Hollander and Wolfe 1973) on the snowy plover CBC data to test for the presence of a positive or negative trend.

Total counts from CBC shorebird data for St. Marks from 1960 through 1989 and 5-year running averages were plotted. Running averages are used to smooth data and to make patterns in the data more apparent (e.g., a 5-year running average would average the current-year count and those of the 2 years before and the 2 years after).

Power and Sample Size

We evaluated both analytical and simulation approaches to estimating statistical power ($1 - \beta$) and to determining sample size requirements to detect population trends. Using analytical techniques described by Harris (1986), Gerrodette (1987), Kraemer and Thiemann (1987), and Cohen (1988), we determined the years required to detect 5% and 10% annual population declines at $\alpha = 0.05$ and $1 - \beta = 0.80$ at CV = 0.3 and at CV = 0.6.

***Simulations with Linear Regression.*—**Because Gerrodette's (1987) analytical approach has been questioned and appears inappropriate for practical population monitoring when sample sizes are low (Link and Hatfield 1990, Gerrodette 1991) and because this approach did not consider variation in the number of visits per year, we developed a Monte Carlo simulation model in the SAS language (SAS Institute, Inc. 1990) for regression analysis (Cobb et al. 1996). Model parameters included percent decline per year, number of model iterations and visits per year, and the CV of counts within a year. For each year, we randomly picked counts from a gamma distribution centered on the declining mean and based upon the CV. We ran the model 1,000 times and counted the number of times that a declining trend was detected (i.e., $1 - \beta$) with linear regression.

To evaluate the effect of increasing the number of sampling years with a fixed number of visits per year, we computed the probability of detecting both a 5% and 10% annual decline at 4 and 8 visits per year for 5 to 15 years at CV = 0.6 and $\alpha = 0.1$. To determine the percentage decline detectable at a fixed power over a range of years, we computed the annual decline rate (proportion) of the total population that could be detected at 4 and 8 visits per year from 5 to 25 years at $1 - \beta = 0.80$, CV = 0.6, and $\alpha = 0.1$.

Based on modeling presented by Cobb et al. (1996), we modeled the effect of within-year variability on the possibility of detection of false trends when there was no actual population change. Our model maintained a mean population of 1,000 birds, and we counted the number of times either a positive or negative trend was erroneously detected at various combinations of CV, visits, and years of surveying.

***Simulations with Nonparametric Methods.*—**The simulation technique was also applied to Theil's nonparametric method (Hollander and Wolfe 1973) and the nonparametric trend detection method presented in Titus et al. (1990). After setting the percent decline per year, number of years, visits per year, and the CV, we generated 1,000 data sets from a gamma distribution. For each data set, we ranked the data (PROC RANK; SAS Institute, Inc. 1990) using the average of all visits for a year, ran the nonparametric test, and counted the number of times that a trend was detected at $\alpha = 0.05$, and CV = 0.3 and CV = 0.6.

***Simulation with t-test between Surveys.*—**We computed the probability of detecting, using a *t*-test, that there was a difference between the first year and the fifth to fifteenth years with a 5% and 10% annual decline. We compared the probabilities with 4 and 8 visits per year and at CV = 0.6 and $\alpha = 0.1$.

***Comparing Counts between Years.*—**Variability may exist in annual count data due to movement of birds, different tidal or weather conditions, random variability, and interobserver differences. Variability other than that reflecting actual population change may also exist in counts between years. We compared data using *t*-tests and power analysis (Cobb et al. 1996) for sites visited during the pilot survey in the winter of 1992–93 and subsequently visited in the winters of 1993–94 and 1994–95 after statewide surveys were completed. We also computed power for ISS data collected by a single observer at Marco River, Florida, from 1980 through 1987.

Detection of Statewide Trends from Multiple Sites

To illustrate 1 approach of detecting statewide trends (i.e., percent change in population numbers at all sites), we analyzed CBC data (1960–1989) of snowy plovers for each statewide site using linear regression and plotted on a Florida map the trend (increasing or decreasing) at each CBC circle. This approach allowed us to quantify a change in a percentage of sites statewide.

RESULTS AND DISCUSSION

Shorebird Distribution and Abundance

Statewide shorebird counts included 272 visits to the 60 final survey sites from 16 December 1993 to 1 March 1994. The survey sites are described in Table 6 and Appendix A; their relative locations are shown in Figs. 6 through 11. Twenty-eight sites were irregularly shaped areas, such as tips of peninsulas, sandbars, or isolated mudflats and averaged 732 m x 254 m in area. The 32 other sites were stretches of relatively homogeneous shore with an average length of 1.1 km. Eleven sites were artificially constructed or enhanced. Water levels at most sites were governed by tidal flow; however, 5 were nontidal and 4 had managed water levels. All nontidal sites were within a few km of the shoreline.

Survey dates, times, and ambient conditions varied among sites and visits (Appendix B). We recorded notes on unusual water levels, disturbances, and problems in observing birds at a site (Appendix C). For all visits combined, we counted 134,442 shorebirds of 25 different species. Using the average number seen at each site, we estimated a mean total of 30,502 shorebirds wintered at the 60 sites. We recorded the highest average number of individuals (2,611) at Lake Ingraham, southeast end in the Everglades. Five other sites averaged >1,000 shorebirds per visit: Lanark Reef in the Panhandle; the Island north of Bunces Pass and Shell Key on the southwest coast; Northwest of Palm Key in the Everglades; and Merritt Island NWR, Black Point Drive on the northeast coast (Table 7).

The coarse categorization of sites into small, medium, or large showed that most shorebirds winter in Florida along the Gulf coast, particularly along Tampa Bay and the southwest coast (Table 8). Diversity of species is another measure

Table 6. Location and description of 60 sites surveyed ≥ 3 times for wintering shorebirds in Florida, 16 December 1993 through 1 March 1994.

Region and site	County	Latitude[a]	Longitude[a]	Size[b]	Tidal	Habitat
Panhandle Coast						
Cape San Blas	Gulf	29° 39.76'	85° 20.97'	1.0 km x 1.0 km	Tidal	Mixed sand/mud flats, tidal marsh
Carrabelle Beach	Franklin	29° 50.0'	84° 40.5'	100 m x 100 m flats, 1.0 km shore	Tidal	Sandy beach, mixed sand/mud flats
Carrabelle River Flats	Franklin	29° 50.37'	84° 39.71'	200 m x 75 m	Tidal	Tidal river, muddy flats, mollusk reef
Crooked Island West, east end	Bay	30° 00.29'	85° 32.86'	300 m x 400 m	Tidal	Sandy beach
Crooked Island East, west end	Bay	29° 57.53'	85° 27.93'	500 m	Tidal	Sandy beach, mixed sand/mud flats
East of Bay North	Franklin	29° 55.6'	84° 26.1'	30 m x 800 m at low tide	Tidal	Mud flats + sea grass at low tide
Fort Pickens, west end	Escambia	30° 19.75'	87° 18.11'	600 m on either side of tip	Tidal	Sandy beach
Lanark Reef	Franklin	29° 52.4'	84° 35.3'	1.0 km of island	Tidal	Mixed sand/mud flats
Marifarms	Bay	30° 16.03'	85° 44.01'	1.5 km x 200 m wide	Tidal	Modified diked marsh, sand/mud flats
Phipps Preserve	Franklin	29° 54.47'	84° 25.84'	> 1.0 km	Tidal	Sandy beach
Shell Island, east end inlet	Bay	30° 04.32'	85° 37.82'	150 m x 200 m	Tidal	Mixed sand/mud flats, bay
Shell Island, west end	Bay	30° 06.94'	85° 43.62'	1.0 km	Tidal	Sandy beach
St. Joseph Peninsula	Gulf	29° 49.2'	85° 25.0'	1.0 km	Tidal	Sandy beach
Yent Bayou	Franklin	29° 47.4'	84° 45.5'	500 m	Tidal	Mixed sand/mud flats
Big Bend Coast						
Cedar Key, Hodges Bridge	Levy	29° 09.93'	83° 01.67'	1.0 km x 1.0 km	Tidal	Tidal marsh
Cedar Key, Seahorse Key	Levy	29° 05.95'	83° 03.66'	1.0 km	Tidal	Mangrove, mixed sand/mud flats
Cedar Key, S of Hodges Bridge	Levy	29° 09.7'	83° 01.72'	1.0 km x 1.0 km	Tidal	Tidal marsh
Hagens Cove	Taylor	29° 46.5'	83° 34.5'	1.0 km	Tidal	Tidal backwater, mixed sand/mud flats
Sprague Island oyster bars	Wakulla	30° 05.5'	84° 12.5'	500 m	Tidal	Tidal marsh, mollusk reef
St. Marks NWR, Mounds Pool #3	Wakulla	30° 06.0'	84° 09.5'	500 m along the pool	Nontidal	Salt marsh, slough
Southwest Coast						
Anclote Key, north end	Pasco	28° 12.5'	82° 51.0'	150 m x 50 m	Tidal	Sandy flats
Anclote Key, south end	Pasco	28° 12.0'	82° 51.0'	1.3 km	Tidal	Sandy beach, mixed sand/mud flat
Caladesi Island, Dunedin Pass	Pinellas	28° 01.0'	82° 49.45'	75 m x 125 m	Tidal	Sandy beach, mixed sand/mud flats
Caladesi Island, north end	Pinellas	28° 03.0'	82° 49.3'	750 m x 250 m	Tidal	Muddy flats, mixed sand/mud flats
Courtney Campbell Causeway, southeast A	Hillsborough	27° 58.0'	82° 33.0'	1.0 km	Tidal	Road, sandy beach

Table 6. Continued.

Region and site	County	Latitude[a]	Longitude[a]	Size[b]	Tidal	Habitat
Southwest Coast, continued						
Courtney Campbell Causeway, southeast B	Hillsborough	27° 58.0'	82° 34.0'	1.0 km	Tidal	Road, sandy beach
Delany Creek Canal	Hillsborough	27° 53.0'	82° 24.5'	1.0 km	Tidal	Mangrove, cordgrass marsh, sandy flats
Ding Darling NWR, tower stop	Lee	26° 27.5'	82° 08.0'	150 m x 20 m	Tidal	Brackish coastal pond, muddy flats
Fort Desoto, east end	Pinellas	27° 38.0'	82° 44.5'	1.0 km	Tidal	Muddy flats, mollusk reef
Fort Desoto, northwest end	Pinellas	27° 37.5'	82° 42.0'	1.6 km	Tidal	Sandy beach + flats
Honeymoon Island	Pinellas	28° 04.0'	82° 49.5'	2.0 km	Tidal	Muddy flats, mollusk reef
Howard County Park, causeway	Pinellas	28° 09.5'	82° 48.0'	1.6 km	Tidal	Sandy flats
Howard County Park, west end	Pinellas	28° 09.5'	82° 49.0'	500 m	Tidal	Sandy flats, mixed sand/mud flats
Island north of Bunces Pass	Pinellas	27° 40.0'	82° 44.0'	500 m	Tidal	Sandy beach, mixed sand/mud flats
Lido Beach	Sarasota	27° 19.5'	82° 35.0'	1.0 km	Tidal	Sandy beach
Little Estero CWA	Lee	26° 25.0'	81° 54.0'	250 m x 250 m	Tidal	Tidal lagoon, sandy beach, muddy flats
McKay Bay	Hillsborough	27° 57.0'	82° 25.0'	750 m x 250 m	Tidal	Muddy flats
Old Tampa Bay, north of Frankland Bridge	Hillsborough	27° 57.0'	82° 33.5'	1.6 km x 400 m	Tidal	Mixed sand/mud flats
Palm Island Resort	Charlotte	26° 53.5'	82° 20.5'	750 m	Tidal	Sandy beach, sandy flats
Passage Key NWR	Manatee	27° 33.5'	82° 44.5'	1.6 km	Tidal	Sandy beach
Point Pinellas, west oyster bar	Pinellas	27° 42.0'	82° 40.0'	1.0 km	Tidal	Mixed sand/mud flats, mollusk reef
Shell Key	Pinellas	27° 40.5'	82° 44.0'	1.1 km	Tidal	Sandy beach, mixed sand/mud flats
Three Rooker Bar, north end	Pinellas	28° 07.0'	82° 50.5'	250 m x 100 m	Tidal	Sandy beach and flats
Three Rooker Bar, southeast end	Pinellas	28° 07.0'	82° 50.7'	750 m	Tidal	Mixed sand/mud flats
Turtle Beach, Midnight Pass	Sarasota	27° 12.5'	82° 30.5'	1.0 km	Tidal	Sandy beach
Everglades Coast						
Cape Romano, Morgan Beach	Collier	25° 50.92'	81° 41.13'	500 m x 20 m	Tidal	Sandy beach
Capri Pass	Collier	25° 58.45'	81° 44.82'	300 m x 50 m	Tidal	Mixed sand/mud flats
Carl Ross Key	Monroe	25° 02.5'	81° 01.2'	100 m x 100 m	Tidal	Muddy flats
Lake Ingraham, southeast end	Monroe	25° 08.67'	81° 05.02'	1.0 km x 200 m	Tidal	Muddy flats
Northwest of Palm Key	Monroe	25° 07.38'	80° 53.73'	100 m x 400 m	Tidal	Seagrass bed
Sandy Key	Monroe	25° 02.0'	81° 00.9'	500 m x 75 m	Tidal	Muddy flats
Snake Bight Channel	Monroe	25° 08.13'	80° 53.79'	1.0 km x 200 m	Tidal	Seagrass bed
Tigertail Beach	Collier	25° 56.77'	81° 44.79'	1.0 km x 100 m	Tidal	Sandy beach, muddy flats

Table 6. Continued.

Region and site	County	Latitude[a]	Longitude[a]	Size[b]	Tidal	Habitat
Northeast Coast						
Bennett Causeway, Merritt Island	Brevard	28° 24.37'	80° 39.6'	40 m x 100 m	Tidal	Sand spit, causeway, mollusk reef
Huguenot Memorial Park	Duval	30° 24.5'	81° 24.5'	4.5 km	Tidal	Rock jetties, mixed sand/mud flats
Kennedy Space Center, Pad 39B	Brevard	28° 37.48'	80° 36.7'	1.0 km x 400 m	Nontidal	Diked impoundment, mixed sand/mud flats
Merritt Island NWR, Black Point Drive	Brevard	28° 40.2'	80° 46.37'	400 m x 1.0 km	Nontidal	Brackish coastal pond, tidal marsh
NASA Causeway, north side	Brevard	28° 30.3'	80° 35.87'	1.7 km	Nontidal	Mowed grass causeway
NASA Causeway, south side	Brevard	28° 30.3'	80° 36.0'	2.8 km	Nontidal	Mowed grass causeway
Port Orange Spoil Islands	Volusia	29° 08.88'	80° 58.54'	200 m x 200 m	Tidal	Spoil islands, mollusk reef

[a] Precision of latitude and longitude varied among observers and sites. Sites with well defined and mapped boundaries, such as passes, bridges, and mainland shores, were more likely to be more precisely located.

[b] Single dimensions indicate a length of shoreline sampled; width varied with tide levels.

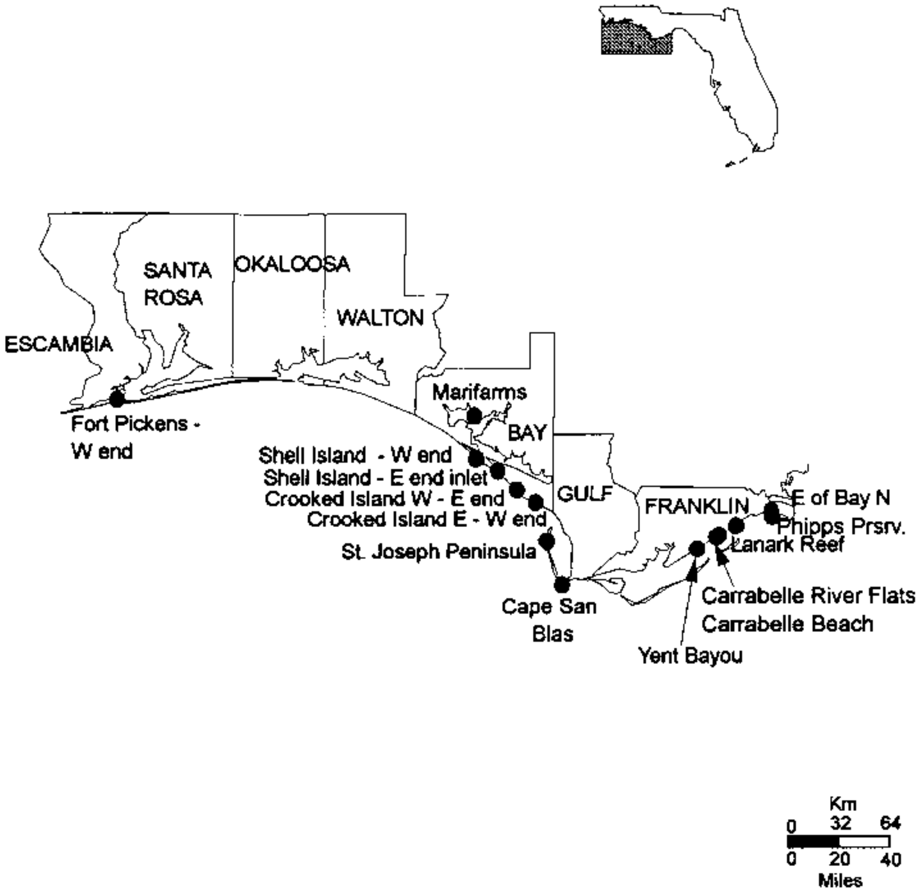

Fig. 6. The 14 sites surveyed for wintering shorebirds along the Panhandle coast of Florida, 16 December 1993 through 1 March 1994.

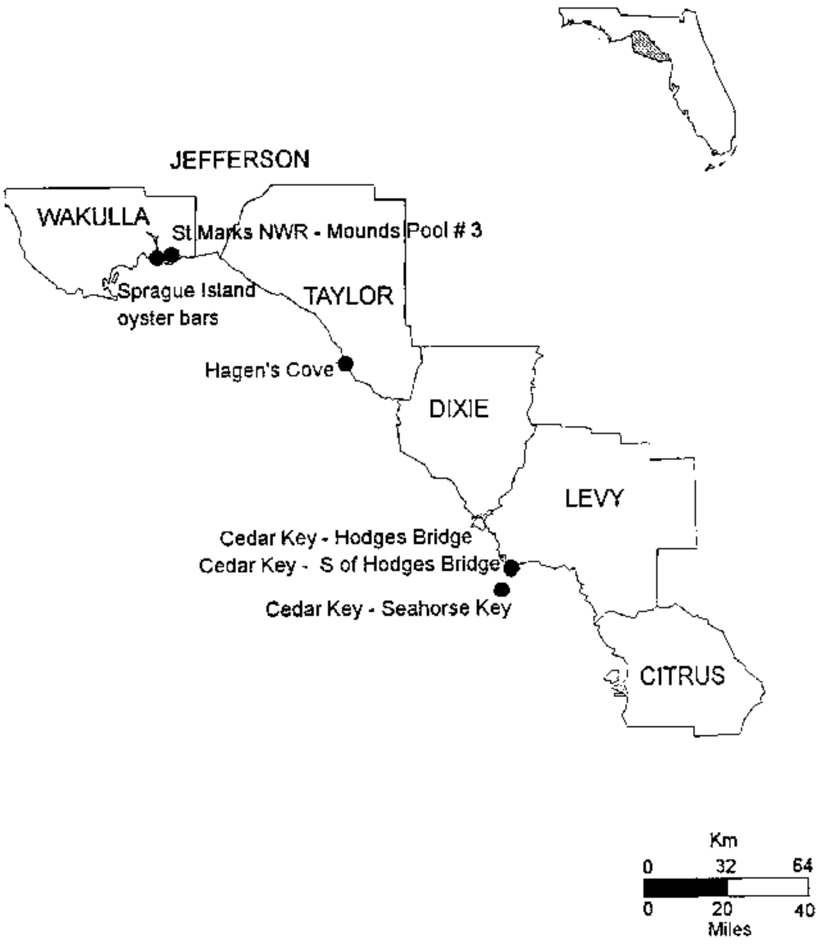

Fig. 7. The 6 sites surveyed for wintering shorebirds along the Big Bend coast of Florida, 16 December 1993 through 1 March 1994.

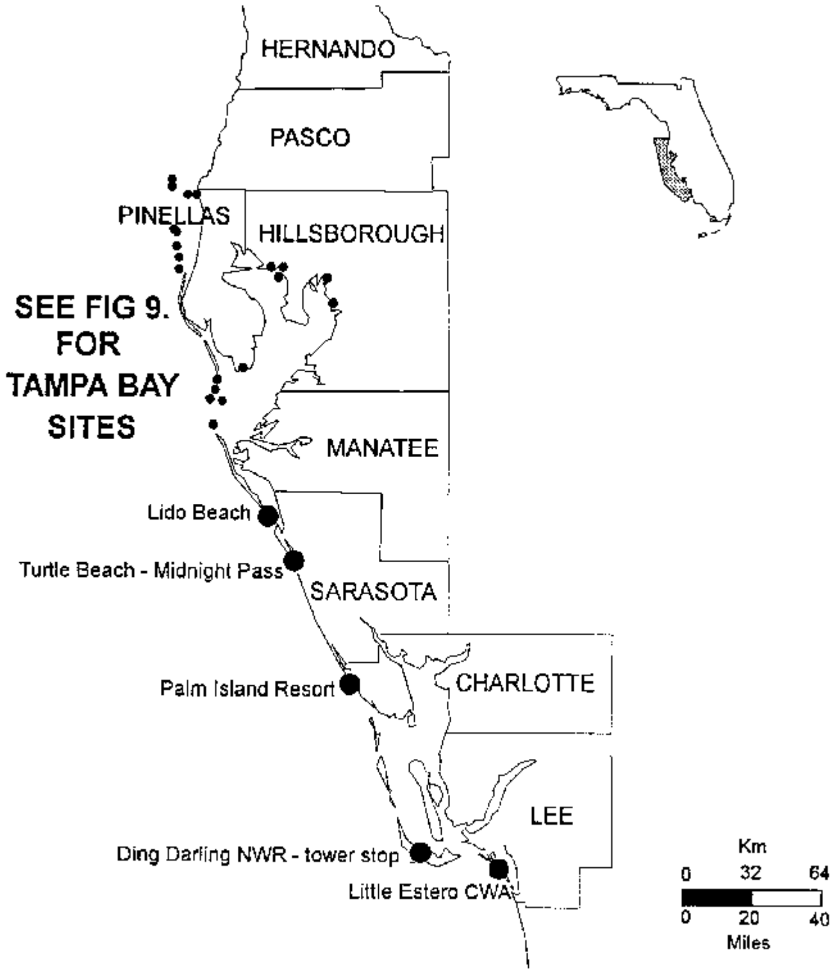

Fig. 8. The 25 sites surveyed for wintering shorebirds along the southwest coast of Florida, 16 December 1993 through 1 March 1994.

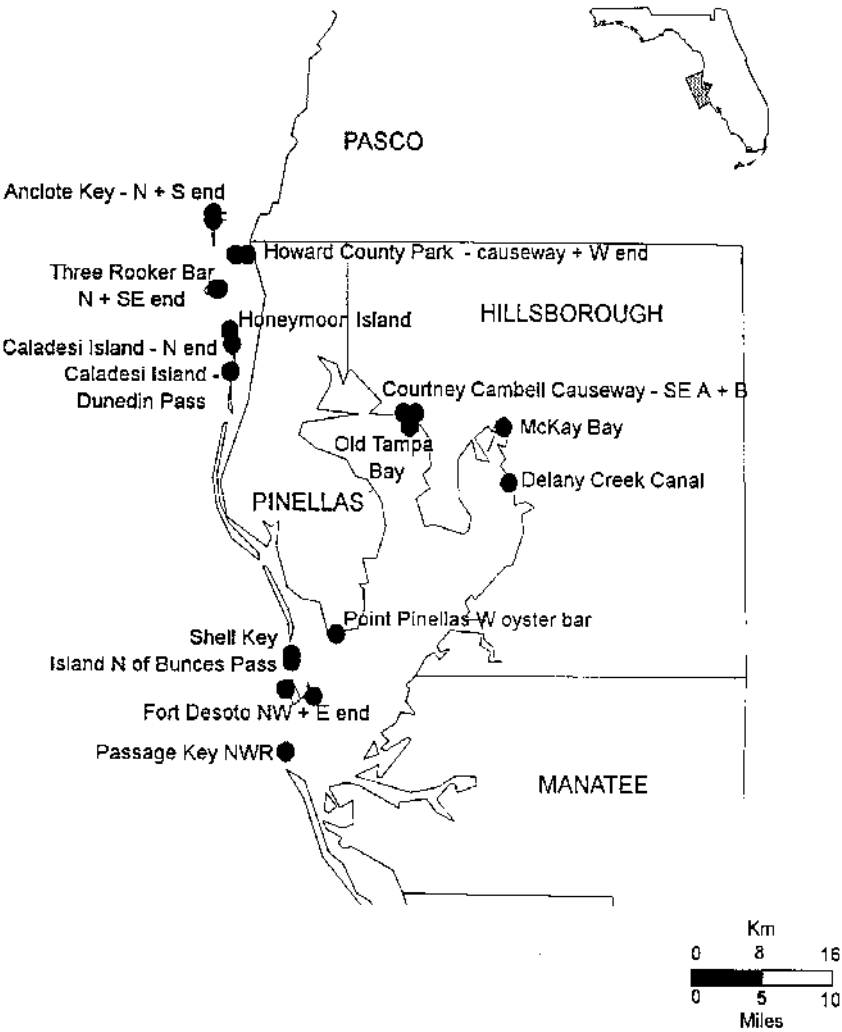

Fig. 9. The 20 sites surveyed for wintering shorebirds in the Tampa Bay area of Florida, 16 December 1993 through 1 March 1994.

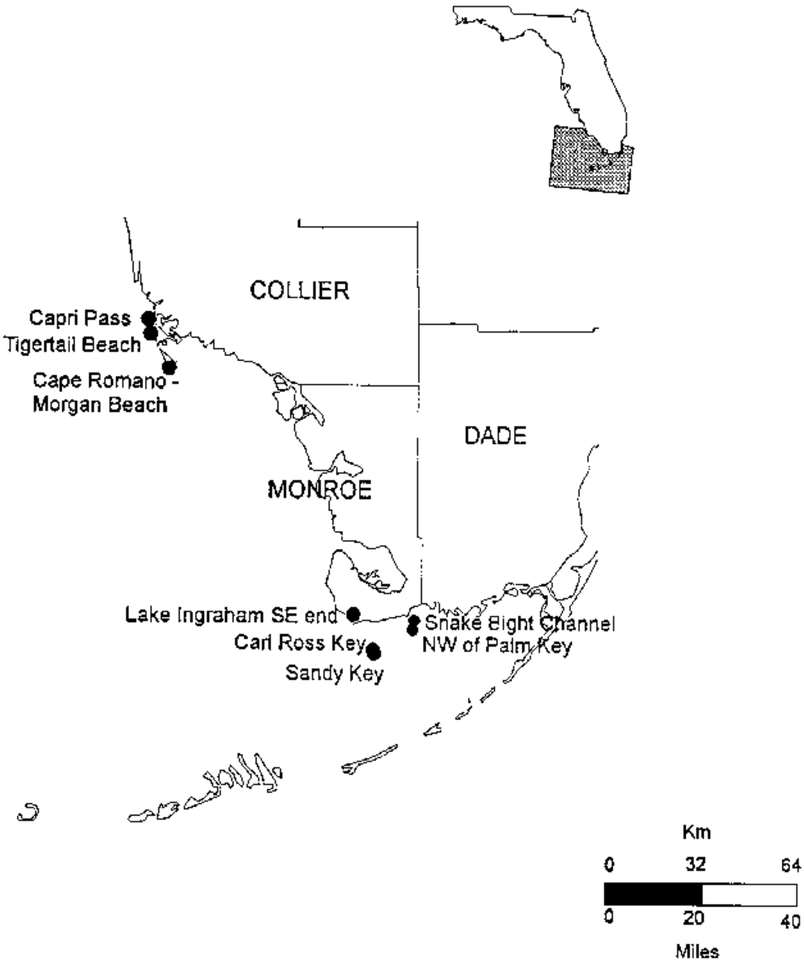

Fig. 10. The 7 sites surveyed for wintering shorebirds along the Everglades coast of Florida, 16 December 1993 through 1 March 1994.

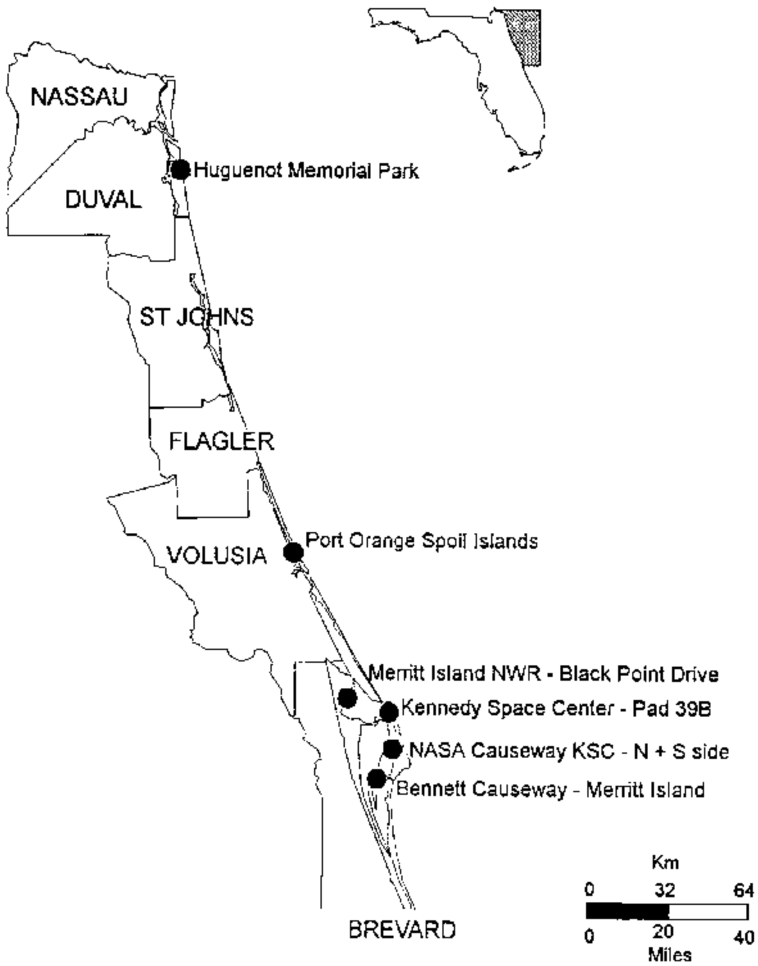

Fig. 11. The 7 sites surveyed for wintering shorebirds along the northeast coast of Florida, 16 December 1993 through 1 March 1994.

Table 7. Average number of wintering shorebird individuals and species at 60 sites surveyed in Florida, 16 December 1993 through 1 March 1994.

		Number of individuals				Number of species			
Region and site	**N[a]**	$\bar{x}$	**SD**	**CV**	**Range**	$\bar{x}$	**SD**	**CV**	**Range**
Panhandle Coast									
Cape San Blas	4	199.0	21.8	0.11	179–230	9.8	1.0	0.10	9–11
Carrabelle Beach	8	319.3	145.6	0.46	18–487	9.3	2.8	0.30	3–12
Carrabelle River Flats	4	77.3	63.6	0.82	5–155	5.0	2.4	0.48	2–7
Crooked Island East, west end	4	81.8	25.4	0.31	61–116	6.3	3.2	0.51	3–9
Crooked Island West, east end	4	69.3	27.7	0.40	36–95	4.8	1.7	0.35	3–7
East of Bay North	7	360.7	271.9	0.75	42–683	4.1	3.1	0.76	0–10
Fort Pickens, west end	4	74.0	34.8	0.47	27–111	4.3	0.5	0.12	4–5
Lanark Reef	4	2,199.0	1,232.6	0.56	442–3,287	14.0	1.2	0.09	13–15
Marifarms	4	551.8	392.4	0.71	198–1015	8.0	3.3	0.41	4–12
Phipps Preserve	6	38.0	32.1	0.84	5–95	4.5	1.5	0.33	2–6
Shell Island, east end inlet	4	181.3	176.9	0.97	29–390	7.8	2.1	0.27	6–10
Shell Island, west end	4	22.0	25.1	1.14	2–55	2.8	2.4	0.86	1–6
St. Joseph Peninsula	4	2.8	4.3	1.54	2–9	1.0	1.2	1.20	0–2
Yent Bayou	8	211.0	149.9	0.71	1–480	8.8	4.0	0.14	1–12
Big Bend Coast									
Cedar Key, Hodges Bridge	5	712.4	1169.0	1.64	14–2716	2.8	1.9	0.68	0–5
Cedar Key, Seahorse Key	4	115.3	141.4	1.23	172–289	2.0	2.4	1.20	0–5
Cedar Key, south of Hodges Bridge	5	328.8	292.5	0.89	140–733	2.6	1.9	0.73	0–4
Hagens Cove	8	470.4	468.6	1.00	8–1198	5.8	2.7	0.47	1–9
Sprague Island oyster bars	4	901.5	929.0	1.03	124–2,136	4.8	2.6	0.54	1–7
St. Marks NWR, Mounds Pool #3	6	812.8	858.1	1.06	13–1,870	5.5	2.3	0.42	2–8
Southwest Coast									
Anclote Key, north end	4	836.3	832.4	1.00	14–1637	6.5	3.1	0.48	2–9
Anclote Key, south end	4	909.5	498.0	0.55	448–1,451	12.0	0.8	0.07	11–13
Caladesi Island, Dunedin Pass	5	348.6	242.2	0.69	112–647	9.4	1.7	0.18	8–12
Caladesi Island, north end	4	496.8	294.5	0.59	200–785	11.0	1.8	0.16	9–13
Courtney Campbell Causeway, southeast A	6	50.2	77.6	1.55	17–190	4.2	4.8	1.14	0–10
Courtney Campbell Causeway, southeast B	6	175.3	245.1	1.40	62–668	5.8	4.4	0.76	0–10
Delany Creek Canal	4	576.5	609.7	1.06	348–1430	6.5	4.4	0.68	0–10
Ding Darling NWR, tower stop	5	349.2	533.1	1.53	190–1278	3.6	3.4	0.94	0–7
Fort Desoto, east end	4	256.0	173.7	0.68	316–387	5.5	4.1	0.75	0–10
Fort Desoto, northwest end	4	848.3	365.4	0.43	414–1,285	7.8	2.9	0.37	4–10
Honeymoon Island	5	929.6	211.1	0.23	678–1,168	13.4	2.3	0.17	10–16
Howard County Park, west end	4	82.0	84.1	1.02	21–206	7.5	3.3	0.44	5–12

Table 7. Continued.

Region and site	N[a]	Number of individuals				Number of species			
		x̄	SD	CV	Range	x̄	SD	CV	Range
Southwest Coast continued									
Howard County Park, causeway	4	208.0	188.8	0.91	20–450	6.8	2.9	0.43	5–11
Island north of Bunces Pass	4	1,886.0	518.5	0.27	1,300–2,497	9.5	3.8	0.40	4–12
Lido Beach	4	164.3	98.4	0.60	48–287	6.3	1.9	0.30	5–9
Little Estero CWA	6	298.0	293.9	0.99	10–800	10.5	3.5	0.33	4–13
McKay Bay	5	353.0	220.8	0.63	116–609	6.2	2.2	0.35	4–9
Old Tampa Bay, north of Frankland Bridge	4	461.8	113.0	0.24	314–582	9.5	2.9	0.31	6–13
Palm Island Resort	4	276.8	112.8	0.41	198–444	8.0	1.8	0.23	6–10
Passage Key NWR	4	609.5	782.6	1.28	87–1,754	6.3	3.3	0.52	3–10
Point Pinellas, west oyster bar	4	475.8	241.5	0.51	313–828	9.5	1.3	0.14	8–11
Shell Key	5	1,856.6	842.5	0.46	456–2,594	11.4	1.1	0.10	10–13
Three Rooker Bar, north end	3	587.0	307.8	0.52	394–942	11.3	2.1	0.19	9–13
Three Rooker Bar, southeast end	4	418.3	282.6	0.68	32–640	8.0	3.6	0.45	5–13
Turtle Beach, Midnight Pass	4	27.5	35.6	1.29	5–80	1.5	0.6	0.40	1–2
Everglades Coast									
Cape Romano, Morgan Beach	4	844.3	658.9	0.78	871–1,610	4.3	3.4	0.79	0–7
Capri Pass	4	813.3	712.7	0.88	211–1,782	7.5	1.3	0.17	6–9
Carl Ross Key	4	7.3	8.6	1.18	12–17	0.8	1.0	1.25	0–2
Lake Ingraham, southeast end	4	2,611.0	2622.2	1.00	708–4,892	7.3	6.3	0.86	0–13
Northwest of Palm Key	4	1,753.3	2713.4	1.55	546–5,800	3.3	2.8	0.85	0–6
Sandy Key	4	137.8	226.9	1.65	33–477	3.5	2.9	0.83	0–7
Snake Bight Channel	5	312.2	644.4	2.06	8–1,463	2.8	4.2	1.50	0–10
Tigertail Beach	4	213.0	379.5	1.78	72–780	4.5	5.4	1.20	0–11
Northeast Coast									
Bennett Causeway, Merritt Island	4	51.3	47.4	0.92	23–122	4.8	1.7	0.35	3–7
Huguenot Memorial Park	4	194.0	155.2	0.80	81–423	5.5	1.3	0.24	4–7
Kennedy Space Center, Pad 39B	4	230.3	164.2	0.71	59–412	7.3	2.2	0.30	5–10
Merritt Island NWR, Black Point Drive	4	1,774.0	1201.2	0.68	1,089–3,571	8.5	2.4	0.28	6–11
NASA Causeway, north side	4	106.5	126.8	1.19	14–292	4.3	1.9	0.44	3–7
NASA Causeway, south side	4	157.3	175.9	1.12	4–370	4.0	1.4	0.35	2–5
Port Orange Spoil Islands	4	87.5	71.1	0.81	3–190	5.0	1.2	0.24	4–6

[a] Number of site visits.

of the importance of a site or region. Lanark Reef had the greatest average number of species (14) per visit. At 6 other sites, all along the southwest coast, we observed an average of >10 species per visit: Anclote Key, south end; Caladesi Island, north end; Honeymoon Island; Little Estero Critical Wildlife Area (CWA); Shell Key; and Three Rooker Bar, north end (Table 7). Based solely on diversity of species, the southwest coast clearly had most of the important sites for wintering shorebirds in Florida.

Both the Panhandle and northeast coasts averaged relatively high numbers of species at all sites (6.8 and 5.5, respectively) despite small numbers of individuals at most sites. For example, all 7 of the sites in the northeast region and 12 of 14 in the Panhandle averaged ≥4 species per visit. In comparison, only half the 6 sites along the Big Bend and half the 8 sites on the Everglades coasts averaged ≥4 species per visit.

These apparent differences in numbers of species may be partly due to difficulties in identifying species at a distance, because shallow waters of the Big Bend and Everglades regions often prevented observers from approaching birds closely (Appendices B, C). These 2 regions had the greatest average maximum distance from the birds, 425 and 523 meters respectively, but the difference from the other regions was not statistically significant ($t = 1.14$, $P = 0.2$, $1 - \beta = 17$, d $= 0.31$, $n = 24.6$). More likely, species numbers reflected differences in habitat among regions, such as availability of modest mudflats and extensive beaches in the northeast and Panhandle and the scarcity of wave-washed beaches in the Big Bend and Everglades regions. Lack of beach habitat restricts use by many species such as piping plovers, snowy plovers, and sanderlings. Conversely, the scarcity of expansive mud or sandflats along the northeast and Panhandle coasts may have been responsible for the rarity of sites with large numbers of individuals. Alternatively, the northern sites in the Panhandle and northeast coast may have colder temperatures that precluded some species.

Table 8. Number of shorebird sites surveyed in each region, categorized by average shorebird abundance observed in Florida, 16 December 1993 through 1 March 1994.

	Mean number of shorebirds observed		
Region	**< 250**	**< 1,000**	**≥ 1,000**
Panhandle	10	3	1
Big Bend	1	5	0
Southwest	6	17	2
Everglades	3	3	2
Northeast	6	0	1
Statewide	26	28	6

Although our survey concentrated on coastal areas, inland sites may also be important for both migrating and wintering shorebirds (Fig. 3). For example, thousands of migrant and wintering shorebirds have been recorded in the abandoned phosphate pits in Polk County (ISS, unpubl. data). Other inland sites that occasionally support large numbers of migrant or wintering shorebirds include the Zellwood muck farms near Lake Apopka and the Everglades agricultural area. Species observed include many not normally seen at coastal sites such as long-billed dowitcher, black-necked stilt, stilt sandpiper, and larger numbers of lesser and greater yellowlegs.

Statewide Results by Species.—Species most commonly observed during the survey were dunlin, western sandpiper, sanderling, and short-billed dowitcher; the rarest species were black-necked stilt, spotted sandpiper, long-billed curlew, common snipe, and purple sandpiper (Table 9, Appendix K). Peeps (western or least sandpipers) and unidentified birds were also commonly observed. We did not observe solitary sandpiper, semipalmated sandpiper, pectoral sandpiper, stilt sandpiper, long-billed dowitcher, or American woodcock, all of which winter in Florida (Stevenson and Anderson 1994) and have been recorded, though rarely and often in interior locations, on recent CBCs in Florida (Appendix D).

As expected, the distribution and relative abundance of shorebird species varied among coastal regions (Figs. 12–29, Table 9). Although dunlins were common throughout the state, they were much less common in the Everglades. In contrast, more western sandpipers were observed in the Everglades than in any other region. Sanderlings were uncommon in the Big Bend and Everglades regions, probably due to the scarcity of wave-washed beaches. Willets were remarkably uncommon along the northeast coast. The small plovers, particularly Wilson's plovers, were most common along the southwest coast, although many piping and snowy plovers wintered in the Panhandle. American oystercatchers and marbled godwits were most common along the Panhandle and southwest coasts. The relative rarity of greater yellowlegs, lesser yellowlegs, and common snipe was probably due to surveys being primarily coastal, rather than conducted in the freshwater wetlands favored by these species (Hayman et al. 1986, Arnold 1994).

No species was seen at every site, but black-bellied plovers were seen at least once at 58 sites and dunlin at least once at 56 of the 60 sites. American avocets, black-necked stilts, long-billed curlews, spotted sandpipers, common snipes, and purple sandpipers were seen at ≤3 of the 60 sites (Appendix K).

Shorebirds frequently move among several neighboring sites (Kelly and Cogswell 1979, Warnock et al. 1995); therefore, we suspect our survey sites were not independent. This has important implications for conservation and monitoring of shorebird populations. If each site has a separate group of wintering individuals, loss of a single small site may not be critical. On the other

Table 9. Estimates of the average number of shorebirds wintering along Florida's coastline, by region. Estimates are based upon the sum of the average number of birds counted at 60 sites from 16 December 1993 through 1 March 1994.

	Statewide		Panhandle		Big Bend		Southwest		Everglades		Northeast	
Species	**Number**	**Sites**	**Number**	**Sites**	**Number**	**Sites**	**Number**	**Sites**	**Number**	**Sites**	**Number**	**Sites**
Dunlin	6,698.2	56	1,354.4	12	1,275.3	6	2,348.0	24	689.3	7	1,031.3	7
Unidentified shorebirds	4,784.0	44	493.0	8	900.0	5	2,036.8	23	1,000.0	1	354.3	7
Western sandpiper	3,523.0	40	201.9	7	24.7	2	1,206.0	21	2,050.8	7	39.8	3
Peep	2,982.7	38	92.4	6	391.6	3	665.2	21	1,487.5	4	346.0	4
Sanderling	2,626.7	49	465.6	13	23.0	1	1,864.8	23	88.0	5	185.3	7
Short-billed dowitcher	2,131.2	45	247.3	6	317.2	5	1,245.3	22	267.6	7	53.8	5
Willet	1,916.2	51	604.0	13	244.9	6	757.3	22	307.2	6	2.8	3
Red knot	1,452.4	27	124.4	3	0.0	0	1,092.0	18	183.0	4	53.0	2
Black-bellied plover	1,191.6	58	177.7	13	44.6	6	588.7	25	168.0	7	212.5	7
Semipalmated plover	926.5	44	99.9	9	6.3	2	683.3	23	108.3	6	28.8	4
Ruddy turnstone	522.2	50	64.0	11	54.0	4	233.5	24	61.0	4	108.8	7
Marbled godwit	324.6	16	180.8	3	4.4	2	90.1	8	49.4	3	0.0	0
Wilson's plover	282.0	29	1.6	3	0.0	0	210.4	21	69.9	5	0.0	0
Least sandpiper	264.3	24	24.1	5	2.8	3	78.2	12	143.0	2	16.3	2
Piping plover	229.1	25	104.6	10	1.1	1	114.9	12	5.8	1	2.8	1
American oystercatcher	157.6	28	81.2	5	9.4	2	59.5	20	0.0	0	7.5	1
Snowy plover	100.7	25	46.4	10	0.0	0	51.6	14	2.8	1	0.0	0
Lesser yellowlegs	95.6	14	0.0	0	2.5	1	4.4	7	8.7	4	80.0	2
Killdeer	76.1	18	4.0	8	5.3	3	22.3	5	0.0	0	44.5	2
Plover spp.	63.8	16	3.6	3	1.0	1	59.2	12	0.0	0	0.0	0
American avocet	57.0	3	0.0	0	0.0	0	56.2	2	0.0	0	0.8	1
Greater yellowlegs	51.3	16	14.0	7	17.6	3	0.9	4	0.0	0	18.8	2
Yellowlegs spp.	26.7	8	0.3	1	13.1	3	0.6	1	0.0	0	12.8	3
Whimbrel	13.2	8	0.8	2	2.3	1	8.2	4	2.0	1	0.0	0
Black-necked stilt	1.6	1	0.0	0	0.0	0	1.6	1	0.0	0	0.0	0
Spotted sandpiper	1.1	3	0.0	0	0.0	0	1.1	3	0.0	0	0.0	0
Long-billed curlew	1.0	2	0.0	0	0.0	0	0.5	1	0.0	0	0.5	1
Common snipe	0.9	2	0.0	0	0.2	1	0.0	0	0.0	0	0.8	1
Purple sandpiper	0.3	1	0.0	0	0.0	0	0.0	0	0.0	0	0.3	1
Total	**30,501.3**	**60**	**4,387.0**	**14**	**3,341.2**	**6**	**13,480.5**	**25**	**6,692.0**	**8**	**2,600.8**	**7**

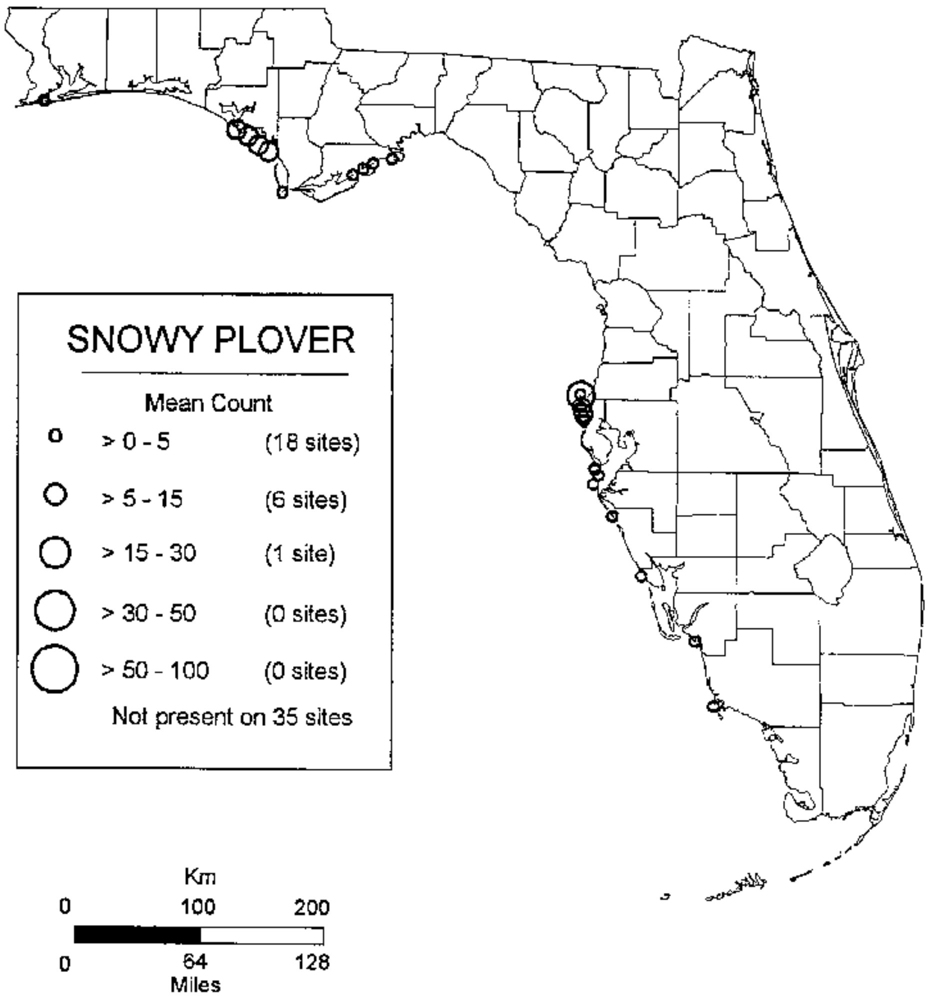

Fig. 12. The mean number of wintering snowy plovers observed during multiple counts at 60 selected sites in Florida, 16 December 1993 through 1 March 1994.

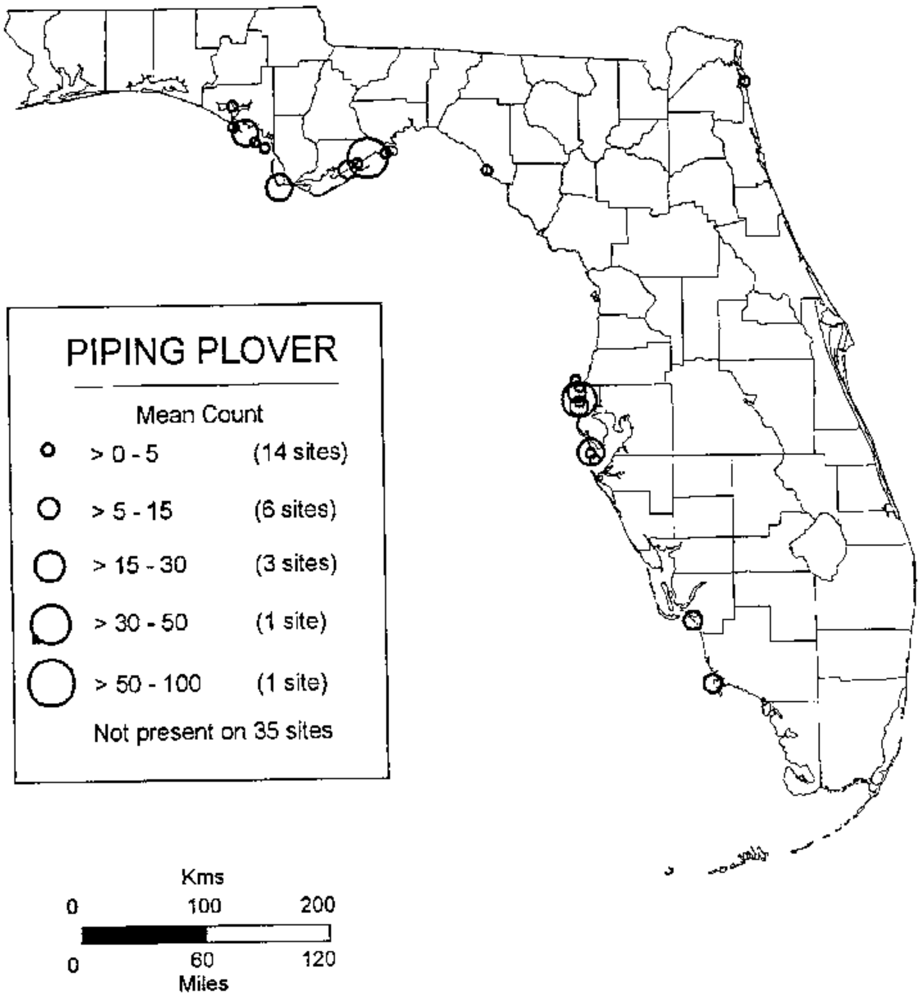

Fig. 13. The mean number of wintering piping plovers observed during multiple counts at 60 selected sites in Florida, 16 December 1993 through 1 March 1994.

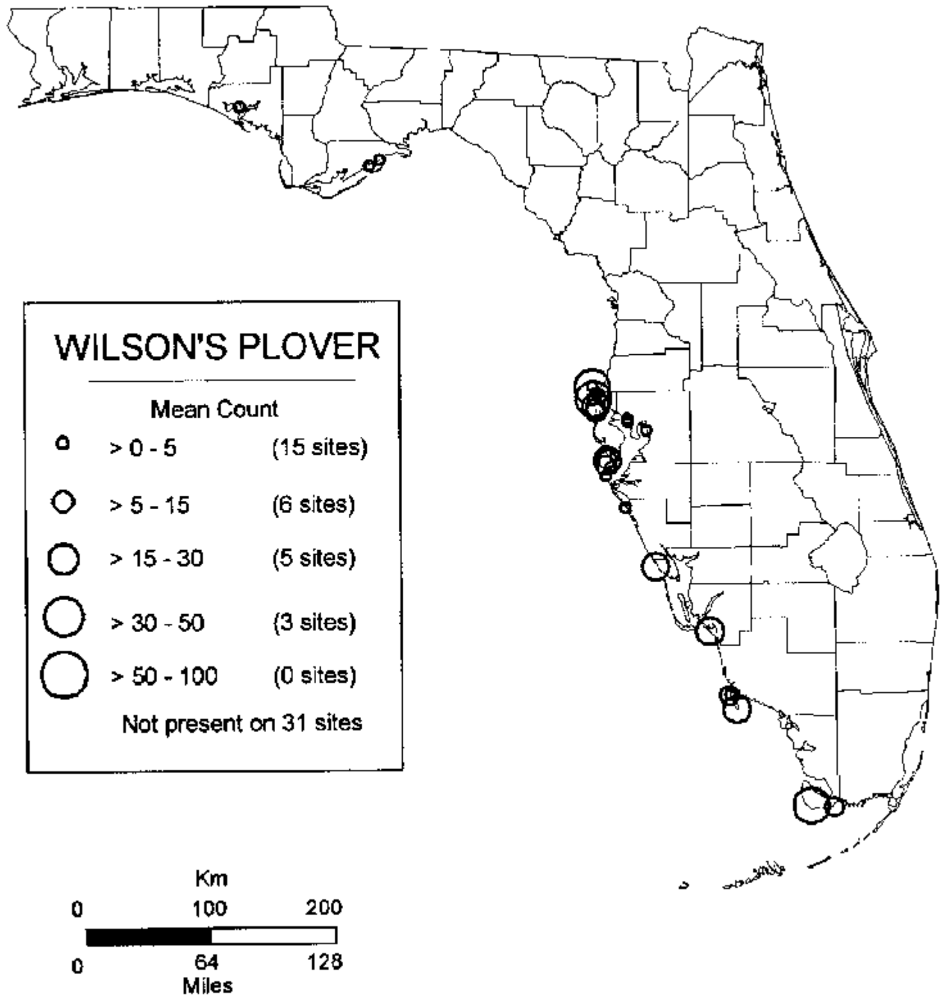

Fig. 14. The mean number of wintering Wilson's plovers observed during multiple counts at 60 selected sites in Florida, 16 December 1993 through 1 March 1994.

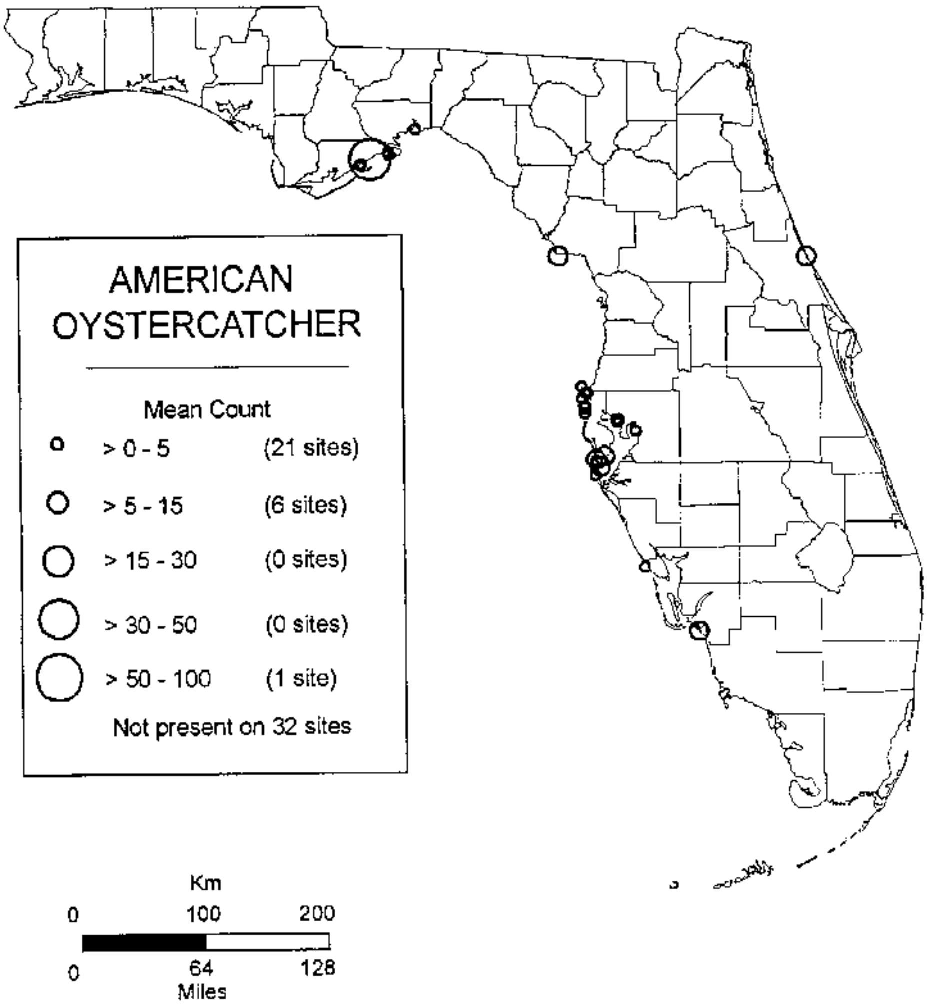

Fig. 15. The mean number of wintering American oystercatchers observed during multiple counts at 60 selected sites in Florida, 16 December 1993 through 1 March 1994.

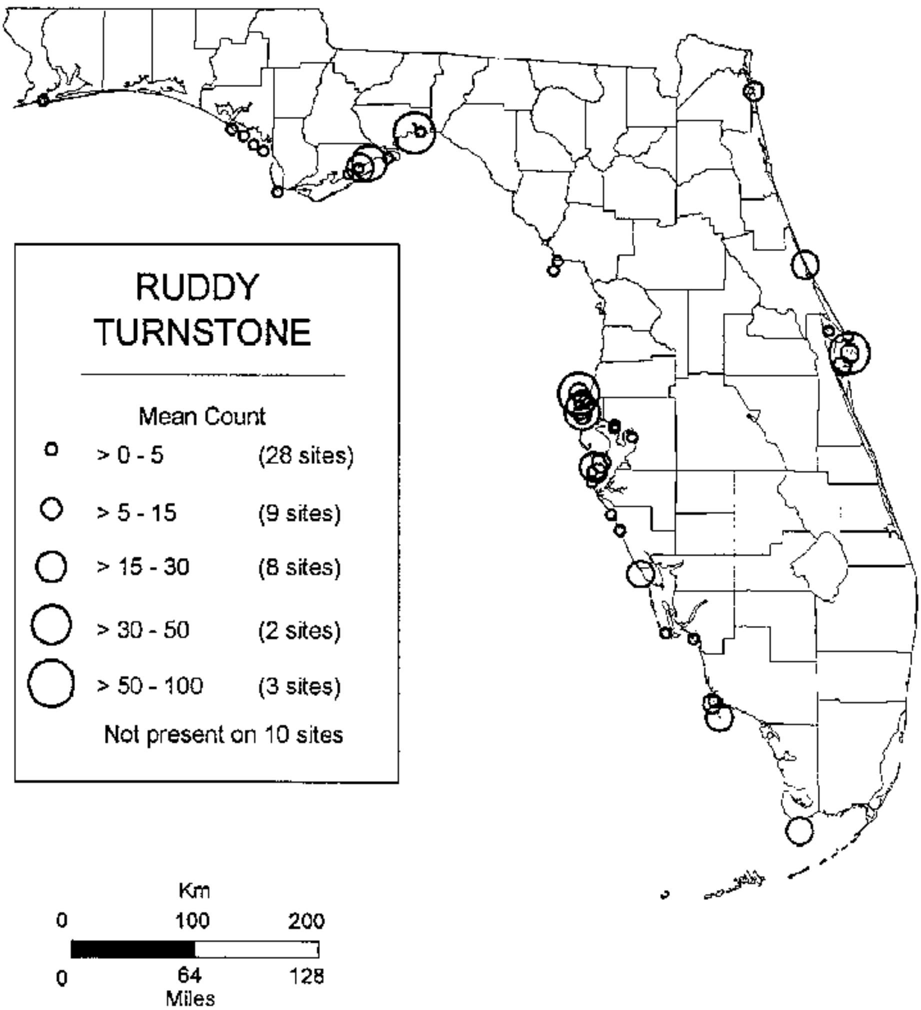

Fig. 16. The mean number of wintering ruddy turnstones observed during multiple counts at 60 selected sites in Florida, 16 December 1993 through 1 March 1994.

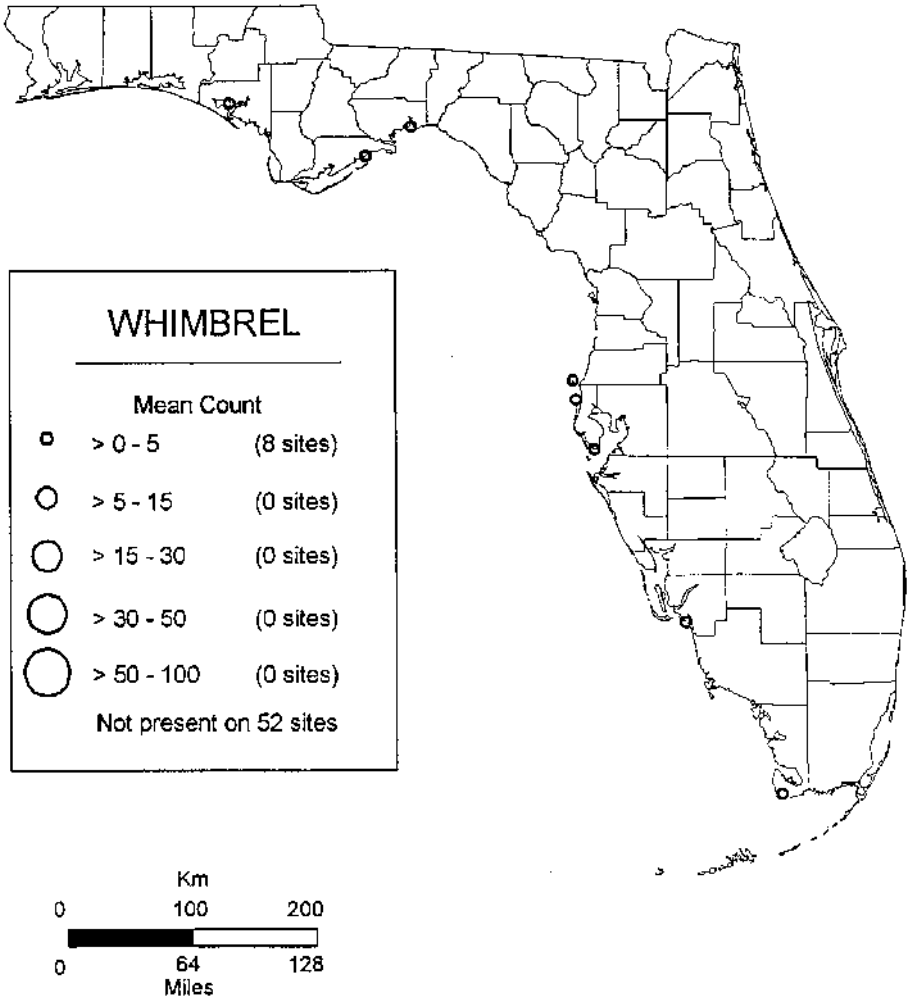

Fig. 17. The mean number of wintering whimbrels observed during multiple counts at 60 selected sites in Florida, 16 December 1993 through 1 March 1994.

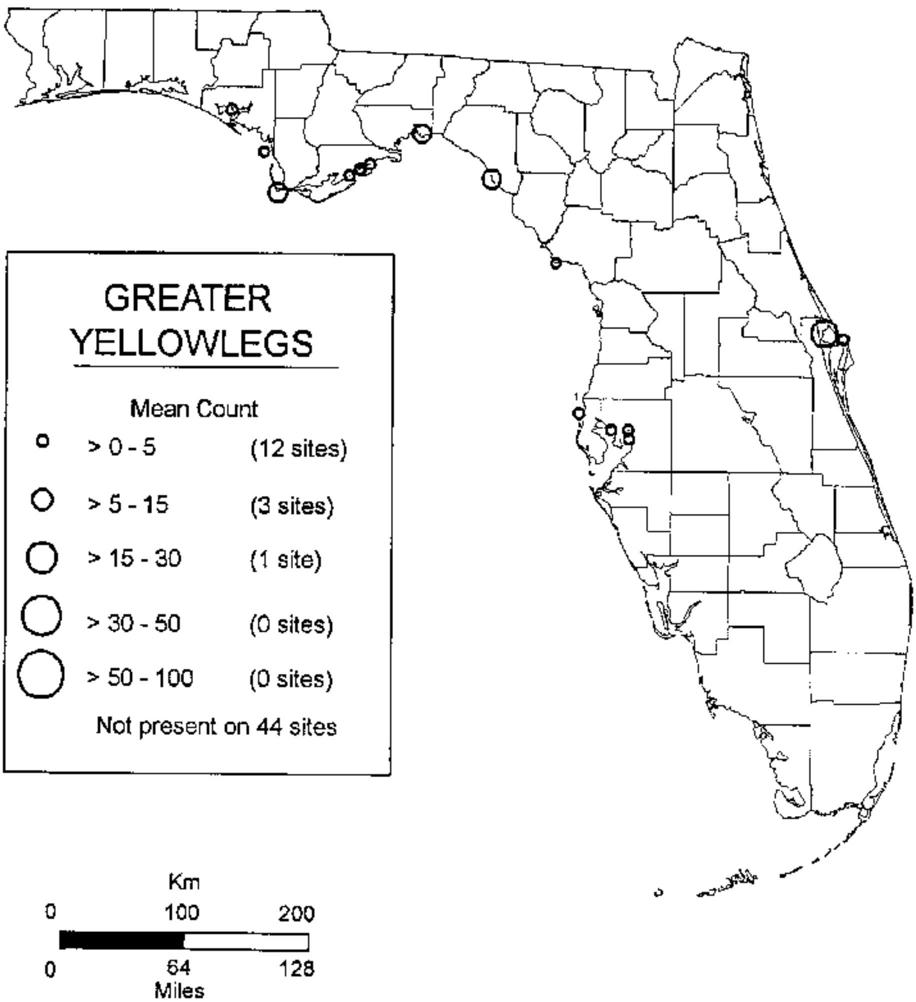

Fig. 18. The mean number of wintering greater yellowlegs observed during multiple counts at 60 selected sites in Florida, 16 December 1993 through 1 March 1994.

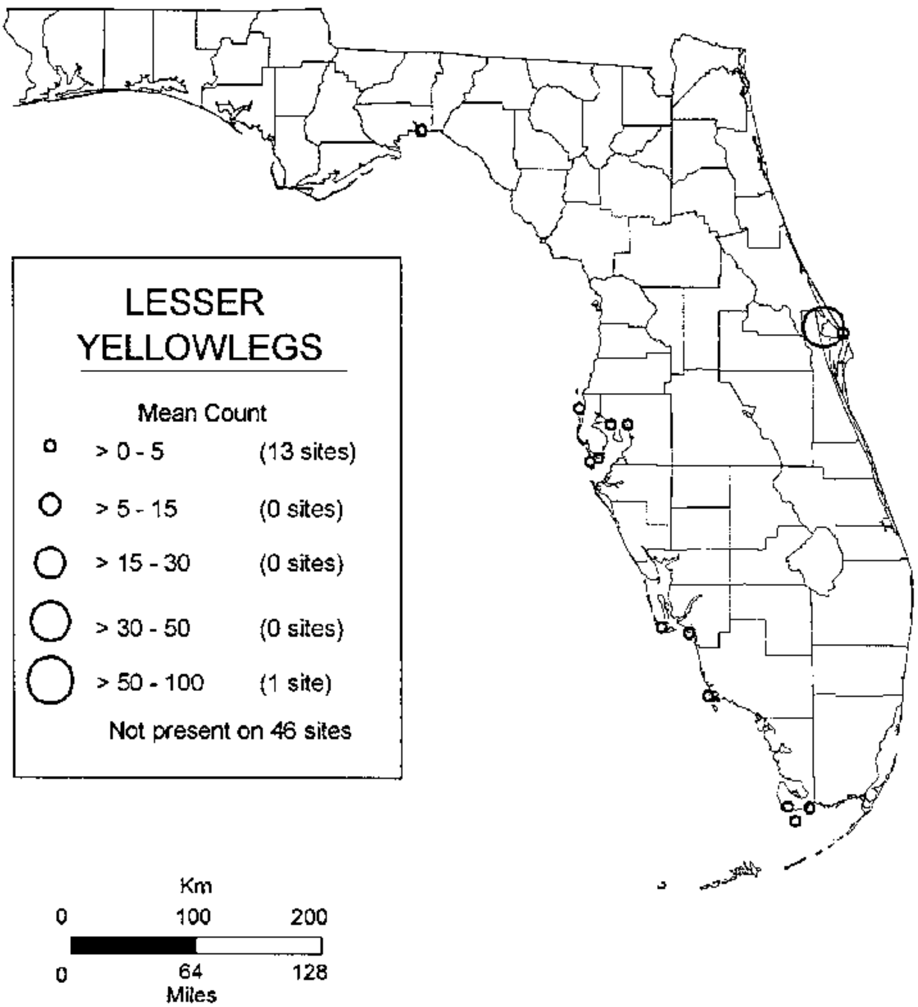

Fig. 19. The mean number of wintering lesser yellowlegs observed during multiple counts at 60 selected sites in Florida, 16 December 1993 through 1 March 1994.

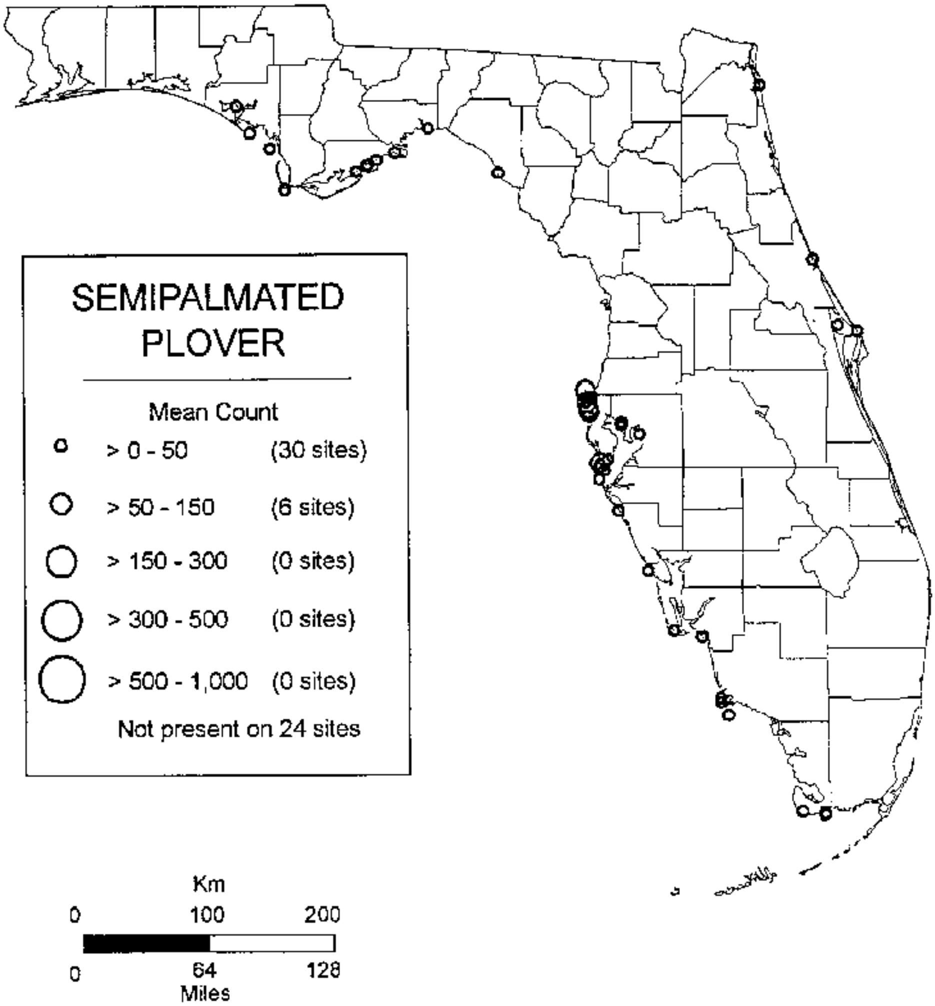

Fig. 20. The mean number of wintering semipalmated plovers observed during multiple counts at 60 selected sites in Florida, 16 December 1993 through 1 March 1994.

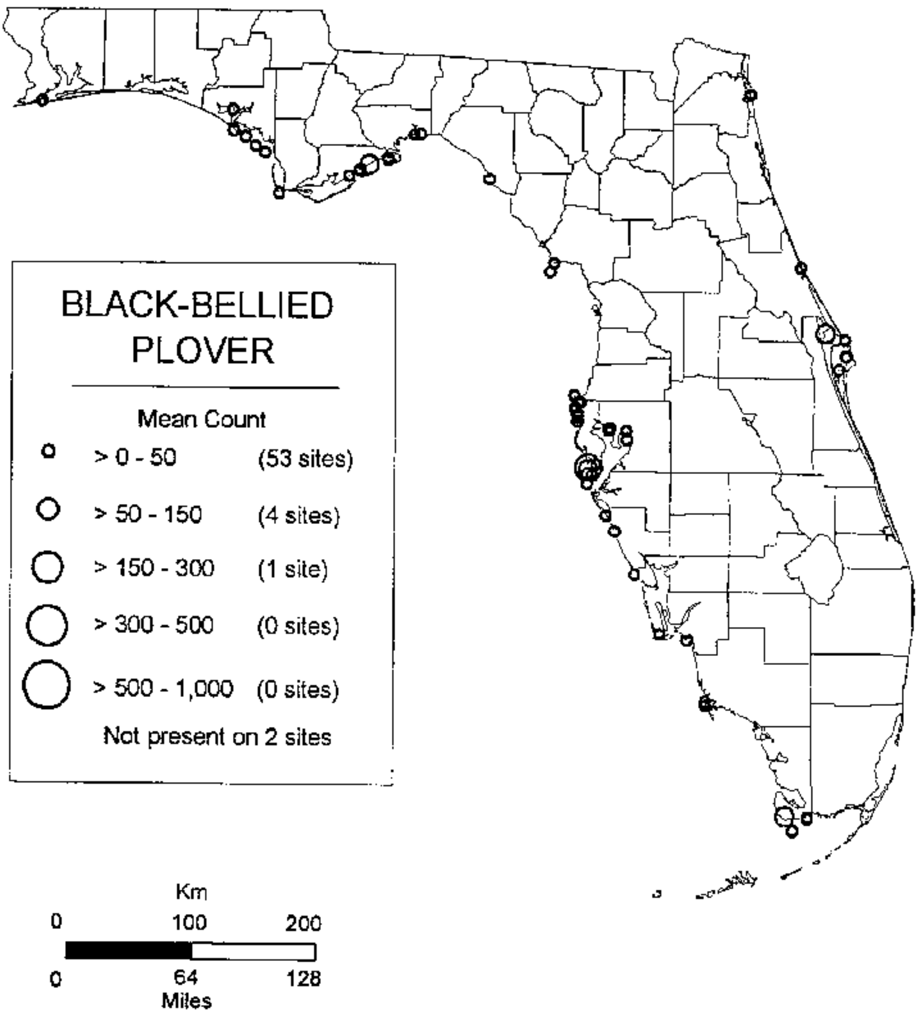

Fig. 21. The mean number of wintering black-bellied plovers observed during multiple counts at 60 selected sites in Florida, 16 December 1993 through 1 March 1994.

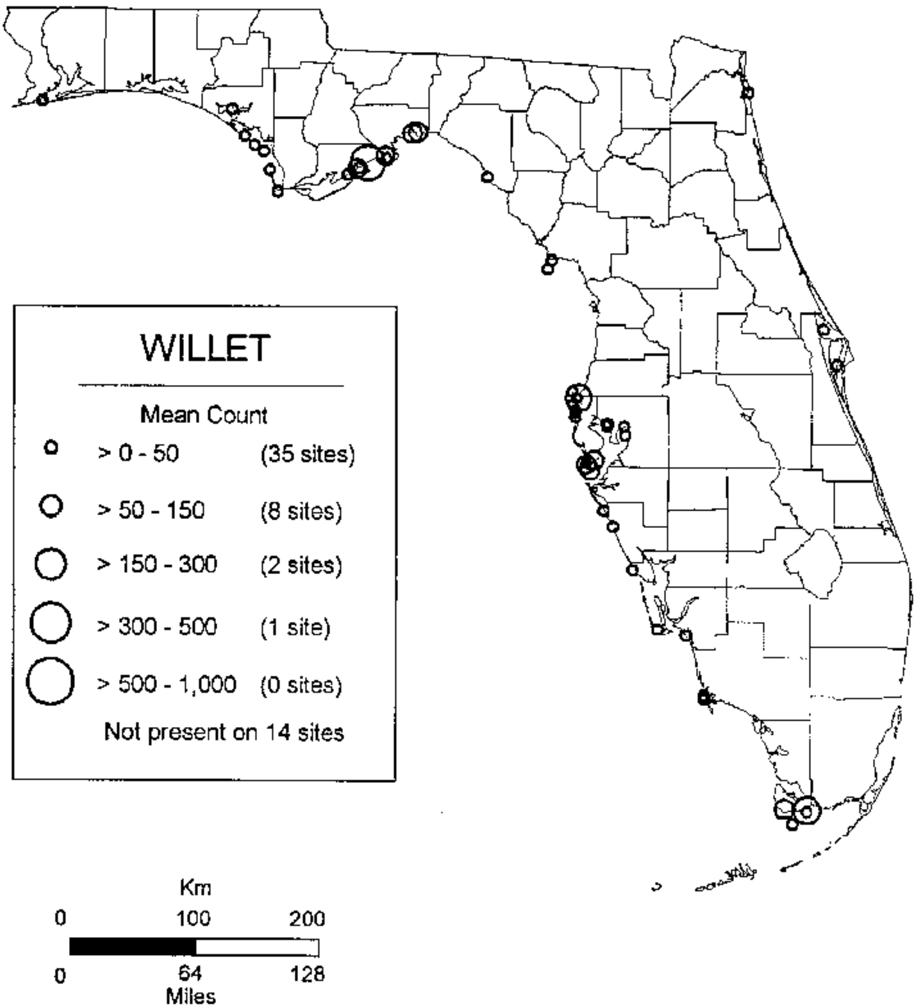

Fig. 22. The mean number of wintering willets observed during multiple counts at 60 selected sites in Florida, 16 December 1993 through 1 March 1994.

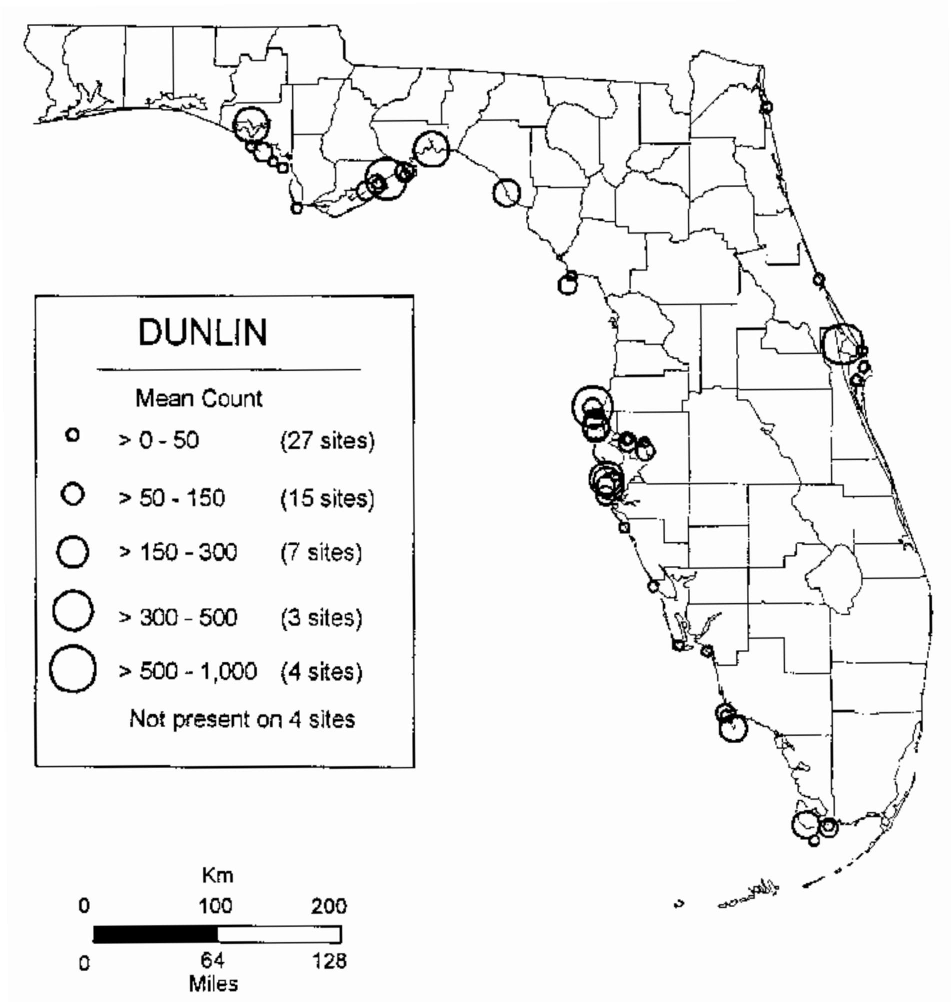

Fig. 23. The mean number of wintering dunlins observed during multiple counts at 60 selected sites in Florida, 16 December 1993 through 1 March 1994.

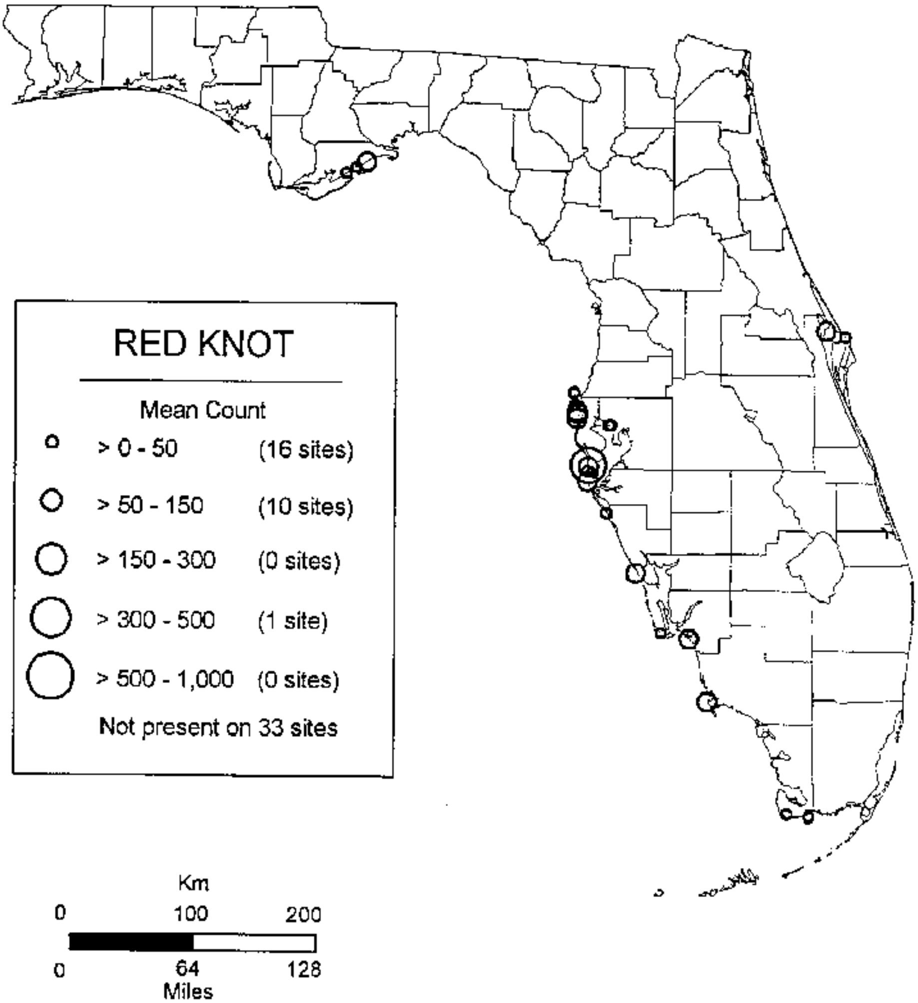

Fig. 24. The mean number of wintering red knots observed during multiple counts at 60 selected sites in Florida, 16 December 1993 through 1 March 1994.

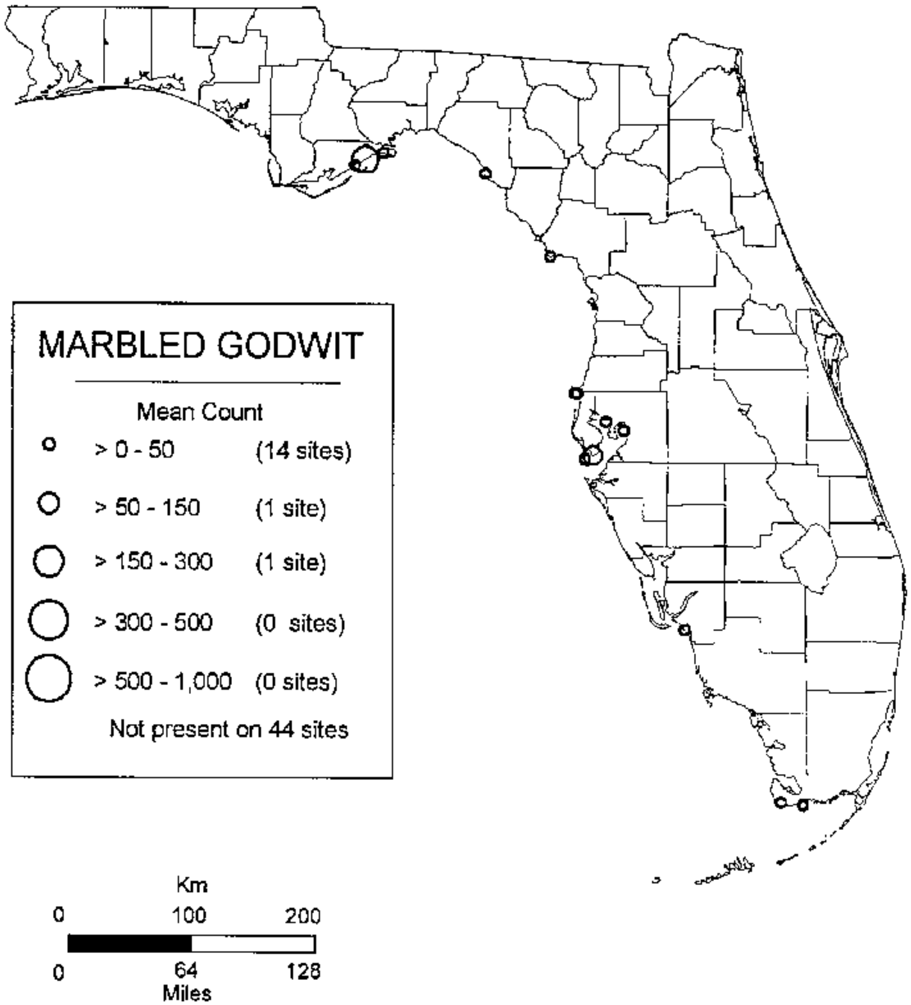

Fig. 25. The mean number of wintering marbled godwits observed during multiple counts at 60 selected sites in Florida, 16 December 1993 through 1 March 1994.

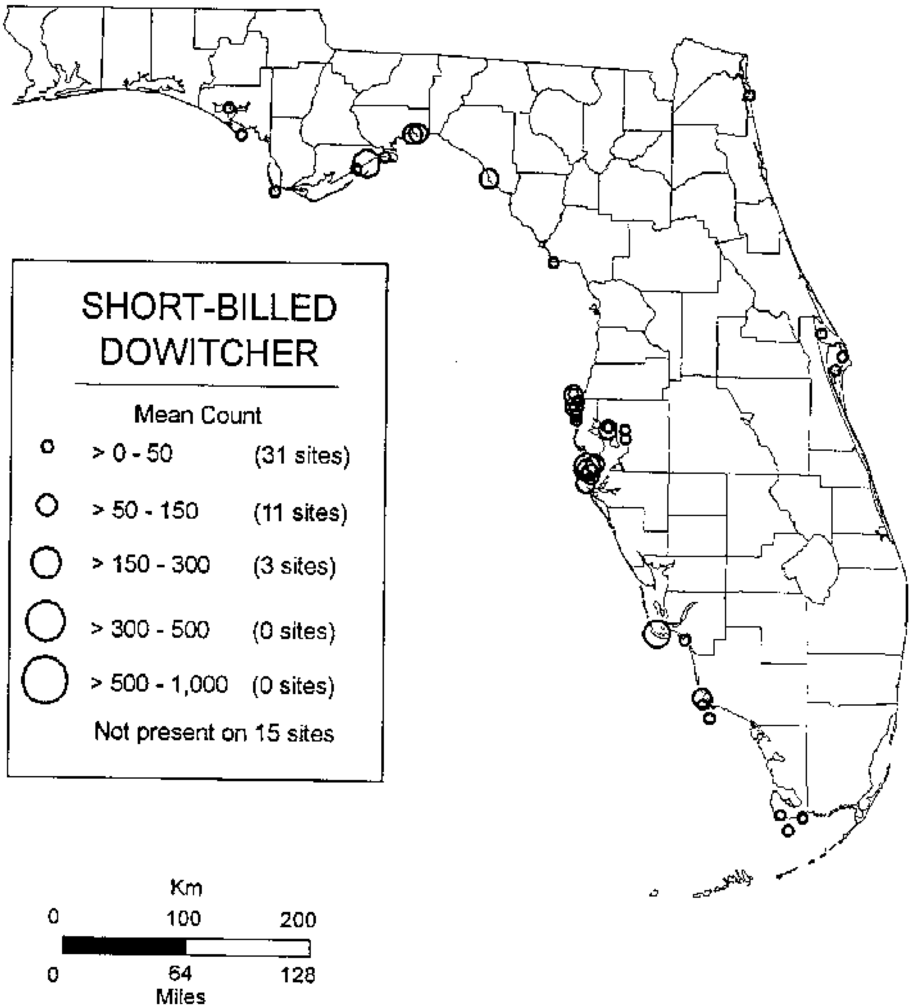

Fig. 26. The mean number of wintering short-billed dowitchers observed during multiple counts at 60 selected sites in Florida, 16 December 1993 through 1 March 1994.

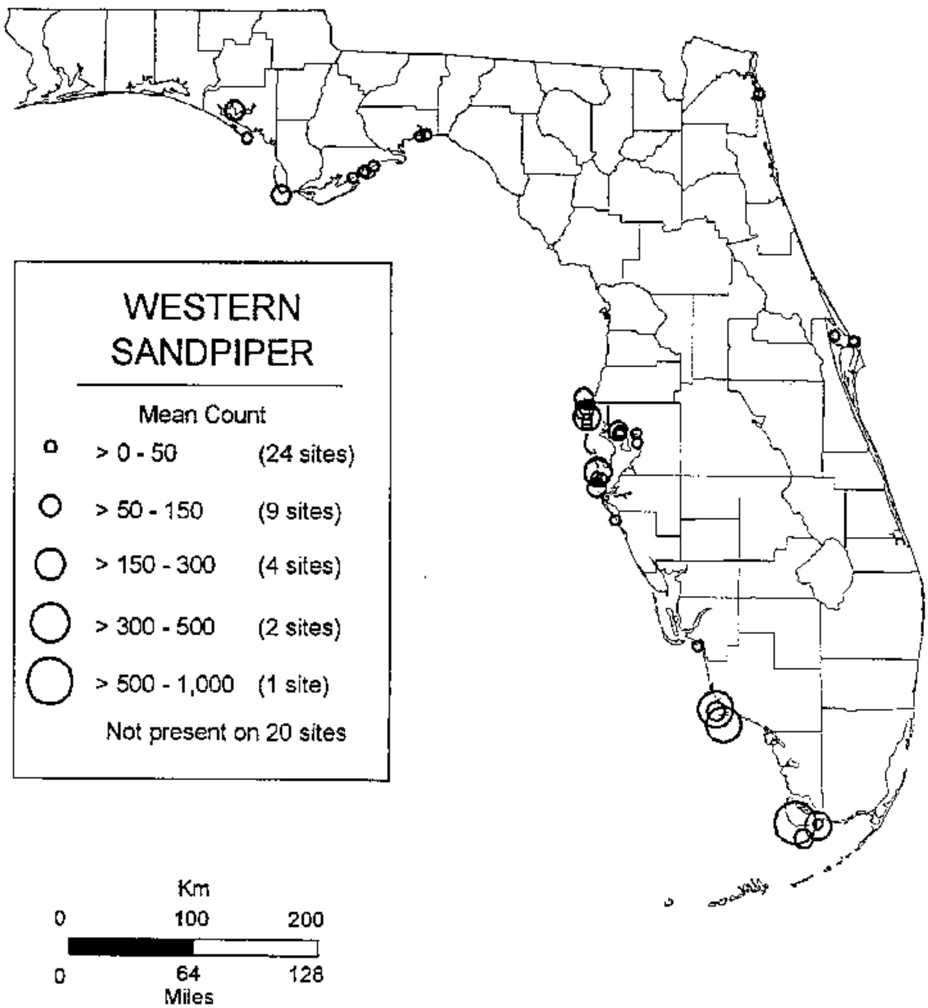

Fig. 27. The mean number of wintering western sandpipers observed during multiple counts at 60 selected sites in Florida, 16 December 1993 through 1 March 1994.

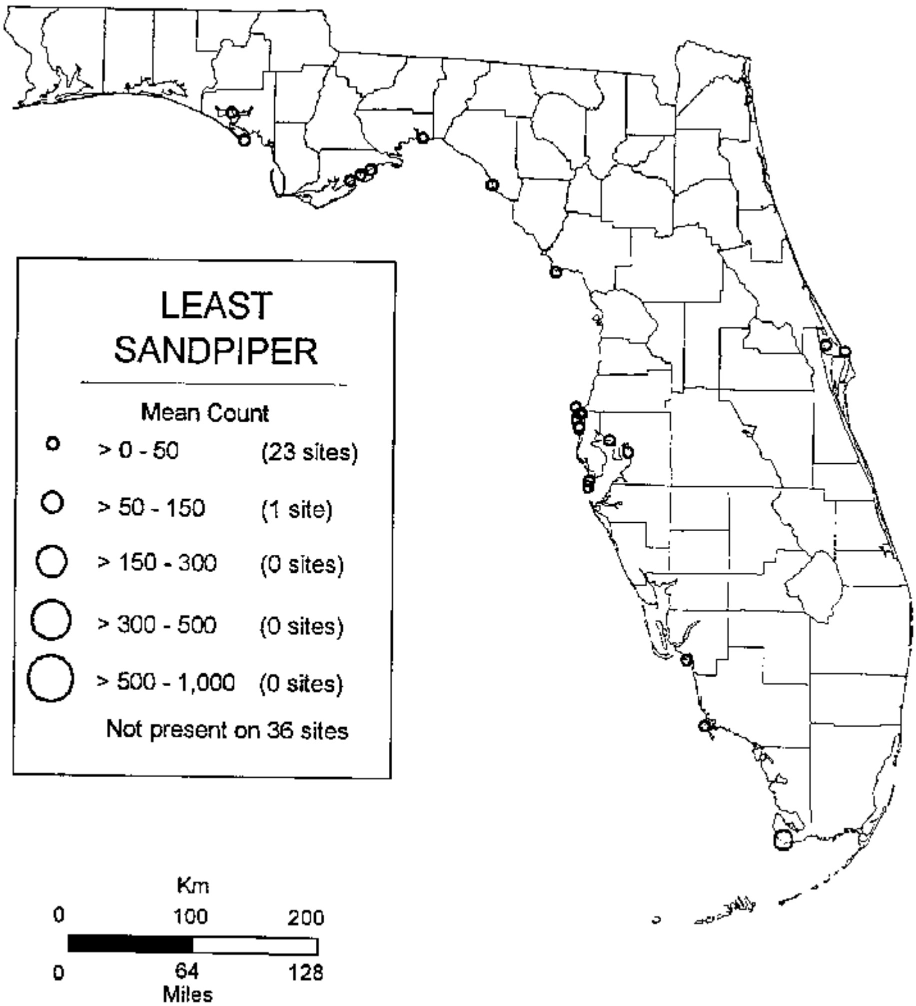

Fig. 28. The mean number of wintering least sandpipers observed during multiple counts at 60 selected sites in Florida, 16 December 1993 through 1 March 1994.

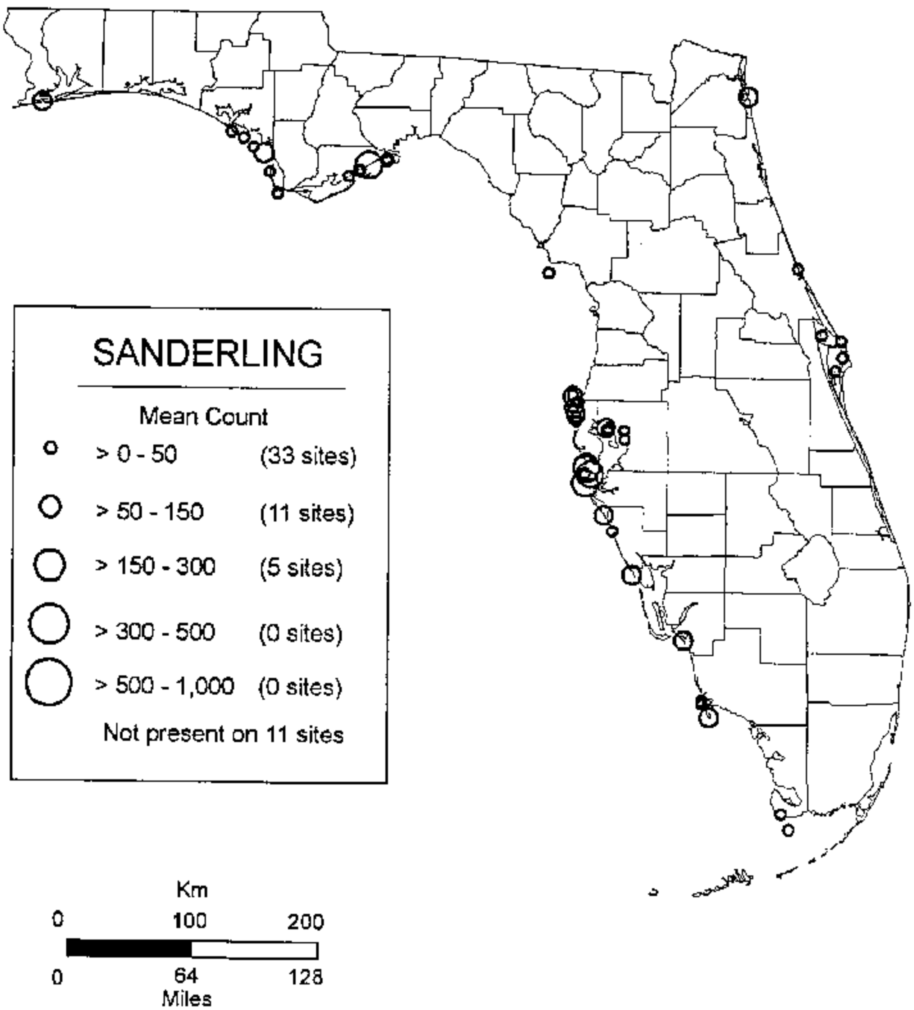

Fig. 29. The mean number of wintering sanderlings observed during multiple counts at 60 selected sites in Florida, 16 December 1993 through 1 March 1994.

hand, if a group of birds uses several nearby sites, each site may be providing a particular foraging or roosting benefit, so loss of any site might affect the wintering shorebird population in the whole local area (Goss-Custard et al. 1995*a*). The use of the Lanark Reef-East of Bay North-Carrabelle-Yent Bayou (Fig. 6) area by marbled godwits (Fig. 25), willets (Fig. 22), and American oystercatchers (Fig. 15) may be a good example. Only by studying marked individuals can the relative importance of individual sites within a cluster of sites be determined. Birds may also move between estuaries or clusters up to 40 km distant, so a given census may underestimate the true local population (Myers 1983). Unless simultaneous counts are made by different observers at different sites or birds are marked, surveys at different sites may make multiple counts of the same individuals and greatly overestimate population sizes.

Historical Changes in Shorebird Distribution.**—**Florida's human population has increased from 968,000 people in 1920 to 2,771,000 in 1950 and to 12,938,000 in 1990 (Marth and Marth 1992). The tremendous development along Florida's coast associated with the increased human population has likely caused changes in shorebird numbers or distribution. Unfortunately, no systematic shorebird surveys were conducted before Florida's development to allow quantitative comparisons of shorebird numbers. Some anecdotal observations of past shorebird numbers are, however, available from Audubon's travels in Florida in the 1830s (Proby 1974) and from Bent (1929) and Howell (1932). CBCs from 1949 through 1953 (Anon. 1949, 1950, 1951, 1952, 1953) also provide historical accounts of shorebird numbers, but because of differing techniques, only qualitative or rank comparison of numbers may be made with our statewide data (Caughley 1977).

Perhaps the most striking difference between our observations and earlier reports is the paucity of shorebirds, particularly small plovers, that we observed on the east coast of Florida (Fig. 12–29). Whereas we found no Wilson's plovers on the east coast (Fig. 14), Howell (1932) considered Wilson's plovers to be "common" statewide, and in 1835 Audubon mentioned this bird as "more abundant than any other" wintering near St. Augustine (Proby 1974). Bent (1929) recorded observations of Wilson's plovers at St. Augustine and New Smyrna, and CBCs at St. Augustine included 4 birds in 1949 and 53 in 1950. In 1952, 1 Wilson's plover was seen near Cocoa and 3 in Miami. In 1953, 22 Wilson's plovers were seen in Miami. CBC records from 1980 through 1989 (Sprandel 1993) also showed few Wilson's plovers at surveyed sites on the east coast. So, while Wilson's plover were absent in our winter survey along the east coast, historically they were present but "occasional" in the area.

Piping plovers were found at just one site along the east coast during the statewide survey (Fig. 13), although they have been found in low numbers in the past. Howell (1932) reported winter observations at Amelia Island, Mayport, and Miami, all on the east coast. A 1927 CBC at Daytona Beach (Anon. 1927), included 40 piping plovers. In 1949, 8 piping plovers were counted at Daytona

Beach; in 1950, 38 were seen in Miami and 26 in St. Augustine; in 1951, 7 were counted in Jacksonville and 3 in Miami; in 1952, 5 were counted near Cocoa, 3 in Daytona Beach, and 2 in Jacksonville; and in 1953, 25 were counted around Cocoa, 3 around Daytona Beach, and 2 around Jacksonville. CBC records from 1980 through 1989 (Sprandel 1993) showed a range of 1 to 5 piping plovers at several circles on the east coast. Wintering surveys for piping plovers conducted in the winter of 1986 found 24 piping plovers on the east coast (Nicholls and Baldassarre 1990). In the winters of 1991 and 1996, 70 and 14 piping plovers, respectively, were found along the east coast (U. S. Fish and Wildlife Service, unpubl. data). Our data suggest that piping plovers are now largely absent from Florida's east coast.

Influences upon Local Distribution and Abundance

***Influence of Water Levels.*—**Water levels at all but 5 of the sites we surveyed were directly affected by tidal fluctuations, and water level greatly influenced the number of birds present at many sites (Table 10). All of the sites, even those with managed water levels, were close enough (<4 km) to the coast to allow shorebird movement and numbers to be influenced by tides. We expected to find most birds feeding when low tides exposed foraging habitat and roosting when high tides covered all but the highest ground. Based upon that assumption, we hoped to classify sites by tide level and bird behavior so that we could predict the best times to survey a site to observe the most birds.

Unfortunately, the sites were not easily classified by tidal usage, at least with the number of surveys we conducted. One problem was that variations in the species present and the size and diversity of the survey sites concealed patterns in shorebird abundance. Because activity and habitat use is related to bill and leg length (Recher 1966, Baker 1979), each species is most active at certain water levels. For example, sanderlings might be roosting at high tide while the longer legged short-billed dowitchers were still able to forage.

Despite these difficulties, we believe it is useful to identify sites that are predominately used at particular tide levels. Further defining sites as feeding or roosting sites is less dependable and, therefore, less useful. We identified East of Bay North; Carrabelle Beach; Passage Key NWR; McKay Bay; Fort Desoto, northwest end; NASA Causeway, north side; Phipps Preserve; Cedar Key, Hodges Bridge; Courtney Campbell Causeway southeast A and B; Delany Creek Canal; Ding Darling NWR, tower stop; Old Tampa Bay, north of Frankland Bridge; Lake Ingraham, southeast end; Northwest of Palm Key; and Snake Bight Channel as low-tide sites because the average count of birds at low tide was more than twice that observed at other tide levels. Due to the low number of visits, only East of Bay North had statistically significant more birds at low tide ($t = 3.66$, $P = 0.01$, df = 6), but the other sites either had insufficient number of visits to allow statistical comparison, or had very low power ($1 - \beta < 5$).

Table 10. Average number of shorebirds observed at different tide levels at 60 sites in Florida, 16 December 1993 through 1 March 1994, and sum of site means by region.

	Tide Levels								
	High			Intermediate			Low		
Region and Site	x̄	SD	N[a]	x̄	SD	N[a]	x̄	SD	N[a]
Panhandle Coast									
Cape San Blas	193.0		1	194.0		1	204.5	36.1	2
Carrabelle Beach	147.5	183.1	2	418.0	99.5	3	335.0	55.6	3
Carrabelle River Flats	155.0		1	74.5	29.0	2	5.0		1
Crooked Island East, west end	62.5	2.1	2	116.0		1	86.0		1
Crooked Island West, east end	57.0		1	92.0	4.2	2	36.0		1
East of Bay North	21.0	29.7	2				496.6	173.0	5
Fort Pickens, west end	111.0		1	79.0	2.8	2	27.0		1
Lanark Reef	2,784.7	469.9	3				442.0		1
Marifarms	669.7	384.1	3				198.0		1
Phipps Preserve	9.5	6.4	2	50.0		1	53.0	36.5	3
Shell Island, east end inlet	232.0	177.5	3				29.0		1
Shell Island, west end	55.0		1	15.0	18.4	2	3.0		1
St. Joseph Peninsula	0.0		1	9.0		1	1.0	1.4	2
Yent Bayou	141.0	198.0	2	310.0	147.2	3	158.7	117.1	3
Sum of site means	**4,638.8**		**25**	**1,357.5**		**18**	**2,074.8**		**26**
Big Bend Coast									
Cedar Key, Hodges Bridge	14.0		1				887.0	1,272.4	4
Cedar Key, Seahorse Key	86.0	121.6	2				144.5	204.4	2
Cedar Key, S of Hodges Bridge	266.0		1	140.0		1	412.7	375.1	3
Hagens Cove	614.8	558.8	5	180.0		1	254.5	79.9	2
Sprague Island oyster bars	1,160.7	944.2	3				124.0		1
St. Marks NWR, Mounds Pool #3	948.6	884.4	5				134.0		1
Sum of site means	**3,090.1**		**17**	**320.0**		**2**	**1,956.7**		**13**
Southwest Coast									
Anclote Key, north end	739.0	1,025.3	2	1,637.0		1	230.0		1
Anclote Key, south end	949.5	709.2	2	869.5	484.4	2			
Caladesi Island, Dunedin Pass	567.0		1	647.0		1	176.3	66.6	3
Caladesi Island, north end	712.0		1	200.0		1	537.5	350.0	2
Courtney Campbell Causeway, southeast A				0.0		1	60.2	82.3	5
Courtney Campbell Causeway, southeast B							175.3	245.1	6
Delany Creek Canal	0.0		1				768.7	579.8	3
Ding Darling NWR, tower stop	0.0		1	1,278.0		1	156.0	142.1	3
Fort Desoto, east end	316.0		1	387.0		1	160.5	227.0	2
Fort Desoto, northwest end	414.0		1	1,014.5	382.5	2	950.0		1
Honeymoon Island	905.0		1	729.0	72.1	2	1,142.5	36.1	2
Howard County Park, causeway	235.0	304.1	2				181.0	107.5	2
Howard County Park, west end	132.0	104.7	2				32.0	15.6	2
Island north of Bunces Pass	2,497.0		1				1,682.3	392.9	3
Lido Beach	170.3	119.6	3				146.0		1
Little Estero CWA	432.0	520.4	2	215.0		1	236.3	231.1	3
McKay Bay	116.0		1				412.2	203.9	4

Table 10. Continued.

	Tide Levels								
	High			Intermediate			Low		
Region and Site	x̄	**SD**	**N[a]**	x̄	**SD**	**N[a]**	x̄	**SD**	**N[a]**
Southwest Coast, continued									
Old Tampa Bay, north of Frankland Bridge							461.8	113.0	4
Palm Island Resort	198.0		1				303.0	122.3	3
Passage Key NWR	124.0		1	280.0	272.9	2	1,754.0		1
Point Pinellas, west oyster bar	381.0	80.6	2				570.5	364.2	2
Shell Key	2,295.5	422.1	2	2,416.0		1	1,138.0	964.5	2
Three Rooker Bar, north end	394.0		1	942.0		1	425.0		1
Three Rooker Bar, southeast end	618.0		1				351.7	305.2	3
Turtle Beach, Midnight Pass	42.5	53.0	2	6.0		1	19.0		1
Sum of site means	**12,237.8**		**32**	**10,621.0**		**18**	**12,069.9**		**60**
Everglades Coast									
Cape Romano, Morgan Beach	827.0	805.9	3	896.0		1			
Capri Pass	560.0	493.6	2				1,066.5	1,011.9	2
Carl Ross Key	0.0		1				9.7	8.7	3
Lake Ingraham, southeast end				0.0		1	3,481.3	2,401.9	3
Northwest of Palm Key	0.0		1				2,337.7	2,999.1	3
Sandy Key	33.0		1	477.0		1	20.5	29.0	2
Snake Bight Channel	8.0		1	0.0		1	517.7	819.9	3
Tigertail Beach	260.0	450.3	3				72.0		1
Sum of site means	**1,688.0**		**12**	**1,373.0**		**4**	**7,505.3**		**17**
Northeast Coast									
Bennett Causeway, Merritt Island	122.0		1	26.0		1	28.5	7.8	2
Huguenot Memorial Park	285.5	194.5	2	124.0		1	81.0		1
Kennedy Space Center, Pad 39B	321.0		1				200.0	186.9	3
Merritt Island NWR, Black Point Drive	1,089.0		1	3,571.0		1	1,218.0	108.9	2
NASA Causeway,north side	82.0		1	14.0		1	165.0	179.6	2
NASA Causeway, south side	233.0		1	370.0		1	13.0	12.7	2
Port Orange Spoil Islands	111.5	111.0	2				63.5	23.3	2
Sum of site means	**2,244.0**		**9**	**4,105.0**		**5**	**1,769.0**		**14**
Entire State									
Sum of site means	**23,898.7**		**95**	**17,776.5**		**47**	**25,375.6**		**130**

[a] Number of site visits and counts.

Similarly, we identified Lanark Reef; Marifarms; Shell Island, west end; Sprague Island oyster bars; St. Marks NWR, Mounds Pool #3; Anclote Key, north and south end; Siesta Key; Hagen's Cove; Huguenot Memorial Park; Fort Pickens, west tip; Shell Key; Caladesi Island, Dunedin Pass; Bennett Causeway, Merritt Island; NASA Causeway, south side; and Tigertail Beach as high-tide sites because the average count of birds at high tide was more than twice the number observed at other tide levels. Although St. Marks NWR, Mounds Pool #3 is an inland pond with no tidal fluctuation it received 7 times greater shorebird use during high tide on the nearby coast. Due to the low number of visits, only Caladesi Island, Dunedin Pass; Bennett Causeway, Merritt Island; Lanark Reef; and NASA Causeway, south side had statistically significant more birds at high tide ($P < 0.05$), but the other sites either had an insufficient number of visits to allow statistical comparison or had very low power ($1 - \beta < 5$). The remaining sites showed a more even distribution of birds among tide levels. Knowledge of tidal influence at some sites can, therefore, be useful in selecting survey times and in assessing potential conservation actions. A larger number of surveys would be needed to understand the variability at any site.

Small sample sizes precluded determination of the more subtle effects of tide actions on shorebird abundance, such as between high and falling tides, and between low and rising tides. However, during the pilot survey, we visited a few sites more frequently and found that specific water levels may be critical for some sites. For example, at East of Bay North, we observed birds only when the sea grass beds were exposed. However, we found little correlation ($r = -0.367$, $P = 0.297$, $1 - \beta = 25$) between the number of birds present and the predicted tide level (Fig. 30). With a predicted tide fluctuation of just 0.55 m observed during the survey, only a slight variation in water level was needed to expose the suitable feeding habitat at this site, and wind direction and intensity altered predicted tide levels. This made it difficult to predict when birds would be using a site based solely on the tide table, even though we knew it was used only when sea grass was exposed.

We found that other sites were used only at high tide. For example, during the pilot survey, few birds used St. Marks NWR, Mounds Pool #3 when water levels on the nearby coast were low ($r = 0.595$, $P = 0.053$) (Fig. 31), perhaps preferring instead to feed on exposed flats in Apalachee Bay. When tides rose in the bay, however, St. Marks NWR, Mounds Pool #3 provided the shorebirds with a refuge from the high water.

Other sites showed less distinct relations between water level and shorebird abundance. During the pilot survey, shorebirds occurred at Bald Point during various tide levels (Fig. 32). Undoubtedly, many variables that we did not measure, including sediment, substrate type, and abundance of forage species, greatly influenced the relationship between water levels and bird behavior. Instead of analyzing the total number of shorebirds present based solely on tide, we may have found clearer results evaluating specific species with known

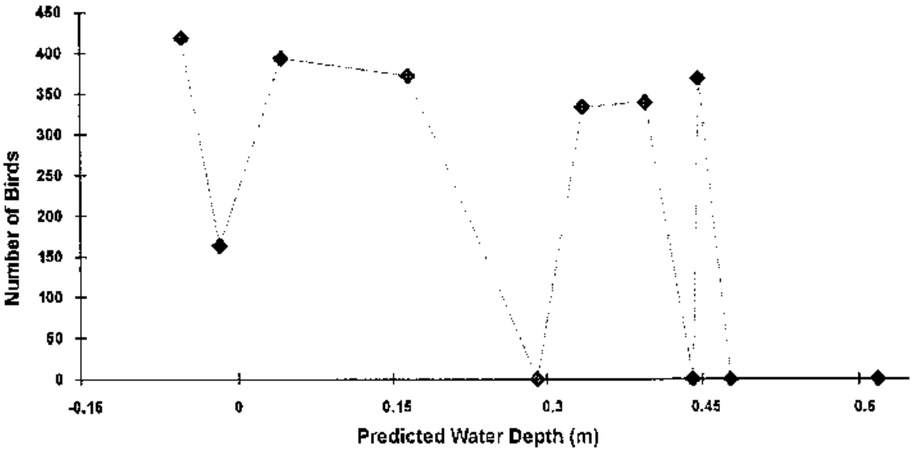

Fig. 30. Total number of wintering shorebirds observed at different tide levels, at the site East of Bay North, Florida, 10 January through 8 March 1993.

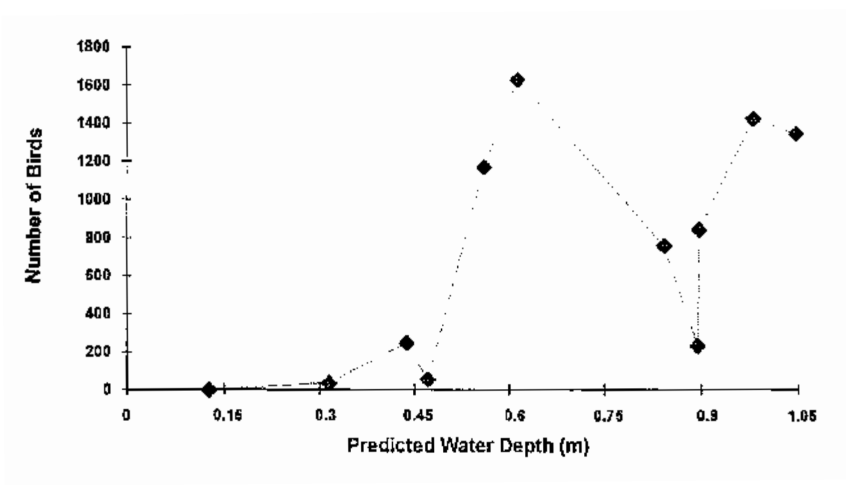

Fig. 31. Total number of wintering shorebirds observed at different tide levels on the coast at St. Marks NWR, Mounds Pool #3, Florida, 10 January through 8 March 1993.

feeding habitats (e.g., Connors et al. 1981). It is not surprising that we could not easily classify sites' tide levels and bird behavior considering the above variables, the influence of wind on tide levels, the physical diversity of sites, and the behavioral differences among species.

Dispersal and Activity Patterns.—We assumed that birds would be concentrated in roosting groups at high tide and more dispersed at low tide feeding areas. By comparing the total number of shorebirds counted at the 4 combinations of clumped versus scattered dispersal and high versus low tide, we confirmed our prediction that birds were most often clumped at high tide ($\chi^2 = 2.77$, $P \leq 0.1$, $n = 81$, df = 1), and scattered at low tide ($\chi^2 = 33.35$, $n = 119$, $P \leq 0.01$, df = 1). Comparison of dispersal patterns with feeding activity confirmed that roosting birds were more often clumped than scattered ($\chi^2 = 6.31$,P ≤ 0.02, $n = 99$, df = 1) and feeding birds were more likely to be scattered than clumped ($\chi^2 = 26.65$, P $\leq$ 0.01, $n = 211$, df = 1). Statewide, at high tide, over twice as many shorebirds were seen roosting as feeding, while at low tide 7 times as many birds were seen feeding as roosting. All sites averaged twice as many total shorebirds feeding at low tide than at high tide and twice as many roosting at high tide than at low tide. Burger (1984*b*) also found smaller flock size and greater number of flocks (i.e., greater dispersal) at low tide. Roosting shorebirds may form flocks in response to raptor predation, poor weather, or limited space; feeding shorebirds may flock to increase their ability to find suitable prey areas, although flocking may also interfere with finding specific prey items (Goss-Custard 1984, Myers 1984, Puttick 1984).

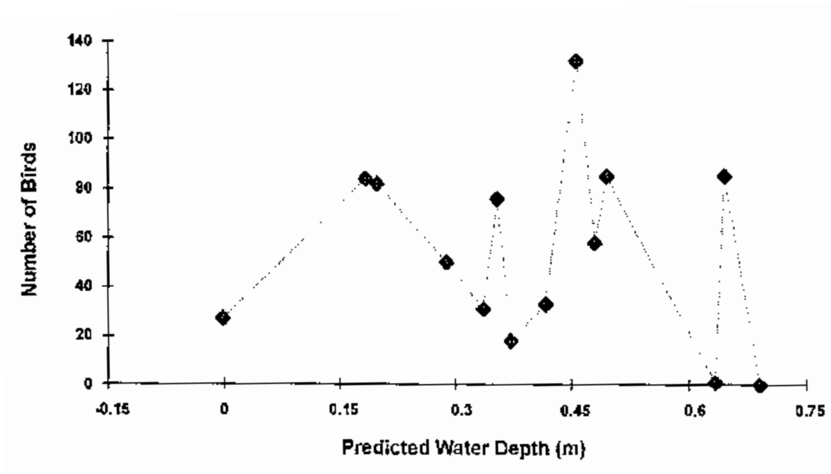

Fig. 32. Total number of wintering shorebirds observed at different tide levels, at Bald Point, Florida, 10 January through 8 March 1993.

Tide levels clearly influenced abundance differently among species (Table 11). Peeps, least sandpipers, western sandpipers, American avocets, lesser yellowlegs, Wilson's plovers, and unidentified shorebirds were observed in greatest numbers at low tide, though the difference in numbers between tide levels was not significant ($P > 0.1$, $1 - \beta < 25$). All other species were observed in greatest numbers at high tide, but only black-bellied plovers, dunlins, ruddy turnstones, and piping plovers had significantly higher numbers ($P \leq 0.01$).

Different species showed different patterns of group behavior (Table 12). Roosting groups of black-bellied plovers, snowy plovers, killdeer, American oystercatchers, greater yellowlegs, willets, marbled godwits, sanderlings,

Table 11. Average number of shorebirds observed at 3 tide levels at 60 sites in Florida, 16 December 1993 through 1 March 1994.

	Tide Levels								
	High			Intermediate			Low		
Species	$\bar{x}$	**SD**	**N[a]**	$\bar{x}$	**SD**	**N[a]**	$\bar{x}$	**SD**	**N[a]**
Black-bellied plover	36.5	58.3	66	29.8	66.3	39	17.3	34.3	96
Snowy plover	7.2	7.5	21	8.2	8.4	21	4.5	5.9	22
Wilson's plover	15.6	14.7	23	16.8	25.4	13	17.4	20.7	35
Semipalmated plover	31.6	50.7	40	42.2	59.0	27	24.6	28.1	63
Piping plover	18.8	22.3	29	11.5	11.2	20	8.5	10.2	28
Killdeer	5.1	8.4	15	2.3	1.2	6	11.8	18.3	20
Plover spp.	18.1	17.7	11	4.8	5.8	6	7.9	6.4	8
American oystercatcher	18.4	28.1	24	5.1	6.1	16	5.0	6.5	36
Black-necked stilt							8.0		1
American avocet	32.7	48.8	3	6.0		1	60.7	20.2	3
Greater yellowleg	8.2	8.1	17	8.2	15.2	6	5.1	6.6	14
Lesser yellowlegs	9.3	4.9	6	149.0		1	13.6	29.2	14
Yellowlegs spp.	15.2	9.0	4				7.9	10.5	9
Willet	80.5	136.2	51	36.1	98.5	30	54.1	120.0	70
Spotted sandpiper				1.0		1	1.3	0.6	3
Whimbrel	3.0	2.4	11	6.5	7.8	2	2.8	2.9	5
Long-billed curlew	1.0		3	1.0	0.0	2			
Marbled godwit	64.0	92.0	13	24.3	20.5	3	27.8	52.9	19
Ruddy turnstone	20.6	24.1	50	22.3	35.3	29	8.6	11.4	56
Red knot	107.9	93.1	19	117.8	200.5	13	89.6	113.5	36
Sanderling	82.5	111.7	54	73.0	84.9	37	58.9	105.9	75
Western sandpiper	137.2	299.8	33	115.5	143.3	17	208.9	396.6	39
Least sandpiper	18.4	46.3	20	8.5	5.7	6	49.6	119.5	14
Peep	74.7	97.1	19	146.3	280.6	13	215.8	538.1	43
Purple sandpiper							1.0		1
Dunlin	287.8	362.1	55	157.5	273.2	32	123.8	178.0	7
Short-billed dowitcher	97.8	111.6	39	110.0	189.6	21	63.4	74.4	58
Common snipe	1.0		1				1.5	0.7	2
Unidentified shorebirds	124.3	164.9	38	91.2	144.2	20	233.7	588.5	62

[a] Number of visits; only visits on which the species was observed are included.

western sandpipers, whimbrels, ruddy turnstones, and dunlins were significantly larger than feeding groups ($P \le 0.1$). In contrast, only American avocets occurred in significantly larger feeding groups ($P \le 0.1$). Different species tended to be in different size groups. For example, the average size of groups of the uncommon marbled godwit was 72 birds when roosting and 24 when feeding, whereas the abundant black-bellied plover occurred in groups averaging just 37 when roosting and 15 when feeding. The differing size of feeding and roosting groups suggests either that some species are less active or that we may have missed finding a roosting or feeding site for some species. For example, in Wakulla County, we observed more dunlin roosting than feeding, probably because many birds roosted at high tide at just 2 sites (St. Marks NWR, Mounds

Table 12. Average number of shorebirds observed feeding, roosting, or in other activities at 60 sites in Florida, 16 December 1993 through 1 March 1994.

	Feeding			**Roosting**			**Other**[a]		
Species	$\bar{x}$	**SD**	**N**[b]	$\bar{x}$	**SD**	**N**[b]	$\bar{x}$	**SD**	**N**[b]
Black-bellied plover	15.8	37.7	125	37.5	53.4	30	46.4	69.9	46
Snowy plover	3.5	2.9	32	10.8	9.1	20	8.0	9.2	12
Wilson's plover	12.9	18.3	28	15.9	20.9	27	24.7	18.6	16
Semipalmated plover	24.8	32.3	86	34.6	63.3	25	49.8	52.7	19
Piping plover	8.4	9.3	54	16.4	21.3	12	32.9	23.4	11
Killdeer	4.6	6.2	25	14.5	23.1	4	12.8	20.7	12
Plover spp.	4.8	4.9	8	17.7	18.8	10	0.9	7.6	7
American oystercatcher	4.3	5.0	30	12.0	16.8	16	12.8	24.2	30
Black-necked stilt	8.0		1						
American avocet	69.0	28.3	2	6.0	0.0	2	45.3	40.6	3
Greater yellowlegs	5.1	8.2	30	15.5	2.1	2	15.4	8.0	5
Lesser yellowlegs	23.9	44.4	15	6.0	5.7	2	6.2	5.5	4
Yellowlegs spp.	6.8	8.4	10				21.3	9.0	3
Willet	40.1	108.7	99	116.2	132.5	23	80.4	143.2	29
Spotted sandpiper	1.2	0.5	4						
Whimbrel	2.2	2.6	9	4.8	4.3	5	4.0	2.7	4
Long-billed curlew	1.0	0.0	4				1.0		1
Marbled godwit	24.3	49.2	23	71.9	83.8	87	4.5	119.8	4
Ruddy turnstone	11.1	20.6	96	25.2	29.1	15	29.8	25.9	24
Red knot	68.4	68.8	32	91.2	106.0	14	151.9	184.3	22
Sanderling	41.0	68.0	109	98.6	118.8	17	135.7	140.2	40
Western sandpiper	77.4	131.1	57	241.8	514.8	93	50.1	474.9	23
Least sandpiper	9.9	16.2	31	3.0	2.0	31	32.8	174.0	6
Peep	124.9	301.9	51	95.8	137.7	113	98.2	814.3	13
Purple sandpiper	1.0		1						
Dunlin	89.9	135.0	89	292.0	440.3	27	314.3	304.5	45
Short-billed dowitcher	60.5	114.5	67	88.0	96.5	21	129.9	117.7	30
Common snipe	1.0		1				1.5	0.7	2
Unidentified shorebirds	147.9	253.8	51	170.4	374.7	30	214.9	640.4	39

[a] Other activities including flying, disturbance, or activities that could not be categorized as roosting or feeding.
[b] Number of visits; only visits on which the species was observed are included.

Pool #3 and Sprague Island oyster bars) but dispersed more widely to unknown sites to feed, possibly in Apalachee Bay. This pattern has important implications for assessing trends in bird abundance both within and among sites because the timing of counts could greatly affect estimates of local abundance. Some species—like dunlin, western sandpiper, and those noted above—clearly concentrate during roosting, but for other species the pattern is not as clear. Myers (1984) reported that shorebird species exhibited a considerable range in flocking behavior from solitary to tight groups.

Many researchers have reported that shorebirds feed on exposed flats during low tide and roost higher on the shore, in fields, or in marshes at high tide (Bent 1929, Wolff 1969, Stenzel et al. 1976, Burger et al. 1977, Gerstenberg 1979, Kelly and Cogswell 1979). In practice, we observed a more complex pattern, with many birds feeding throughout the tide cycle (Baker and Baker 1973) or feeding when the flock was roosting (Heppleston 1971). Clearly, tide affects shorebird distribution among habitats, but it affects individual sites differently (Burger 1984*b*).

Several weather-related variables also affect the abundance and distribution of wintering shorebirds. Lower temperatures affect shorebirds by increasing their energy requirements and by indirectly decreasing prey availability (Evans 1976). Strong winds affect shorebirds by increasing their energy requirements, indirectly reducing available foraging areas, and decreasing prey availability (Burger 1984*b*, Goss-Custard 1984). In a study of Jamaica Bay, Burger (1984*b*) was able to account for 60% of the variability in the number of shorebirds by including variables for time, tide, and weather.

Disturbance of Shorebirds.—Knowing how shorebirds react to disturbance may help in implementing conservation actions and in designing reliable surveys. At 48 of the 60 sites visited, humans were the main cause of disturbance (Table 13). The number of human disturbances ranged from 0 to 19.4 per hour (Table 13). Though not significantly different ($P > 0.25$, $1 - \beta <$ 10), the mean number of disturbances per hour was highest along the northeast coast and lowest in the Everglades and in the Panhandle (Table 13). Disturbance rates varied greatly among sites (CV = 1.7) depending upon a site's accessibility and attractiveness to humans. Our subjective estimates of peak daily disturbance rates were not highly correlated ($r = 0.27$, $P = 0.03$) with the observed maximum hourly rate. This may have been due to differences in observers' application of the qualitative categories on the data forms. Disturbance rate also varied greatly between visits to a site (CV = 0.96) depending upon the number of persons present ($F = 14.4$, $P = 0.0002$, b = 0.048 increase of disturbances per hour for number of persons present, df = 247). We did not see any difference between the number of persons present for a visit and the weather conditions ($P = 0.7$, $1 - \beta$ = 10) or whether the visit was on a weekend ($P = 0.6$, $1 - \beta = 10$).

Table 13. Average and maximum disturbance rates to shorebirds at 60 sites in Florida, 16 December 1993 through 1 March 1994.

			Human disturbance rate			
			Hourly			Daily[a]
Region and site	Primary cause	N[b]	$\bar{x}$[c]	SD	Maximum[d]	
Panhandle Coast						
Cape San Blas	Human	2	1.6	0.8	2.1	20
Carrabelle Beach	Human	8	1.3	1.0	3.0	5
Carrabelle River Flats	Human	3	1.3	2.3	4.0	1
Crooked Island East, west end	Human	4	4.6	2.5	7.2	5
Crooked Island West, east end	Human	4	1.7	0.7	2.7	1
East of Bay North	Natural	7	0.0	0.0	0.0	1
Fort Pickens, west end	Human	4	1.9	1.7	4.0	20
Lanark Reef	Natural	4	0.4	0.1	0.6	0
Marifarms	Natural	3	0.4	0.3	0.6	1
Phipps Preserve	Natural	6	1.7	1.6	3.5	0
Shell Island, east end Inlet	Human	3	1.1	1.0	2.0	1
Shell Island, west end	Human	3	2.4	4.2	7.2	1
St. Joseph Peninsula	Human	2	1.0	1.4	2.0	1
Yent Bayou	Natural	8	1.2	1.4	3.6	0
Entire Region		**61**	**0.9**	**1.4**	**3.0**	
Big Bend Coast						
Cedar Key, south of Hodges Bridge	Natural	4	2.1	2.8	6.0	5
Cedar Key, Hodges Bridge	Natural	4	1.4	1.9	4.0	5
Cedar Key, Seahorse Key	Human	3	0.8	1.4	2.4	20
Hagens Cove	Human	8	0.4	0.6	1.7	1
Sprague Island oyster bars	Natural	4	0.7	1.1	2.4	0
St. Marks NWR, Mounds Pool #3	Human	6	0.4	0.7	1.5	1
Entire Region		**29**	**1.4**	**1.7**	**3.0**	
Southwest Coast						
Anclote Key, north end	Human	4	0.3	0.5	1.1	20
Anclote Key, south end	Human	4	1.4	1.3	3.0	20
Caladesi Island, Dunedin Pass	Human	5	1.9	2.3	5.2	20
Caladesi Island, north end	Human	4	2.5	3.2	7.2	20
Courtney Campbell Causeway, southeast A	Human	6	0.0	0.0	0.0	5
Courtney Campbell Causeway, southeast B	Human	6	13.0	7.3	18.0	5
Delany Creek Canal	Natural	4	0.7	1.3	2.6	1
Ding Darling NWR, tower stop	Natural	2	2.0	2.8	4.0	1
Fort Desoto, east end	Human	3	5.7	3.5	9.0	20
Fort Desoto, northwest end	Human	4	0.7	0.5	1.2	20
Honeymoon Island	Human	5	2.8	3.5	8.8	20
Howard County Park, causeway	Human	4	2.2	1.7	4.0	20
Howard County Park, west end	Human	4	1.3	1.0	2.4	20
Island north of Bunces Pass	Human	4	0.7	0.8	1.3	20
Lido Beach	Human	4	3.1	0.7	4.0	20
Little Estero CWA	Human	6	1.8	2.2	6.1	20
McKay Bay	Natural	5	0.4	0.9	2.0	20
Old Tampa Bay, north of Frankland Bridge	Human	4	0.7	0.8	1.7	5
Palm Island Resort	Human	4	3.1	1.4	4.5	20
Passage Key NWR	Human	4	1.0	2.0	4.0	5
Point Pinellas, west oyster bar	Human	4	0.9	1.1	2.0	20
Shell Key	Human	5	2.3	2.6	6.0	20

Table 13. Continued.

			Human disturbance rate			
			Hourly			Daily[a]
Region and site	**Primary cause**	**N[b]**	$\bar{x}$[c]	**SD**	**Maximum[d]**	
Three Rooker Bar, north end	Human	3	5.9	5.1	9.0	20
Three Rooker Bar, southeast end	Human	4	1.8	2.1	4.0	20
Turtle Beach, Midnight Pass	Human	4	2.7	1.0	4.0	20
Entire Region		**106**	**1.9**	**2.7**	**4.6**	
Everglades Coast						
Cape Roman, Morgan Beach	Human	2	5.0	1.4	6.0	5
Capri Pass	Human	4	0.5	1.0	2.0	5
Carl Ross Key	Human	3	0.0	0.0	0.0	5
Lake Ingraham, southeast end	Human	4	0.0	0.0	0.0	1
Northwest of Palm Key	Human	4	0.0	0.0	0.0	5
Sandy Key	Human	3	0.0	0.0	0.0	1
Snake Bight Channel	Human	5	0.0	0.0	0.0	1
Tigertail Beach	Human	2	8.1	1.3	9.0	5
Entire Region		**27**	**1.0**	**2.5**	**2.1**	
Northeast Coast						
Bennett Causeway, Merritt Island	Human	4	0.5	1.0	2.0	5
Merritt Island NWR, Black Point Drive	Natural	4	0.0	0.0	0.0	1
Huguenot Memorial Park	Human	4	3.2	1.5	4.5	20
Kennedy Space Center, Pad 39B	Human	4	0.0	0.0	0.0	0
NASA Causeway KSC, north side	Human	4	2.5	2.7	6.2	1
NASA Causeway KSC, south side	Human	4	10.7	7.4	19.4	1
Port Orange Spoil Islands	Human	4	7.7	5.3	14.4	20
Entire Region		**28**	**3.5**	**5.1**	**6.6**	
Statewide		**251**	**1.7**	**2.8**	**4.0**	

[a] Estimate of the daily maximum amount of disturbance based upon subjective assessment of observed disturbance and evidence of disturbance.
[b] Number of visits.
[c] Mean number of disturbances per hour.
[d] Maximum hourly rate observed on all visits.

The activity code for disturbance also was an indication of level of disturbance. This activity code was used on 60 of 272 visits (22%) and included a total of 8,843 shorebirds disturbed with 4,936 birds feeding, 1,254 roosting, and 2,653 exhibiting mixed activity or flying. The use of the disturbance activity code was much lower than that recorded on the visit form in which 1 disturbance was listed on 166 of the 272 (61%) visits with an average of 1.1 disturbances per visit. It should be noted that we did not distinguish disturbances caused by the observer. Future surveys should distinguish disturbance caused by the observer.

Avian Predators.—During 272 regular visits, only 3 avian predators were observed: a falcon swooping on shorebirds at McKay Bay, a parasitic jaeger (*Stercorarius pomarinus*) at Passage Key NWR, and a northern harrier (*Circus cyaneus*) flying over at Crooked Island West, east end. Although raptors were undoubtedly wary of observers, it is surprising that only 3 raptors were recorded during >194 hr of observation. The effect of avian predators upon local Florida shorebird populations appears insignificant, but should be studied further. Falcon predation is most likely to occur at dawn or dusk (B. Millsap, pers. commun.), so we may not have been present when predation was most likely to occur. Page and Whitacre (1975) observed 120 shorebirds eaten by a merlin (*Falco columbarius*) and found the remains of 374 predated shorebirds at Bolinas Lagoon on the central California Coast. Kus et al. (1984) found a greater percentage of juvenile dunlin as the prey of merlin and short-eared owl (*Asio flammeus*). Dobler and Spencer (1989) observed peregrine falcons (*Falco peregrinus*) selecting shorebirds as prey >60% of the time in Washington. A pilot study of radio-tagged willets around Lanark Reef during the winter of 1994–95 found the remains of 1 willet predated by a short-eared owl (FGFWFC, unpubl. data).

Accuracy of Survey Results

Locating Survey Sites.—Of the 217 potential sites initially compiled (Sprandel 1993), 193 (89%) were evaluated at least once from the ground in November or December 1993. Of the 24 potential sites not surveyed from the ground, 12 were surveyed from a fixed-wing aircraft, 1 was an inland site, 1 was a mapping error, 1 was a spoil island that no longer existed, 3 had information provided by other sources, and 6 were too difficult to reach (e.g., private property or poor boat access).

In addition to the 193 potential sites that were ground surveyed, 80 other sites were visited, for a total of 273 preliminary sites. These 80 new additional sites included sites discovered on aerial surveys, sites found during ground surveillance in the survey areas, or multiple smaller sites created by dividing large initial sites. Of the additional 80 sites, 5 were rated high enough to be selected for subsequent visits (Marifarms; Yent Bayou; Cedar Key, south of Hodges Bridge; Northwest of Palm Key; and Port Orange Spoil Islands). Thus, of the 60 highest sites about 8% were not found in our initial review of potential sites.

The pilot survey in the Panhandle and subsequent statewide survey provided information on efficiencies of continued searches by trained observers. During the 1993 pilot survey, 14 sites in the Panhandle counties of Bay, Gulf, Franklin, and Wakulla were surveyed both by air and on the ground. Despite this previous survey, 4 additional high-ranking sites were found during the statewide survey: Marifarms (found from air survey), Yent Bayou (found by ground survey), Sprague Island oyster bars (mentioned in coastal mail survey), and the Carrabelle River Flats (mentioned in coastal mail survey). In these 4 counties, 28% of the top sites were discovered after a second year of surveys. During the winter of 1994–95 (the third survey year), another potentially important feeding area was found by following a radio-tagged willet, and during the winter of 1996–97 a roosting area was found. Clearly, even after 2 years of surveys, all potentially important sites were not found or, perhaps, use of sites by shorebirds changed. Therefore, it is important that future surveys include complete aerial surveys of the coastline to search for new sites and that local birders again be asked about the location of shorebird roosting and feeding sites.

Although we visited 89% of the potential sites compiled, we visited 189 (69%) of the 273 preliminary sites only once. Depending upon usage of the site and the influences of tide or wind, the single visit may not have reflected the average shorebird abundance at the site. For sites where we had more definite information about maximum abundance of the site, we made 2 visits. During the statewide survey, 20% of the final 60 sites had a clear differential between high- and low-tide shorebird abundance. Applying this same 20% ratio to the 130 "discarded" sites visited just once, 26 would have distinct tide differentials, and therefore half (13) of these would likely have been visited at the wrong tidal level (i.e., when fewest birds would be expected). Furthermore, with just 1 visit, random variation in the number of birds at a site might result in a visit when numbers were very low. Using the average site CV of 0.86 and the mean of 59 birds counted for the unselected preliminary sites visited just once, then 26 of 130 or 20% of the 1-visit sites would have an actual population mean count of >200 shorebirds based on a sampling from the normal distribution. Therefore, combining the effects of tide differential and high variability, as many as 25% of the sites visited just once may have had a mean of >200 birds. Thus, we should not say that a site was marginal based on just 1 visit. If 2 visits were made to the site, only about 5% of the sites with a low mean count would have had an actual population mean count of >200 shorebirds. Conversely, of the 32 sites picked for subsequent visits based on having a biological score of ≥ 10 based on just 1 visit, the final biological score based on the 4 regular visits was < 10 for 11 of them (34%). For future surveys we recommend that a minimum of 2 visits to a site be made.

Based upon estimates made during aerial surveys of 217 sites, as many as 49 sites with >100 birds and 15 sites with >1,000 birds were not subsequently surveyed by ground, largely due to difficulties in reaching the sites (Table 14). All but 1 of the 15 largest sites were on the southwest coast. Because of errors in identifying exact locations and estimating shorebird numbers from aircraft, the number of important sites that were not further surveyed may not be accurate. Nevertheless, some potentially important sites were not included in the ground survey, and future surveys should allow for more intensive and extesive ground checking of all high-count sites identified from aerial surveys. Furthermore, we suggest that the coastal flights be conducted twice to account for differences in utilization due to tide and high variability.

With over 13,000 km of shoreline (Livingston 1990), a complete search of coastal Florida would not be possible. Another approach to locating shorebirds would be to correlate shorebird abundance with habitat and prey abundance. Shorebird densities have been correlated with invertebrate densities (Wolff 1969, Colwell 1993, Colwell and Landrum 1993), tidal elevation (Nehls and Tiedemann 1993), and sediment characteristics (Yates et al. 1993). Large-scale landscape features, such as the presence of sand tips, occurrence of undisturbed offshore islands, or influx of nutrients from freshwater streams, might provide "search images" for statewide searches for potentially new sites.

Because all surveys took place during daylight hours, we may also have missed some important feeding or roosting sites. Shorebirds, particularly those that are tactile predators, are known to be both diurnal and nocturnal feeders, with some species feeding at higher numbers nocturnally (Robert et al. 1989). Shorebird species in Florida that have been reported to feed nocturnally include American oystercatcher (Burger 1984*b*), black-bellied plover (Dugan 1981, Pienkowski 1982), Wilson's plover (Thibault and McNeil 1994), piping plover (Burger 1984*b*, Staine and Burger 1994), willet (Stenzel et al. 1976, Burger 1984*b*), ruddy turnstone (Burger 1984*b*), red knot (Prater 1972), sanderling (Burger 1984*b*), and dunlin (Evans 1976, Mouritsen 1994). Mouritsen (1994) reported that dunlins tended to use different habitats during day and night, with day foraging favoring sites where pecking was effective, and at night preferring sites where probing was effective. The nocturnal and diurnal distribution of individual Wilson's plovers differed substantially (Thibault and McNeil 1994). Telemetry studies of black-bellied plovers suggested that birds change their feeding sites nocturnally (Dugan 1981). Preliminary attempts to capture willets in the winter of 1994–95 on Lanark Reef showed a different pattern of nocturnal roosting than had been observed during the day. We know little of the nocturnal behavior or distribution of shorebirds in Florida. Future surveys should consider nocturnal counts, if advances in image enhancement or infrared detection would make them practical.

Comparison with Other Surveys.—The sites previously surveyed with ISS surveys provided the only quantitative estimate of shorebirds at preliminary sites. The statewide survey had a lower mean for 13 of the 14 ISS sites surveyed (only McKay Bay had a larger mean), but the difference was only significant at 2 sites, Mayport ($P = 0.0001$, df = 46) and the Lower Suwannee ($P = 0.02$, df = 8). This should not necessarily be viewed as an indication of shorebird declines; the ISS sites may be much larger areas than those used in our survey.

CBC data provide another source of information about the distribution of shorebirds wintering in Florida (Sprandel 1993), but only qualitative comparisons can be made with our survey data (Figs. 12–29). Beyond the obvious problems of surveying different geographic locations and sites of

Table 14. Sites with >100 wintering shorebirds in Florida that were located by aerial survey, 1 November through 9 December 1993, but were not later surveyed from the ground.

Abundance Region and site	**County**	**Latitude**	**Longitude**
> 1,000 shorebirds			
Southwest Coast			
Apollo Beach Shoreline	Hillsborough	27° 46.0'	82° 25.0'
Carl Johnson, east	Lee	26° 22.0'	81° 51.5'
East of Punta Rassa[a]	Lee	26° 28.8'	81° 58.7'
Gandy Causeway	Pinellas	27° 52.5'	82° 35.5'
Hillsborough Island 2D	Hillsborough	27° 52.5'	82° 26.0'
Hillsborough Island 3D	Hillsborough	27° 50.0'	82° 26.0'
MacDill Air Force Base, south end	Hillsborough	27° 51.5'	82° 33.0'
North of Courtney Campbell, mud flats	Pinellas	27° 58.6'	82° 36.1'
North of Courtney Campbell, Cooper's Point	Pinellas	27° 58.7'	82° 41.4'
North Captiva Island, south end	Lee	26° 33.5'	82° 12.0'
Northeast of E.T. Simmons Park	Hillsborough	27° 49.9'	82° 26.3'
South of Cockroach Bay	Hillsborough	27° 40.1'	82° 31.7'
South Longboat Key, New Pass	Sarasota	27° 29.0'	82° 35.1'
Sunken Island, Alafia Banks	Hillsborough	27° 51.0'	82° 25.0'
Northeast Coast			
Mouth of Jolly River	Nassau	30° 43.2'	81° 30.3'
> 100–1,000 shorebirds			
Panhandle Coast			
East of Carrabelle River	Franklin	29° 50.5'	84° 39.0'
Big Bend Coast			
6.4 km southeast of Suwannee River	Levy	29° 16.0'	83° 06.0'
Deer Island[a]	Levy	29° 15.0'	83° 04.0'
East of Cedar Key	Levy	29° 08.0'	83° 00.0'
East of Cedar Key Bridge	Levy	29° 09.0'	83° 01.0'
Horseshoe Cove[a]	Dixie	29° 27.0'	83° 13.0'
Mouth of Big Bayou	Wakulla	30° 05.0'	84° 13.0'
Mouth of St. Marks River	Wakulla	30° 05.0'	84° 11.0'
Palm Island, southeast of Suwannee River[a]	Levy	29° 20.0'	83° 10.0'
Southeast of Hagens Cove	Taylor	29° 46.0'	83° 35.0'
Southeast of Hickory Mound	Taylor	30° 03.0'	83° 55.0'
Southeast of Steinhatchee River	Taylor	29° 39.0'	83° 24.0'
West of Horseshoe Beach	Dixie	29° 27.0'	83° 18.0'
Southwest Coast			
Big Island Gap	Pinellas	27° 54.5'	82° 28.5'
Bishop Harbor, south side	Manatee	27° 34.4'	82° 34.0'
Bonita Springs	Lee	26° 20.0'	81° 51.0'
Casperson Beach, Venice Airport	Sarasota	27° 03.0'	82° 27.0'
Cockroach Bay	Hillsborough	27° 39.2'	82° 32.0'
Gasparilla Island, east side	Charlotte	26° 46.0'	82° 16.0'
Jewfish Key	Manatee	27° 29.3'	82° 40.1'
MacDill Air Force Base, east side	Hillsborough	27° 51.5'	82° 31.0'
North of Gulf Harbors	Pinellas	28° 14.6'	82° 45.5'
North Captiva Island, east of boat dock	Lee	26° 35.5'	82° 12.5'
North Captiva Island, west side	Lee	26° 35.5'	82° 13.5'
North of Pine Island	Lee	26° 42.6'	82° 07.8'
North of Terra Ceia, Sunshine Skyway[a]	Manatee	27° 35.3'	82° 36.5'

Table 14. Continued.

Abundance **Region and site**	**County**	**Latitude**	**Longitude**
Southwest Coast continued			
Perico	Manatee	27° 30.5'	82° 41.5'
Perico, back in bay	Manatee	27° 29.3'	82° 40.1'
Remlap	Hillsborough	27° 50.5'	82° 24.0'
Sand Bay, north of Anclote River[a]	Pinellas	28° 12.8'	82° 46.2'
Everglades Coast			
Canoe Trail	Collier	25° 50.0'	81° 36.2'
Cluett Key	Monroe	25° 01.3'	80° 51.9'
East of Clive Key	Monroe	25° 05.1'	80° 56.7'
Everglades City	Collier	25° 56.8'	81° 41.7'
Garfield Bight	Monroe	25° 10.6'	80° 48.5'
Long Beach, south end of Big Pine Key	Monroe	24° 37.6'	81° 22.3'
North of Sand Dollar	Collier	25° 51.0'	81° 30.0'
North of Sandy Key	Monroe	25° 03.4'	81° 01.9'
Northwest of Sandy Key	Monroe	25° 04.5'	81° 02.9'
Palm Key	Monroe	25° 06.6'	80° 52.1'
Ten Thousand Islands	Collier	25° 54.9'	81° 34.8'
West of Man of War	Monroe	25° 01.8'	80° 55.6'
Northeast Coast			
Amelia Island, south of Pier	Nassau	30° 36.4'	81° 26.5'
Bird Island, Nassau Sound	Duval	30° 29.1'	81° 27.0'
Fort George River	Duval	30° 25.4'	81° 25.2'
Haulover Canal Spoil Islands	Brevard	28° 43.6'	80° 46.1'
Intercoastal Waterway, southwest of Capo Creek	St. Johns	30° 01.6'	81° 21.3'
South Amelia River	Nassau	30° 34.1'	81° 28.3'
Vilano Point	St. Johns	29° 54.4'	81° 17.6'

[a] Nearest landmark was difficult to ascertain during aerial surveys; site may not be precisely on the named landmark.

different sizes (CBC circles are 24.1 km in diameter), differences in species distributions between the 2 data sets may have been due to several causes. First, different dispersal patterns of the birds would likely be evident in the different sizes of sampling areas. More dispersed species would probably show up as having greater numbers within the larger CBC circles, but species that congregate would likely be found in our survey which targeted congregations of birds. Secondarily, some differences between the 2 surveys may be due to identification difficulties. For example, we suspect that problems with differentiation of lesser and greater yellowlegs and of western and least sandpipers may have affected our surveys, whereas the distribution of semipalmated sandpipers on the CBC may be suspect. Although comparing our survey data with CBC data is problematic, the 2 data sets can be used together to evaluate the relative distribution of wintering shorebirds in Florida.

For the snowy plover, the CBC and our distributions (Fig. 12) coincide with concentrations found along the Panhandle and the southwest coast. For the piping plover, the CBC shows several areas on the east coast with an average of 1 to 5 plovers, while our survey just showed 1 (Fig. 13). However, we had twice as many piping plovers statewide than were found in the CBC (Table 15). Our survey pinpointed the statewide importance of Lanark Reef in the Panhandle. Wintering surveys for piping plovers conducted in the winter of 1986 found 24 piping plovers on Florida's Atlantic coast and a total of 351 on Florida's Gulf coast (Nicholls and Baldassarre 1990). In 1991, the International Piping Plover census found 70 on the Atlantic coast and 481 on the Gulf coast, and the 1996 census found 24 on the Atlantic and 351 on the Gulf (U. S. Fish and Wildlife Service, unpubl. data). For the semipalmated plover, our survey found sites in the Florida Bay area, but failed to show any birds along the southeast coast and did not detect the concentrations found in the CBC in northeast Florida (Fig. 20). Our survey and the CBC survey both showed the importance of the southwest coast from Pinellas to Monroe counties for semipalmated plovers.

Black-bellied plovers appeared cosmopolitan according to both surveys (Fig. 21). For willets, both distributions showed greater numbers on the Gulf coast, but our survey failed to show any concentrations in St. Johns County on the northeast coast (Fig. 22). For dunlins, the distributions generally were similar, but our survey showed only small concentrations along the northeast coast (Fig. 23). Our survey did not identify any red knots on the northeast coast.

Our survey showed large numbers of American oystercatchers (Fig. 15) in the Panhandle around Lanark Reef, whereas the CBC survey showed larger numbers in Levy County and on the northeast coast. Both surveys showed concentrations of American oystercatchers around Tampa Bay. Our survey did a much better job of finding ruddy turnstones in the Panhandle (Fig. 16).

Our survey showed that Lanark Reef and the Tampa Bay area were important to the marbled godwit, but few were found on the northeast coast (Fig. 25). The distribution of whimbrel was patchy, but we did not find any on the east coast (Fig. 17). Our survey failed to find greater yellowlegs south of the Tampa area but did show that lesser yellowlegs apparently preferred more southern latitudes. We found fewer short-billed dowitchers along the northeast coast than the CBC surveys. Shorebirds in northeastern Florida may not be as concenrated due to high human disturbance and low nutrient input from few streams. Where shorebirds are widely dispersed, the CBC counts would tend to show greater abundance than our surveys.

We consistently found large numbers of western sandpipers in and around Collier County but found few on the east coast (Fig. 27). There was no noticeable difference in the distribution of the least sandpiper (Fig. 28) between our survey and the CBC. We found consistent numbers of sanderlings in Franklin, Gulf, and Bay counties (Fig. 29).

Table 15. Mean number of shorebirds counted at 60 sites in Florida, 16 December 1993 through 1 March 1994. Survey sites are included where the mean number of shorebirds counted was either ≥1% of the species' Atlantic flyway total based upon ISS counts or ≥10% of the average counted in Florida CBCs from 1980 through 1989. Summed means for all survey sites are also included.

Species and site	Region	ISS %	CBC %	$\bar{x}$
Black-bellied plover				
State totals (all sites)		**2.5**	**26.4**	**1191.6**
Snowy plover				
Anclote Key, south end	Southwest	4.3	16.3	17.0
Crooked Island East, west end	Panhandle	3.4	13.2	13.8
Crooked Is. West, east end	Panhandle	2.9	11.1	11.5
Three Rooker Bar, north end	Southwest	2.3	9.0	9.3
Shell Island, east end inlet	Panhandle	1.9	7.2	7.5
Honeymoon Island	Southwest	1.6	6.2	6.4
Shell Island, west end	Panhandle	1.4	5.5	5.8
Palm Island Resort	Southwest	1.1	4.1	4.3
State totals (all sites)		**25.2**	**96.9**	**100.7**
Wilson's plover				
Three Rooker Bar, north end	Southwest	3.8	12.8	36.3
Anclote Key, south end	Southwest	3.7	12.3	35.0
Lake Ingraham, southeast end	Everglades	3.5	11.7	33.3
Island north of Bunces Pass	Southwest	2.5	8.5	24.3
Honeymoon Island	Southwest	2.3	7.7	21.8
Little Estero CWA	Southwest	2.2	7.6	21.5
Cape Romano, Morgan Beach	Everglades	1.9	6.5	18.5
Palm Island Resort	Southwest	1.9	6.5	18.5
Tigertail Beach	Everglades	1.1	3.6	10.3
State totals (all sites)		**29.4**	**99.3**	**282.0**
Semipalmated plover				
State totals (all sites)		**2.5**	**41.9**	**926.5**
Piping plover				
Lanark Reef	Panhandle	3.0	50.2	51.8
Honeymoon Island	Southwest	2.2	36.3	37.4
Cape San Blas	Panhandle	1.3	21.1	21.8
Shell Key	Southwest	0.9	15.7	16.2
Shell Island, east end inlet	Panhandle	0.9	15.5	16.0
Three Rooker Bar, southeast end	Southwest	0.9	14.6	15.0
Three Rooker Bar, north end	Southwest	0.7	11.3	11.7
State totals (all sites)		**13.3**	**222.4**	**229.1**
Killdeer				
State totals (all sites)			**0.7**	**76.1**
American oystercatcher				
Lanark Reef	Panhandle	3.7	11.9	71.8
State totals (all sites)		**8.1**	**26.1**	**157.6**
Black-necked stilt				
State totals (all sites)		**0.0**	**1.9**	**1.6**
American avocet				
McKay Bay	Southwest	0.2	11.2	54.2
State totals (all sites)		**0.3**	**11.7**	**57.0**
Greater yellowlegs				
State totals (all sites)			**5.2**	**51.3**

Table 15. Continued.

Species and site	Region	ISS %	CBC %	$\bar{x}$
Lesser yellowlegs				
State totals (all sites)		**0.1**	**7.0**	**95.6**
Willet				
Lanark Reef	Panhandle	3.4	6.9	358.0
Snake Bight Channel	Everglades	1.8	3.6	188.2
Howard County Park, causeway	Southwest	1.5	3.0	156.8
Island north of Bunces Pass	Southwest	1.4	2.8	146.0
Point Pinellas, west oyster bar	Southwest	1.3	2.6	132.3
Fort Desoto, northwest end	Southwest	1.2	2.4	122.8
Sprague Island oyster bars	Big bend	1.2	2.3	121.3
East of Bay North	Panhandle	1.1	2.3	119.0
State totals (all sites)		**18.3**	**36.9**	**1,916.2**
Spotted sandpiper				
State totals (all sites)			**0.3**	**1.1**
Whimbrel				
State totals (all sites)		**0.6**	**18.1**	**13.2**
Long-billed curlew				
State totals (all sites)			**11.1**	**1.0**
Marbled godwit				
Lanark Reef	Panhandle	11.3	55.0	161.3
Point Pinellas, west oyster bar	Southwest	5.8	28.2	82.5
Snake Bight Channel	Everglades	3.0	14.5	42.6
Carrabelle Beach	Panhandle	1.1	5.2	15.4
State totals (all sites)		**22.8**	**110.8**	**324.6**
Ruddy turnstone				
State totals (all sites)		**0.5**	**15.4**	**522.2**
Red knot				
Shell Key	Southwest	0.3	13.0	380.4
State totals (all sites)		**1.2**	**49.6**	**1,452.4**
Sanderling				
State totals (all sites)		**3.4**	**41.9**	**2,626.7**
Western sandpiper				
Lake Ingraham, southeast end	Everglades	1.6	8.3	1191.7
State totals (all sites)		**4.6**	**24.6**	**3,523.0**
Least sandpiper				
State totals (all sites)		**0.1**	**5.5**	**264.3**
Purple sandpiper				
State totals (all sites)			**3.6**	**0.3**
Dunlin				
Merritt Island NWR, Black Point Dr.	Northeast	1.1	6.3	873.8
State totals (all sites)		**8.1**	**48.4**	**6,698.2**
Short-billed dowitcher				
State totals (all sites)		**3.5**	**19.7**	**2,131.2**
Common snipe				
State totals (all sites)		**0.0**	**0.1**	**0.9**

It would be difficult to quantitatively compare shorebird distribution from the CBC and our survey. One could group the sites by coastal region and use nonparametric methods to compare the rank of coastal area within each species between the 2 surveys to identify any bias against a particular coastal region. Alternatively, the species within each coastal area could be ranked to see if 1 survey has a bias against a particular species. Any nonparametric method would have to consider the different number of sites censused by both surveys. We recommend that future surveys try to visit potentially undersurveyed areas.

***Identification and Observer Variability.*—**The bias of a count is the measure of the deviation of the estimators from the real value. Biases contribute to the inaccuracy of the count and therefore introduce greater variability that further reduces the power of a monitoring effort to detect trends.

Differences in visual acuity, alertness, experience, knowledge, and number of observers can bias bird counts (Verner 1985). The occurrence of mixed-species flocks may tempt observers not to identify each individual. Observer expectancy (Balph and Balph 1983) may particularly bias the count of mixed flocks in favor of the most common species. Rappoldt et al. (1985) reported a relative stochastic error between observers of 37% for flocks of roosting shorebirds. Some observers may count each individual, while other observers estimate the total number of birds in the flock and estimate the percentage composition. In large flocks, individuals of species that are uncommon or difficult to identify are likely to go undetected, though a regression of species count versus flock size for our surveys showed a positive correlation ($P < 0.0001$, $F = 57.8$, $r^2 = 0.17$).

Without a known and constant population at a site, it is impossible to directly measure observer bias at a site. Observer differences may, however, be implied from differences in attributes associated with each individual's counts. Despite training efforts before the surveys, we suspect that observers varied in their approaches and capability to identify birds (Table 16). For example, observer B showed a significantly lower average time spent observing ($t = 2.76$, $P = 0.01$, df = 56). However, most sites that observer B surveyed were isolated and required travel by boat and, consequently, the 30-minute minimum was often violated to reach multiple sites at the proper tide level on the same day. All observers with 2 years experience spent a greater average time (65 minutes versus 33) during the visits than all first-year observers ($t = 5.22$, $P \leq 0.001$, df = 269). Differences could not be quantified between observers without simultaneous multiple counts by different individuals at the same site (Cobb et al. 1995). Most likely, differences in species present, site conditions, and bird behavior contributed to variation among observers as much as differences in individual skill.

The percent of unidentified birds increased with the minimum distance between the observers and the birds ($F = 13.241$, $b = 0.044$ percent unidentified

Table 16. Percent of wintering shorebirds unidentified by individual surveyor at 60 sites in Florida, 16 December 1993 through 1 March 1994.

Observer	Years experience	Number of visits: Total	Number of visits: Without birds	Total birds counted	% unidentified	Average % unidentified by visit (SD)	Visit duration, minutes (SD)
A	1	24	0	9,627	14.5	12.2 (13.1)	38.5 (24.2)
B	1	40	10	31,023	12.9	2.3 (12.6)	18.8 (14.4)
C	1	18	4	6,443	45.7	29.4 (35.0)	32.6 (23.4)
D	2	34	2	7,998	10.9	2.7 (7.7)	49.4 (23.9)
E	2	9	0	1,526	8.8	19.1 (30.8)	110.3 (26.2)
F	2	77	2	34,487	18.2	15.6 (22.8)	48.0 (36.5)
G	2	9	1	1,721	4.7	1.4 (3.9)	54.1 (47.8)
H	1	60	6	40,007	13.3	11.0 (18.2)	41.7 (25.2)

per meter distance, P = 0.0003, df = 244) and with the maximum distance between the observers and the birds (F = 26.420, b = 0.021 percent unidentified per meter distance, P = 0.0001, df =243). The percent unidentified also increased as the total number of shorebirds increased (F = 5.001, b = 0.0036 percent unidentified per added shorebird, P = 0.026, df = 244). Although second-year observers had a lower average percentage unidentified than first-year observers (21.6% versus 10.7%), the difference was not significant (t = 1.28, P = 0.24, $1 - \beta = 10$). Sites in the Panhandle that were visited both in 1993 and 1994 had a lower average percentage unidentified (14.4% versus 9.6%), but the difference was not significant (t = 0.963, P = 0.367, $1 - \beta = 5$).

Accuracy in identifying birds is also influenced by the birds' activity. Feeding birds were more dispersed and active, while roosting birds, though clustered and approachable, were often in a posture that made identification difficult. We were unable to identify 15.4% of the feeding birds, while 18.2% of roosting birds were unidentified ($\chi^2 = 145.2$, $P < 0.005$, n = 12,656, df = 2). For flying birds, 31.4% were unidentified.

The mean of the CV for sites visited by the same observers in 1993 and 1994 (Table 17) were 0.642 and 0.688 respectively. A paired t-test showed no significant difference between the CVs for the sites from 1993 and 1994 (t = –0.298, P = 0.774, $1 - \beta = 5$), so there is no evidence that repeated visits by the same observer had lower variance after a second year.

Accuracy of Initial Guess.—The number of birds estimated in the initial guess made at the start of each visit was correlated with the actual number of individuals counted during the visit (F = 160.664, b = 0.62 estimated birds per actual total birds, P = 0.0001, df = 250). A b of 0.62 indicates that our initial guess tended to underestimate the actuate shorebird count by 38%. Some observers occasionally counted groups to come up with an "initial guess." This, no doubt, caused the significance to be artificially high. The initial guess may be meaningless for some visits. For example, at large sites that could not be easily observed from 1 point, the initial observation was often incomplete and therefore lower. Additionally, if birds are arriving during the visit, the initial count would have been low. The accuracy of the initial guess was not strongly correlated with the rate of arrival or departure (F = 0.112, b = –0.201, $P = 0.738$, df = 220, $1 - \beta = 4$). We suggest that an initial guess of the number of birds is a sound precaution against getting no count, but it is no substitute for a complete count.

We found no clear relation between accuracy and total number of birds (F = 0.458, b = 0.011 accuracy percentage per total birds, $P = 0.499$, df = 227, $1 - \beta = 9$). In order to improve accuracy and precision we recommend that future surveys include training sessions and adherence to a count protocol that includes a minimum time spent at each site.

Ranking Winter Shorebird Sites

Biological Importance.—The development of a ranking scheme allows future surveys and conservation efforts to concentrate on the most important sites. We ranked survey sites in Florida according to their biological importance to wintering shorebirds (Table 18). The scores for determining the importance of a shorebird wintering site are useful only if they are based upon accurate and reliable measures of biological importance. Our ranking scheme valued highly those sites that supported many individuals or many species, sites containing a large part of the total population of a species, and sites used by vulnerable species.

Some ranking schemes use the maximum counts for a site (Runde 1991) or for a season (Fuller 1980); however, we used the average of all counts at a site due to biases inherent in taking the highest count. We assumed that the average count gave an accurate representation of the number of shorebirds at the site and that sites are surveyed at the same relative number of "best" and "worst" of times. By averaging counts, we tended to rank sites higher if they were used more consistently at different tide levels. A better score might be derived using shorebird-use days or hours (Williams 1980), but the effort required to obtain these data would be prohibitive.

Species richness was also based upon the average of winter counts. The total number of birds by itself is insufficient because a site with many individuals of a common species will rank higher than a site with many individuals of a rare species (Lloyd 1984).

The importance of a site relative to the Atlantic flyway and to the Florida winter population were also ranking variables. Although the exact sizes of the

Table 17. Comparison of mean counts for the total of all species and coefficient of variation (CV) made on multiple years using field techniques of the Winter Shorebird Survey, 1993 through 1995.

	1993			**1994**			**1995**			**Regression 93–95**		***t*-test 93 vs 94**		***t*-test 94 vs 95**		***t*-test 93 vs 95**	
Site	$\bar{x}$	**CV**	**N**	$\bar{x}$	**CV**	**N**	$\bar{x}$	**CV**	**N**	**P**	**1-B[a]**	**P**	**1-B[b]**	**P**	**1-B[b]**	**P**	**1-B[b]**
Bald Point	54.4	0.7	14	87.1	0.61	29	38.6	0.59	5	0.8411	0	0.12	65	0.05	43	0.41	15
Carrabelle Beach	210.4	0.62	14	285.1	0.47	12	180.5	0.51	4	0.4821	0	0.3	27	0.15	N/A	0.6	N/A
East of Bay North	216.6	0.85	11	318.5	0.87	8	84.5	0.89	3	0.3736	0	0.36	14	0.2	N/A	0.24	N/A
Lanark Reef	1872.3	0.2	3	2030.8	0.56	5	N/A			N/A		>0.5	N/A				
St. Marks, Mounds Pool #3	644.5	0.91	12	873.4	0.87	9	N/A			N/A		0.45	12				
Cape San Blas	406.2	0.73	6	222.0	0.25	5	N/A			N/A		0.2	N/A				
Phipps Preserve	61.5	0.95	8	38.9	0.76	7	N/A			N/A		0.36	N/A				
Ochlockonee Point	35.0	0.18	3	33.2	1.11	4	N/A			N/A		>0.5	N/A				
Yent Bayou	N/A			219.5	0.58	11	212.5	0.22	4	N/A		N/A	N/A	0.25	N/A		

[a] Power analysis was computed based on Cobb et al. (1996).
[b] Power analysis was computed based on Cohen (1988).

Table 18. Final 60 Winter Shorebird Survey sites ranked by their biological importance to wintering shorebirds based upon 5 variables. Sites are ranked by biological importance within each coastal region.

Region and site	Abundance	Richness	Flyway	Florida	Vulnerability	Total
Panhandle Coast						
Lanark Reef	10	10	8	10	9	47
Cape San Blas	4	8	2	4	5	23
Carrabelle Beach	4	6	2	4	4	20
Shell Island, east end Inlet	2	6	2	4	4	18
Marifarms	6	6	2	0	2	16
Yent Bayou	4	6	2	0	4	16
Crooked Island West, east end	1	4	2	4	4	15
Crooked Island East, west end	1	4	2	0	4	11
East of Bay North	5	2	2	0	1	10
Shell Island, west end	0	2	2	0	3	7
Carrabelle River Flats	1	4	0	0	2	7
Phipps Preserve	0	4	0	0	3	7
Fort Pickens, west end	1	2	0	0	2	5
St. Joseph Peninsula	0	2	0	0	2	4
Big Bend Coast						
Sprague Island oyster bars	6	4	2	4	3	19
St. Marks NWR, Mounds Pool #3	8	4	2	0	1	15
Hagens Cove	5	4	2	0	1	12
Cedar Key, south of Hodges Bridge	5	2	2	0	1	10
Cedar Key, Hodges Bridge	8	0	0	0	1	9
Cedar Key, Seahorse Key	4	2	0	0	1	7
Southwest Coast						
Shell Key	10	10	4	8	6	38
Honeymoon Island	6	10	4	8	9	37
Island north of Bunces Pass	10	8	4	6	5	33
Three Rooker Bar, north end	6	10	4	6	6	32
Anclote Key, south end	6	10	4	6	6	32
Little Estero CWA	5	8	4	6	8	31
Point Pinellas, west oyster	5	6	4	6	5	26
Caladesi Island, north end	5	8	2	4	7	26
Fort Desoto, northwest end	6	6	4	4	5	25
Anclote Key, north end	6	6	2	4	5	23
Caladesi Island, Dunedin Pass	5	8	2	0	7	22
Three Rooker Bar, southeast end	5	6	2	4	4	21
Passage Key NWR	6	4	2	4	3	19
Palm Island Resort	4	6	2	0	5	17
McKay Bay	6	4	2	4	1	17
Old Tampa Bay, north of Frankland Bridge	5	6	2	0	2	15
Fort Desoto, southeast end	4	6	2	0	2	14
Courtney Campbell Causeway, southeast B	4	6	2	0	2	14
Delany Creek Canal	6	6	0	0	2	14
Howard County Park, west end	1	6	2	0	4	13
Ding Darling NWR, tower stop	6	4	2	0	1	13
Lido Beach	4	4	2	0	3	13
Howard County Park, causeway	4	4	2	0	2	12
Courtney Campbell Causeway, southeast A	2	6	0	0	4	12
Turtle Beach, Midnight Pass	1	0	0	0	1	2
Lake Ingraham, southeast end	10	8	6	8	4	36
Snake Bight Channel	10	4	6	6	3	29

Table 18. Continued.

Region and site	Abundance	Richness	Flyway	Florida	Vulnerability	Total
Everglades Coast						
Tigertail Beach	5	6	4	6	5	26
Cape Romano, Morgan Beach	10	6	2	4	3	25
Northwest of Palm Key	10	2	2	4	1	19
Capri Pass	6	4	2	0	2	14
Sandy Key	4	2	0	0	2	8
Carl Ross Key	5	2	0	0	1	8
Northeast Coast						
Merritt Island NWR, Black Point Drive	10	6	2	4	2	24
Huguenot Memorial Park	2	4	0	0	4	10
Kennedy Space Center, Pad 39B	4	4	0	0	1	9
Port Orange Spoil Islands	1	4	0	0	3	8
Bennett Causeway, Merritt Island	1	4	0	0	2	7
NASA Causeway, north side	2	2	0	0	2	6
NASA Causeway, south side	2	2	0	0	2	6

flyway population and the Florida winter population are not known, the relative abundance of species within Florida and the Atlantic flyway were important in this rating. A site that supports at least 1% of a biogeographical population of an avian species can be regarded as internationally important (Fuller 1980, Lloyd 1984). Myers et al. (1987) proposed that a hemispherically important site for shorebirds should harbor at least 30% of the flyway population of a species and that regionally important sites should support 5% of the flyway population. In our statewide survey, there were 35 instances where a site averaged at least 1% of the flyway population of any species (Table 15). The most important (≥3%) usage for the flyway population included snowy plovers at Anclote Key, south end and at Crooked Island East, west end; Wilson's plovers at Three Rooker Bar, north end; Anclote Key, south end; and Lake Ingraham, south end; marbled godwits at Point Pinellas, west oyster bar and Snake Bight Channel; and piping plovers, American oystercatchers, willets, and marbled godwits at Lanark Reef.

Our variable measuring flyway importance considered the importance of a site to all species observed at the site. The flyway index is the sum of the proportion of each species at the site (Harrington et al. 1989). The average for each species is compared against the potential total Atlantic flyway population as estimated from ISS data collected at migration concentration sites (Harrington et al. 1989). ISS counts are notably small for some species. For example, ISS recorded 1,718 piping plovers, while the nationwide piping plover census (Haig and Plissner 1992) recorded 5,482 breeding and 3,451 wintering piping plovers. Comparing ISS numbers with estimates of birds wintering in South America (Morrison and Ross 1989), ISS had 10,466 willets compared to 44,370, 2,377 whimbrels compared to 24,874, and 78,288 sanderlings compared to 111,815.

Thus, our method of estimating a site's importance to the flyway population may measure relative importance more accurately than absolute importance. Similarly, the index for the Florida winter population should be used to estimate relative importance (Table 15).

The Tampa Bay area (Fig. 9) contained 20 of the final 60 sites, including 7 of the top 10. These important sites include Shell Key; Honeymoon Island; the Island north of Bunces Pass; Three Rooker Bar north and southeast end; Point Pinellas, west oyster bar; and Caladesi Island, Dunedin Pass. The Tampa Bay area is particularly important to Wilson's plovers, with as many as 20% of the flyway population wintering there. The Tampa Bay area provides Wilson's plovers a combination of warm climate, protected islands, feeding flats, and nutrient-rich waters supporting large number of fiddler crabs, a favorite prey item (Tomkins 1944). The area was also preferred by the other small plovers and it hosted 10% of the threatened snowy plovers and 5% of the threatened piping plovers. As many as 5% of the willets and marbled godwits also winter in the Tampa Bay area.

Biases of Biological Importance Variables.**—**Inherent in a ranking scheme is a value system that places relative values on individuals and species. For example, choosing to preserve a site with 10 piping plovers, which are rare, rather than a site with 100 dunlins, which are common, represents a relative value. Although the value system may not be explicit, valuation is implied by the variables included and the range of scores for each variable. Site rankings, like diversity indices, can be divided into indices that are most affected by rare species or indices most affected by abundance of the most common species (Magurran 1988).

The ranking variables used in our study were not orthogonal (i.e., 1 variable may not change independently of another). For example, the increased occurrence of a rare species affected the scores generated for total numbers, the scores assigned to both the flyway and Florida importance scores, and the vulnerability score. Spearman's rank correlation coefficients among biological variables (Table 19) showed strong correlation ($r_s > 0.50$, $P < 0.0002$) between 8 of 10 of the pairs of biological variables. The only pairs that were not significantly correlated were shorebird abundance of the site and vulnerability of the species and shorebird abundance of the site and species richness. This interdependence of variables may make the index more discriminating. It also means that some variables may not be contributing much to the overall ranking. For example, having both a Florida importance and a flyway variable may not significantly change the total ranking, though it is intuitively attractive for use in identifying sites to most efficiently conserve shorebird populations in Florida.

The first principal component (eigenvalue = 3.46) (SAS PRINCOMP, SAS Institute, Inc. 1990) showed that all of the 5 biological variables contributed equally (eigenvectors ranged from 0.35 to 0.49) and accounted for 69% of the total variability. This further demonstrates the strong coupling among these variables and makes it difficult to logically pick fewer variables. Therefore, we retained the use of all 5 original variables.

The ranking of a site should be independent of the number of visits to a site. Rankings based on just the top counts at sites were dependent upon the number of visits, which varied among sites. Therefore, we used the average count in computing ranking scores. Scores for the 60 sites of our study ranged from 2 to 47 points. This broad spread of scores suggested that we could readily distinguish important sites from less important ones.

***Sensitivity Analysis of Biological Importance Scores.*—**Sensitivity analysis may be defined as the process of determining how quickly the total ranking changes with small changes in single components. A ranking may be defined as "too sensitive" if small changes (e.g., ≤ 0.5 SD) in values cause great changes in the overall ranking (e.g., from the lower third to the top third). Alternatively, sensitivity could be defined by comparing the resultant rank with the original rank using a Spearman's rank correlation coefficient.

To assess the sensitivity of the shorebird abundance variable, we replaced the 8 categories within the abundance variable with a linear scale from 0 to 10. This change did not affect the relative ranking of sites ($r_s = 0.08$, $P = 0.14$) but did make the most important site, Lanark Reef, appear even more important.

The ranking scheme used the average count at the site as an index to the abundance of the shorebirds at the site. If, however, a site was used only intermittently, its average may not have been as high as other sites but would still be important to shorebirds. For example, if there were 2,000 dunlin dividing their time between 2 sites, the average count at both sites might be 1,000, but

Table 19. Spearman's rank correlations (and P values) between biological variables used to rank 60 Winter Shorebird Survey sites in Florida.

	Usage	Richness	Flyway %	Florida %	Vulnerability
Usage	1.00	0.39 (0.0023)	0.60 (0.0001)	0.58 (0.0001)	0.10 (0.4519)
Richness		1.00	0.67 (0.0001)	0.62 (0.0001)	0.79 (0.0001)
Flyway %			1.00	0.77 (0.0001)	0.58 (0.0001)
Florida %				1.00	0.63 (0.0001)
Vulnerability					1.00

both sites would be important to the 2,000 dunlin. To see if using the average count was affecting site rankings, we compared the average count with the maximum number of individual shorebirds observed at a site. Statewide, the sum of the maximum counts for each species at a site was over twice as high as the average count at each site (66,364 versus 30,502). This probably reflects movement of birds among sites rather than a real difference in total winter population. The difference between the mean and the sum of the highest count by species was significantly different at 41 of the 60 sites ($P \leq 0.05$). A Spearman's rank correlation coefficient of the average counts and the sum of the highest counts by species showed a high correlation ($r_s = 0.94724$, $P = 0.0001$, $n = 60$), so using the average count did not bias the overall rating.

The inclusion of 1 versus 2 flyway values was not particularly important to the total ranking of the sites ($r_s = 0.071$, $P = 0.041$, $n = 60$). There was a high correlation between sites that are important to the Atlantic flyway and to the Florida winter population ($r_s = 0.93$, $P = 0.001$).

The importance of the species vulnerability score is most evident for the site Northwest of Palm Key. This site had the sixth highest average total count (1,753); however, the vulnerability score was the lowest at 1 because the species present were less vulnerable (black-bellied plover, dunlin, western sandpiper) or unidentified. Reducing the vulnerability score by half caused only minor changes in the overall ranking.

These sensitivity analyses showed that the total ranking was not overly sensitive to small changes in any of the variables. It is important, however, to retain the original subcomponents of the score and to be aware of sites that rank high in any category. For example, although the flyway score is composed of the sum of percentages, it is important to remember which sites contain at least 5% of the total flyway population of a species (Table 15).

Another potential bias concerning the relation of variables is whether the ranking of individual variables should be merely added, or perhaps the sum of squares should be used (Manley and Davidson 1993). Summing component values may be like averaging and does not give any information about the range of scores. Summing masks extreme values in any 1 variable that could make a site valuable. For example, if site A had scores of 6, 10, 2, 10, and 2, the sum of these values would be 30, while the sum of squares would be 244. If site B had scores of 6, 6, 6, 6, and 6, the sum would still be 30, but the sum of squares would be 180. The totals are the same for both sites, but perhaps site A is potentially more important because it has a higher score in 2 of the 5 variables. A Spearman's rank correlation coefficient comparison of the ranking of shorebird sites produced by these 2 methods was highly correlated ($r_s = 0.98$, $P = 0.0001$, $n = 60$) so we retained our original scheme.

The above ranking system always allowed us to pick the best sites, but we did not consider whether the sites complemented each other in terms of species conservation. An iterative selection approach might be used to maximize complementarity between sites (Kershaw et al. 1994). For example, if we had 3 sites—site A with 200 dunlins and 100 willets, site B with 100 dunlins and 200 willets, and site C with 10 short-billed dowitchers—sites A and B would be considered most important. An iterative approach would note that no short-billed dowitchers were conserved using just sites A and B. Similarly, we could stratify the state by region and try to conserve the most important sites in each region. Because good sites tended to be valuable to multiple species we retained our simpler scheme.

Evolution of Biological Ranking Scores.—The ranking scheme was revised several times during the pilot survey in our attempts to remove biases. Originally, we rewarded sites with historical (ISS or CBC) surveys 10 additional points based on the idea that this reflected consistent usage. The ranking scheme was quite sensitive to the historical variable. For example, removing the history variable caused the newly discovered site East of Bay North to increase in rank from twelfth to seventh in the pilot survey. The difference in scores between a historic site and a recently discovered site was 10 points, which was equivalent to increasing the average count from 50 to 1,000 individuals. We decided not to use the history variable based on this sensitivity analysis and incomplete spatial coverage of Florida by the ISSs and CBCs.

The biological vulnerability variable also went through several revisions. Initially, following Runde (1991), we used the average bioscore (from Millsap et al. 1990) of all species present. After reviewing the shorebird species ranking in Millsap et al. (1990), we realized that updating the bioscores following a thorough review of post-1990 shorebird literature would provide a more accurate ranking (Appendix E). We also determined that using the average vulnerability of all species present would be biased by the presence of a single individual with a high or low vulnerability score. For example, the presence of a single killdeer could lower the average for a site greatly. To avoid this problem, the rating was changed from the average of species to the average bioscore of all individuals. This was an improvement, but we still had the problem that a site with many individuals of a common species (e.g., 600 dunlins) and a few of a vulnerable species (e.g., 10 piping plovers) would not rate a high score even though highly vulnerable species were present. Furthermore, a site used by only a few individuals of a rare species (e.g., 3 snowy plovers) would appear extremely vulnerable relative to sites with a variety of species. Our final scheme, which gives points based upon species present, avoids overweighting by occasional individuals of a common species, prevents common birds from overwhelming the value of a few rare birds, has a wider range of values than previous schemes, and adds further value to sites with rare shorebird species.

Consistency of Biological Importance Ranking Scores.—The goal of the site ranking was to determine which sites were biologically important for monitoring and species protection. Determining a site's importance is only useful, however, if the site is consistently used from year to year.

Although fidelity of specific birds to specific sites during migration (Smith and Houghton 1984) and fidelity of large numbers of birds to a few sites during migration (Harrington et al. 1989) have been studied, little is known about site fidelity during winter. For example, although band recovery rates are generally very low for shorebirds (Morrison and Myers 1989), Harrington et al. (1988) suggested high site fidelity in red knots wintering in Florida. Also, Johnson and Baldassarre (1988) found that 12 of 19 piping plovers banded in coastal Alabama returned to the same site the following year. Color-banded piping plovers in Florida also showed high winter site fidelity between years (Below 1990). Individual willets and marbled godwits in California habitually used roosts and feeding areas about 1 kilometer apart (Kelly and Cogswell 1979). Site fidelity may vary considerably among and within species, with species like the red knot moving up to 30 km over short periods, and dunlins rarely moving (Evans and Pienkowski 1984).

Another method of determining how consistently shorebirds use sites over time is to apply the biological ranking scheme to a long-term data set of multiple sites and to compare site rankings from year to year. The CBC provides nearly continuous coverage of many Florida sites and is the only available long-term data set. We assumed that there was the same level of consistency of shorebird usage exhibited for CBC circles as for our sites. This is a difficult assumption to prove because the CBC circles have a diameter of 24 km while our sites have a maximum width of ≤1 km. If birds moved regularly among specific sites within a CBC circle, counts for the 24-km-wide circle would likely be more consistent than would counts from a small 1-km-wide site. The biological importance scoring was applied to the CBC circles from 1980 through 1989 (Table 20). Although the total biological importance scores calculated from CBC circles should not be directly compared with the statewide shorebird survey, the CBC counts should provide a reasonable demonstration of consistency of use. The circles within each year were then ranked based upon the site scoring achieved for that year. The ranking of a site varied from year to year and we sorted the sites based upon the average rank of the CBC circle over the entire 10 years (Table 20). The average standard deviation of the rank for all sites was 4.6, but for those sites in the top 10, the average standard deviation of the rank was only 2.9. Those sites whose average rank was in the top 10 had at least a 95% chance of being in the top 16 for any given year.

Significance in annual changes in site rank of CBC sites was tested using the Spearman's rank correlation coefficient (Snedecor and Cochran 1967). For the

Table 20. Christmas Bird Count circles in Florida ranked by their biological importance to wintering shorebirds from 1980 through 1989. Circles are listed in descending order of importance as winter shorebird habitat.

	Rank					Bioscore	
Circle	x̄	**Highest**	**Lowest**	**SD**	**Years**	x̄	**SD**
North Pinellas	1.8	1	3	0.8	9	48.9	1.5
St. Petersburg	2.8	1	6	1.8	10	47.4	2.1
Coot Bay, Everglades	3.2	1	7	1.8	10	47.3	2.0
Tampa	3.6	1	7	1.8	10	46.1	2.3
Jacksonville	4.9	3	8	1.7	10	44.6	1.3
St. Augustine	6.7	4	10	1.9	9	43.1	2.8
Sanibel, Captiva	7.5	2	14	3.4	10	42.6	3.4
Cocoa	9.2	5	18	3.8	10	39.8	5.4
Cedar Key	10.0	5	18	4.0	10	39.8	3.9
Lower Keys	11.1	7	15	2.8	10	38.6	3.0
Port St. Joe	11.8	7	15	3.4	9	36.8	3.3
Merritt I. NWR	11.8	9	17	2.3	10	36.9	2.8
Naples	12.8	5	21	4.2	10	36.7	4.7
Sarasota	14.9	10	19	3.0	10	34.9	2.8
Bay Co.	15.8	9	28	6.5	10	33.4	7.6
Bradenton	16.3	8	28	7.5	7	32.0	7.3
Key Largo	17.9	10	32	6.6	10	31.7	5.8
Ponce Inlet	19.5	19	20	0.7	2	30.0	0.0
Fort Myers	19.7	15	27	4.4	10	29.7	4.6
Dade Co.	19.8	11	39	7.4	10	30.1	6.1
St. Marks	20.8	14	29	4.7	10	28.8	4.4
Perdido Bay	21.1	12	28	5.1	10	27.0	5.9
Fort Pierce	23.3	16	35	6.5	10	26.3	5.5
Econlockhatche	23.5	17	31	5.1	6	26.7	4.3
Venice, Englewood	23.6	16	28	4.0	10	24.5	4.4
Fort Lauderdale	24.6	19	37	6.0	10	25.2	5.0
Gulf Circle	25.4	8	38	10.5	7	24.7	9.0
Fish Creek	27.0	27	27		1	24.0	
Choctawhatchee	27.3	13	36	8.6	8	22.5	6.9
Gainesville	27.9	17	33	5.3	10	21.9	5.4
South Brevard	28.1	22	38	5.3	10	21.1	4.0
Stuart	28.1	15	36	5.9	10	21.8	6.4
New Port Richey	28.4	17	34	5.3	10	21.6	4.9
Lakeland	29.1	20	41	6.2	10	20.3	5.0
Boca Grande	29.4	18	37	6.3	7	20.9	5.8
Biscayne NP	30.2	21	37	5.9	10	20.1	4.1
West Palm Beach	32.2	26	39	4.3	10	18.2	3.5
Brooksville	33.5	24	41	5.5	10	16.4	4.5
Myakka R. SP	35.5	29	44	5.7	10	15.0	4.6
Orlando	35.8	26	42	6.8	4	9.5	7.2
Pensacola	36.1	28	41	4.9	10	14.5	3.4
Kissimmee Valley	36.3	23	45	6.1	10	13.8	6.1
Crystal R.	36.5	33	40	4.9	2	16.0	4.2
Lake Wales	36.8	27	43	5.5	10	14.2	3.0
Hamilton Co.	38.8	24	46	6.8	8	9.1	8.2
Mount Dora	38.9	35	45	3.6	10	11.2	2.9
Lake Placid	40.0	36	44	5.7	2	14.0	4.2
Peace River	41.5	40	43	2.1	2	12.5	2.1
Corkscrew Swamp	42.6	39	49	3.2	9	7.7	2.7
West Volusia	43.3	37	48	3.3	10	4.7	3.3
Marianna	43.5	38	49	3.4	10	4.3	2.2
Singing Forest	45.4	37	51	4.9	8	2.9	4.7
Prairie Lakes	46.0	45	47	1.4	2	1.5	2.1
Ortona, Glades	46.7	45	48	1.5	3	5.7	1.5
Northeast Florida	50.0	50	50		1	2.0	

years 1980 through 1989, the change in ranking from 1 year to the next was not significant ($r_s < 0.4$, $P < 0.01$).

Although the ranking and rank correlation measured the degree of association between sites among years and not the changes in a particular site, this site ranking suggested that a good site remained relatively good. Therefore, a site that was highly ranked based on the CBC data for a year had a good chance of being highly ranked in subsequent years. The implication is that the site ranking will work the same for our survey.

Potential Impacts to Sites

***Criteria for Ranking Impacts.*—**By ranking potential threats to shorebirds at a site, we can decide which sites have the greatest risk of degradation and thus are most in need of protection. Threats to shorebirds on wintering grounds include human disturbance, environmental contaminants, and habitat loss and degradation (Senner and Howe 1984). Our system for ranking potential impacts addressed these 3 parameters.

The response of local shorebird populations to habitat elimination or disturbance is not easily predicted. Some movement of birds to other sites could occur, but this depends upon the relative abundance and quality of the lost site and the available alternate sites. At sites where food shortage is already a limiting factor, an increase in density due to an influx of displaced birds would make an already difficult situation worse (Goss-Custard 1979). Food may be difficult to find in winter due to decreased day length, decreased food availability, and increased depth of invertebrates in the substrate at lower temperatures (Goss-Custard 1980). Low temperature or high wind can also affect shorebird survival (Davidson 1981). At areas with limited resting space, the loss of a roost site could cause increased stress. These situations cannot be predicted because our knowledge of foraging requirements and prey abundance for shorebirds wintering in Florida is very limited (contrast with Goss-Custard et al. 1977, 1995*b*,*c*). We conservatively assumed that increased disturbance or degradation of a site adversely affects local populations of shorebirds.

Our disturbance impact variable consisted of both an estimated peak disturbance per day component and an observed hourly disturbance rate component. Disturbance of birds by human activity is of concern because many birds winter close to coastal urban areas and are thus accessible to people. In a coastal setting, birds may be disturbed by people walking or running, off-road vehicles, and domestic pets. Undisturbed periods of resting and feeding are believed to be important to wintering shorebirds (Senner and Howe 1984). Burger (1981) considered shorebirds the group of birds most vulnerable to disturbance, because they frequently vacated an area when disturbed. Burger and Gochfeld (1991) documented decreases in foraging time of sanderlings as the number of people within 100 m increased, and Staine and Burger (1994) measured a reduced peck rate for piping plovers disturbed at night. The greatest disturbance impacts are likely during roosting periods because birds tend to be more concentrated (Senner and Howe 1984). Pfister et al. (1992) showed that front-beach roosting species shifted roost-sites or abandoned a site in response to disturbance. Although migrant shorebirds may not become acclimated to disturbance (Roberts and Evans 1993), it is not known if wintering populations acclimate. Klein et al. (1995) showed a shift in distributions of black-bellied plovers, willets, and sanderlings in response to visitation levels on Sanibel Island.

Our second impact variable dealt with the potential of environmental contamination. Spills of crude oil may pose the greatest local threat to shorebirds along Florida's coast. Birds are directly threatened by oiling of their feathers and, because shorebirds feed by wading, oiling can be expected on the belly, breast, and head. This oiling causes loss of thermal insulation. During the 1993 Tampa Bay oil spill, shorebirds were not heavily oiled initially, but about 9% of the shorebirds on Shell Key were oiled a week after the spill (P. Blair in Douglass 1993). Larsen and Richardson (1990) reported that a major oil spill in Grays Harbor, Washington, caused behavioral changes and possible mortality among wintering shorebirds. Smith and Bleakney (1969) reported that oiled shorebirds spent a greater amount of time preening than non-oiled birds. Ingestion of oil may cause death by dehydration by interfering with ion transport and water balance in the gut (Ohlendorf et al. 1978).

Secondarily, oil spills and dissolved oil fractions may affect shorebirds by causing mortality to sea grass beds and to invertebrates, which readily take up the oil (National Research Council 1985). Biological effects of spills are usually greater in lower energy environments where oil accumulates, so there may be a greater impact along the Gulf coast because it has lower energy waters and more shorebirds. Tropical marine systems that are biologically structured, such as coral reefs, mangroves, and sea grass beds, tend to hold sediment in place. The oil stays trapped in sediment until heavy rains cause the oil to be released, which in effect causes another spill (Jackson et al. 1989). Spilled oil can also be trapped in mussel beds (Babcock et al. 1993), and in Alaska, the black oystercatcher (*Haematopus bachmani*) needed more time to search for food at oiled sites (Edgar 1993). In Florida, an oil spill could cause problems for birds using oyster bars as roosts or for American oystercatchers feeding on oiled oysters. Our ranking of contamination potential was based on the volume of pollutant shipping at Florida ports (Department of Natural Resources 1988). This parameter could be improved by considering shipping lanes, distance from a port, and pollutant type.

Our final impact variable was used to assess the risk of habitat loss and degradation. A variety of development and human activities result in loss of coastal habitat, including dredging and excavation, spoil disposal, impounding, and sediment diversions (Senner and Howe 1984). Predicting future development patterns is difficult, especially for a specific individual site. Because land development is strongly correlated with human population growth in an area, we used trends in human populations as an index of the potential for land to be developed. We computed relative growth by determining current and projected population levels by county (Kiplinger 1992, Marth and Marth 1992). These population growth levels were applied only if the site was private property. We assumed that publicly owned lands would remain undeveloped, although we recognize this is not always the case.

We ranked the study shorebird sites based upon impact scores (Table 21). The sites Delany Creek Canal; Palm Island Resort; McKay Bay; Courtney Campbell Causeway, southeast B; and Old Tampa Bay, north of Frankland Bridge; all located along the southwest coast, had the highest (≥14) potential for impacts from pollutants, disturbance, and development.

***Other Environmental Impacts.*—**Environmental contaminants other than oil, both from point and non-point pollution sources, may impact shorebirds, but we did not include them in the impact score because contaminant levels are not available for all sites. The main pollutants of concern for shorebirds are organochlorine pesticides and herbicides, which reach coastal wetlands (Senner and Howe 1984). These compounds may affect egg laying or poison adult birds (Flickinger and King 1972, Ohlendorf et al. 1978). White et al. (1983) reported high DDE levels (40 to 64 ppm) in long-billed dowitchers and American avocets wintering on the Texas coast near agricultural lands. Schick et al. (1987) reported low (0.01 to 1.2 ppm) DDE levels in dunlins in Washington but occasional high levels (up to 32 ppm) in wintering sanderlings from California. Only 2 regularly monitored NOAA sites in Florida (Little Oyster bar near Panama City and Postil Point in Choctawhatchee Bay) recorded high levels of DDT, DDE, or DDD (O'Connor 1992), but local concentrations may be higher at specific locations. Although DDT has been banned in the United States since 1972, it is still commonly used in South America, where many shorebirds winter (Morrison and Ross 1989).

Heavy metals at high concentrations can be toxic to shorebirds, but little is known about the contamination among shorebird populations or variations in toxicity levels. The main source of heavy metals in estuaries is probably the direct discharge of effluent from manufacturing and refining sites (e.g., Vermeer and Castilla 1991). Thirteen of 32 NOAA sites monitored in Florida contained high levels of some heavy metal (O'Connor 1992). High levels of cadmium (Evans and Moon 1981 as cited in Senner and Howe 1984) and mercury

Table 21. Variables and scores used to rank 60 Winter Shorebird Survey sites in Florida based on potential impact to shorebird populations.

Region and site	Disturbance rate[a]		Pollution potential[b]			Development potential		Impact scores			
	Hourly mean	Daily peak	Nearest port	Distance (km)	Vol. shipped (mill. of m^3)	Growth[c]	Ownership	Disturbance	Pollutant	Development	Total
Panhandle Coast											
Fort Pickens, west end	1.9	20	Pensacola	11	0.8	24	Public	6	3	0	9
Crooked Island East, west end	4.6	5	Port St. Joe	24		24	Public	6	1	0	7
Cape San Blas	1.6	20	Port St. Joe	16		1	Public	6	1	0	7
Marifarms	0.4	1	Panama City	14	0.7	24	Both	1	2	3	6
Shell Island, west end	2.4	1	Panama City	7	0.7	24	Public	3	2	0	5
Crooked Island West, east tip	1.7	1	Panama City	20	0.7	24	Public	2	2	0	4
Shell Island, east end inlet	1.1	1	Panama City	9	0.7	24	Public	2	2	0	4
Carrabelle Beach	1.3	5				2	Public	4	0	0	4
East of Bay North	0.0	1				2	Private	1	0	3	4
Yent Bayou	1.2	0				2	Private	1	0	3	4
Phipps Preserve	1.7	0				2	Private	1	0	3	4
St. Joseph Peninsula	1.0	1	Port St. Joe	11		1	Public	2	1	0	3
Carrabelle River Flats	1.3	1				2	Public	2	0	0	2
Lanark Reef	0.4	0				2	Public	0	0	0	0
Big Bend Coast											
Cedar Key, south of Hodges Bridge	2.1	5	Cedar Key	3		5	Both	5	1	3	9
Cedar Key, Hodges Bridge	1.4	5	Cedar Key	4		5	Both	4	1	3	8
Cedar Key, Seahorse Key	0.8	20	Cedar Key	5		5	Public	6	1	0	7
St. Marks NWR, Mounds Pool #3	0.4	1	St Marks	3	0.8	4	Public	1	3	0	4
Sprague Island Oyster Bar	0.7	0	St Marks	3	0.8	4	Public	1	3	0	4
Hagens Cove	0.4	1	Steinhatchee	21		1	Public	1	1	0	2
Southwest Coast											
Delany Creek Canal	0.7	1	Manatee	23	2.4	126	Both	2	10	8	20
			Tampa	5	17.5						
Palm Island Resort	3.1	20	Boca Grande	21	0.9	52	Private	7	3	6	16
McKay Bay	0.4	20	Tampa	11	17.5	126	Public	5	10	0	15

Table 21. Continued.

Region and site	Disturbance rate[a]		Pollution potential[b]			Development potential		Impact scores			
	Hourly mean	Daily peak	Nearest port	Distance (km)	Vol. shipped (mill. of m^3)	Growth[c]	Ownership	Disturbance	Pollutant	Development	Total
Southwest Coast continued											
Courtney Campbell Causeway, southeast B	3.0	5	Manatee	21	2.4	126	Public	5	10	0	15
			Tampa	17	17.5						
Old Tampa Bay, north of Franklin Bridge	0.7	5	Manatee	19	2.4	126	Public	4	10	0	14
			Tampa	15	17.5						
Fort Desoto, east end	5.7	20	Manatee	20	2.4	276	Public	8	5	0	13
Courtney Campbell Causeway, southeast A	0.0	5	Manatee	21	2.4	126	Public	3	10	0	13
			Tampa	16	17.5						
Shell Key	2.3	20	Manatee	16	2.4	276	Public	7	5	0	12
Fort Desoto, northwest end	0.7	20	Manatee	19	2.4	276	Public	6	5	0	11
Point Pinellas, west oyster bar	0.9	20	Manatee	10	2.4	276	Public	6	5	0	11
Island north of Bunces Pass	0.7	20	Manatee	17	2.4	276	Public	6	5	0	11
Three Rooker Bar, north end	5.9	20				276	Public	8	0	0	8
Turtle Beach, Midnight	2.7	20				104	Public	7	0	0	7
Lido Beach	3.1	20				104	Public	7	0	0	7
Honeymoon Island	2.8	20				276	Public	7	0	0	7
Caladesi Island, north end	2.5	20				276	Public	7	0	0	7
Howard County Park, causeway	2.2	20				276	Public	7	0	0	7
Little Estero CWA	1.8	20				100	Public	6	0	0	6
Anclote Key, south end	1.4	20				87	Public	6	0	0	6
Three Rooker Bar, southeast end	1.8	20				276	Public	6	0	0	6
Howard County Park, west end	1.3	20				276	Public	6	0	0	6
Caladesi Island, Dunedin	1.9	20				276	Public	6	0	0	6
Anclote Key, north end	0.3	20				87	Public	5	0	0	5
Passage Key NWR	1.0	5				26	Public	4	0	0	4
Ding Darling NWR, tower stop	2.0	1				100	Public	3	0	0	3

Table 21. Continued.

Region and site	Disturbance rate[a] Hourly mean	Daily peak	Pollution potential[b] Nearest port	Distance (km)	Vol. shipped (mill. of m^3)	Development potential Growth[c]	Ownership	Impact scores Disturbance	Pollutant	Development	Total
Everglades Coast											
Cape Romano, Morgan Beach	5.0	5				27	Public	6	0	0	6
Tigertail Beach	8.1	5				27	Public	6	0	0	6
Capri Pass	0.5	5				27	Public	4	0	0	4
Northwest of Palm Key	0.0	5				8	Public	3	0	0	3
Carl Ross Key	0.0	5				8	Public	3	0	0	3
Lake Ingraham, southeast side	0.0	1				8	Public	1	0	0	1
Sandy Key	0.0	1				8	Public	1	0	0	1
Snake Bight Channel	0.0	1				8	Public	1	0	0	1
Northeast Coast											
Huguenot Memorial Park	3.2	20	Jacksonville	20	5.2	88	Public	7	5	0	12
NASA Causeway, south side	10.7	1	Cocoa	12	1.3	73	Public	6	3	0	9
Port Orange Spoil Islands	7.7	20	Daytona Beach	9	0.0	74	Public	8	1	0	9
Bennett Causeway, Merritt Island	0.5	5	Cocoa	9	1.3	73	Public	4	3	0	7
Merritt Island NWR, Black Point Drive	0.0	1				73	Public	1	0	0	1
Kennedy Space Center, Pad 39B	0.0	0				73	Public	0	0	0	0

[a] Number of direct disturbances by people or pets. Hourly rates are mean number of disturbances observed during surveys; daily maxima are categorical estimates made by the observer.
[b] Only ports within 24 km of the site are listed. Volume shipped is the annual amount of petroleum and other potential pollutants that are shipped through the named ports.
[c] Growth represents estimated increase in human population density per decade per 2.6 km^2.

(Parslow 1973) have been found in shorebirds wintering in Britain. White et al. (1980) reported levels of selenium in shorebirds from Texas that might be sufficient to cause reproductive failure or toxicity, though Goede (1993) reported that selenium levels are generally high in shorebirds and may act as antioxidants. Furthermore, Goede et al. (1989) found that high levels of selenium, mercury, arsenic, or cadmium in migrant or wintering dunlins declined rapidly before breeding and may not affect reproduction.

Some areas in Florida may pose specific environmental threats to wintering shorebird populations. In Florida Bay, the decrease in fresh water reaching the bay, sea grass die-off, and subsequent increase in nutrients and algal blooms have reduced the amount of available habitat for marine organisms (Bancroft 1993, Paulic and Hand 1994). Increase of nitrogen from fertilizer, sugarcane farms, or phosphate, along with the contribution of pesticides from agricultural activities around Lake Okeechobee, all contribute to the problem. NOAA researchers reported finding detectable levels of pesticides in 5 of 34 sampling stations (Kirchhoff 1995) and there is evidence of high levels of PCBs and DDTs. Additionally, high levels of mercury in oysters have been recorded at specific sites (Cantillo et al. 1993), and mercury has been discovered in cormorants and mergansers (Kirchhoff 1995).

The Tampa Bay estuary is important to wintering shorebirds in Florida and, with 1.9 million people living in the metropolitan area, it has been impacted by many human actions. Inputs of pathogens and toxic chemicals have contaminated some parts of the Tampa Bay estuary. A primary concern has been eutrophication of the bay caused by stormwater runoff, atmospheric deposition, and wastewater treatment plants. Hillsborough Bay is consistently classified as having poor water quality (Paulic and Hand 1994) with high toxicity (Long et al. 1995); Delaney Creek, in particular, has very poor water quality (Hand et al. 1994). Compared to other sites nationwide, oysters from Tampa Bay have high concentrations of mercury, zinc, and chlordane, and the bay sediments have high concentrations of DDT, other chlorinated pesticides, and lead (Long et al. 1991). Benson et al. (1994) found high selenium levels in McKay Bay. Tampa Bay is part of the National Estuary Program, and plans are being put into place for development of management actions including sea grass restoration and monitoring and reducing pollutants (Greening and Eckenrod 1995).

Because some shorebird species forage in sea grass beds, loss of these areas may adversely affect shorebird populations. Dredge-and-fill projects and shoreline alterations have resulted in a 40% loss of sea grass beds in Tampa Bay since 1950, though there has been an increase from 1982 to 1990 in sea grass (Paulic and Hand 1994). Sea grass can be scarred and degraded by boats operating in shallow water. Some shorebird areas in Tampa Bay with propeller-damaged sea grass beds include the area around Fort Desoto (greatly affected), north of Courtney Campbell Causeway (moderately affected), and Point Pinellas (minimally affected) (Clark 1995). Other areas with dense human population and high shorebird numbers—such as the Florida Keys and Charlotte Bay (Sargent et al. 1995)—also have large areas of sea grass scarring. Sea grass is also affected by eutrophication, turbidity from runoff, dredging, and increased freshwater inflows (Paulic and Hand 1994).

Coastal engineering projects such as seawall or beach nourishment have potential to impact important shorebird areas (e.g., Caxambas Pass seawall [Stephen 1995]) and all such projects should consider environmental impacts (Rosen 1993). Beach nourishment projects do not necessarily damage benthic communities (Marsh and Turbeville 1982) and might be used to create or maintain suitable shorebird habitat.

Sensitivity Analysis of Impact Scores.—Increasing the relative weight of the disturbance variable caused a marked increase in the impact ranking of sites that were popular with human visitors. For example, Fort Desoto, east end had high visitation, a high disturbance score, and was subsequently included in the high impact category. Due to differences in observed hourly disturbance rates and estimated daily peak disturbances, just using the hourly rate variable would cause the NASA Causeway, south side site to change from medium impact to high impact, while sites in the southwest coast with high estimated peak rate but low observed rate—like Fort Desoto, northwest end—would be changed from high to medium impact.

Sites in the southwest coast, particularly those around Tampa Bay, were most sensitive to the weighting of pollutants because of the presence of Port Manatee and Port of Tampa. The ranking was sensitive to the assumption about how close a site needed to be to a port to have an oil spill potential. Increasing the affected range from 24 to 40 km also caused Port Manatee and Port of Tampa to have greater influence on important sites in the southwest coast, including McKay Bay; Passage Key NWR; Caladesi Island, north end; Caladesi Island, Dunedin Pass; Shell Key; Island north of Bunces Pass; Fort Desoto, northwest and southeast end; Honeymoon Island; Point Pinellas, west oyster bar; and Three Rooker Bar, southeast end. This variable caused the greatest change in the total impact ranking.

The development variable provided only a gross granularity for estimating growth, because all private sites within the same county were assumed to have the same development potential. The assumption that public land would not be developed meant that errors in recording the ownership greatly affected the ranking. For example, Crooked Island East, west end; Crooked Island West, east end; Shell Island, west end; and Shell Island, east end inlet were mistakenly originally recorded as private property and, therefore, susceptible to development. When corrected, the impact ranking of Crooked Island East, west end and Crooked Island West, east end changed from high to medium, and Shell Island, west end and Shell Island, east end inlet changed from the high to low. Some public lands (e.g., military bases) might still be susceptible to development, but we assumed the potential for development would be minor compared with private lands. Conversely, some privately owned sites, such as Phipps Preserve, are set aside as nature preserves and are not likely to be developed. We chose to leave these areas in the private land category because future use of the area might change.

Spearman's rank correlation coefficient was used to measure the degree of association among impact variables (Table 22). There was orthogonality between pollution and disturbance, and pollution and development, but there was a modest negative correlation ($r_s = -0.24$, $P = 0.066$) between disturbance and development. Perhaps the negative correlation between disturbance and development was because sites that were surveyed were rare protected sites (e.g., state parks) within generally developed areas.

Important and Vulnerable Wintering Shorebird Sites.—Our classification of biological importance produced site scores that ranged from 0 to 14, 15 to 26, and 27 to 47 points for low, medium, and high categories, respectively. The impact scores ranged from 0 to 4, 5 to 10, and 11 to 20 for low, medium, and high categories, respectively. We ranked the sites using results of the logical overlay for the study data (Table 23, Fig. 5). Of the 60 sites we compared, Shell Key and the Island north of Bunces Pass had the highest risk and are thus most in need of conservation actions to protect the wintering shorebirds. Other medium or high risk sites might be considered for designation by the FGFWFC as Critical Wildlife Areas. Of the 9 sites with high biological scores, only 3 sites were deemed to be at low risk: Lake Ingraham, southeast end; Snake Bight Channel; and Lanark Reef. There was no correlation between the impact rank and biological rank ($r_s = -0.008$, $P = 0.503$, $n = 60$) for the 60 sites. Both good and average sites are at risk and allocation of conservation resources should consider both the biological importance of a site and its presumed risk of impact.

Table 22. Spearman's rank correlations (and P values) between impact variables, used to rank 60 Winter Shorebird Survey sites in Florida, 16 December 1993 through 1 March 1994.

	Disturbance	**Pollutant**	**Development**
Disturbance	1.0	0.10 (0.43)	-0.24 (0.066)
Pollutant		1.0	0.11 (0.39)
Development			1.0

Monitoring Winter Shorebird Numbers

Variance in Shorebird Count Data.—CVs of total shorebird counts ranged from 0.11 to 2.06 with a mean CV of 0.86 (Table 7). Counts at Cape San Blas; Honeymoon Island; and Old Tampa Bay, north of Frankland Bridge had the lowest CVs (≤ 0.25), while those at Snake Bight Channel and Sandy Key had the highest CVs (≥ 1.65). Although the number of shorebirds using a site varied greatly, winter surveys may prove better for collecting data for detecting population trends than surveys conducted in other seasons. For example, at 1 of 3 ISS and 2 of 3 pilot study sites, total winter counts had a lower CV than in other seasons (Table 24), but the differences in CV were not significantly lower ($P > 0.25$, $1 - \beta < 40$) at any sites except St. Marks NWR, Mounds Pool #3 (F = 9.99, $P = 0.038$, df = 4).

Reducing Variation within Years.—For the statewide study, there was no definite correlation between the CV and the mean ($r = 0.1$, $P = 0.1$); therefore, the data could not be normally transformed by either a logarithmic (Chatfield 1989) or square-root transformation (Sokal and Rohlf 1981). Restricting analyses to only the 3 highest counts at each site was not a valid approach for reducing variability.

Hypothetically, increasing the sample size (N) might decrease total variance. Interestingly, in the pilot study the 5 sites with the fewest visits had a mean CV of 0.48; the 5 sites with the most visits had a mean CV of 0.80, which was significantly different ($t = 2.13$, $P = 0.065$, df = 8, $1 - \beta = 37$). For the statewide survey, the 17 sites visited more than 4 times had a mean CV of 0.85, while the 43 sites visited 4 or less times had a mean CV of 0.73, but this difference was not significant ($t = 1.21$, $P = 0.230$, df = 58, $1 - \beta = 10$).

Our modeling to evaluate the effect of increasing sample size on count variability showed that increasing the number of visits increased the repeatability of the CV but did not change the average CV (Fig. 33). Increasing the number of visits similarly increased the repeatability of the means without changing the average mean (Fig. 34). The purpose of increasing visits should therefore be to make the CV and mean more reliable and approach the "true" variation of the population.

Grouping data by specific environmental conditions (e.g., tide) might have also reduced variation, but it also reduced the sample size by excluding surveys that were not collected under the specific conditions. Furthermore, because no 2 visits represent the same exact tidal or wind conditions, subjective choice must be made in grouping surveys. Grouping the count data by high tide at St. Marks NWR, Mounds Pool #3 during the pilot survey increased the count mean ($t = -1.34$, $P = 0.198$, df = 16, $1 - \beta = 13$) and reduced the CV (Table 25),

Table 23. Winter Shorebird Survey sites categorized by potential risk.

Region and site	Impact score	Biological score	Potential risk
Panhandle Coast			
Cape San Blas	Medium	Medium	Medium
Carrabelle Beach	Low	Medium	Low
Carrabelle River Flats	Low	Low	Low
Crooked Island West, east end	Low	Low	Low
Crooked Island East, west end	Medium	Low	Low
East of Bay North	Low	Low	Low
Fort Pickens, west end	Medium	Low	Low
Lanark Reef	Low	High	Low
Marifarms	Medium	Medium	Medium
Phipps Preserve	Low	Low	Low
Shell Island, east end inlet	Low	Medium	Low
Shell Island, west end	Medium	Low	Low
St. Joseph Peninsula	Low	Low	Low
Yent Bayou	Low	Medium	Low
Big Bend Coast			
Cedar Key, Hodges Bridge	Medium	Low	Low
Cedar Key, Seahorse Key	Medium	Low	Low
Cedar Key, south of Hodges Bridge	Medium	Low	Low
Hagens Cove	Low	Low	Low
Sprague Island oyster bars	Low	Medium	Low
St. Marks NWR, Mounds Pool #3	Low	Medium	Low
Southwest Coast			
Anclote Key, north end	Medium	Medium	Medium
Anclote Key, south end	Medium	High	Medium
Caladesi Island, Dunedin Pass	Medium	Medium	Medium
Caladesi Island, north end	Medium	Medium	Medium
Courtney Campbell Causeway, southeast A	High	Low	Low
Courtney Campbell Causeway, southeast B	High	Low	Low
Delany Creek Canal	High	Low	Low
Ding Darling NWR, tower stop	Low	Low	Low
Fort Desoto, east end	High	Low	Low
Fort Desoto, northwest end	High	Medium	Medium
Honeymoon Island	Medium	High	Medium
Howard County Park, causeway	Medium	Low	Low
Howard County Park, west end	Medium	Low	Low
Island north of Bunces Pass	High	High	High
Lido Beach	Medium	Low	Low
Little Estero CWA	Medium	High	Medium
McKay Bay	High	Medium	Medium
Old Tampa Bay, north of Frankland Bridge	High	Low	Low
Palm Island Resort	High	Medium	Medium
Passage Key NWR	Low	Medium	Low
Point Pinellas, west oyster bar	High	Medium	Medium
Shell Key	High	High	High
Three Rooker Bar, north end	Medium	Medium	Medium
Three Rooker Bar, southeast end	Medium	High	Medium
Turtle Beach, Midnight Pass	Medium	Low	Low

Table 23. Continued.

Region and site	Impact score	Biological score	Potential risk
Everglades Coast			
Cape Romano, Morgan Beach	Medium	Medium	Medium
Capri Pass	Low	Low	Low
Carl Ross Key	Low	Low	Low
Lake Ingraham, southeast end	Low	High	Low
Northwest of Palm Key	Low	Medium	Low
Sandy Key	Low	Low	Low
Snake Bight Channel	Low	High	Low
Tigertail Beach	Medium	Medium	Medium
Northeast Coast			
Bennett Causeway, Merritt Island	Medium	Low	Low
Huguenot Memorial Park	High	Low	Low
Kennedy Space Center, Pad 39B	Low	Low	Low
Merritt Island NWR, Black Point Drive	Low	Medium	Low
NASA Causeway, north side	High	Low	Low
NASA Causeway, south side	Medium	Low	Low
Port Orange Spoil Islands	Medium	Low	Low

Table 24. Seasonal variation in the number of winter shorebirds counted at 3 ISS sites and 3 additional survey sites.

						Coefficient of variation	
Site	Survey dates	Season[a]	Years	Mean visits/yr	Mean number of shorebirds	$\bar{x}$	SD
ISS sites							
Marco River	1980–87	Winter	8	6.3	1,204.1	0.49	0.21
		Spring	8	7.1	827.6	0.70	0.47
		Fall	7	10.4	714.3	0.51	0.12
Romano	1980–87	Winter	4	2.0	7,602.1	0.67	0.51
		Spring	4	3.3	2,971.9	0.78	0.04
		Fall	4	6.0	5,496.0	0.53	0.37
Mayport	1977–81	Winter	4	10.8	798.8	0.49	0.14
		Spring	2	3.0	932.5	0.31	0.28
		Fall	4	2.1	706.6	0.56	0.11
Winter shorebird sites							
Bald Point	1993–95	Winter	3	14.0	61.3	0.66	0.14
		Spring	3	8.3	120.4	0.77	0.16
		Fall	3	10.3	29.7	0.49	0.45
Carrabelle Beach	1993–95	Winter	3	8.3	230.2	0.48	0.14
		Spring	3	8.3	157.5	0.79	0.15
		Fall	3	9.7	65.3	0.90	0.24
St. Marks NWR,	1993–95	Winter	3	6.7	595.8	0.87	0.06
Mounds Pool #3		Spring	2	8.0	331.0	1.46	0.15
		Fall	2	11.0	181.2	1.74	0.44

[a] Winter = December to February; spring = March to June; fall = July to November.

despite the decreased sample size. For Carrabelle Beach, grouping the data based on low tide increased the mean slightly ($t = -0.159$, $P = 0.876$, df = 17, $1 - \beta = 5$) and increased the CV, probably due to the effect of a decreased sample size. Grouping the ISS data at high and low tide at Mayport and high tide at Marco River reduced variation in the data (Table 25), but it was not significant ($P > 0.1$, $1 - \beta < 20$). Not all high or low tides are equivalent due to different water levels. Grouping data is only profitable if the reduction of sample size (reduced N) is offset by the increase in similarity of the data (reduced sum of squares). Burger (1984*b*), in a study of Jamaica Bay with a large number of visits, was able to account for 60% of the variability in the number of shorebirds by including variables for time, tide, and weather. No matter how many variables are included, there is an element of stochasticity in activity and location of shorebirds (Baker 1973, 1974). In future surveys, we suggest planning all counts to be conducted at similar tide levels and that water depth be quantitatively measured. We emphasize the need for multiple counts at a site to understand variability and site usage.

Howe et al. (1989), in analysis of ISS data, chose to average the 3 highest counts within a 21-day period centered on the peak migration date. Colwell and Cooper (1993) suggested using the maximum count from multiple shorebird surveys. Runde (1991) used the highest count at wading bird colonies to determine population trends. Fuller (1980) used the highest count within a season to assess waterfowl populations. For the pilot study data, picking the top 3 counts dramatically reduced the coefficient of variation (Table 26).

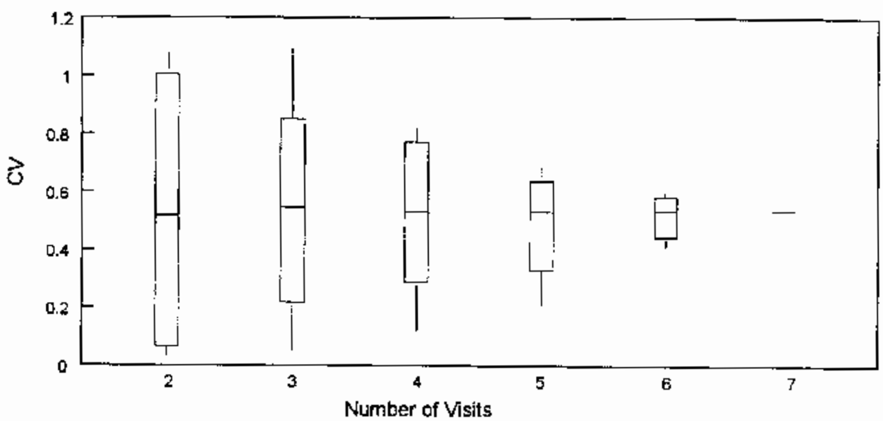

Fig. 33. Effect of increasing the number of visits on the Coefficient of Variation (CV), based on simulation. The vertical line represents range of CVs, the box represents 1 standard deviation from the mean, and the horizontal line in the box represents the mean CV.

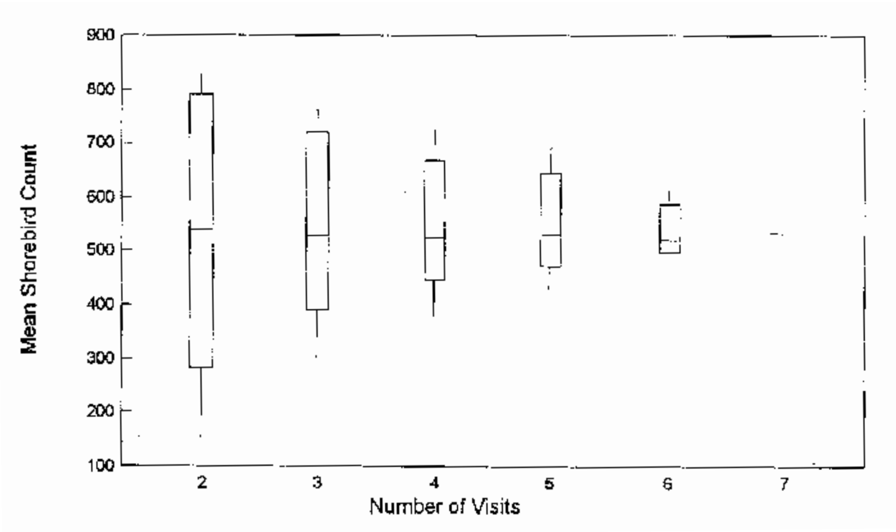

Fig. 34. Effect of increasing the number of visits on the mean number of birds counted based on simulation. The vertical line represents range of means, the box represents 1 standard deviation from the mean, and the horizontal line in the box represents the average mean.

Table 25. Variation in the number of winter shorebirds counted at different tide levels at 2 ISS sites and 2 additional survey sites during winter, December through February.

						Coefficient of variation	
Site	Survey dates	Tide	Years	Mean visits/yr	Mean number of shorebirds	$\bar{x}$	SD
ISS sites							
Marco River	1980–87	All	8	6.3	1,204.1	0.49	0.21
		High	7	4.3	1,238.7	0.30	0.27
		Low	6	2.3	11,970.0	0.68	0.51
Mayport	1977–81	All	4	10.8	798.8	0.49	0.14
		High	4	3.0	621.2	0.41	0.20
		Low	4	3.3	954.2	0.41	0.21
Winter shorebird sites							
St. Marks NWR,	1993	All	1	12.0	644.5	0.91	
Mounds Pool #3		High	1	6.0	1,011.3	0.44	
Carrabelle Beach	1993	All	1	14.0	210.3	0.62	
		Low	1	5.0	221.6	0.70	

Picking the 3 highest counts, the 3 middle counts, or the 3 lowest counts will reduce variation because these counts are numerically closest together. Although this method may be appealing because it dramatically decreases the CV, a problem with this method is that the mean and CV are directly dependent on the sample size. Picking the top 3 counts based upon our model of data from 7 counts from the pilot study showed a decreased CV (Fig. 35) and increased mean (Fig. 36). As the sample size was increased in model runs, the mean increased, and the average CV decreased. This same pattern was repeated on the data generated with a fixed mean and standard deviation. Because the mean was dependent upon the sample size, this method was invalid. Any trend analysis (including trend of maximum shorebird abundance at a site) that uses the maximum counts and does not consider the effect of sample size will be flawed.

Variation by Species.—Analyzed by species, the average CV for all species was 1.50 (Table 27), with no species having a CV less than 1.00. A higher CV perhaps suggests that the species has a higher variability in site use. Red knots, with a CV of 1.52, probably use a wide range of sites, while a species like the black-bellied plover, with a CV of 1.06, is more likely to use a site with suitable habitat more consistently. CVs for western sandpiper (1.56) and least sandpiper (1.86) may have been the result of identification problems. Depending upon viewing conditions, these birds may have been identified as western sandpipers, least sandpipers, peeps, or unidentified on some sites. The wide difference between the average CV for species (1.50) and the average CV for the total count at a site (0.86) was surprising. As environmental conditions change due to tidal rhythm, different species arrive or depart to utilize different habitats (Recher 1966). So, while total numbers appeared more consistent, the species composition did change. In future surveys, we suggest emphasizing the monitoring of individual species rather than the total number of shorebirds at a site.

Table 26. Comparison of variation in winter shorebird counts at St. Marks NWR, Mounds Pool #3 and Carrabelle Beach, Florida, January through March 1993, when using all counts or only the 3 highest counts.

			Number of birds		
Site	**Counts used**	**N[a]**	$\bar{x}$	**SD**	**CV**
St. Marks NWR, Mound Pool #3	All	12	644.5	587.6	0.91
	3 Highest	3	1,412.0	63.2	0.04
Carrabelle Beach	All	14	210.3	129.8	0.62
	3 Highest	3	393.3	30.5	0.07

[a] Number of visits.

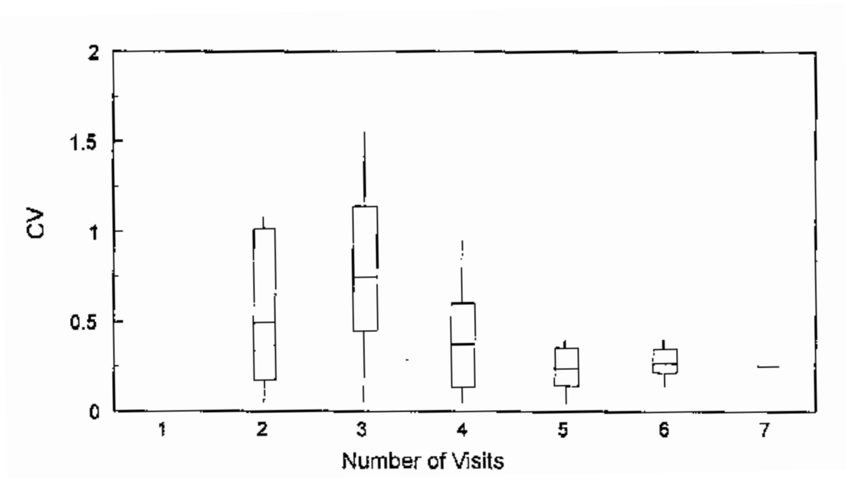

Fig. 35. Effect of increasing the number of visits on the Coefficient of Variation (CV) when only the 3 highest counts are used to compute the CV. Computed from simulation based on winter shorebird pilot survey data, 11 January through 8 March 1993. Vertical line represents range of CVs, the box represents 1 standard deviation from the mean CV, and the horizontal line represents the mean CV.

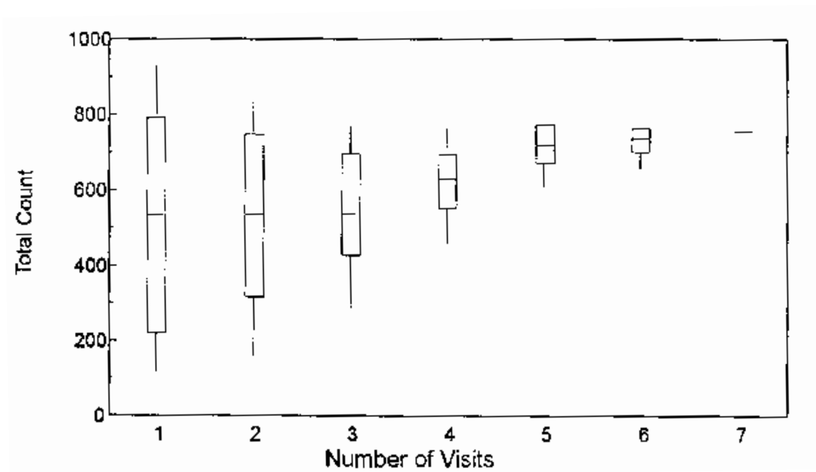

Fig. 36. Effect of increasing the number of visits on the mean when only the highest 3 counts are used to compute the mean. Computed from simulation based on winter shorebird pilot survey data, 11 January through 8 March 1993. Vertical line represents 1 standard deviation from the mean, the horizontal line represents the average mean.

Trend Detection

Year-to-year variations in population numbers may reflect stochastic environmental changes, such as weather or changes in food availability (Virkalla 1991), or they may suggest longer term population trends.

Linear Regression.**—**Linear regression can be useful for analyzing trends at a single location over time. Our linear regression on the Bay County snowy plover CBC data yielded an increase of 1.7 snowy plovers per year ($P = 0.05$). For this analysis, we assumed that total numbers of shorebirds should be used in trend analysis of CBC data rather than shorebirds per party hours. We felt that if a flock of 600 dunlins is present, for example, they will tend to be observed no matter how many party hours were expended. For snowy plovers, it is more complicated, with many occurring in groups with other shorebirds, and others occurring singly over stretches of beaches. Regressing individuals/party hour/year for Bay County showed a significant ($P = 0.02$) increase of 0.0023 individual snowy plovers/party hour.

Table 27. Average coefficient of variation (CV)[a] for numbers of shorebirds counted, by species, at sites where birds were observed, 16 December 1993 through 1 March 1994.

Species	CV	SD	Number of sites
Black-bellied plover	1.06	0.53	58
Snowy plover	1.39	0.58	25
Wilson's plover	1.45	0.58	29
Semipalmated plover	1.31	0.56	44
Piping plover	1.13	0.47	25
Killdeer	1.74	0.66	18
Plover spp.	1.91	0.48	16
American oystercatcher	1.31	0.64	28
Greater yellowlegs	1.62	0.54	16
Lesser yellowlegs	1.88	0.45	14
Yellowlegs spp.	1.76	0.53	8
Willet	1.31	0.44	50
Whimbrel	1.34	0.64	8
Marbled godwit	1.74	0.54	16
Ruddy turnstone	1.30	0.56	50
Red knot	1.52	0.51	27
Sanderling	1.11	0.57	49
Western sandpiper	1.59	0.59	40
Least sandpiper	1.86	0.55	24
Peep	1.82	0.43	38
Dunlin	1.32	0.54	56
Short-billed dowitcher	1.45	0.46	45
Unidentified shorebirds	1.47	0.45	44
Mean of all species	**1.50**	**0.26**	**32**

[a] CV is the average CV of the count for a species at a site averaged over all sites.

Nonparametric Methods.—Nonparametric tests do not assume normality, so they may be better suited for the detection of trends when there are high or heterogenous variances. Based upon Lehmann's (1975) approach, Titus at al. (1990) developed a nonparametric test for the presence of either a positive or negative trend. For a given location, counts over multiple years are arranged in ascending order and assigned ranks. The null hypothesis is that the counts are random and do not change with time. Alternatively, if the counts tend to increase or decrease with time, the ranks would do so similarly (Titus et al. 1990). The nonparametric test cannot be used to show the level of increase or decrease, only the significance of a positive or negative trend. Our nonparametric analysis on the CBC snowy plover data in Bay County suggested a positive trend ($P = 0.11$, $z = -1.624$, $n = 14$). This indicates a positive trend with unknown slope. The P is larger, and therefore less significant, than that from the linear regression model. If the data tended to fit the assumptions of the linear regression model, the linear regression fit will tend to be better and have a more significant P value. If, however, the data violated the assumptions of linear regression, the nonparametric techniques may be preferred, and the results of linear regression would be unreliable.

Theil's method provides another nonparametric test for the slope coefficient (Hollander and Wolfe 1973). The counts for each year are compared with every preceding year to determine if they are increasing or decreasing. If the sum of all these comparisons is positive (and large enough), there is a positive trend. With the CBC snowy plover data for Bay County, we got a positive slope ($P = 0.11$, $C = 24$, $n = 13$). Theil's method also provided an estimate of the slope, based upon computing the slope of each year compared with every preceding year, ordering the slopes, and picking the median. For the snowy plover data, we computed a 1.55 bird increase per year with a 95% confidence interval of –0.43 to 3.5 individuals change per year.

t-test between Surveys.—A final approach could be to collect data at 2 times, perhaps at year 1 and year 5, then compare means using a *t*-test. From 2 data sets all that can be said is that the 2 populations are different, not that there is a trend. It would be hard to know if the second data set, even if different, is only an annual fluctuation in a longer cycle of no change or an opposite change from the change suggested from the *t*-test. The *t*-test method assumes that changes are due to real population trends and not between-year variation. This assumption cannot be shown to be valid.

Both linear regression and nonparametric methods could be applied to winter shorebird data. If the nonparametric methods are used, the count for a single year would be the average count of all visits within a year. The linear regression model could fit multiple counts within a year.

It should be noted that there are many methods of trend detection not explored here (e.g., Edwards and Coull 1987, Chatfield 1989, Montgomery et al. 1990). Statistical Navigator, a computer-assisted statistical consultant (The Idea Works, Inc. 1991) suggested ARIMA Modelling, Lag-sequential analysis, and Interrupted-time series analysis.

Running averages are helpful for reducing between-year variation and in looking for patterns in data when the underlying trend is obscured by noise (Montgomery et al. 1990). Five-year running averages have been used with some success in estimating trends in songbird populations, but the variances in counts of flocking birds may make this approach problematic. Plots of total shorebird counts from CBC data for St. Marks, 1960 through 1989, and a 5-year running average count exemplified the smoothing effect of running averages, but this approach did not necessarily make it easier to detect a trend (Fig. 37).

Power and Sample Size

The statistical power of a test refers to the ability of a test to avoid missing a trend when there really is a trend. More precisely, power is $1 - \beta$, where β is the probability of saying there was no change when there really was a change. More precisely still, β is the probability of failing to reject the null hypothesis of change when there really was a change. Gerrodette (1987) proposed a formula for computing the power using CV, percent decline, and number of years. When we plotted the years required to detect a trend (Fig. 38) at $\alpha = 0.05$ and power $(1 - \beta) = 0.80$, we displayed that it takes longer to detect a trend with an increased CV or smaller annual decline. Gerrodette's equation does not consider multiple visits a year, so we are not able to model the effect of increasing the number of visits.

Harris (1986) proposed an analytical method for determining sample size using CV, number of years, and sample size within a year. This method involves relating sample size and a desired standard deviation to the slope of the trend line. This technique can be used to determine the power by setting a standard error such that the confidence interval of the slope of the trend line is below zero. For example, to determine the sample size required to detect a 10% decline with a 95% confidence level, set the standard error required such that 2 standard deviations (95% confidence level) from the 10% decline trend line fall below zero. This would be a 0.05 standard error.

Kraemer and Thiemann (1987) also proposed an analytical method for determining sample size using CV, number of years, and sample size within a year. By computing a critical effect size, one can look up in a master table the power of any test.

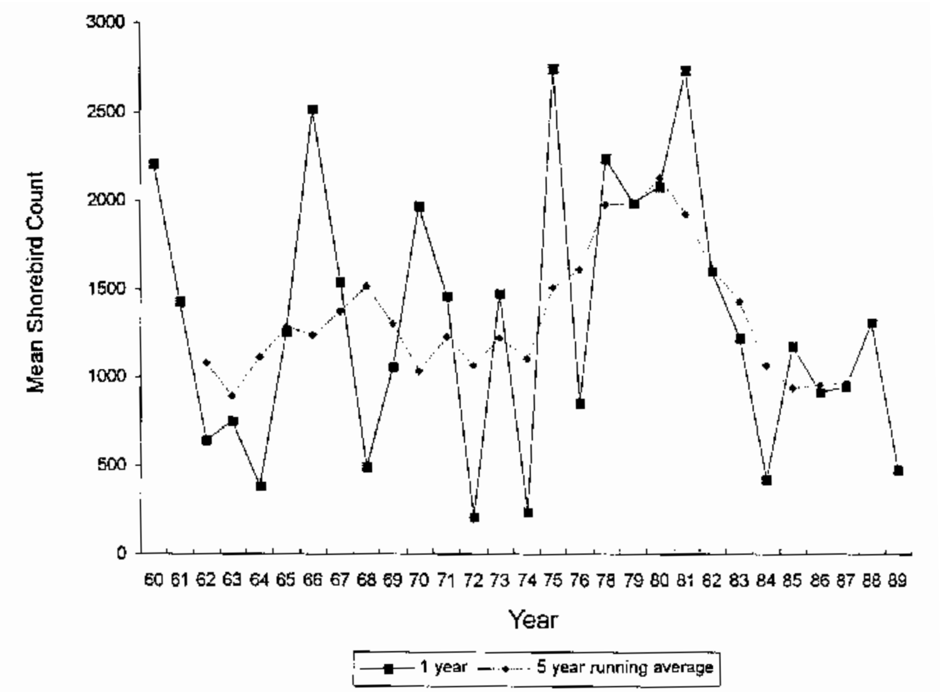

Fig. 37. Total shorebirds counted at St. Marks Christmas Bird Count, St. Marks, Florida, 1960 through 1989.

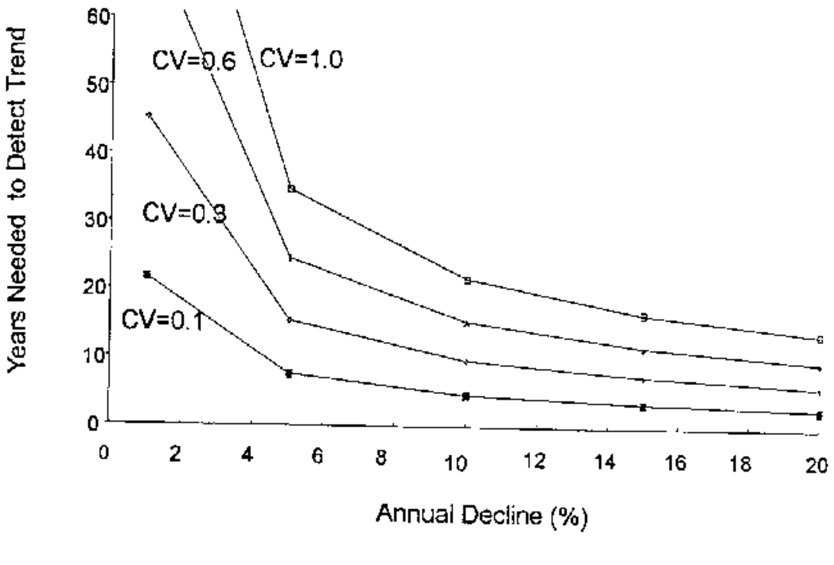

Fig. 38. Number of years required to detect an annual decline in counts at different Coefficients of Variation (CVs). Based on Gerrodette (1987).

The number of visits that would be required to detect a 5% and 10% rate of annual population decline at a specified CV and α of 0.05 (Table 28) varied considerably between techniques. Based on techniques described by Harris (1986), Cohen (1988), Kraemer and Thiemann (1987), Titus et al. (1990), Hollander and Wolfe (1973), and on our simulations, the number of visits required to detect a 5% decline over 5 years (α = 0.05, CV = 0.3) would be 10, 24, 158, >100, >100, and 61, respectively. The Titus et al. (1990) nonparametric technique required more visits than the linear regression to detect a trend after 5 years, but required fewer visits to detect a trend after 10 years. The power of Theil's nonparametric test (Hollander and Wolfe 1973) closely parallels Titus's nonparametric technique. With all trend detection techniques, fewer visits were required per year to detect a trend if either the sampling period was longer, there was a lower annual CV, or there was a greater annual decline rate.

Due to financial constraints, the maximum number of visits per year may be fixed. Therefore, another way to analyze power is to determine the power to detect a trend at a fixed number of annual visits or a fixed rate of decline per year (Table 29). For example, planners could be interested in determining the chance of detecting a 5% decline after 5 years with just 4 visits a year. Using this approach, we have only a 5% chance of detecting such a decline. A final way of evaluating power is to determine what annual rate of decline might be detected with a fixed number of visits after a given number of years (Table 30).

Statistically significant differences between counts in subsequent years may be due to differences in actual population levels of the birds, or may be artifacts of high within-year variability. As the number of years of a survey increases, the probability of a false trend will increase (Table 31).

Table 28. Number of visits required to detect 5% and 10% annual declines in shorebird populations at different CVs for 5 and 10 years of sampling with 2 different coefficients of variation, at α = 0.05.

		5% annual decline		**10% annual decline**	
Method and reference	**CV**	**5 years**	**10 years**	**5 years**	**10 years**
Analytic calculation	0.3	10	2	3	1
Harris (1986)	0.6	33	5	9	2
Analytic calculation	0.3	158	37	37	13
Kraemer and Thiemann (1987)	0.6	600	145	158	37
Analytic calculation with simulation	0.3	24	3	5	1
Cohen (1988)	0.6	100	11	23	3
Simulations with linear regression	0.3	61	5	17	1
Cobb et al. (1996)	0.6	>100	18	69	5
Simulations with Theil's nonparametric methods	0.3	>100	5	41	2
Hollander and Wolfe (1973)	0.6	>100	5	>100	4
Simulations with nonparametric methods	0.3	>100	5	40	2
Titus et al. (1990)	0.6	>100	15	>100	5

Variability may exist within a year due to movement of birds, different tidal or weather conditions, random variability, and observer differences. Variability may also exist in counts between years (e.g., our comparison of data for sites visited during the pilot survey in the winter of 1992–93, and subsequently visited in the winters of 1993–94 and 1994–95; Table 17). Of the 8 sites visited in the 2 years (1992–93 and 1993–94), none of the mean counts between years were significantly different at $P = 0.2$, but the data had low power ($1 - \beta = 12$ to 65). In 1993–94 versus 1994–95, the only significant difference in counts was at Bald Point ($P = 0.05$). Power analysis (Cobb et al. 1996) showed zero power for regression for the 3 sites surveyed for the 3 years.

The plot of the ISS data for all shorebirds and dunlin from Marco River showed high variability within and between years (Fig. 39, Fig. 40). The mean total counts for the winters from 1980–1989 ranged from 809 to 1,715, with a CV ranging from 0.26 to 0.71. Evaluating the ISS data for Marco Island, the overall percentage change of 252% for total number of shorebirds was significant ($P = 0.012$). For dunlins, the overall change of 188% was not significant ($P = 0.224$), but due to high within-year variability (CV = 0.88), the power ($1 - \beta$) to detect a trend was only 4 (Cobb et al. 1996).

Table 29. Power ($1 - \beta$) to detect 5% and 10% annual declines in shorebird population with 4 and 8 visits a year at CV = 0.6 and $\alpha = 0.1$.

		5% annual decline		10% annual decline	
Method	**Years**	**4 visits**	**8 visits**	**4 visits**	**8 visits**
Simulations with linear regression	5	5	6	11	21
	10	38	58	89	99
	15	86	99	100	100
Simulation with *t*-test between surveys	5	14	18	25	45
	10	30	50	63	93
	15	52	90	86	99

Table 30. Annual rate of decline in winter shorebird populations that can be detected, based upon simulations, with linear regression at 4 and 8 visits per year from 5 to 25 years at b = 0.80, CV = 0.6, and $\alpha = 0.1$.

Years	4 visits	8 visits
5	28	20
6	20	15
7	16	11
8	13	9
9	10	7
10	9	6
15	4	3
25	3	2

Table 31. The percentage of false trends in shorebird counts that will be detected with linear regression at different CV levels, over multiple years, and with different number of counts per year.[a]

		Percent of false trends	
CV	**Years**	**4 counts per year**	**8 counts per year**
0.3	3	0.0	0.0
	4	1.0	0.5
	5	2.6	2.6
	10	8.1	6.7
	20	9.4	8.6
0.6	3	0.0	0.0
	4	1.2	0.7
	5	2.9	1.8
	10	8.6	6.7
	20	9.0	7.2
0.9	3	0.0	0.0
	4	1.1	0.5
	5	2.0	1.5
	10	6.7	7.4
	20	8.8	8.5

[a] $\alpha = 0.1$. Simulations assume no change and count the number of times a trend was erroneously detected.

Conclusions about Trend Detection

There are a variety of estimators for required sample size. The simulation method is intuitively appealing because it is based on simple principles of the distribution of counts. It is applicable to both linear regression and nonparametric methods. The other more mathematical techniques are prone to violations of assumptions (Link and Hatfield 1990). Based on the simulation technique with a linear regression, it would require 5 visits a year for 10 years to detect a 10% annual decline at CV = 0.6. This is a net loss of 62% of the total population.

Based on the winter counts, we have a better understanding of the variance to be expected in shorebird count data. No general method was found for reducing the CV for a site by either increasing samples or by considering specific environmental conditions. The method of taking the top 3 counts was discarded due to dependence on sample size.

Both linear regression and nonparametric detection techniques would be applicable to detecting trends at a specific site. Policy makers need to make decisions about how much of a population decline justifies management action for a particular species, and ensure that the monitoring period is long enough to justify assuming that changes seen are not just part of a cyclic change, which is common in Arctic-nesting species.

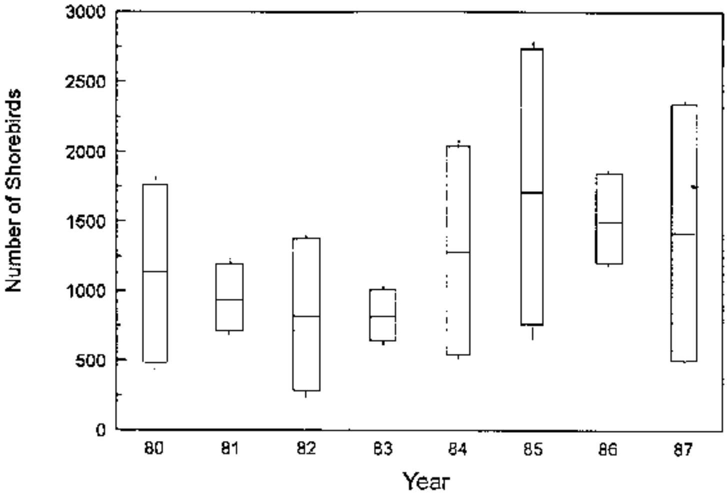

Fig. 39. Number of shorebirds counted in winter at International Shorebird Survey site Marco River, Florida, 1980 to 1987. Vertical line represents range of counts, the box represents 1 standard deviation from the mean, and the horizontal line represents the mean.

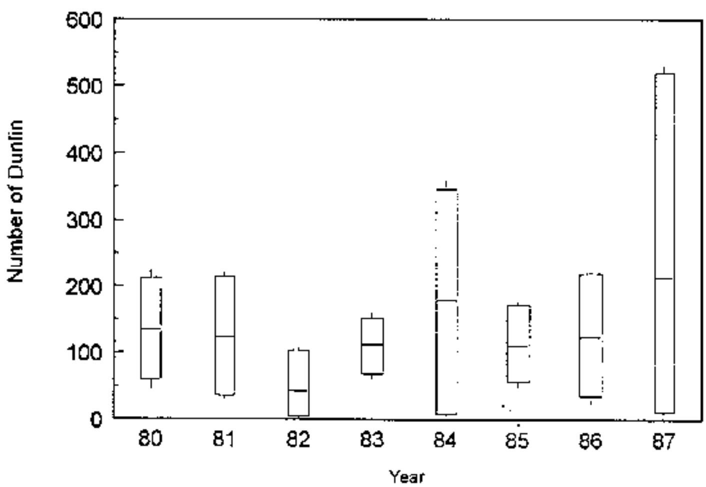

Fig. 40. Number of dunlin counted in winter at International Shorebird Survey site Marco River, Florida, 1980 to 1987. Vertical line represents range of counts, the box represents 1 standard deviation from the mean, and the horizontal line represents the mean.

Detection of Overall Trends from Multiple Sites

Based on the linear regression model, one could pool all the data for all monitoring sites and do a linear regression on the pooled data. This technique would be applicable if there is coverage of all sites for all years (Geissler and Sauer 1990). Lumping multiple sites requires assumptions about equal observability and equal probability of sampling. Future analysis approaches could include the route-regression methodology developed for the Breeding Bird Survey (Geissler and Noon 1981). Route-regression is based on the notion that "trend" can be estimated as the ratio of the count for a year and the previous year. If there are missing counts or changes in locations, or if observer differences are important, then regional trends can be estimated as weighted average of the route trends (Geissler and Sauer 1990). Thus, an overall statewide trend could be detected. The route-regression method has been applied with migration counts of shorebird data (Howe et al. 1989). Statistical consultation may be required to apply this technique and its use of jackknife variance in future shorebird data analyses. Additionally, Titus et al. (1990) expanded their nonparametric method to work for multiple sites, and this would be applicable to multiple shorebird sites in Florida.

Snowy plovers were found in at least 3 years at 14 of 55 CBC circles in Florida from 1960 through 1989. Our analysis of these sites showed a statistically significant increase ($P = 0.1$) at 4 sites on the Gulf, a decrease at 1 site, and no significant trend at 9 sites (Fig. 41). The average statistical power ($1 - \beta$) of the 14 regressions was 25 with a range of 0 to 49. If this data set typifies the variability in shorebird counts, it would be difficult to know what change one could infer about the trend in statewide populations of snowy plovers.

Sampling Sites within the State

A sampling scheme suitable for detecting an overall trend might be different from a scheme for detecting change at individual sites. For example, sampling might be required at both known important sites and at randomly chosen sites statewide. This would allow us to determine if populations were declining or if birds just moved between survey sites.

For the statewide survey, the top 6 of 60 sites accounted for 40% of the statewide total, while the top 10 sites had 52% of the statewide total. For the CBC in Florida, the top 4 circles (out of 55) had an average of 38% of the total, whereas the top 10 circles had 60% of the overall count. For the pilot survey data, the top 3 of 14 sites had an average of over 70% of the total shorebirds counted. Thus, the distribution of total birds among sites is highly skewed with a few sites having most of the shorebirds.

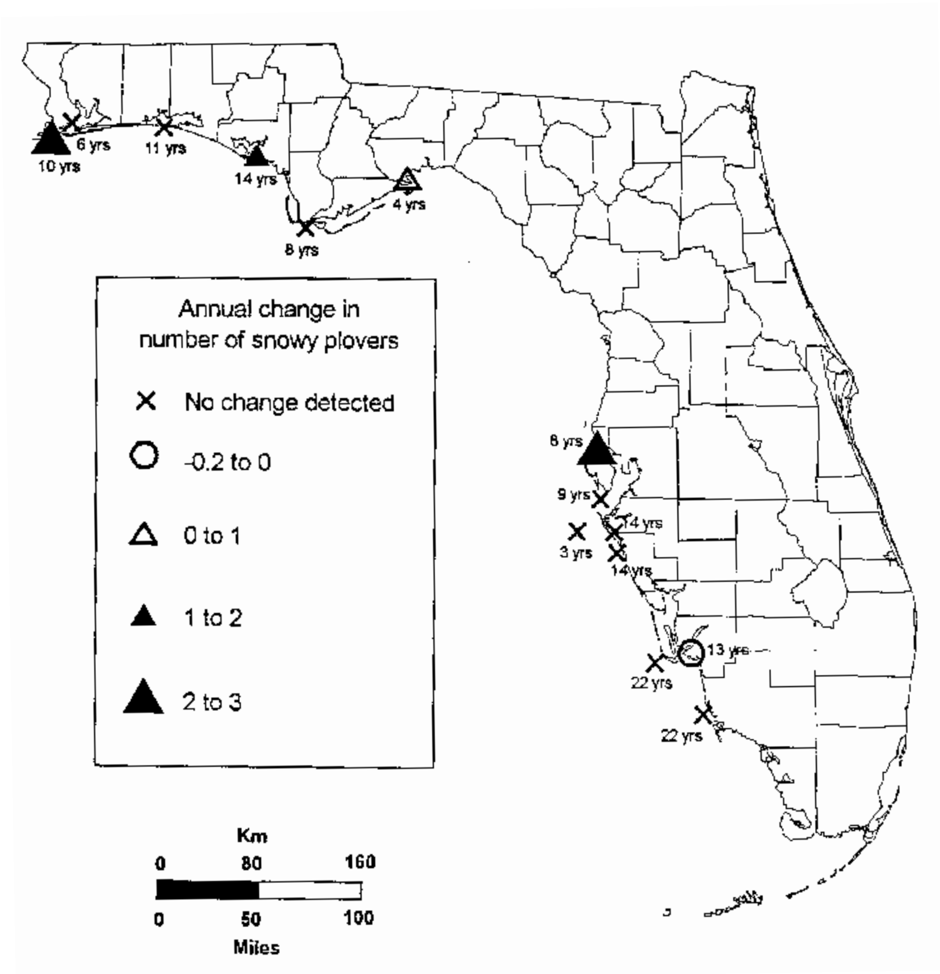

Fig. 41. Significant trends (linear regression at $p \leq 0.1$) in the number of snowy plovers observed at 14 Christmas Bird Count circles in Florida. Adjacent to each site is the number of years the surveys were conducted between 1960 and 1989.

If a random sample were applied to such a distribution, there is a chance either no important sites or too many important sites would be included in the sample. As a result, the sample may not adequately represent the population (Yamane 1967). Alternatively, sites might be stratified into 3 size groups (e.g., small, medium, or large) based upon the shorebird abundance of the site. Sites could then be picked randomly within each group. Stratification may increase the precision of the overall estimate. A sample size could be picked such that all of the major sites and some medium and small sites would be surveyed. Sites could also be stratified by coastal area. This 2-level stratification would imply randomly picking large, medium, and small sites within each coastal area. After considering logistical concerns, available resources, and biological scores of the 60 sites, we recommend picking the top 9 sites statewide, and 2 sites within each coastal region for continued monitoring.

What a Trend at a Site in Florida Means

Knowledge of causality of shorebird trends and population dynamics is limited. No clear conclusion has been made yet about whether shorebirds are regulated or limited on breeding or wintering grounds (Duffy et al. 1981, Evans and Pienkowski 1984). Few data are available to document breeding trends for most obligate coastal shorebird species, either those breeding in Florida or those breeding in the Arctic. Determining the meaning of a trend in Florida requires comparison of sites and species within Florida and an understanding of overall flyway trends (Fig. 42). FGFWFC surveys could provide basic coverage of the state, and these data could be supported by auxiliary data sets. Analysis of ISS data (Howe et al. 1989) or Maritime Shorebird Survey (Morrison et al. 1994) would provide information about overall trends, and analysis of the CBC could provide additional support for winter trends detected. For example, if there is an increase in shorebird abundance at wintering sites in Florida, without an overall increase in flyway population, this may suggest a degradation of wintering sites in South America. Pfister et al. (1992) provided an example of comparing trends at a single site and flyway trends to infer site changes. Goss-Custard et al. (1995*a*) proposed to model the loss of habitat and to generalize to the regional or global populations.

MANAGEMENT IMPLICATIONS

Conservation of Shorebirds

Niles et al. (1994) listed goals for shorebird conservation in Delaware Bay. We considered their ideas along with findings from our study to develop the following goals that may be used to direct the conservation of winter shorebird populations and habitats in Florida.

Geographic Scope[1]	Species Scope[2]	Overall Conditions[3]	Possible Meaning of Trend
1 site	Decrease/increase 1 species	No state or flyway change	Change by one species at this site
1 site	Decrease/increase many species	No state or flyway change	Site has generally degraded /improved or nearby site improved/degraded
Several nearby sites	Decrease/increase 1 species	No state or flyway change	Regional decline or distribution shift of species
Several nearby sites	Decrease/increase many species	No state or flyway change	Regional change not detected at higher scale.
Disjoint sites	Decrease/increase 1 species	No state or flyway change	Species decline/increase not detected at higher scale
Decline in some sites and increase in others	Decrease/increase in 1 to many species	No state or flyway change	Site or regional movement of population
Statewide	Decrease/increase 1 species	No flyway change	Distribution shift away from/to Florida.
Statewide	Decrease/increase many species	No flyway change	Distribution shift away from/to Florida.
Flyway	Decrease/increase 1 species	Overall change	General species decline/increase
Flyway	Decrease/increase many species	Overall change	General shorebird decline/increase

[1] Geographic scope describes the geographic range for which a change has been detected.
[2] Species scope describes the number of species in which a change has been detected.
[3] Overall conditions describes the change in shorebird populations at the next higher geographic level.

Fig. 42. Understanding what a change in winter shorebird usage at sites in Florida means.

1. Identify and conserve important habitat for wintering shorebirds.
2. Monitor population trends of wintering shorebirds.
3. Enhance public awareness of shorebirds and thereby promote support for their conservation.
4. Minimize human disturbance of wintering shorebirds.
5. Monitor contaminants and minimize their effect on wintering shorebirds.
6. Minimize the impact of spilled petroleum products and other materials on shorebird populations and habitat.
7. Manage impounded habitats for wintering shorebirds.

These goals refer solely to activities within Florida. Although most species of shorebirds that winter in Florida migrate elsewhere to breed and are subject to impacts outside Florida's borders, conservationists here cannot control potential impacts outside the state. Also, although the goals aim to conserve shorebird populations, most conservation actions will actually be directed toward people or habitat rather than toward shorebird populations. Finally, the listed goals are not equally important nor independent of each other.

***Habitat Conservation.*—**By far the most important goal is to conserve shorebird habitat. Our survey showed that shorebirds are not evenly distributed along the coast—some coastal habitats are clearly more attractive than others. We assume that loss of the most highly used sites would result in a decline in the number of wintering shorebirds. The site ranking produced both a list of biologically important sites and sites at risk of being detrimentally impacted. This information may be used to develop individual management strategies for sites based on their biological importance, rates of disturbance, proximity to pollutants and oil shipping, control of water levels, and ownership of the site (Table 32). For all sites, but particularly those listed in Table 32, land managers and local conservation groups should be encouraged to carry out the habitat protection activities. Many of these activities would also benefit breeding shorebirds and other wildlife.

Although the current survey was extensive, density of sites and access to sites varied widely and may have biased our identification of the most important sites. Therefore, additional surveys would be useful to verify the relative importance of sites or to identify sites that were overlooked or not visited. New techniques may be needed to improve our assessments of the number of shorebirds using areas such as the flats of Florida Bay. Efforts should be directed at determining survey techniques for this area, including the use of shallow-draft poke boats or shoe-like flotation devices. Ground surveys should be conducted at some potentially important sites that were observed during aerial surveys but not surveyed by ground (Table 14). A more intensive survey along the southwest coast would be especially helpful. A resurvey of the northeast coast of Florida may be useful in verifying differences between species' distributions from this survey versus CBC.

Much remains to be learned about the ecological requirements of wintering shorebirds. Although we can rank sites according to the relative abundance of shorebirds, we have little knowledge of why shorebirds use particular sites and, therefore, we cannot accurately identify optimal habitat or detect declines in habitat quality. Further research into habitat characteristics and distribution of prey would be useful in identifying or creating new habitat and in determining whether observed population trends were related to changes in habitat quality.

Table 32. Potential management activities to benefit the 29 most important winter shorebird survey sites in Florida. All sites would likely benefit from further management, but activities are suggested only for sites where management would be most effective or practical.

Region and site	Monitoring[a]	Education[b]	Posting/warden[c]	Contaminants[d]	Water level mgmnt[e]	Protection[f]
Panhandle Coast						
Cape San Blas			Yes			
Carrabelle Beach			Yes			
Lanark Reef	Yes		Yes			CWA
Marifarms			Yes	Pollutants	Yes	Easement
Shell Island, east end inlet		Yes				
Yent Bayou						Easement
Big Bend Coast						
Sprague Island oyster bars						
St. Marks NWR, Mounds Pool #3					Yes	
Southwest Coast						
Anclote Key, north end			Yes			CWA
Anclote Key, south end	Yes		Yes			CWA
Caladesi Island, Dunedin Pass		Yes				
Caladesi Island, north end		Yes				
Fort Desoto, northwest end		Yes		Oil		
Honeymoon Island	Yes	Yes				
Island north of Bunces Pass	Yes		Yes	Oil		CWA
Little Estero CWA	Yes		Yes			
McKay Bay				Oil, Pollutants	Yes	
Palm Island Resort						Easement
Passage Key NWR				Oil		
Point Pinellas, west oyster bar				Oil, Pollutants		Easement
Shell Key	Yes		Yes	Oil		CWA
Three Rooker Bar, north end	Yes		Yes			CWA
Three Rooker Bar, southeast end			Yes			CWA

Table 32. Continued.

Region and site	Monitoring[a]	Education[b]	Posting/warden[c]	Contaminants[d]	Water level mgmnt[e]	Protection[f]
Everglades Coast						
Cape Romano, Morgan Beach			Yes			Easement
Lake Ingraham, southeast end	Yes			Pollutants		
Northwest of Palm Key				Pollutants		
Snake Bight Channel	Yes			Pollutants		
Tigertail Beach		Yes	Yes			CWA
Northeast Coast						
Merritt Island NWR, Black Point Drive					Yes	

[a] Candidate sites for monitoring are those with the highest biological importance (i.e., total biological importance score ≥ 29).
[b] Candidate sites for education activities are those on public lands with management staff and facilities and a disturbance rate of >2 per hour.
[c] Candidate sites for posting or a warden are important biological sites for which education would not be sufficient. All posting is subject to property owner approval.
[d] Sites with greater than 2 million m^3 of oil within 24 km should be updated with oil spill plans. Sites in enclosed bays should be monitored for pollutants.
[e] Inland sites within 4 km of coast may have water levels managed for supporting shorebirds.
[f] Sites that are private property are candidates for conservation easement; public or private sites needing legal protection are candidates for designation as critical wildlife areas. All sites are only candidates for protection; establishment of easements or critical wildlife areas would be subject to landowner approval.

For important shorebird habitat that is privately owned and subject to development, various levels of protection are possible. Short-term protection as a Critical Wildlife Area may be possible for consistently important sites with firm boundaries and consenting landowners. Conservation easements may provide more lasting, legally binding protection without acquisition. Public acquisition through one of the public land acquisition programs may be appropriate for sites which a landowner wishes to sell. Sites with wintering numbers of threatened piping plovers or snowy plovers may have additional protection under Section 7 of the Endangered Species Act (Sidle et al. 1991, Wood 1994).

Many government comprehensive plans include goals for protection of threatened species and preservation of coastal areas. The regional plan for Tampa Bay (Tampa Bay Regional Planning Council 1991) includes goals for increasing acreage of conservation areas, encouraging landowners to preserve native habitats for endangered species, and providing public education programs about the importance of Tampa Bay. The county plan for Pinellas County lists the importance of sea grass meadows, and has a goal to restore beach and dune communities (Pinellas County Planning Department 1992). The regional plan for Southwest Florida lists the importance of barrier islands, passes, and inlets (Southwest Florida Regional Planning Council 1991.) The Collier County natural resources management plan (Benedict 1984) recognizes the importance of barrier islands, and includes a goal for establishing a permanent long-term monitoring program for biological parameters. The Lee County coastal study recognizes the impact of growth and drainage alteration on coastal systems (Godschalk et al. 1988). The Franklin County comprehensive master plan recognizes that the local wildlife is seriously threatened due to increased development (Franklin County Planning Department 1991). Planning agencies should be made aware of wintering shorebird resources in their area and review and revise their plans in light of areas sensitive to shorebirds.

Population Monitoring.—Although long-term surveys may be required to detect population trends, regular monitoring of winter shorebird populations would be useful, especially at the most important locations or where surveys can be easily conducted. For example, the top 6 sites we surveyed hosted 40% of the estimated statewide population of wintering shorebirds and the top 11 sites supported 54% of the shorebirds. Annual statewide surveys will likely always be impractical, but annual surveys at the most highly used sites could be used as an index to statewide population changes.

We recommend that 9 sites with the highest biological scores (Table 18) be surveyed. The top 9 sites were selected because a gap exists between scores of the ninth and tenth ranked sites. These 9 sites supported 38% of the shorebirds surveyed. If a minimum of 2 sites are surveyed in each coastal region to insure some geographic diversity, 5 additional highly ranked sites would be selected. Together, these 14 sites supported 51% of the birds counted in our survey.

Ideally, FGFWFC biologists could routinely survey these sites 4 times each winter as part of annual operations, or existing ISS cooperators or other experienced volunteers could survey sites in a cooperative effort with FGFWFC biologists. For sites where major development or restoration is planned, surveys before and after development would be very useful in monitoring the impact upon local shorebird populations. Assessments of impacts should consider the effects on both roosting and feeding shorebirds and habitats (e.g. Goss-Custard et al. 1977, 1991; Goss-Custard and Yates 1992).

Shorebird numbers at sites selected for long-term monitoring could be compared using regression, nonparametric methods, or simply *t*-tests between years. Selection of a technique for detecting changes in shorebird numbers should be based on logistics, available resources, and statistical performance. All efforts to detect trends in shorebird numbers suffered from the high variability among counts. To better understand this variation, sites in the Panhandle that were most frequently visited in the winters of 1992–93, 1993–94, and 1994–95 should continue to be revisited at least 4 times each winter. This will provide further information about the variation between years, and allow continued application of the power model (Cobb et al. 1996). To understand patterns in the movement of shorebirds among sites, birds in 1 area should be observed (e.g., willets could be radio-tagged near Lanark Reef in Franklin County) and their movements tracked among local sites. Quantifying invertebrate prey densities and variabilities might help explain shorebird variability. Color banding of birds and simultaneous multiple counts would be most useful, although simultaneous multiple counts without color banding would still provide some data on movement. Level of observer variability might be quantified by conducting simultaneous counts by 3 different observers.

Education and Minimizing Disturbance.—The attitudes and perceptions of Florida's citizens toward wildlife vary widely (Duda et al. 1989), and these should be considered in efforts to change public opinion and behavior through education. A direct educational effort could teach citizens to avoid sites heavily used by wintering shorebirds and to keep pets leashed. Educational programs could be designed based on U.S. Fish and Wildlife Service programs for piping plovers (e.g., Beers 1991) or the Western Hemisphere Shorebird Reserve Network Shorebird Education Project (Wetlands for the Americas 1993).

In addition, parks and wildlife refuges offer excellent opportunities for education. Sites with information kiosks and trained staff could inform large numbers of people about shorebird biology and how to minimize disturbance. Some remote sites support high numbers of shorebirds and are accessible only by boat. Marinas provide opportunities to inform boaters who might visit these sites about the shorebirds. Pamphlets, for example, could be provided at boat launches to educate boaters about shorebird resources in the area and the impact boaters can have on shorebirds and their habitat. Ideally, education efforts should include research into the problem, an appraisal of community concern, a plan for implementation of the educational program, and finally an evaluation of its effectiveness (Blanchard and Nettleship 1991).

Important sites that are susceptible to disturbance should be candidates for posting, fencing, or other restrictions to keep pedestrians, vehicles, and pets out of sensitive sites (Melvin et al. 1991). Often, based on historical patterns of shorebird use, a small portion of the beach front or tip could be closed to protect roosting areas (Pfister et al. 1992). Buffer zones that are a minimum of 50 meters from the mean high-tide mark could be created (Helmers 1992). In areas where beach driving is allowed, driving could be restricted to certain areas or seasons or higher beach driving fees could provide for staff to enforce current regulations (Primack 1980, Cox et al. 1994). On important sites without existing staff, patrols by FGFWFC or Marine Patrol officers might be the most effective means of ensuring that shorebirds remain undisturbed. For example, islands such as Anclote Key could be posted and patrolled regularly to inform boaters of shorebird resources. Volunteers and salaried wardens have been effective elsewhere in ensuring that beach users understand about closed areas (Melvin et al. 1991) and they may be a useful alternative in Florida wherever traditional law enforcement officers are not available. The impact of disturbance in wildlife refuges may be counteracted with guided tours and low-disturbance zones where people stay in their cars (Klein et al. 1995).

Contaminants and Oil Spills.—Reviewers of United States Coast Guard Area Contingency Plans and the FGFWFC Oil Sensitivity Atlas should be aware of these important winter shorebird sites and incorporate them into plans. Especially important to consider are sites within Tampa Bay and—due to shipping near the Florida Keys—Florida Bay (Townsend 1990). The potential for impacts to wintering shorebirds would be reduced by changes in navigation standards to minimize oil spills. These changes include implementing vessel-free zones, improving traffic separation schemes, enhancing pilot training, and redesigning vessels and navigational equipment. Survival of oiled birds would probably increase if wildlife rehabilitators are provided with instructions on handling and caring for oiled shorebirds. It is particularly important to prevent cramps to the birds' legs and maintain their salt balance (Burridge and Kane 1985, Kasprzyk and Harrington 1989). The plan for emergency response to spills of hazardous materials (Bird Emergency Aid and Kare Sanctuary, Inc. 1991) would be improved if it included contingencies for wintering shorebird sites most susceptible to pollutant impacts. For sites currently monitored for pollutants (Long et al. 1991, O'Connor 1992), research should be conducted on the biological effects of pollutants.

***Habitat Management.*—**In impounded wetlands, habitat manipulation such as staggered drawdowns can control water levels, restrict emergent vegetation, and increase production of invertebrates (Rundle and Fredrickson 1981, Eldridge 1992, Helmers 1992, Rehfisch 1994). Human-made or -modified peripheral wetlands may be used for feeding and safe-roosting areas in places where alteration of natural estuaries has occurred (Davidson and Evans 1986). Wetlands managed for waterfowl can also be productive for shorebirds and cooperative efforts to manage for both groups should be encouraged. The T. M. Goodwin Waterfowl Management Area in Brevard County is an example of an area that could provide habitat for waterfowl and shorebirds. Mosquito control impoundments can also be important shorebird habitat (Clarke et al. 1984, Brush et al. 1986). At some sites, such as McKay Bay, control of spreading spartina or mangroves may be needed to assure continued use of the site by shorebirds (Evans 1986, Goss-Custard and Moser 1988, Olinger 1994).

The proper placement and management of dredge material islands may provide roosting or feeding habitats for shorebirds (Parnell et al. 1986). Although our study focused on coastal habitats, shorebirds may also use inland habitats such as flooded agricultural fields (Sykes and Hunter 1978, Hands et al. 1991) or abandoned phosphate mines (P. Fellers, unpubl. data).

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Appendix A. Shorebird survey sites in Florida that are actively managed to benefit wildlife (n = 13) or where management activities incidentally benefit shorebirds (n = 21).

Region and Site	Management Activity
Active Management	
Panhandle	
Phipps Preserve	Posted for nesting terns and plovers
Cape San Blas	Posted, started this summer, by AFB - Eglin.
Big Bend	
Hagens Cove	Managed area for hunters. Control of access.
St Marks NWR, Mounds Pool #3	Water levels controlled for duck populations.
Cedar Key, Seahorse Key	March–June entire island closed for nesting birds.
Southwest	
Honeymoon Island	Exotic plant removal, prescribed burning, bird resting area marked.
Shell Key	Active Auduboners and ferry captain.
Passage Key NWR	All access to isle prohibited, illegal to anchor.
Ding Darling NWR, tower stop	National wildlife refuge protection.
Everglades	
Sandy Key	The island is posted.
Tigertail Beach	The feeding, resting, and nesting area is posted.
Northeast	
Merritt Island NWR, Black Point Drive	Managed water levels.
Huguenot Memorial Park	Critical Wildlife Area/nesting sites posted.
Incidental Management	
Panhandle	
St Joseph Peninsula	Park regulations and mgmnt.
Crooked Island West, east end	Tyndall AFB regulations & Tyndall Nat. Res. mgmnt.
Crooked Island East, west end	Tyndall AFB regulations & Tyndall Nat. Res. mgmnt.
Shell Island, west end	Tyndall AFB regulations & Tyndall Nat. Res. mgmnt.
Shell Island, east end inlet	Park regulations and mgmnt.
Marifarms	Diked area has been breached to restore tidal flow.
Fort Pickens, west end	USNPS regulations and management.
Big Bend	
St Marks NWR, Mounds Pool #3	Vehicles restricted from roads.
Cedar Key, Seahorse Key	Univ. Fla. (Gainesville) lab and caretakers employed.
Southwest	
McKay Bay	Public awareness.
Palm Island Resort	Protection of dunes.
Caladesi Island, Dunedin Pass	Some park wildlife management.
Caladesi Island, north end	Some park wildlife management.
Lido Beach	Some dune and beach grass management.
Fort Desoto, east end	No development in the park.
Fort Desoto, northwest end	No development in the park.
Point Pinellas, west oyster bar	Land (shoreline) set aside as park.
Northeast	
NASA Causeway KSC, north side	No fishing; public access limited; no motorboats.
NASA Causeway KSC, south side	No fishing; public access limited; no motorboats.
Kennedy Space Center, Pad 39B	No public access.
Huguenot Memorial Park	Dune restoration/protection; park patrolled.

Appendix B. Tabulation of data recorded on observation forms during surveys of winter shorebirds at 60 sites in Florida, 16 December 1993 through 1 March 1994.

1. Survey dates: 12/16/93–3/1/94.

Region	Start	End	Counts
Panhandle	12/18/93	2/28/94	69
Big Bend	12/17/93	2/28/94	32
Southwest	12/16/93	2/26/94	110
Everglades	01/10/94	3/01/94	33
Northeast	12/28/93	2/15/94	28
Statewide	**12/16/93**	**3/01/94**	**272**

2. Average survey times.

		Start		End		Duration (minutes)		
Region	**N**	**Range**	$\bar{x}$	**Range**	$\bar{x}$	**Range**	$\bar{x}$	**SD**
Panhandle	69	07:10–17:35	12:40	07:40–17:50	13:34	10–172	54	36
Big Bend	32	09:30–17:20	12:47	10:15–18:00	13:40	5–150	53	40
Southwest	110	07:44–17:45	11:56	07:50–18:00	12:35	5–162	40	28
Everglades	33	09:00–15:30	12:39	09:45–16:40	12:57	5–75	18	15
Northeast	28	07:55–17:45	12:34	08:20–17:58	13:17	13–116	42	25
Statewide	**272**	**07:10–17:45**	**12:22**	**07:40–18:00**	**13:05**	**5–172**	**42**	**32**

3. Average distances (km) covered for survey.

Region	$\bar{x}$	SD
Panhandle	1.12	0.66
Big Bend	1.53	1.49
Southwest	0.76	0.48
Everglades	0.74	0.25
Northeast	1.64	1.52
Statewide	**1.03**	**0.92**

4. Tide characteristics during surveys. Numbers represent the number of times tidal conditions were encountered during survey.

Region	High	High Rising	High Falling	Half tide Rising	Half tide Falling	Low Rising	Low Falling	Low
Panhandle	18	7	0	18	0	8	3	15
Big Bend	9	6	2	1	1	4	1	8
Southwest	18	10	4	10	8	18	12	30
Everglades	10	2	0	2	2	5	2	10
Northeast	4	0	5	4	1	5	2	7
Statewide	**59**	**25**	**11**	**35**	**12**	**40**	**20**	**70**

Appendix B. Continued.

5. Relative water level at inland sites.

Region	Normal	Lower	Higher
Panhandle	6	1	0
Big Bend	0	0	5
Southwest	2	0	0
Everglades	0	0	0
Northeast	7	9	1
Statewide	**15**	**10**	**6**

6. Average temperature (C°).

Region	$\bar{x}$	SD	Range
Panhandle	14.3	5.7	–3–24
Big Bend	16.7	5.5	4–23
Southwest	19.8	4.4	–5–28
Everglades	25.1	1.7	21–27
Northeast	18.9	4.4	12–28
Statewide	**18.6**	**5.7**	**–3–28**

7. Wind direction.

Region	N	NE	E	SE	S	SW	W	NW
Panhandle	17	10	6	7	4	6	4	9
Big Bend	7	5	6	4	4	0	0	5
Southwest	9	26	7	10	12	13	8	17
Everglades	0	11	3	14	5	0	0	0
Northeast	6	4	3	2	7	0	1	4
Statewide	**39**	**56**	**25**	**37**	**32**	**19**	**13**	**35**

8. Average wind speed (km/hr).

Region	$\bar{x}$	SD	Range
Panhandle	9.3	6.1	0–32
Big Bend	11.3	5.1	3–24
Southwest	10.6	7.7	0–32
Everglades	15.6	9.5	5–40
Northeast	13.5	7.2	0–25
Statewide	**11.3**	**7.5**	**0–40**

Appendix B. Continued.

9. Weather conditions.

Region	**Sunny**	**Partly Cloudy**	**Overcast**	**Fog**	**Drizzle**	**Rain**
Panhandle	24	28	9	5	0	1
Big Bend	13	11	7	0	1	0
Southwest	43	36	20	4	4	2
Everglades	23	6	4	0	0	0
Northeast	12	12	4	0	0	0
Statewide	**115**	**93**	**44**	**9**	**5**	**3**

10. Initial guess of total shorebird numbers.

Region	$\bar{x}$	**SD**	**N**	**Range**
Panhandle	187	285	58	0–1,600
Big Bend	371	608	32	0–3,000
Southwest	293	355	109	0–2,000
Everglades	765	1871	32	0–9,000
Northeast	265	662	21	0–3,000
Statewide	**336**	**784**	**252**	**0–9,000**

11. Initial guess of total gulls and terns.

Region	$\bar{x}$	**SD**	**N**	**Range**
Panhandle	61	101	61	0–650
Big Bend	68	96	32	0–400
Southwest	179	295	101	0–1,600
Everglades	330	1053	32	0–5,000
Northeast	931	1361	20	0–5,000
Statewide	**216**	**613**	**246**	**0–5,000**

12. Total number of people in census area.

Region	$\bar{x}$	**SD**	**N**	**Range**
Panhandle	2.4	2.6	68	0–150
Big Bend	2.5	2.0	32	1–71
Southwest	9.7	17.9	109	0–71
Everglades	12.4	23.8	32	1–150
Northeast	8.4	10.2	28	1–11
Statewide	**7.2**	**14.9**	**269**	**0–150**

Appendix B. Continued.

13. Top ranked causes of human disturbance on a site visit.

Region	**People on foot**	**Vehicles**	**Pets**	**Boats**	**Other**
Panhandle	32	3	1	2	2
Big Bend	4			5	1
Southwest	55		1	4	1
Everglades	6				
Northeast	4	7		5	
Statewide	**101**	**10**	**2**	**16**	**4**

Other prime causes of disturbance:

Air Force jet	Shell Island, west end
Airplane flew over	Delany Creek Canal
Helicopter flew over	Yent Bayou
Helicopter flight	Hagens Cove

14. Second ranked causes of human disturbance on site visit.

Region	**People on foot**	**Vehicles**	**Pets**	**Boats**	**Other**
Panhandle	2	4	1		
Big Bend					
Southwest	4	7	16	6	1
Everglades					
Northeast	3	2	1		
Statewide	**9**	**13**	**18**	**6**	**1**

15. Third ranked causes of human disturbance on site visit.

Region	**People on foot**	**Vehicles**	**Pets**	**Boats**	**Other**
Panhandle					
Big Bend					
Southwest		3	3	14	3
Everglades					
Northeast			1	1	
Statewide		**3**	**4**	**15**	**3**

Other prime causes of disturbance:

Low flying aircraft	Passage Key NWR
Ultra-light aircraft	Island north of Bunces Pass
Low flying ultra-lights	Little Estero CWA

Appendix B. Continued.

16. Observer's distance (m) from birds during the count.

	Closest				Farthest			
Region	$\bar{x}$	**SD**	**N**	**Range**	$\bar{x}$	**SD**	**N**	**Range**
Panhandle	41	88	66	3–700	171	267	65	15–1,500
Big Bend	115	130	31	8–600	378	423	31	60–1,500
Southwest	45	124	102	3–1,200	155	215	102	12–2,000
Everglades	35	25	22	10–100	307	553	22	30–2,000
Northeast	35	26	28	3–75	185	114	28	20–400
Statewide	**51**	**105**	**249**	**3–1200**	**204**	**304**	**248**	**12–2,000**

17. Estimated percent change in the total number of individuals during the count.

Region	**0–10%**	**11–70%**	**71–150%**	**> 150%**
Panhandle	52	5	2	2
Big Bend	17	10	1	
Southwest	74	21	6	
Everglades	21	2		1
Northeast	23	5		
Statewide	**187**	**43**	**9**	**3**

18. Number of counts with birds flying in or out.

Region	**Arriving**	**Departing**	**Both**	**Neither**
Panhandle	3	2	12	49
Big Bend	2	3	13	10
Southwest	20	12	15	56
Everglades	3	3	2	15
Northeast	2	1	4	21
Statewide	**30**	**21**	**46**	**151**

19. Number of counts by distribution of shorebirds.

Region	**Clumped**	**Scattered**	**Both**
Panhandle	13	51	2
Big Bend	14	14	
Southwest	48	54	
Everglades	6	16	
Northeast	10	18	
Statewide	**91**	**153**	**2**

Appendix C. Field notes describing features or events that may have influenced observations made during visits to 60 sites in Florida, 16 December 1993 through 1 March 1994.

Subject and Site	Date	Time	Field Notes
Water conditions			
Cape San Blas	2/01/94	15:20	Tide seems low even though tide=high.
Cape San Blas	2/11/94	08:05	Tide low but mediated by strong S wind.
Marifarms	1/12/94	10:50	Lowest water level seen.
Phipps Preserve	1/09/94	07:24	Lowest level I've ever seen here.
Cedar Key, Hodges Bridge	1/21/94	14:00	High winds blowing water out/low levels.
Howard County Park, causeway	1/14/94	15:50	Flats exposed on E end by 17:30.
Howard County Park, causeway	1/16/94	08:40	Wide flats on both sides.
Howard County Park, causeway	2/11/94	13:00	Water level very high.
Howard County Park, west end	1/16/94	09:10	Some flats + seagrass on E side.
Black Pt Wildlife Drive MINWR	2/15/94	08:36	Lowest water level seen; mostly mudflats.
Port Orange Spoil Islands	2/30/93	14:50	Lowest water seen.
Human disturbance			
Cedar Key, Hodges Bridge	1/21/94	14:00	Two fisherman slowly approached the site throughout the survey and accounted for the disturbance.
Marifarms	2/28/94	13:15	At end of survey, big navy hydroplane roared toward site, out of water & over dike into water inside of dike, continued through clump of shorebirds (flushed) & across flats toward me stopped, pivoted & back over dike. Surprisingly didn't bother birds much.
Crooked Island East, west end	1/14/94	09:10	Vehicle disturbance was by observers ATV.
Crooked Island West, east end	1/13/94	14:45	Vehicle disturbance was by ATV of surveyor. Steady rain this morning.
Crooked Island West, east end	2/07/94	13:55	Vehicle disturbance by ATV of observer.
Crooked Island West, east end	2/02/94	14:00	Disturbance from observers' ATV.
Phipps Preserve	2/19/94	08:08	Some departed due to observer.
Shell Island, west	12/27/93	15:10	Air force jet
St Joseph Peninsula	1/28/94	15:05	Disturbance was from observers ATV.
Yent Bayou	1/18/94	15:40	Helicopter flew over.
Hagens Cove	2/26/94	11:05	Helicopter flight.
Caladesi Island, north end	1/13/94	12:35	State park 3 wheelers, jet skis.
Caladesi Island, Dunedin Pass	1/02/94	12:30	Soccer ball.
Caladesi Island, Dunedin Pass	1/06/94	13:00	Busy public beach, state park 3 wheelers.
Courtney Campbell Causeway, southeast B	2/04/94	11:15	Jet skis.
Courtney Campbell Causeway, southeast B	2/15/94	12:30	Jet skis.
Delany Creek Canal	1/15/94	09:52	Airplane flew over.
Old Tampa Bay, n. of Frankland Bridge	12/16/93	10:55	Fisherman on flats, vehicles on beach.
Fort Desoto, east end	1/08/94	09:50	Marathon being run today.
Honeymoon Island	1/06/94	09:20	Tire tracks.
Island north of Bunces Pass	1/23/94	10:30	Ultra-light aircraft flushed 80% of birds.
Lido Beach	2/08/94	12:30	Lifeguard vehicles on beach.
Little Estero CWA	2/23/94	15:00	Low flying small planes, ultra-lights. Six wildlife photographers on sandbars today.
McKay Bay	1/17/94	11:30	Natural disturbances, site hard to access.

Appendix C. Continued.

Subject and site	Date	Time	Field Notes
Human disturbance, continued			
Palm Island Resort	2/08/94	16:20	Resort vehicles.
Passage Key NWR	2/07/94	14:45	Low flying aircraft.
Shell Key	2/16/94	09:07	Owners let dog run through birds.
Shell Key	2/07/94	12:10	Dogs off leash.
Shell Key	1/23/94	09:00	Dogs off leash running through flocks.
Three Rooker Bar, southeast end	2/21/94	13:45	Unleashed dogs.
Natural disturbance			
Honeymoon Island	1/19/94	13:15	Tern kept flying over & flushing
McKay Bay	1/15/94	11:50	Falcon swooped on shorebirds
Passage Key NWR	1/26/94	09:50	Parasitic jaegar flew by
Crooked Island West, east end	2/02/94	14:00	Northern harrier flew over
General notes			
Cape San Blas	2/11/94	08:05	Brief shower passed during survey. Birds seemed unaffected—continued feeding. Strong storm front had moved through during early morning.
Carrabelle Beach	1/08/94	14:10	Much movement in the birds today.
East of Bay North	12/28/93	09:22	All birds on sea grass actively feeding.
Phipps Preserve	1/15/94	08:30	At low tide, shorebirds disperse to W to feed (some almost all the way to St. Teresa beach). Can't I.D. from this distance but can estimate total numbers.
Cedar Key, South of Hodges Bridge	2/18/94	11:45	Strong E wind combined with distance made positive identification difficult.
Cedar Key, South of Hodges Bridge	2/28/94	14:35	High water levels; shorebirds pushed back in the marsh making identification difficult.
Cedar Key, Hodges Bridge	2/18/94	12:15	E wind very strong (gusting to 26kph) very difficult to focus on smaller species; unknown. Disturbances also made counting difficult.
Cedar Key, Seahorse Key	2/21/94	17:20	No shorebirds observed
Delany Creek Canal	1/01/94	12:30	Flats exposed on both sides of creek
Old Tampa Bay, n. of Frankland Bridge	1/01/94	10:50	Birds far out on flats—not directly identifiable from any vantage point.
Old Tampa Bay, n. of Frankland Bridge	12/16/93	10:55	Two fisherman wading into group—birds don't mind, much aircraft flying overhead
Fort Desoto, east end	1/15/94	13:50	Plovers roosting in grassy area.
Honeymoon Island	12/31/93	14:10	Difficult counting conditions: plovers were huddled on S side of seaweed clumps to avoid wind. 600 other shorebirds flying in Gulf side + feeding.
Howard County Park, causeway	1/16/94	08:40	Willet grazing in exposed sea flats—a nice "pastoral" scene. Sea grass + sand/mud flats exposed.

Appendix C. Continued.

Subject and Site	Date	Time	Field Notes
General notes, Continued			
Howard County Park, west end	1/03/94	11:50	County park ranger stated that on a warm winter day all beaches were filled.
Island north of Bunces Pass	2/07/94	13:20	About another 1000 birds on Gulf side
Little Estero CWA	2/09/94	13:45	People tend to avoid gulls/terns but do not see roosting plovers/peeps and walk right through them. Kids playing on the beach seem to disturb the birds more than adults—chasing the birds.
McKay Bay	12/16/93	10:00	Very bad lighting, dark mud flats = hard counting.
Three Rooker Bar, north end	2/21/94	12:30	Bad lighting—hard to count birds.
Carl Ross Key	1/28/94	10:45	10,000+ shorebirds on N side of key/not able to access/SE wind had a lot of flats exposed.
Sandy Key	2/12/94	10:20	Mud flats exposed a lot/several hundred birds N of sandy on bank/not able to access.
Sandy Key	1/28/94	11:10	5,000+ birds on north side of island/not able to access/tide was low due to SE wind.
Snake Bight Channel	2/11/94	13:20	No shorebirds observed at this site but, 10,000+ shorebirds at Gibby point shoreline/not able to access.
Snake Bight Channel	1/28/94	12:30	No shorebirds observed at this site, but tide is higher due to SE wind/2,000 to 3,000 shorebirds on flat 1 km away/not able to access to count.
Snake Bight Channel	11/27/94	15:10	Thousands of shorebirds at Gibby point shoreline/not able to access.
NASA Causeway, north side	1/21/94	11:41	All birds on seldom exposed sand spit off point; lowest water levels due to strong northerly winds

Appendix D. Total annual counts of shorebirds by species from CBCs in Florida. Annual total was obtained by averaging counts for each species for each circle from 1980 through 1989.

Species	Scientific name	Florida total
Black-bellied plover	*Pluvialis squatarola*	4,522
Snowy plover	*Charadrius alexandrinus*	104
Wilson's plover	*Charadrius wilsonia*	284
Semipalmated plover	*Charadrius semipalmatus*	2,212
Piping plover	*Charadrius melodus*	103
Killdeer	*Charadrius vociferous*	10,773
American oystercatcher	*Haematopus palliatus*	604
Black-necked stilt	*Himantopus mexicanus*	83
American avocet	*Recurvirostra americana*	486
Greater yellowlegs	*Tringa melanoleuca*	993
Lesser yellowlegs	*Tringa flavipes*	1,361
Solitary sandpiper	*Tringa solitaria*	8
Willet	*Catoptrophorus semipalmatus*	5,186
Spotted sandpiper	*Actitis macularia*	367
Whimbrel	*Numenius phaeopus*	73
Long-billed curlew	*Numenius americanus*	9
Marbled godwit	*Limosa fedoa*	293
Ruddy turnstone	*Arenaria interpres*	3,398
Red knot	*Calidris canutus*	2,928
Sanderling	*Calidris alba*	6,275
Semipalmated sandpiper	*Calidris pusilla*	218
Western sandpiper	*Calidris mauri*	14,295
Least sandpiper	*Calidris minutilla*	4,814
Pectoral sandpiper	*Calidris melanotos*	1
Purple sandpiper	*Calidris maritima*	7
Dunlin	*Calidris alpina*	13,826
Stilt sandpiper	*Calidris himantopus*	98
Short-billed dowitcher	*Limnodromus griseus*	10,822
Long-billed dowitcher	*Limnodromus scolopaceus*	36
Common snipe	*Gallinago gallinago*	1,771
American woodcock	*Scolopax minor*	57
Peep spp.	*Calidris spp.*	19,327
Dowitcher spp.	*Limnodromus spp.*	10,858
Yellowlegs spp.	*Tringa spp.*	2,200
Plover spp.	*Charadrius spp.*	2,703
Unidentified shorebirds		85,640

Appendix E. Conservation action scores and biological vulnerability scores for shorebird species as revised from 1990 species ranking[a].

Common name	Action	Biological score
Black-bellied plover	14	21.7
Snowy plover	4	37.3
Wilson's plover	14	25.7
Semipalmated plover	9	21.7
Piping plover	9	35.0
Killdeer	10	3.0
American oystercatcher	21	29.3
Black-necked stilt	24	18.0
American avocet	19	15.0
Greater yellowlegs	14	13.7
Lesser yellowlegs	14	14.7
Solitary sandpiper	21	10.3
Willet	14	13.7
Spotted sandpiper	21	8.7
Upland sandpiper	25	12.0
Whimbrel	16	34.0
Marbled godwit	14	32.0
Ruddy turnstone	14	26.7
Red knot	14	28.3
Sanderling	14	27.7
Semipalmated sandpiper	21	25.7
Western sandpiper	14	21.7
Least sandpiper	14	14.7
White-rumped sandpiper	14	25.7
Pectoral sandpiper	14	27.7
Dunlin	14	21.0
Short-billed dowitcher	14	23.7
Long-billed dowitcher	14	17.7
Common snipe	19	10.7
American woodcock	19	12.0
Wilson's phalarope	16	6.7

[a] Original scores were provided by Millsap et al. (1990).

Appendix F. Mean number of small plovers observed at 60 sites in Florida, 16 December 1993 through 1 March 1994.

	Snowy plover			Wilson's plover			Semipalmated plover			Piping plover			Small unidentified plover		
Region and site	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**
Panhandle Coast															
Cape San Blas	1.3	1.3	0–3	0.0	0.0		14.5	8.9	3–24	21.8	3.7	17–26	1.3	2.5	0–5
Carrabelle Beach	0.8	1.4	0–3	0.1	0.4	0–1	9.3	9.7	0–30	0.9	1.1	0–3	0.0	0.0	
Carrabelle River Flats	0.0	0.0		0.0	0.0		6.0	10.1	0–21	0.0	0.0		0.0	0.0	
Crooked Island West, east end	11.5	9.3	0–22	0.0	0.0		0.0	0.0		4.0	3.3	0–8	0.0	0.0	
Crooked Island East, west end	13.8	11.1	2–28	0.0	0.0		0.8	1.5	0–3	0.5	0.6	0–1	0.0	0.0	
East of Bay North	0.0	0.0		0.0	0.0		1.3	3.4	0–9	0.0	0.0		0.0	0.0	
Fort Pickens, west end	0.3	0.5	0–1	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Lanark Reef	3.3	6.5	0–13	1.3	1.3	0–3	9.8	8.6	1–19	51.8	34.5	5–87	0.0	0.0	
Marifarms	0.0	0.0		0.3	0.5	0–1	38.8	38.5	3–74	2.5	3.0	0–6	0.0	0.0	
Phipps Preserve	0.2	0.4	0–1	0.0	0.0		0.0	0.0		0.3	0.5	0–1	0.0	0.0	
Shell Island, east end Inlet	7.5	8.3	0–19	0.0	0.0		3.5	6.4	0–13	16.0	21.2	0–47	0.8	1.5	0–3
Shell Island, west end	5.8	8.3	0–18	0.0	0.0		0.0	0.0		0.8	1.5	0–3	0.0	0.0	
St. Joseph Peninsula	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Yent Bayou	2.3	2.9	0–8	0.0	0.0		16.1	13.2	0–31	6.1	4.7	0–13	1.6	1.9	0–5
Big Bend Coast															
Cedar Key, Hodges Bridge	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Cedar Key, Seahorse Key	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Cedar Key, south of Hodges Bridge	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Hagens Cove	0.0	0.0		0.0	0.0		5.3	6.9	0–17	1.1	1.7	0–5	1.0	2.8	0–8
Sprague Island oyster bars	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
St. Marks NWR, Mounds Pool #3	0.0	0.0		0.0	0.0		1.0	2.4	0–6	0.0	0.0		0.0	0.0	
Southwest Coast															
Anclote Key, north end	0.3	0.5	0–1	0.3	0.5	0–1	51.8	102.2	0–205	4.5	7.1	0–15	0.0	0.0	
Anclote Key, south end	17.0	13.8	4–33	35.0	40.2	4–94	124.3	129.9	21–305	4.5	7.1	0–15	13.8	24.3	0–50
Caladesi Island, Dunedin Pass	3.0	2.3	0–5	7.6	4.8	4–15	28.6	18.4	10–59	5.2	3.9	2–12	9.4	10.9	0–25
Caladesi Island, north end	1.3	1.3	0–3	8.5	9.3	0–20	61.3	22.9	33–89	4.3	2.5	1–7	3.3	3.9	0–8
Courtney Campbell Causeway, SE A	0.0	0.0		0.0	0.0		1.2	1.8	0–4	0.0	0.0		0.0	0.0	
Courtney Campbell Causeway, SE B	0.0	0.0		2.0	4.4	0–11	14.7	23.1	0–58	0.0	0.0		0.0	0.0	

Appendix F. Continued.

	Snowy plover			Wilson's plover			Semipalmated plover			Piping plover			Small unidentified plover		
Region and site	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**
Southwest Coast continued															
Delany Creek Canal	0.0	0.0		1.8	2.9	0–6	2.5	5.0	0–10	0.0	0.0		0.0	0.0	
Ding Darling NWR, tower stop	0.0	0.0		0.0	0.0		0.2	0.4	0–1	0.0	0.0		0.0	0.0	
Fort Desoto, northwest end	1.0	2.0	0–4	1.8	3.5	0–7	3.5	3.5	0–7	2.5	3.8	0–8	0.0	0.0	
Fort Desoto, southeast end	0.0	0.0		5.8	7.6	0–16	15.8	11.8	0–28	0.0	0.0		1.3	2.5	0–5
Honeymoon Island	6.4	11.0	1–26	21.8	20.7	0–53	57.2	40.6	16–111	37.4	12.3	26–56	9.2	20.6	0–46
Howard County Park, causeway	0.0	0.0		4.3	8.5	0–17	7.8	7.6	2–19	0.0	0.0		0.0	0.0	
Howard County Park, west end	0.0	0.0		0.5	1.0	0–2	6.5	4.7	0–11	0.8	0.5	0–1	0.5	1.0	0–2
Island north of Bunces Pass	0.5	1.0	0–2	24.3	24.1	1–58	46.5	42.2	0–100	4.3	5.7	0–12	0.0	0.0	
Lido Beach	2.3	1.0	1–3	4.0	3.7	0–9	15.0	15.5	0–34	0.0	0.0		0.0	0.0	
Little Estero CWA	2.3	3.7	0–8	21.5	22.6	0–62	3.2	3.9	0–9	8.7	11.9	0–25	0.3	0.8	0–2
McKay Bay	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		4.0	8.9	0–20
Old Tampa Bay, n. of Frankland Bridge	0.0	0.0		1.0	1.4	0–3	8.0	8.4	1–19	0.0	0.0		0.0	0.0	
Palm Island Resort	4.3	2.9	2–8	18.5	7.3	8–24	2.3	2.6	0–5	0.0	0.0		0.0	0.0	
Passage Key NWR	1.8	2.4	0–5	0.3	0.5	0–1	23.8	36.0	0–76	0.0	0.0		0.0	0.0	
Point Pinellas, west oyster bar	0.0	0.0		1.8	3.5	0–7	5.8	4.9	1–12	0.0	0.0		7.8	15.5	0–31
Shell Key	2.0	2.3	0–5	9.2	11.1	0–24	73.4	63.6	0–172	16.2	13.3	0–36	4.0	8.9	0–20
Turtle Beach, Midnight Pass	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Three Rooker Bar, north end	9.3	5.0	4–14	36.3	37.9	12–80	91.7	69.4	27–165	11.7	12.0	0–24	2.0	2.6	0–5
Three Rooker Bar, Southeast end	0.3	0.5	0–1	4.5	4.1	0–8	38.8	29.1	8–67	15.0	16.8	0–36	3.8	7.5	0–15
Everglades Coast															
Cape Romano, Morgan Beach	0.0	0.0		18.5	20.2	0–37	23.3	27.2	0–52	0.0	0.0		0.0	0.0	
Capri Pass	0.0	0.0		1.5	1.9	0–4	10.8	13.2	0–30	0.0	0.0		0.0	0.0	
Carl Ross Key	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Lake Ingraham, southeast end	0.0	0.0		33.3	31.3	0–74	43.0	59.5	0–130	0.0	0.0		0.0	0.0	
Northwest of Palm Key	0.0	0.0		0.0	0.0		6.8	13.5	0–27	0.0	0.0		0.0	0.0	
Sandy Key	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Snake Bight Channel	0.0	0.0		6.4	14.3	0–32	8.0	17.9	0–40	0.0	0.0		0.0	0.0	
Tigertail Beach	2.8	5.5	0–11	10.3	16.2	0–34	16.5	21.1	0–44	5.8	11.5	0–23	0.0	0.0	

Appendix F. Continued.

	Snowy plover			Wilson's plover			Semipalmated plover			Piping plover			Small unidentified plover		
Region and site	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**
Northeast Coast															
Bennett Causeway, Merritt Island	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Huguenot Memorial Park	0.0	0.0		0.0	0.0		1.3	1.5	0–3	2.8	3.0	0–7	0.0	0.0	
Kennedy Space Center, Pad 39B	0.0	0.0		0.0	0.0		5.3	10.5	0–21	0.0	0.0		0.0	0.0	
Merritt Island NWR, Black Point Drive	0.0	0.0		0.0	0.0		22.0	25.9	0–50	0.0	0.0		0.0	0.0	
NASA Causeway, north side	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
NASA Causeway, south side	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Port Orange Spoil Islands	0.0	0.0		0.0	0.0		0.3	0.5	0–1	0.0	0.0		0.0	0.0	

Appendix G. Mean number of black-bellied plovers, killdeer, and yellowlegs observed at 60 sites in Florida, 16 December 1993 through 1 March 1994.

	Black-bellied plover			Killdeer			Greater yellowlegs			Lesser yellowlegs			Yellowlegs spp.		
Region and site	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**
Panhandle Coast															
Cape San Blas	6.3	1.7	4–8	0.0	0.0		7.5	7.0	3–18	0.0	0.0		0.0	0.0	
Carrabelle Beach	5.9	4.3	0–13	0.1	0.4	0–1	0.6	1.4	0–4	0.0	0.0		0.0	0.0	
Carrabelle River Flats	4.8	2.2	2–7	0.0	0.0		0.8	1.5	0–3	0.0	0.0		0.0	0.0	
Crooked Island East, west end	7.8	4.3	4–14	0.3	0.5	0–1	0.8	1.0	0–2	0.0	0.0		0.0	0.0	
Crooked Island West, east end	3.8	1.7	2–6	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
East of Bay North	1.9	3.3	0–8	1.1	1.9	0–5	0.0	0.0		0.0	0.0		0.0	0.0	
Fort Pickens, west end	1.3	0.5	1–2	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Lanark Reef	88.8	58.6	11–153	0.3	0.5	0–1	0.5	0.6	0–1	0.0	0.0		0.0	0.0	
Marifarms	43.0	27.7	9–75	0.5	1.0	0–2	3.5	4.5	0–10	0.0	0.0		0.3	0.5	0–1
Phipps Preserve	3.5	4.1	0–11	0.3	0.8	0–2	0.0	0.0		0.0	0.0		0.0	0.0	
Shell Island, east inlet	5.5	3.7	1–10	0.3	0.5	0–1	0.0	0.0		0.0	0.0		0.0	0.0	
Shell Island, west end	1.0	2.0	0–4	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
St. Joseph Peninsula	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Yent Bayou	4.5	3.0	0–8	1.1	1.0	0–3	0.4	0.7	0–2	0.0	0.0		0.0	0.0	
Big Bend Coast															
Cedar Key, Hodges Bridge	1.8	4.0	0–9	0.0	0.0		0.2	0.4	0–1	0.0	0.0		0.8	1.8	0–4
Cedar Key, Seahorse Key	4.8	9.5	0–19	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Cedar Key, s. of Hodges Bridge	2.6	3.2	0–7	0.0	0.0		0.0	0.0		0.0	0.0		1.0	2.2	0–5
Hagens Cove	20.9	31.9	0–97	0.3	0.7	0–2	7.8	7.5	0–17	0.0	0.0		0.0	0.0	
Sprague Island oyster bars	7.8	10.6	0–23	0.3	0.5	0–1	0.0	0.0		0.0	0.0		0.0	0.0	
St Marks NWR, Mounds Pool #3	6.8	8.5	0–21	4.8	3.1	2–9	9.7	11.4	0–28	2.5	4.2	0–10	11.3	12.4	0–30
Southwest Coast															
Anclote Key, north end	19.0	14.9	6–36	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Anclote Key, south end	32.3	2.1	30–35	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Caladesi Island, Dunedin Pass	26.2	26.8	3–70	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Caladesi Island, north end	9.8	6.4	1–15	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Courtney Campbell Causeway, Southeast A	0.7	0.8	0–2	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	

Appendix G. Continued.

	Black-bellied plover			Killdeer			Greater yellowlegs			Lesser yellowlegs			Yellowlegs spp.		
Region and site	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**
Southwest Coast continued															
Courtney Campbell Causeway, Southeast B	1.2	1.5	0–3	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Delany Creek Canal	3.0	2.4	0–5	1.0	1.4	0–3	0.3	0.5	0–1	0.0	0.0		0.0	0.0	
Ding Darling NWR, tower stop	48.8	104.1	0–235	0.0	0.0		0.0	0.0		0.2	0.4	0–1	0.0	0.0	
Fort Desoto, east end	3.3	4.7	0–10	1.5	3.0	0–6	0.0	0.0		0.0	0.0		0.0	0.0	
Fort Desoto, northwest end	32.5	30.2	0–71	1.0	2.0	0–4	0.0	0.0		0.0	0.0		0.0	0.0	
Honeymoon Island	44.6	36.0	1–83	0.0	0.0		0.2	0.4	0–1	0.4	0.9	0–2	0.0	0.0	
Howard County Park, causeway	2.3	1.7	0–4	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Howard County Park, west end	1.3	1.5	0–3	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Island north of Bunces Pass	116.0	113.7	22–267	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Lido Beach	2.5	1.9	1–5	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Little Estero CWA	6.8	7.7	0–21	0.0	0.0		0.0	0.0		0.3	0.5	0–1	0.0	0.0	
McKay Bay	9.2	8.5	3–22	2.0	3.4	0–8	0.2	0.4	0–1	0.2	0.4	0–1	0.6	1.3	0–3
Old Tampa Bay, n. of Frankland Bridge	9.0	6.9	4–19	16.8	21.5	5–49	0.3	0.5	0–1	0.3	0.5	0–1	0.0	0.0	
Palm Island Resort	12.8	13.4	1–32	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Passage Key NWR	14.5	7.1	5–22	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Point Pinellas, west oyster bar	2.8	2.5	0–6	0.0	0.0		0.0	0.0		0.3	0.5	0–1	0.0	0.0	
Shell Key	170.6	121.5	34–300	0.0	0.0		0.0	0.0		2.8	6.3	0–14	0.0	0.0	
Three Rooker Bar, north end	12.7	6.5	6–19	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Three Rooker Bar, southeast end	5.3	5.0	0–12	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Turtle Beach, Midnight Pass	2.0	4.0	0–8	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Everglades Coast															
Cape Romano, Morgan Beach	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Capri Pass	39.8	50.1	3–113	0.0	0.0		0.0	0.0		3.0	6.0	0–12	0.0	0.0	
Carl Ross Key	7.0	8.2	0–16	0.0	0.0		0.0	0.0		0.3	0.5	0–1	0.0	0.0	
Lake Ingraham, southeast end	74.8	118.5	0–250	0.0	0.0		0.0	0.0		1.3	2.5	0–5	0.0	0.0	
Northwest of Palm Key	27.5	34.7	0–72	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Sandy Key	5.8	8.0	0–17	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Snake Bight Channel	6.0	13.4	0–30	0.0	0.0		0.0	0.0		4.2	9.4	0–21	0.0	0.0	
Tigertail Beach	7.3	14.5	0–29	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	

Appendix G. Continued.

Region and site	Black-bellied plover $\bar{x}$	Black-bellied plover SD	Black-bellied plover Range	Killdeer $\bar{x}$	Killdeer SD	Killdeer Range	Greater yellowlegs $\bar{x}$	Greater yellowlegs SD	Greater yellowlegs Range	Lesser yellowlegs $\bar{x}$	Lesser yellowlegs SD	Lesser yellowlegs Range	Yellowlegs spp. $\bar{x}$	Yellowlegs spp. SD	Yellowlegs spp. Range
Northeast Coast															
Bennett Causeway, Merritt Island	2.5	0.6	2–3	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Huguenot Memorial Park	4.8	1.3	3–6	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Kennedy Space Center, Pad 39B	10.8	14.2	0–30	39.5	20.0	25–69	0.8	1.0	0–2	4.8	4.9	0–11	1.0	1.2	0–2
Merritt Island NWR, Black Point Drive	132.5	82.8	26–218	5.0	6.2	0–4	18.0	15.9	3–39	75.3	65.3	14–49	11.3	13.0	0–23
NASA Causeway, north side	32.8	36.4	1–70	0.0	0.0		0.0	0.0		0.0	0.0		0.5	1.0	0–2
NASA Causeway, south side	9.5	12.8	0–28	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Port Orange Spoil Islands	19.8	30.8	4–66	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	

Appendix H. Mean number of American oystercatchers, willets, whimbrels, marbled godwits, and short-billed dowitchers observed at 60 sites in Florida, 16 December 1993 through 1 March 1994.

	American oystercatcher			Willet			Whimbrel			Marbled godwit			Short-billed dowitcher		
Region and site	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**
Panhandle Coast															
Cape San Blas	0.0	0.0		5.5	5.2	0–12	0.0	0.0		0.0	0.0		18.5	12.2	8–30
Carrabelle Beach	5.0	8.5	0–24	88.1	73.7	3–247	0.0	0.0		15.4	17.7	0–45	20.9	20.0	0–56
Carrabelle River Flats	0.5	1.0	0–2	1.8	1.7	0–4	0.0	0.0		0.0	0.0		0.0	0.0	
Crooked Island East, west end	0.0	0.0		1.3	1.5	0–3	0.0	0.0		0.0	0.0		0.0	0.0	
Crooked Island West, east end	0.0	0.0		2.3	3.3	0–7	0.0	0.0		0.0	0.0		0.0	0.0	
East of Bay North	0.3	0.8	0–2	119.0	122.6	0–370	0.0	0.0		4.1	7.2	0–19	36.7	76.0	0–203
Fort Pickens, west end	0.0	0.0		7.5	3.4	4–12	0.0	0.0		0.0	0.0		0.0	0.0	
Lanark Reef	71.8	34.5	28–110	358.0	269.7	45–704	0.3	0.5	0–1	161.3	110.1	2–254	164.3	157.3	9–343
Marifarms	0.0	0.0		2.0	2.4	0–5	0.5	0.6	0–1	0.0	0.0		1.0	1.4	0–3
Phipps Preserve	3.7	2.7	0–8	6.7	7.6	0–19	0.0	0.0		0.0	0.0		0.0	0.0	
Shell Island, east inlet	0.0	0.0		3.0	3.5	0–8	0.0	0.0		0.0	0.0		6.0	12.0	0–24
Shell Island, west end	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
St. Joseph Peninsula	0.0	0.0		0.8	1.0	0–2	0.0	0.0		0.0	0.0		0.0	0.0	
Yent Bayou	0.0	0.0		8.3	7.1	0–20	0.0	0.0		0.0	0.0		0.0	0.0	
Big Bend Coast															
Cedar Key, Hodges Bridge	0.0	0.0		3.2	2.9	0–6	0.0	0.0		0.4	0.9	0–2	23.0	49.2	0–111
Cedar Key, Seahorse Key	0.0	0.0		7.5	15.0	0–30	0.0	0.0		0.0	0.0		0.0	0.0	
Cedar Key, s. of Hodges Bridge	5.6	12.5	0–28	11.8	17.6	0–41	0.0	0.0		0.0	0.0		16.2	35.7	0–80
Hagens Cove	0.0	0.0		45.0	65.9	0–187	0.0	0.0		4.0	7.5	0–22	74.6	122.4	0–297
Sprague Island oyster bars	3.8	4.5	0–9	121.3	84.6	0–194	2.3	2.6	0–5	0.0	0.0		83.3	113.9	0–244
St Marks NWR, Mounds Pool #3	0.0	0.0		56.2	80.9	0–203	0.0	0.0		0.0	0.0		120.2	136.3	0–323
Southwest Coast															
Anclote Key, north end	0.5	0.6	0–1	0.0	0.0		0.8	1.5	0–3	0.0	0.0		23.0	22.2	0–44
Anclote Key, south end	1.5	1.0	0–2	21.3	31.3	3–68	0.0	0.0		0.0	0.0		63.8	53.5	18–141
Caladesi Island, north end	4.8	4.6	0–10	3.8	6.2	0–13	0.0	0.0		0.0	0.0		6.0	7.3	0–15
Caladesi Island, Dunedin Pass	1.6	1.7	0–4	0.2	0.4	0–1	0.0	0.0		0.0	0.0		22.4	30.7	0–56
Courtney Campbell Causeway, Southeast A	1.2	1.6	0–4	1.3	1.5	0–3	0.0	0.0		0.0	0.0		24.7	40.6	0–102

Appendix H. Continued.

Region and site	American oystercatcher x̄	SD	Range	Willet x̄	SD	Range	Whimbrel x̄	SD	Range	Marbled godwit x̄	SD	Range	Short-billed dowitcher x̄	SD	Range
Southwest Coast continued															
Courtney Campbell Causeway, Southeast B	1.5	3.2	0–8	1.2	1.5	0–3	0.0	0.0		0.0	0.0		12.5	15.2	0–36
Delany Creek Canal	1.0	1.4	0–3	14.8	11.4	0–27	0.0	0.0		0.3	0.5	0–1	1.8	2.1	0–4
Ding Darling NWR, tower stop	0.0	0.0		25.6	40.3	0–96	0.0	0.0		0.0	0.0		196.2	340.6	0–800
Fort Desoto NW	5.5	3.5	2–9	122.8	244.2	0–489	0.0	0.0		0.0	0.0		93.5	154.9	0–323
Fort Desoto SE	0.0	0.0		2.8	5.5	0–11	0.0	0.0		0.0	0.0		6.5	13.0	0–26
Honeymoon Island	3.4	1.8	1–6	0.6	0.9	0–2	4.2	5.8	0–12	0.0	0.0		40.6	32.7	0–90
Howard County Park, causeway	1.0	2.0	0–4	156.8	141.8	2–324	0.0	0.0		0.5	1.0	0–2	18.3	27.5	0–59
Howard County Park, end	0.3	0.5	0–1	48.8	95.5	0–192	0.0	0.0		0.3	0.5	0–1	4.5	4.2	0–10
Island N of Bunces Pass	0.3	0.5	0–1	146.0	153.6	48–375	0.0	0.0		3.3	4.6	0–10	132.5	182.6	0–387
Lido Beach	0.0	0.0		4.3	4.9	0–9	0.0	0.0		0.0	0.0		0.0	0.0	
Little Estero CWA	12.0	10.1	0–28	8.5	5.1	0–14	1.5	1.0	0–3	0.2	0.4	0–1	4.7	9.6	0–24
McKay Bay	0.0	0.0		11.6	10.8	3–30	0.0	0.0		0.0	0.0		30.8	50.4	0–118
Old Tampa Bay, n. of Frankland Bridge	1.3	1.0	0–2	7.8	7.9	0–16	0.0	0.0		1.8	3.5	0–7	102.3	69.2	45–203
Palm Island Resort	0.5	1.0	0–2	4.8	5.3	0–12	0.0	0.0		0.0	0.0		0.0	0.0	
Passage Key NWR	2.5	1.7	0–4	0.0	0.0		0.0	0.0		0.0	0.0		62.5	125.0	0–250
Point Pinellas, west oyster bar	13.8	13.8	2–33	132.3	84.1	28–201	1.8	0.5	1–2	82.5	55.5	35–146	138.5	103.4	8–250
Shell Key	5.6	3.8	2–12	19.4	38.4	0–88	0.0	0.0		1.4	3.1	0–7	176.8	142.5	5–393
Three Rooker Bar, north end	1.0	1.0	0–2	21.7	35.0	0–62	0.0	0.0		0.0	0.0		72.7	91.9	0–176
Three Rooker Bar, southeast end	0.5	1.0	0–2	0.0	0.0		0.0	0.0		0.0	0.0		11.0	20.7	0–42
Turtle Beach, Midnight Pass	0.0	0.0		1.5	2.4	0–5	0.0	0.0		0.0	0.0		0.0	0.0	
Everglades Coast															
Cape Romano, Morgan Beach	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		29.3	34.5	0–67
Capri Pass	0.0	0.0		13.3	22.7	0–47	0.0	0.0		0.0	0.0		147.0	155.1	0–364
Carl Ross Key	0.0	0.0		0.0	0.0		0.	0.0		0.0	0.0		0.0	0.0	
Lake Ingraham southeast	0.0	0.0		67.5	78.2	0–143	2.0	4.0	0–8	5.5	7.1	0–15	18.5	21.7	0–42
Northwest of Palm Key	0.0	0.0		30.8	41.2	0–87	0.0	0.0		1.3	2.5	0–5	24.5	49.0	0–98
Sandy Key	0.0	0.0		7.3	9.2	0–20	0.0	0.0		0.0	0.0		4.3	8.5	0–17
Snake Bight Channel	0.0	0.0		188.2	398.3	0–900	0.0	0.0		42.6	88.2	0–200	26.8	38.3	0–90
Tigertail Beach	0.0	0.0		0.3	0.5	0–1	0.0	0.0		0.0	0.0		17.3	34.5	0–69

Appendix H. Continued.

	American oystercatcher			Willet			Whimbrel			Marbled godwit			Short-billed dowitcher		
Region and site	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**
Northeast Coast															
Bennett Causeway, Merritt Island	0.0	0.0		1.5	1.9	0–4	0.0	0.0		0.0	0.0		9.0	12.0	0–26
Huguenot Memorial Park	0.0	0.0		0.8	1.0	0–2	0.0	0.0		0.0	0.0		3.3	6.5	0–13
Kennedy Space Center, Pad 39B	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Merritt Island NWR, Black Point Drive	0.0	0.0		0.5	1.0	0–2	0.0	0.0		0.0	0.0		5.5	6.4	0–12
NASA Causeway, north side	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		12.5	24.3	0–49
NASA Causeway, south side	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0		23.5	42.5	0–87
Port Orange Spoil Islands	7.5	5.1	4–15	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	

Appendix I. Mean number of ruddy turnstones, red knots, dunlins, and unidentified birds at 60 sites in Florida, 16 December 1993 through 1 March 1994.

	Ruddy turnstone			Red knot			Dunlin			Unidentified		
Region and site	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**
Panhandle Coast												
Cape San Blas	1.3	1.9	0–4	0.0	0.0		42.8	11.1	29–54	1.3	2.5	0–5
Carrabelle Beach	0.6	1.4	0–4	29.6	29.4	0–69	63.8	37.5	12–118	36.0	37.5	0–116
Carrabelle River Flats	18.8	20.1	0–39	0.0	0.0		43.8	36.4	0–89	0.0	0.0	
Crooked Island East, west end	1.5	1.3	0–3	0.0	0.0		3.0	3.8	0–8	0.0	0.0	
Crooked Island West, east end	0.5	1.0	0–2	0.0	0.0		1.0	1.4	0–3	0.0	0.0	
East of Bay North	0.0	0.0		0.0	0.0		91.9	142.4	0–344	63.4	111.3	0–300
Fort Pickens, west end	2.5	1.3	1–4	0.0	0.0		0.0	0.0		0.0	0.0	
Lanark Reef	32.3	32.2	5–78	50.8	66.4	1–147	602.8	312.7	215–965	311.5	339.2	0–650
Marifarms	0.0	0.0		0.0	0.0		303.3	244.3	105–626	43.3	50.1	0–92
Phipps Preserve	2.7	4.1	0–11	0.0	0.0		0.8	1.6	0–4	16.8	29.4	0–75
Shell Island, east inlet	1.8	2.9	0–6	0.0	0.0		121.5	148.4	10–324	3.5	7.0	0–14
Shell Island, west end	1.5	1.7	0–3	0.0	0.0		8.0	16.0	0–32	0.0	0.0	
St. Joseph Peninsula	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Yent Bayou	1.6	1.4	0–4	44.0	41.2	0–116	72.0	66.1	0–212	17.3	25.7	0–71
Big Bend Coast												
Cedar Key, s. of Hodges Bridge	0.0	0.0		0.0	0.0		34.4	43.0	0–102	256.2	278.8	0–600
Cedar Key, Hodges Bridge	0.2	0.4	0–1	0.0	0.0		11.6	21.7	0–50	330.0	519.8	0–1,200
Cedar Key, Seahorse Key	2.0	3.4	0–7	0.0	0.0		78.0	104.5	0–221	0.0	0.0	
Hagens Cove	0.0	0.0		0.0	0.0		182.8	125.5	0–370	90.3	120.5	0–280
Sprague Island oyster bars	51.0	42.4	0–102	0.0	0.0		447.0	580.0	0–1,218	177.0	254.3	16–551
St Marks NWR, Mounds Pool #3	0.8	2.0	0–5	0.0	0.0		521.5	599.0	0–1,283	46.5	60.7	0–144
Southwest Coast												
Anclote Key, north end	5.8	8.5	0–18	3.0	6.0	0–12	526.3	644.8	0–1,370	12.5	25.0	0–50
Anclote Key, south end	58.0	64.2	1–150	14.8	25.7	0–53	63.0	22.9	30–80	72.5	76.3	0–180
Caladesi Island, Dunedin Pass	4.0	4.1	0–10	59.6	76.8	0–165	63.6	60.2	0–145	59.0	60.3	0–143
Caladesi Island, north end	6.8	4.8	1–12	112.3	133.1	6–300	183.0	246.4	14–537	39.3	34.2	0–80
Courtney Campbell Causeway, Southeast A	3.3	4.2	0–9	9.7	15.6	0–36	0.2	0.4	0–1	0.0	0.0	
Courtney Campbell Causeway, Southeast B	0.7	1.0	0–2	0.8	1.3	0–3	23.0	52.9	0–131	7.8	12.2	0–25

Appendix I. Continued.

	Ruddy turnstone			Red knot			Dunlin			Unidentified		
Region and site	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**
Southwest Coast continued												
Delany Creek Canal	0.8	1.5	0–3	0.0	0.0		84.0	58.8	0–135	351.0	568.7	0–1,200
Ding Darling NWR, tower stop	0.2	0.4	0–1	6.0	13.4	0–30	10.6	23.7	0–53	28.0	43.8	0–100
Fort Desoto, east end	2.0	4.0	0–8	0.5	1.0	0–2	77.8	54.5	0–126	38.0	48.7	0–102
Fort Desoto, northwest end	10.8	10.0	0–23	1.8	3.5	0–7	228.8	261.7	0–540	102.8	117.6	1–250
Honeymoon Island	32.4	19.4	2–52	73.0	39.0	31–122	155.2	111.5	31–308	96.2	59.9	15–160
Howard County Park, causeway	5.0	5.2	0–10	0.0	0.0		7.3	14.5	0–29	0.3	0.5	0–1
Howard County Park, west end	5.3	5.1	0–12	0.0	0.0		0.8	1.5	0–3	0.3	0.5	0–1
Island north of Bunces Pass	23.5	30.1	0–63	142.0	123.1	0–280	183.3	277.7	0–595	596.3	941.4	0–2,000
Lido Beach	3.0	4.2	0–9	1.8	3.5	0–7	13.8	27.5	0–55	0.0	0.0	
Little Estero CWA	3.3	4.9	0–11	85.8	102.8	0–241	13.0	18.3	0–47	7.2	11.8	0–30
McKay Bay	0.0	0.0		0.0	0.0		5.6	8.8	0–20	163.0	166.0	0–390
Old Tampa Bay, n. of Frankland Bridge	0.5	1.0	0–2	0.0	0.0		58.3	42.2	17–99	209.8	121.8	37–322
Palm Island Resort	19.5	1.3	18–21	100.3	82.0	51–223	0.8	1.0	0–2	26.3	52.5	0–105
Passage Key NWR	4.8	3.4	0–8	75.0	150.0	0–300	63.5	124.3	0–250	25.0	50.0	0–100
Point Pinellas, west oyster bar	7.8	5.3	2–14	0.0	0.0		23.5	29.1	0–60	36.0	38.3	0–85
Shell Key	19.2	22.2	0–45	380.4	265.0	113–775	363.2	330.3	24–886	80.0	178.9	0–400
Three Rooker Bar, north end	15.3	10.2	8–27	19.7	34.1	0–59	84.7	75.3	0–144	33.3	57.7	0–100
Three Rooker Bar, southeast end	1.5	1.9	0–4	5.8	9.6	0–20	115.3	138.4	0–277	50.0	70.7	0–150
Turtle Beach, Midnight Pass	0.3	0.5	0v1	0.0	0.0		0.0	0.0		2.5	5.0	0–1
Everglades Coast												
Cape Romano, Morgan Beach	27.3	31.6	0–58	0.0	0.0		215.0	248.4	0–440	0.0	0.0	
Capri Pass	2.5	3.8	0–8	124.3	112.6	31–286	109.5	131.7	0–300	0.0	0.0	
Carl Ross Key	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Lake Ingraham, southeast end	0.0	0.0		30.5	61.0	0–122	245.3	283.3	0–500	0.0	0.0	
Northwest of Palm Key	0.0	0.0		16.3	32.5	0–65	51.3	59.2	0–105	1,000.0	2,000.0	0–4,000
Sandy Key	23.5	39.2	0–82	0.0	0.0		13.3	26.5	0–53	0.0	0.0	
Snake Bight Channel	0.0	0.0		12.0	26.8	0–60	8.0	17.9	0–40	0.0	0.0	
Tigertail Beach	7.8	10.8	0–23	0.0	0.0		47.0	87.5	0–178	0.0	0.0	

Appendix I. Continued.

Region and site	Ruddy turnstone $\bar{x}$	Ruddy turnstone SD	Ruddy turnstone Range	Red knot $\bar{x}$	Red knot SD	Red knot Range	Dunlin $\bar{x}$	Dunlin SD	Dunlin Range	Unidentified $\bar{x}$	Unidentified SD	Unidentified Range
Northeast Coast												
Bennett Causeway Merritt Island	12.0	4.2	9–18	0.0	0.0		4.3	8.5	0–17	12.5	25.0	0–50
Huguenot Memorial Park	13.8	27.5	0–55	0.0	0.0		36.0	32.1	0–75	4.5	4.2	0–10
Kennedy Space Center, Pad 39B	0.8	1.0	0–2	0.5	1.0	0–2	47.5	55.9	2–124	36.0	26.6	11–73
Merritt Island NWR, Black Point Drive	0.8	1.5	0–3	52.5	75.8	0–164	873.8	430.3	449–1,385	264.0	268.2	81–650
NASA Causeway, north side	13.0	5.3	8–20	0.0	0.0		34.3	68.5	0–137	3.0	6.0	0–12
NASA Causeway, south side	50.3	49.0	2–106	0.0	0.0		32.3	39.1	0–79	10.3	19.8	0–40
Port Orange Spoil Islands	18.3	19.6	4–47	0.0	0.0		3.3	5.9	0–12	24.0	27.3	0–60

Appendix J. Mean number of small sandpipers at 60 sites in Florida, 16 December 1993 through 1 March 1994.

	Sanderling			Western sandpiper			Least sandpiper			Unidentified peep		
Region and site	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**
Panhandle Coast												
Cape San Blas	3.5	1.0	2–4	73.8	33.3	35–103	0.0	0.0		0.0	0.0	
Carrabelle Beach	37.5	28.4	0–88	1.4	2.9	0–8	0.9	2.5	0–7	2.5	4.4	0–13
Carrabelle River Flats	0.8	1.0	0–2	0.3	0.5	0–1	0.0	0.0		0.0	0.0	
Crooked Island East, west end	52.3	13.7	34–67	0.0	0.0		0.0	0.0		0.0	0.0	
Crooked Island West, east end	46.3	20.4	25–67	0.0	0.0		0.0	0.0		0.0	0.0	
East of Bay North	38.0	50.8	0–139	0.0	0.0		0.0	0.0		3.0	7.9	0–21
Fort Pickens, west end	62.5	32.1	19–96	0.0	0.0		0.0	0.0		0.0	0.0	
Lanark Reef	186.5	78.8	70–242	44.8	17.8	28–69	0.3	0.5	0–1	59.3	112.6	0–228
Marifarms	0.0	0.0		71.8	47.0	14–123	22.0	39.4	0–81	19.3	38.5	0–77
Phipps Preserve	3.0	7.3	0–18	0.0	0.0		0.0	0.0		0.0	0.0	
Shell Island, east inlet	3.3	2.6	1–7	7.5	12.4	0–26	0.3	0.5	0–1	1.0	2.0	0–4
Shell Island, west end	5.0	4.4	0–10	0.0	0.0		0.0	0.0		0.0	0.0	
St. Joseph Peninsula	2.0	3.4	0–7	0.0	0.0		0.0	0.0		0.0	0.0	
Yent Bayou	25.1	21.1	0–51	2.5	4.9	0–14	0.8	2.1	0–6	7.4	18.1	0–52
Big Bend Coast												
Cedar Key, Hodges Bridge	0.0	0.0		0.0	0.0		0.0	0.0		341.2	653.4	0–1,500
Cedar Key, Seahorse Key	23.0	38.4	0–80	0.0	0.0		0.0	0.0		0.0	0.0	
Cedar Key, s. of Hodges Bridge	0.0	0.0		0.0	0.0		1.0	2.2	0–5	0.0	0.0	
Hagens Cove	0.0	0.0		0.0	0.0		0.8	2.1	0–6	36.8	77.4	0–217
Sprague Island oyster bars	0.0	0.0		8.0	9.8	0–20	0.0	0.0		0.0	0.0	
St. Marks NWR, Mounds Pool #3	0.0	0.0		16.7	40.8	0–100	1.0	2.0	0–5	13.7	32.0	0–79
Southwest Coast												
Anclote Key, north end	37.5	36.8	0–88	143.8	287.5	0–575	0.0	0.0		7.5	15.0	0–30
Anclote Key, south end	116.5	46.5	54–160	92.5	107.7	8–242	4.0	4.9	0–10	175.0	202.1	0–350
Caladesi Island, Dunedin Pass	48.8	33.4	14–87	0.2	0.4	0–1	0.0	0.0		9.2	20.6	0–46
Caladesi Island, north end	46.5	64.1	4–141	1.5	3.0	0–6	2.0	4.0	0–8	2.8	4.3	0–9
Courtney Campbell Causeway, Southeast A	6.0	9.2	0–21	0.2	0.4	0–1	0.0	0.0		1.8	4.5	0–11
Courtney Campbell Causeway, Southeast B	56.7	66.9	0–185	50.8	119.7	0–295	1.7	1.9	0–4	0.8	2.0	0–5

Appendix J. Continued.

Region and site	Sanderling $\bar{x}$	Sanderling SD	Sanderling Range	Western sandpiper $\bar{x}$	Western sandpiper SD	Western sandpiper Range	Least sandpiper $\bar{x}$	Least sandpiper SD	Least sandpiper Range	Unidentified peep $\bar{x}$	Unidentified peep SD	Unidentified peep Range
Southwest Coast continued.												
Delany Creek Canal	0.3	0.5	0–1	2.5	3.0	0–6	1.3	2.5	0–5	110.5	87.4	0–212
Ding Darling, tower stop	0.0	0.0		0.0	0.0		0.0	0.0		32.8	56.3	0–130
Fort Desoto, east end	45.5	53.4	0–120	40.0	48.2	0–109	0.5	1.0	0–2	15.0	23.8	0–50
Fort Desoto, northwest end	225.3	162.5	65–450	2.5	5.0	0–10	0.0	0.0		12.5	25.0	0–50
Honeymoon Island	89.2	59.8	25–181	197.8	160.5	27–450	7.8	6.8	0–18	52.0	67.5	0–170
Howard County Park, causeway	1.8	1.7	0–4	1.0	2.0	0–4	2.0	2.4	0–5	0.0	0.0	
Howard County Park, west end	6.8	4.6	2–13	3.0	2.9	0–7	1.8	2.9	0–6	1.0	2.0	0–4
Island north of Bunces Pass	199.3	271.8	0–597	208.8	240.4	0–550	0.0	0.0		59.5	95.4	0–200
McKay Bay	5.6	12.5	0–28	40.4	90.3	0–202	0.0	0.0		24.0	39.1	0–90
Little Estero CWA	112.5	178.0	0–465	0.5	1.2	0–3	0.7	1.6	0–4	2.5	5.6	0–14
Lido Beach	116.5	84.0	20–225	1.3	2.5	0–5	0.0	0.0		0.0	0.0	
Old Tampa Bay, n. of Frankland Bridge	5.8	8.3	0–18	26.8	35.5	0–75	0.0	0.0		12.3	15.1	0–31
Palm Island Resort	87.0	30.8	56–120	0.0	0.0		0.0	0.0		0.0	0.0	
Passage Key NWR	248.3	207.2	62–500	75.3	95.8	0–200	0.0	0.0		12.5	25.0	0–50
Point Pinellas, west oyster bar	0.0	0.0		0.0	0.0		0.0	0.0		21.3	25.3	0–50
Shell Key	287.6	204.2	64–577	184.8	246.7	0–600	40.0	89.4	0–200	20.0	44.7	0–100
Turtle Beach, Midnight Pass	21.3	39.2	0–80	0.0	0.0		0.0	0.0		0.0	0.0	
Three Rooker Bar, southeast end	16.8	9.4	8–30	92.5	110.7	0–229	8.3	11.8	0–25	49.3	70.7	0–150
Three Rooker Bar, north end	83.7	17.6	65–100	40.0	62.5	0–112	8.3	10.4	0–20	43.0	51.4	0–100
Everglades Coast												
Cape Romano, Morgan Beach	62.3	68.0	0–132	468.8	757.0	0–1,600	0.0	0.0		0.0	0.0	
Capri Pass	3.3	6.5	0–13	308.5	230.4	80–570	0.0	0.0		50.0	100.0	0–200
Carl Ross Key	0.0	0.0		0.0	0.0		0.0	0.0		0.0	0.0	
Lake Ingraham, southeast end	3.3	5.9	0–12	893.8	1,001.7	0–2,330	142.5	212.7	0–450	1,050.0	1,377.2	0–2,900
Northwest of Palm Key	0.0	0.0		220.0	258.7	0–500	0.0	0.0		375.0	567.9	0–1,200
Sandy Key	8.8	14.4	0–30	62.5	125.0	0–250	0.0	0.0		12.5	25.0	0–50
Snake Bight Channel	0.0	0.0		10.0	22.4	0–50	0.0	0.0		0.0	0.0	
Tigertail Beach	10.5	19.7	0–40	87.3	160.2	0–327	0.5	1.0	0–2	0.0	0.0	

Appendix J. Continued.

	Sanderling			Western sandpiper			Least sandpiper			Unidentified peep		
Region and site	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**	$\bar{x}$	**SD**	**Range**
Northeast Coast												
Bennett Causeway, Merritt Island	8.8	9.0	1–20	0.0	0.0		0.0	0.0		0.0	0.0	
Huguenot Memorial Park	99.0	84.7	22–209	27.5	24.5	0–59	0.0	0.0		0.0	0.0	
Kennedy Space Center, Pad 39B	21.3	19.2	10–50	3.3	6.5	0–13	3.8	4.9	0–11	55.3	84.0	1–178
Merritt Island NWR, Black Point Drive	1.3	2.5	0–5	9.0	18.0	0–36	12.5	25.0	0–50	290.3	493.5	22–1,030
NASA Causeway, north side	10.3	9.0	2–19	0.0	0.0		0.0	0.0		0.3	0.5	0–1
NASA Causeway, south side	30.5	43.4	0–92	0.0	0.0		0.0	0.0		0.0	0.0	
Port Orange Spoil Islands	14.3	13.4	2–31	0.0	0.0		0.0	0.0		0.3	0.5	0–1

Appendix K. Shorebird species seen at less than 5 of 60 survey sites in Florida, 16 December 1993 through 1 March 1994.

Species	Site	Region	$\bar{x}$	SD	Range
Black-necked stilt	McKay Bay	Southwest	1.6	3.6	0–8
American avocet	Bennett Causeway, Merritt Island	Northeast	0.8	1.5	0–3
	Little Estero CWA	Southwest	2.0	3.1	0–6
	McKay Bay	Southwest	54.2	35.7	0–89
Spotted sandpiper	Point Pinellas, west oyster bars	Southwest	0.3	0.5	0–1
	Ding Darling NWR, tower stop	Southwest	0.6	0.9	0–2
	Old Tampa Bay, north of Frankland Bridge	Southwest	0.3	0.5	0–1
Long-billed curlew	Huguenot Memorial Park	Northeast	0.5	0.6	0–1
	Little Estero CWA	Southwest	0.5	0.5	0–1
Purple sandpiper	NASA Causeway, south side	Northeast	0.3	0.5	0–1
Common snipe	NASA Causeway, south side	Northeast	0.8	1.0	0–2
	St. Marks NWR, Mounds Pool #3	Big Bend	0.2	0.4	0–1