APPENDIX E: POPULATION VIABILITY ANALYSIS

Population viability analysis (PVA) is a structured and systematic analysis of the interacting factors, including abundance, rates of survival and productivity, demographic and environmental stochasticity, and catastrophes, that determine a population's risk of extinction. PVA's have a variety of applications, including, in recent years, use as tools in establishing recovery goals for some threatened and endangered species. General information on PVA's and their use is found in a large and growing body of scientific literature. Persons who want to learn about population viability analysis may find information in Shaffer (1987); Begon and Mortimer (1986), chapter 3; Lindenmayer *et al.* (1993); National Research Council (1995), chapter 7; and numerous other sources.

A draft of the following PVA for the Atlantic Coast piping plover, dated 7 April, 1994, was sent to 13 experts outside the recovery team for review and comment. Five substantive responses were received. Three comment letters expressed overall support for data, methodology, and recommendations, but suggested that model parameters, especially survival rates and co-efficients of variation of survival and fecundity, might be excessively optimistic (i.e., the actual population is less secure than the model predicts). Two other commenters felt that survival rates for plovers in the southern part of the range might be higher than those observed in Massachusetts, perhaps due to shorter migration distances. One of these letters also stated that various model parameters, especially co-efficients of variation of survival and fecundity used to model catastrophic events, were overly pessimistic. Two commenters felt that more "sensitivity analyses" (to better gauge the factors that contribute most to population viability) would make the PVA more useful. Finally, two letters indicated that a metapopulation model would more accurately reflect actual population dynamics than one which treats Atlantic Coast piping plovers as one panmictic[1] population.

In response to these comments and as a result of further discussions among the modelers, recovery team, and U.S. Fish and Wildlife Service biologists, refinements in the analysis were made and additional scenarios were modeled. However, a metapopulation model has yet to be developed.

Although the PVA continues to treat Atlantic Coast piping plovers as a single population, S.M. Melvin and J.P. Gibbs (pers. comm. 1994) agree that a metapopulation model would be more predictive of actual population dynamics. A "metapopulation" comprises a number of smaller subpopulations distributed across separate habitat patches. Within a metapopulation, there are barriers that inhibit dispersal between subpopulations, and environmental conditions may vary between habitat patches.

A metapopulation structure may increase or decrease the extinction probability of the population as a whole. Each of the subpopulations, because of its smaller size, may be more susceptible to extirpation than the larger population. The potential for loss of small local populations

[1] A "panmictic" breeding population is subject to random mating.

is greater the smaller the subpopulation, the greater the distance between subpopulations, and the poorer the ability of the species to disperse between habitat patches to augment or re-colonize adjacent populations and habitat. On the other hand, a metapopulation may have a greater probability of persistence than a single large population, if subpopulations are relatively independent with regard to environmental conditions and if individuals can readily disperse between subpopulations. Thus, it is not possible to predict in advance if and how metapopulation modeling would change our understanding of piping plover population dynamics.

Development of a metapopulation model for the Atlantic Coast piping plover will be a near-term priority of the recovery program, and has been included in recovery task 3.7. This type of model will improve our understanding of population viability and will also assist biologists assessing the impacts of proposed projects undergoing Section 7 consultation and any Section 10(a)(1)(B) permit applications.

The population viability model developed for the Atlantic Coast piping plover by Melvin and Gibbs (1994) follows.

VIABILITY ANALYSIS FOR THE ATLANTIC COAST POPULATION OF PIPING PLOVERS

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We developed a stochastic population growth model, based on age-specific survival rates and varying levels of fecundity and population size, to estimate probabilities that the Atlantic Coast population of piping plovers would fall to extinction or below various population thresholds during the next century. The model described below has been modified from our earlier draft (7 April 1994) as a result of comments received from USFWS biologists and several reviewers. We present revised estimates of extinction probabilities and offer recommendations for delisting criteria for the Atlantic Coast population.

METHODS

The Model

Gibbs performed initial analyses using Lotus Spreadsheet software with an @-Risk add-on, but then rewrote the model as a computer program in Turbo-Pascal, which greatly increased its simplicity, speed, and flexibility. The model recognizes three age classes (fledglings, adults 1 year old, and adults > 1 year old) and is based on an annual post-breeding census of the population. Only the female portion of the population is modeled; we assume a 1:1 sex ratio. The number of fledglings present in the population at the time of census is calculated as:

(1) $F(t+1) = F(t)*SF*CP*PB + A(t)*SA*CP,$

and the number of adults present as:

(2) $A(t+1) = F(t)*SF + A(t)*SA,$

where:

F = number of fledglings,
SF = annual survival rate of fledglings,
CP = female chicks fledged per female per year (chicks per pair divided by 2),
PB = proportion of 1-year old adults breeding,

A = number of adults,
SA = annual survival rate of adults

Equation (1) represents the production of fledglings in the census year. The first half of the equation represents the production of fledglings by 1-year-old birds (i.e., surviving fledglings produced the previous year). Note that the previous year's fledglings, F(t), survive their first winter (i.e., *SF) before they breed (i.e., *CP), and that only a portion of these 1-year-olds breed (i.e., *PB). Similarly, the second half of the equation represents adults alive the previous year that survive the winter (i.e., *SA) and then breed (i.e., *CP). All surviving adults > 1 year old and 50% of 1-year-olds are assumed to breed if the population has not reached carrying capacity.

Equation (2) represents survival of fledglings through their first winter to adulthood, i.e., F(t)*SF, and survival of adults from one year to the next, i.e., A(t)*SA, and calculates the total number of adult females expected to be present at a post-breeding census of the population.

The effect of habitat limitation on the population is modeled by transforming breeding adults produced in excess of an input carrying capacity (K) into nonbreeding "floaters". Floaters experience the same survival rates as other adults, and re-enter the breeding population during a subsequent season if a breeding opportunity becomes available (i.e., if the population falls below K).

Environmental-related variation is modeled in two ways. First, survival rates are permitted to vary annually according to normal distributions of means and coefficients of variation (CV) estimated from banding studies and truncated at 0 and 1. Annual variation in survival of adults 1 year old and > 1 year old is assumed to be perfectly correlated. Second, annual values of fecundity are permitted to vary according to a normal distribution of mean and CV estimated from field studies and truncated at 0. Demographic stochasticity is modeled by drawing a random number of individuals in any year from a binomial distribution of $\underline{n}$ = number of individuals alive the previous year and $\underline{P}$ = the probability of survival. Similarly, a number of first-year breeders is determined from a binomial distribution of $\underline{n}$ = number of fledglings surviving to their first year and $\underline{P}$ = the proportion of 1-year-old birds breeding.

Each simulation consisted of 5,000 iterations. The number of breeding adults was tallied at year 100 of each iteration to calculate probabilities that the population (N) = 0 or $\leq$ 50, 100, and 500 pairs.

The current model incorporates two additional scenarios that we believe are realistic: (1) reduced fecundity for pairs that exceed the recovery objective, and (2) Allee effects if the population falls below 100 pairs. Each is discussed briefly below.

1. Reduced fecundity for pairs that exceed recovery objective.

We assume that until the recovery objective for abundance is reached, maximum legal protection and "on-the-ground" management will be afforded to all breeding pairs in order to achieve some fecundity objective and sustain population growth. However, it is realistic to assume that if the population exceeds the recovery objective for abundance, protection, and management will be relaxed for "surplus" pairs that exceed this objective. This could occur by reducing or eliminating efforts to monitor nesting plovers, manage pedestrians, vehicles, or predators, or protect habitat, and through "incidental take" allowed under Section 10 permits. We believe such reductions in management intensity would lead directly to reduced fecundity.

In the revised model, we assume that if the Atlantic Coast population increases above the recovery objective for abundance, mean fecundity for surplus pairs will drop to 0.5 chicks/pair. We believe that 0.5 chicks fledged/pair is a realistic and, perhaps, optimistic fecundity that could be expected for Atlantic Coast plovers if intensive management and legal protection were to be eliminated. For example, mean annual fecundity for piping plovers in North Carolina from 1988 to 1993 was only 0.54, in spite of increasingly intensive management.

2. Allee effect.

Allee effects are density dependent effects that draw small populations away from carrying capacity and toward extinction (Allee 1931, Allee *et al.* 1949, Ferson and Akcakaya 1990). Examples of Allee effects might include reduced reproductive output when population densities become so low that males and females have difficulty finding each other to breed, or reduced survival or fecundity caused by inbreeding.

We believe mean fecundity of the Atlantic Coast population could decrease substantially if the population declined to very low levels, simply as a result of increasing proportions of the population failing to reproduce because of their inability to find and successfully pair with a member of the opposite sex. On the breeding grounds, the Atlantic Coast population is distributed over > 3,000 km of coastline, from North Carolina to Newfoundland. Although piping plovers are very mobile and seem to be good dispersers, a population that fell below 100 pairs would be distributed over the landscape at a very low density and the probability of encountering and attracting an unpaired member of the opposite sex during any given 3-month nesting season might be low.

We have incorporated an Allee effect into the model by assuming that if the Atlantic Coast population declines below a threshold of 100 pairs, mean fecundity will decline at a linear rate from the input fecundity when N = 100 pairs to 0.0 when N = 0 pairs. We believe that, if anything, we have been conservative in our modeling of an Allee effect. If the Atlantic Coast population fell substantially below 100 pairs, we might expect additional increases in extinction probability caused by : 1) increased coefficients of variation for both fecundity and survival, and 2) increased negative effects of demographic stochasticity on fecundity (for example, if only 4 plovers returned to Maine or Maryland in a given year, there is a 12.5% probability that all 4 would be of the same sex).

Inputs

<u>Fecundity</u>

Mean and CV of fecundity (chicks fledged per pair) were calculated from data reported for the U.S. portion of the Atlantic Coast population (USFWS 1993e). Mean and CV of fecundity in a given year were calculated as weighted averages across states, with population sizes as weights. These annual values were then averaged across years (unweighted) to calculate an overall mean and CV of fecundity. For the five-year period 1989-1993, we calculated a mean fecundity of 1.21 chicks fledged per pair and CV of 0.15 for the U.S. portion of the Atlantic Coast population. However, we increased the CV of fecundity input to the model to 0.4, to represent greater variance in fecundity that might occur over the 100-year simulation period. We believe such long-term variance in fecundity is realistic and could be caused by catastrophes or long-term variation in quality or availability of breeding habitat, predator populations, or intensity and effectiveness of management on the breeding grounds.

We assumed that only 50% of 1-year-old birds breed, and that 100% of adults > 1 year old breed. Small numbers of piping plovers have been reported to remain on wintering areas during the breeding season (Haig and Oring 1988b) and ≤ 5-10% of plovers reported in Massachusetts during May and June appear unpaired. Cairns (1977) reported that 15-16% of the piping plovers at her study area in Nova Scotia appeared to be unpaired or did not nest. In Manitoba, Haig and Oring (1988a,b) reported that many adults did not find a mate or nest in a given year, but that 1-year-old birds "frequently bred".

Survival

We estimated mean annual survival rates for two age classes of piping plovers (fledgling to 1 year old, and > 1 year old), based on resightings of birds color-banded in Massachusetts (L.H. MacIvor, C.R. Griffin, and S.M. Melvin, University of Massachusetts-Amherst, unpubl. data). MacIvor *et al.* color-banded 103 breeding adults and 61 flightless chicks (aged 10 to 25 days) on beaches from Chatham to Provincetown on outer Cape Cod, Massachusetts, from 1985 to 1988. They captured incubating adults using wire box traps (Wilcox 1959) and captured chicks by hand. They banded all birds with a single aluminum legband and unique combinations of 2 or 3 plastic colored legbands. They searched for banded plovers on outer Cape Cod from mid March through the end of August or first week in September in 1986 through 1989, and solicited observations of color-banded plovers from other biologists in Massachusetts and elsewhere along the Atlantic Coast. They estimated mean annual survival rates and coefficients of variation for both fledglings and birds > 1 year old, based on resightings of color-marked birds, using Program Jolly (Pollock *et al.* 1990). We input mean annual survival rates of 0.74 for adults > 1 year old and 0.48 for fledglings (from fledging to 1 year old) (MacIvor *et al.* unpubl. data). We increased the coefficients of variation for survival input to the model to 0.20 for both age classes (Table A), to account for potential long-term increases in variance of survival rates caused by catastrophes or other factors.

Carrying Capacity

We estimated the current carrying capacity (K) for the entire Atlantic Coast population (including Canada) at 2,000 pairs. This estimate was made by the Atlantic Coast Piping Plover Recovery Team following discussions with biologists coordinating plover efforts in all the Atlantic Coast states and provinces, and is felt to be conservative. Experience in New England, where plover numbers have doubled since 1986, has expanded our definition of suitable habitat and demonstrated that habitats may support far more pairs and higher productivity than previously estimated. Furthermore, efforts to assure dynamic functioning of plover habitat by allowing natural processes of erosion and accretion to occur could yield major improvements in habitat quality in some parts of the species' range.

Extinction Thresholds

In discussions during winter, 1994, the recovery team agreed that the recovery goal for the Atlantic Coast population of piping plovers should provide a > 95% probability of persistence (i.e., < 5% probability of extinction) for 100 years. Because extinction obviously represents the antithesis of recovery, the recovery team was also interested in estimating probabilities that the Atlantic Coast population would fall below thresholds of 50, 100, and 500 pairs during the next 100 years.

Table A summarizes the parameter estimates that we input to our model, and compares them with inputs used by Ryan *et al.* (1993) to model the Great Plains population of piping plovers.

RESULTS

Fecundity Needed For A Stationary Population

We estimated a mean annual fecundity of 1.245 chicks fledged per pair is needed to maintain a stationary population, based on empirical estimates of adult and immature survival and percentages of the two adult age classes that breed each year.

A review of census results for the Atlantic Coast population between 1989 and 1993 suggests that the actual fecundity needed to maintain a constant population may be slightly lower, perhaps 1.0 to 1.1 chicks /pair. Observed mean fecundity for the U.S. portion of the Atlantic Coast population between 1989 and 1993 was 1.21; during that time, population estimates increased by 21%, from 724 to 875 pairs (note, however, this increase resulted entirely from an 82% increase in the New England subpopulation driven by a mean fecundity of 1.69 during this period). Populations in New York and New Jersey remained relatively constant during this period, with mean fecundities of only 1.04 and 0.97, respectively. The Delaware to North Carolina subpopulation experienced a 10% population decline between 1989-1993; mean annual fecundity from 1988 to 1993 was 0.84.

There are several possible explanations for these apparent discrepancies between model results and actual observations:

1. The survival estimates used in the model may be underestimates. Survival rates were calculated based on re-sightings between 1986 and 1989 of plovers banded on outer Cape Cod from 1985 to 1988. Any banded birds not re-sighted were assumed to be dead, however some of these may have dispersed outside the study area and gone undetected. In the model, if we increased mean fledgling survival by only 5%, this lowered the fecundity needed for a stationary population to 1.15.

2. Survival rates for plovers breeding outside Massachusetts may be different than the estimates we used in the model. R. Cross (Virginia Department of Game and Inland Fisheries, unpubl. data) estimated annual survival rates of 75% and 83% for adults and 44% for fledglings at Chincoteague National Wildlife Refuge in Virginia. Loegering (1992) estimated survival rates of 67-72% for adults and 41% for fledglings on Assateague Island National Seashore in Maryland. It is possible that plovers nesting in Canada or New England may have lower survival rates than birds that nest farther south, because of higher mortality resulting from longer migration flights.

3. The assumption that only 50% of 1-year-olds breed may be an underestimate. Increasing the percentage of 1-year-olds assumed to breed to 75% decreased the model's prediction of stationary fecundity to about 1.15.

4. When both #1 and #3 above were changed in the model simultaneously, fecundity needed for a stationary population was reduced to 1.05.

5. We cannot discount the possibility that some surplus birds produced in New England are dispersing to other Atlantic Coast states or provinces and helping to "subsidize" other subpopulations that would otherwise be declining because of inadequate fecundity.

6. Each year since 1989, fecundity estimates have not been available for 17-33% of the U.S. Atlantic Coast population. If fecundities are substantially different for unmonitored segments of the U.S. or Canadian populations, this could mean that the actual mean fecundity for the entire Atlantic Coast population is slightly different than the estimates we input to the model.

Extinction Probabilities

We first calculated extinction probabilities for the entire Atlantic Coast population (U.S. and Canada combined) based on estimates of survival rates from MacIvor *et al.* (Table B). When mean fecundity = 1.25 (our estimate needed for a stationary population), the goal of < 5 % extinction probability for 100 years was not met even when population size and carrying capacity were increased to 10,000 pairs.

When we increased fecundity to 1.50, a population of 2,000 pairs was needed to achieve the goal of < 5% extinction probability. Even at this level, however, the population had a 10% chance of falling below 50 pairs and a 26% chance of falling below 500 pairs (Table B).

We next examined extinction probabilities for the entire Atlantic Coast population when mean survival rates decreased by 5 and 10 % for 1-year-old and > 1-year-old birds, respectively, during the first 50 years of the simulation, and then remained stable (within bounds set by coefficients of variation) for the remaining 50 years of the simulation period (Table C). We suggest that declining survival rates over the next 50 years may represent a realistic scenario that should be considered in recovery planning. Such long-term declines in survival might be caused by one or more of the following:

1) continuing declines in availability or quality of winter or migration habitat,

2) increased human disturbance on wintering grounds,

3) increased mortality from disease or parasites,

4) increased mortality from toxic chemicals (e.g., oil spills),

5) increased predation rates, perhaps resulting from increased numbers of peregrine falcons, red foxes, or feral cats along the Atlantic Coast, and/or

6) reduced fitness or longevity caused by unforeseen genetic factors.

Results of simulations presented in Table C demonstrate the sensitivity of extinction probabilities to even small changes in survival rates. With declining survival, a mean fecundity of 1.50 results in declining populations with high probabilities of extinction within 100 years. Even a population as large as 10,000 pairs has a 29% probability of extinction in 100 years.

Extinction probabilities for Atlantic Coast plovers were more sensitive to fecundity, survival rates, and variability in those parameters than to initial population size, at least within the narrow range of population sizes set by our estimate of carrying capacity. If it is unrealistic to substantially increase population size beyond 2,000 pairs, then the alternative must be to maintain fecundity at high enough levels to provide a margin of safety. This is not to say, however, that population size is not important. We believe the best ways to buffer against decreased fecundity and survival or increased variance in those parameters are to: (1) manage intensively to insure adequate fecundity and survival, and (2) maximize population size and number of breeding and wintering sites for each subpopulation. The larger and more evenly distributed the Atlantic Coast population is, both on the breeding and wintering grounds and during migration, the less will be the overall effects of environmental stochasticity, catastrophes, or reduced or inconsistent management. Given the difficulty of managing to improve survival, optimizing both abundance and distribution of all subpopulations would seem to be the best buffer against declines in mean survival for the population as a whole. Also, increasing population size may delay time to extinction, allowing managers more time to develop strategies to improve survival or fecundity.

GENETIC CONSIDERATIONS

Potential effects of population genetics on the long-term viability of the Atlantic Coast population of piping plovers are poorly understood. Haig and Oring (1988) used protein electrophoresis to examine genetic variability and differentiation between piping plover chicks (n=122) from Saskatchewan, Manitoba, North Dakota, Minnesota, and New Brunswick. For the 36 presumptive loci examined, they concluded that genetic variability within populations was comparable to other bird species, that inbreeding was not a significant factor within any of the populations sampled, and that little genetic differentiation had occurred between populations. Lack of differentiation between populations may be explained either by relatively recent declines and isolation of regional populations, or by adequate gene flow within and between populations to offset effects of genetic drift. Patterns of mating, dispersal, and distribution in piping plovers (Haig and Oring 1988a,b) are probably adequate to allow rates of gene flow > 1 individual/population/generation between Atlantic Coast subpopulations, the most conservative estimate of amount of gene flow needed to offset effects of genetic drift (Wright 1931).

Effective population size (N_e) (Frankel and Soulé 1981) has not been estimated for the Atlantic Coast population. Demographic characteristics that undoubtedly reduce N_e below actual population size (N) for the Atlantic Coast population include:

1) non-random mating within the population (exacerbated by a distribution pattern of breeding birds scattered along a narrow band of habitat > 2,000 km long),

2) unequal reproductive contributions between individuals and subpopulations,

3) differential reproductive contributions between age classes.

However, N_e / N may be higher for piping plovers than for some other vertebrates because: (1) percentage of adults > 1 year old not attempting to breed in a given year may be ≤ 10%; (2) dispersal of ≥ 1 individual ≥ 100 km per generation probably occurs (Haig and Oring 1988b; MacIvor, Griffin and Melvin, unpubl. data); (3) sex ratio is approximately 1:1; and/or (4) variation in overall population size has been small, at least over the past eight years of intensive monitoring and management.

Several workers have estimated N_e for vertebrates at 0.2-0.5 of actual population size (N) (Barrowclough and Coats 1985, Harris and Allendorf 1989, Mace and Lande 1991). If N_e for piping plovers falls within this range, then a recovery objective of a population of 1,200 pairs of Atlantic Coast piping plovers (USFWS 1988e) would, at best, fall perilously close to the often-quoted minimum N_e of 500 individuals needed to preserve sufficient genetic variation in a population to maintain long-term fitness and evolutionary potential (Franklin 1980, Frankel and Soulé 1981). Hopefully, the demographic and behavioral characteristics of piping plovers are such that N_e / N is substantially > 0.5. We believe that an estimation of N_e for the Atlantic Coast population should be identified as a recovery task in the revised recovery plan.

RECOMMENDED DELISTING CRITERIA

Based on results of the viability analysis summarized and discussed above, we recommend the following recovery objectives for Atlantic Coast piping plovers to meet the conceptual goal of assuring > 95% probability of persistence for 100 years.

1. Increase all 4 subpopulations to current estimates of carrying capacity: Atlantic Canada = 400 pairs, New England = 600 pairs, New York/New Jersey = 550 pairs, Delaware to North Carolina = 450 pairs.

Throughout the year, the Atlantic Coast population should be as evenly dispersed as possible, distributed among many well-managed, productive nesting sites during the breeding season and many high-quality, secure sites during winter. Carrying capacity of winter habitat for Atlantic Coast piping plovers is unknown.

This recommendation increases by 800 pairs the population objective contained in the 1988 recovery plan for the Atlantic Coast population (USFWS 1988e). That objective was established before estimates of survival rates were available, and without benefit of our current understanding of potential carrying capacity or responses of populations to management of predation, human disturbance, and off-road vehicles. That objective was also not based on any quantitative viability analysis, but simply sought to achieve a sizeable (50%) increase over the 1986 population estimate. At the time, such an increase was felt to be a reasonable compromise between what could actually be accomplished through management, and what historical populations had been. Analysis presented in this document (Table B) suggests that, even when mean fecundity is 1.5, a population of 1,200 pairs has an 11% probability of extinction and a 55% chance of falling below 500 pairs, if variances of survival and fecundity are ≥ 0.2 and 0.4, respectively.

We caution that a recovery objective of 2,000 pairs (4,000 individuals) falls within the range of minimum population size currently recommended for long-term viability in vertebrates. While population biologists have been reluctant or unable to establish definite rules-of-thumb for population sizes that insure viability over given time periods, several have suggested "several thousand" to ≥ 10,000 individuals as minimum levels needed to insure 95% probability of persistence for 1 or more centuries (Soulé 1987, Belovsky 1987, Thomas 1990). Recent papers by Wilcove *et al.* (1993) and Tear *et al.* (1993) have criticized the USFWS for not listing species earlier, before they decline to such low levels that recovery is more difficult or unlikely, and for establishing unrealistically low recovery goals.

We recognize that the Atlantic Coast population of piping plovers currently represents about 1/2 of the world's population of this species. However, at present we have little confidence that the Great Plains population will contribute to the viability of the Atlantic Coast population, given the lack of evidence of interchange between the two populations, and the current projections of rapid population decline recently predicted by Ryan *et al.* (1993) for the Great Plains population.

2. Maintain mean fecundity of 1.5 chicks fledged per pair for each of the 4 subpopulations and the Atlantic Coast population as a whole.

We caution that in a future scenario of declining survival and increased variance of survival and fecundity (Table C), a population of 2,000 pairs with mean annual fecundity of 1.5 has an extinction probability of 31%, well above the <5% rule-of-thumb established by the recovery team. Managers must continue to vigilantly monitor critical demographic parameters of the Atlantic Coast population (see criterion 5), and be prepared to adjust abundance or fecundity objectives upward if declining survival or increased variances become evident.

We also recognize the possibility that survival rates for Atlantic Coast plovers may vary latitudinally, in which case adoption of subpopulation-specific fecundity objectives may be warranted in the future.

3. 1 and 2 above should be achieved for at least 5 consecutive years.

4. Institute long-term management programs that are sufficient to maintain existing carrying capacity, adequate fecundity and survival rates, and low variances in these parameters after delisting.

5. Institute long-term monitoring programs that will be adequate to effectively detect declines in fecundity or population declines caused by declining survival rates.

6. Conduct a detailed estimation of effective population size for the Atlantic Coast population.

This analysis should be based on the best available data, and should seek to determine if a population size of 2,000 pairs is sufficient to maintain long-term genetic diversity.

Table A. Comparison of parameter estimates used in modeling Atlantic Coast and Great Plains populations of piping plovers.

Parameter		Atlantic Coast		
		Observed	Input	Great Plains[1]
Adult survival:	Mean	0.7387	0.70-0.74	0.66
	CV	0.0805	0.20	0.50
Imm. survival:	Mean	0.4836	0.44-0.48	0.46 - 0.66
	CV	0.1011	0.20	0.50 - 0.71
Fecundity:	Mean	1.21	variable	0.86
	CV	0.15	0.40	0.59
Fecundity needed for stationary population		1.245	variable	1.13
Proportion of adults > 1 year-old breeding		–	1.00	1.00
Proportion of 1 year-olds breeding		-	0.50	1.00

[1] Source: Ryan *et al.* 1993

Table B. Extinction probabilities for Atlantic Coast piping plover population.

Survival estimates for adults and fledglings are 0.7387 and 0.4836, respectively; these means remain stable during the simulation period, and vary randomly each year within bounds set by coefficients of variation (CV) of survival = 0.2 for both age classes. CV of fecundity is 0.4. Proportion of 1-year-old birds breeding = 0.5, proportion of > 1 year-old birds = 1.0. Number of iterations = 5000; simulation period = 100 years. Fecundity = mean number of chicks fledged per pair; K = carrying capacity; N = population size (number of pairs) = recovery objective. Fecundity is reduced for pairs that exceed the recovery objective; Allee effects are invoked if N < 100 pairs.

			Probability @ 100 years			
Fecundity	K	N	N=0	N≤50	N≤100	N≤500
1.25	2,000	1,200	35	78	81	95
1.25	2,000	1,500	31	73	76	92
1.25	2,000	2,000	22	59	63	82
1.25	3,000	3,000	23	58	61	81
1.25	4,000	4,000	23	57	62	82
1.25	5,000	5,000	23	56	60	82
1.25	10,000	10,000	20	56	60	82
1.50	2,000	1,200	11	26	29	55
1.50	2,000	1,300	9	22	24	50
1.50	2,000	1,400	8	22	24	47
1.50	2,000	1,500	9	20	22	44
1.50	2,000	1,600	6	18	20	44
1.50	2,000	1,700	7	17	19	40
1.50	2,000	1,800	6	16	17	39
1.50	2,000	1,900	5	13	15	36
1.50	2,000	2,000	4	10	11	26

Table C. Extinction probabilities for Atlantic Coast piping plovers assuming declining survival.

Mean adult and fledgling survival rates begin at 0.74 and 0.48, respectively, then decline by 5 and 10% respectively, at a linear rate between year 1 and 50, then remain stable at 0.70 and 0.44, respectively, between year 50 and 100. Coefficients of variation (CV) of survival estimates are 0.2 for both age classes. CV of fecundity is 0.4. Proportion of 1 year-old birds breeding is 0.5; proportion of > 1 year-old birds breeding is 1.0. Number of iterations = 5000; simulation period = 100 years. Fecundity = mean number of chicks fledged per pair; K = carrying capacity; N = population size (number of pairs) = recovery objective. Fecundity is reduced for number of pairs that exceed the recovery objective, and Allee effects are invoked if N < 100 pairs.

			Probability @ 100 years			
Fecundity	K	N	N=0	N≤50	N≤100	N≤500
1.50	2,000	1,200	40	87	90	97
1.50	2,000	1,500	39	84	86	97
1.50	2,000	2,000	32	70	76	90
1.50	3,000	3,000	32	70	74	91
1.50	4,000	4,000	29	68	73	91
1.50	5,000	5,000	28	66	72	90
1.50	10,000	10,000	29	68	73	91

APPENDIX F:
GUIDELINES FOR THE USE OF PREDATOR EXCLOSURES TO PROTECT PIPING PLOVER NESTS

NOTE: A stand-alone version of these guidelines, dated February 1996, that includes background information and literature cited is available, on request, from the U.S. Fish and Wildlife Service, Weir Hill Road, Sudbury, MA 01776, Attn: Anne Hecht. Most of this background information is also found in task 1.42, pages 77-78 of this plan. See also pages 41-43 in the Introduction of the plan for a summary of how predation pressure has contributed to the plover's threatened status.

Pre-use Evaluation

Since the use of exclosures is not without risks, the predation threat must be assessed and the potential benefits and risks evaluated. Rates of nest depredation observed during the previous season, abundance of predator tracks on the beach, and other indicators of predator numbers and activity should be considered. Even on beaches that are generally suitable for exclosures, some individual nest sites may be physically inappropriate, such as where the beach face is too steep.

Exclosures draw attention to the exact location of nests, which may attract potential vandals as well as people who are simply curious about these rare birds. Measures to minimize this threat include use of symbolic fences and signs to keep people far away from the exclosures, public information brochures, interpretive displays, wardens, and law enforcement.

Authorization

Any person constructing predator exclosures must have a letter of authorization from the State wildlife agency designating him/her an agent of the State for the purpose of constructing and monitoring the exclosures. Authorization letters should list any approved deviations from recommendations on exclosure design, construction, or monitoring provided in these guidelines. Persons authorized to deploy exclosures should be very familiar with the biology and behavior of piping plovers. These authorizations are necessary to meet legal requirements under Sections 9 and 10 of the Endangered Species Act; they also facilitate timely communication of any revisions to these guidelines with those deploying exclosures.

Exclosure Design

Exclosures should be constructed of 2 X 2 inch or 2 X 4 inch welded wire fence and supported by at least four sturdy metal or wooden stakes. Fences should be buried at least 8 inches in the sand (12 inches is better) and should be a *minimum of 36 inches* above the sand. Tops of posts supporting the fence must be below the top wire to prevent use of the posts as perches by crows and other avian predators (other signs and posts in the area should be similarly designed to discourage perching).

Triangular, rectangular, and circular exclosure designs have all been used effectively. *Minimum* distance from the nest to the fence should be *five feet* (ten foot diameter for a circular exclosure). Exclosures that are taller and/or wider than the minimum dimensions reduce risks that an incubating plover will hit the fence if it is startled and make it harder for a potential predator to discern what is inside, and their use is strongly encouraged.

If avian predators such as crows, grackles, ravens, or gulls are present in the area, either a net or twine top must be installed, as exclosures may cue these avian predators to the nest location. On some sites, common or fish crows (*Corvus brachyrynchos* and *C. ossifragus*) have systematically penetrated twine tops, but net tops appear more likely to invite other bird species to perch on them, creating a risk that the incubating plovers may abandon the nest. Material used for net tops (generally fruit-tree or blueberry netting) should have a mesh size of *3/4 inches* or less; mesh should lie flat and form square holes without stretching (do not use nets that are intended to be stretched). Nets should be cut to fit the top of the exclosure with minimum overhang, pulled taut, and securely attached to wire fence with hog clips or similar devices. Alternatively, seining twine may be strung in parallel rows about 6 to 8 inches apart across the top of the exclosure. Use of monofilament, which was used in the past to top exclosures, is no longer recommended and only parallel rows of twine should be strung (no perpendicular patterns); both monofilament and perpendicular string patterns have been associated with entanglement of adult plovers. Rigid tops, including fencing, should *never* be used on top of exclosures, as they attract perching birds.

<u>Construction</u>

Exclosure construction is most safely and efficiently accomplished with a crew of two to four persons. Construction should be practiced around a "dummy nest" until the operation can be done smoothly. Construction time should not exceed 20 minutes and can generally be accomplished in less than 10 minutes without sacrificing quality of construction (i.e., secure installation of posts and careful attachment of wire fencing and tops). Unless the incubating bird stays on the nest, a basket or similar device should be inverted on the nest to mark its location. Once construction is completed, rake or otherwise smooth out the sand immediately around the fence so that the surface of the sand is flush with the bottom wire, assuring easy access for birds walking through the fence.

Exclosures should be constructed after a full clutch of eggs has been confirmed. Exceptions allowing for exclosure of incomplete clutches may be approved by State agencies for beaches where egg predation is very likely to occur before clutch completion and plover monitoring is done by experienced biologists.

Exclosures should be constructed early or late in the day, to avoid exposing the eggs to the hot sun and to prevent attracting curious bystanders. Construction during rainy, very windy, or otherwise inclement weather must also be avoided.

Monitoring

As soon as construction is completed, all persons should move well away from the nest, preferably to a location out of sight of the birds. The nest should be monitored until an adult returns to the nest, resumes incubation, and then exchanges with its mate. If neither adult returns to the nest within 60 minutes or the birds' behavior appears abnormal, the exclosure should be removed.

Exclosed nests should be monitored at least every other day from a safe distance. At sites where this frequency of monitoring is not feasible, risks and benefits of exclosure use should be carefully evaluated and use of exclosures should only proceed with explicit authorization from a representative of the State wildlife agency.

Monitors should be alert for evidence that crows, gulls, or other birds are perching on exclosure fences or tops. Loss of several nests to the same predator species during a short time period or tracks that suggest a predator is systematically visiting exclosures should be immediately reported to the State wildlife agency and the USFWS. Both perching and evidence of "smart predators" that may be cued to exclosures should be evaluated immediately to determine whether exclosures should be modified or removed (see next section). Monitors should also assure that sand, wrack, or other debris around the base of the exclosure does not obstruct the ability of the plovers to walk under the bottom horizontal wire around a significant portion of the exclosure (plovers almost always walk into the exclosures).

Whenever exclosure failure (nest depredation or abandonment) is detected, a thorough investigation of the site should be made. Tracks, fur, means of entry, or egg-shell remains may aid the identification of predators. Means of predator entry into the exclosure may suggest needed modifications in exclosure design. In cases of suspected nest abandonment, an extremely thorough search of the area should be made for any signs of adult mortality, including predator track patterns; signs of a struggle; or plover feathers, bones, or other remains. The area should also be monitored for several days for sightings of one or both adults.

Removal of Exclosures

Where "smart" foxes or coyotes are systematically entering exclosures or tracks suggest that they are harassing plovers, exclosures should be immediately removed and efforts should be initiated to trap and remove the offending fox(es) or coyote(s).

Where avian species are perching on top of exclosures on more than a very infrequent basis, monitors may attempt prudent modifications, such as substitution of string tops for netting and/or clipping and removing the top row of wire on the fencing. However, if these modifications do not promptly alleviate the problem, subsequent plover nests on that site should not be exclosed during the remainder of the season. Whether or not exclosures that have already been erected should be removed should be determined by weighing the risk of nest abandonment by the incubating plovers due to perching against the risk of nest depredation if the exclosure is removed. It may be prudent to remove a few exclosures and monitor nest survival before removing all exclosures from the site.

Reporting

Please REPORT ANY OBSERVATIONS OF POTENTIAL PROBLEMS TO YOUR STATE WILDLIFE AGENCY IMMEDIATELY. Situations that are especially important to report include any evidence of adult plover mortality or unusual numbers of nest depredations or abandonments. Please also send copies of reports regarding exclosure problems to:

U.S. Fish and Wildlife Service
Weir Hill Road
Sudbury, MA 01776
Attention: Anne Hecht
Telephone: 508-443-4325; Fax: 508-443-2898

APPENDIX G: GUIDELINES FOR MANAGING RECREATIONAL ACTIVITIES IN PIPING PLOVER BREEDING HABITAT ON THE U.S. ATLANTIC COAST TO AVOID TAKE UNDER SECTION 9 OF THE ENDANGERED SPECIES ACT

NOTE: A stand-alone version of these guidelines dated April 15, 1994 is available, on request, from the U.S. Fish and Wildlife Service, Weir Hill Road, Sudbury, MA 01776, Attn: Anne Hecht. The stand-alone version also includes a brief synopsis of the legal requirements that afford protection to nesting piping plovers, a brief summary of the life history of piping plovers and potential threats due to recreational activities during the breeding cycle, and literature cited.

The following information is provided as guidance to beach managers and property owners seeking to avoid potential violations of Section 9 of the Endangered Species Act (16 U.S.C. 1538) and its implementing regulations (50 CFR Part 17) that could occur as the result of recreational activities on beaches used by breeding piping plovers along the Atlantic Coast. These guidelines were developed by the Northeast Region, U.S. Fish and Wildlife Service, with assistance from the U.S. Atlantic Coast Piping Plover Recovery Team. The guidelines are advisory, and failure to implement them does not, of itself, constitute a violation of the law. Rather, they represent the USFWS's best professional advice to beach managers and landowners regarding the management options that will prevent direct mortality, harm, or harassment of piping plovers and their eggs due to recreational activities.

Some land managers have threatened and endangered species protection obligations under Section 7 of the ESA or under Executive Orders 11644 and 11989 (see pages 47-48) that go beyond adherence to these guidelines. Nothing in this document should be construed as lack of endorsement of additional piping plover protection measures implemented by these land managers or those who are voluntarily undertaking stronger plover protection measures.

The USFWS recommends the following protection measures to prevent direct mortality or harassment of piping plovers, their eggs, and chicks.

MANAGEMENT OF NON-MOTORIZED RECREATIONAL USES

On beaches where pedestrians, joggers, sun-bathers, picnickers, fishermen, boaters, horseback riders, or other recreational users are present in numbers that could harm or disturb incubating plovers, their eggs, or chicks, areas of at least a 50-meter radius around nests above the high tide line should be

delineated with warning signs and symbolic fencing[2]. Only persons engaged in rare species monitoring, management, or research activities should enter posted areas. These areas should remain fenced as long as viable eggs or unfledged chicks are present. Fencing is intended to prevent accidental crushing of nests and repeated flushing of incubating adults, and to provide an area where chicks can rest and seek shelter when large numbers of people are on the beach.

Available data indicate that a 50-meter buffer distance around nests will be adequate to prevent harassment of the majority of incubating piping plovers. However, fencing around nests should be expanded in cases where the standard 50-meter radius is inadequate to protect incubating adults or unfledged chicks from harm or disturbance. Data from various sites distributed across the plover's Atlantic Coast range indicate that larger buffers may be needed in some locations (see Table 3, page 12). This may include situations where plovers are especially intolerant of human presence, or where a 50-meter-radius area provides insufficient escape cover or alternative foraging opportunities for plover chicks.[3]

In cases where the nest is located less than 50 meters above the high tide line, fencing should be situated at the high tide line, and a qualified biologist should monitor responses of the birds to passersby, documenting his/her observations in clearly recorded field notes. Providing that birds are not exhibiting signs of disturbance, this smaller buffer may be maintained in such cases.

On portions of beaches that receive heavy human use, areas where territorial plovers are observed should be symbolically fenced to prevent disruption of territorial displays and courtship. Since nests can be difficult to locate, especially during egg-laying, this will also prevent accidental crushing of undetected nests. If nests are discovered outside fenced areas, fencing should be extended to create a sufficient buffer to prevent disturbance to incubating adults, eggs, or unfledged chicks.

Pets should be leashed and under control of their owners at all times from April 1 to August 31 on beaches where piping plovers are present or have traditionally nested. Pets should be prohibited on these beaches from April 1 through August 31 if, based on observations and experience, pet owners fail to keep pets leashed and under control.

Kite flying should be prohibited within 200 meters of nesting or territorial adult or unfledged juvenile piping plovers between April 1 and August 31.

Fireworks should be prohibited on beaches where plovers nest from April 1 until all chicks are fledged.

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[2] "Symbolic fencing" refers to one or two strands of light-weight string, tied between posts to delineate areas where pedestrians and vehicles should not enter.

[3] For example, on the basis of data from an intensive three year study that showed that plovers on Assateague Island in Maryland flush from nests at greater distances than those elsewhere (Loegering 1992), the Assateague Island National Seashore established 200 meter buffers zones around most nest sites and primary foraging areas (NPS 1993b). Following a precipitous drop in numbers of nesting plover pairs in Delaware in the late 1980's, that State adopted a Piping Plover Management Plan that provided 100 yard buffers around nests on State park lands and included intertidal areas (DNREC 1990).

MOTOR VEHICLE MANAGEMENT

The USFWS recommends the following minimum protection measures to prevent direct mortality or harassment of piping plovers, their eggs, and chicks on beaches where vehicles are permitted. Since restrictions to protect unfledged chicks often impede vehicle access along a barrier spit, a number of management options affecting the timing and size of vehicle closures are presented here. Some of these options are contingent on implementation of intensive plover monitoring and management plans by qualified biologists. It is recommended that landowners seek concurrence with such monitoring plans from either the USFWS or the State wildlife agency.

Protection of Nests

All suitable piping plover nesting habitat should be identified by a qualified biologist and delineated with posts and warning signs or symbolic fencing on or before April 1 each year. All vehicular access into or through posted nesting habitat should be prohibited. However, prior to hatching, vehicles may pass by such areas along designated vehicle corridors established along the outside edge of plover nesting habitat. Vehicles may also park outside delineated nesting habitat, if beach width and configuration and tidal conditions allow. Vehicle corridors or parking areas should be moved, constricted, or temporarily closed if territorial, courting, or nesting plovers are disturbed by passing or parked vehicles, or if disturbance is anticipated because of unusual tides or expected increases in vehicle use during weekends, holidays, or special events.

If data from several years of plover monitoring suggest that significantly more habitat is available than the local plover population can occupy, some suitable habitat may be left unposted if the following conditions are met:

1. The USFWS OR a State wildlife agency that is party to an agreement under Section 6 of the ESA provides written concurrence with a plan that:

A. Estimates the number of pairs likely to nest on the site based on the past monitoring and regional population trends.

AND

B. Delineates the habitat that will be posted or fenced prior to April 1 to assure a high probability that territorial plovers will select protected areas in which to court and nest. Sites where nesting or courting plovers were observed during the last three seasons as well as other habitat deemed most likely to be pioneered by plovers should be included in the posted and/or fenced area.

AND

C. Provides for monitoring of piping plovers on the beach by a qualified biologist(s). Generally, the frequency of monitoring should be not less than twice per week prior to May 1 and not less than three times per week thereafter. Monitoring should occur daily whenever moderate to large numbers of vehicles are on the beach. Monitors should document locations of territorial or courting plovers, nest locations, and observations of any reactions of incubating birds to pedestrian or vehicular disturbance.

AND

2. All unposted sites are posted immediately upon detection of territorial plovers.

Protection of Chicks

Sections of beaches where unfledged piping plover chicks are present should be temporarily closed to all vehicles not deemed essential. (See the provisions for essential vehicles below.) Areas where vehicles are prohibited should include all dune, beach, and intertidal habitat within the chicks' foraging range, to be determined by either of the following methods:

1. The vehicle free area should extend 1,000 meters on each side of a line drawn through the nest site and perpendicular to the long axis of the beach. The resulting 2,000-meter-wide area of protected habitat for plover chicks should extend from the ocean-side low water line to the bay-side low water line or to the farthest extent of dune habitat if no bay-side intertidal habitat exists. However, vehicles may be allowed to pass through portions of the protected area that are considered inaccessible to plover chicks because of steep topography, dense vegetation, or other naturally-occurring obstacles.

OR

2. The USFWS OR a State wildlife agency that is party to an agreement under Section 6 of the ESA provides written concurrence with a plan that:

A. Provides for monitoring of all broods during the chick-rearing phase of the breeding season and specifies the frequency of monitoring.

AND

B. Specifies the minimum size of vehicle-free areas to be established in the vicinity of unfledged broods based on the mobility of broods observed on the site in past years and on the frequency of monitoring. Unless substantial data from past years show that broods on a site stay very close to their nest locations, vehicle-free areas should extend at least 200 meters on each side of the nest site during the first week following hatching. The size and location of the protected area should be adjusted in response to the observed mobility of the brood, but in no case should it be reduced to less than 100 meters on each side of the brood. In some cases, highly mobile broods may require protected areas up to 1,000 meters, even where they are intensively monitored. Protected areas should extend from the oceanside low water line to the bay-side low water line or to the farthest extent of dune habitat if no bayside intertidal habitat exists. However, vehicles may be allowed to pass through portions of the protected area that are considered inaccessible to plover chicks because of steep topography, dense vegetation, or other naturally-occurring obstacles. In a few cases, where several years of data document that piping plovers on a particular site feed in only certain habitat types, the USFWS or the State wildlife management agency may provide written concurrence that vehicles pose no danger to plovers in other specified habitats on that site.

<u>Timing of Vehicle Restrictions in Chick Habitat</u>

Restrictions on use of vehicles in areas where unfledged plover chicks are present should begin on or before the date that hatching begins and continue until chicks have fledged. For purposes of vehicle management, plover chicks are considered fledged at 35 days of age or when observed in sustained flight for at least 15 meters, whichever occurs first.

When piping plover nests are found before the last egg is laid, restrictions on vehicles should begin on the 26th day after the last egg is laid. This assumes an average incubation period of 27 days, and provides a 1 day margin of error.

When plover nests are found after the last egg has been laid, making it impossible to predict hatch date, restrictions on vehicles should begin on a date determined by <u>one</u> of the following scenarios:

1. <u>With intensive monitoring</u>: If the nest is monitored at least twice per day, at dawn and dusk (before 0600 hrs and after 1900 hrs) by a qualified biologist, vehicle use may continue until hatching begins. Nests should be monitored at dawn and dusk to minimize the time that hatching may go undetected if it occurs after dark. Whenever possible, nests should be monitored from a distance with spotting scope or binoculars to minimize disturbance to incubating plovers.

<u>OR</u>

2. <u>Without intensive monitoring</u>: Restrictions should begin on May 15 (the earliest probable hatch date). If the nest is discovered after May 15, then restrictions should start immediately.

If hatching occurs earlier than expected, or chicks are discovered from an unreported nest, restrictions on vehicles should begin immediately.

If ruts are present that are deep enough to restrict movements of plover chicks, then restrictions on vehicles should begin at least five days prior to the anticipated hatching date of plover nests. If a plover nest is found with a complete clutch, precluding estimation of hatching date, and deep ruts have been created that could reasonably be expected to impede chick movements, then restrictions on vehicles should begin immediately.

Essential Vehicles

Because it is impossible to completely eliminate the possibility that a vehicle will accidently crush an unfledged plover chicks, use of vehicles in the vicinity of broods should be avoided whenever possible. However, the USFWS recognizes that life-threatening situations on the beach may require emergency vehicle response. Furthermore, some "essential vehicles" may be required to provide for safety of pedestrian recreationists, law enforcement, maintenance of public property, or access to private dwellings not otherwise accessible. On large beaches, maintaining the frequency of plover monitoring required to minimize the size and duration of vehicle closures may necessitate the use of vehicles by plover monitors.

Essential vehicles should only travel on sections of beaches where unfledged plover chicks are present if such travel is absolutely necessary and no other reasonable travel routes are available. All steps should be taken to minimize number of trips by essential vehicles through chick habitat areas. Homeowners should consider other means of access, e.g., by foot, water, or shuttle services, during periods when chicks are present.

The following procedures should be followed to minimize the probability that chicks will be crushed by essential (non-emergency) vehicles:

1. Essential vehicles should travel through chick habitat areas only during daylight hours, and should be guided by a qualified monitor who has first determined the location of all unfledged plover chicks.

2. Speed of vehicles should not exceed five miles per hour.

3. Use of open 4-wheel motorized all-terrain vehicles or non-motorized all-terrain bicycles is recommended whenever possible for monitoring and law enforcement because of the improved visibility afforded operators.

4. A log should be maintained by the beach manager of the date, time, vehicle number and operator, and purpose of each trip through areas where unfledged chicks are present. Personnel monitoring plovers should maintain and regularly update a log of the numbers and locations of unfledged plover chicks on each beach. Drivers of essential vehicles should review the log each day to determine the most recent number and location of unfledged chicks.

Essential vehicles should avoid driving on the wrack line, and travel should be infrequent enough to avoid creating deep ruts that could impede chick movements. If essential vehicles are creating ruts that could impede chick movements, use of essential vehicles should be further reduced and, if necessary, restricted to emergency vehicles only.

SITE-SPECIFIC MANAGEMENT GUIDANCE

The guidelines provided in this document are based on an extensive review of the scientific literature and are intended to cover the vast majority of situations likely to be encountered on piping plover nesting sites along the U.S. Atlantic Coast. However, the USFWS recognizes that site-specific conditions may lead to anomalous situations in which departures from this guidance may be safely implemented. The USFWS recommends that landowners who believe such situations exist on their lands contact either the USFWS or the State wildlife agency and, if appropriate, arrange for an on-site review. Written documentation of agreements regarding departures from this guidance is recommended.

In some unusual circumstances, USFWS or State biologists may recognize situations where this guidance provides insufficient protection for piping plovers or their nests. In such a case, the USFWS or the State wildlife agency may provide written notice to the landowner describing additional measures recommended to prevent take of piping plovers on that site.

APPENDIX H:
GUIDELINES FOR THE PREPARATION AND EVALUATION OF CONSERVATION PLANS FOR ATLANTIC COAST PIPING PLOVERS PURSUANT TO SECTION 10(A)(1)(B) AND 10(A)(2) OF THE ENDANGERED SPECIES ACT

Section 10(a)(2) of the Endangered Species Act requires U.S. Fish and Wildlife Service evaluation of conservation plans accompanying applications for incidental take[4] of threatened and endangered species that occurs in the course of otherwise lawful activities. The ESA requires applicants to prepare conservation plans that specify "... the impact which will likely result in such taking; [and] what steps the applicant will take to minimize and mitigate [such] impacts..." (Section 10(a)(2)(A)(ii) and (iii)). Approval of permit applications is contingent on a finding by the USFWS that, "the applicant will, to the maximum extent practicable, minimize and mitigate the impacts of such taking; ... [and] the taking will not appreciably reduce the likelihood of the survival and recovery of the species in the wild" (Section 10(a)(2)(B)(ii) and (iv). In amending the ESA to provide for incidental take permits, Congress directed the USFWS to "consider the extent to which the conservation plan is likely to enhance the habitat of the listed species or increase the long-term survivability of the species or its ecosystem" (H.R. Report No. 97-835, 97th Congress, 2nd Session).

Detailed information about Section 10 permits may be found in the Draft Interim Handbook of Habitat Conservation Planning and Incidental Take Permit Processing (USFWS 1994b). A seven-page brochure, entitled "What's all this stuff about 'Habitat Conservation Planning' and 'Incidental Take Permits?'" (USFWS 1994c) provides an introduction to the general Section 10 process. To date, one Section 10 permit for piping plovers has been issued by the USFWS; dated April 1996, this permit was issued to the Massachusetts Division of Fisheries and Wildlife.

The guidelines in this document are specific to the Atlantic Coast piping plover and are intended to:

(1) guide potential applicants in developing conservation plans for piping plovers on the Atlantic Coast that minimize, mitigate, and monitor the impacts of take, and allow continued steady progress towards recovery, and

(2) assist the USFWS in evaluating the impacts of any proposed conservation plans on the survival and recovery of the Atlantic Coast piping plover population.

These guidelines are based on (1) the population viability model for the Atlantic Coast piping plover population (Appendix E), (2) information on piping plover ecology, and (3) general principles of conservation biology. However, it should be emphasized that they are guidelines, not strict

[4] "Take," as defined under the ESA is discussed on page 46 of this recovery plan.

requirements. Applications for incidental take permits and conservation plans that do not stringently adhere to these guidelines will be evaluated for their merit. Carefully crafted Section 10(a)(1)(B) permits have the potential to contribute to long-term protection of this species (see recovery task 1.64) if they recognize the species' biological requirements and the dynamic nature of its habitat; adopt a cautious approach that does not unduly reduce plover productivity, abundance, distribution, and density; and provide for adjustments based on new information, especially information about impacts of the conservation plan on plovers within the affected area.

It is not possible to foresee all types of incidental take of piping plovers and/or conservation plans that may be proposed in applications for Section 10(a)(1)(B) permits. These guidelines anticipate conservation plans addressing two types of take: (1) mortality or harassment of breeding plovers, their eggs, and chicks due to inadequate protection from motorized and non-motorized recreational activities or from other (non-recreational) types of off-road vehicle use, and (2) harm due to significant habitat modification or degradation that results in death or injury to piping plovers by significantly impairing essential behavioral patterns including breeding, feeding, or sheltering (see 50 CFR 17.3). Some of these guidelines are germane to both of these types of take, while others are relevant to one or the other. If conservation plans for other types of take are proposed, development of additional guidelines may be appropriate.

Guidelines for Minimizing, Mitigating, and Evaluating Harassment or Mortality of Breeding Plovers, their Eggs, and Chicks

Guidelines 1 through 7 address situations where take will occur because less protection is afforded than that recommended in Appendix G (Guidelines for Managing Recreational Activities in Piping Plover Breeding Habitat on the U.S. Atlantic Coast to Avoid Take under Section 9 of the Endangered Species Act). These guidelines (1 through 7) assume that allowable take under Section 10 will cause limited reductions in productivity of breeding plovers, but will not cause take of breeding adults or permanently degrade habitat suitability.

1. **Permits for incidental take that will reduce productivity of breeding plovers should only be allowed within recovery units[5] where the subpopulation has already achieved at least 70% of its portion of the recovery goal as specified on page 57 of the recovery plan.** Take under Section 10 should not be permitted until plover numbers reach 440 pairs in the New England recovery unit, 400 pairs in New York-New Jersey recovery unit, and 280 pairs in the Southern recovery unit. The recovery team believes that 70% of a recovery unit's population goal should be the minimum threshold for allowing reductions in plover productivity. However, even after the 70% threshold is attained, conservation plans should maintain a cautious approach to take, especially if other recovery units lag substantially in their progress towards recovery.

[5] Recovery units, their role in the recovery effort for the Atlantic Coast Piping Plover, and recovery unit subpopulation targets are discussed on pages 54-55 and 57 of this plan.

Attainment of 70% of the recovery goal will provide a minimal buffer against any unforeseen events that might send the plover subpopulation in a recovery unit into a steep decline. Spreading these increases across the four recovery units will reduce vulnerability to catastrophes that would exist if gains were limited to one or two geographic regions. Furthermore, experience in many areas where population increases have occurred has shown that key information on how to best protect piping plovers in an area and the experience needed to implement this protection is gained during the process of increasing productivity and effecting regional population growth. The recovery team believes that a solid population increase is a vital pre-condition to implementing a conservation plan that allows take without appreciably reducing the likelihood of the survival and recovery of the Atlantic Coast piping plover population.

2. **Piping plovers within the conservation plan area should attain average productivity of at least 1.5 chicks per pair for three years prior to authorization of take, <u>and</u> the conservation plan should assure that average productivity within the conservation plan area remains at or above this level.** Current information (see Appendix E) shows that this is the productivity rate needed to assure continued progress towards recovery. This minimum productivity level may be adjusted for specific recovery units if new data on survival or other demographic variables shows that different productivity levels will assure continued progress towards full recovery.

Negative impacts on species' security can be further reduced by plans that seek to minimize the variance in productivity by maintaining productivity of 1.5 chicks per pair at *each site* within the conservation plan area.

3. **Conservation plans should assure that the plover population within the plan area continues to increase, unless the area has attained its estimated carrying capacity.** The plan should provide an estimate of future population growth rates within the area to be covered under the permit. If the area is believed to be saturated, then the plan must assure that the population does not decline.

4. **Whenever possible, conservation plans should encompass plovers and habitat within an entire State or other large region.** Piping plover habitat is subject to frequent and unpredictable natural changes due to coastal formation processes, including both occurrence of and lack of major storm events, that may change its suitability. Variable predation pressure, flood-tides during the nesting season, recreation pressure, and intensity of management furnish other examples of factors that may affect productivity of plovers at given sites. Relatively large planning units will increase opportunities for averaging effects of these types of events on plover distribution and productivity, and will facilitate meaningful evaluation of the impacts of the conservation plan on species' recovery. Smaller planning areas will be highly vulnerable to factors that confound evaluation of the plan's impacts. While larger conservation planning areas are preferable to smaller ones, the recovery team recognizes that multi-State plans may be administratively infeasible.

5. **Whenever possible, permits should be issued for an initial period of 2 to 6 years.** In cases where take is due to recreational or other activities that can be adjusted in response to observed impacts on piping plovers, permits should be subject to review after 2 to 6 years. This will allow a reasonable period for gauging the effects of the permit and will also provide opportunities to

reevaluate permits in light of changes in the overall status of the population. Shorter permit periods (1 to 3 years) may be particularly desirable in the early stages of Section 10 permitting for piping plovers.

6. **Whenever possible, conservation plans should allow plovers to select their nesting sites/feeding areas and then allocate allowable take to areas where the smallest number of birds will be affected, rather than establishing fixed areas where take will occur.** While factors affecting plover productivity are becoming better understood, there are still many gaps in biologists' ability to predict where on a given beach plovers will breed most successfully. Furthermore, plover habitat is subject to coastal formation processes that may modify habitat quality over time. Under conditions of low human disturbance, plovers' nesting and feeding preferences remain the best indicators of which habitat should be protected in a given year. Conservation plans that maintain maximum opportunities for plovers to select their nesting and feeding areas are likely to have lower long-term impacts on plover recovery than those that designate fixed beach areas where take may occur each year. If a conservation plan establishes a fixed area where take will occur regardless of changes in habitat quality, allowable levels of take should be lower than when a more flexible plan allows areas where take may occur to be moved in response to the birds' preferences.

7. **Conservation plans should equitably distribute responsibilities to avoid take among non-Federal landowners.** Much physically suitable piping plover habitat remains unoccupied or under-occupied because recreational use precludes successful plover breeding or because regional populations have declined well below carrying capacity. However, piping plovers have demonstrated an ability to recolonize and substantially increase their numbers at sites where vigorous protection measures have been implemented (recovery plan, pages 6-7 and 31), often at significant expense to the landowner or another organization. The continued cooperation of these entities in recovery efforts for this and other threatened and endangered species may be compromised if they perceive that others who have taken less vigorous steps to protect birds and/or habitat will be allowed to take eggs or chicks of the few plovers that occur on their beaches. Indeed, the entire recovery effort may founder if cooperators believe that their efforts to increase productivity are creating opportunities for permitted take by other parties. For this reason, conservation plans that create incentives for contributing to the recovery effort are preferable. Such plans might allocate take temporally (allowing take on all beaches in an area after a certain level of chick production has been achieved each year) or in proportion to number of chicks fledged on each beach in recent seasons.

<u>Guidelines for Minimizing, Mitigating, and Evaluating Harm Due to Significant Habitat Modification</u>

The following guidelines pertain to situations where significant habitat modification or degradation will result in death or injury to piping plovers by significantly impairing essential behavioral patterns including breeding, feeding, or sheltering.

8. **Take that reduces the carrying capacity of piping plover habitat should be authorized only if there is sufficient protected habitat elsewhere in the recovery unit to support the minimum subpopulation specified in delisting criterion 1, page 57 of the recovery plan.** In cases where habitat will be degraded by construction of structures, roads, parking-lots, or other medium- or long-

term habitat modifications, plover recovery must not be precluded by reductions in the overall carrying capacity. Allowances should also be made for natural changes in habitat suitability due to coastal formation processes, including both occurrence and lack of major storm events. Allowable take should be allocated very cautiously in portions of the plover's range where carrying capacity is less well understood. The recovery team anticipates that confidence in estimates of carrying capacity will increase in these areas as productivity increases and effects of population growth on distribution and density of nesting pairs are determined.

9. **Any reduction in habitat suitability must be mitigated by increased productivity and abundance of plovers nesting elsewhere within the recovery unit; increases to offset take should occur as close geographically as possible to the site where the habitat degradation occurs.** Piping plovers that have nested on a given site display a high degree of fidelity to that site (see page 28 of the recovery plan), and some pairs may continue to nest on a site even if habitat has been degraded in ways likely to reduce their productivity. Therefore, availability of alternative suitable habitat is not sufficient to mitigate impacts of habitat degradation. To compensate for decreases in productivity of plovers that may continue to nest on degraded sites or that may not breed at all, mitigation must also include measures to enhance productivity of plovers on other sites where they are already established. Sites where plovers are currently under-managed and productivity is low are likely to yield greater marginal increases in productivity than sites where substantial efforts are already in place.

General Guidelines

The following guidelines may be pertinent to Section 10 permits for either (1) harassment or mortality of breeding plovers, their eggs, and/or chicks, or (2) significant habitat modification.

10. **A given amount of take will cause less reduction in overall security of the population if it is distributed over multiple sites than if it is concentrated at one or a few sites.** A species' overall security is enhanced by distributing breeding individuals among multiple sites. This reduces the population's vulnerability to environmentally-driven variance due to events such as predation, oil-spills, or flood-tides (Goodman 1987). In addition, a species' security is eroded by formation or enlargement of gaps in its range that decrease inter-site immigration and colonization rates (Gilpin 1987). As stated under guideline #2, conservation plans should strive to maintain productivity of 1.5 chicks per pair at each site within the conservation plan area. Take should also be avoided at the edges of any existing gaps in the species' breeding range.

11. **Conservation plans should contribute to the health of the beach ecosystem.** Provision of "a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved" (Section 2(b)) is a stated purpose of the ESA; Congressional direction to the USFWS with regard to Section 10 permits further directs consideration of impacts on a species' ecosystem (H.R. Report No. 97-835, 97th Congress, 2nd Session). Preparation and evaluation of conservation plans, therefore, should consider impacts on natural beach formation processes, vegetation, and other wildlife. On any site where the Federally listed northeastern beach tiger beetle (*Cicindela dorsalis dorsalis*), seabeach amaranth (*Amaranthus pumilus*), or roseate tern (*Sterna dougallii*) may be

affected, conservation plans must consider impacts on those species. Impacts on any species that are candidates for Federal listing or Federal species of concern should also be considered; for example, dune blue curls (*Trichostema sp.*), is a plant that occurs on vegetated secondary dunes in North Carolina and is a Federal species of concern. See page 45 of the recovery plan for a discussion of other rare species (including State-listed species) that may occur in piping plover habitat.

12. **Conservation plans should provide for monitoring of piping plovers on all affected sites, including any sites where protection is to be increased to mitigate reductions in habitat suitability.** Monitoring is essential to assuring that components of the conservation plan that address guidelines 2, 3, 6, and 9 are working effectively. Data collection should include information listed in task 1.12 of the recovery plan, as well as other information that may be pertinent to implementation and evaluation of a particular conservation plan. The plan should also specify minimum skills, knowledge, and experience of the monitors.

APPENDIX I: GUIDELINES FOR CONDUCTING SURVEYS FOR PIPING PLOVERS IN ATLANTIC COAST WINTERING HABITAT

The following guidelines have been adapted from J. Fussell (1990) and T. Eubanks (1992) and are included in the recovery plan to assist individuals in conducting piping plover surveys along the Atlantic Coast. These guidelines should assist U.S. Fish and Wildlife Service biologists in ensuring that useful information is collected by Federal action agencies for Section 7 consultations.

Surveying piping plovers can be difficult because they appear to depend on a variety of habitats throughout the winter season, and habitat use varies depending on tidal regime, weather conditions, season, and disturbance. Plovers are often found in tight clusters on prime feeding sites, and may be overlooked, especially in large shorebird concentrations. While some ornithologists find censusing of plovers on roosting habitat to be the most efficient (Fussell 1990), an inexperienced eye may easily miss a cluster of roosting plovers, because they are often huddled down in the sand or along the wrack line (Eubanks 1992).

The following are important considerations for conducting piping plover winter surveys:

1. Consult Available Information: Prior to conducting a survey, consult the local USFWS Field Office and/or State Nongame/Heritage Program for the most up-to-date listing of known piping plover wintering sites in the State (also see list of known and potential piping plover wintering sites on the southern Atlantic Coast, Appendix K). Available information on a site may negate the need for a survey, or may vary the scope and/or intensity of the survey. It is important to note the nearest known plover occurrence in relation to the project site, because it may provide some insight into possible piping plover occurrence within the survey/project area.

2. Survey Timing and Frequency: In order to determine presence of piping plovers at a site, a series of field surveys should be conducted during the winter period. It is recommended that at least one survey be conducted per week (or four surveys per month) over a three-month period. Surveys should preferably be conducted during December and January when the plovers are most sedentary, and during one month in the migration period (August 1 - October 15 or February 15 - April 15). Piping plovers exhibit diurnal shifts in habitat use, thus observations should be conducted for a minimum of five hours during daylight hours and should be evenly distributed throughout this period. Survey time periods should be conducted during daylight hours from 30 minutes after sunrise to 30 minutes before sunset and should include a wide range of tidal conditions and habitat types. The amount of time necessary to survey each site will obviously depend on the amount and type of habitat to be covered. Areas should be surveyed slowly and thoroughly (large mixed flocks of roosting shorebirds especially need to be thoroughly and carefully searched in order to locate piping plovers).

3. Other pertinent data: Surveyors should note the presence or absence of other shorebird species during each survey. This information may be helpful in assessing the probability of piping plovers

frequenting a specific coastal site. Also, weather conditions and tidal stage should be noted because habitat use may vary depending on these factors. Habitats with and without plovers should be characterized.

4. Surveyor Qualifications: Surveyors should be knowledgeable about shorebird identification, and be capable of discerning a piping plover in winter plumage from other small plovers. Surveyors should also be familiar with plover ecology and behavior to ensure a thorough survey.

5. Survey Conditions: Surveys should not be conducted during poor weather (e.g., heavy winds > 25 mph, heavy rains, severe cold) since birds may seek protected areas during these times.

6. Recording of Data: Daily surveys should be recorded and summarized and plover locations should be recorded on maps indicating areas surveyed and habitat types. A sample form for data collection is provided below.

SUGGESTED SURVEY FORM

Site Name (and County):

Date:

Time Begin/End:

Weather Conditions: (temp., wind speed and direction, cloud cover)

Tidal Stage (incoming low, outgoing low, incoming high, outgoing high):

Area of Coverage (km/mi):

Ownership of Site:

Number of Plovers Observed:

Habitat (sandflat, mudflat, beach):

Historical Information on Site:

Nearest Known Plover Occurrence (site name/miles or km):

Banded Plovers (combinations):

Other Shorebird Species Observed:

Approximate Number of Shorebirds Seen Within Census Area:

Additional Comments Pertinent to the Survey:

(Include a map of the survey area with plover locations marked on it. Photocopies of aerial photos are particularly useful.)

APPENDIX J:
ESTIMATED COST OF U.S. ATLANTIC COAST PIPING PLOVER PROTECTION ACTIVITIES DURING THE 1993 BREEDING SEASON

The recovery team received assistance from State piping plover coordinators, national wildlife refuges, national parks, and others in compiling the attached summary of expenditures associated with protection of piping plovers on U.S. Atlantic Coast beaches in 1993. Definitions of costs to be included in various categories were provided by the recovery team. Efforts were made to include plover management costs incurred by Federal, State, and local government agencies, as well as private organizations. These figures reflect only direct cost of protection activities; they do not include any positive or negative impacts on local or regional economies that may have occurred due to changes in land use.

With very few exceptions, costs furnished to the recovery team were incorporated into the summary without revision. The recovery team believes that estimates provided by cooperating organizations include both under- and over-estimates of true costs, but that the summary of 1993 costs accurately reflects the *overall* magnitude of the Atlantic Coast piping plover protection effort. Cost figures reflect several one-time, extraordinary expenditures that are unlikely to be repeated annually in the same locations, however, experience over nine years of piping plover recovery efforts has shown that comparable extraordinary costs are likely to be incurred somewhere in the plover's range each season.

Piping Plover Protection Effort
October 1, 1992 - September 30, 1993

State	Activity													Total ($)
	On-site Management			Data Compilation, Reports, Planning			Admin. costs ($)	Off-site Info. and Education		Transport ation ($)	Materials and Equip. ($)	Other ($)		
	paid staff		volun- teers (hrs)	paid staff		volun- teers (hrs)		hours	$					
	hours	$		hours	$									
Maine	3,190	23,400	900	880	19,200	30	3,000	190	2,200	3,500	1,700	1,400		54,400
Massachusetts	23,200	226,200	9,340	4,040	62,500	600	32,000	1,400	17,8000	39,600	24,100	92,000		494,200
Rhode Island	5,690	75,200	2,610	630	8,700	360	3,700	150	3,100	2,700	10,300	800		104,500
Connecticut	1,800	17,500	760	280	3,900	10	1,300	100	2,100	1,600	1,300	0		27,700
New York	14,610	213,100	10,9400	4,800	134,800	140	45,000	700	13,4000	47,600	44,600	151,400		649,900
New Jersey	6,370	85,200	3,910	1,350	34,100	20	29,200	320	6,200	8,700	17,800	4,900		186,100
Delaware	1,520	11,200	130	430	5,700	150	1,100	120	1,300	2,000	3,100	0		24,400
Maryland	6,410	60,600	550	920	7,000	30	8,700	160	3,000	9,700	1,800	0		90,800
Virginia	3,000	48,900	1,980	550	9,800	80	5,000	150	3,500	17,500	4,800	1,700		91,200
North Carolina	560	7,600	190	310	4,200	20	2,800	20	300	6,200	1,500	37,500		60,100
Regional	0	0	0	1,040	38,000	0	7,000	50	4,000	0	0	0		49,000
TOTAL	66,350	768,900	31,310	15,230	327,900	1,440	138,800	3,360	56,900	139,100	111,000	289,700		1,832,300

APPENDIX K:
KNOWN PIPING PLOVER WINTERING SITES ON THE SOUTHERN ATLANTIC COAST AND THE CARIBBEAN

The following list of wintering sites was compiled in order to identify areas along the Atlantic and Florida Gulf Coasts believed essential to piping plover conservation. This list incorporates all presently known wintering sites along the Atlantic and Florida Gulf Coasts, but should be viewed as a preliminary list. The Great Lakes/Northern Great Plains recovery plan lists all essential habitat on the Gulf Coast. Wintering habitat, like Atlantic Coast breeding habitat, is dynamic and sites may become more or less suitable through time. Sites that provide good habitat one year may not do so in the future, and sites with poor habitat may develop suitable habitat in the future. In North Carolina, for instance, sites such as Holden Beach/Shallote Inlet and Figure 8 Island/Rich Inlet may have improved through tidal flat development, as plover numbers have increased there in the past several years; however, sites such as Shackleford Banks and Bird Shoals have had fewer plovers in recent years and may be deteriorating in habitat quality (e.g., increased vegetation). Thus, prioritization of sites may be difficult because of the dynamic nature of plover habitat. The following list incorporates data from approximately 1983 to 1993 (Haig and Oring 1985, Hoopes *et al.* 1989, Fussell 1990, Nicholls and Baldassarre 1990a, Haig and Plissner 1992).

Note: * denotes more than one discrete wintering area per site.

NORTH CAROLINA: Wintering sites along the northern coast from Dare County to Carteret County are primarily within public ownership and receive some degree of protection and management. Wintering sites south of Carteret County are primarily on private or town-owned beaches; human disturbance during the winter may be a problem at some sites.

Currituck/Dare County
- Currituck Outer Banks*
- Cape Hatteras National Seashore
    - Oregon Inlet/Bodie Island
    - Cape Point
    - Hatteras Inlet

Hyde County
- Cape Hatteras National Seashore
    - Ocracoke Island*

Carteret County
- Cape Lookout National Seashore
    - Portsmouth Island/North Core Banks*
    - South Core Banks*
    - Shackleford Banks*

Rachel Carson's Estuary/Bird Shoals
Bogue Banks/Bogue Inlet

New Hanover County
Figure 8 Island
Wrightsville Beach/Mason Inlet
Masonboro Island/Masonboro Inlet
Carolina Beach/Carolina Beach Inlet

New Hanover/Brunswick Counties
Fort Fisher State Recreation Area/Corncake Inlet

Brunswick County
Zeke's Island Estuarine Preserve
Long Beach/Lockwood Folly's Inlet
Holden Beach/Shallote Inlet
Sunset Beach/Mad Inlet
Bird Island/Mad and Little River Inlets

SOUTH CAROLINA: The most suitable sites in South Carolina are remote and are accessible only by boat. In addition, most sites are either State or Federally-owned and are being maintained as wildlife sanctuaries.

Horry County
Waites Island/Little River Inlet

Georgetown County
Huntington Beach State Park/Murrells Inlet
North Island/North Inlet
South Island

Charleston County
Cape Romain NWR/Cape Island
Seabrook Island
Deveaux Bank

Beaufort County
Hilton Head Island/south end
Hunting Island State Park
Harbor Island/St. Helena Sound
Little Caper's Island/Pritchard's Inlet

GEORGIA: As in South Carolina, most of the wintering sites in Georgia are relatively inaccessible. Many sites are State- or Federally-owned, and some of the privately-owned sites are restricted to the general public.

Chatham County
Tybee Island
Little Tybee Island
Williamson Island
Wassaw Island NWR
Ossabaw Island
Liberty County
St. Catherine's Island*
McIntosh County
Blackbeard Island NWR
Sapelo Island
Glynn County
Little St. Simon's Island
Pelican Spit
Jekyll Island
Camden County
Cumberland Island National Seashore*
Little Cumberland Island

FLORIDA ATLANTIC COAST: Some sites are in public ownership; however, there are few management and protection efforts for the piping plover. Human disturbance may be a problem at several sites.

Duval County
Ward's Bank
Talbot Island
Little Talbot Island
St. John's County
Anastasia State Recreation Area/St. Augustine Inlet
Fort Mantanzas National Monument/Mantanzas Inlet
Volusia County
Smyrna Dunes Park/Ponce Inlet
Martin County
Martin County
Dade County
Crandon Park
Virginia Key

Monroe County

- Caloosa Cove/Plantation Key
- Ohio Key
- The Donut/West Summerland Key
- Boca Grande Key
- Woman's Key
- Bahia Honda State Recreation Area
- Carl Ross Key

FLORIDA GULF COAST: Similar to Florida Atlantic Coast. Human disturbance and shoreline/inlet manipulations may be a threat.

Collier County

- Marco Island/Sand Dollar Island

Lee County

- Bunche Beach
- Cayo Costa State Park
- Fort Myers Beach/Estero Island
- North Captiva Island

Charlotte County

- Charlotte Beach State Recreation Area

Sarasota County

- Midnight Pass

Manatee County

- Beer Can Island
- Anna Maria Island
- Passage Key NWR

Pinellas County

- Caladesi Island State Park
- Dunedin Causeway
- Dunedin Pass/Clearwater Beach
- Fred Howard County Park
- Fort Desoto State Park
- Honeymoon Island State Park
- Sand Key
- Sunshine Skyway
- Three Rooker Bar

Pinellas/Pasco County

- Anclote Key State Park

Taylor County

- Hagen's Cove

Franklin County
- Alligator Point/Phipp's Reserve
- Carabelle Beach
- Dog Island
- Lanark Reef
- St. George Island State Park
- St. Vincent's NWR

Gulf County
- Cape San Blas
- St. Joseph Peninsula State Park
- St. Joseph Bay

Bay County
- East Crooked Island/Tyndall Air Force Base
- West Crooked Island/Tyndall Air Force Base
- Shell Island/Tyndall Air Force Base

Santa Rosa County
- Santa Rosa Island/Eglin Air Force Base

Escambia County
- Gulf Islands National Seashore - Santa Rosa, Fort Pickens, and Perdido Key Areas
- Grand Lagoon State Park

OUTSIDE THE UNITED STATES:

Caribbean
- Cuba
- Puerto Rico
- Bermuda
- Virgin Islands/St. Croix
- Bahamas
  - St. Andros Island
  - Allan Cay
  - Waderick Cay
  - East Plana Cay
  - Eleuthera Island
- Greater Antilles
  - Grand Turk Island
  - New Providence Island

Mexico-Gulf Coast (see Haig and Plissner 1992)