Great Lakes Piping Plover Habitat Characteristics, Reproductive Success, and Habitat Availability

Arlene P. Olivero

REU Program

August 10, 1994

Mentor: Dr. Francesca C. Cuthbert

ACKNOWLEDGMENTS

The help of numerous people made this REU project possible. I would particularly like to thank Dr. Francesca Cuthbert, Lauren Wemmer, Alice Doolittle, Robert Vande Kopple, Dr. David Karowe, and Dr. Ted Anderson.

ABSTRACT

This study found Great Lakes Piping Plovers nesting primarily on wide, sparsely vegetated, sand and cobble beaches. The occupied beaches often included an ephemeral wetland or pond and were separated from the treeline by a wide series of dunes and unforested land. There was a higher percentage of rock cover at the nest than in the surrounding nest area ($p < .000$), and the distance from the waterline to treeline was significantly greater at the nest than in the surrounding territory ($p=.008$) and surrounding beach ($p = .025$). Reproductive success was positively correlated to the percentage of rock cover in the nesting territory ($p = .021$) and percentage of rock cover on the beach ($p = .032$), and negatively correlated to the percentage of beach transects with evidence of dogs was ($p = .048$). In Emmet, Charlevoix, and Cheboygan county 6.72 miles or approximately 6% of the Michigan mainland shoreline met the minimum physical nesting requirements for Piping Plovers. However, the estimate of 6% of apparently suitable nesting habitat may be further reduced when the levels of recreational use at the identified sites are considered. These results indicate that nesting habitat availability may be a factor limiting the population, and that it is imperative to identify and protect Great Lakes Piping Plover habitat.

INTRODUCTION

The distribution and abundance of species are influenced by both abiotic and biotic factors. Although dispersal, predation, competition, parasitism, and tolerance for physical and chemical conditions influence the distribution of species (Krebs 1992), human destruction and alteration of natural habitats has been the primary cause of the declining abundance and distribution of many species (Harris 1988; Burgess and Sharpe 1981; Hansson 1992). As human alteration of natural habitats continues to increase, it is imperative to protect habitat where threatened species can successfully survive, grow, and reproduce (Hansson 1992). However before appropriate management strategies for threatened species can be implemented, suitable habitat and the factors influencing the reproductive success of the species must be identified.

The Piping Plover (*Charadrius melodus*) is a small shorebird that is threatened or endangered across its entire range (Haig 1992). Piping Plovers occur in three disjunct populations along sections of the northern Great Plains from Nebraska to the southern Canadian prairie provinces, along portions of the Atlantic coast from North Carolina to southern Canada, and along portions of the western Great Lakes (Haig 1992). Although substantial continent wide Piping Plover declines have been observed during the last century, the most severe population decline has occurred in the Great Lakes region (Haig 1992). In the Great Lakes, Piping Plovers historically nested in Michigan, Minnesota, Wisconsin, Illinois, Indiana, Ohio, Pennsylvania, New York, and Ontario, Canada and may have numbered between 500 and 680 nesting pairs (Russell 1983). However, by 1979 the Great Lakes population had been reduced to only 38 pairs nesting in Michigan (Lambert and Ratcliff 1981), and by 1986 the population had dropped to only 17 breeding pairs (Wemmer et al. 1993). In 1986, the Great Lakes Piping Plover was listed as federally endangered, and currently it is considered the most endangered species in the Great Lakes (USFWS 1994)

The Great Lakes Piping Plover population decline has been attributed to habitat loss, human disturbance, and high rates of egg and chick predation (USFWS 1994). Although Piping Plovers were hunted in the late 1800's, it is thought that the Great Lakes population had recovered from the impact of hunting by the 1940's (Russell 1983). Increased beach development and recreational use since the 1940's has been the primary cause of the loss of Piping Plover habitat (Cairns and McLaren 1980; Cairns 1982). In addition, high Great Lakes water levels since the 1970's may have reduced available shoreline habitat (Russell 1983). Direct disturbance by people, pets, and recreational vehicles may have also lowered reproductive success in the Great Lakes region. Prindiville Gaines and Ryan (1988) found that in North Dakota Piping Plover nesting success was lower in territories with evidence of cattle or motor vehicle disturbance, and Flemming et al. (1988) found that in Nova Scotia, increased human disturbance altered Piping Plover chick behavior and resulted in fewer chicks surviving to age 17 days. Populations of certain nest and chick predators have also increased significantly in the Great Lakes Region since the 1940's. For example, the population of Ring-billed Gulls in Michigan rose from about 20,000 nesting pairs in 1960 to approximately 700,000 pairs in the early 1980's (Brewer 1991).

The federal recovery plan for the Great Lakes Piping Plover population calls for increasing the population to 150 breeding pairs, with 100 pairs in Michigan, 15 in Wisconsin, and 35 in other

Great Lakes States. (Powell, 1991). However, although predator exclosures and fencing to restrict human use have been erected at most known nesting sites in the Great Lakes since 1989, the Great Lakes Piping Plover population has failed to increase significantly since its listing in 1986 (Wemmer et al. 1993). Although reasons for the apparent lack of population growth remain unclear (Powell 1991), stabilization and increase of the Great Lakes Piping Plover population in the future will require further identification and protection of suitable habitat and identification of factors effecting reproductive success.

Although previous studies have quantified Piping Plover habitat characteristics and factors influencing reproductive success on the Great Plains and Atlantic Coast (Cairns, 1982; Prindiville Gains and Ryan, 1988; Patterson et al. 1991; Burger, 1987;), quantitative data on 1) characteristics of the breeding habitat of Great Lakes Piping Plovers, 2) information on the relationship between habitat quality and reproductive success in the Great Lakes, and 3) the availability of suitable habitat in the Great Lakes Region is limited (Lambert and Ratcliff, 1981; Niemi and Davis, 1979; Powell and Cuthbert, 1992; Norstrom, 1990; Allen, 1987). The objectives of this study were to 1) quantify the physical characteristic and levels of human disturbance at occupied breeding sites 2) investigate the relationship between reproductive success and physical characteristics and levels of human disturbance, and 3) identify areas of potentially suitable but unoccupied breeding habitat in Emmet, Charlevoix, and Cheboygan counties in northern Michigan.

METHODS

Habitat Characteristics

Study sites - - - I collected data on habitat characteristics at all 14 active nest sites on Michigan mainland. These sites include Cross Village South, Cross Village Central, Cross Village North, Sturgeon Bay South, Sturgeon Bay Central, Sturgeon Bay North, Waugashance Pt. East, Waugashance Pt. West, Grand Marais Inner Bay, Grand Marais Lonesome Pt., Vermilion 12, Vermilion 2, Vermilion 15, and Pointe Aux Chenes (Figure 1). Four nest sites on North Manitou

Island and a single nest on High Island were occupied in 1994, but were not sampled in this study. However, some measurements of nest site characteristics of three nests on North Manitou Island were taken by Lauren Wemmer and Kelly Millenbah and are included in this report.

Nest Site Characteristics --- At each nest, I measured the height of the dune and the distance from the nest to waterline, beginning of the dune system, treeline, and ephemeral pond. When the distance from the waterline to treeline was > 400m, I recorded the absence of a treeline as did Lambert and Ratcliff (1981). To quantify the characteristics of the area surrounding the nest, I divided the area around the nest into 4 quadrants, and extended a 12 m transect from the nest at a randomly selected angle in each quadrant (Patterson et al. 1991). At points at 3 m intervals along each transect I recorded 1) percentage of vegetative cover, 2) percentage of cobble/gravel, and 3) dominant rock class. I determined the percentage of vegetative cover by placing a 1 m by 1 m square on the ground at each point and then estimated the percentage of vegetation cover within the grid (Patterson et al. 1991). I determined the percentage of rock cover by placing a 30 cm by 30 cm 100 point grid at each point; the number of points which covered rock were then recorded. I classified the dominant rock class at each point as either cobble or gravel. Cobble was defined as rocks >1 cm and gravel as rocks < 1cm. (Powell and Cuthbert, 1992). To further quantify the characteristics of the nest site, I placed a 1 by 1 meter vegetation plot over the nest cup, and determined the percentage of rock cover on a 30 by 30 cm square plot placed adjacent to the edge of the nest cup at a randomly selected direction.

Beach Characteristics --- I determined the length of the beach and the area of openness surrounding each nest site. Length of the beach was defined as the length of shoreline where the distance from the water to tree line was >25 m. The area of openness was defined as the unforested area between the waterline and treeline along the length of the beach. In the Lower Peninsula, I determined the length and area of openness of the beach surrounding the nests from 1987 aerial photos (DNR, 1987). In the Upper Peninsula, I determined the length and area of openness along the beach at Grand Marais Inner Bay and Vermilion from 1986 aerial photos (DNR, 1986). At Point Aux Chenes, I determined the beach length and area of openness from a 1992 aerial photo (USFS, 1992). I used a Modified Acreage Grid (64 dots per square inch) to estimate the area of openness on each nesting beach (Bryan, 1942). I could not calculate the length and area of openness surrounding the beach at Grand Marais Lonesome Pt. because significant shoreline changes have occurred since the last aerial photos were taken in 1986.

At nest sites where the surrounding beach was greater than 1 mile in length, I measured the physical characteristics along a 1 mile section of beach surrounding each nest site. At nest sites where the surrounding beach was less than 1 mile in length, I measured the physical characteristics along the entire beach. At each nest site, I ran one transect from the waterline to the treeline at the nest, and additional transects at intervals of 150 m radiating out from either side of the nest along the length of the beach. I measured the distance from the waterline to the treeline and waterline to the beginning of the foredune on each transect. In addition, I estimated the percentage of vegetation and rock cover at points at 3 m intervals along each transect between the waterline and beginning of the foredune as did Prindiville Gains and Ryan, 1988. The percentage of vegetation cover was determined by using a 1 m by 1 m square in the same method as stated in the previous section. Similarly, the percentage of rock cover was determined by using a 30 cm by 30 cm 100 point grid in the same manner as stated in the previous section.

I calculated the mean distance from the waterline to treeline and mean distance from the waterline to foredune by averaging the measurements from all transects within 1 mile of the nest. I calculated the mean percentage of rock cover and mean percentage of vegetative cover on the beach surrounding the nest site by taking the average of all the sample points on the 1 mile area surrounding the nest site.

Nesting Territory Characteristic - - - Wilcox (1959) stated that Piping Plover chicks remain within 500 ft (approximately 155 m) of the nest for 30-35 days prior to fledging. I therefore used the nest transect and the two adjacent transects to further characterize the primary nesting territory at each nest. I calculated the mean distance from waterline to foredune and the mean distance from waterline to treeline in the primary nesting territory by averaging the measurements along the three transects. I calculated the mean percentage of rock cover and vegetation cover in the territory by averaging the measurements recorded at each point along the three transects

Disturbance - - - I quantified the level of human disturbance at beaches by counting the number of human trails intersecting each of the transects on the beach during sampling day. I calculated the average level of human disturbance at the beach by averaging the number of tracks recorded on each transect at the beach. I calculated the mean level of human disturbance in the territory by averaging the number of tracks on the three transects closest to the nest. I also recorded the presence of dog tracks and tracks of Piping Plover predators (Common Ravens, American Crows, Ring-Billed Gulls, fox, coyotes, raccoons...) on each transect. I recorded all measures of disturbance on sunny days between July 10th and July 25th.

Reproductive Success

Sites were visited several times per week from nest initiation through fledging to monitor chick survival. Chicks were determined to have fledged if they survived to 25 days and were seen flying. The reproductive success at each nest sites was defined as the number of chicks fledged per pair.

Statistical Analysis

I used Paired T tests to determine of at all 14 sites the average distance from the waterline to foredune and average distance from the waterline to treeline differed between the nest vs. the primary territory, the nest vs. the entire beach, and the primary territory vs. the entire beach. I also used Paired T tests to determine if the average percentage of rock cover and average percentage of vegetation cover differed at the nest point vs. the area surrounding the nest, in the area surrounding the nest vs. the territory area, in the area surrounding the nest vs. the entire beach, and the primary territory vs. the entire beach.

I investigated the relationship between habitat characteristics and reproductive success by determining if number of chicks fledged per pair varied with physical characteristics or levels of human disturbance on beaches. I performed regressions between number of chicks fledged per pair and 1) beach width, 2) territory width, 3) distance from waterline to treeline for the beach, 4) distance from the waterline to treeline in the territory, 5) percentage of rock cover on the beach, 6) percentage of rock cover in the territory, 7) percentage of vegetative cover on the beach, 8) percentage of vegetative cover in the territory, 9) average number of human trails per transect for the beach, 10) average number of human trails per the five transects nearest the nest, 11) number of transects with evidence of dogs per total number of transects, and 12) number of transects with evidence of Piping Plover predators. Nest sites were also placed into either low or high disturbance classes. Sites were placed in the low disturbance category if they had an average of less than 10 human trails per transect and were placed into the high disturbance category if they had an average of greater than 10 human trails per transect. A Wilcoxon Signed Rank test was used to determine if the number of chicks fledged per chicks hatched differed between low and high disturbance sites. Similarly, the nest sites were placed into low and high predator concentration classes and low and high dog disturbance classes. Sites were placed in the low disturbance category if the number of predators per number of transects was less than 0.5. Nest sites where the total number of predators per number of transects was greater than or equal to .05 were considered high predator density sites.

Potential Suitable Habitat

I used the C-Map Geographic Information System Version 2.1 (MSU, 1989-1992) to determine areas of beach and sandune habitat in Emmet, Charlevoix, and Cheboygan county. The C-Map GIS system classified the area of beach and sandune habitat based on the distance from the treeline to lake shore from 1978 aerial photos (Vande Kopple per comm., 1994). I calculated the area and length of shoreline of each polygon classified as either beach or sand dune by the C-Map GIS system. I then calculated the area and length of shoreline of each polygon that was greater than 65 m wide. Because no Piping Plover nest was found at a section of beach where the distance from the waterline to treeline was less than 65 m, I assumed that beach and sandune areas less than 65 m wide would not be suitable for Piping Plover nesting.

I found no active Piping Plover nests located in beach or sandune polygons where the length of the shoreline where the treeline was greater than 65 m away was less than .2 contiguous miles. I therefore assumed that beach and sandune polygons with less than .2 contiguous miles of > 65 m beach or sandune were not suitable for Piping Plovers. I also found no active Piping Plover nest located in a polygon where the open area along the >65 wide distance was less than 7.1 acres. I then classified each polygon as having a high, medium, or low potential Piping Plover habitat suitability. Polygons having high potential as Piping Plover habitat had a greater than .2 mile long contiguous area where the distance from the waterline to treeline was greater than 65m and where the open area was greater than or equal to 7.1 miles. Polygons having medium potential as Piping Plover habitat had a greater than 0.2 mile long contiguous area where the distance from the waterline to treeline was greater than 65 m but had open areas of less than 7.1 acres. Polygons having low potential as Piping Plover habitat had less than 0.2 miles of contiguous land where the waterline to treeline was greater than 65 m and less than 7.1 acres of open land surrounding the area where the distance from the waterline to treeline was greater than 65 m.

Because the GIS classification of beach and sandune habitat was based on 1978 aerial photos and did not provide information on the distance from the waterline to foredune, the percentage of rock cover, the percentage of vegetative cover, and level of human disturbance, I ground checked all polygons with high and medium potential as Piping Plover habitat to determine the length of shoreline suitable for Piping Plover nesting in each polygon . I classified an area as meeting the minimal nesting habitat requirements for Piping Plovers if 1) distance from the waterline to foredune was greater than or equal to 8 m, 2) the distance from the waterline to treeline was greater than or equal to 65 m, 3) the percentage of vegetative cover was less than 10%, and 4) the percentage of rock cover was greater than 10% with at least a few patches of rock cover greater than 20%. The distance of 8 m from the waterline to foredune and the distance of 65 m from the waterline to treeline were chosen because they were the minimum distances recorded at any Piping Plover nest during this study. The criteria of 10 % vegetation cover was chosen because the percentage of vegetative cover on the beach was less than 10% in 92.9% of the nests sampled in this study. The criteria of 10% and 20% rock cover were chosen because 85.7% of nests had greater than 10% rock cover in the nest area and 94% had greater than 20% rock cover at the nest.

RESULTS

Descriptive Statistics

Habitat Characteristics

Nest Site - - - The mean, standard deviation, and range in the measurements of distance from the waterline to fordune, waterline to treeline, nest to waterline, nest to dune, nest to pond or river, percentage of rock cover at the nest plot, percentage of rock cover in the nest area, percentage of vegetative cover at the nest plot, percentage of vegetative cover in the nest area, and height of the dune at the nest are reported in Table 1.

Nest Territory - - - The mean, standard deviation, and range in the measurements of average waterline to foredune, average waterline to treeline, percentage of rock cover, and percentage of vegetative cover in the nest territory are reported in Table 2.

Beach Characteristics - - - The mean, standard deviation, and range in measurements of average waterline to foredune, average waterline to treeline, percentage of rock cover, percentage of vegetative cover, length and area of openness on the occupied beach area are reported in Table 3.

Table 1 : Nest Site

Characteristic	Average	Range
Waterline to foredune (m)	48.7 +- 44.4	8 - 178
Waterline to treeline (for distances < 400 m) (m)	172.0 +- 60.0	65 - > 400
Nest to waterline (m)	26.3 +- 17.1	7 - 59
Nest to dune (m)	22.4 +- 32.9	1 - 119
Nest to pond/river (m)	133.7 +- 134.6	25 - 452
% rock cover at nest plot	48.8 +- 26.9	0 - 97%
% rock cover in nest area	31.5 +- 27.3	0 - 92
% vegetation cover at nest plot	8.7 +- 15.6	0 - 48
% vegetation cover in nest area	6.6 +- 9.3	0 - 33
Height of the dune (m)	2.3 +- 2.4	0 - 7

Table 2: Nest Territory Characteristics

Characteristic	Average	Range
Waterline to foredune (m)	42.1 +- 35.5	8.7 - 105
Waterline to treeline (m)	163.5 +- 65.1	53.3 - > 400
% rock cover	27.9 +- 21.2	0 - 81
% vegetation cover	3.11 +- 5.7	0 - 18

Table 3: Beach Characteristics

Characteristic	Average	Range
Waterline to foredune (m)	34.4 +- 25.3	9.4 - 80
Waterline to treeline (m)	156.2 +- 63.9	76.3 - 295.1
% rock cover	23.9 +- 21.2	0 - 72.3
% vegetation cover	3.8 +- 5.7	.1 - 10.7
Length of beach (miles)	2.1 +- 1.2	.8 - 4.2
Area of openness (acres)	103.0 +- 66.9	31 - 196

Inferential Statistics

Waterline to Foredune

To gain normality and equal variance of the distributions, the values were log transformed before Paired T tests were performed. Analysis indicated that at the .05 level of significance 1) the average width of the nesting territory was not significantly wider than the average beach width (p = .09790; n=14), 2) the average width at the nest was not significantly wider than the territory (p = 28606; n=14), and 3) the width at the nest was not significantly wider than the average beach width (p = .07229; n=14). Therefore, the width at of the beach was not significantly different at the nest site, nesting territory, or surrounding beach. (Figure 2)

Waterline to Treeline

Because the data were normally distributed with equal variance, values were not log transformed before Paired T tests were performed. Analysis showed that at the .05 level of significance, the distance from the waterline to treeline was 1) significantly greater on the nest transect than on the territory (p=.008; n=14), 2) significantly greater on the territory than on the beach (p=.026; n=14), and 3) significantly greater on the nest transect than on the beach (p=.025; n=14). Thus, the nest was located where the waterline to treeline was significantly greater than in the surrounding nesting territory or surrounding beach, and the nesting territory was located where the waterline to treeline was significantly greater than in the surrounding beach. (Figure 3)

Percentage of Rock Cover

Because the data were normally distributed with equal variance, the data were not log transformed before Paired T tests were run. Analysis indicate that 1) the average percentage of rock cover was not significantly greater in the territory than on the entire beach (p=.0926; n=14), 2) the average percentage of rock cover was not significantly greater in the nest area than in the territory (p=.3605; n=14), and 3) that the percentage of rock cover was significantly greater in the plot adjacent to the nest than in the nest area (p<.000; n = 17). Therefore the percentage of rock cover is higher at the nest site than in the surrounding area, territory, or beach, but no difference in the average percentage of rock cover between the nest area, territory, and beach exists . (Figure 4)

Percentage of Vegetation

To gain normality and equality of variance, the arc sin square root transformation was performed. Analysis tests showed that 1) the percentage of vegetative cover on the territory was not significantly greater than on the beach (p=.9642; n=14), 2) the percentage of vegetative cover on the nest area was not significantly different from percentage on the territory (p =.4140; n = 14), 3) the percentage of vegetative cover on the nest plot was not significantly greater than the % vegetation cover in the nest area (p=.7427; n = 17). Therefore the percentage of vegetative cover remained relatively constant across nesting site, nesting area, territory, and beach . (Figure 5)

Reproductive Success

During the 1994 breeding season, the Great Lakes Piping Plover population had an average fledglings/nesting attempt of 1.33 +- 1.42 and an average fledglings/breeding pair 1.47 +- 1.43 per pair (Wemmer et al. 1994). The 19 nesting pairs in Michigan made 21 known nesting attempts. Seventeen of these nests hatched at least one chick. Of the 4 nests where no chicks hatched, the eggs at Cross Village South and North Manitou West were predated before predator exclosures could be erected, Vermilion Nest #15 was abandoned, and at Sturgeon South eggs were suspected to be infertile. Of the 17 nests that hatched at least one chick, 12 nests fledged at least one chick.

Regressions between the number of chicks fledged per pair and the measured variables indicated that reproductive success was significantly correlated with the percentage of rock cover in the territory (p = .021) (Figure 6), percentage of rock cover on the beach (p = .032) (Figure 7), and the percentage of transects with evidence of dogs (p = .048) (Figure 8). Reproductive success was not significantly correlated too human disturbance, predator abundance, distance from waterline to treeline, waterline to foredune, or percentage of vegetative cover in the territory or beach (Table 4)

Table 4: Reproductive Success Regressions

Regression	P value	R^2
chick/pair vs. territory width	.469	.054
chick/pair/ beach width	.550	.037
chick/pair vs. tree line in territory	.574	.033
chick/pair vs. tree line on beach	.623	.025
chick/pair vs. % rock in territory	.021	.426
chick/pair vs. % rock on beach	.032	.383
chick/pair vs. % vegetation on territory	. 810	.000
chick/pair vs. % vegetation on beach	.109	.160
chick/pair vs. distance to pond	.063	.303
chick/pair vs. human disturbance on beach	.671	.019
chick/pair vs. disturbance in territory	.196	.16
chick/pair vs. dog/transect	.048	.337
chick/pair vs. predators/transects	.395	.073
High vs. low human disturbance	.893	.000
High vs. low predator abundance	.715	.000

Identification of Suitable Habitat

Of the 77 miles of shoreline in Emmet County, 23 miles were classified by GIS as beach or sandune. Ground checks indicated that only 6.72 miles of the beach or sandune area met the minimum physical nesting requirements for Piping Plovers. (Figure 9)

Of the 25 miles of Michigan mainland shoreline in Charlevoix county, 5.4 miles were classified as beach or sandune. Ground checks indicated that only .68 miles of these beach and sandune areas met the minimum nesting requirements of Piping Plovers. (Figure 10)

Of the 23 miles of shoreline in Cheboygan county, 4 miles contained beach and sandune areas (Duncan Bay and Light House Point were not classified on GIS as beach and sandune, but were included in this estimate). Ground checks indicate that only .22 miles of the beach met the minimum nesting habitat requirements for Piping Plovers (Figure 11)

In this three county area a total of 7.62 miles or 6% of the entire shoreline and 23% of the available beach and sandune area possess characteristics that meet the minimum physical nesting habitat requirements for Piping Plovers. (See Appendix for notes on the suitability of each beach and sandune polygon in these three counties)

DISCUSSION

Habitat Characteristics

Results from this study indicate that the distance between the waterline and treeline may be an important factor determining Piping Plover habitat selection. Piping Plovers may be choosing to nest in areas where the distance from waterline to treeline is greater than in the surrounding territory or beach area to minimize levels of nest and chick predation. Certain mammalian predators may be reluctant to travel far from forest cover, and several studies have shown that the concentration of mammalian and avian predators are greater at the forest edge (Gates and Gysel, 1978; Chasko and Gates, 1982; Andren, 1992). Although no significant relationship was found between # chick fledged per hatched and distance from the treeline, pressure to avoid nest and chick predation may still be driving the Piping Plovers choice to nest at the areas of greatest waterline to treeline distance.

Previous work has also identified beach width as an important factor influencing Piping Plover habitat selection. Prindiville Gaines and Ryan (1988) suggest that narrower stretches of beach may be lower quality Piping Plover nesting sites because nest on narrow beaches are at greater risk of damage from storms and high water levels. Predators may be more successful locating nests along narrow beaches (Prindiville Gaines and Ryan 1988). Although Prindiville Gaines and Ryan (1988) found Piping Plovers in North Dakota nested at sections of the beach that were significantly wider than unoccupied area, this study did not find the same pattern. I suggest that although Piping Plover may prefer to occupy wide stretches of beach, these wide stretches must also contain other essential characteristics such as cobble, sparse vegetation, or adequate distance from the waterline to the treeline. Lack of other essential habitat characteristics at the wider areas of some of the beaches sampled in this study may explain why some of the Piping Plovers chose to nest on sections of the beach that were narrower than the surrounding territory or beach in this study. Above a critical minimum width, the distance from the waterline to foredune may also not decrease the chance of destruction from storms or the risk of nest and chick predation. If the nesting sites in this study were on beaches wider than this critical minimum width, no significant difference in beach width between the nest, territory, or beach would be expected.

The percentage of rock cover may also influence Piping Plovers habitat selection. Although wide variation in the amount of rock cover at the sampled sites were observed, Piping Plovers nests were located at sites with significantly more rock cover than the surrounding nest area. Burger (1987) also found that Piping Plover nests in New Jersey were at spots with more rock and shell cover than random points, and Whyte (1985) found that Piping Plovers in Saskatchewan established nests on gravel more often than was expected by chance. Piping Plovers may choose to nest in areas of high rock cover to better camouflage their nest. This camouflage may result in lower nest predation rates (Burger 1987), however a Piping Plover nest predation study on

Assateague Island did not support this prediction (Patterson et al. 1991). My study also found a nearly significant trend for Piping Plover territories to contain more rock cover than the average amount of rock cover on the beach. Although this trend was not statistically significant, it may indicate Piping Plovers are making a biologically significant choice to occupy sections of beach which have a greater percentage of rock cover. This choice may have important effects on the reproductive success of the Piping Plovers since the results of this study and work by Prindiville Gaines and Ryan in North Dakota in 1988 indicate that Piping Plover reproductive success is higher on territories with greater rock cover.

Although no significant differences in the percentage of vegetation cover at the nest site, nest area, territory, or beach were detected in this study, my results still support previous work that indicate Piping Plovers prefer to nest on sparsely vegetated beaches. For example, Prindiville Gaines and Ryan (1988) found Piping Plovers in North Dakota occupying territories with an average of between 3.1% (1985) and 4.0% (1985) vegetation cover, and Patterson et al. (1991) found Piping Plovers on Assateague Island occupying nesting sites where the average vegetation at the nest was 8.3 % (Maryland), 14.8 (Wild Beach) and 19.3% (Tom's Cover Hook). In this study, 82.3% of all nests had less than 5% vegetative cover at the nest, 78.6% of all sites had less than 5% vegetative cover in the nest area, 78.6% of all nest had less than 5% vegetation cover in the territory, and 85.8% of all nests had less than 6% vegetative cover in the surrounding one mile area. Sparse vegetation may decrease levels of predation by providing Piping Plovers with good visibility. For example, in North Dakota, territories with successful nests had either less vegetation or more clumped vegetation than territories with unsuccessful nests (Prindiville Gaines and Ryan, 1988).

The presence of an ephemeral pond or river may also influence the habitat selection of Piping Plovers. For example, 14 of the 17 sampled nests had an ephemeral pond within 400 m of the nest. Ratcliff and Lambert (1981) suggest ephemeral ponds and rivers may increase the abundance of insects in the immediate beach area, and serve as important alternate feeding sites. Although no significant relationship between reproductive success and distance from a ephemeral pond across the 14 sites with ephemeral ponds or rivers were found in this study, three of the five broods from which no chicks fledged were located on beaches without an ephemeral pond or river. Further studies should be done to determine the frequency of use of the ephemeral ponds and rivers as foraging sites and comparisons between the prey abundance at beaches with and without ephemeral ponds should be attempted.

Reproductive Success

Reproductive success was significantly correlated with percentage of rock cover in the nesting territory and on the beach. A higher percentage of rock cover on a territory or beach may increase Piping Plover reproductive success by decreasing egg and chick predation rates. Piping Plover eggs and adults appear to be better camouflaged on a rocky substrate, and abundant rock cover may provide chicks with important cryptic hiding places where they can crouch to avoid predation or human disturbance. Although Patterson et al. (1991) found no consistent relationship between the percent of sand, shell, or cobble around a nest and nest predation, Prindiville Gaines and Ryan (1988) also found there was more gravel and it was more evenly distributed on successful nesting territories in North Dakota than on unsuccessful nesting territories.

Reproductive success was also significantly correlated with the percentage of transects with evidence of dogs. Dogs may have a negative effect on Piping Plover reproductive success because they can directly chase and kill chicks. Chicks may also be weakened by direct chasing or by being forced to hide and feed in the cobble and vegetated area of the beache which appear to have a lower abundance of insects than the open shoreline area. Although human disturbance alone was not significantly correlated with chick reproductive success in this study, human disturbance often accompanies the presence of dogs and may further negatively effect Piping Plover reproductive success. For example, Flemming (1984) reported that fledging success was significantly higher in areas with low human disturbance (3.1 young/successful nest) than in areas with high human disturbance (1.6 young/successful nest), and Cairn's (1982) found that the number of fledglings/pair on undisturbed beaches in Nova Scotia (1.3-2.1 fledglings/pair) was significantly higher than on beaches with higher recreational use (.07-1.1 fledglings/pair). Flemming (1984) also determined that human disturbance resulted in decreased chick foraging, increased chick sitting and vigilance, increased chick brooding, and a decreased probablility of chick survival to 17 days.

Although other measured variables such as vegetative cover, beach width, distance from the waterline to treeline, and abundance of predators were not significantly correlated with reproductive success, reproductive success may have been influenced by additional factors that were not measured in this study. For example, weather may play an important role in reproductive success. This summer's dry weather during the two week period during which most chicks hatched may have prevented high hatchling mortality. Because the Piping Plover population also occurs at a very low density, the Piping Plovers may not be occupying suboptimal habitat. If variables interacted or had only a small effect on reproductive success, significant effects of particular variables may have also been difficult to detect. For example, at Point Aux Chenes human disturbance, no rock cover, and high predator abundance may have interacted and led to the demise of two of the tree chicks, even though each factor alone would not have caused the chicks demise. In optimal habitat, the range of measured characteristics may have fallen within a range where their effect on reproductive success was no longer significant, even if outside the observed range a significant effect may occur. Finally, because my sample size was so small, additional studies may be needed to further identify factors influencing the reproductive success of Piping Plovers in the Great Lakes.

Potential Piping Plover Habitat

Lambert and Ratcliff (1981) stated that "there appears to be an abundance of unused Piping Plover habitat in Michigan". However, my study of potential habitat in Emmet, Charlevoix, and Cheboygan county indicated that only 6% of the entire shoreline and 23% of available beach and sandune habitat in Emmet, Charlevoix, and Cheboygan county possessed characteristics that met the minimum physical nesting habitat requirements for Piping Plovers. Of the 6% of apparently suitable shoreline, only 3.2% was in areas currently occupied by breeding Piping Plovers. The estimate of that only 6% shoreline suitability may also be even lower when the level of human disturbance at the sampled sites is considered. For example, Petoskey State Park, Bliss Township State Park, Northpoint Park, and Fisherman's Island State Park are public recreation areas. In particular, Petoskey State Park and Bliss Township State Park receive extremely heavy human use during the summer which may render many potentially suitable sections of these beaches low quality Piping Plover habitat.

Lambert and Ratcliff (1981) also state that "the abundance of habitat is not a factor limiting the population". However, the small amount of Piping Plover habitat identified in the three sampled counties may indicate that habitat is a factor limiting the population. Although other factors such as stochastic variation in birth rates, death rates, age structure, sex ratios, and genetic drift or inbreeding may also be limiting the Piping Plover population, habitat availability may be a significant factor limiting the population, especially in this three county area. Piping Plovers may be able to nest a higher densities in currently occupied breeding sites, however, it is imperative that suitable Piping Plover habitat is protected and that potentially suitable habitat for this species is identified and evaluated for protection.

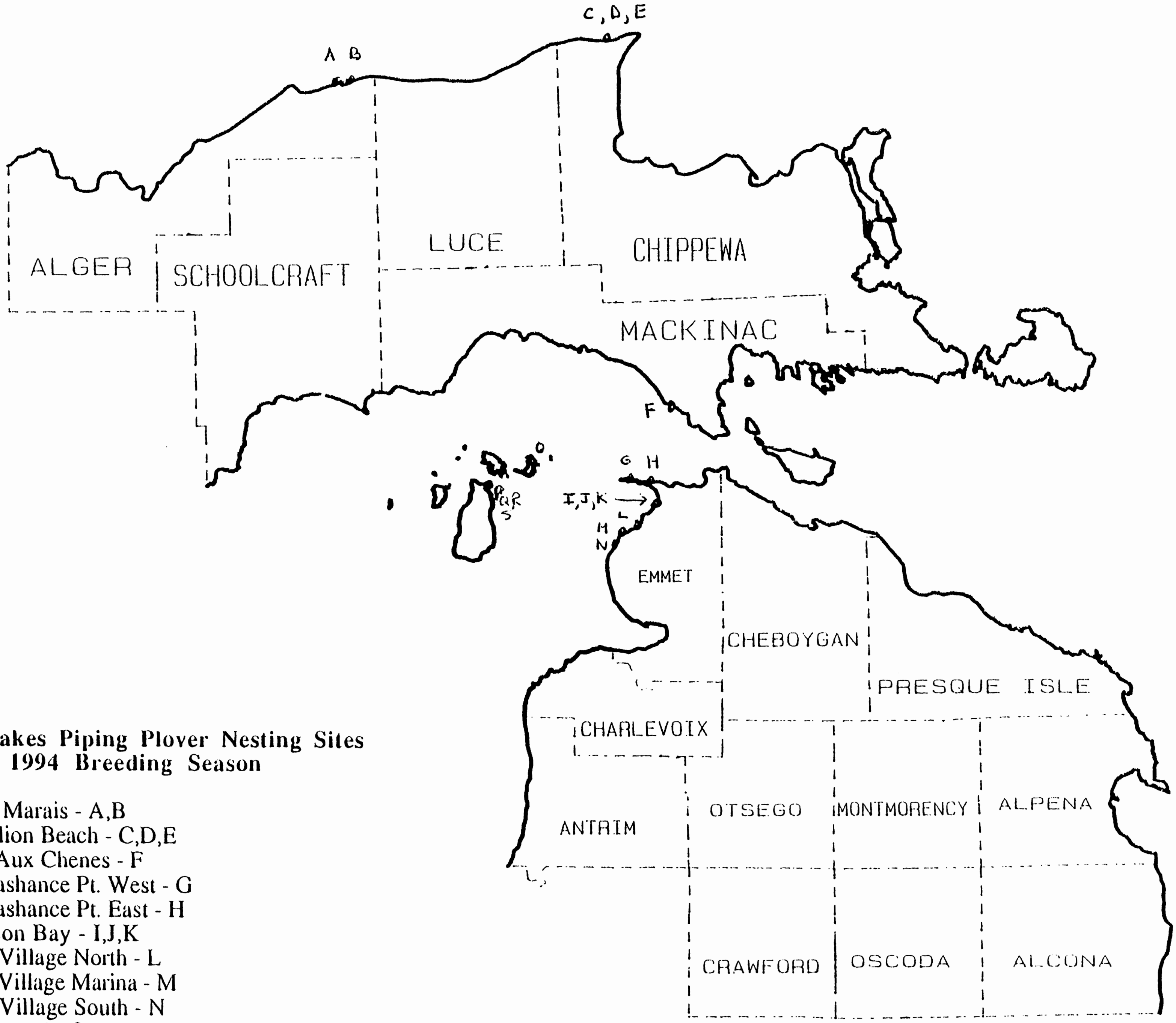
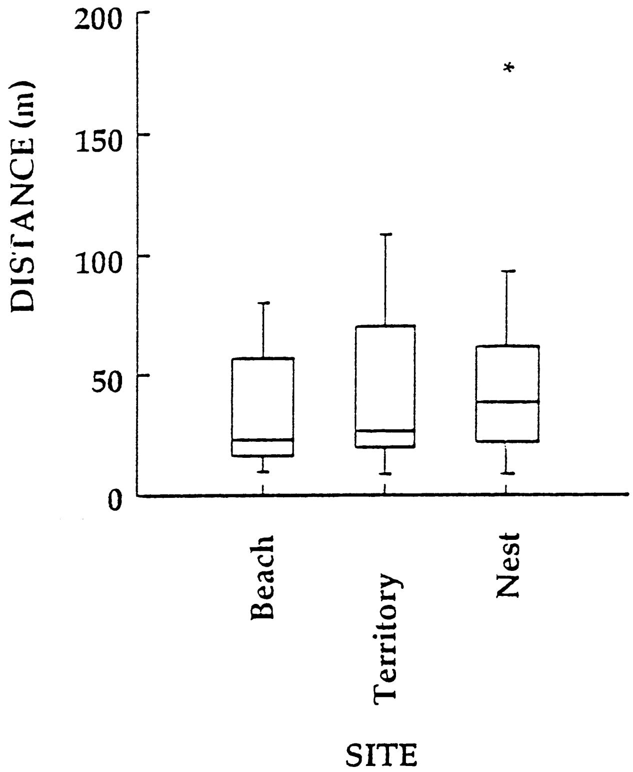


Figure 1: Great Lakes Piping Plover Nesting Sites
1994 Breeding Season

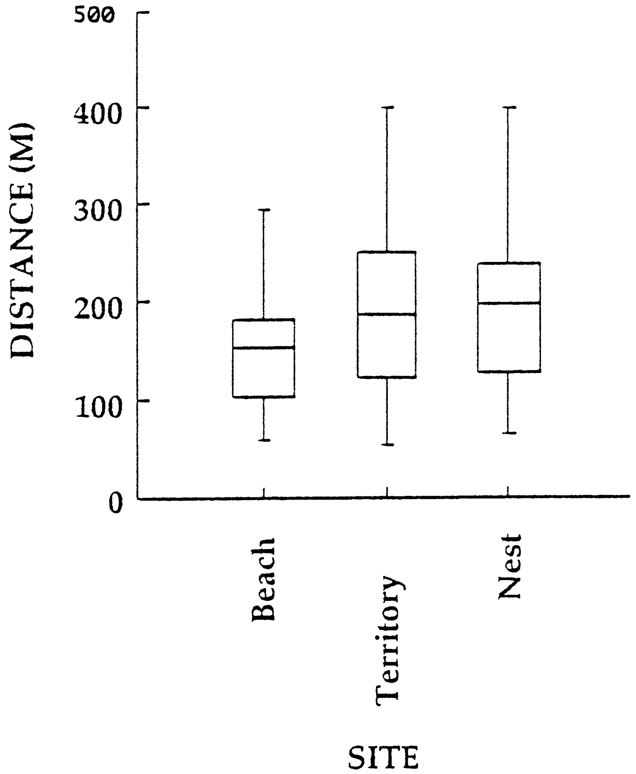
Grand Marais - A,B
Vermilion Beach - C,D,E
Point Aux Chenes - F
Waugashance Pt. West - G
Waugashance Pt. East - H
Sturgeon Bay - I,J,K
Cross Village North - L
Cross Village Marina - M
Cross Village South - N
High Island - O
North Manitou Island - P,Q,R,S

Figure 2 - Distance from Waterline to Foredune



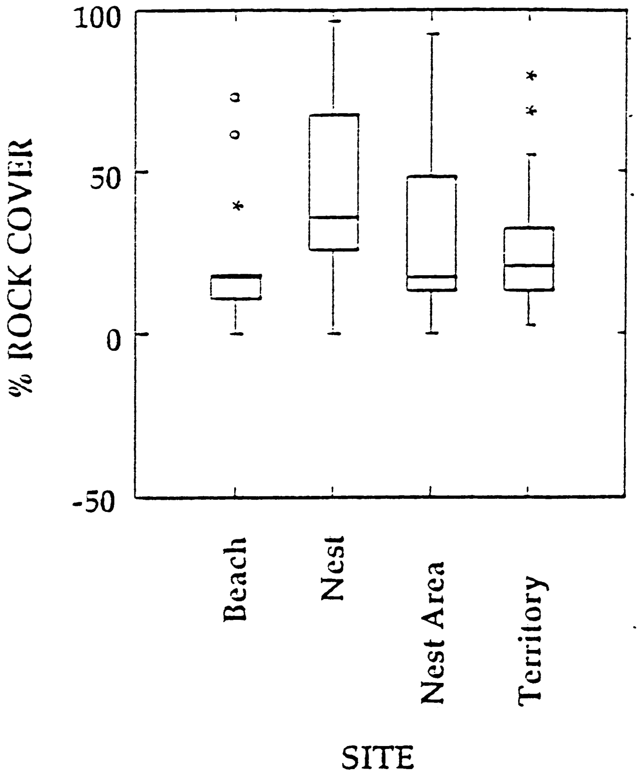
Nest vs. Territory	p = .097
Territory vs. Beach	p = .286
Nest vs. Beach	p = .072

Figure 3 - Distance from Waterline to Treeline



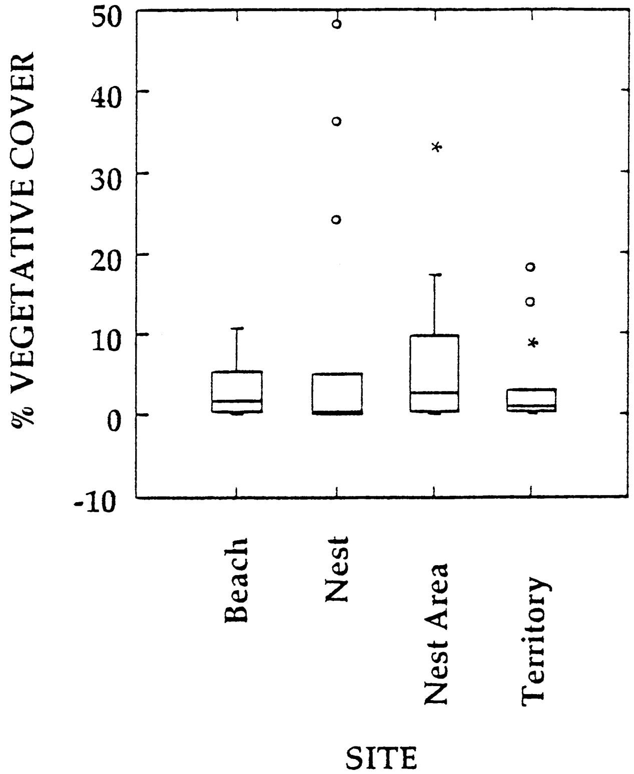
Nest vs. Territory	p = .008
Territory vs. Beach	p = .026
Nest vs. Beach	p = .025

Figure 4: Percentage of Rock Cover



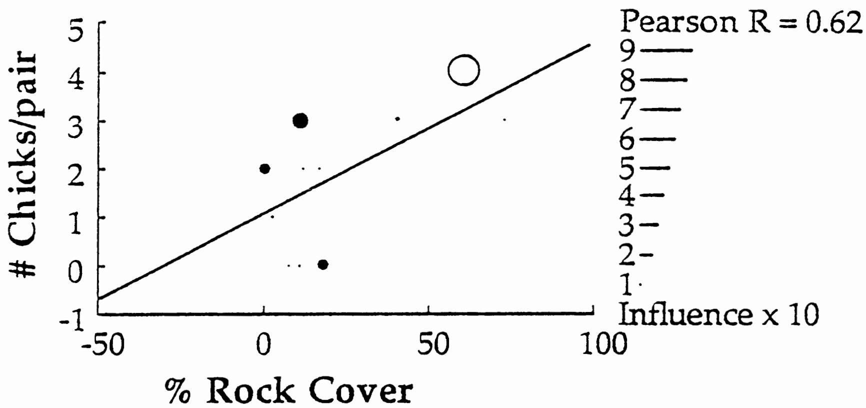
Nest vs. Nest area	p = <.000
Nest area vs. Territory	p = .097
Territory vs. Beach	p = .286

Figure 5: Percentage of Vegetative Cover



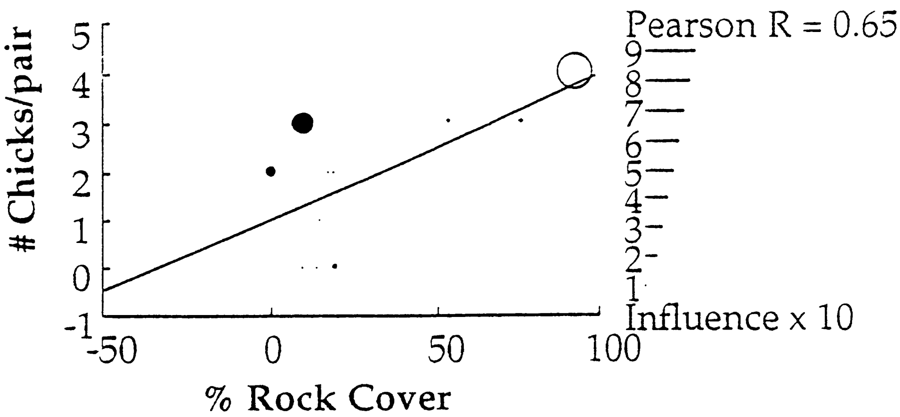
Nest vs. Nest area	p= .742
Nest area vs. Territory	p = .414
Territory vs. Beach	p = .964

Figure 6: Reproductive Success vs. Percentage of Rock Cover on the Beach



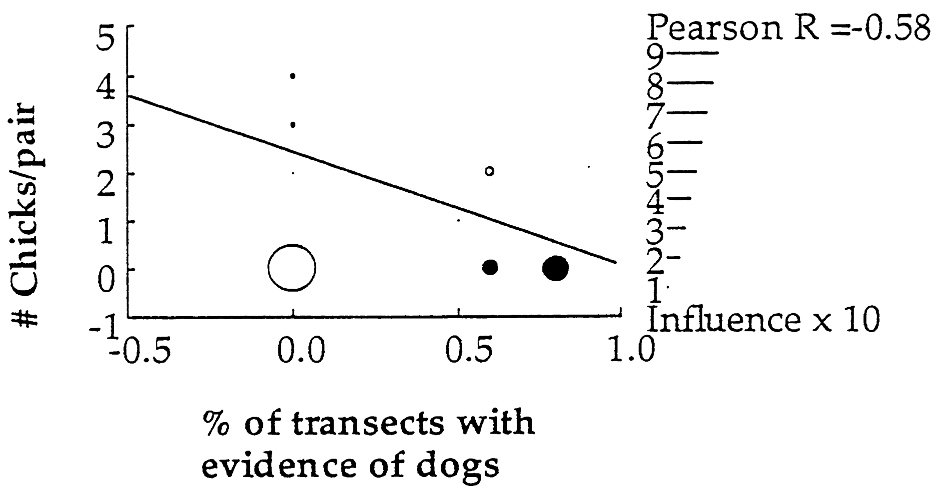
REPRO=1.040+0.035*ROCKBEAC

Figure 7: Reproductive Success vs. Percentage of Rock Cover on Territory



REPRO=0.986+0.030*ROCKTER

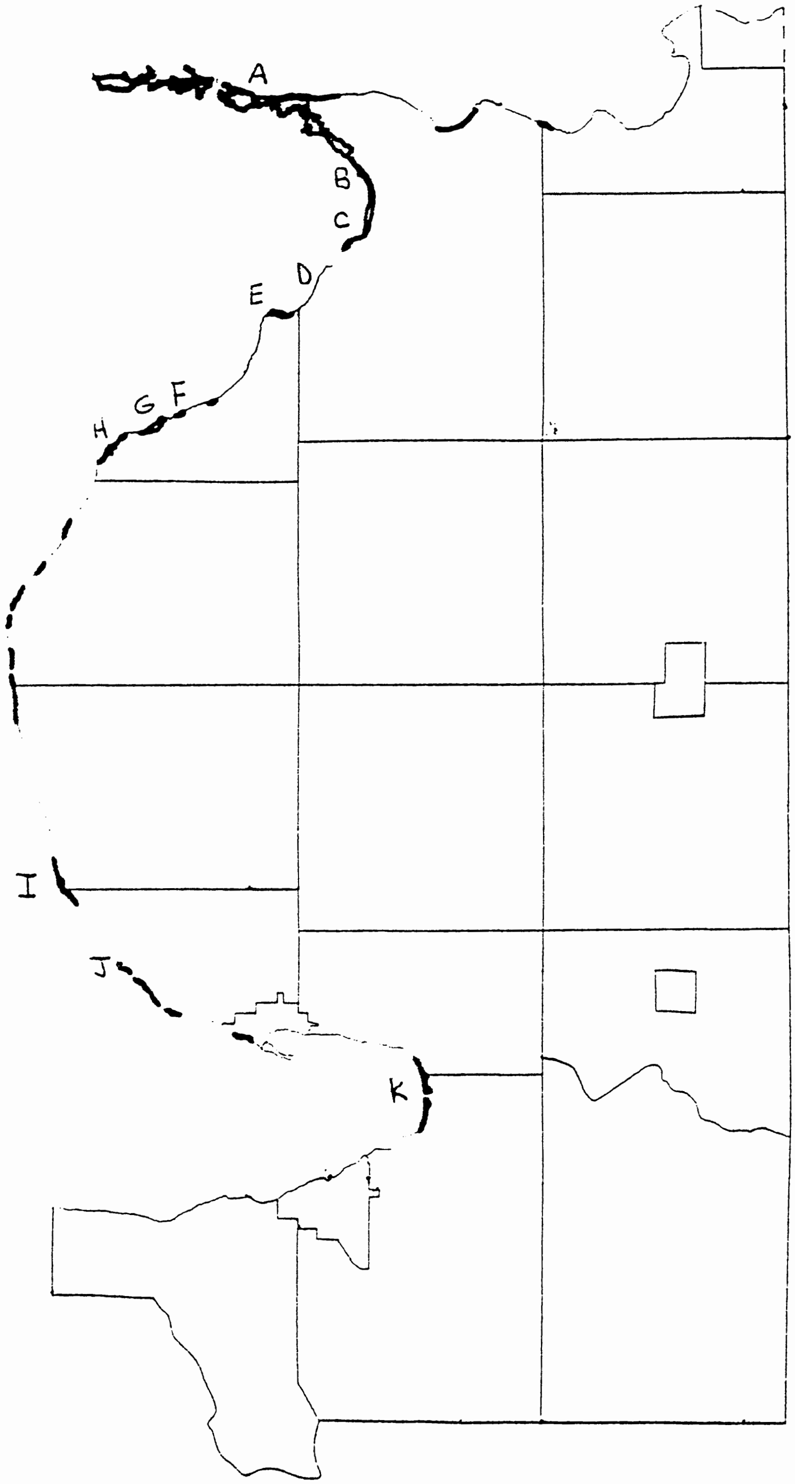
Figure 8: Reproductive Success vs. Dogs



REPRO=2.448 -2.381*DOGS

Figure 9: Emmet County Potential Piping Plover Habitat

* total miles of shoreline = 77 miles
* total miles meeting minimum nesting requirements for Piping Plovers = 6.72 miles (9%)



Waugashance Pt. - A
Sturgeon Bay - B
Sturgeon Bay South - C
Bliss Township Park - D
Cross Village North 1 - E
Cross Village North 3 - F
Cross Village Marina - G
Cross Village South - H
Seven Mile Point - I
Thorn Swift - J
Petosky Sate Park - K

Scale = 1: 300000

Figure 10: Charlevoix County Potential Piping Plover Habitat

North Point Nature Preserve - A
Fisherman's Island State Park - B

* total miles of shoreline = 25 miles
* total miles meeting minimum nesting requirements for Piping Plovers = .68 miles (3%)

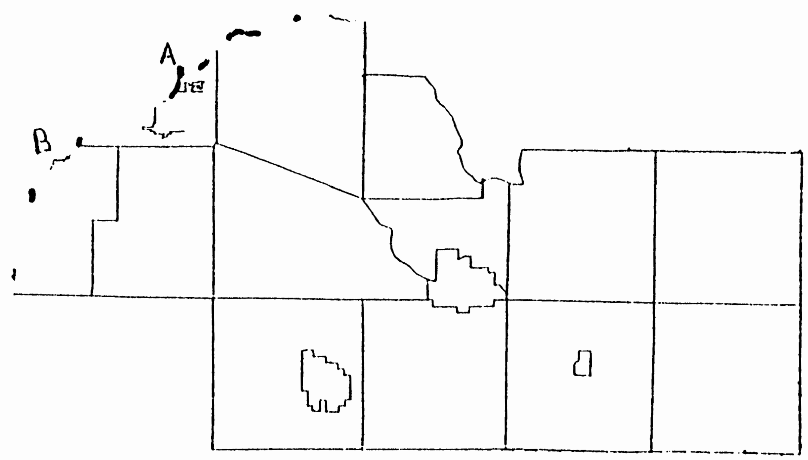
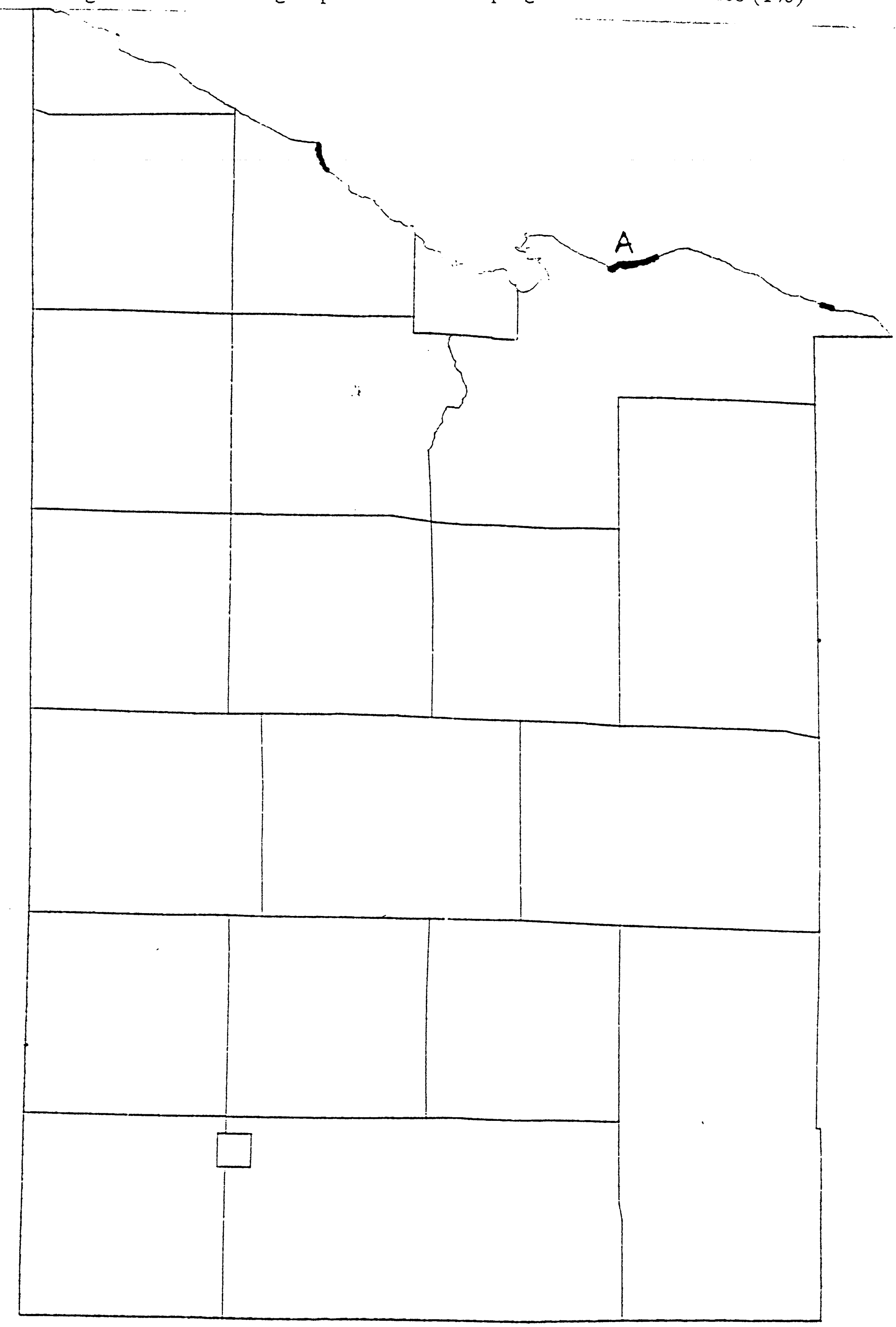


Figure 11: Cheboygan County Potential Piping Plover Habitat

Grass Bay - A

* total miles of shoreline = 23 miles
* total miles meeting minimum nesting requirements for Piping Plovers = .22 miles (1%)



Appendix - Potential Piping Plover Habitat

Beach and Sandune Areas in Emmet County

Polygon	Size (acres)/ Shoreline Distance (Miles)	Potentially Suitable Size (acres)/Shoreline Distance (miles)	Actually Suitable Shoreline Distance (miles)	Comments on Physical characteristics	Comments on Human Disturbance
Cecil Bay	7.7/.1	.5/.02	-	narrow, vegetated	moderate
Big Stone Bay	17.4/1.2	4.1/.20	.06	narrow, vegetated, sparse cobble	extermely high (campground)
Waugashance Pt.	71.9/3.5	71.9/3.5	1.25	wide, abundance cobble. sparse vegetation	moderate
Sturgeon Bay	116.3/2.2	113.0/2.2	.72	narrow, moderate cobble, sparse vegeation	high
Sturgeon Bay south	10.8/.38	9.9/.29	.09	narrow, moderate cobble, sparse vegetaion	high
Bliss Township Park	103.5/1.1	99.5/.96	1.03	wide, smarse cobble, sparse vegetation	high
Cross Village North 1	158.5/2.3	155.0/2.0	.97	wide, moderate cobble, sparse vegetaion	moderate
Cross Village North 2	4.4/.2	3.6/.10	-	-	-
Cross Village North 3	8.7/.3	7.2/.20	.24	wide, moderate cobble,sparse vegetation	moderate
Cross Village Marina	39.5/.8	37.0/.65	.63	wide moderate cobbe, sparse vegetation	high
Cross Village South	35.8/1.0	30.8/.7	.47	wide, moderate cobble,	moderate
Island View	8.9/.5	3.9/.14	-	-	-
Orchard North	4.0/.3	0/0	-	-	-
Orchard South	11.1/.7	1.0/.06	-	-	-
Robinson North	5.2/.3	1.1/.03	-	-	-
Robinson South	7.8/.5	2.6/.12	-	-	-
Middle Village	22.4/1.2	5.8/.3	0	treeline to close,	moderate
Seven Mile Point	42.5/1.9	26.1/1.10	.19	wide, moderate cobble, sparse vegetation	moderate
Thorn Swift	9.2/.4	5.2/.20	.12	wide, abundant cobble, sparce vegetation	low
Forest Beach North	26.2/.9	21.1/.7	.03	trees to close, narrow, sparse cobble	moderate

Forest Beach South	8.0/.4	3.7/.13	-	-	-
Harbor Point North	6.6/.3	3.8/.15	-	-	-
Harbor Point South	3.6/.2	2.4/.08	-	-	-
Petoskey State Park	57.2/1.7	54.9/1.38	.65	wide, sparse cobble, sparse vegetation	extremely high
TOTAL	787.2 acres/ 23.28 miles	664.1 acres/ 14.21 miles	6.72 miles		

Beach and Sandune Areas in Charlevoix County

Polygon	Size (acres)/ Shoreline Distance (Miles)	Potentially Suitable Size (acres)/Shoreline Distance (miles)	Actually Suitable Shoreline Distance (miles)	Comments on Physical Habitat	Comments on Human Disturbance
Ninemile Point	3.8/.2	2.7/.1	-	-	-
Ninemile Point South	8.6/.5	1.4/.1	-	-	-
Big Rock Point	12.7/.8	5.0/.2	0	narrow, trees to close	-
North Point Northshore	7.3/.5	3.4/.1	-	-	-
North Point	7.0/.3	2.7/.2	.37	wide, sparse cobble, sparse vegetation	high
Charlevoix	7.3/.5	0	-	-	-
Bells Bay	5.9/.3	3.2/.1	-	-	-
Fisherman Island State Park	38.1/1.1	33.0/.7	.31	wide, abundant cobble, sparse vegetation	moderate
FISP - South	10.6/.7	5.0/.4	0	trees to close	-
Norwood	7.7/.5	3.9/.3	0	narrow, trees to close	moderate
SUMMARY	109 acres/ 5.4 miles	89.1 acres/ 2.2 miles	.68 miles		

Beach and Sandune Areas in Cheboygan County

Polygon	Size (acres)/ Shoreline Distance (Miles)	Potentially Suitable Size (acres)/Shoreline Distance (miles)	Actually Suitable Shoreline Distance (miles)	Comments on Physical characteristics	Comments on Human Disturbance
Point Nipigon	19.3/1.3	6.8/.47	0	narrow, sandy, trees to close, abundant vegetation	moderate
Grass Bay	27.8/1.5	12.7/.9	.19	narrow, abundant vegetation, sparse cobble	high
Shaughnessy Rd	6.1/.4	4.8/.17	-	-	-
Duncan Bay	not on GIS/.24	not on GIS/.22	0	wide, sandy, sparse vegetation	extremely high
Light House Point	not on GIS/.68	not on GIS/.39	.03	narrow, abundant vegetation,	low
SUMMARY	/4.12	/2.35	.22 miles		

Literature Cited

Andren, L. Corvid density and nest predation in relation to forest fragmentation : a landscape perspective. Ecology 73(3): 794-804

Bradstreet, M.S., G.W. Page and W.G. johnson. 1977. Shorebirds at Long Point, Lake Erie, 1966-1971: seasonal occurrence, habitat preference, and variation in abundance. Can. Field Nat. 91:225-236

Brewer, Richard. G.A. McPeek, and RIJ. Aams, Jr. 1991. The atlas of breeding birds of Michigan. Michigan STae Universtiy Press. East Lansing, Michigan

Burger, J. 1987 Physical and social determinants of nest site selection in Piping Plovers in New Jersey. Condor 89:811-818.

Burgess, R.L. and Sharpe, D.M. 1981. Forest Island Dynamics in Man dominated Landscapes. Springer Verlag. NY

Cairns, W.E. 1982. Biology and behavior of breeding Piping Plovers. Wilson Bull. 94:531-545

Cairns, W.E. and McLaren, I.A. 1980. Status of the Piping Plover on the east coasts of North America. Am. Birds 34:206-208.

Cottrille, B.D. 1957. Summer distribution of the PIping Plover in Midhigan. Jack-Pine Warbler 35:26-33

DNR 1986, 1987 Aerial Photographs

Flemming, S.P. R.D. Chiasson, P.C. Smith, P.J. Austin-Smith and R.P. Bancroft. 1988. Piping Plover status and responses to recreational activity. J. Field Ornithology. 59:321-330.

Gains, E.P. and M.R. Ryan. 1988 Piping plover habitata uae and reproductive success in North Dakota. J. Wild. Manage. 52:266-273.

Gates, J.E. and L.W. Gysel. 1978. Avian nest dispersion and fledglings success in field-forest ecotones. Ecology 59(5): 871-883

Haig, S.M. 1992. Piping Plover. The Birds of North America, No. 2: 1-17

Hansson, L. 1992. Ecological Principles of Nature Conservation: Applications in Temperate Boreal Environments. Elsevier Applied Science London and New York.

Krebs C.J. 1994. Ecology: The experimental analysis of Distribution and Abundance 4th ed. Harper Collins College Publishers.

Lambert, A. and Ratcliff, R. 1981. Present status of the Piping Plover in Michigan. Jack-Pine Warbler 59:(2):44-53

Mayer, P.M. and Ryan, M.M. 1991. Electric fences reduce mammalian predation on Piping Plover nests and chicks. Wildl. Soc. Bull. 19:59-63

Neimi, G.J. and T.E. Davis. 1979. Notes on the nesting ecology of the Piping Plover. Loon 51:74-79.

Nordstrom, L.H. 1990. Assessment of Habitat Suitability for Reestablishment of Piping Plovers in the Great Lakes National Lakeshores. Master's Thesis University of Missouri - Columbia.

Patterson, M.E., J.S. Fraser, and J.W. Roggenbuck. 1991. Factors affecting Piping Plover productivity on Assateague Island.

Powell, A.N. 1991. Great Lakes Piping Plovers: REcovery or Extirpation. Endangered Species UPDATE. Vol. 8 No 9 and 10 p 1-4

Powell, A.N., and Cutbert, F.J. 1992. Augmenting Small Populations of Plovers: and Assessment of Cross Fostering and Captive Rearing. Conserv. Bio. 7(1)160-168

Powell, A.N. and Cuthbert, F.J. 1992. Habitat and reproductive success of Piping Plovers nesting on Great Lakes Islands. Wilson Bull. 104(1), p 1550-161.

Primack, R.B. Essentials of Conservation Biology. Sinauer Associates. Inc. Sunderland, Massachusetts

Prindiville Gaine, E. and Ryan, M.R. 1988. Piping Plover habitat use and reproductive success in North Dakota. J. Wildl. Mange. 52(2):266-273

Russell, R.P., Jr. 1983. The piping plover in the Great Lakes region. Am. Birds 37:951-955

USFWS 1994 Cross Village Marina Memo

Vande Kopple, Robert 1994 personal communications

Wemmer, L.C., Doolittle, A.W., and Cuthbert, F.C. 1993. Piping Plover Breeding Biology and Management in the STate of Michigan, 1993. 14 pp.