

**PIPING PLOVER BREEDING BIOLOGY  
AND REPRODUCTIVE SUCCESS  
ON ASSATEAGUE ISLAND**

by

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(ABSTRACT)

I studied the piping plover on Assateague Island during the 1986 and 1987 breeding seasons. In 1987, I estimated the population to be 69 pairs. During both years, plovers nested on only a few portions of the island. I think that this pattern of nesting was determined by the distribution of three types of foraging habitats: bayside mud and sand flats, saltwater pools formed by storm tides, and a drawn down waterfowl impoundment. Reproductive rates were lower than two recent estimates of the level necessary to maintain a stable population. The primary problem was poor nest success and the leading cause of nest loss was nest predation by red foxes (Vulpes vulpes) and raccoons (Procyon lotor). I was not able to identify factors responsible for chick mortality, but my data show a relationship between chick survival and foraging habitat. Broods feeding on bayside foraging areas had a much higher survival rate than broods which did not have access to these areas. Management efforts should focus on reducing nest predation. Recent experiments have indicated that

predator exclosures constructed around individual nests can be used to reduce nest predation. These exclosures should be tested on Assateague. Future research efforts should focus on the role of foraging habitat in breeding site selection and the relationship between chick survival and the type of foraging used.

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## INTRODUCTION

Piping plovers (Charadrius melodus) are shorebirds that nest in the Great Lakes watershed, on the northern Great Plains of the United States and Canada, and on Atlantic coastal beaches from Newfoundland to South Carolina (Federal Register 1985, Haig and Oring 1985, U.S. Fish and Wildlife Service 1988a). Due to increasing concern about population declines, the piping plover has appeared on all of the Audubon Society's Blue Lists since 1973 (Arbib 1972-1979, Tate 1981, Tate and Tate 1982). In January of 1986, piping plovers nesting in the Great Lakes watershed were listed as endangered and the remaining populations were listed as threatened under the Endangered Species Act (Federal Register 1985).

The population decline has been attributed to loss of breeding habitat, and poor productivity (U.S. Fish and Wildlife Service 1988a). Factors thought to be contributing to habitat loss include beach development (Wilcox 1959, Raithel 1983, Williams et al. 1988), beach stabilization (Raithel pers. commun), and recreational use (Raithel pers. commun., MacIvor et al. pers. commun., Strauss pers. commun.). Low productivity has been attributed to high nest predation (MacIvor et al. pers. commun., McLean et al. pers. commun., Strauss pers. commun.) and recreational disturbance (Cairns 1977, Flemming 1984, Strauss pers. commun.).

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Barrier islands are the most important piping plover breeding areas in Virginia and Maryland (Via 1979, U.S. Fish and Wildlife Service 1988a). Assateague Island contains most of the suitable nesting habitat in Maryland (Cairns and McLaren 1980) and is also an important breeding area in Virginia (U.S. Fish and Wildlife Service 1988a). Prior to this study, there had been only one complete survey of breeding piping plovers on the Maryland portion of Assateague Island. This survey was conducted in 1985. The estimated population was 18-20 pairs (Hoffman 1985). Chicks were observed at only 5-6 locations. The Virginia portion of the island was surveyed in 1985 also, yielding a population estimate of 16-18 pairs (Ailes 1985). A total of 21 young were produced.

The two previous studies indicated that Assateague Island supported a relatively large population of breeding plovers, but provided few details about piping plover breeding ecology or factors influencing productivity on the island. The goals of this study were to provide more detailed information on the density and reproductive status of piping plovers nesting on Assateague Island. The objectives of this study were to:

1. Estimate piping plover population size and number of breeding pairs on the Maryland and Virginia portions of Assateague Island;
2. Document breeding chronology;
3. Describe nests and nesting habitat;

4. Determine if nesting habitat is used in proportion to availability;
5. Estimate territory size;
6. Estimate nesting success
  - a. Identify causes of nest failure
  - b. Estimate rate of renesting;
7. Estimate fledgling survival;
8. Compare habitat use, number of nesting pairs, and reproductive success in areas with different levels and types of human use.

## **STUDY AREA**

Assateague Island is a 7700 ha barrier island off the coast of Maryland and Virginia (Fig. 1). It is approximately 59 km long and 0.3 to 4.0 km wide (Mackintosh 1982). There are three administrative units on the island: Assateague Island National Seashore, Assateague State Park, and Chincoteague National Wildlife Refuge (Fig. 1). I worked on only the Maryland portion of the island in 1986. In 1987, I worked on both the Maryland and Virginia portions of the island.

## **MACROHABITAT CHARACTERISTICS**

Habitat characteristics differ throughout the island. On the northern 8 km of the island (Fig. 1), only isolated dunes are found. This section is relatively narrow, less than 300 m at some points. Storm driven spring tides occasionally wash all the way across the island to Sinepuxent Bay at several places on this portion of the island. In many areas, this overwashing creates unvegetated strips of sand extend that from the ocean tidal zone to the bay. These unvegetated strips allow plover broods to gain access to bayside mud

and sand flats. The berm (Table 1) in this area is wide, ranging from 140 to 380 m.

From the McCabe house to the state park (Fig. 1), the island is broader and a shrub zone separates the bay and the beach. In 1986, much of the dune line in this section was missing. High, storm driven tides in the spring washed across the beach to the McCabe house road and formed temporary pools in one area. The National Park Service reconstructed the dune in this area after the 1986 breeding season, creating a narrow berm on the ocean side and a sparsely vegetated interdune zone (Table 1) west of the dune to the McCabe house road. No saltwater pools formed in this area in 1987.

The island from the state park to the Maryland ORV zone is characterized by a narrow berm (typically 14 to 17m) in front of a well established dune line. Over much of the area, campgrounds and other visitor facilities are just west of the dunes. Where campgrounds do not occur, the interdune zone is usually heavily vegetated. The ocean and bay are separated by an extensive shrub zone and, in many areas, by a forest zone.

A dune runs the entire length of the Maryland ORV section (Fig. 1), but gaps caused by overwashing storm tides occur in many areas. The berm in front of the dunes is of variable width (12 to 135 m). Overwash gaps (Table 1) may be 150 m deep from the break in the dunes to dense vegetation. The bay is separated from the beach by a broad shrub and forest zone.

The Wild Beach in Virginia (Fig. 1) has a well established dune line. The berm is typically narrow (30 to 60 m), although wider berms (180-260 m) occur in two areas. Winter and spring storms form temporary pools on these wider portions. The interdune zone is usually heavily vegetated, and access to the bay is blocked by shrub and forest zones.

The Wash Flats area (Fig. 1) is a waterfowl impoundment behind the dunes and parallel to a portion of the Wild Beach. The Wash Flats is separated from the Wild Beach by a strip of dense vegetation, usually more than 250 m wide. Water in the impoundment is drawn down in the spring, providing unvegetated nesting areas for shorebirds. Plovers nesting in this area do not have unvegetated access to the ocean or the bay.

Tom's Cove Hook between the Wild Beach and the ORV crossover (Fig. 1) has a narrow berm in front of a well established dune line. West of the dune line in this area are roads, parking lots, and other visitor facilities. Tom's Cove Hook from the ORV crossover to Fishing Point (Fig. 1) is characterized by a wide berm (more than 280 m wide at some points). High spring tides may wash all the way to the dunes, forming extensive pools up to several inches deep. The interdune zone is heavily vegetated. At Fishing Point, only isolated dunes are found. High spring tides may wash over the entire width of the island in some places and much of the beach between the ocean and Toms Cove is unvegetated.

## HUMAN ACTIVITY

In 1986 and 1987, recreationists were allowed to operate off-road vehicles on Tom's Cove Hook in Virginia and on the southernmost 21 km in Maryland (Fig. 1). In the remaining areas, only foot traffic was permitted, except for park and refuge personnel, who operated vehicles on all portions of the island.

## PLOVER MANAGEMENT

A symbolic fence consisting of fence posts connected by iron cable was used to protect nesting habitat on the Hook on Chincoteague National Wildlife Refuge. Visitor activities were restricted to a narrow area above the high energy beach (Table 1). Recreational use on most of the Wild Beach was unrestricted except for two 1.5 km sections where recreationists were restricted to a narrow zone above the high energy beach. Since 1982, the Fish and Wildlife Service has been trapping potential shore bird predators (red fox (Vulpes vulpes) and raccoon (Procyon lotor)) during the state of Virginia's regular trapping season (U.S. Fish and Wildlife Service 1988b). Between 1982 and 1987, 349 raccoons and 70 red foxes were removed (U.S. Fish and Wildlife Service 1988b).

On Assateague Island National Seashore, no piping plover nesting areas were protected by symbolic fencing, although most overwash gaps in the ORV section were blocked with symbolic fences to prevent ORV access. Signs describing the piping plover and its status were placed at major access points north of the state park. No attempt was made to control predators.

## WEATHER

Average temperatures ranged from 6.2 to 26.0 °C during the two study seasons (Table 2). Average monthly precipitation ranged from 0.97 to 23.88 cm (Table 2).

## METHODS

### BREEDING POPULATION ESTIMATE

I estimated the population size based on the number of first nests. This process required identification of renests. To determine if a nest was a renest or a first nest, I examined data on its location, initiation date, final observation date, and other relevant observations during the period of the nest's existence relative to similar data for surrounding nests. In general, I considered a nesting attempt to be a renest if: (1) it was initiated after a nest loss in the same area, (2) it was not separated from the previous nesting attempt by the nest of another pair, and (3) observations during the earlier nesting attempt did not indicate that another pair was present.

I believe that some of the plover pairs that nested on the Wash Flats initially nested the Wild Beach. To prevent double counting in these two areas, I assumed that all birds which nested unsuccessfully on the Wild Beach attempted to renest on the Wash Flats. This is a conservative approach and may have resulted in my slightly underestimating the population.

## NEST SEARCHES

I searched potential piping plover nesting habitat between the wrack line (Table 1) and continuous vegetation using transects which ran parallel to the ocean. I began surveying these areas in April (Table 3). In May, I began to focus my attention on those areas where plovers or plover tracks had been observed previously. During June, I conducted partial searches approximately once every 4-6 days in areas where I observed nest failures or had observed plovers but no nests. In July, I conducted surveys primarily in areas where nest failures had occurred. I discontinued surveys during the third week in July.

In addition to searching nesting habitat between the wrack line and continuous vegetation, I looked for nests in three other areas. I began to search the Wash Flats area (Fig. 1) in mid-May of 1987 when I learned that this area had been used by nesting plovers in 1985. I surveyed this area once every 6-7 days until mid-July. Finally, I searched Fox Hill Levels and Big Levels (Fig. 1) three times between April and the end of June in 1986 and 1987.

I located nests by following plover tracks and observing the behavior of plovers located in potential nesting areas. Birds found on the beach usually were aware of my presence before I located them. In such cases, I remained motionless and observed the bird's behavior. Plovers actively incubating usually returned to the nest after a few minutes or repeatedly approached the site where they were

originally observed. If a plover immediately left the area, I continued the survey. If a plover remained in the area but did not act as if it were near a nest, I left the area, usually after no more than 10 minutes. Once a nest was located, I did not approach closer than 80 m during subsequent nest searches.

## **NEST OBSERVATIONS**

When a new nest was discovered, I approached it closely enough to determine the number of eggs through binoculars. Nest locations in Maryland and on the Wild Beach in Virginia were not marked, but several nests on the Hook and most nests on the Wash Flats were marked with a 35 cm wooden stick placed approximately 9 m from the nest. Upon discovery of each nest, I marked observation points for viewing nests at distances which I felt were great enough so that birds would not be disturbed during subsequent observations (usually 60-140 m). However, some nests were in thick vegetation so that incubating birds were visible only after I approached within a few meters. In these cases, I approached nests closely enough to determine if a plover was on the nest.

To determine nest success and hatch dates, I observed nests daily in 1986 and on alternate days in 1987. Observations usually were no more than five minutes in length.

## **CAPTURE AND BANDING**

In 1987, I banded 32 adults. I used a 43 x 48 x 30 cm drop trap (Mills and Ryder 1979) placed over the nest to capture and band adults. All captured birds were banded with a USFWS aluminum leg band, a plastic flag, and two plastic color bands. All trapping efforts occurred before 0900 (EST), after 1650 (EST), or on cloudy days so that eggs would not be damaged by exposure to the sun. If birds did not return to the nests, the trap was removed after 15-29 minutes (N=14). Elapsed time (time bird flushed from the nest to time observer left) for successful attempts never exceeded 33 minutes ( $\bar{x}$ =22 minutes, N=32).

I used two types of coverings for the drop trap. The first was a brown cast net with a fine mesh. Plovers were reluctant to return to the nest when this trap was used. I was successful during only 7 of 19 attempts with this version of the trap. The second covering was made from a mist net. Birds were captured on 25 of 27 attempts using this version of the trap.

## **BROOD OBSERVATIONS**

I observed broods on a regular basis to determine fledging success. In Maryland, I observed broods daily for the first week

after hatch, and every other day thereafter until the chicks were at least 27 days old or could no longer be found. In Virginia, I attempted to observe chicks every other day for at least 28 days. In addition to the observations described above, I observed 12 Maryland broods while chicks were less than 10 days old for a combined total of 44.45 hours in an attempt to identify factors causing chick mortality.

I determined fledging success on the basis of age rather than by attempting to observe each chick in flight. The youngest chicks I observed in flight were 19 days old (N=2). Five other chicks were observed in flight 24-26 days after hatch. It is possible that these chicks were capable of flight at an earlier age. Most chicks were observed in flight only after they were closely approached by an observer. Cairns (1977) reported that chicks of fledging age can out-run humans and suggested that they may prefer escape on foot to flight. One 25 day old chick on Assateague was capable of flight and appeared to be independent. I observed it on the brood's feeding territory, but the adults could not be located. In North Dakota, plover chicks have been observed in flight and considered fledged 21-28 days after hatch (Gaines and Ryan 1988). Whyte (1985) observed several chicks in flight 20-24 days after hatch and believed that chicks were fully fledged by the 27th day after hatch.

Based on the observations described above, I used 24 days as the basis for determining fledging success.

I took a conservative approach when determining a chicks age for the fledging success estimates. I considered the first day I observed a chick to be its first day of life. All chicks that disappeared before an age of 24 days were presumed not to have fledged, while those that I was able to locate at an age of 24 days or older were considered fledged.

I used a different approach to estimate the age of chicks when they perished. If I observed the nest on the day before hatch occurred, I considered my first observation of the chick to be the first day of life. If I had not observed the nest on the previous day, I considered its first day of life to be the mid point between the last nest observation and the time hatch was discovered. I used the same approach when assigning age of chick mortality. As a result, data that I present to show the distribution of chick mortality may indicate that some chicks perished at an age greater than 24 days.

## **MONITORING HUMAN USE**

I recorded human activity during nest searches, nest observations, and brood observations. Each person or vehicle observed in plover habitat was recorded. I recorded observations as I passed individuals.

## **HABITAT MEASUREMENTS**

After hatch, when plovers had left the nest site, I measured nesting habitat characteristics. The area around the nest was divided into four quadrants. In each quadrant, I extended a 12 m transect from a randomly selected angle beginning at the nest. Three randomly selected, 1 x 0.5 m plots were then sampled along each transect. Percent coverage by grass, forbs, shrubs, and dead vegetation was estimated for each 1 x 0.5 m plot using five cover classes (0-5%, 5-25%, 25-50%, 50-75%, and 75-100%). To calculate average percent vegetative cover for the nest site, I assigned each 1 x 0.5 m plot a value equal to the midpoint of the estimated vegetation cover class (e.g. 2.5% for the 0-5% class), summed the values of all 12 plots, then divided by 12.

I also sampled a one-meter circular plot around the nest, recording estimated percent vegetation cover and percent sand, shell, and cobble cover. Finally, I measured distances from the nest to the wrack line and to continuous vegetation. In Maryland and on portions of the Wild Beach not used for nesting, I selected random points between the wrack line and continuous vegetation and recorded similar habitat data.

## **BROOD FORAGING HABITAT CATEGORIES**

I have grouped broods into five categories (High Energy Beach, Bay, Storm Pool, Wash Flats, and Miscellaneous) based on the types of foraging habitats used during the first 3 weeks after hatch. Broods in the High Energy Beach category (N=12) occupied territories that did not contain saltwater pools and were separated from bayside feeding areas by dense intervening vegetation. They fed on the high energy beach and in the dunes. Broods in the Bay category (N=20) fed primarily on bayside sand or mud flats and showed little or no use of the high energy beach. Eight of these broods (40%) were never observed on or near the high energy beach (N=11-18 observations per brood). The remaining broods in this category were seen on or near the high energy beach on no more than 25% of the observations (N=4-21 observations per brood). Broods in the Storm Pool category (N=3) were never seen on the high energy beach (N=8-13 observations). Two were separated from bayside feeding areas by intervening vegetation, while a third was observed on a bayside sand flat during 38% of the observations (N=8). Broods on the Wash Flats remained in the waterfowl impoundment. I was not able to identify distinct foraging areas within the impoundment.

The Miscellaneous category includes three broods which I could not readily place in any of the other categories. Two of these broods fed along Ocean City Inlet as well as the high energy beach. Both had unvegetated access to the bay, although they were never observed

feeding on the bay. Additionally, one of these broods fed around a temporary saltwater pool. The final brood occupied a territory on the Wild Beach which did not provide access to bayside foraging areas, but was adjacent a tidal pool area. However, during the six observations before the brood perished, it was never observed foraging on the tidal pool area.

## RESULTS AND DISCUSSION

### POPULATION ESTIMATES

I estimated the breeding population on the Maryland portion of Assateague Island to be 17 pairs in 1986 (Table 4). In 1987, I estimated the Maryland breeding population to be 23 pairs and the Virginia population to be 46 pairs (Table 4).

My population estimates depend to a large extent on my ability to locate nests. While it is not possible to actually determine how effective I was at finding nests, the following observations suggest I was successful at finding nests early in the incubation period. Thirty-one of the 125 nests (25%) were located prior to clutch completion. Successful nests located after clutch completion were observed for an average of 19 days (Table 5).<sup>1</sup> I found only three broods that hatched from unlocated nests, all of which were on the Wash Flats. On the basis of these observations I believe my method of determining the breeding population provides reasonable estimates.

The 1985 population estimate for the Maryland portion of the island was 18-20 pairs (Hoffman 1985), suggesting that the

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<sup>1</sup> (Estimated incubation periods range from 26-29 days (Wilcox 1959, Cairns 1977, Haig 1987)).

population has been relatively stable over the past three years. The population estimate for Virginia was only 16-18 pairs in 1985 (Ailes 1985). The large difference between the 1985 and 1987 estimates may reflect differences in survey intensity rather than an increase in the population.

Nationally, piping plover populations reportedly are declining. The estimated decrease in the Atlantic Coast population between 1979 and 1984 was 27-30% (Haig and Oring 1985). However, populations in Virginia have not shown a decline in recent years. In 1985, the population at Chincoteague National Wildlife Refuge was described as stable (Haig 1985). Other barrier islands off the coast of Virginia have been surveyed since 1975. While individual islands show population shifts, the results of these surveys do not suggest a population decline for the state as a whole (Williams et al. 1988).

## **NESTING AREAS**

I found piping plovers nesting in four major areas on the island: north of the McCabe House, on a 4.3 km section of the Wild Beach, on the Wash Flats, and on the Hook from the ORV cross-over to Fishing Point (Fig. 2). Additionally, a few pairs were observed nesting in two other areas. Two pairs nested between the McCabe House and the state park interpretive trail in 1986, and one pair nested

in this area in 1987. During both years, a single pair nested in an overwash gap approximately 1 km north of the Maryland/Virginia state line. The same general distribution was observed in 1985, except no plovers were observed between the McCabe House and the state park in Maryland (Hoffman 1985, Ailes 1985).

## **BREEDING BIOLOGY**

### **Arrival of Breeding Birds**

Piping plovers are first observed on Assateague Island in mid-March (I. Ailes, B. Rodgers pers. commun.). Plovers were present in most of the nesting areas (Table 4) when I first arrived at the end of March. However, in 1986, the two territories south of the McCabe House did not appear to be occupied until a storm formed temporary saltwater pools in this area during the last week in April.

### **Courtship and Nest Initiation**

Courtship activities had already begun by early April. I frequently saw birds in pairs during even the earliest surveys in

April. Courtship displays were observed as early as 30 March in 1986 and 4 April in 1987. I found the first nest scrape on 4 April in 1986 and on 10 April in 1987.

I found 23 nests in 1986 and 102 nests in 1987. The earliest nest located contained one egg and was found on 18 April 1987. In 1986, nest initiation in Maryland peaked during the third week in May (Fig. 3). In 1987, nests were initiated at a relatively constant rate from the last week in April through the third week in June (Fig. 4). However, there were differences among the major nesting areas (Fig. 5). Nesting occurred earliest in Maryland and on the Wild Beach. Nesting occurred later on the Wash Flats because many of the plovers that nested in this area originally attempted to nest on the Wild Beach. The Hook appeared to be more heavily impacted by high spring tides, and this may have accounted for the delayed nesting in this area.

### **Renesting**

I considered 29 nesting attempts to be renests (excluding possible renests on the Wash Flats). The average time between nest loss and initiation of a second clutch was 9.05 days (SE = 0.69). Average distance between renests and the initial nesting attempts

was 209 m (SE = 59.06). Three renests were more than 600 m from the original nest (Fig. 6).

Similar periods between piping plover renesting attempts have been observed in two other studies. In Nova Scotia, the estimated interval between nest loss and initiation of a second clutch for two pairs was five days (Cairns 1977). At Big Quill Lake, Saskatchewan, the average interval was 6.8 days (range = 2 - 20 days, N=6) in 1980 and 9 days (range = 4 - 18 days, N=8) in 1981 (Whyte 1985).

Average distances between renests and original nests at Big Quill were 103 m (range = 60 - 185 m, N=6) in 1980 and 64 m (range = 13 - 129 m, N=8) in 1981 (Whyte 1985). Whyte reported that pairs tended to locate second attempts farther away from the initial attempt when distances between adjacent plover territories were greater. Two of the Assateague Island pairs that renested more than 600 m from the original nest occupied territories which were separated from the nearest territories by large distances. The initial nesting attempts of these two pairs were over 800 m from the nearest nesting attempts of another pair.

I believe that as many as 11 plover pairs which nested on the Wash Flats initially attempted to nest on the Wild Beach. Several observations support this belief. First, I observed banded plovers moving between the two areas. Second, there was a decrease in the number of pairs on the Wild Beach during the nesting season. On 16 May, there were 12 active nests. By 1 June, 10 of these nesting attempts failed. While I believe that two of these pairs renested

on the Wild Beach, the eight remaining territories were deserted after nest loss. Finally, nest initiations on the Wash Flats occurred later than on the Wild Beach, and seemed to follow the pattern of nest losses on the Wild Beach by one to two weeks during the end of May and the first week of June (Fig. 7).

Haig (1987) also found that some plover pairs changed nesting territories after nest loss. In Manitoba, 64% of the males (N=22) and 71% of the females (N=24) that renested switched territories before renesting (Haig 1987). Haig reported that plovers more frequently abandoned territories when nests were destroyed by storms than when nests were predated.

In addition to changing territories after nest loss, some pairs may break up and reneest with new partners. Whyte (1985) reported that two of four banded females abandoned their territories after nest loss while the males remained and renested with another mate. Haig (1987) reported that 41% of the adults which lost nests (N=96) abandoned their territories and were never seen on the study area again, while 52% renested. In her study, 41% of the renesting males and 28% of the renesting females (N=19) switched mates prior to renesting. These observations suggest that the number of breeding pairs within a nesting area may change during the breeding season.

### Late Arrivals

In 1986, I observed a small influx of plovers on the north end of Maryland during the last week in June and early July. Overall, from 6-9 plovers were involved. In one territory, a male who had previously appeared to be unmated was observed in a courtship display with a female on several occasions. The other new arrivals appeared to be already paired. In two areas these plovers engaged in courtship displays, but I did not observe any nesting attempts by these pairs. I believe that these plovers came from other breeding areas after unsuccessful nesting attempts.

### Clutch Size

I defined a complete clutch as a nest with four eggs, or a nest that had fewer than four eggs upon discovery, and the same number of eggs if observed at least three days later. Average clutch size in complete nests was to 3.67 eggs (Table 6). Observed clutch size in other studies has ranged from 2.83 to 3.96 eggs (Table 7).

## Egg Laying and Incubation Period

At two nests, a period of 4-5 days passed between the time I discovered the first egg and the time the second egg was laid. At two other nests, 3-4 days passed between the time the second and fourth eggs were laid. I was not able to determine the length of the entire laying period because I did not attempt to count eggs if a plover was on the nest.

In Nova Scotia and Saskatchewan, the laying interval between the first and last egg was 6-7 days (N=9) (Cairns 1977, Whyte 1985). The laying period for four-egg clutches in Manitoba averaged 6.2 days (range 4-8 days, N=10) (Haig 1987).

I located seven nests that were ultimately successful when they contained only one egg. Chicks were first observed from 29 to 35 days after these nests were discovered (Table 8). Ten other successful nests were located prior to clutch completion. At these nests, I first observed chicks 21 - 33 days after nest discovery (Table 8).

Cairns (1977) reported that incubation began after the third or fourth egg was laid and lasted 27-29 days (N=7 nests). At two other nests, incubation lasted at least 31-38 days. These nests were only 3 m apart, and Cairns suggested that increased territorial interactions between these pairs may have prolonged incubation periods. Haig (1987) reported that incubation began when the first egg was laid and lasted an average of 25.7 days (range 22-31, N=9).

In New York, Wilcox (1959) observed an average incubation period of 28.1 days (range=27-30, N=14).

The studies cited above suggest that four egg clutches are laid over a period of approximately six days and that incubation lasts approximately 28 days. A 34 day egg laying/incubation period is consistent with my observations.

### Fledging and Departure

Within 1-2 days of hatch, broods on Assateague left the nest site and moved to feeding territories. Typically, the family group remained together until chicks were able to fly. In 20 of 27 broods, I observed both adults with the brood at least once when chicks were 20 or more days old. After the third week, parents appeared to become less attentive and chicks fed further apart. Broods began leaving their territories in mid-July, although one brood with chicks 34 days of age was still on its feeding territory on 27 August in 1986. Mean age of fledged chicks when last observed on their feeding territory was 31 days (SE=0.59, N=49).

Observations from other studies have indicated that it is not unusual for one of the adults to desert the brood 7-10 days after hatch (Cairns 1977, Whyte 1985, Haig 1987). Gaines and Ryan (1988) reported that broods began to leave their feeding territories after

three weeks. Five broods in Saskatchewan left their feeding territories 27-30 days after hatch (Whyte 1985). Cairns (1977) reported that two broods in Nova Scotia left their feeding territories 32 and 47 days after hatch. Observations of marked birds have indicated that family groups do not remain together during migration (Cairns 1977, Whyte 1985).

## **NESTING HABITAT**

### **Nest Placement**

In Maryland, most nests (80%) were north of the McCabe House in areas without a dune line. A few nests were on dunes, in overwash gaps, and behind the primary dune (Table 9). Most nests on the Wild Beach (78%) were on dunes (Table 9). On the Hook, most nests were placed on the berm or on dunes (Table 9).

Average distance from nests to the wrack line was 82 to 144 m (Table 10). For nests separated from the bay by continuous zones of vegetation, average distance from nests to continuous vegetation was 75 to 99 m (Table 10). For nests not separated from the bay by vegetation, average distance between nests and the bay was 130 to 378 m (Table 10). Average beach width (distance from the wrack line to the bay tidal zone or complete vegetative cover) differed

significantly among the nesting areas, ranging from 157 to 276 m (Table 11). Average beach width was significantly wider in all nesting areas when compared to sections of the island where no plovers nested (Table 11). Within the northern 11 km nesting area, average beach width at random points was significantly less than average beach width at plover nests (Table 12).

The Wash Flats nesting area is not adjacent to the ocean or bay and is uniformly flat. Average distance from nests to complete vegetative cover was 133 m (SE=19.34, N=22).

Plovers generally nest well above the high tide line (Bent 1929), probably to avoid having nests washed out by high tides. However, Cairns (1977) found some nests in Nova Scotia on two-meter wide strips of beach between the wrack line and grassy dune vegetation. On three beaches in New Jersey, average distances from nests to water were 53 m (SE=21, N=5), 54 m (SE=35, N=17) and 61 m (SE=38, N=14) (Burger 1987). Although she did not report beach width, Burger did report that nests on these beaches were closer to the dunes and vegetation than to water. Whyte (1985) reported that average distance between plover nests and complete grassland cover at Big Quill Lake in Saskatchewan was only 4.69 m (range=0.9-28 m, N=37). He also found plovers nesting in alkaline patches as small as 17 m<sup>2</sup>. These observations suggest that beaches on portions of Assateague Island not used by breeding piping plovers in 1986 and 1987 were wide enough to support nesting despite being significantly narrower than beaches where nesting occurred.

I believe that the difference in average beach width between nesting areas and unused areas was related to foraging habitat rather than the amount of available nesting habitat. On the northern 11 km of Maryland and at Fishing Point, beach width was greater in areas that were not separated from the bay by zones of continuous vegetation ( $\bar{x}=345$  vs.  $\bar{x}=211$ , 21 df,  $P=0.0001$ ). Unused nesting areas in Maryland and the Wild Beach did not provide access to bayside feeding areas. On the Hook, 9 plover nests (38%) were in wide areas (250 to 350 m) that had large storm-formed saltwater pools. On the Wild Beach, 7 plover nests (30%) were in two wide areas (182 to 261 m) that supported these pools. On sections of the Wild Beach and of Maryland where plovers did not nest, there were no wide areas with pools.

### Vegetative Cover

The vegetative cover at nest sites consisted primarily of grass and forb species (Table 13). The most abundant grass species at nest sites on the Wash Flats was purple grass (Triplasis purpurea) while American beach grass (Ammophila breviligulata) was the most abundant grass on the other nesting areas (Table 14). Sand spurrey (Spergularia marina) was the most abundant forb species on the Wash Flats, sea rocket (Cakile edentula) was the most abundant

forb on the Hook, and seaside goldenrod (Solidago sempervirens) was the most abundant forb on the Wild Beach and in Maryland (Table 15). Bayberry was the most abundant shrub in all areas.

The average vegetative cover within 1 m of the nest ranged from 9.0 to 16.1 % (Table 16). At six nests (4.9%), vegetative cover in the one meter plot was greater than or equal to 50%. The average percent vegetative cover within 12 m of nest sites ranged from 7.2 to 17.4% in different nesting areas (Table 17). Nests on the Wild Beach had significantly greater vegetative cover than nests on the Wash Flats and in Maryland (Table 17). However, the two most heavily vegetated nest sites (> 50% vegetative cover) were north of the McCabe House in Maryland. On the Northern 11 km of Maryland, there was no significant difference between percent vegetation cover at nest sites and random points (Table 18).

Typically, piping plover nesting habitat is described as sparsely vegetated beaches (Bent 1929, Wilcox 1959, Haig 1987). Plovers are thought to desert nesting areas when vegetation becomes too dense (Wilcox 1959). However, few studies have quantitatively analyzed vegetative cover at nest sites, so it is not yet possible to identify the point at which vegetation cover becomes too dense for nesting. Niemi and Davis (1979) found a plover nesting in an area with 42% vegetative cover. Plovers nest on sites with up to 50% vegetative cover even in sparsely vegetated areas like the northern 11 km of Assateague Island.

Average vegetative cover within 12 m of random points on sections of Maryland and the Wild Beach not used by nesting piping plovers was significantly greater than vegetative cover in nesting areas on the northern 11 km of Maryland and the Wash Flats, but was similar to vegetative cover at nest sites on the Wild Beach (Table 17). This indicates that vegetative cover on portions of Maryland and the Wild Beach not used by breeding plovers was sparse enough to provide suitable nesting habitat.

### **Nest Substrate**

Sixty-one nests (49.6%) were placed on substrate consisting entirely of sand, and the remaining nests were placed on a mixture of sand, shell, and cobble. The average composition of the substrate at nests that had a combination of sand, shell, and cobble (N=62) was 62% sand, 22% shell, and 17% cobble. Nest sites on the northern 11 km of Maryland more frequently contained shell and cobble in addition to sand than random plots (Table 19).

Several studies suggest that piping plovers prefer to place nests in areas with shelly or gravelly substrate (Whyte 1985, Prindiville 1986, Burger 1987). Plovers showed this tendency on Assateague also. However, plovers on the Atlantic Coast continue to nest in areas with little or no shell and cobble in the substrate.

The average shell cover at nesting sites on Brigantine Beach ranged from 1 to 14% over a four year period (Burger 1987). On Assateague, 87% of the nests on the Wild Beach were on pure sand substrates and almost half of the nests on the entire island were on pure sand substrates.

### Human Activity

Nesting areas were not readily differentiated by the type of human access (foot only or ORV) and amount of early season recreational activity. Sixteen pairs established nests on the Hook where ORV use is allowed, but only one pair nested in the Maryland ORV section. The amount of early season recreational use observed in both ORV areas was similar (Table 20). Additionally, in both areas, the amount of ORV use is restricted based on a formula designed to allow a maximum of 12 vehicles per mile (I. Ailes, B. Rodgers pers. commun.).

No plovers nested in developed recreational areas, and during April and May, these areas received heavier recreational use than actual nesting areas (Table 21). However, plovers did not nest in all of the undeveloped, light use areas. Plovers were found nesting on only 4.3 km out of a possible 16.7 km of the Wild Beach section (Fig. 2). Additionally, no plovers were observed nesting on the Wash

Flats south of the cross-dike even though no recreationists were ever observed in this area.

Recreational use reportedly has reduced the amount of available plover nesting habitat in some areas. In Rhode Island, piping plovers failed to nest on Maschaug Beach for several years after ORV access to the beach was improved (Raithel pers. commun.). In 1987, ORV use was no longer possible on a portion of South Beach Island in Massachusetts. During this season, 4 pairs (50% of the population) nested in habitat that had been unavailable during previous years due to heavy ORV use (C. Griffin pers. commun.). Strauss (pers. commun.) believed that four plover territories on Barnstable Beach, Massachusetts were abandoned prior to nest establishment due to the presence of recreationists.

However, in other areas, plovers have continued to nest despite the presence of vehicles and pedestrians. Plovers began nesting on Maschaug Beach again 4 years after ORV access had been improved (Raithel pers. commun.). Niemi and Davis (1979) found plovers nesting successfully within 10 m of frequently used roads. Tire tracks were found within a few centimeters of one successful nest. Strauss (pers. commun.) reported that one of the most consistently used plover territories over a 5 year period was exposed to heavy pedestrian and vehicular traffic. Piping plovers have been nesting on the Hook at Chincoteague National Wildlife Refuge since at least 1978 despite heavy recreational use (Britton 1982, Ailes 1985).

Since plovers nested in areas with all types of recreational access, did not attempt to nest in all the light use foot-access-only areas, and have been nesting on the Hook for a number of years despite ORV use, I believe that recreational activity was not a major factor in determining the distribution of nesting on Assateague Island during the 1986 and 1987 breeding seasons.

## **NEST SPACING**

Average distance to the nearest nest of another pair (measured parallel to the wrack line) ranged from 93 m to 282 m in different nesting areas (Table 22). The nearest simultaneously active nests were 47 m apart.

In Nova Scotia, average distance between nests was 51 m (N=23 nests) and 53 m (N=27 nests) over a two year period (Cairns 1977). The closest active nests in Cairns' study were 3 m apart. Average distances between nests at Big Quill Lake in Saskatchewan were 155 m (range = 25 to 254 m, N=11 pairs) and 157 m (range = 51 to 256 m, N=9 pairs) over a two year period (Whyte 1985). On four beaches in New Jersey, average distances between nests were 70 to 153 m (N=132 nests) (Burger 1987). Plover nests at Lake Superior were placed a minimum of 50 m apart (Niemi and Davis 1979). Wilcox (1959) reported

that nests were rarely closer than 30 m apart and were usually more than 60 m apart.

With a mostly unbanded population and limited observation time, I was not able to estimate territory size. However, the average distance between nests observed in other studies generally has been less than the average distances I observed on all nesting areas except the Wash Flats. Combined with the large sections of the island that were not used for nesting, this suggests plover density on Assateague Island is not being limited by territorial interactions.

## **FORAGING HABITAT**

### **Types of Foraging Habitats**

Plovers foraged in several different types of habitats on Assateague. These included the high energy beach, bayside mud and sand flats, temporary saltwater pools formed by extremely high tides, and a drawn down waterfowl impoundment. Most broods on the island were categorized as feeding predominantly on bayside feeding areas or the Wash Flats (Table 23). The Storm Pool category was small, but I believe this reflects the poor nest success on the Hook in areas that potentially could have produced broods in this

category. Also, three pairs nesting in the vicinity of saltwater pools on the Wild Beach failed to produce young.

Use of foraging areas similar to those on Assateague has been observed in other studies. At Kouchibouguac Park, New Brunswick, the high energy beach appeared to be the main feeding area for piping plovers (Tull 1984). However, plovers also fed along isolated dune ponds and tidal flats on the lagoon side of the beach, and use of these areas increased in June and July. Cairns (1977) reported that plovers fed on sand flats on the lagoon side of Cadden beach and on the high energy beach. She did not report the relative amount of use each area received, however, a map showing nesting pairs' feeding territories indicates that 68% of the territories (N=22) were on the lagoon side of the island. Four of the seven pairs (57%) with feeding territories on the seaward side of the island also had feeding territories on the lagoon side. During recent surveys of barrier islands in Virginia, broods were more frequently observed on mudflats than on the high energy beach (K. Terwilliger pers. commun.). Flemming (pers. commun.) found that approximately 90% of the broods he observed in Nova Scotia fed on the bayward side of barrier islands rather than the high energy beach.

Although little is known about piping plover diet or the types of foraging habitats used by plovers, my observations on Assateague Island and observations from the studies cited above indicate that saltwater pools and bayside sand and mud flats are important foraging habitats in many areas.

## Nesting Distribution and Foraging Habitat

Plover nesting on Assateague Island appeared to be related to the distribution of such foraging habitats as bayside mud and sand flats, storm pools, and the waterfowl impoundment. Most plovers nesting on the northern 11 km of Maryland and on the Hook had access to bayside mud and sand flats and/or storm formed tidal pools. The Wild Beach nesting area was bounded on the north and south by large tidal pool areas and was parallel to the Wash Flats (Fig. 2).

The role of foraging habitat in breeding site selection has not been studied; however, two other researchers have noted a relationship between nesting activity and foraging habitats similar to those I described on Assateague. Fussell (1986) reported that some piping plover territories at Kathryn Jane Inlet, Cape Lookout National Seashore in North Carolina appeared to be closely associated with pools formed by a hurricane. The other nesting pairs were found on overwashes or inlet flats which provided unvegetated access to Core Sound. Areas that provided suitable nesting habitat, but were separated from the Sound by zones of grass or shrub thickets were not used. On Metompkin Island in Virginia, plover nests tended to be grouped in areas that provided easy access to mudflats (Cross 1987).

## Use of Foraging Habitats

I believe that adults nesting on the Wild Beach fed on the Wash Flats. Several observations support this belief. First, plovers were seen flying between the two areas. Additionally, plovers seemed to be absent from nesting areas on the Wild Beach much of the time during nest initiation. On 28 April I located 7 nest scrapes; however, I did not see any plovers in the vicinity of these scrapes. Because the Wild Beach is so narrow, I believe I would have been able to see the plovers if they had been feeding on the high energy beach. I also located two nests with incomplete clutches on this date; however, no adults were observed in the vicinity of these nests. Overall, adults were not observed at 7 of 10 Wild Beach nests located with a clutch of fewer than three eggs. These 10 nests were observed a total of 40 times prior to the estimated time of clutch completion. Adults were observed in the vicinity of these nests during only 19 observations (48%). I believe that on many occasions, adults were not observed at these nests because they were foraging on the Wash Flats.

In one other instance, an adult was observed feeding in an area that was not adjacent to the nesting territory. On the Hook, a banded plover that had an active nest was observed feeding on a bayside mud flat over 900 m from the nest. Since so few of the adults were uniquely banded, it is possible that feeding at areas distant from the nest occurred more frequently than I noted.

Cairns (1977) also noted that piping plovers used feeding areas that were not adjacent to nesting areas. After reaching Cadden Beach, Nova Scotia in the spring, piping plovers initially fed in loose flocks on neutral feeding areas (Cairns 1977). During incubation, much feeding occurred on the nesting territory, but pairs also fed on the neutral tidal flats.

Other shorebirds also have been observed using feeding areas outside of their nesting territories during the nesting period. In Greenland, ringed plovers (Charadrius hiaticula) fed on both defended territories and neutral areas during territory establishment (Pienkowski 1984a). In one nesting area, adult ringed plovers most frequently foraged on intertidal flats well away from the nesting territory. Nonincubating female golden plovers (Pluvialis apricaria) in Norway went to distant feeding areas away from the nesting territory during seven of eight observations (Byrkjedal 1985). Howe (1982) reported that willets (Catoptrophorus semipalmatus) often maintained feeding and nesting territories separated by as much as 500 m.

Plover broods on Assateague did not always use the foraging areas that were used by the adults during nest initiation and incubation. Broods on the Wild Beach did not move to the Wash Flats to feed. Chicks in three broods on the northern end of Maryland were not observed on mud flats that had been used by adults during courtship and nest incubation.

Some broods moved considerable distances to feeding areas. Five of 38 broods moved more than 600 m (distance measured parallel to the wrack line) to foraging areas. Overall, 18 of 38 broods moved to feeding areas more than 100 m from the nest (Fig. 8).

At Cadden Beach, Nova Scotia, piping plover broods continued to return to the nesting area when not feeding (Cairns 1977). Broods at Big Quill Lake, Saskatchewan (N=7) abandoned the nest site approximately two days after hatch and moved to feeding areas (Whyte 1985). Four of the seven broods fed in areas directly below the nest. The remaining broods ranged widely and were seen as far as 310 m, 430 m, and 1600 m from the nest.

Several other shorebird species are known to abandon nesting territories and move to new feeding areas after hatch. Most ringed plover broods breeding at Mestersvig, Greenland left nest sites after hatch and moved to better foraging areas (Pienkowski 1984a). Little ringed plovers (Charadrius dubius) in Holland usually left the nesting territory and went to new feeding spots after the chicks hatched (Simmons 1956). After hatch, seven of eight killdeer broods (Charadrius vociferus) in Minnesota were taken to feeding territories away from the nesting territory (Lennington 1980). Holmes (1966) reported that dunlin broods (Caladris alpina) roamed freely after hatching, feeding in areas which had not been part of the nesting territory.

Cairns (1977) reported that plovers maintain both feeding and nesting territories during the breeding season. Use of foraging

areas that are distant from the nest site suggests that these are two distinct types of territories. This hypothesis is supported by Cairns' (1977) data. In several cases, the nesting and feeding territories of a pair were separated by the nesting territories of another pair.

There are several possible explanations for the use of different foraging areas during nesting and brood rearing. Because they cannot fly, broods may not have access to foraging areas used by adults earlier in the season. The Wild Beach and Wash Flats on Assateague are separated by a zone of dense grass and shrub vegetation that is generally more than 250 m wide.

Movement of broods to new foraging areas also may indicate that prey availability changes throughout the season. Pienkowski (1984b) believed that ringed plover broods at Mestersvig moved because of changes in prey availability. The new feeding sites had greater densities of small flies, the major prey item taken during this period. Holmes (1966) reported that dunlin nesting in Alaska changed foraging habitats during the breeding season in response to changes in prey availability (43-44). Another possible explanation for the use of different foraging areas during the season is that dietary needs may change.

In two other studies, movement of piping plover broods has been attributed to other factors. Whyte (1985) suggested that the movement of three broods at Big Quill Lake was due to the fact that adjacent territories were no longer occupied rather than changes in

food supply. Strauss (pers. commun.) observed some broods in Massachussets moving to feeding areas over 200 m from nest sites, but he thought that many of these broods were forced to move as a result of human disturbance.

## **PRODUCTIVITY**

### **Nest Success**

I found 125 nests on Assateague during the two breeding seasons. Additionally, I found 3 broods from unlocated nests on the Wash Flats. Fifty-eight of the clutches found prior to hatch (46%) produced at least one chick. Daily nest survival rate (Mayfield 1975) was highest on the Wash Flats and lowest on the Hook (Table 24). Probability of nest success calculated using Mayfield's method and a 34-day egg laying/incubation period ranged from 9% - 84% on different nesting areas (Table 24).

I knew the actual number of eggs present in 55 of the successful nests. At least 70% of these eggs hatched (Table 25). Twenty-seven eggs (13%) were abandoned on the nest after the remaining eggs hatched. I was unable to determine the fate of 15% of the eggs in successful nests.

## Factors Influencing Nest Success

Nest Predation.-- Predation was the leading cause of nest loss, accounting for 63% of the total nest failures (Table 26). Red foxes were the primary predators in Maryland and on the Hook (Table 27). In both areas I believe that only one or two fox families were responsible for all losses. Raccoons (Procyon lotor) were the major predators on the Wild Beach (Table 27). No predation was observed on the Wash Flats.

Nest predation has been found to be a leading cause of nest loss in many studies (Table 28). Red foxes were also the primary predators on Barnstable Beach (1982-1986) and Coast Guard Beach (1985-1986) (Strauss pers. commun., MacIvor et al. pers. commun.). Other potential predators include opossums (Didelphis virginiana), skunks (Mephitis mephitis), domestic pets, grackles (Quiscalus spp.), gulls (Larus spp.), and fish crows (Corvus ossifragus) (U.S. Fish and Wildlife Service 1988a, this study).

Predation has been identified as a factor contributing to the decline of piping plovers (U.S. Fish and Wildlife Service 1988a). An issue that has not been addressed in detail is why predation pressure has increased to the point that it appears to be major factor in the current population decline. On nesting beaches that are used by recreationists, it has been suggested that predation pressure has increased because predators are attracted to these

areas by garbage and foodscraps that recreationists leave behind. (Federal Register 1985, Strauss pers. commun.).

A reason that red fox predation may have become a problem only recently is that the red fox may not be a natural component of Atlantic Coastal beach communities. European red foxes were introduced into New York, Maryland, and Virginia between 1650 and 1750 by fox hunters (Churcher 1959, Gilmore 1949). The native red fox may have been limited to northern boreal forests or the northwestern portion of the continent, and the present population in the middle eastern U.S. may be descended from European introductions (Churcher 1959, Rhoads 1903, Gilmore 1946).

Finally, predation pressure may have increased as a result of human-induced changes in plover habitat. The loss of prime nesting habitat due to beach development may force plovers to nest in areas that would otherwise be avoided due to high predation pressure. Habitat changes associated with beach stabilization efforts also may increase the risk of predation.

Beach stabilization efforts change potential plover nesting habitat in several ways. First, stabilization efforts create a narrower, steeper berm (Dolan 1973, Godfrey and Godfrey 1973). Narrower beaches may make it easier for predators to locate nests. However, my data from Assateague do not suggest a relationship between beach width and nest success. Nest survival rates were similar on the Wild Beach and Hook (the widest and narrowest nesting areas) (Tables 11 and 24). However, this comparison may not be

appropriate since different predators were responsible for the losses in each area. Within nesting areas, beach width and distance from the nest to the wrack line did not differ between nests lost to predators and other nests (Table 29).

Two other ways that beach stabilization changes nesting habitat are by promoting vegetation growth closer to the high tide line and promoting denser vegetation growth on dunes (Dolan 1973 and Godfrey and Godfrey 1973). Prindiville (1986) found that vegetative cover around unsuccessful piping plover nests was greater than at successful nests during the first year of her two-year study. Burger (1987:16) suggested that plovers nesting near vegetation may be exposed to increased predation because predators (fox and American crow (Corvus brachyrhynchos)) can apparently learn to search vegetation for nests or chicks.

A study by Byrkjedal (1987) indicates a second way in which increased vegetation cover may increase the risk of predation. He suggested that for a shorebird that responds to mammalian predators by leaving the nest, there is a minimum flushing distance. Beyond a certain minimum distance, a predator is less likely to find the nest if a bird flushes. When a predator is closer than this distance, it is more advantageous for the plover to remain on the nest rather than flush. It is possible that vegetation may reduce plovers' ability to detect predators until after this minimum distance, thereby increasing the risk of predation when the bird flushes.

Nest survival rates on Assateague Island were lowest on the Hook and the Wild Beach, the two most heavily vegetated nesting areas (Tables 17 and 24), although the difference in vegetative cover was not great. When all nesting areas were combined, predated nests had significantly greater vegetative cover within 12 m of the nest than other nests, but again, the difference in average cover was not great (Table 30). Within nesting areas, mean percent vegetative cover within 12 m of the nest at predated nests was not significantly greater than at other nests (Table 30). Also, mean percent vegetative cover within one meter of the nest did not differ significantly between predated and other nests (Table 30).

A final way in which beach stabilization may increase the risk of predation is by reducing overwash. Overwash forms a coarse, shelly covering on the berm (Godfrey and Godfrey 1973). Several researchers (Whyte 1985:90, Burger 1987:17, Gaines and Ryan 1988) have suggested that piping plovers may select shell and gravel substrate to provide camouflage for their eggs. Gaines and Ryan (1988) reported that nests placed on gravel substrates had significantly higher success (51%, N=71) than nests on alkali substrates (15%, N=21).

Substrate type on Assateague did not appear to influence nest survival rates. In Maryland, probability of nest survival was significantly higher on pure sand substrates than on substrates with a mixture of sand shell and cobble (Table 31). On the Wild Beach the difference was not significant, although nests on pure sand substrates had lower survival rates (Table 31). On the Hook, nests

on pure sand substrates had higher survival rates, although the difference was not significant (Table 31). Within nesting areas, the percentage of sand in the substrate did not differ between nests lost to predators and other nests (Table 32).

Recreational Disturbance.-- I have no evidence that suggests direct loss of nests due to recreational activity was a major problem. The only nest lost that I attributed to direct human destruction occurred on the Hook (Table 26). This nest was crushed by a car. I was not able to identify the probable cause of 21 (31%) nest losses. At ten of these nests (48%), however, I believe the cause to be other than human destruction since signs of human activity would have been evident if recreationists had been directly responsible for the loss. At the remaining nests, high winds or heavy rain erased all evidence that may have indicated the fate of the nest.

Recreational use was not observed to result in nest desertion. The only nest abandonment observed occurred in late April after a violent storm that may have destroyed two of the three eggs in the clutch.

The indirect effects of human activities are more difficult to assess. Recreational activity increased after May on the north end of Maryland and on the Hook in Virginia (Tables 33-34), but nest productivity in these two areas did not decrease significantly as a result. Daily survival rates and probability of nest survival for early season nests (initiated prior to the fourth week in May) and

late season nests (initiated during or after the fourth week in May) were not significantly different (Table 35). Egg hatchability<sup>2</sup> in successful nests was similar for early and late season nests (Table 36). Although 19% of the eggs in successful nests in these two areas were abandoned after the remaining eggs hatched, the percentage of nests with abandoned eggs was highest early in the season (Table 37).

Many observations linking human disturbance to decreased nest success involve direct mortality: e.g. nests being crushed by cars or stepped on by people (U.S. Fish and Wildlife Service 1988a:20). The symbolic fencing on the Hook appears to provide adequate protection from direct destruction. Since these fences were first used in this area in 1978, none of the piping plover nests within the fences are known to have been lost to direct human destruction (Britton 1982, Ailes 1985, this study). At the current level of recreational use and density of nesting plovers, direct destruction of nests by humans does not appear to be a problem in Maryland, on the Wild Beach, and on the Wash Flats.

The indirect effects of human activities on productivity are not well understood. While some plovers may flush from nests when people are more than 80 m away (Cairns 1977), they can apparently become habituated to human activity nearer the nest. On a heavily used recreational beach in Massachusetts, plovers allowed people to approach within 20 m before flushing, (Strauss pers. commun.).

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<sup>2</sup> Number of chicks observed immediately after hatch divided by number of eggs in the clutch.

Cairns (1977:79) found that some plovers on heavily used recreational beaches allowed humans to approach as close as 3 m before flushing. She felt that the mere presence of people probably does not affect reproductive success (Cairns and McLaren 1980). Flemming (1984:24) found no difference in nest success when comparing areas with different levels of recreational activity.

Research Activities.-- It is not possible to precisely assess the extent to which my research activities affected nest success. However, on the basis of the following observations, I believe that the impact of research activities on nest productivity was not great, and that it would be appropriate to use similar methods in future studies.

There was no indication that research activities caused plovers to abandon nests. The only abandoned nest I observed was deserted after a severe, two-day storm that may have destroyed two of the eggs in the clutch. This storm began early in the incubation period, one to two days after the third egg had been laid.

Nest success did not appear to be related to the amount of time that nests were under observation. Success rate of clutches found prior to clutch completion (N=31) was greater (0.55) than the overall success rate (0.46, N=125). In 1986, 82% of the pairs eventually produced at least 1 young. In one area (Wash Flats), the success rate of nests located prior to hatch was 0.91.

Trapping did not appear to influence nest success. Sixty-five percent of the nests that I attempted to trap (N=40) eventually

produced hatchlings. Success rate of untrapped nests that survived to trapping age (approximately 12 days, N=61) was 0.53. All nests that I attempted to trap twice (N=6) produced hatchlings.

### Chick Survival and Fledging Rate

Average brood size on the first observation after hatch was 2.5 chicks (Table 38). In Virginia, initial brood size was lower than brood size in Maryland (Table 38). In part, this is due to smaller clutch sizes in Virginia (Table 39). Virginia also had a larger number of eggs with unknown fates (Table 25).

Percent chick survival in different nesting areas ranged from 8.3-100% (Table 40). In 11 broods (29%), all chicks were missing and presumed dead prior to fledging. Only 11 broods (29%) fledged 100% of their chicks. I was not able to estimate fledging success on the Wash Flats due to the fact that I had trouble observing chicks and identifying individual broods in this area.

Most chick mortality (79%) occurred during the first 10 days after hatch (Fig. 9). No mortality occurred between day 10 and 18, while mortality increased again after day 17. Average brood size at time of fledging was 1.81 chicks (N=27 broods). Reproductive rate (chicks fledged per nesting pair) was 0.19 - 2.00 chicks per breeding pair (Table 40).

The age distribution of chick mortality I observed on Assateague differs from that observed by Flemming (1984:31) and Prindiville (1986:11). In Nova Scotia, Flemming reported that most chick mortality occurred between 10 and 17 days after hatch. Prindiville did not observe any mortality in broods after chicks reached an age of 16 days. Estimated reproductive rates in other areas have ranged from 0.0 to 2.1 young per nesting pair (Table 41).

Determining the level of productivity necessary to maintain a stable population is difficult due to absence of data on adult and post-fledging survival rates. In North Dakota, Gaines and Ryan (1988) calculated a minimal piping plover adult survival rate of 0.634. Using a juvenile survival rate that was 80 - 100% of the adult survival rate, they estimated that between 1.15 and 1.44 chicks must be fledged per pair to maintain a stable population. In Massachusetts, Griffin et al. (pers. commun.) observed an adult survival rate of 0.73 and a juvenile survival rate of 0.43. Using these survival rates, 1.25 - 1.35 chicks must be fledged per pair to maintain a stable population. These estimates suggest that the reproductive rate in Maryland was slightly lower than necessary to maintain a stable population, while the observed reproductive rate on the Wild Beach and Hook in Virginia was much lower than the required level.

## Factors Affecting Chick Survival

I was able to account for the loss of only one chick. It belonged to a brood that fed west of the dunes between the state park and the McCabe House. This chick was discovered crushed on the road leading to the McCabe House. During the 44 hours of extended brood observations, I observed only one predation attempt. A ghost crab seized a recently hatched chick, but an adult plover immediately attacked the crab forcing it to release the chick.

Fledging success did not differ between areas with and without ORV use (Table 42). However, fledging success differed significantly among broods using different foraging habitats (Table 43). Seven of 12 broods in the High Energy Beach category (58%) fledged no chicks, while only 3 of 19 broods in the Bay category (16%) fledged no chicks. The age distribution of chick mortality also differed among foraging habitats (Fig. 10). Seventy-nine percent of the chicks in the High Energy Beach category (N=33) died during the first 10 days of life, while only 13% of the chicks in the Bay category (N=53) died during this period. This suggests that broods in the two different foraging habitats were influenced by different mortality factors or the same factors operating at different intensities. Higher mortality rates and earlier demise of broods in the High Energy Beach category could indicate a deficiency in food resources, higher predation rates, or differences in the level of human disturbance.

Little is known about factors affecting chick survival. Recreational disturbance is thought to be an important factor in some areas (U.S. Fish and Wildlife Service 1988a). Strauss (pers. commun.) reported that recreational disturbance caused some plovers on Barnstable to move to less disturbed feeding areas more than 200 m from the nests. The probability of fledging for broods that moved less than 200 m was almost twice as high as that for broods that moved more than 200 m. On Assateague Island, 12 of 38 broods moved to feeding areas more than 200 m from the nest. Average percent fledging success in these broods was higher than in broods moving less than 200 m, although the difference was not significant (Table 44). This suggests that plovers on Assateague were not being forced to lower quality foraging areas.

Cairns' (1977) study is frequently cited to indicate the adverse impacts recreational activity may have on piping plover reproductive success. She observed a reproductive rate of 1.3 to 2.1 chicks/pair at a low human-use beach while eight smaller beaches that had higher levels of recreational use had a combined reproductive rate of 0.7 to 1.1 young/pair.

Cairns speculated that the difference in the amount of recreational use might have been responsible for the difference in productivity. A weakness with this hypothesis is that at least two (possibly three) of the eight high human use beaches had a reproductive rate in the same range as that observed at the low human use beach. Other factors such as differences in predation rates or

habitat quality were not evaluated. Since Cairns' study, plover productivity at Cadden beach has plummeted, largely due to avian nest predation. In 1983, two of the eight high use beaches had a reproductive rate higher than that observed on Cadden beach in 1976 (Flemming 1984), suggesting that other factors influencing fledging rates on these beaches should be evaluated.

A second study from Nova Scotia is commonly used to demonstrate the adverse impacts of recreational activity. Flemming et al. (1988) found that broods in areas receiving 20 or fewer recreational visits per week had higher fledging rates than broods in areas with 24 or more human visits per week. Furthermore, they reported that broods appeared to react to humans approaching within 160 m. During the first three minutes of this type of disturbance, chicks spent more time sitting and being vigilant and less time feeding and brooding. ORV's did not appear to cause a major disturbance; chicks ignored or passively avoided moving vehicles.

## CONCLUSIONS

I estimated the piping plover population on Assateague Island to be 69 pairs in 1987. This represents 9% of the known Atlantic Coastal breeding population, 46% of the known population in Virginia, and 100% of the known population in Maryland (Piping Plover Recover Team unpubl. data). The population appears to have been relatively stable since 1985. While this is counter to the national trend of declining populations, it is consistent with the trend observed on Virginia's barrier islands since 1975.

Piping plovers arrive on Assateague in mid-March. Nest initiation begins in mid-to-late April. Egg laying and incubation last approximately 34 days. Chicks are able to fly in about 25 days, but often remain on their feeding territories until they are 30 days old. The earliest broods may leave their feeding territories beginning in mid-July. However, late hatching broods may still be on their feeding territories until the end of August.

Although plovers nested in only a few areas on the island (Fig. 2) and nesting activity appears to have been limited to these areas since at least 1985, I found no evidence that the distribution was limited by lack of suitable nesting habitat. The Wild Beach was the most heavily vegetated of the potential nesting areas examined and I found 23 nesting attempts on portions of this beach. Results from

this and other studies suggest that plovers prefer to nest on shelly substrates, but pure sand substrates are commonly used when shell covered areas are not available. The difference in beach widths between nesting areas and unused areas probably reflects the presence of foraging areas rather than a minimum beach width necessary for nesting. Results from other studies suggest that unused beaches on Assateague were still wide enough to support nesting.

I was not able to estimate territory size, but comparison of the average distance between nests on Assateague to distances observed in other studies (Wilcox 1959, Cairns 1977, Whyte 1985, Burger 1987) suggests that territorial interactions were not limiting the amount of available nesting habitat.

I do not believe that recreational use was a major factor in determining the observed nesting distribution. Plovers nested in areas with both types of recreational access (ORV and foot only) and did not nest in some areas which received relatively light recreational use. I found no evidence that plovers were abandoning territories or nests as a result of recreational disturbance.

I think that the pattern of nesting observed on the island was determined by the presence and accessibility of certain types of foraging habitats. Foraging habitats that seemed to influence nesting distribution included bayside mud and sand flats, saltwater pools formed by storm tides, and the drawn down waterfowl impoundment.

Productivity on Assateague differed greatly among nesting areas, and overall, was slightly lower than two recent estimates of the level necessary to maintain a stable population (Gaines and Ryan 1987, C. R. Griffin et al. pers. commun.)

Poor nest success was a major problem, particularly on the Hook where 93% of the pairs that did not fledge any chicks were unsuccessful in the nesting stage. The leading cause of nest loss was nest predation, accounting for at least 63% of the nest failures. The primary predators were red foxes and raccoons. One nest (0.8%) was crushed by a car, but I do not have any other evidence that links poor nest productivity to disturbance associated with recreational use.

Chick mortality appears to be substantial (51%, N=101). However, high prefledging mortality rates appear to be typical for *charadrii* (Table 45). Of the three major nesting areas on Assateague for which chick survival was estimated, only the Wild Beach falls substantially below the survival rates reported for other *charadrii* (Table 45).

I was not able to identify factors responsible for chick mortality. One chick was crushed by a car, but this occurred on a road which is not open to recreational vehicles and only one brood used this area during 1986 and 1987. Chick survival was similar between areas with and without ORV use. Chick survival was related to the type of foraging habitat used. Broods feeding on bayside foraging habitats had a much higher survival rate than broods that

did not have access to bayside feeding areas or saltwater pools (Table 43).

## **MANAGEMENT RECOMMENDATIONS**

Efforts to improve productivity should focus on reducing nest predation. Two methods of reducing predation are predator removal and predator exclosures.

The refuge has been trapping predators since 1983, removing as many as 86 raccoons and 35 foxes in a single year (Ailes pers. commun.). However, nest predation rates were high during the 1987 breeding season. Since one or two predators may be responsible for the predation in a single nesting area, and since foxes and raccoons may readily disperse into vacant habitat, unfocused trapping will probably not be effective. If trapping is used, efforts should be concentrated on specific individuals immediately prior to the breeding season. During the breeding season, nesting areas should be monitored for predators and trapping should be continued as often as needed to keep the nesting area predator free.

Electric fences have been used to reduce fox activity in other shorebird nesting areas (Forster 1975, Patterson 1977). In North Dakota, electric fences were used to protect nesting beaches adjacent to lakes, and nest success increased (P. Mayer and M. Ryan

pers. commun.). Electric fencing appeared to reduce fox predation on shorebird nests at Chincoteague National Wildlife Refuge in 1979, but was not effective during the following two years (Britton 1982).

Predator exclosures constructed around individual nests are another alternative. Experiments with killdeer and piping plovers indicate that these birds continue to attend nests that are protected by these exclosures (Nol and Johnson 1979, Griffin et al. pers. commun.). The exclosures around killdeer nests effectively reduced avian predation, but due to the small size, raccoons were able to reach the eggs (Nol and Johnson 1979). Larger exclosures were used around plover nests, and preliminary experiments suggest that they may effectively reduce mammalian predation (C. R. Griffin et al. pers. commun.).

Direct destruction of nests by recreationists was not a problem during the 1986 and 1987 breeding season. Symbolic fencing appears to be an effective means of eliminating this problem. Indirect impacts are more difficult to identify. However, it appears that nesting plovers are capable of habituating to some levels of recreational activity. Since plovers nest well above the high tide line, restricting recreational use to narrow zones immediately adjacent to the high energy beach using symbolic fencing may effectively eliminate significant disturbance to plovers nesting on beaches with a wide berm.

Foraging areas used by the plovers should be identified. On beaches where broods forage on bayside mud and sand flats, the

symbolic fencing used to protect the nesting area may also adequately protect foraging sites. However, in areas where plovers feed primarily on the high energy beach, it may be necessary to close the beach to recreational use even if nest sites can be adequately protected.

## **RESEARCH NEEDS**

Plover Foraging Ecology--. Cairns (1982) reported that piping plover feeding and nesting territories were usually contiguous, but in some cases, a pair's nesting and feeding territories were separated by the nesting and feeding territories of another pair. Combined with the fact that piping plovers and other shorebird broods readily abandon nest sites, this indicates that nesting and feeding territories are two distinct types of territories. Studies evaluating plover habitat have focused on nesting habitat, while little is known about the role of foraging habitat in breeding site selection. This aspect of plover ecology needs to be examined if efforts to identify and protect critical habitat are to be successful. Since adults and chicks may use different foraging areas, studies examining foraging behavior should be conducted throughout the breeding season.

My observations indicate that important foraging areas on Assateague Island include mudflats, damp sand flats, and salt water pools. Use of these types of foraging areas has been noted in several other studies (Cairns 1977, Tull 1984, Fussell 1986, Cross 1987, Terwilliger pers commun., Flemming pers. commun.). Since artificial beach stabilization reduces overwash, forms narrower, steeper beaches, and promotes vegetation growth (Dolan 1973, Godfrey and Godfrey 1973), it is possible that these efforts degrade plover breeding habitat by decreasing the availability and accessibility of the foraging habitats described above. The effects of beach stabilization on plover foraging habitat should be evaluated.

Another important foraging area on the island was a waterfowl impoundment on the Wash Flats. This suggests the possibility of increasing breeding habitat by creating artificial foraging habitat suitably juxtaposed to nesting habitat. Additional research should be conducted on the Wash Flats to determine chick survival, types of prey taken by plovers, and factors influencing prey availability.

Chick survival in broods using bayside foraging habitats was higher than survival in broods that did not have access to these areas and fed on the high energy beach. This could have been due to differences in the availability and/or quality of prey, differences in predation pressure, or differences in the level of human disturbance.

The early deaths of chicks in the High Energy Beach category is consistent with the hypothesis that differential fledging success

results from variable foraging habitat quality. Precocial shorebird chicks frequently exhibit little weight gain or even weight loss during the first day or two after hatch (Soikkeli 1967, Cairns 1977, Pienkowski 1984b), but they grow rapidly afterwards. Pienkowski (1984b) found that ringed plover chicks in Greenland grew at a rate of 2-2.5 g per day beginning 2-3 days after hatch and continuing through most of the pre-fledging period. Thus, inadequate food supply could result in deaths at an early age. Cairns (1982) data also suggests the possibility that mortality at an early age was due to inadequate food resources. In her study, chicks with the lowest weights between the ages of 6 and 13 days died before reaching an age of 14 days.

High productivity in bayside foraging areas could also result from different predation rates. Plovers could seek these areas because predation pressure is lower. If foxes and raccoons are the primary chick predators, this hypothesis seems less likely than the previous one since plovers showed a preference for mudflats on Metompkin Island where there was no evidence that mammalian predators were present (Cross 1987). However, mammalian predators are not the only potential chick predators; others include gulls and ghost crabs, which may occur at greater densities on the front beach.

I believe it is unlikely that human disturbance is the sole factor responsible for the difference in chick survival since the lowest fledging rate observed was on the Wild Beach in Virginia. While Strauss (pers. commun.) thought that recreational disturbance

was forcing broods to move to new foraging areas, thereby increasing mortality, this did not appear to be the case on Assateague. Chick survival rates in broods moving to foraging areas more than 200 m from the nest were similar to the survival rates in broods moving shorter distances. Finally, plovers on Metompkin Island also appeared to have a preference for mudflat foraging habitats even though this island receives little recreational use during the breeding season (Cross 1987).

It is also possible that the three factors described above (quality of the foraging areas, predation rates, and human disturbance) interact to produce differences in chick survival. For example, chicks foraging in poor quality habitats may have a lower tolerance for interruptions to foraging activities. Or, human disturbance may intensify predation pressure by distracting adults which might otherwise be protecting chicks from natural predators such as ghost crabs.

Each of the three hypotheses regarding the relationship between chick survival and foraging habitat needs to be evaluated. Foraging habitat studies should evaluate the relative abundance of prey items in different foraging habitats and compare growth of chicks feeding in different foraging habitats. Extended brood observations may help to identify the role of predation in chick mortality, although many researcher-hours of observation will be required. Predator foraging patterns should be studied to estimate the relative predation pressure in different foraging habitats.

Research on the role of recreational disturbance should focus on the distance at which plovers react to humans and the degree to which they become habituated to human presence.

Nest Predation.-- Plover management can be improved through a better understanding of factors influencing nest predation rates. An important question which needs to be addressed is why predation appears to be an important factor in the current decline. It has been suggested that human presence on the beach attracts predators and increases predation rates. While this is a plausible hypothesis, these claims are poorly documented. A specific goal of predation studies should be to determine the extent to which humans influence the activities of predators. If humans do attract predators, it may be possible to change the recreational behaviors which attract predators while still leaving some beaches open to recreational use. The relationship of other human activities (e.g. habitat changes resulting from beach stabilization efforts) on predation rates should also be evaluated.

Foxes and raccoons were the primary nest predators; however, they were not a problem in the same areas. Additionally, in one nesting area, no nest predation was observed. Predator foraging patterns should be examined to determine why this is the case. It may be possible to reduce predation pressure by creating breeding habitat in areas with lower predation rates.

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## VITA

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## **TABLES**

Table 1. Definitions of terms describing beach habitat.

| Habitat Term      | Definition                                                                                                                                                                                                              |
|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| High Energy Beach | - portion of the beach which is subject to wave action during normal tides.                                                                                                                                             |
| Wrack Line        | - layer of seaweed and other debris which accumulates above the high tide line.                                                                                                                                         |
| Berm              | - horizontal portion of the beach between the wrack line and the dune line. On portions of the island where there is no dune line, this refers to the area between the wrack line and the bay or continuous vegetation. |
| Interdune Zone    | - area west of the dune line extending to complete vegetative cover.                                                                                                                                                    |
| Overwash Gap      | - break in the dune line formed by over-washing storm tides.                                                                                                                                                            |

Table 2. Temperature and precipitation on Assateague Island 1986 (National Oceanic and Climatic Data Center).

|        | TEMPERATURE (°C) |              |      | PRECIPITATION (cm) |                       |                       |
|--------|------------------|--------------|------|--------------------|-----------------------|-----------------------|
|        | Avg.<br>Max.     | Avg.<br>Min. | Avg. | Total (cm)         | Days w/<br>>0.25 (cm) | Days w/<br>>1.27 (cm) |
| 1986   |                  |              |      |                    |                       |                       |
| March  | 13.7             | 0.3          | 7.1  | 0.97               | 2                     | 0                     |
| April  | 16.6             | 5.9          | 11.3 | 5.41               | 5                     | 1                     |
| May    | 23.0             | 11.3         | 17.2 | 3.15               | 2                     | 1                     |
| June   | 26.9             | 15.7         | 21.6 | 4.34               | 5                     | 0                     |
| July   | 31.0             | 20.1         | 25.6 | 5.13               | 5                     | 1                     |
| August | 28.4             | 18.7         | 23.6 | 23.88              | 8                     | 6                     |
| 1987   |                  |              |      |                    |                       |                       |
| March  | 11.0             | 1.3          | 6.3  | 11.66              | 9                     | 3                     |
| April  | 14.3             | 6.7          | 10.5 | 10.08              | 7                     | 2                     |
| May    | 21.2             | 11.7         | 16.4 | 9.09               | 6                     | 3                     |
| June   | 28.2             | 17.6         | 22.8 | 5.33               | 4                     | 1                     |
| July   | 31.1             | 20.9         | 26.0 | 13.31              | 6                     | 6                     |
| August | 29.7             | 20.2         | 25.0 | 3.86               | 5                     | 0                     |

Table 3. Number of searches for piping plover nests, by section on Assateague Island during April and May, 1986-1987.

| SECTION                      | 1986  |     | 1987  |     |
|------------------------------|-------|-----|-------|-----|
|                              | APRIL | MAY | APRIL | MAY |
| MARYLAND                     |       |     |       |     |
| Ocean City Inlet - 4.0 km    | 6     | 7   | 4     | 5   |
| 4.0 km - State Park          | 6     | 6   | 5     | 4   |
| State Park - Dune Crossing 3 | 6     | 3   | 4     | 1   |
| Dune crossing 3 - Stateline  | 6     | 3   | 5     | 1   |
| VIRGINIA                     |       |     |       |     |
| Wild Beach                   |       |     | 4     | 3   |
| Toms Cove                    |       |     | 4     | -   |
| Hook                         |       |     | 3     | 5   |

Table 4. Piping plover population estimates for Assateague Island 1986-1987.

|                                        | Number of Breeding Pairs |      |
|----------------------------------------|--------------------------|------|
|                                        | 1986                     | 1987 |
| <hr/>                                  |                          |      |
| MARYLAND                               |                          |      |
| Northern 8 km                          | 14                       | 21   |
| McCabe-State Park                      | 2                        | 1    |
| Orv Section                            | 1                        | 1    |
| TOTAL                                  | 17                       | 23   |
|                                        |                          |      |
| VIRGINIA                               |                          |      |
| Hook                                   |                          | 16   |
| Wild Beach and Wash Flats <sup>1</sup> |                          | 30   |
| TOTAL                                  |                          | 46   |
|                                        |                          |      |
| ISLAND                                 |                          | 69   |
| <hr/>                                  |                          |      |

<sup>1</sup>Some plovers that originally nested on the Wild Beach renested on the Wash Flats after their initial nesting attempts failed.

Table 5. Average number of days successful nests located after clutch completion were observed, Assateague Island 1986-1987.

|            | N  | $\bar{x}$ (Days) | SE   | Range |
|------------|----|------------------|------|-------|
| Wash Flats | 17 | 16.5             | 2.07 | 1-28  |
| Maryland   | 20 | 20.6             | 1.33 | 7-27  |
| Wild Beach | 3  | 22.3             | 3.76 | 16-29 |
| Hook       | 1  | 26.0             | -    | -     |
| Total      | 41 | 19.1             | 1.15 | 1-29  |

Table 6. Clutch size<sup>1</sup> in piping plover nests on Assateague Island 1986-1987.

|                | N  | $\bar{x}$ (Eggs) | SE   |
|----------------|----|------------------|------|
| MARYLAND       |    |                  |      |
| 1986           |    |                  |      |
| ORV Sect.      | 1  | 4.00             | -    |
| Northern 11 km | 11 | 3.82             | 0.12 |
| 1987           |    |                  |      |
| ORV Sect.      | 1  | 3.00             | -    |
| Northern 11 km | 23 | 3.70             | 0.15 |
| SUBTOTAL       | 36 | 3.72             | 0.10 |
| VIRGINIA       |    |                  |      |
| 1987           |    |                  |      |
| Hook           | 19 | 3.63             | 0.14 |
| Wild Beach     | 18 | 3.67             | 0.14 |
| Wash Flats     | 22 | 3.64             | 0.14 |
| SUBTOTAL       | 59 | 3.64             | 0.08 |
| ISLAND         |    |                  |      |
| 1986           | 12 | 3.83             | 0.11 |
| 1987           | 83 | 3.65             | 0.07 |
| TOTAL          | 95 | 3.67             | 0.06 |

<sup>1</sup>I defined a complete clutch as a nest with four eggs or a nest with fewer than four eggs when discovered, and the same number of eggs at least three days later.

Table 7. Piping plover clutch sizes reported in various studies.

| Area          | N (Nests) | $\bar{x}$ (Eggs) | Source               |
|---------------|-----------|------------------|----------------------|
| New Jersey    | 12        | 2.83             | Burger 1987          |
| New Jersey    | 17        | 3.27             | Burger 1987          |
| New Jersey    | 17        | 3.29             | Burger 1987          |
| New Jersey    | 19        | 3.44             | Burger 1987          |
| New Jersey    | 14        | 3.45             | Burger 1987          |
| Massachusetts | 51        | 3.49             | MacIvor et al. 1985  |
| New Jersey    | 21        | 3.50             | Burger 1987          |
| Massachusetts | 42        | 3.52             | MacIvor et al. 1986  |
| Virginia      | 19        | 3.53             | Cross 1987           |
| New Jersey    | 8         | 3.66             | Burger 1987          |
| North Dakota  | 150       | 3.66             | Prindiville 1986     |
| Assateague    | 95        | 3.67             | This study           |
| New Jersey    | 14        | 3.71             | Burger 1987          |
| Minnesota     | 11        | 3.72             | Niemi and Davis 1979 |
| New York      | 526       | 3.84             | Wilcox 1959          |
| New Jersey    | 13        | 3.85             | Burger 1987          |
| Saskatchewan  | 32        | 3.88             | Whyte 1985           |
| Manitoba      | 73        | 3.9              | Haig 1987            |
| Nova Scotia   | 68        | 3.96             | Cairns 1982          |

Table 8. Number of days between nest discovery and first observation of chicks for piping plover nests discovered with incomplete clutches, Assateague Island 1986-1987.

| Initial #<br>of Eggs | Final #<br>of Eggs | Number of<br>Nests | Days Between Nest Discovery<br>And Hatch |
|----------------------|--------------------|--------------------|------------------------------------------|
| 1                    | 3                  | 2                  | 30 - 33                                  |
| 1                    | 4                  | 5                  | 29 - 35                                  |
| 2                    | 3                  | 3                  | 21 - 33                                  |
| 2                    | 4                  | 2                  | 27 - 28                                  |
| 3                    | 4                  | 5                  | 24 - 29                                  |

Table 9. Habitats in which piping plover nests were found,  
Assateague Island, 1986-1987.

| Area       | Berm |    | Dune |    | Overwash Gap |   | Interdune |   | Total |
|------------|------|----|------|----|--------------|---|-----------|---|-------|
|            | N    | %  | N    | %  | N            | % | N         | % | N     |
| Maryland   | 45   | 80 | 6    | 11 | 3            | 5 | 2         | 4 | 56    |
| Wild Beach | 3    | 13 | 18   | 78 | 0            | 0 | 2         | 9 | 23    |
| Hook       | 11   | 50 | 10   | 45 | 1            | 5 | 0         | 0 | 22    |
| Total      | 59   | 58 | 34   | 34 | 4            | 4 | 4         | 4 | 101   |

Table 10. Beach measurements at piping plover nests, Assateague Island 1986-1987.

|                                          | N  | $\bar{x}(m)$ | SE    | Range (m) |
|------------------------------------------|----|--------------|-------|-----------|
| <b>Distance to wrack line</b>            |    |              |       |           |
| Maryland                                 | 56 | 144          | 9.26  | 41 - 295  |
| Wild Beach                               | 23 | 82           | 8.24  | 34 - 196  |
| Hook                                     | 22 | 139          | 12.33 | 53 - 249  |
| <b>Distance to continuous vegetation</b> |    |              |       |           |
| Maryland                                 | 43 | 81           | 7.72  | 4 - 243   |
| Wild Beach                               | 23 | 75           | 6.95  | 20 - 177  |
| Hook                                     | 19 | 99           | 13.81 | 33 - 212  |
| <b>Distance to bay<sup>1</sup></b>       |    |              |       |           |
| Maryland                                 | 13 | 130          | 23.21 | 47 - 276  |
| Hook                                     | 3  | 378          | 12.17 | 354 - 391 |
| <b>Beach width<sup>2</sup></b>           |    |              |       |           |
| Maryland                                 | 56 | 236          | 8.97  | 127 - 384 |
| Wild Beach                               | 23 | 157          | 9.34  | 113 - 261 |
| Hook                                     | 22 | 276          | 26.82 | 132 - 569 |

<sup>1</sup>Excluding nests separated from the bay by a continuous zone of vegetation.

<sup>2</sup>Distance from the wrack line to continuous vegetation cover or the bay's edge.

Table 11. Average beach width (distance from the wrack line to the bay or continuous vegetation) at piping plover nests and at random points in areas not used by breeding plovers, Assateague Island 1986-1987.

|                          | N   | $\bar{x}$ (m) | SE    |   |
|--------------------------|-----|---------------|-------|---|
| Hook                     | 22  | 276           | 26.82 | A |
| Maryland Nests           | 56  | 236           | 8.97  | B |
| Wild Beach Nests         | 23  | 157           | 9.34  | C |
| Maryland Random Points   | 116 | 125           | 5.16  | D |
| Wild Beach Random Points | 20  | 109           | 8.04  | D |

Groups with different letters are significantly different ( $P \leq 0.05$ ).

Test results using ANOVA and Fisher's LSD.

Table 12. Beach width at piping plover nests and random points on the northern 11 km of Assateague Island 1986-1987.

|               | N  | $\bar{x}$ (m) | SE    | P                   |
|---------------|----|---------------|-------|---------------------|
| Nests         | 53 | 240           | 9.13  | 0.0051 <sup>1</sup> |
| Random Points | 29 | 197           | 11.37 |                     |

<sup>1</sup>T-test results.

Table 13. Percent vegetative cover within 12 m of piping plover nests by growth form, Assateague Island 1986-1987.

| AREA       | N  | GRASS<br>% |     | FORB<br>% |     | SHRUB<br>% |   | DEAD<br>% |   |
|------------|----|------------|-----|-----------|-----|------------|---|-----------|---|
| Wash Flats | 22 | 4.5        | A   | 5.0       | A B | 2.5        | A | 2.5       | A |
| Maryland   | 56 | 6.8        | A   | 3.8       | A   | 3.0        | A | 2.7       | A |
| Hook       | 22 | 8.2        | A B | 4.0       | A B | 2.5        | A | 2.8       | A |
| Wild Beach | 23 | 13.3       | B   | 6.3       | B   | 2.5        | A | 2.6       | A |

Groups with different letters are significantly different ( $P \leq 0.05$ ).

Kruskall Wallis test results (corrected for ties) (Zar 1984).

Grass

Comparison of Wild Beach vs Wash Flats  $P < 0.001$

Comparison of Wild Beach vs Maryland  $0.001 < P < 0.002$

All other comparisons  $P > 0.050$

Forbs

Comparison of Wild Beach vs Maryland  $0.005 < P < 0.010$

All other comparisons  $P > 0.050$

Table 14. Percent of 1 x 0.5 m sample quadrats in which various grass species occurred in piping plover nesting areas, Assateague Island 1986-1987.

| Species                |                                | Maryland<br>N=672 | Wild           |               | Wash           |
|------------------------|--------------------------------|-------------------|----------------|---------------|----------------|
|                        |                                |                   | Beach<br>N=276 | Hook<br>N=264 | Flats<br>N=264 |
| American Beach Grass   | <u>Ammophila breviligulata</u> | 19                | 54             | 40            | 9              |
| Salt Meadow Cord Grass | <u>Spartina patens</u>         | 7                 | 0.4            | 3             | 0.3            |
| Sand Spurr             | <u>Cenchrus tribuloides</u>    | 2                 | 12             | 11            | 0              |
| Panic Grass            | <u>Panicum</u> spp.            | 1                 | 2              | 2             | 0              |
| Purple Grass           | <u>Triplasis purpurea</u>      | 0.6               | 0.7            | 3             | 12             |
| Crab Grass             | <u>Digitaria sanguinalis</u>   | 2                 | 1              | 1             | 0              |
| Spike Grass            | <u>Chasmanthium laxum</u>      | 0.1               | 0              | 0             | 5              |
| Other                  |                                | <0.5              | <0.5           | <0.5          | <0.5           |

Table 15. Percent of 1 x 0.5 sample quadrats at which various forb species occurred in piping plover nesting areas, Assateague Island 1986-1987.

| Species               |                                | Wild     |       | Wash  |       |
|-----------------------|--------------------------------|----------|-------|-------|-------|
|                       |                                | Maryland | Beach | Hook  | Flats |
|                       |                                | N=672    | N=276 | N=264 | N=264 |
| Seaside Goldenrod     | <u>Solidago sempervirens</u>   | 12       | 17    | 5     | 9     |
| American Three Square | <u>Scirpus americanus</u>      | 12       | 0     | 0     | 2     |
| Seaside Spurge        | <u>Euphorbia polygonifolia</u> | 3        | 3     | 2     | 0     |
| Searocket             | <u>Cakile edentula</u>         | 1        | 12    | 9     | 0     |
| Evening Primrose      | <u>Oenothera humifusa</u>      | 0.1      | 2     | 5     | 5     |
| Sand Spurrey          | <u>Spergularia marina</u>      | 0        | 0     | 0     | 23    |
| Glasswort             | <u>Salicornia</u> spp.         | 0        | 0     | 0     | 3     |
| Russian Thistle       | <u>Salsola kali</u>            | 0.1      | 0     | 1     | 0     |
| Other                 |                                | <0.5     | <0.5  | <0.5  | <0.5  |

Table 16. Mean percent vegetation cover within a one meter radius of piping plover nests, Assateague Island 1986-1987.

|            | N  | $\bar{x}$ (%) | SE   |
|------------|----|---------------|------|
| Maryland   | 56 | 9.0 A         | 1.78 |
| Wild Beach | 23 | 12.0 A B      | 2.13 |
| Wash Flats | 22 | 12.9 A B      | 3.79 |
| Hook       | 22 | 16.1 B        | 2.87 |

Groups with different letters are significantly different ( $P \leq 0.05$ ).

Kruskall-Wallis test results (corrected for ties) (Zar 1984):

Overall comparison  $P = 0.022$

Comparison of Hook - Maryland  $0.020 < P < 0.050$

All other comparisons  $P > 0.050$

Table 17. Mean percent vegetation cover within 12 m of piping plover nests and random points, Assateague Island 1986-1987.

|                         | N   | $\bar{x}$ (%) | SE   |
|-------------------------|-----|---------------|------|
| Wash Flats Nests        | 22  | 7.2 A         | 2.01 |
| Maryland Nests          | 56  | 8.8 A         | 1.43 |
| Hook Nests              | 22  | 10.3 AB       | 1.47 |
| Maryland Rand. Points   | 117 | 15.9 B        | 1.17 |
| Wild Beach Nests        | 23  | 17.4 B        | 2.26 |
| Wild Beach Rand. Points | 20  | 17.6 B        | 2.97 |

Nests with different letters are significantly different ( $P \leq 0.05$ ).

Kruskall-Wallis test results (corrected for ties) (Zar 1984):

|                                    |                    |                     |
|------------------------------------|--------------------|---------------------|
| Comparison of all areas            |                    | $P < 0.001$         |
| Comparison of Wild Beach Nests     | - Wash Flats Nests | 0.001 $< P < 0.002$ |
| Comparison of Wild Beach Nests     | - Maryland Nests   | 0.001 $< P < 0.002$ |
| Comparison of Wild Beach R. Points | - Wash Flats Nests | 0.005 $< P < 0.010$ |
| Comparison of Wild Beach R. Points | - Maryland Nests   | 0.010 $< P < 0.020$ |
| Comparison of Maryland R. Points   | - Wash Flats Nests | $P < 0.001$         |
| Comparison of Maryland R. Points   | - Maryland Nests   | $P < 0.001$         |
| All other comparisons              |                    | $P > 0.050$         |

Table 18. Mean percent vegetation cover at piping plover nest sites and random points on the northern 11 km of Assateague, 1986-1987.

|                             | N  | $\bar{x}$ (%) | SE                     |
|-----------------------------|----|---------------|------------------------|
| Northern 11 km Nests        | 53 | 9.0           | 1.51                   |
|                             |    |               | P = 0.957 <sup>1</sup> |
| Northern 11 km Random Plots | 29 | 8.1           | 1.45                   |

<sup>1</sup>Mann-Whitney U Test results (corrected for ties).

Table 19. Substrate types at piping plover nests and random points, Assateague Island 1986-1987.

|                              | 100% Sand | Sand, Shell,<br>and Cobble |                        |
|------------------------------|-----------|----------------------------|------------------------|
| Northern 11 km Nests         | 23        | 30                         | P < 0.001 <sup>1</sup> |
| Northern 11 km Random Points | 25        | 4                          |                        |

<sup>1</sup> $\chi^2 = 14.15$ .

Table 20. Number of vehicles observed per hour on the ORV access sections on Assateague Island during April and May 1986-1987.

| Area     | Week Days            |               | Weekends             |               | # of Nests |
|----------|----------------------|---------------|----------------------|---------------|------------|
|          | Hours of Observation | Cars Per Hour | Hours of Observation | Cars Per Hour |            |
| Maryland | 156.2                | 1.6           | 57.4                 | 9.6           | 1          |
| Virginia | 28.9                 | 2.6           | 16.8                 | 10.3          | 16         |

Table 21. Number of people observed per hour on the foot access sections on Assateague Island during April and May, 1986-1987.

| Area                          | Week Days            |                 | Weekends             |                 | # of Nests |
|-------------------------------|----------------------|-----------------|----------------------|-----------------|------------|
|                               | Hours of Observation | People Per Hour | Hours of Observation | People Per Hour |            |
| MD - Developed <sup>1</sup>   | 33.1                 | 8.5             | 16.6                 | 38.9            | 0          |
| VA - Developed <sup>2</sup>   | 3.8                  | 23.9            | 1.3                  | 35.4            | 0          |
| MD - Undeveloped <sup>3</sup> | 191.0                | 0.3             | 130.0                | 3.0             | 23         |
| VA - Undeveloped <sup>4</sup> | 82.8                 | 0.6             | 32.0                 | 0.6             | 33         |

<sup>1</sup>State park northern boundary to northern boundary of Maryland ORV section.

<sup>2</sup>Southern Wild Beach boundary to start of Va. ORV access area.

<sup>3</sup>Island north of the Maryland state park northern boundary.

<sup>4</sup>Wild Beach.

Table 22. Average distance from a piping plover nest to the nearest nest of another pair, Assateague Island 1986-1987.

| Area       | Year              | N  | $\bar{x}$ (m) | SE    |
|------------|-------------------|----|---------------|-------|
| Maryland   | 1986 <sup>1</sup> | 21 | 282           | 44.25 |
|            | 1987 <sup>2</sup> | 30 | 179           | 25.78 |
| Wild Beach | 1987              | 23 | 201           | 19.87 |
| Wash Flats | 1987              | 22 | 93            | 13.02 |
| Hook       | 1987              | 23 | 175           | 28.17 |

<sup>1</sup>Excluding the pair nesting near the state line.

<sup>2</sup>Excluding the 2 pairs nesting south of the McCabe house.

**Table 23. Piping plover broods classified by foraging habitats used during the first 3 weeks after hatch, Assateague Island 1986-1987.**

| Foraging<br>Habitat | MD |      | VA |      | Island |      |
|---------------------|----|------|----|------|--------|------|
|                     | N  | %    | N  | %    | N      | %    |
| High Energy Beach   | 9  | 30.0 | 3  | 9.7  | 12     | 19.7 |
| Bay                 | 19 | 63.3 | 1  | 3.2  | 20     | 32.8 |
| Storm Pool          | 0  | 0.0  | 3  | 9.7  | 3      | 4.9  |
| Wash Flats          | 0  | 0.0  | 23 | 74.2 | 23     | 37.7 |
| Miscellaneous       | 2  | 6.7  | 1  | 3.2  | 3      | 4.9  |

Table 24. Probability of piping plover nest survival calculated using Mayfield's Method, Assateague Island 1986-1987.

| Area       | # of<br>Nests | Daily Surv.<br>Rate | Prob. of<br>Nest Surv. |
|------------|---------------|---------------------|------------------------|
| Wash Flats | 22            | 0.9947 A            | 0.8354 A               |
| Maryland   | 56            | 0.9737 B            | 0.4042 B               |
| Wild Beach | 23            | 0.9511 BC           | 0.1818 C               |
| Hook       | 24            | 0.9328 C            | 0.0939 C               |

Rates with different letters are significantly different ( $P \leq 0.05$ ).

Results from comparisons using Hensler's (1985) methods.

|                                        | Daily Surv.  | Nest Surv. Prob. |
|----------------------------------------|--------------|------------------|
| Comparison of Wash Flats vs Hook       | $P < 0.0001$ | $P < 0.0001$     |
| Comparison of Wash Flats vs Wild Beach | $P = 0.0002$ | $P < 0.0001$     |
| Comparison of Wash Flats vs Maryland   | $P = 0.0009$ | $P = 0.0008$     |
| Comparison of Maryland vs Hook         | $P = 0.0065$ | $P = 0.0003$     |
| Comparison of Maryland vs Wild Beach   | $P = 0.0668$ | $P = 0.0299$     |
| Comparison of Wild Beach vs Hook       | $P = 0.3120$ | $P = 0.3163$     |

Table 25. Fate of 202 eggs from 55 successful piping plover nests, Assateague Island 1986-1987.

|                 | Nests<br>N | Missing Prior<br>to Hatch |          | Hatched    |           | Abandoned on<br>Nest |           | Unknown<br>Fate |           |
|-----------------|------------|---------------------------|----------|------------|-----------|----------------------|-----------|-----------------|-----------|
|                 |            | N                         | %        | N          | %         | N                    | %         | N               | %         |
| <b>MARYLAND</b> |            |                           |          |            |           |                      |           |                 |           |
| <b>1986</b>     |            |                           |          |            |           |                      |           |                 |           |
| ORV Sect.       | 1          | 0                         | 0        | 3          | 75        | 0                    | 0         | 1               | 25        |
| Northern 11 km  | 10         | 0                         | 0        | 29         | 76        | 6                    | 16        | 3               | 8         |
| <b>1987</b>     |            |                           |          |            |           |                      |           |                 |           |
| ORV Sect.       | 1          | 0                         | 0        | 2          | 67        | 1                    | 33        | 0               | 0         |
| Northern 11 km  | 15         | 0                         | 0        | 44         | 77        | 12                   | 21        | 1               | 2         |
| <b>SUBTOTAL</b> | <b>27</b>  | <b>0</b>                  | <b>0</b> | <b>78</b>  | <b>76</b> | <b>19</b>            | <b>19</b> | <b>5</b>        | <b>5</b>  |
| <b>VIRGINIA</b> |            |                           |          |            |           |                      |           |                 |           |
| <b>1987</b>     |            |                           |          |            |           |                      |           |                 |           |
| Hook            | 3          | 0                         | 0        | 6          | 60        | 2                    | 20        | 2               | 20        |
| Wild Beach      | 5          | 0                         | 0        | 12         | 67        | 1                    | 6         | 5               | 27        |
| Wash Flats      | 20         | 2                         | 3        | 46         | 64        | 5                    | 7         | 19              | 26        |
| <b>SUBTOTAL</b> | <b>28</b>  | <b>2</b>                  | <b>2</b> | <b>64</b>  | <b>64</b> | <b>8</b>             | <b>8</b>  | <b>26</b>       | <b>26</b> |
| <b>ISLAND</b>   |            |                           |          |            |           |                      |           |                 |           |
| 1986            | 11         | 0                         | 0        | 32         | 76        | 6                    | 14        | 4               | 10        |
| 1987            | 44         | 2                         | 1        | 110        | 69        | 21                   | 13        | 27              | 17        |
| <b>TOTAL</b>    | <b>55</b>  | <b>2</b>                  | <b>1</b> | <b>142</b> | <b>70</b> | <b>27</b>            | <b>13</b> | <b>31</b>       | <b>15</b> |

Table 26. Probable cause of piping plover nest loss on Assateague Island 1986 - 1987.

|                 | Cause of Loss        |               |            |          |           |             |              |
|-----------------|----------------------|---------------|------------|----------|-----------|-------------|--------------|
|                 | Total #<br>of Losses | Predator<br>% | Tides<br>% | Car<br>% | Pony<br>% | Plover<br>% | Unknown<br>% |
| <b>MARYLAND</b> |                      |               |            |          |           |             |              |
| <b>1986</b>     |                      |               |            |          |           |             |              |
| ORV Sect.       | 1                    | 0             | 0          | 0        | 0         | 0           | 100          |
| Northern 11 km  | 8                    | 63            | 0          | 0        | 0         | 13          | 25           |
| <b>1987</b>     |                      |               |            |          |           |             |              |
| ORV Sect.       | 0                    | 0             | 0          | 0        | 0         | 0           | 0            |
| Northern 11 km  | 17                   | 71            | 0          | 0        | 0         | 0           | 29           |
| <b>SUBTOTAL</b> | <b>26</b>            | <b>65</b>     | <b>0</b>   | <b>0</b> | <b>0</b>  | <b>4</b>    | <b>31</b>    |
| <b>VIRGINIA</b> |                      |               |            |          |           |             |              |
| <b>1987</b>     |                      |               |            |          |           |             |              |
| Hook            | 21                   | 52            | 5          | 5        | 0         | 0           | 38           |
| Wild Beach      | 18                   | 78            | 0          | 0        | 0         | 0           | 22           |
| Wash Flats      | 2                    | 0             | 0          | 0        | 50        | 0           | 50           |
| <b>SUBTOTAL</b> | <b>41</b>            | <b>61</b>     | <b>2</b>   | <b>2</b> | <b>2</b>  | <b>0</b>    | <b>32</b>    |
| <b>ISLAND</b>   |                      |               |            |          |           |             |              |
| <b>1986</b>     | <b>9</b>             | <b>56</b>     | <b>0</b>   | <b>0</b> | <b>0</b>  | <b>11</b>   | <b>33</b>    |
| <b>1987</b>     | <b>58</b>            | <b>64</b>     | <b>2</b>   | <b>2</b> | <b>2</b>  | <b>2</b>    | <b>31</b>    |
| <b>TOTAL</b>    | <b>67</b>            | <b>63</b>     | <b>1</b>   | <b>1</b> | <b>1</b>  | <b>1</b>    | <b>31</b>    |

Table 27. Predators of piping plover nests, Assateague Island 1986 - 1987.

|                | # of Nests<br>Predated | Red Fox<br>% | PREDATOR     |           | Unidentified<br>% |
|----------------|------------------------|--------------|--------------|-----------|-------------------|
|                |                        |              | Raccoon<br>% | Bird<br>% |                   |
| MARYLAND       |                        |              |              |           |                   |
| 1986           |                        |              |              |           |                   |
| ORV Sect.      | 0                      | 0            | 0            | 0         | 0                 |
| Northern 11 km | 5                      | 80           | 0            | 0         | 20                |
| 1987           |                        |              |              |           |                   |
| ORV Sect.      | 0                      | 0            | 0            | 0         | 0                 |
| Northern 11 km | 12                     | 67           | 0            | 17        | 17                |
| SUBTOTAL       | 17                     | 71           | 0            | 12        | 18                |
| VIRGINIA       |                        |              |              |           |                   |
| 1987           |                        |              |              |           |                   |
| Hook           | 11                     | 73           | 9            | 18        | 0                 |
| Wild Beach     | 14                     | 0            | 79           | 14        | 7                 |
| Wash Flats     | 0                      | 0            | 0            | 0         | 0                 |
| SUBTOTAL       | 25                     | 32           | 48           | 16        | 4                 |
| ISLAND         |                        |              |              |           |                   |
| 1986           | 5                      | 80           | 0            | 0         | 20                |
| 1987           | 37                     | 43           | 32           | 16        | 8                 |
| TOTAL          | 42                     | 48           | 29           | 14        | 10                |

Table 28. Summary of predation of piping plover nests from various studies.

| Area          |         | # of Nests | Predator Loss % | Source                  |
|---------------|---------|------------|-----------------|-------------------------|
| Minnesota     | 1982    | 24         | 37 <sup>1</sup> | Wiens and Cuthbert 1984 |
| Minnesota     | 1983    | 22         | 12 <sup>1</sup> | Wiens and Cuthbert 1984 |
| Massachusetts | 1985    | 23         | 52 <sup>2</sup> | MacIvor et al. 1985     |
| Massachusetts | 1986    | 32         | 56 <sup>2</sup> | MacIvor et al. 1986     |
| North Dakota  | 1984    | 53         | 48 <sup>1</sup> | Prindiville 1986        |
| North Dakota  | 1985    | 97         | 57 <sup>1</sup> | Prindiville 1986        |
| Saskatchewan  | 1980-81 | 38         | 62 <sup>1</sup> | Whyte 1985              |
| Chincoteague  | 1978    | 3          | 33 <sup>1</sup> | Britton 1982            |
| Chincoteague  | 1979    | 9          | 19 <sup>1</sup> | Birtton 1982            |
| Chincoteague  | 1980    | 6          | 85 <sup>1</sup> | Britton 1982            |
| Chincoteague  | 1981    | 6          | 60 <sup>1</sup> | Britton 1982            |
| Chincoteague  | 1983    | 7          | 0 <sup>1</sup>  | Ailes 1985              |
| Chincoteague  | 1984    | 3          | 56 <sup>1</sup> | Ailes 1985              |
| Chincoteague  | 1985    | 3          | 26 <sup>1</sup> | Ailes 1985              |
| Massachusetts | 1982-86 | 78         | 38 <sup>2</sup> | Strauss 1987            |
| Assateague    | 1986    | 23         | 22 <sup>2</sup> | This study              |
| Assateague    | 1987    | 102        | 36 <sup>2</sup> | This study              |

<sup>1</sup>Percent of total eggs.

<sup>2</sup>Percent of total nests.

Table 29. Mean beach width and distance to the tidal zone at nests lost to predators and other nests, Assateague Island 1986-1987.

|                        | # of<br>Nests | $\bar{x}$ (m) | SE    |                     |
|------------------------|---------------|---------------|-------|---------------------|
| BEACH WIDTH            |               |               |       |                     |
| Maryland               |               |               |       |                     |
| Predated Nests         | 17            | 251           | 16.7  | P=0.20 <sup>1</sup> |
| Other Nests            | 31            | 226           | 11.3  |                     |
| Wild Beach             |               |               |       |                     |
| Predated Nests         | 14            | 153           | 10.5  | P=0.45              |
| Other Nests            | 5             | 171           | 25.5  |                     |
| Hook                   |               |               |       |                     |
| Predated Nests         | 11            | 275           | 35.0  | P=0.10              |
| Other Nests            | 3             | 424           | 102.8 |                     |
| DISTANCE TO WRACK LINE |               |               |       |                     |
| Maryland               |               |               |       |                     |
| Predated Nests         | 17            | 160           | 18.2  | P=0.13              |
| Other Nests            | 31            | 128           | 11.1  |                     |
| Wild Beach             |               |               |       |                     |
| Predated Nests         | 14            | 90            | 12.1  | P=0.15              |
| Other Nests            | 5             | 70            | 4.53  |                     |
| Hook                   |               |               |       |                     |
| Predated Nests         | 11            | 149           | 18.3  | P=0.79              |
| Other Nests            | 3             | 159           | 18.2  |                     |

<sup>1</sup>T-test results.

Table 30. Mean percent vegetation cover at predated and others nests, Assateague Island 1986-1987.

|                   | N  | Vegetation w/in<br>1 m of nest<br>$\bar{x}$ (%) | Vegetation w/in<br>12 m of nest<br>$\bar{x}$ (%) |       |                     |
|-------------------|----|-------------------------------------------------|--------------------------------------------------|-------|---------------------|
| <b>Maryland</b>   |    |                                                 |                                                  |       |                     |
| Predated Nests    | 17 | 5.37                                            | P=0.35 <sup>1</sup>                              | 7.90  | P=0.09 <sup>1</sup> |
| Other Nests       | 31 | 9.13                                            |                                                  | 8.07  |                     |
| <b>Wild Beach</b> |    |                                                 |                                                  |       |                     |
| Predated Nests    | 14 | 14.87                                           | P=0.14                                           | 19.26 | P=0.40              |
| Other Nests       | 5  | 6.13                                            |                                                  | 14.83 |                     |
| <b>Hook</b>       |    |                                                 |                                                  |       |                     |
| Predated Nests    | 11 | 19.09                                           | P=0.88                                           | 11.23 | P=0.70              |
| Other Nests       | 3  | 17.50                                           |                                                  | 12.29 |                     |
| <b>Overall</b>    |    |                                                 |                                                  |       |                     |
| Predated Nests    | 42 | 12.13                                           | P=0.26                                           | 12.56 | P=0.01              |
| Other Nests       | 39 | 9.39                                            |                                                  | 9.26  |                     |

<sup>1</sup>Mann-Whitney U test results (corrected for ties).

Table 31. Probability of nest survival for piping plover nests on different substrates, Assateague Island 1986-1987.

|                         | # of<br>Nests | Daily Surv.<br>Rate    | Prob. of<br>Nest Surv. |
|-------------------------|---------------|------------------------|------------------------|
| <b>Maryland Nests</b>   |               |                        |                        |
| Pure Sand               | 23            | 0.9853                 | 0.6036                 |
|                         |               | P = 0.026 <sup>1</sup> | P = 0.021              |
| Sand, Shell, Cobble     | 33            | 0.9630                 | 0.2779                 |
| <b>Wild Beach Nests</b> |               |                        |                        |
| Pure Sand               | 20            | 0.9459                 | 0.1512                 |
|                         |               | P = 0.261              | P = 0.388              |
| Sand, Shell, Cobble     | 3             | 0.9722                 | 0.3837                 |
| <b>Wash Flat Nests</b>  |               |                        |                        |
| Pure Sand               | 7             | 0.9911                 | 0.7372                 |
|                         |               | P = 0.591              | P = 0.569              |
| Sand, Shell, Cobble     | 15            | 0.9963                 | 0.8802                 |
| <b>Hook Nests</b>       |               |                        |                        |
| Pure Sand               | 11            | 0.9489                 | 0.1679                 |
|                         |               | P = 0.318              | P = 0.326              |
| Sand, Shell, Cobble     | 11            | 0.9194                 | 0.0573                 |
| <b>All Nests</b>        |               |                        |                        |
| Pure Sand               | 61            | 0.9688                 | 0.3408                 |
|                         |               | P = 0.838              | P = 0.838              |
| Sand, Shell, Cobble     | 62            | 0.9672                 | 0.3223                 |

<sup>1</sup>Hensler's (1985) test results.

Table 32. Mean percent sand cover at piping plover nests lost to predators and other nests, Assateague Island 1986-1987.

|                | # of<br>Nests | % Sand<br>Cover | SE   |                     |
|----------------|---------------|-----------------|------|---------------------|
| Maryland       |               |                 |      |                     |
| Predated Nests | 17            | 76              | 6.4  | P=0.99 <sup>1</sup> |
| Other Nests    | 31            | 76              | 5.8  |                     |
| Wild Beach     |               |                 |      |                     |
| Predated Nests | 14            | 95              | 4.6  | P=0.84              |
| Other Nests    | 5             | 97              | 3.0  |                     |
| Hook           |               |                 |      |                     |
| Predated Nests | 11            | 87              | 5.9  | P=0.63              |
| Other Nests    | 3             | 70              | 30.0 |                     |

<sup>1</sup>T-test results.

**Table 33. Number of people observed per hour on the north end of Maryland, Assateague Island before and after May 31, 1986-1987.**

|               | Week Days               |                    | Weekends                |                    |
|---------------|-------------------------|--------------------|-------------------------|--------------------|
|               | Hours of<br>Observation | People Per<br>Hour | Hours of<br>Observation | People Per<br>Hour |
| Before May 31 | 191.0                   | 0.3                | 130.0                   | 3.0                |
| After May 31  | 298.2                   | 1.5                | 159.8                   | 5.4                |

Table 34. Number of vehicles observed per hour on the Hook on Assateague Island before and after May 31, 1986-1987.

|               | Week Days   |          | Weekends    |          |
|---------------|-------------|----------|-------------|----------|
|               | Hours of    | Cars Per | Hours of    | Cars Per |
|               | Observation | Hour     | Observation | Hour     |
| Before May 31 | 73.8        | 2.6      | 16.8        | 10.3     |
| After May 31  | 26.8        | 8.9      | 11.6        | 14.6     |

Table 35. Probability of piping plover nest survival for early<sup>1</sup> and late nesters<sup>2</sup>, Assateague Island 1986-1987.

| Area               | # of Nests | Daily Surv. Rate | P-value | Prob. of Nest Surv. | P-value <sup>3</sup> |
|--------------------|------------|------------------|---------|---------------------|----------------------|
| North End          |            |                  |         |                     |                      |
| Early Season       | 20         | 0.9763           | 0.5940  | 0.4427              | 0.5989               |
| Late Season        | 33         | 0.9706           |         | 0.3631              |                      |
| Hook               |            |                  |         |                     |                      |
| Early Season       | 4          | 0.9542           | 0.3772  | 0.2031              | 0.5105               |
| Late Season        | 20         | 0.9271           |         | 0.0763              |                      |
| North End and Hook |            |                  |         |                     |                      |
| Early Season       | 24         | 0.9731           | 0.1285  | 0.3952              | 0.1580               |
| Late Season        | 53         | 0.9571           |         | 0.2250              |                      |

<sup>1</sup>Initiated prior to the fourth week in May.

<sup>2</sup>Initiated on or after the fourth week in May.

<sup>3</sup>Comparison using Hensler's (1985) technique.

Table 36. Egg hatchability<sup>1</sup> in successful piping plover nests initiated prior to the fourth week in May (early nests) and in successful nests initiated on or after the fourth week in May (late nests), Assateague Island 1986-1987.

|             | N  | $\bar{x}$ (%) | SE                  |
|-------------|----|---------------|---------------------|
| Early Nests | 9  | 72.2          | 8.2                 |
|             |    |               | P=0.70 <sup>2</sup> |
| Late Nests  | 19 | 75.9          | 3.4                 |

<sup>1</sup>Number of chicks observed immediately after hatch divided by the number of eggs in the clutch.

<sup>2</sup>Mann-Whitney U test results (corrected for ties).

Table 37. Egg abandonment in successful piping plover nests by hatch date on Assateague Island<sup>1</sup>, 1986-1987.

| Hatch Dates      | # of Nests<br>Hatching | # of nests w/<br>Abandoned Eggs | % of nests w/<br>Abandoned Eggs |
|------------------|------------------------|---------------------------------|---------------------------------|
| May 17 - June 6  | 3                      | 3                               | 100                             |
| June 7 - June 20 | 11                     | 5                               | 45                              |
| June 21 - July 4 | 8                      | 6                               | 75                              |
| July 5 - July 18 | 9                      | 2                               | 22                              |

<sup>1</sup>Data only from the northern 11 km and the Hook.

Table 38. Average piping plover brood size during the first observation after hatch, Assateague Island 1986-1987.

|                 | # of Broods | $\bar{x}$ | SE   |
|-----------------|-------------|-----------|------|
| <b>MARYLAND</b> |             |           |      |
| 1986            |             |           |      |
| ORV Section     | 1           | 3.00      | -    |
| Northern 11 km  | 13          | 2.62      | 0.21 |
| 1987            |             |           |      |
| ORV Section     | 1           | 2.00      | -    |
| Northern 11 km  | 15          | 2.93      | 0.25 |
| SUBTOTAL        | 30          | 2.77      | 0.16 |
| <b>Virginia</b> |             |           |      |
| Hook            | 3           | 2.00      | 0.00 |
| Wild Beach      | 5           | 2.40      | 0.24 |
| Wash Flats      | 20          | 2.30      | 0.27 |
| SUBTOTAL        | 28          | 2.29      | 0.20 |
| <b>ISLAND</b>   |             |           |      |
| 1986            | 14          | 2.64      | 0.20 |
| 1987            | 44          | 2.50      | 0.16 |
| TOTAL           | 58          | 2.53      | 0.13 |

Table 39. Clutch size in successful piping plover nests,  
Assateague Island 1986-1987.

|            | N  | $\bar{x}$ (Eggs) | SE   |
|------------|----|------------------|------|
| Maryland   | 27 | 3.8              | 0.08 |
| Wild Beach | 5  | 3.6              | 0.24 |
| Wash Flats | 20 | 3.6              | 0.15 |
| Hook       | 3  | 3.3              | 0.33 |

Table 40. Piping plover fledging success, Assateague Island<sup>1</sup>  
1986-1987.

| Area           | Broods<br>N | Chicks Fledged<br>N | Fledged<br>% | Pairs<br>N     | Fledging Rate<br>(Chicks/pair) |
|----------------|-------------|---------------------|--------------|----------------|--------------------------------|
| MARYLAND       |             |                     |              |                |                                |
| 1986           |             |                     |              |                |                                |
| ORV Section    | 1           | 1                   | 33.3         | 1              | 1.00                           |
| Northern 11 km | 13          | 17                  | 50.0         | 16             | 1.06                           |
| 1987           |             |                     |              |                |                                |
| ORV Section    | 1           | 2                   | 100.0        | 1              | 2.00                           |
| Northern 11 km | 15          | 25                  | 56.8         | 22             | 1.14                           |
| VIRGINIA       |             |                     |              |                |                                |
| 1987           |             |                     |              |                |                                |
| Hook           | 3           | 3                   | 50.0         | 16             | 0.19                           |
| Wild Beach     | 5           | 1                   | 8.3          | 5 <sup>2</sup> | 0.20                           |

<sup>1</sup>I was not able to determine fledging success on the Wash Flats.

<sup>2</sup>Some pairs which originally nested on the Wild Beach, renested on the Wash Flats so I based the fledging rate estimate in this area on the number of successful nests.

Table 41. Estimated piping plover reproductive rates reported from various studies.

|             | N<br>(Pairs) | Young Fledged Per<br>Breeding Pair | Source                  |
|-------------|--------------|------------------------------------|-------------------------|
| Manitoba    | 4            | 0.00                               | Haig 1987               |
| Manitoba    | 4            | 0.00                               | Haig 1987               |
| Va.         | 16           | 0.19                               | This study              |
| Manitoba    | 17           | 0.2                                | Haig 1987               |
| Mass.       | 29           | 0.34                               | MacIvor et al. 1987     |
| Manitoba    | 12           | 0.4                                | Haig 1987               |
| Rhode Is.   | 14           | 0.57                               | Raithel 1983            |
| Rhode Is.   | 10           | 0.60                               | Raithel 1983            |
| Saskat.     | 9            | 0.67                               | Whyte 1985              |
| New Jersey  | 93           | 0.83                               | Recovery Team           |
| Maine       | 10           | 0.9                                | Haig 1985               |
| Mass.       | 52           | 0.98                               | MacIvor et al. 1985     |
| N. D.       | 91           | 1.04                               | Prindiville 1986        |
| Md.         | 17           | 1.06                               | This study              |
| Saskat.     | 11           | 1.09                               | Whyte 1985              |
| Mass.       | 89           | 1.1                                | Recovery Team 1987      |
| Rhode I.    | 17           | 1.13                               | Recovery Team 1987      |
| Md.         | 23           | 1.17                               | This study              |
| New Jersey  | 32           | 1.2                                | Haig 1985               |
| Nova Scotia | 62           | 1.2                                | Flemming 1984           |
| Maine       | 6            | 1.2                                | Haig 1985               |
| Conn.       | 24           | 1.29                               | Recovery Team 1987      |
| Rhode I.    | 11           | 1.36                               | Raithel 1983            |
| New Jersey  | 59           | 1.4                                | Haig 1985               |
| Manitoba    | 31           | 1.4                                | Haig 1987               |
| N. D.       | 46           | 1.48                               | Prindiville 1986        |
| Manitoba    | 30           | 1.6                                | Haig 1987               |
| Minn.       | 15           | 1.7                                | Wiens and Cuthbert 1984 |
| Maine       | 12           | 1.75                               | Recovery Team 1987      |
| Maine       | 10           | 1.8                                | Haig 1985               |
| Minn.       | 21           | 2.1                                | Wiens and Cuthbert 1984 |

Table 42. Average piping plover brood fledging success in areas with and without recreational ORV use, Assateague Island 1986-1987.

|                     | N  | $\bar{x}$ (%) | SE                  |
|---------------------|----|---------------|---------------------|
| Orv use allowed     | 5  | 56.7          | 19.44               |
|                     |    |               | P=0.67 <sup>1</sup> |
| Orv use not allowed | 33 | 48.2          | 6.92                |

<sup>1</sup>Mann-Whitney U test results (corrected for ties).

Table 43. Average piping plover brood fledging success by foraging habitat, Assateague Island 1986-1987.

| Foraging Habitat<br>Category | # of<br>Broods | $\bar{x}$ (%) | SE    |
|------------------------------|----------------|---------------|-------|
| Bay                          | 20             | 69.2 A        | 7.95  |
| Tidal Pool                   | 3              | 66.7 AB       | 16.67 |
| Misc.                        | 3              | 22.2 AB       | 11.11 |
| High Energy Beach            | 12             | 18.8 B        | 8.59  |

Groups with different letters are significantly different ( $P \leq 0.05$ ).

Kruskall Wallis (corrected for ties) test results (Zar 1984).

Overall comparison  $P = 0.002$

Comparison of Bay vs High Energy Beach  $0.002 < P < 0.005$

All other comparisons  $P > 0.050$

Table 44. Average piping plover brood fledging success in broods moving varying distances to feeding territories, Assateague Island 1986-1987.

| Distance Moved | N  | $\bar{x}$ (%) | SE    |
|----------------|----|---------------|-------|
| < 200 m        | 26 | 45.55         | 7.97  |
| > 200 m        | 12 | 59.72         | 10.75 |

P = 0.2583<sup>1</sup>

<sup>1</sup>Mann-Whitney U test results (corrected for ties).

Table 45. Fledging success among shorebirds.

| Species                        | % Young Fledging  | Young Fledged Per Adult | Source                            |
|--------------------------------|-------------------|-------------------------|-----------------------------------|
| Oyster Catcher                 |                   |                         |                                   |
| <u>Haematopus ostralegus</u>   | 37                | 0.45 <sup>1</sup>       | Harris 1967                       |
|                                | 59                | 0.75 <sup>1</sup>       |                                   |
|                                | 75                | 0.66                    | Boyd 1962 <sup>2</sup>            |
|                                | 5                 | 0.05                    |                                   |
|                                | 78                | 1.03                    |                                   |
| Avocet                         |                   |                         |                                   |
| <u>Recurvirostra avosetta</u>  | 38                | 0.55                    | Boyd 1962 <sup>2</sup>            |
| Lapwing                        |                   |                         |                                   |
| <u>Vanellus vanellus</u>       | 67                | 0.14                    | Boyd 1962 <sup>2</sup>            |
|                                | 64                | 0.97                    |                                   |
|                                | 14.3              | 0.52                    | Jackson and Jackson 1980          |
|                                | 34.3              |                         |                                   |
|                                | 22.0              |                         |                                   |
|                                | 25.9              |                         |                                   |
|                                | 18.9 <sup>3</sup> |                         |                                   |
|                                | 9.8 <sup>3</sup>  |                         |                                   |
|                                | 6.9 <sup>3</sup>  |                         |                                   |
|                                | 0 <sup>3</sup>    |                         |                                   |
|                                | 31.9              |                         |                                   |
| Snowy Plover                   |                   |                         |                                   |
| <u>Charadrius alexandrinus</u> | 75-83             | 1.8-2.0                 | Warriner et al. 1986 <sup>4</sup> |
|                                | 20-27             | 0.4-0.5                 |                                   |
|                                | 26-29             | 0.7                     |                                   |
|                                | 18-19             | 0.3                     |                                   |
|                                | 63-67             | 1.3                     |                                   |
|                                | 20                | 0.5                     |                                   |
|                                | 50                | 0.71                    | Boyd 1962 <sup>2</sup>            |

Table 45 (cont'd). Fledging success among shorebirds.

| Species                      | % Young Fledging | Young Fledged Per Adult | Source                 |
|------------------------------|------------------|-------------------------|------------------------|
| Ringed Plover                |                  |                         |                        |
| <u>Charadrius hiaticula</u>  | 50 <sup>5</sup>  |                         | Pienkowski 1984        |
|                              | 44 <sup>6</sup>  |                         |                        |
|                              | 46 <sup>6</sup>  |                         |                        |
|                              | 46               | 0.52                    | Boyd 1962 <sup>2</sup> |
| Little Ringed Plover         |                  |                         |                        |
| <u>Charadrius dubius</u>     | 74               | 1.11                    | Boyd 1962 <sup>2</sup> |
| Mountain Plover              |                  |                         |                        |
| <u>Charadrius montanus</u>   | 57 <sup>7</sup>  |                         | Graul 1975             |
| Black-fronted Dotterel       |                  |                         |                        |
| <u>Charadrius melanops</u>   | 71               | 0.92                    | Child and Child 1984   |
| Eurasian Dotterel            |                  |                         |                        |
| <u>Charadrius morinellus</u> | 35               | 0.64                    | Brykjedal 1987         |
|                              | 56               | 0.69                    | Child and Child 1984   |
| Golden Plover                |                  |                         |                        |
| <u>Pluvialis apricania</u>   | 73               | 0.59                    | Brykjedal 1987         |
| Turnstone                    |                  |                         |                        |
| <u>Arnaria interpres</u>     | 40-50            |                         | Nettleship 1967        |
|                              | 81               | 1.17                    | Boyd 1962 <sup>2</sup> |
|                              | 73               | 1.24                    |                        |

Table 45 (cont'd). Fledging success among shorebirds.

| Species                    | % Young Fledging | Young Fledged Per Adult | Source                 |
|----------------------------|------------------|-------------------------|------------------------|
| Knot                       |                  |                         |                        |
| <u>Calidris canutus</u>    | 40-50            |                         | Nettleship 1967        |
|                            | 50               | 0.83                    | Boyd 1962 <sup>2</sup> |
| Temminck's stint           |                  |                         |                        |
| <u>Calidris temminckii</u> | 50-70            | 0.5-0.9                 | Hilden 1978            |
| Dunlin                     |                  |                         |                        |
| <u>Calidris alpina</u>     | 50               |                         | Holmes, 1966           |
| Redshank                   |                  |                         |                        |
| <u>Tringa totanus</u>      | 50               | 0.74                    | Boyd 1962 <sup>2</sup> |

<sup>1</sup>From stable population.

<sup>2</sup>Young fledged per adult calculated by multiplying average # of eggs per female x fraction of eggs laid which hatch x fraction of young hatched which fly.

<sup>3</sup>Population decline observed during this period.

<sup>4</sup>Young per female, some adults attempted two broods.

<sup>5</sup>Productivity thought to exceed that necessary to maintain a stable population.

<sup>6</sup>Productivity considered to be only marginally sufficient to maintain a stable population.

<sup>7</sup>Does not include broods which lost all chicks.

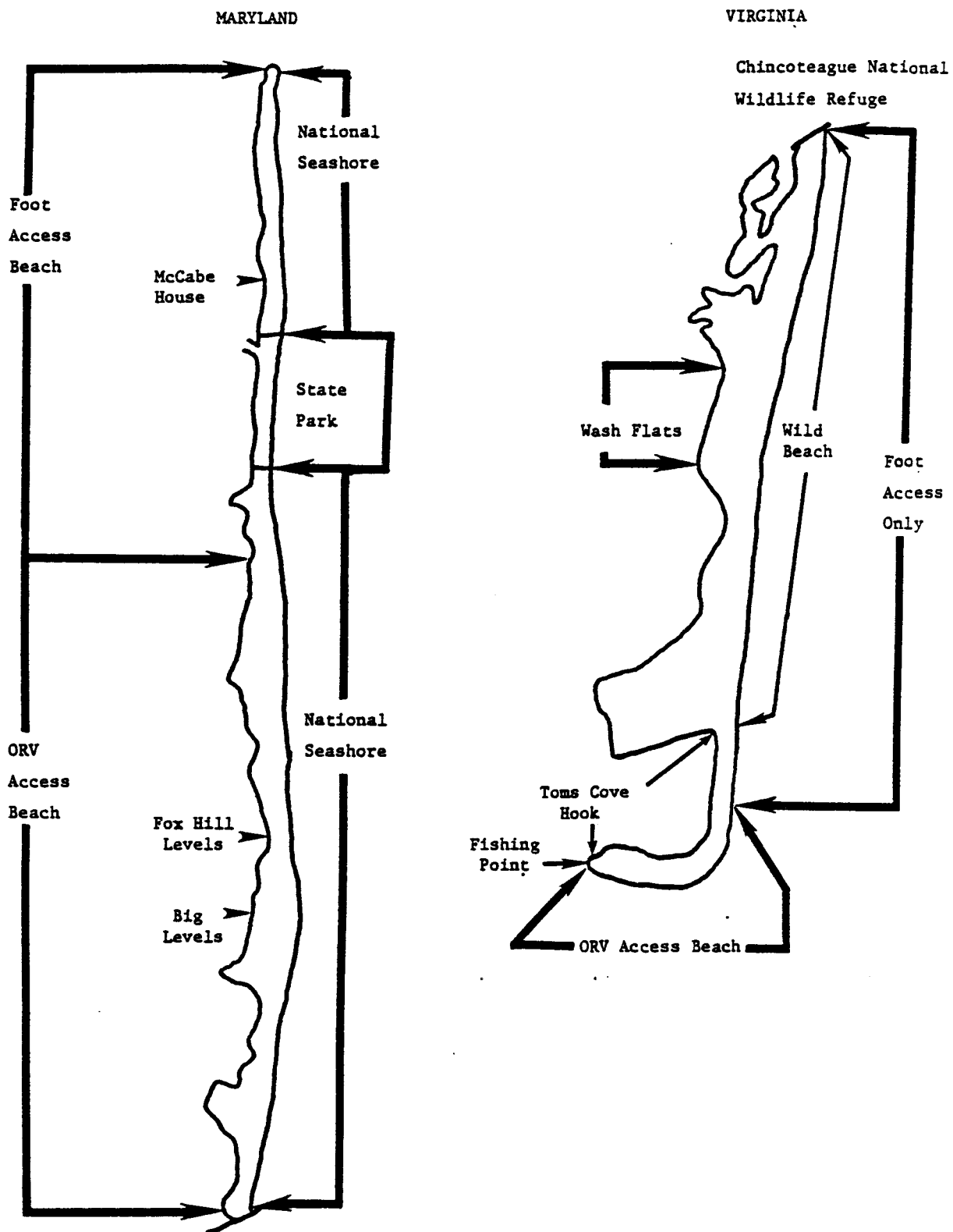


Figure 1. Map of Assateague Island.

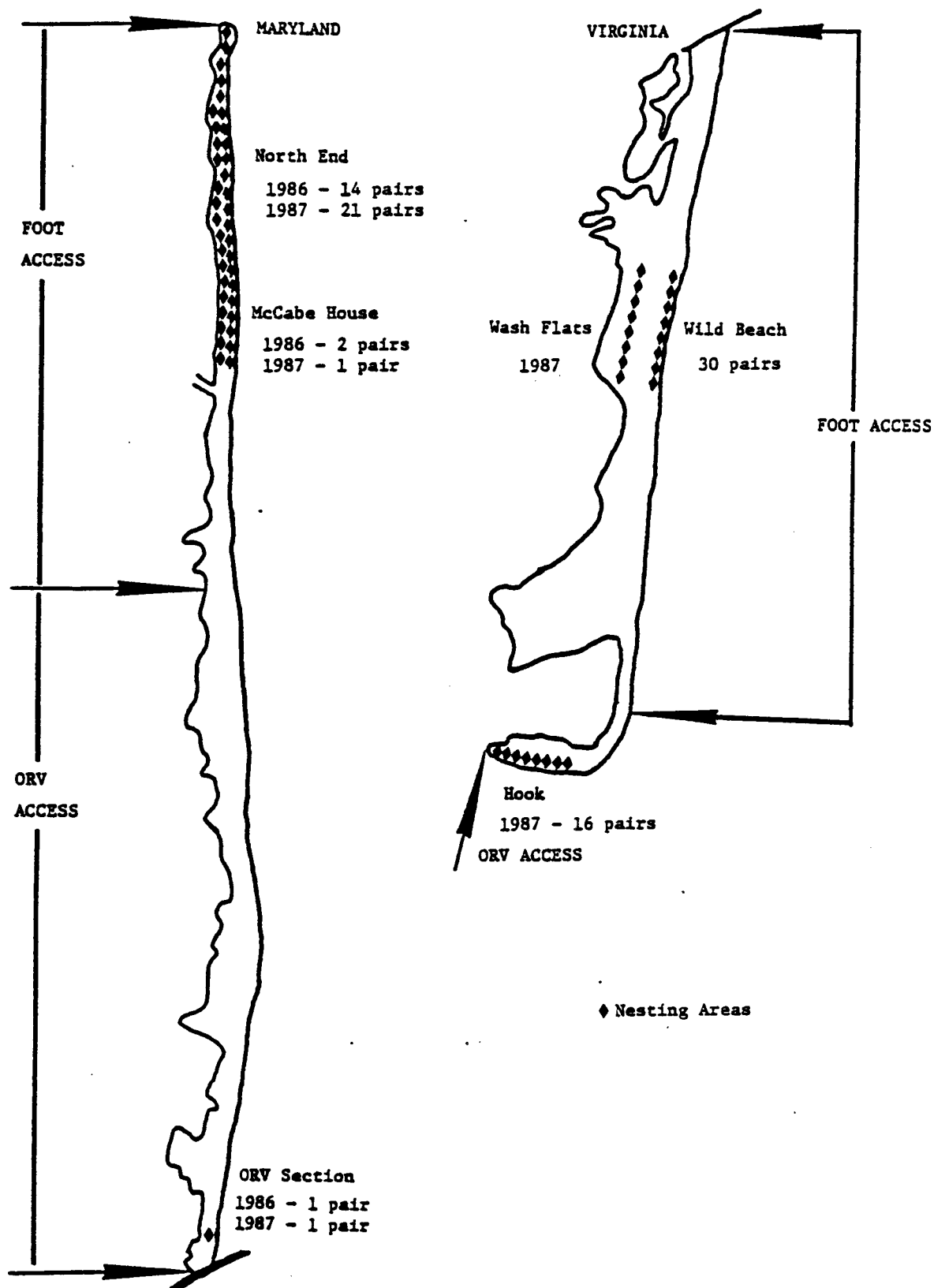


Figure 2. Piping plover nesting areas on Assateague Island 1986-1987.

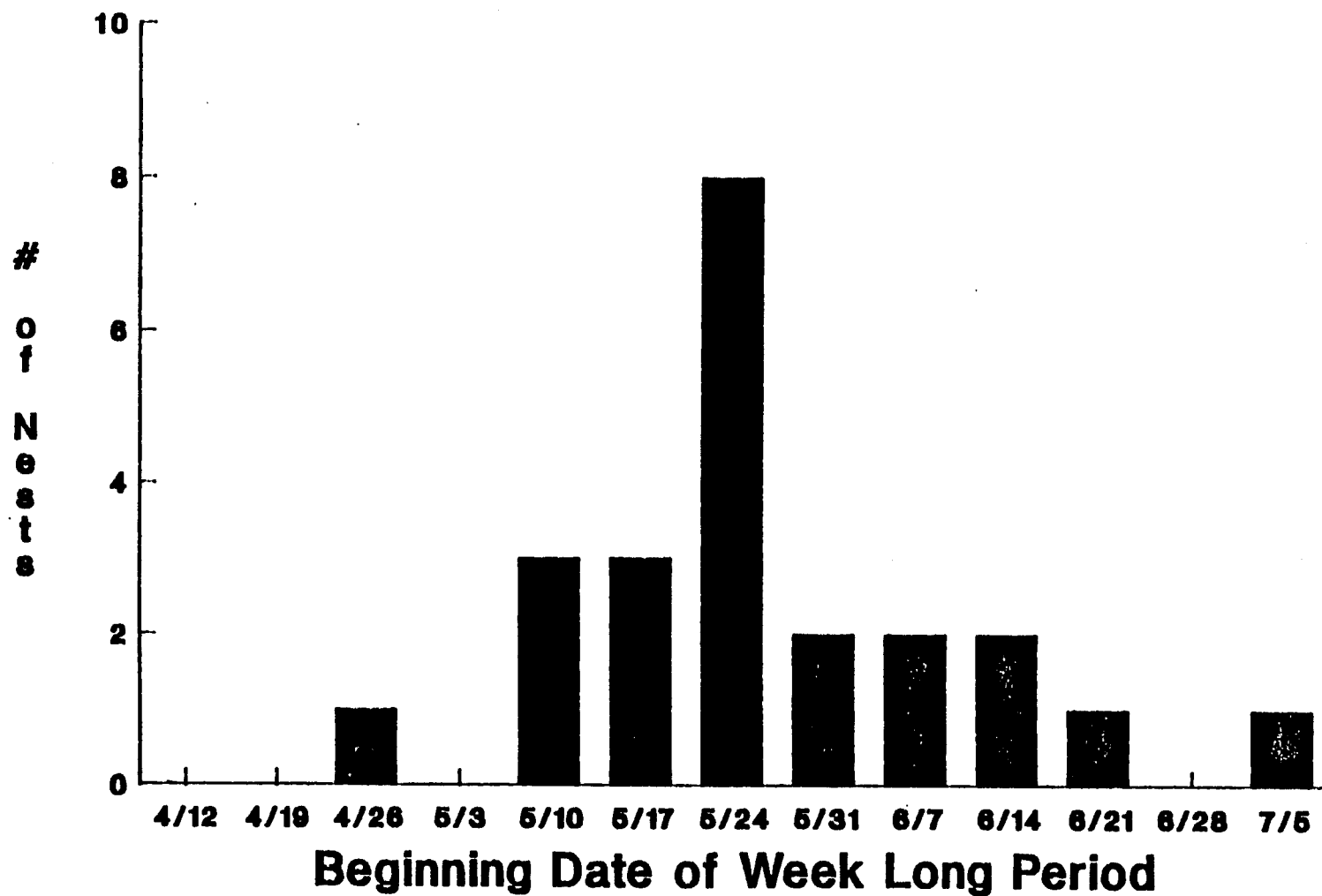


Figure 3. Estimated date of nest initiation by piping plovers on the Maryland portion of Assateague Island 1986.

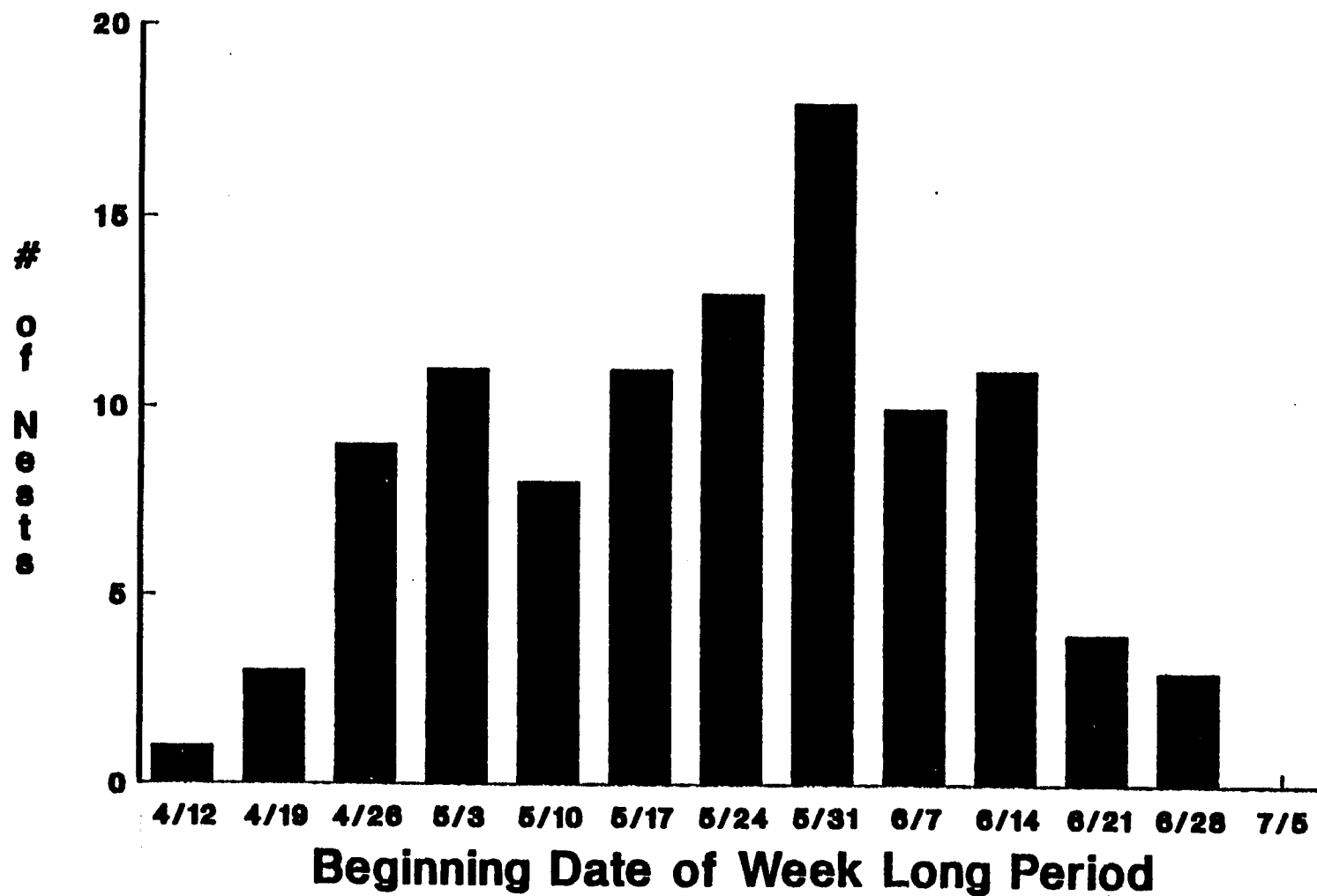


Figure 4. Estimated date of nest initiation by piping plovers on Assateague Island 1987.

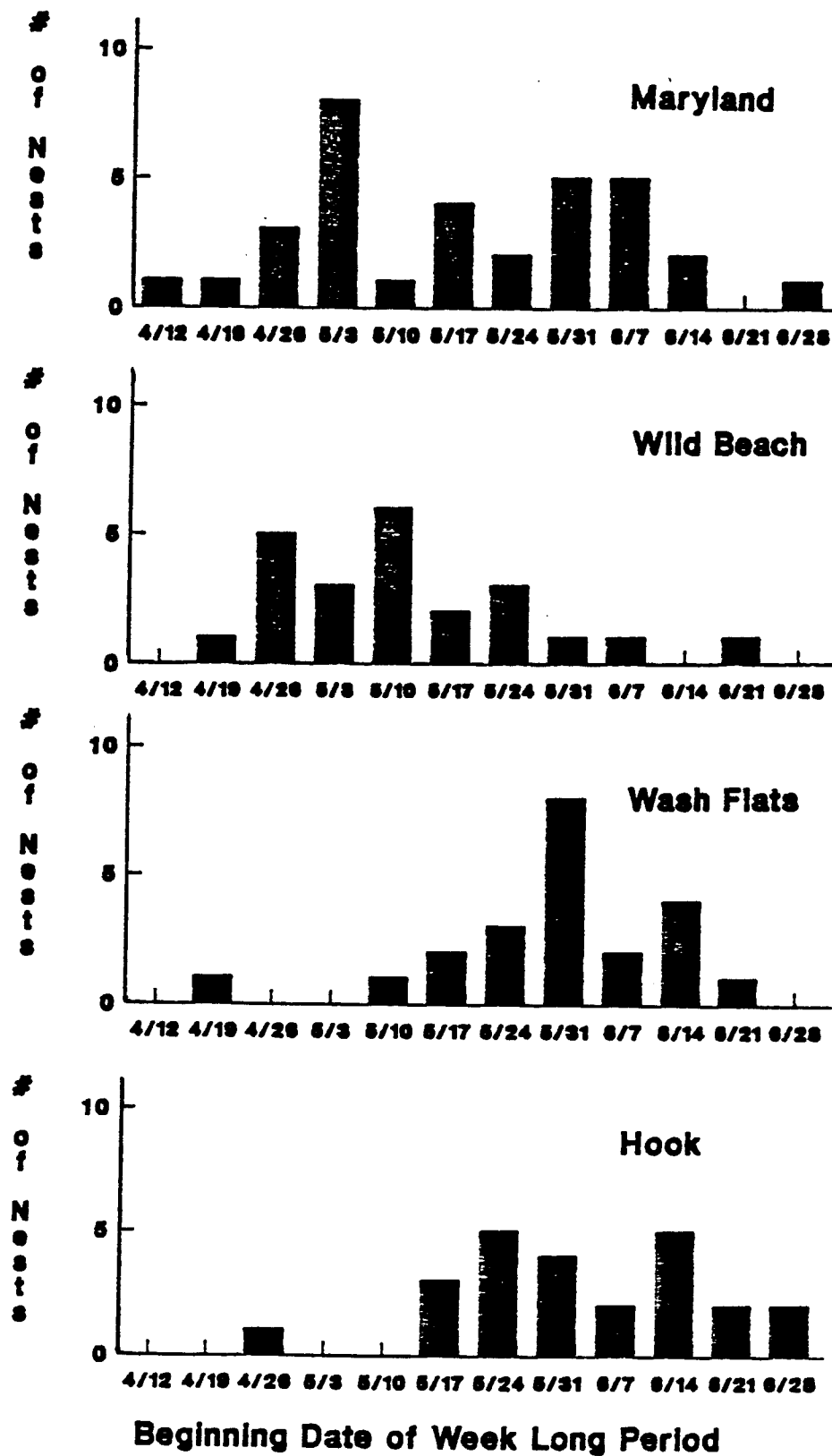


Figure 5. Estimated date of nest initiation by piping plovers on Assateague Island 1987.

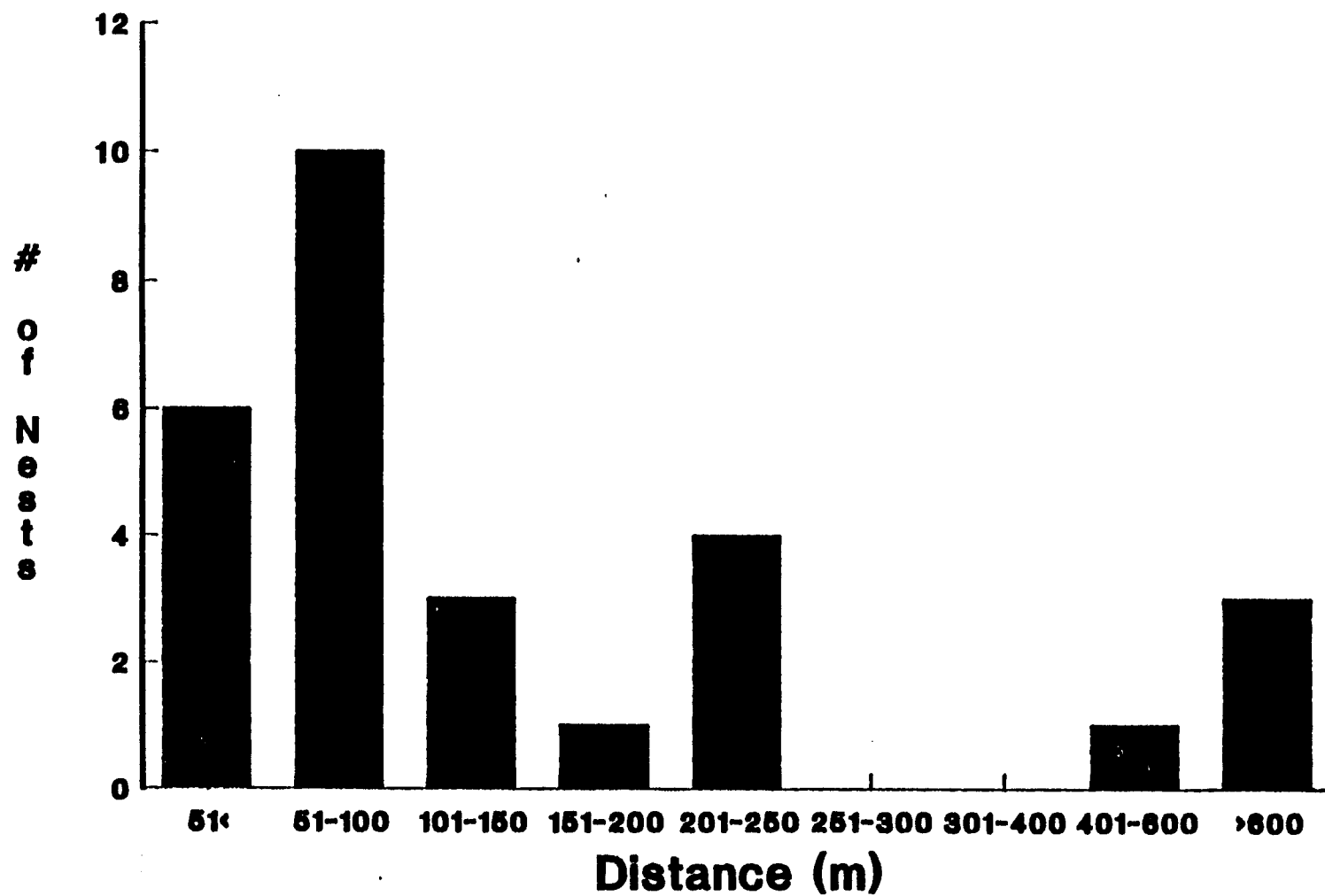


Figure 6. Distances between original nests and piping plover renests on Assateague Island 1986 - 1987.

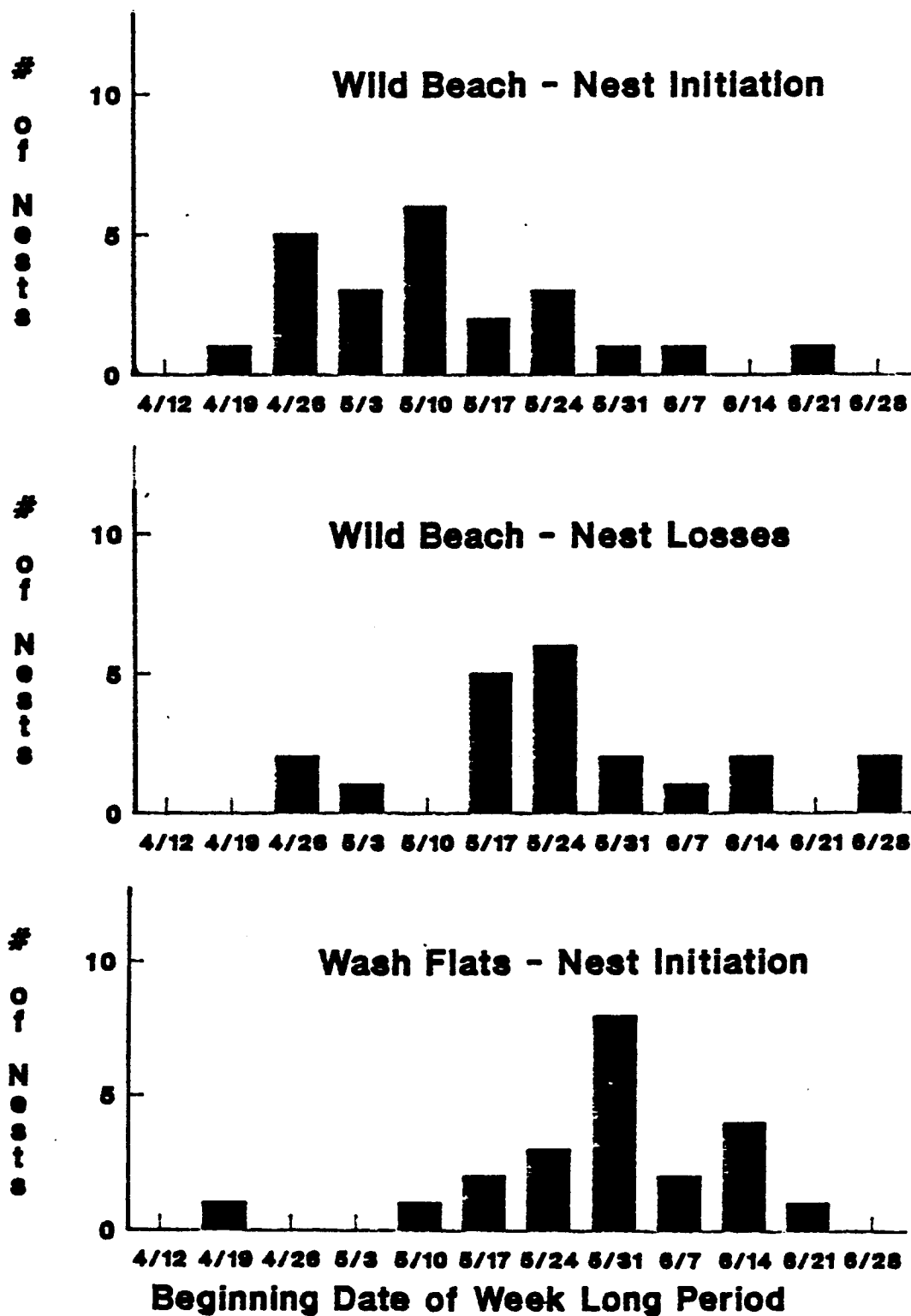


Figure 7. Estimated date of nest initiation and nest losses on the Wild Beach and Wash Flats, Assateague Island 1987.

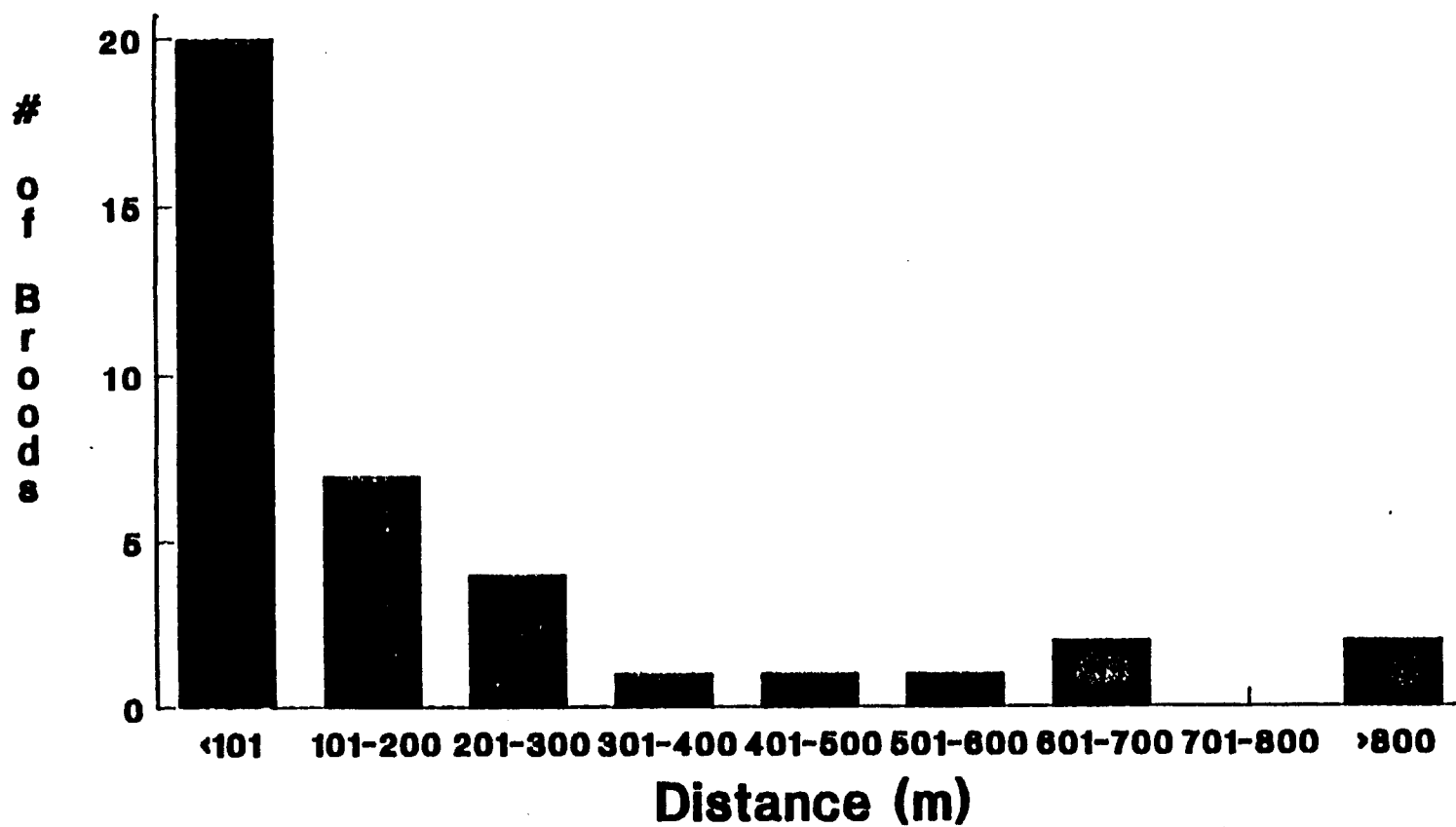


Figure 8. Distances piping plover broods moved to foraging areas on Assateague Island 1986 - 1987.

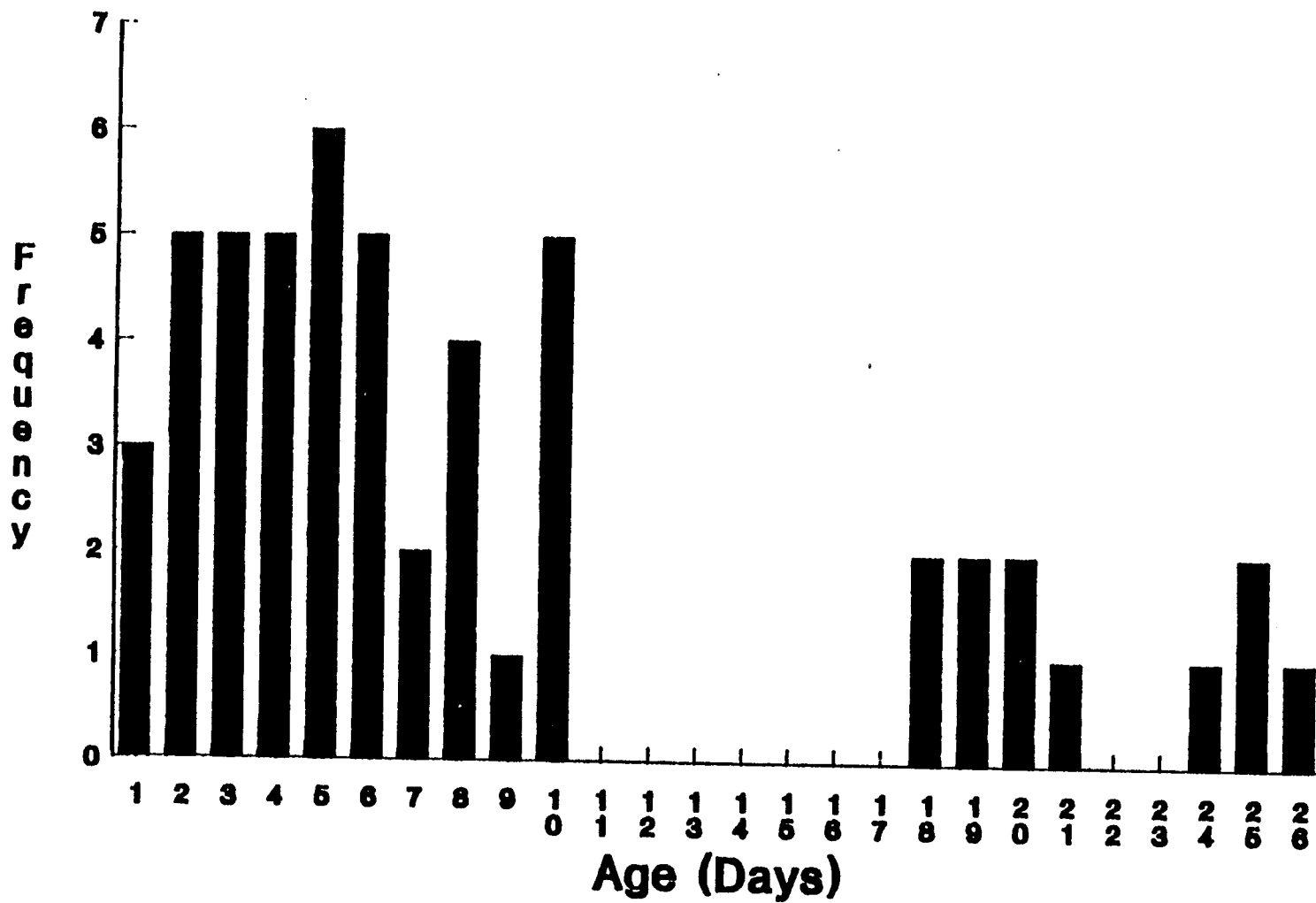


Figure 9. Age distribution of piping plover chick mortality on Assateague 1986 - 1987.

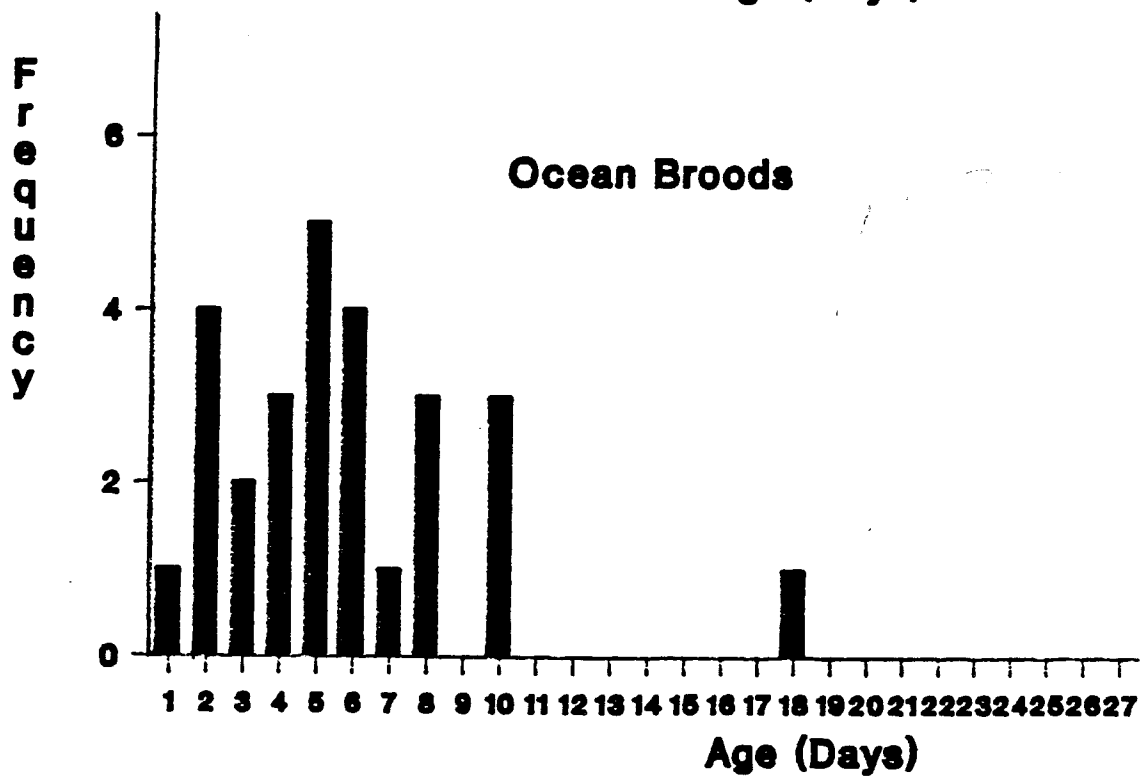
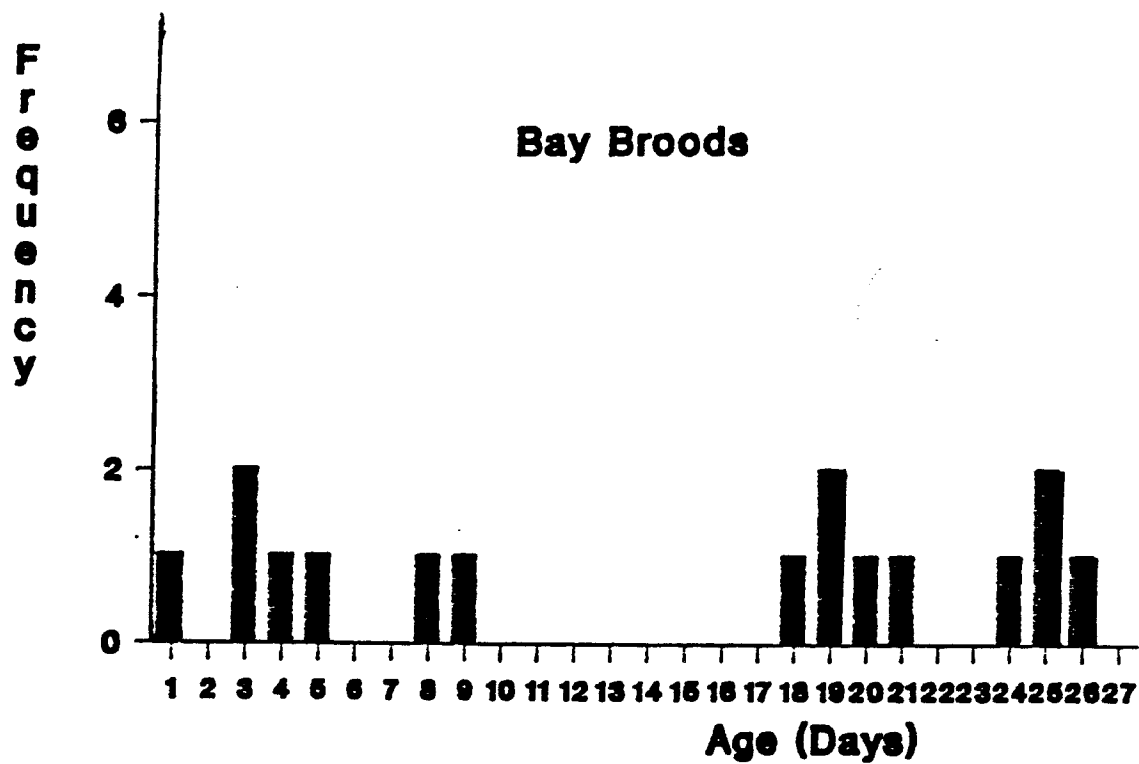


Figure 10. Age distribution of piping plover chick mortality by brood foraging habitat Assateague Island 1986 - 1987.