BROWN, M. AND J. J. DINSMORE. 1986. Implications of marsh size and isolation for marsh bird management. J. Wildl. Manage. 50:392–397.

BURGER, J. 1985. Habitat selection in temperate marsh-nesting birds. Pp. 253–281 *in* Habitat selection in birds (M. L. Cody, ed.). Academic Press, New York, New York.

CRAIG, R. J. 1984. Comparative foraging ecology of Louisiana and Northern waterthrushes. Wilson Bull. 96:173–183.

DAY, R. W. AND G. P. QUINN. 1989. Comparisons of treatments after an analysis of variance in ecology. Ecol. Monogr. 59:433–463.

DEGRAFF, R. M. AND D. D. RUDIS. 1983. New England wildlife: habitat, natural history, and distribution. U.S. Forest Service General Tech. Report NE-108.

KANTRUD, H. A. AND R. E. STEWART. 1984. Ecological distribution and crude density of breeding birds on prairie wetlands. J. Wildl. Manage. 48:426–437.

MORRISON, M. L., K. A. WITH, AND I. C. TIMOSSI. 1986. The structure of a forest bird community during winter and summer. Wilson Bull. 98:214–230.

OFFICE OF TECHNOLOGY ASSESSMENT. 1984. Wetlands: their use and regulation. U.S. Gov. Printing Office, Washington, D.C.

WELLER, M. W. 1981. Freshwater marshes. Univ. Minnesota Press, Minneapolis.

——— AND C. E. SPATCHER. 1965. Role of habitat in the distribution and abundance of marsh birds. Iowa State Univ. Special Report 43.

WELTY, J. C. 1982. The life of birds. Saunders College Pub., New York, New York.

YAHNER, R. H. 1986. Structure, seasonal dynamics, and habitat relationships of avian communities in small even-aged forest stands. Wilson Bull. 98:61–82.

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Habitat and reproductive success of Piping Plovers nesting on Great Lakes islands.— Piping Plovers (*Charadrius melodus*) historically nested along the Great Lakes. Russell (1983) estimated there may have been up to 802 breeding pairs in the Great Lakes region. In the 1940s and 1950s the Great Lakes Piping Plover population declined dramatically following shoreline development and subsequent loss of nesting habitat (Russell 1983). By 1979 the population had decreased to 38 pairs (Lambert and Ratcliff 1981). The Great Lakes Piping Plover population was listed as federally endangered in 1986 (U.S. Fish and Wildlife Service 1985). At the time of listing, only 17 breeding pairs remained in the Great Lakes population, and viable breeding areas were reduced from locations in eight Great Lakes states to sites entirely within the state of Michigan (Haig et al. 1988). The Great Lakes Piping Plover population has remained relatively stable since 1986, but in 1990 the population decreased by 35% to only 11 breeding pairs (Powell, in press). Although habitat loss may have been the primary cause of the decline in Piping Plover populations in the Great Lakes region thirty years ago, current sites used by breeding plovers are protected, and reasons for the decline in recent years are difficult to elucidate (Haig et al. 1988). The population is now extremely vulnerable and may have reached a size where natural recovery is unlikely.

Islands have historically been an important component of breeding habitat for the Great Lakes Piping Plover population. In Michigan, Piping Plovers once nested on North and South Manitou islands, North and South Fox islands, and Beaver Island (Hatt et al. 1948, Cotrille 1957). In the past decade, Piping Plovers have nested only on Beaver and High

islands (Lambert and Ratcliff 1981). Despite knowledge that Piping Plovers have historically nested at these island sites, there is a paucity of information on habitat characteristics and nesting success of island-nesting plovers in the Great Lakes (Cotrille 1957, Niemi and Davis 1979, Lambert and Ratcliff 1981, Pike 1985, Nordstrom 1990). Because of their relative isolation, these islands appear to constitute an important remnant of Piping Plover nesting habitat. The purpose of this study was to estimate the proportion of the Great Lakes Piping Plover population that uses these islands, describe nesting habitat, and estimate reproductive success.

Study area and methods.—This study was conducted on two islands in Charlevoix County, Michigan. These islands are part of the Beaver Archipelago in northern Lake Michigan. Beaver Island (45°45'N, 85°30'W), the largest island in Lake Michigan (150.2 km^2), has 67.1 km of shoreline. High Island (45°45'N, 85°40'W), 6.45 km west of Beaver Island, is 15.0 km^2 in area and has 20.2 km of shoreline (Hatt et al. 1948). Both islands are characterized by large dune systems and extensive sand beaches on their western shores. High Island includes a northeastern point approximately 1.5 km long that consists primarily of large cobble and sand. This point has been the site of a nesting colony Ring-billed Gulls (*Larus delawarensis*), Herring Gulls (*L. argentatus*), Caspian Terns (*Sterna caspia*) and, until 1989, Common Terns (*S. hirundo*). The size of the northeastern point and the width of island beaches vary from year to year with fluctuating lake levels (Cuthbert 1981).

The islands were searched systematically for Piping Plover activity by walking the beaches both along the shorelines and behind the dunes, from 15 May to 15 August, 1987, through 1990. Potential Piping Plover habitat was surveyed weekly for evidence of nesting plovers. Once courtship or territorial behavior was observed, we retreated to a distance where plovers were not disturbed and waited until they returned to a nest. Observations of Piping Plovers were then made every two to five days from a distance of at least 25 m with binoculars and spotting scopes. Piping Plover nests were not marked; natural features in the nest area were used for location cues. In 1990, predator exclosures were placed around plover nests on Beaver Island (Rimmer and Deblinger 1990). Nests were checked from one to four times a week until hatching or nest failure. After the eggs hatched, plover families were observed until the chicks fledged or disappeared. Hatching success was determined by the percentage of eggs laid that hatched. Fledging success was defined as the percentage of chicks that survived to fledging. Reproductive success was reported as the mean number of fledglings produced per nesting attempt.

Measurements of habitat characteristics around nest sites were made after the eggs hatched and the chicks had left the area, or after nest failure. Beach width was measured on calm days, from the edge of the lake to the beginning of the dune system. Dune width was measured from the rise in elevation on the lake side to the rise in elevation from the inland side of the foredunes. Measurements were not made from nests or dunes to the treeline, because in all cases the tree line was over 400 m away (Lambert and Ratcliff 1981).

Results.—Piping Plovers nested on High and Beaver islands during the four years of this study. No plovers were found on the Manitou islands, or on South Fox, Garden, Hat, Hog, Pismire, Squaw, Trout or Whiskey islands (M. Holden, National Park Service and M. J. Hamas, Central Michigan Univ., pers. comm.) (Fig. 1). Island-nesting plovers represented 14.3% of the Great Lakes Piping Plover population in 1987 (N = 2), 36.4% in 1988 (N = 4), 38.5% in 1989 (N = 5), and 25% in 1990 (N = 5).

The dune systems on the western shores of both islands are characterized by a smaller foredune located from 20 to 40 m from the lakeshore (dependent on lake water levels), a flat area behind the foredunes consisting of cobble (rounded stones <10 cm diameter) mixed with sand, and a larger dune system farther inland. The shoreline on the lake side of the foredunes is typically wide sandy beach with less than 5% vegetation and a 1–3 m wrack

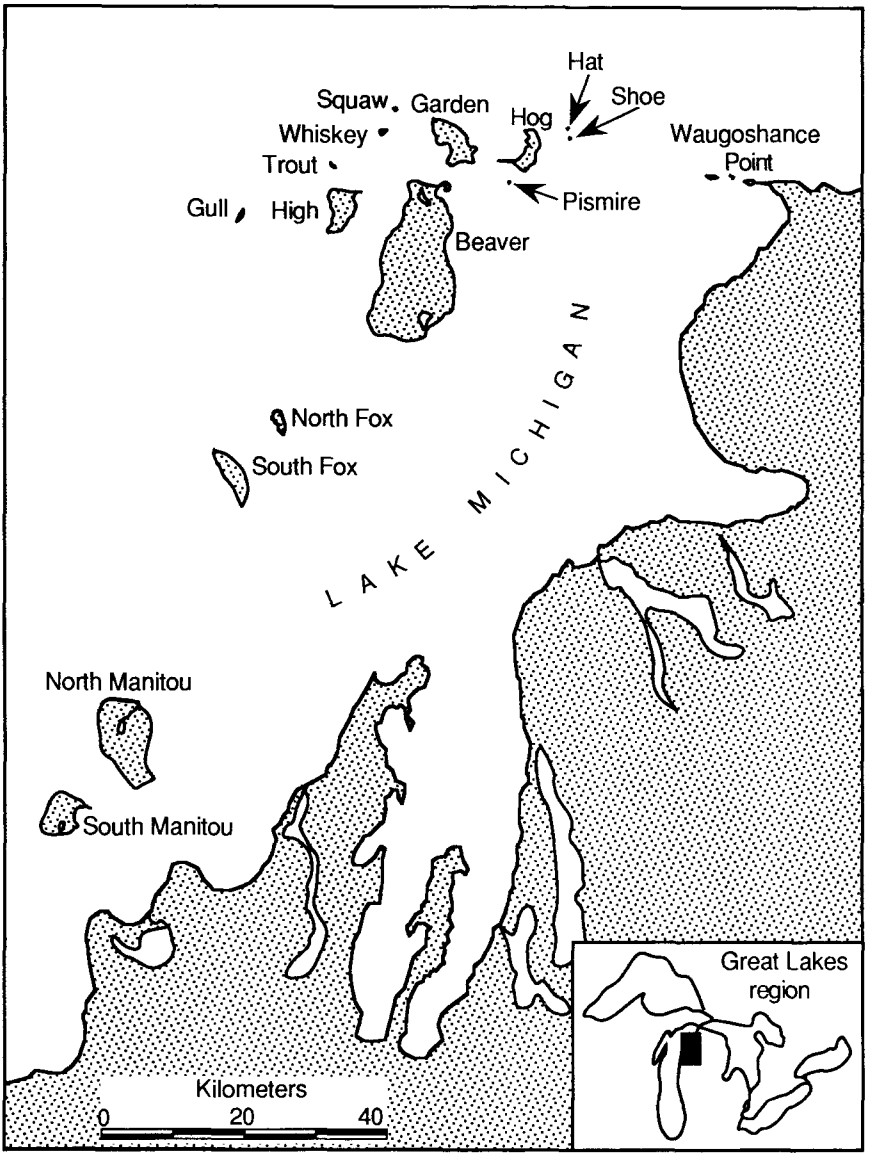

FIG. 1. Map of the islands of northern Lake Michigan. Inset shows the enlarged area in black.

line of organic debris. Small ephemeral pools with patches of sedges (*Carex* spp.) are located along these beaches on the shoreline. The vegetation on the foredunes is primarily willow (*Salix glaucopylloides*), beach grass (*Ammophila breviligulata*) and bearberry (*Arctostaphlos uva-ursi*); cover estimates ranged from 75 to 100%. The intermediate area between the dunes is patchily vegetated, with bearberry being the dominant species. A system of raised strips of cobble alternating with sand runs parallel to the foredunes.

In 1988 and 1989, a pair of Piping Plovers nested on the beach at McFadden's Point on the western shore of Beaver Island. This is state-owned property and is undeveloped and relatively undisturbed. In both years, the nest site was located on the inland side of the foredunes on a raised area of cobble surrounded by sand and sparse vegetation. In 1990, two pairs of plovers nested on Donegal Bay on the western shore of Beaver Island. This was unusual because this area has been developed with summer homes, and plovers have not nested there in over 15 years (M. J. Hamas, Central Michigan Univ., pers. comm.). Both nests were located behind the foredune in patches of cobble. One of these nests was located within 100 m of a cottage and surrounded by dunes on all other sides. The second nest was located 34 m from the road and was surrounded on three sides by cottages from 100 to 300 m distant. Both nests were provided with predator exclosures and posted as off-limits to people, dogs, and vehicles in a 50–100 m band surrounding the nest area. All four nests on Beaver Island were located behind the foredunes, with mean distances (±SD) of 69 ± 7 m to the lake and 10 ± 4 m to the dunes. Beaches at these nest sites were 34 ± 1 m wide, and dunes were 25 ± 4 m wide.

Piping Plovers nested on the western beach of High Island in all four years of this study. Five of the eight nests at this site were located behind the foredunes in cobble and sparse vegetation. Mean distances (±SD) of these nests were 87 ± 9 m from the lake and 30 ± 8 m from the dunes. Beaches at these sites were 23 ± 3 m wide, and dunes were 32 ± 5 m wide. Of the three nests on the lake side of the dune, one was destroyed during a storm when waves washed 25 m onto the beach. These nests were along the wrack line within 5 m of the foredune, 22 ± 2 m from the lake, and 4 ± 1 m from the dunes. A Piping Plover nest was located on the northeastern point of High Island in 1988 and 1989. In both years, the nest was constructed on a raised strip of cobble 150 m from the far end of the point. Two to three Herring Gull nests were located within 20 m of the nests, and from 7000 to 10,000 Ring-billed Gulls nested approximately 150 m west of the Piping Plovers.

Piping Plover chicks left the nest sites within 24 h of hatching. In cases where nests were located behind the foredune, chicks followed their parents over the dunes, through dense vegetation, to reach the lakeshore. Chicks remained on the lakeshore with one or both parents until fledging. Usually plover families remained in an area within 200 m, perpendicular to a direct line to the nest site, unless disturbed by human activity on the beach. Young plovers foraged primarily along the ephemeral pools adjacent to the shore and remained close to the vegetative cover there. Young plovers were never observed behind the foredunes after leaving the nest site.

Piping Plovers in this study were not banded. Although several of the adults nesting on the islands had been banded in the past, the bands were aluminum, and it was impossible to distinguish individual birds. However, from 1987 to 1990, a lame female nested on the western beach of High Island. This bird nested in the same general location, approximately 100 m south of the point on the beach. For two years, this individual nested behind the foredune and was successful in fledging young in 1987 and 1989. In 1988, the nest was washed out and the pair did not renest on the islands. In 1990, the lame bird was paired and was observed making a nest scrape on the lake side of the foredunes on 21 May, but was disturbed by people camping on the beach over Memorial Day weekend. This plover was next seen on the mainland at Waugoshance Point, Emmet County, Michigan, on 20 June and attempted to renest there.

TABLE 1
REPRODUCTIVE SUCCESS OF ISLAND NESTING PIPING PLOVERS FROM 1987 TO 1990

	1987	1988	1989	1990
Number of breeding pairs	2	4	5	5
Number of nests	2	3	5	3
Hatching success (%)	100	92	80	92[a]
Fledging success (%)	63	50	13	18
Number of young fledged per nest	2.5 ± 2.1[b]	1.5 ± 1.7	0.4 ± 0.9	0.7 ± 1.2

[a] Includes 2 nests with exclosures.
[b] Mean ± SD.

Reproductive success of Piping Plovers nesting on the islands was variable among years. Hatching success was high, ranging from 80% in 1989 to 100% in 1987 (Table 1). Overall reproductive success for island plovers ranged from 0.4 to 2.5 chicks fledged per nesting attempt (Table 1). In comparison, the mean number of young fledged per nest in the Great Lakes region was 1.5 ± 0.5 from 1987 to 1990 (T. Allan and R. Wolinski, unpublished data), 1.1 ± 0.6 from 1980 to 1985 at Chain of Lakes, North Dakota (Prindiville Gaines and Ryan 1988), and 0.8 ± 0.4 from 1983 to 1986 in New Jersey (Burger 1988).

Exclosures used in 1990 protected all eggs from predation. The one egg that did not hatch in 1990 was infertile. Egg failure in 1988 and 1989 was caused by storms and American Crow (*Corvus brachyrhynchos*) predation. Fledging success was much lower than hatching success and ranged from 13% to 63% (Table 1). Chick mortality was primarily due to predation, although in 1990 one 10-day-old chick disappeared after a severe storm, and three 7-day-old chicks died of exposure after their parents were killed by a Great Horned Owl (*Bubo virginianus*). In 1988 and 1989, chicks that hatched from the nest on the northeastern point of High Island were presumed eaten by gulls within two days of hatching. In both years, this nest was located within 20 m of Herring Gull nests and surrounded by loafing Ring-billed and Herring gulls. During incubation, the parents were extremely diligent, with both adults remaining within 10 m of the nests at all times. Gulls were observed walking and flying over the nest area, and were frequently chased by the adult plovers. Chicks were observed being brooded on the nest the first day of hatching but disappeared within 24 h.

Discussion.—Islands provide breeding habitat for up to 38.5% of the entire Great Lakes Piping Plover population. Beach width has been reported as an important factor for Piping Plover nesting habitat, with beaches wider than 20 m being preferred for nesting (Lambert and Ratcliff 1981, Haig et al. 1988, Prindiville Gaines and Ryan 1988). Beach width on the Great Lakes islands falls within the ranges reported for the Great Lakes and East Coast when width is measured from the water's edge to the dunes (Lambert and Ratcliff 1981, Burger 1987). However, the actual width of the beach area is much wider when the area behind the dunes is taken into account. This is important because Piping Plovers nesting on these islands tend to use habitat located on the inland side of the foredunes for nesting. Piping Plover nest surveys and habitat measurements in the Great Lakes region are often conducted on the lake side of the foredunes. The subsequent lack of information on inland habitat may lead to underestimates of habitat availability, habitat use, and population size. Although Pike (1985) reported Piping Plover nests behind the foredunes at Waugoshance Point, Michigan, they were either late nests or renesting attempts. This was not the case on the islands, where nests located behind the dunes were initiated as early as 10 May.

Faanes (1983) suggested that good visibility around the nest was an important factor in nest site selection. All of the island nests were in areas of good visibility regardless of location behind or in front of the dunes. On both Beaver and High islands, the beach area along the lakeshore is used extensively by gulls for loafing. However, gulls were never observed on the inland side of the dunes. Crows were seen occasionally in both areas but as single individuals. Both crows and gulls are known predators of Piping Plover eggs and young (Cairns 1982, MacIvor et al. 1990, Rimmer and Deblinger 1990). Location of island nests behind the foredunes may be a strategy to avoid gull predation and may account for their high hatching success.

There is evidence that Piping Plovers from the Great Plains, Great Lakes, and East Coast populations mix on the wintering ground, and there is occasional gene flow between these populations (Haig and Oring 1988a). Although natal site fidelity is generally low, Piping Plovers do return to the general area of their natal sites to breed (Wilcox 1959; Haig and Oring 1988b, 1988c; Wiens and Cuthbert 1988). Adults nesting on Great Lakes islands did return to previous nesting sites from year to year regardless of previous nest success. Despite a high mean hatching success of island Piping Plovers over the four year period, the number of young fledged per nest was similar to other studies (Cairns 1982, Burger 1988, Prindiville Gaines and Ryan 1988, Wiens and Cuthbert 1988). The number of young fledged per nest was highly variable and declined each year of the study. The causes of the low fledging success are unclear but may be due to events that affect small populations. The decline in reproductive success is coupled with a decreasing population of breeding adults in the Great Lakes Piping Plover population (Haig et al. 1988, Powell 1991). The number of young fledged each year from these islands may not be enough to maintain recruitment in an already small population. Unfortunately, survival of fledged young to breeding age and their recruitment into the Great Lakes population is unknown.

Islands are important breeding sites for Piping Plovers. Quality breeding habitat for Piping Plovers is still available on the Great Lakes islands. These areas support fewer predator species than mainland sites and have low levels of human disturbance. This is important because disturbance due to human activity has been shown to decrease reproductive success of Piping Plovers nesting along the Atlantic coast (Cairns and McLaren 1980, Flemming et al. 1988). Beach areas on the Manitou islands, Beaver Island, and High Island have been closed to human use during the Piping Plover breeding season for the past several years. Despite these factors and high hatching success of island plovers, recruitment into the Great Lakes Piping Plover population continues to decline. Piping Plover management in the Great Lakes must include alternate techniques in addition to habitat and nest protection if this population is to survive.

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LITERATURE CITED

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

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

——— AND I. A. MCLAREN. 1980. Status of the Piping Plover on the east coast of North America. Am. Birds 34:206–208.

COTRILLE, B. D. 1957. Summer distribution of the Piping Plover in Michigan. Jack-Pine Warbler 35:26–33.

CUTHBERT, F. J. 1981. Caspian Tern colonies of the Great Lakes: responses to an unpredictable environment. Ph.D. diss., Univ. of Minnesota, Minneapolis, Minnesota.

FAANES, C. A. 1983. Aspects of the nesting ecology of Least Terns and Piping Plovers in central Nebraska. Prairie Nat. 15:145–154.

FLEMMING, S. P., R. D. CHIASSON, P. C. SMITH, P. J. AUSTIN-SMITH, AND R. P. BANCROFT. 1988. Piping Plover status in Nova Scotia related to its reproductive and behavioral responses to human disturbance. J. Field Ornithol. 59:321–330.

HAIG, S. M., W. HARRISON, R. LOCK, L. PFANNMULLER, E. PIKE, M. RYAN, AND J. SIDLE. 1988. Recovery plan for the Piping Plovers (*Charadrius melodus*) of the Great Lakes and northern Great Plains. U.S. Fish Wildl. Serv., Washington, D.C.

——— AND L. W. ORING. 1988a. Distribution and dispersal in the Piping Plover. Auk 105:630–638.

——— AND ———. 1988b. Genetic differentiation of Piping Plovers across North America. Auk 105:260–267.

——— AND ———. 1988c. Mate, site, and territory fidelity in Piping Plovers. Auk 105: 268–277.

HATT, R. T., J. VAN TYNE, L. C. STUART, C. H. POPE, AND A. B. GROBMAN. 1948. Island life: a study of the land vertebrates of the islands of Lake Michigan. Cranbrook Press, Bloomfield Hills, Michigan.

LAMBERT, A. AND B. RATCLIFF. 1981. Present status of the Piping Plover in Michigan. Jack-Pine Warbler 59:44–52.

MACIVOR, L. H., S. M. MELVIN, AND C. R. GRIFFIN. 1990. Effects of research activity on Piping Plover nest predation. J. Wildl. Manage. 53:443–447.

NIEMI, 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. M.S. thesis, Univ. Missouri, Columbia, Missouri.

PIKE, E. A. 1985. The Piping Plover at Waugoshance Point. Jack-Pine Warbler 63:36–41.

POWELL, A. N. Early experience in captive reared shorebirds: implications for endangered species management. Acta XX Congr. Intern. Ornith. (in press).

PRINDIVILLE GAINES, E. AND M. RYAN. 1988. Piping Plover habitat use and reproductive success in North Dakota. J. Wildl. Manage. 52:266–273.

RIMMER, D. W. AND R. D. DEBLINGER. 1990. Use of predator exclosures to protect Piping Plover nests. J. Field Ornithol. 61:217–223.

RUSSELL, R. P. 1983. The Piping Plover in the Great Lakes region. Am. Birds 37:951–955.

U.S. FISH AND WILDLIFE SERVICE. 1985. Determination of endangered and threatened status for the Piping Plover. Federal Register 50(238):50720–34.

WIENS, T. P. AND F. J. CUTHBERT. 1988. Nest-site tenacity and mate retention of the Piping Plover. Wilson Bull. 100:545–553.

WILCOX, L. 1959. A twenty year banding study of the Piping Plover. Auk 76:128–152.

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