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**Subject:** PIPL literature  
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**Attachments:** [Collazo.Chap5.1995.pdf](#)

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Hi Pete,

Would you or David (and possibly Anne Hecht) be able to review the attached literature about PIPL at CAHA and CALO, which seems to suggest that CAHA may be a "sink" for PIPL. I'd like to have a conference call with you in a month or so (mid-September?) to have a preliminary discussion about the "sink" issue and whether or not PIPL are "different" in North Carolina compared to up north, so I can understand the concepts better. In other words, would you agree with the analysis provided in the study (highlighted portions, etc.)? If not, what would you consider to be effective counter-arguments to the analysis?



Collazo.Chap5.1995.pdf

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FACTORS AFFECTING REPRODUCTION AND  
MIGRATION OF WATERBIRDS ON THE  
NORTH CAROLINA BARRIER ISLANDS

Final Report  
to the  
National Park Service  
Cape Hatteras and Cape Lookout Seashores

by

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Many field assistants made the completion of this project possible. For their contribution, we would like to thank Lori Peoples, Michael Sanderson, Brian Warson, José A. Colón, Anna Bass, Robert Smith, Kathy Steed and Jackie Howard. We owe our greatest expression of gratitude to Suzanne Wrenn. Suzanne survived the entire ordeal. She was the lead of the early field work, worked with the Parks to ensure proper coordination among the parties, worked and coordinated graduate student activities, and was responsible for monitoring piping plovers in Cape Hatteras Seashores. Simply put, she was invaluable.

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**Breeding biology and effects of human  
disturbance on Piping Plovers (Charadrius  
melodus) on the Outer Banks of North Carolina.**

Chapter V

by

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Due to its threatened status on the East Coast, the piping plover and its breeding success was of special interest to our study of shorebirds in CAHA and CALO. North Carolina's seashores represent the southern edge of the piping plover's breeding range, and plover productivity here historically has been low. Habitat and conditions for piping plovers breeding in North Carolina are different than those experienced by birds in northern regions, where most previous piping plover research has been conducted. Factors that affect reproductive success in northern regions involve human disturbance, habitat loss and predation. A major goal of our study was to determine how these and other factors may be influencing production by piping plovers on North Carolina seashores.

In addition to general monitoring of piping plover breeding activity, observations of breeding pairs were conducted to better understand the interaction of disturbance, foraging habitat use and predation in affecting productivity. We investigated the nature of interactions between adults and chicks during brood rearing in detail, in order to better understand the determinants of successful reproduction. These studies included examination of possible indirect effects, such as temperature, on chick survivorship. We will first present a brief summary of population dynamics, including reproductive success, during our study. Additional

details were provided in project annual reports. We will then present and discuss our intensive studies of breeding biology.

Unlike other parts of our project, data collection for the piping plover study continued through the summer of 1994. The two students involved in other parts of the project have written and defended their theses, whereas the student conducting the piping plover work is still analyzing data and writing her thesis. What is reported here represents the final product of other components of the project, but for the piping plover study an additional product, a Ph.D. thesis, will be forthcoming at a later date. In this report we indicate additional analyses to be provided in this thesis, as well as results of analyses already completed. Although not included in our project, we present some additional data from the 1995 breeding season on CALO.

#### Summary of Population Dynamics

Population numbers of breeding piping plovers increased slightly over the duration of our study (Table 1). The slight growth comes from increases at CALO, whereas numbers at CAHA were steady. The reported increase from 1992 to 1993 on CALO may represent increased accuracy of censusing due to experience of researchers rather than actual population

increase, but gains from 1993 to 1994 almost certainly are real.

Distribution of pairs among different nesting areas of the parks remained fairly consistent (Table 1). The number of pairs nesting at Ocracoke declined with each year, and pairs increased at New Drum Inlet on both NCB and SCB, but declined in 1995. These two nesting areas at New Drum Inlet contained the highest density of pairs.

Reproductive success for the two seashores was quite low (Table 2) and was lower than the average for Atlantic coast plovers (1.33 chicks per breeding pair from 1988-1994, USFWS 1995). Plover productivity varied between years, locations and management strategies. Reproductive success on CAHA remained relatively constant, whereas success on CALO was markedly greater in 1993 than in the other two years. Use of predator exclosures and weather conditions were major determinants of productivity. On CAHA number of fledglings per nesting pair increased from 0.67 for the first two years to 0.82 in 1994 when predator exclosures were used (Table 2). Productivity was highest in 1993 on CALO when exclosures were used and storms were few. Frequent storms resulted in low productivity in 1994, in spite of use of exclosures. On CALO in 1995 when exclosures were used on all nests and storms were few, the highest hatching success (63%) was attained.



A total of 196 nests were monitored on CAHA and CALO from 1992-1994. Of these nests, 132 (67%) did not hatch, 47 (24%) produced fledglings, and 17 (9%) hatched but fledged no chicks. Of all hatched nests, 73% fledged at least one chick. These general statistics illustrate that on CAHA and CALO, piping plover reproductive success is most strongly affected by factors acting during the incubation period. Among shorebirds, rates of nest loss tend to be lower in Arctic regions and higher in the tropics compared to temperate areas. The proportion of chicks that fledge varies similarly, but less dramatically. Rates of loss of piping plover chicks in North Carolina are typical of what one expects of a shorebird at this latitude, but hatching success appears somewhat lower than expected. There is some evidence that beach-nesting species have lower hatching rates than other species, so whether the rates we observed are lower than they were historically is unclear. Predation and storm overwash are the primary causes of nest loss (Table 3). Frequent loss of nests to storms is a factor in which piping plovers and other beach-nesting species differ from other shorebirds, one which may have led evolutionarily to other, compensating differences in breeding biology, such as extended nesting seasons and frequent renesting. This factor might even restrict breeding range. High rates of nest predation, on the other hand, could be a more recent phenomenon linked to human influences.

There was consistently higher hatching success in some nesting areas (such as Cape Point and Power Squadron Spit) than in others (such as Ocracoke (CAHA), Ocracoke Inlet (CALO) and New Drum Inlet (Table 4). These differences may be due to variation in predator pressure or overwash frequency. Predation is high at Ocracoke, where 50% to 100% of nests are predated. Predators usually take a third to a half of the nests at Hatteras Spit. Predation frequency varies on NCB. Nests on Portsmouth Flats, Kathryn-Jane Flats and New Drum Inlet have had up to 40% predation rate during different years. Most flooding of nests occurred on NCB. Flooding was prevalent on Portsmouth Flats, where 40% to 44% of nests failed from flooding each year. Nests along Portsmouth Flats are adjacent to expansive flats that are promptly flooded from Core Sound during northeast winds. About a third of nests (25% to 44%) at Kathryn-Jane and New Drum Inlet (NCB) flooded during stormy years. These two areas do not receive sound water as readily as Portsmouth Flats, yet the areas lie low and collect rainwater.

During the duration of our study, reproductive success has been generally low (Table 1) while population size has increased slightly (Table 2). This pattern is a curious one, and begs the question of how North Carolina populations are regulated. Individuals may continually immigrate

from more productive populations to maintain the North Carolina population, or adult and/or juvenile survivorship may be substantially better for North Carolina populations than for others so that they maintain themselves with relatively low reproductive rates. Higher rates of survival and lower rates of productivity are typical of more southern bird populations compared to more northern ones. That an increase in population numbers occurred after a successful year of reproduction in North Carolina (1993) and that population numbers decreased on NCB after a poor year of reproduction (1994) illustrates that the population might be self-sustaining rather than dependent on immigration. It also suggests that population size might be limited by productivity. Yet whether the population is below carrying capacity due to low productivity or is limited by habitat availability is far from clear. If the former is the case, one expects population size to vary with previous productivity. The required level of productivity for stability must be quite low, given recent population behavior. Alternatively, if habitat is limiting one expects population levels to fluctuate as habitat changes due to losses to vegetative growth and gains from storm overwashes, rather than with variation in productivity. Determining how the population is regulated, including and understanding of differences in biology related to an extreme southern and peripheral location, is the key to devising appropriate management. We will return to this theme at the end of the piping plover section.

## Factors affecting reproductive success on CAHA and CALO

Human disturbance:- With continuing increases in human activity at CAHA and CALO, study of the consequences of these activities on piping plovers breeding in these parks is critical. Humans and vehicles can flush adults from eggs or young, prevent access to preferred nesting or foraging habitat, crush eggs or young, and attract predators to areas that plovers utilize. Although we were unable to investigate the question of human disturbance directly through experimentation, observations of nesting adults and broods revealed the magnitude of human disturbance on our study sites.

During observations, records of intrusions and disturbance events were taken through "all-events" samples (Altmann 1974). All instances of intrusions were indicated during a ten-minute sampling period. Intruder type, behavior and distance from plovers were recorded, as well as any reaction by plover adults and chicks. Samples were taken at various time of day, breeding stage and chick age on CAHA and CALO. Further details of the methodology of our intrusion study are given in the 1994 project annual report.

Data from 73 "intense" ten-minute sampling periods were used to determine intrusion rate. During intense samples all intrusions within 50 meters of the focal bird(s) were recorded, as well as any birds flying high directly over the focal bird(s). Number of intrusions during these periods ranged from zero to 268, with a mean of 9.37 and median of two. The median is a more accurate depiction of average intrusion rate as the frequency distribution of number of intrusions per sample period is clearly skewed (Figure 1). Twelve samples had no intrusions, and 44 samples had three or fewer intrusions. Four samples with large numbers of intrusions (over 30) were obtained from groups located near tern colonies, and most intrusions consisted of nesting or flying terns. There were only three instances of human disturbance during intense samples, each involving one or more moving vehicles. There was no response to any of these intrusions.

Data from 708 intense and non-intense 10-minute sampling periods (118 hours) were used to analyze reactions of piping plovers to intrusions. In almost half of the samples (322) no intrusions were observed during the ten minutes. Of 687 intrusion episodes (which may include one or a group of intruders) 86 (13%) were considered human disturbance (aircraft, vehicles, humans, researchers) and 601 (87%) were "natural" intrusions

(terns, gulls, shorebirds, crows, etc.). Most types of human intrusions (84%) consisted of passing vehicles or planes that elicited little or no response. There were 18 human intrusions that evoked a response (3% of all intrusion episodes). There were seven intrusions of planes, helicopters or boats to which plovers responded with calls or became alert. There were six intrusions of vehicles to which plovers responded with alert behaviors. The most extreme case involved a chick feeding at the ocean shore that was nearly hit by a passing truck. There were four instances of an observer evoking calls or defensive behaviors. In the final instance a group of five people standing over 50 meters away caused the tending adult to lead chicks away from the disturbance.

Most intrusions that elicited responses were by potential predators or competitors. Adult plovers were usually alert to crows and great black-backed gulls, and were aggressive towards other plovers, ghost crabs, gull-billed terns, great black-backed, herring and laughing gulls. Tables 5 and 6 provide detailed and consolidated summaries of the various types of intrusion encounters and reactions of piping plovers. Although only a few encounters with ghost crabs were recorded during disturbance sampling periods, observations of adult plovers with chicks indicate that adults will commonly leave chicks in order to chase away crabs.

Data from our intrusion samples indicate human disturbance is not a significant factor affecting reproductive success of piping plovers on CAHA and CALO within the areas the birds currently use. With the present rate and nature of human disturbance on these beaches, there is no need to terminate beach access to visitors. It is possible, however, that areas that might be used are avoided due to human disturbance, namely the ocean intertidal zone. We will return to this possibility later.

Further analyses of disturbance effects are presently being conducted. Scan sample data taken during observations of incubation and brood rearing will be used to compare behaviors of plovers breeding on CAHA (higher level of disturbance) and CALO (lower level of disturbance). This analysis will estimate time diverted from essential activities as a result of nesting in areas used heavily by humans compared to those used little. This analysis is part of the intensive time budget studies described below.

Predation:-Over the three years of our study, predation accounted for 34% of nest losses on CAHA and CALO (Table 3). Since nest predation is rarely witnessed directly, determination of causes of nest loss unfortunately requires inferences from evidence remaining at the nest

site. We kept guesswork to a minimum. Losses that could not be reliably determined were designated as "unknown loss". By this method, the data on known losses serve as the best sample possible of causes of nest loss. We determine primary predators to be raccoons and crows. Predation by crows was witnessed on CALO in 1992. Since predator exclosures virtually eliminated predation on nests (see below), primary nest predators are likely those that can be physically barred from the nest with exclosure. Thus grackles, mice, crabs, and other small animals are probably not primary predators. Raccoon prints are commonly seen regularly in nesting areas on both CAHA and CALO, as well as cat and nutria prints. Mink tracks are regularly seen at the north end of Ocracoke, and mink have entered an exclosure to take eggs.

Although mink predation is limited to a small area (north end of Ocracoke), it is intense within that area, and appears to almost preclude successful reproduction. Mink are known to have similarly large effects on nesting success of other shorebirds, for example spotted sandpipers. Spread of mink within the seashores could be devastating to the piping plover population. The situation needs to be monitored, and management action may become necessary if the mink spread.



Predation of chicks is even more difficult to reliably determine than predation of eggs, as it normally occurs at night. A Herring gull was seen to eat two newly-hatched chicks at Portsmouth flats. There was some evidence of mink predation on chicks at the north end of Ocracoke in 1994. Cat tracks are seen commonly at Cape Point, Hatteras Spit and Ocracoke on CAHA, and Portsmouth Flats, Kathryn-Jane Flats and New Drum on CALO. Gull-billed terns were seen to take chicks on CAHA in 1995 (M. Lyons, pers. com.). Crows are likely to take piping plover chicks since crow predation on least tern chicks nesting near piping plovers was witnessed repeatedly at High Hills on CALO. There is unfortunately little information regarding activity, such as foraging, of piping plovers at night. Poor foraging habitat or restriction of foraging time by high daytime temperatures or storms may increase nighttime foraging and vulnerability to predation. Since chick mortality rates of piping plovers are not abnormal when compared to closely related and ecologically similar species, effective management measures to curb predation during incubation likely are more realistic than efforts to reduce chick mortality.

We can use reactions of plovers recorded during focal sampling and intrusion sampling (outlined previously) to indicate what species are considered to be a threat. Plovers with eggs or chicks normally react to crows with calling, alert behaviors and crouching over eggs. Gull-billed

terns and great black-backed gulls were generally ignored during incubation, yet were chased in flight by adults tending chicks while the chicks crouched. Ghost crabs elicited unique chasing behaviors by adults that functioned to drive the crabs away from chicks. Herring and laughing gulls evoked chasing or alert behaviors from adults incubating or tending chicks, but only at close distances.

Placement of exclosures around some nests on CAHA and CALO allowed us to experimentally manipulate vulnerability of nests to predation. Details of the methodology for our exclosure study is given in the 1994 project annual report. Nests with exclosures experienced significant increases in hatching success ( $X^2 = 18.88$ ,  $p < .0001$ ,  $df=1$ ; exclosed  $N = 46$ , control  $N = 76$ ), confirming that predation is a major factor affecting reproductive success on CAHA and CALO. Exclosures are recommended for both the parks to increase piping plover productivity. Since losses during incubation comprise the largest portion of reproductive failures and hatching success without exclosures is low, the use of exclosures is one of the most effective and most easily implemented possible methods to increase piping plover productivity on North Carolina seashores. In light of washover and predation probabilities and chick mortality rates, we can extrapolate the productivity to be expected when exclosures are used. On CAHA, about 10 chicks should be produced for

every 10 exclosed nests. On CALO, about 4.5 chicks should be produced for every 10 exclosed nests.

These estimates will be lower if effectiveness of exclosures decreases with subsequent years, which would occur if predators learn to associate prey with exclosures. There is some preliminary indication that this is occurring on NCB. During the present breeding season (1995), raccoons have circled exclosures. This behavior has been evidenced at different nesting areas on the island, which would suggest it to be a general response among the raccoon population. A raccoon entered one exclosure by climbing the fence and crawling under the netting. Fixing the netting much more tightly to the exclosure fencing would alleviate this type of predation, yet the attraction of raccoons to nests no doubt harasses the plovers and may cause abandonment.

Weather:-Breeding success of plovers nesting on CALO fluctuated with weather. Hatching success in 1993, a year of relatively good weather, was markedly greater than in 1992 and 1994, years that had storms and flooding during May (Table 4). Accordingly, nest losses due to flooding or winds are greater in 1992 and 1994 on CALO (Table 3). On CALO, strong northeast winds raise tides in Core Sound and cause water to flow from the sound towards the sand flats where piping plovers nest. Contrary to the

normal weather pattern, colder northeast winds continued to blow in early May of 1992, and caused the flooding of five nests and delayed many first nest attempts until late May. In 1994 a combination of northeast winds and a storm on May 21st caused the loss of 14 first nests.

In addition to its direct effects, adverse May weather has other deleterious effects. Cold and stormy weather will delay initiation of nests and force renesting. Nests initiated later in the breeding season appear to have diminished success compared to early nests. This is a common pattern in birds. Comparing nests during 1993, when losses to flooding did not occur, of 28 nests initiated in May, six nests fledged a total of 13 chicks (21% fledging success, 2.17 chicks per fledged nest). Of 16 nests initiated in June, four nests fledged a total of four chicks (25% fledging success, 1 chick per fledged nest). It is more likely for large broods to fledge if they hatch earlier in the breeding season. So it appears that on NCB a successful year requires favorable weather so that early nests hatch.

While weather effects can certainly be harmful, they cannot easily be managed and are little different than they were historically. Since severe storms are more prevalent along North Carolina shores than in other breeding areas along the east coast (D. Bartoff of NOAA weather, pers. com.), weather effects may have always limited productivity in North

Carolina compared to more northern areas, and may even limit the species' breeding distribution.

Temperature: -Piping plovers breeding at the southern end of the range presumably experience higher ambient temperatures than those in northern regions. When temperatures are high during incubation eggs must be shaded by adults to prevent death of embryos from overheating. In Wilson's plovers once temperatures rose above 31o C (87.8o F), incubation rates increased in order to shade eggs (Bergstrom 1982). Beach temperatures on CAHA and CALO frequently rise above this temperature starting in Mid-May. Increased time spent on incubation would likely decrease time available for foraging (Walters 1984) at a time when heat stress demands more energy resources. When precocial chicks such as those of piping plovers first hatch, they are unable to thermoregulate and depend on their parents to warm and cool them (Ricklefs 1983). During extremely high temperatures chicks may spend little time foraging and instead are brooded or crouch in the shade. In one instance at CALO when temperatures were above 90o F, two one-day old chicks and one egg were shaded constantly by both adults during observations in the heat of the day. The chicks were brooded continually for 5.5 hours and only foraged sporadically during the final half hour of an observation after

temperatures declined. The adults foraged only briefly at the nearby ocean. During the next day, no chicks were found with the pair.

High temperatures encountered by piping plovers in the southern portions of the breeding range therefore are likely to have many indirect effects on chick foraging time, and perhaps consequently on mortality rate. On NCB, mortality rate increased for chicks hatched later in the breeding season (Figure 2). It is possible that high temperature shortens the effective breeding season of piping plovers nesting on North Carolina seashores. Mortality may be caused directly by insufficient foraging time, or indirectly by higher predation rates due to increased foraging at night.

Correlational analyses of temperature and time spent foraging by chicks are currently in progress. These analyses are a component of time budget studies described below. We will use our data to estimate the amount of foraging time available at favorable temperatures as a function of season.

Habitat:-A factor crucial to piping plover reproductive performance is the availability of suitable foraging habitat. Chicks foraging in habitats rich in resources travel less, forage more and have increased growth (Loefering 1992). We sought to identify habitats on CAHA and CALO that

In general, dry sand flats and interdunal areas (used for nesting) were widely available, yet were uncommonly used for foraging. These two habitat types were used by newly hatched chicks during their first foraging attempts near the nest site. Once all chicks were mobile, groups foraged at mudflats or wet flats. Mudflats were located at the west end of a pond at Cape Point, along the sound on Hatteras Spit, at the north end of NCB, behind wet flats on Portsmouth Flat and along the sound at New Drum Inlet. On CAHA, wet flats were located on the east end of the pond and within the interior of Cape Point, near the drain pond at the South Beach, along a tidal pond and within the interior of Hatteras Spit and on the north end of Ocracoke. On NCB, wet flats were generally located towards the sound from the nesting areas on Portsmouth Flat, Kathryn-Jane Flat, and Old Drum Inlet, and in the interior of New Drum Inlet. Access to the sound shore is limited; Hatteras Spit on CAHA and New Drum and Ocracoke inlets on CALO are the only sound shores available to plover groups.

During behavioral observations, habitat use by foraging piping plover adults and chicks was recorded with scan samples. If any plovers were foraging during the scan, the habitat type, distance from vegetation, density of vegetation and other distance estimates were noted. The 1994 project annual report provides more detail of methods. Initial analyses of

1993 data indicate that plovers foraging on CAHA use either wet or mud flats, and CALO plovers forage primarily on wet flats. On CAHA, there were 38 instances (51%) of use of mudflats and 31 instances (42%) of use of wet flats (N = 74). On CALO, there were 252 instances of wet flat use (or wet flat habitat in combination with other habitats such as dry or mud flats) (90%, N = 279). These differences between CAHA and CALO may be due to differing availability of habitats in the two parks. Mudflats on CALO are only available at Portsmouth flats and small areas of New Drum Inlet. Samples from CAHA were taken from groups located in various areas, but were mainly taken at either Hatteras Spit or Ocracoke. Samples from CALO tended to come from groups in New Drum or Kathryn-Jane Flats. On CAHA, plovers tended to forage less than five meters from dense or moderately dense vegetation. Plovers foraging on CALO tended to be either within sparse vegetation or less than five meters from dense vegetation.

Data from other years will be entered and analyzed, and a more definitive assessment of foraging habitat selection will be provided in the thesis. Also, we intend to link foraging data from scan samples to peck rate data from chicks collected during focal samples in order to gain some understanding of foraging rates in different habitat types. Finally, data from focal samples and scan samples will be used to compare time spent



foraging and traveling by chicks in different habitats. These analyses will enable us to assess habitat quality in greater detail than reported here.

Use of ocean intertidal zone by plover chicks is of special interest because of possible conflicts with park visitor use. Although mudflats and wet flats are more commonly used, chicks were seen at the ocean shore at Hatteras Spit, Cape Point and Ocracoke on CAHA during our study. Chicks seen at the ocean were usually around fledging age. On CALO, most frequent use of the ocean shore by chicks occurred at Kathryn-Jane Inlet and Portsmouth Flats after the chicks had fledged. Some use by young chicks at Portsmouth Flats also was witnessed, and in one instance a chick was nearly struck by a vehicle. Chicks at New Drum have very rarely fed along the ocean shore. More often older chicks feed at the sound. Thus slightly more use of the ocean intertidal zone was observed at CALO compared to CAHA, but use was still infrequent.

Since vehicles are frequent along the shores of CAHA and infrequent along CALO, and use of the ocean intertidal zone by young chicks was observed more at CALO, one might conclude that human disturbance reduces use of this habitat. This idea can best be tested experimentally by closing portions of outer beach to visitors. Without such a study, only a very general comparison of highly used (CAHA) and infrequently used

(CALO) habitats is possible. Since use of the ocean intertidal zone by piping plover broods on CALO, where there are more breeding pairs than CAHA, is not substantially more frequent than on CAHA, it can be concluded that reduced human disturbance does not greatly alter habitat use. Either adults have little inclination to bring their broods to the shore, or even minimal disturbance is sufficient to discourage them from doing so. This suggests that the ocean intertidal zone is not highly preferred habitat for brood rearing in North Carolina. The preferred habitat appears to be mudflats and wet sandflats, habitats that are much more prevalent on CALO due to the absence of dune stabilization measures.

Geographic location:-Our brief study of piping plover breeding biology has revealed that factors affecting reproductive success in North Carolina are different than those in northern regions. Being along the edge of the piping plover's breeding range, the environment at North Carolina seashores is likely to have more unfavorable conditions for reproduction (e.g. predators, diseases and weather conditions). Storms in the early part of the breeding season cause breeding losses and delays, and high temperatures, especially late in the breeding season, impose heat stress that may indirectly cause chick mortality. For these reasons, productivity goals set in the recovery plan (1.5 fledged chicks/pair/year), established from studies of more northern populations, are probably unrealistic for

North Carolina. Still, productivity can be improved over current levels, especially through use of predator exclosures. The little information that exists suggests that more realistic productivity levels may be sufficient to increase the population.

To provide additional perspective on piping plover reproductive success within the seashores, we provide comparative data we collected from Wilson's plovers. Wilson's plovers are an ecologically similar species and North Carolina is in the middle of their breeding range. We estimate hatching success of Wilson's plovers to be 23%-50%, compared to 33% for piping plovers. The two species appear to be experiencing similar, high levels of nest loss within the seashores.

#### Nesting habitat

On CAHA and CALO, piping plovers nest in the vicinity of the wet sandflats and mud flats in which their broods forage. Nest locations tend to be in drier areas, often on dry sandflats or even interdunal area adjacent to wet flats or mud flats. One of our objectives was to provide the Park Service with locations of nests and foraging areas in a form that could be used both to locate sites in the field and incorporate locations into GIS data bases. We previously provided nest locations and foraging area

locations plotted on copies of aerial photographs in our project annual reports. Unfortunately aerial photos, while ideal for mapping exact nest locations, have not proven suitable for digitized mapping for GIS, and GIS maps suitable for field use are not yet available. The locations plotted on aerial photography provided previously are the best source of precise information for field use currently. We have mapped nest locations and foraging area locations onto topographic maps of portions of CAHA and CALO. Unfortunately, due to the age of the maps, locations could not be exactly mapped. Some nesting areas (such as the overwash area at Kathryn-Jane Inlet on NCB) were not present on the topographic maps, making accurate mapping difficult. We feel that these maps are inadequate for input of GIS data, and attempts to plot locations on GIS habitat maps currently available were equally imprecise. We recommend using a GPS (global positioning system) unit to obtain locations for use in GIS data bases.

#### Intensive studies of breeding biology

A total of about 1000 hours of observational data has been collected: 270 hours from CAHA, and 665 hours from CALO. The data consist of: 1) scan samples indicating adult and chick behavior, distances between adults and chicks, and foraging locations; 2) all-events samples recording type

and behavior of intruders, distances between plovers and intruders and reactions of plovers to intruders; 3) focal samples of chick and adult behavior measuring time budgets and peck rates of chicks, and providing additional information concerning interactions with intruders and competitors. In association with these samples we recorded general information such as temperature, wind speed, tide, weather, age of chicks, number of chicks, date and time of day.

These observational data will allow us to examine interactions of adults with their broods in detail. We will determine how time budgets and distance relationships (which determine how well adults can protect their chicks) vary with factors such as brood size, habitat and temperature. A goal of these analyses is to better understand determinants of chick survival. These analyses will comprise the bulk of the material to be reported later in Susan Philhower's dissertation.

## Conclusions

Most frequently cited causes of the decline of piping plovers are habitat loss or degradation and human disturbance. Human development has replaced former nesting and foraging habitat of plovers throughout their breeding range, especially in the northeastern United States (USFWS

1995). Dune stabilization inhibits the formation of washover areas, and causes the loss of wide flats for nesting and foraging. Plovers nesting in degraded habitat are usually closer to human activity. With no access to sound or moist flats, the only foraging habitat available in many areas is along ocean intertidal zone.

In CAHA and CALO, nesting areas are usually adjacent to wet flats, mud flats or sound flats and these areas are favored for foraging by adults and chicks. Because of the availability and protection of these wide flats, plovers are not generally near human activity. Indeed, our observations suggest human disturbance does not significantly affect piping plover breeding activity. An important conclusion is that conditions in North Carolina are very different than those in other areas, notably the northeast, in which piping plovers have been studied, and based on which the species recovery plan has been structured (USFWS 1995). Effective management likely will differ between North Carolina and other areas as a result. For example, beach closures, which are effective in other areas, likely will have little impact in North Carolina. It is not clear that ocean intertidal zone will be used much even if such habitat is closed to humans. At the very least, experimental closures should be conducted before adopting closure as a general policy.

There are very few breeding areas for the species in which habitat is as little altered, or little disturbed, by humans as CALO. Yet here, in the absence of the problems to which the decline of the species generally is attributed, the dynamics of the population appear less favorable than in areas to the north, and no better than those observed at CAHA, where habitat alteration and human presence are greater. We must search for other factors to explain the exceptionally low productivity of the North Carolina populations.

There is a critical need to understand the population dynamics of piping plovers in North Carolina, both in terms of how they differ from historical dynamics on site, and from the dynamics of populations in other areas. There are two important reasons to suspect that population dynamics in North Carolina are different than those observed in the northeast, (1) the southern location of the North Carolina population and (2) the fact that the North Carolina population represents the limit of the species' range. It is likely that due to the first factor productivity will be lower and survival higher in North Carolina, and from the second factor that conditions will be less favorable for the species in North Carolina. Presumably whatever factors limit the range of the bird impact them much more on the edge of the range than elsewhere.

The most critical step in understanding population dynamics will be to determine how the population is regulated, specifically whether the small population reflects limited habitat, or is due to poor productivity, such that the population is below carrying capacity. This can be assessed by closely tracking whether populations fluctuate according to variation in productivity, or according to changes in availability of habitat. Without this knowledge, it will be difficult to set reasonable population objectives, or formulate effective management strategies.

We suspect that productivity is limited in North Carolina by the relatively high frequency of storm overwash in nesting areas. This is the type of factor, since it varies in a clinal fashion, that could limit the breeding distribution. High temperatures, by restricting foraging time during the day, could directly or indirectly limit productivity, and breeding range, as well. Such factors may constrain the potential for positive impacts of management. That is, it may be unreasonable to expect to increase productivity as much, or increase populations as fast, as can be accomplished elsewhere. However, we also suspect, based on the population increases observed despite very low levels of productivity, that mortality rates of adults may be lower in North Carolina, and thus that a small increase in productivity in North Carolina may have as big an effect



on population size as a larger increase elsewhere. We can only hypothesize about survival rates, though, because relevant data on survival of North Carolina birds do not exist. Equally important is the lack of data on return rates. Without these data, one can not determine whether the North Carolina populations are self-sustaining, or represent sinks dependent on immigration from elsewhere for their continued existence.

We conclude that the most effective means to influence population dynamics in a favorable way is to reduce predation. Predation on chicks is more difficult to affect, and the data do not indicate predation rates to be abnormally high during the chick stage. We therefore favor attempts to reduce predation during the egg stage, and have shown that this can readily be accomplished with predator exclosures. We also recommend that mink be prevented from spreading to other plover nesting areas. The major predators of piping plover eggs appear to be crows and raccoons, species whose abundance clearly has increased due to human presence. This fact is another reason to suspect that if piping plover populations in North Carolina are suffering from reduced productivity compared to historical levels, that it is predation on eggs that has increased, rather than other sources of nest loss.

A major difference between the two seashores is that dune stabilization characterizes one (CAHA) but not the other (CALO). Dune stabilization reduces availability of nesting habitat, and this is probably the reason the population on CALO is so much larger than that on CAHA. On the other hand, dune stabilization probably also accounts for reduced levels of nest loss to flooding on CAHA. That the population trend on CALO is more positive than that on CAHA argues for habitat availability being limiting on CAHA rather than productivity. On CALO the number of breeding pairs on NCB from 1993-1995 (28, 32, 29, respectively) is to some extent related to reproductive success of the previous year (.27, .68, .19, respectively), which suggests that the population may be limited by productivity.

In conclusion, the conservation of piping plovers in the North Carolina seashores is more complicated than it at first appears. A simple view is that the population is small because productivity is so much lower than elsewhere. There is no doubt that productivity is extremely low, yet the population currently is increasing. Two explanations are possible. First, the dynamics of the North Carolina populations might be very different from those of more northern populations, so that only low levels of productivity are necessary to maintain fairly closed populations. Second, the North Carolina populations might depend on immigration from

better areas elsewhere for their continued existence, thus acting as sinks that drain birds from healthier source populations. If this is the case, these dynamics may be recent, arising from greatly reduced levels of productivity that have produced a problem that needs to be fixed through management. Or North Carolina, at the limits of the species' distribution where conditions are always marginal, may always have been a sink, in which case efforts to manage for healthy populations will be ineffective. One may pick one of these scenarios as most likely, and manage accordingly. The alternative is to conduct the studies of survivorship and return rates necessary to determine which is accurate.

## Literature cited

- Altmann, J. 1974. Observational study of behavior sampling methods. *Behaviour*, 49: 227-267.
- Bergstrom, P. W. 1982. Ecology of incubation in Wilson's plover (*Charadrius wilsonius*). Ph.D. dissertation, University of Chicago. Chicago, Illinois.
- Loefering, J. P. 1992. Piping plover breeding biology, foraging ecology and behavior on Assateague Island National Seashore, Maryland. MS Thesis, Virginia Polytechnic Institute and State University. Blacksburg, Virginia.
- Ricklefs, R. E. 1983. Avian postnatal development. pp. 1-83 in D. S. Farner, J. R. King, and K. C. Parkes, eds. *Avian Biology*, vol. 7. Academic Press, New York.
- U.S. Fish and Wildlife Service. 1995. Piping plover (*Charadrius melodus*), Atlantic Coast Population, Revised Recovery Plan. Technical/Agency Draft. Hadley, Massachusetts.

Walters, J. R. 1984. The evolution of parental behavior and clutch size in shorebirds. In *Shorebirds: Breeding Behavior and Populations*. (J. Burger and B. L. Olla, Eds.). Plenum Press, New York, New York.

Table 1. Numbers and distribution of breeding pairs of piping plovers on CAHA and CALO, 1992-1995.

Location	Number of pairs *			
	1992	1993	1994	1995
CAHA				
Bodie Island	0	0	0	~
Cape Point	4	5	5	~
South Beach	0	1	1	~
Hatteras Spit	4	3	3	~
Ocracoke	4	3	2	~
CAHA TOTAL	12	12	11	~
CALO				
Ocracoke Inlet	2	0	2	2
Portsmouth Flat	8	9	7	8
Kathryn-Jane Flat	11	9	12	11
Old Drum	2	1	1	2
New Drum Inlet (NCB)	5	9	10	6
New Drum Inlet (SCB)	3	4	5	4
Power Squadron Spit	2	3	2	2
CALO TOTAL	33	35	39	35
TOTAL	45	47	50	~

\* Includes pairs that did not nest but held territories

Table 3. Causes of piping plover nest loss on Cape Hatteras National Seashore and North Core Banks, 1992-1995.

Year/Location	Total # of nests	Total # of losses	Predator		Flooding/Sand		Human		Abandoned		Unknown	
			N	%	N	%	N	%	N	%	N	%
1992 CAHA	14	6	3	50	0	0	0	0	0	0	3	50
NCB	39	30	6	20	11	37	0	0	0	0	13	43
TOTAL	53	36	9	17	11	21	0	0	0	0	16	30
1993 CAHA	21	12	5	42	0	0	0	0	0	0	6	50
NCB	48	30	10	30	5	15	0	0	4	13	11	37
TOTAL	69	42	15	36	5	12	0	0	4	10	17	41
1994 CAHA	18	8	7	88	1	12	0	0	0	0	0	0
NCB	56	46	14	30	19	41	0	0	4	9	9	20
TOTAL	74	54	21	39	20	37	0	0	4	7	9	17
1995 NCB	38	14	5	36	5	36	0	0	2	14	2	14
92-95 TOTAL	234	146	50	34	41	28	0	0	10	7	44	30

### CAHA Nest Losses to predation

<del>1992</del>	total losses	lost to predators
1992	6	3
1993	12	5
1994	8	7
Total	26	15

$$\frac{15}{26} = 57.69\% \\ (58\%)$$

Table 4. Numbers, distribution and hatching success of piping plover nests on CAHA and CALO, 1992-1995.

Location	Number of nests and hatching success							
	1992	Hatch %	1993	Hatch %	1994 #	Hatch %	1995	Hatch %
CAHA								
Bodie Island	0	~	0	~	0	~	~	~
Cape Point	5	80	6	83	6	83	~	~
South Beach	0	~	2	50	1	100	~	~
Hatteras Spit	5	40	4	50	6	50	~	~
Ocracoke	4	50	6	11	5	20	~	~
CAHA TOTAL	14	57	21	42	18	56	~	~
CALO								
Ocracoke Inlet	2	0	0	~	1	0	3	33
Portsmouth Flat	12	33	14	36	8	38	8	63
Kathryn-Jane Flat	14	29	17	41	25	12	16	69
Old Drum	2	0	2	50	2	0	2	100
New Drum Inlet (NCB)	9	11	15	33	20	20	9	56
New Drum Inlet (SCB)	N/A	~	3	66	9	11	~	~
Power Squadron Spit	N/A	~	5	80	1	100	~	~
CALO TOTAL	39	23	56	43	66	20	38	63
TOTAL	53	32	77	43	84	27		



Table 5. De. summary of type of intruder and response of piping plovers during . on episodes.

Type of intruder	None	Slight alert	Alert	Call	Lead chicks	Crouch Run	Head Bob	False Incub	Broken Wing	Run to	Hunch Run	Agressn	Fly Chase	Fight	Avoid	Run	Fly	Unkn	Total
Least tern	29	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	32
> 10 LT	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
2-10 LT	17	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18
Common tern	67	1	0	4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	76
2-10 Com. terns	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30
30-44 Com terns	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Black Skimmer	8	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
2-10 Black Skim	9	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
24 Black Skim	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1-3 Gull-billed terns	25	1	0	3	0	0	0	1	0	0	0	0	6	1	0	0	0	0	41
Laughing Gull	32	1	2	1	0	0	0	0	0	0	0	0	10	1	0	0	0	1	49
2-5 Laugh gull	6	1	1	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	11
Herring gull	5	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	8
Great blackb. gull	3	1	2	1	0	0	0	0	0	0	1	0	4	0	0	0	0	0	12
Unspec. gull	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	4
2-5 Gulls	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Willet	23	1	1	0	0	0	0	1	0	0	0	0	1	1	0	1	0	0	29
2-4 Willets	4	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	7
Black bellied plover	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1-4 Sanderlings	3	2	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	7
1-3 Piping plovers	1	0	0	1	0	0	0	0	0	0	6	5	7	3	0	0	0	0	23
1-2 Wilson's plovers	7	0	1	0	1	0	0	0	0	0	0	3	4	1	0	0	0	0	17
Amer. Oysterc.	26	0	4	2	0	0	0	1	0	0	0	0	3	0	0	1	0	0	37
2-10 Amer Oyst	11	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
Turnstone	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Osprey	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Ghost crab	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	4
2-4 Rabbits	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Crow	8	1	5	19	0	1	0	0	0	0	1	0	7	0	0	1	0	0	51
2-4 Crows	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	7
1-3 Grackles	7	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
Red-winged Blkbd	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Meadowlark	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
2 Swallows	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Cormarant(s)	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Egret	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
Glossy Ibis	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Human(s)	6	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	10
Plane(s)	38	1	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43
Vehicle(s)	24	3	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	30
Other	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	2
Observer	0	0	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4
Unspec. gull	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Unspec. tern(s)	26	0	0	0	1	0	0	0	0	0	1	0	15	1	1	1	0	0	47
Unknown	2	0	1	0	0	0	1	0	0	0	0	0	1	1	0	1	0	0	10
Unknown shorebd	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
None	322	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	322
Total	773	16	30	41	3	1	2	4	1	2	13	10	66	11	1	8	1	1	1009

Figure 1. Frequency distribution of number of intrusions in ten minute periods

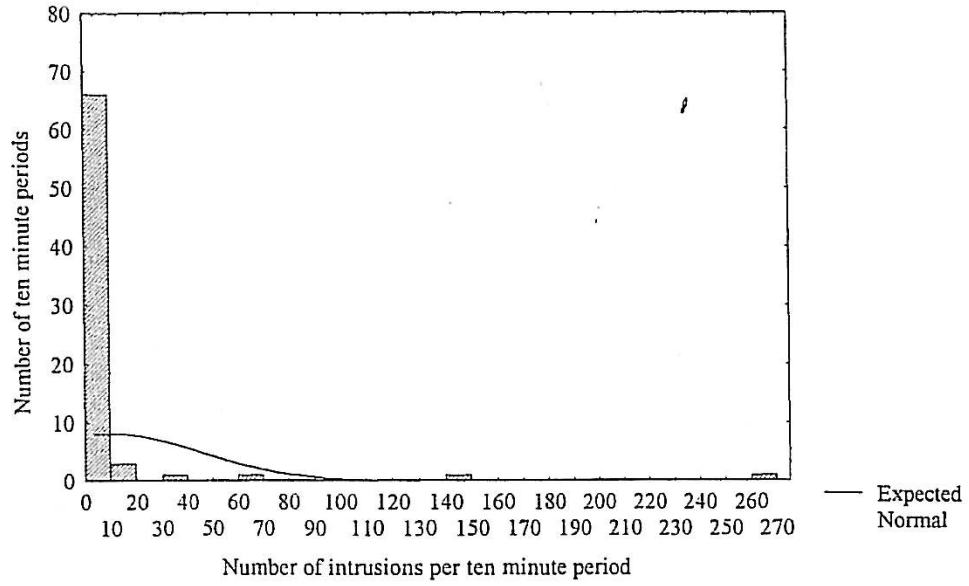


Figure 2. Mortality rate of piping plover chicks hatched in different 10 day periods on NCB, 1992-1994. Numbers indicate sample size.

