Gulls and Terns as Indicators of Man's Impact Upon Lake Superior

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GULLS AND TERNS AS INDICATORS OF MAN'S IMPACT UPON LAKE SUPERIOR

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I. INTRODUCTION

This paper reports the results of a study of breeding gulls and terns on the Lake Superior shoreline in Wisconsin. During May, June and July of 1974 we censused nesting herring gulls Larus argentatus, ring-billed gulls Larus delawarensis, and common terns Sterna hirundo along the entire shoreline. In the fall of 1974 we investigated human activities on Lake Superior that might affect these bird populations. In this paper we document the 1974 status of the three nesting species, including numbers and locations of breeding pairs and reproductive success. We identify those areas critical to the species and discuss human activities that affect or may come to affect their populations. This report has two main purposes. First, we present baseline data on nesting gulls and terns so that future human impacts can be detected and evaluated. Second, we recommend measures for the management and protection of these wildlife resources.

Of all the Great Lakes, Lake Superior and its shoreline have been least altered by man. However, human activity and use of resources in the region will greatly increase in future years. Protection of this natural environment requires careful planning and depends upon accurate information about both human and natural components of the ecosystem. Gulls and terns are highly sensitive to changes in their environment. This sensitivity, the existence of comparative data on their numbers and status from other areas, and the growing literature on man's effects on these species make them ideal as ecological indicators for the Lake Superior region.

Gulls and terns are valuable resources, among the most prominent of wildlife on the lake. Agile in flight and brilliantly white in color, they add significantly to the human's experience at the lakeshore. The gulls calling one to another have strange, melodic voices. The terns fly buoyantly; or they hover on pointed wings where they have spied fish fins, until suddenly they dive deeply headfirst to splash, disappear, then fly up once more. We hope Wisconsin's harbors and beaches will always have these birds.

Not everyone will want to read the entire report. The summary contains the important results and conclusions. Recommendations for management and protection of gulls and terns appear in Section VI and nesting areas critical to the species are discussed in Section IV. In Section IV D, we present our observations on the rare piping plover Charadrius melodus, a species also nesting on the Superior shoreline.

We have prepared appendices primarily to assist those who may wish to repeat the survey in future years. Appendices A, B and C provide information on the life histories of the two gull species and the common tern, treating in detail many points we can only briefly mention in the main text. In particular, they include evaluations of the factors that affect gull and tern reproductive success.

The six appendices are:

A. Background Information on the Herring Gull
B. Background Information on the Ring-billed Gull
C. Background Information on the Common Tern
D. Breeding Gulls and Terns in the Lake Superior Area and in Wisconsin
E. Critical Nest Areas
F. Locations and Descriptions for Lone Herring Gull Pairs

This material is on file with the University of Wisconsin Sea Grant College Program; the Department of Wildlife Ecology, University of Wisconsin-Madison; the Wisconsin Department of Natural Resources; and the Apostle Islands National Lakeshore.

Abbreviated portions of this report will soon be published as articles in *The Passenger Pigeon* and *The Loon*.

II. DESCRIPTION OF THE STUDY AREA

The Wisconsin waters of Lake Superior contain approximately 2,675 square miles in surface area. Our study was conducted along the Wisconsin shoreline of Lake Superior and among the Apostle Islands (see Figure 1). The total shoreline is 325 miles long including 156 miles on the mainland and about 169 miles among the islands themselves.

The western end of the lake, primarily Douglas County and western Bayfield County, is characterized by a generally flat shore with sand and pebble beaches. The area has a heavy red clay soil and is deeply cut by ravines and water channels — a natural characteristic typical of areas with heavy red clay soil (Zube and Dega, 1964).

The Bayfield Peninsula is notable for its steep topography, exposed rock bluffs, established vegetative cover and the clay bluffs which account for over 50% of the mainland shoreline. These bluffs rise to over 100 feet above lake level. Sand beaches are located within the bays of the Bayfield Peninsula. The upland soil adjacent to the shoreline is predominantly red clay that is highly vulnerable to erosion (Zube and Dega, 1964).

The twenty-two Apostle Islands, including Long Island to the south, are the only naturally occurring islands in the study area. "The Apostle Islands Unit" of the Apostle Islands National Lakeshore, established in 1970, consists of twenty of the twenty-two islands. These islands contain approximately 39,500 acres of land (Matteson et al., 1973). They range in size from Gull Island, 3 acres, to Stockton Island, 10,054 acres. The islands are at the tops of partially submerged sandstone hills belonging to the Bayfield Peninsula's northeasterly extension. They vary in height from 50 feet above the lake level (York and North Twin) to 480 feet (Oak), and occupy an area 30 miles long and 80 miles wide (North Central Field Committee, 1965). Madeline Island, with many permanent and seasonal homes, lies south of the National Lakeshore.

The Kakagon-Bad River Slough area to the east in Ashland County provides a distinctive contrast to the sandstone and clay bluffs. Long Island and Chequamegon Point with their long and low sandy features and the expansive marsh lands are the area's most distinct natural characteristics. Coastal lands are essentially flat and at lake level elevation.

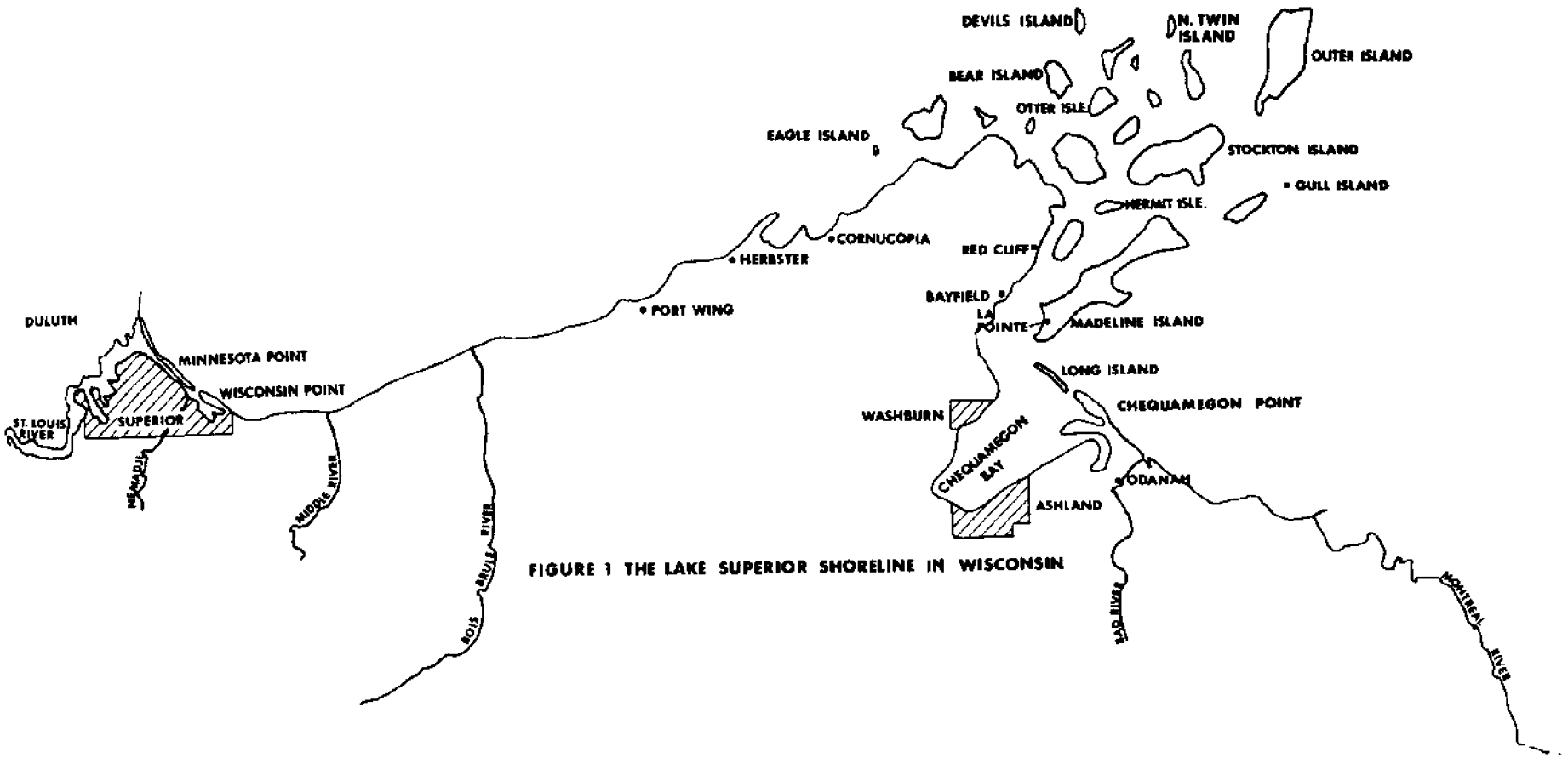

FIGURE 1 THE LAKE SUPERIOR SHORELINE IN WISCONSIN

Acres of wild rice, alder thickets, heaths and aquatic plants grow in the area (North Central Field Committee, 1965).

The dominant tree cover of the study area consists of a mixed hardwood-coniferous forest. The forest cover is continuous with only minor variations.

The climate of the area is characterized by seasonal variations with severe cold spells (-40 to -60 degrees F.) regular in winter, while hot, humid conditions occur in the area 10-20% of the time during the summer. The lake itself can modify temperatures up to 20 degrees F. 20 miles inland, making it warmer near the lake in winter, depending on ice cover, and cooler in summer. The lake also causes an increase in fog during the spring and summer months giving near shore areas 30-50 days of fog annually (Lake Superior Project,1972-73). The five-month period from May to September accounts for 65% of the annual rainfall; the mean annual precipitation is 28.04 inches (Zube and Dega, 1964).

Water temperatures in the area vary due to the effects of surface winds. Temperatures range from 32 degrees F. in May to 55-66 degrees F. during the summer months. However, upwellings of 40 degree F. water may occur along the shorelines at any time (McCown, 1973).

One out of five days may have wind velocities exceeding 30 mph during the five-month boating season and as a result small craft warnings may be in effect along the south shore 80% of the time (McCown, 1973).

The largest concentration of residents in the study area is at Duluth-Superior with a combined population of 267,000. Ashland is the next largest community, with 9,615 people. Between Duluth-Superior and Ashland the villages of Port Wing, Cornucopia, Red Cliff, Bayfield, La Pointe and Washburn (and Odanah just south of Ashland) each have less than a thousand inhabitants. The population of these small communities has been decreasing since 1940, due to a decline in agricultural employment, a lack of strategic raw materials in this area, with the exception of wood, and little urban-industrial expansion. However, by the year 2000 the demand for recreation will have tripled and the U.S. Department of the Interior (1971) is predicting a dramatic increase in population for the area.

III. METHODS AND DATA

For the breeding survey we examined all portions of the Wisconsin shoreline of Lake Superior to obtain a complete record of nest locations and numbers for the three study species.

In the last three weeks of May we circled all the Apostle Islands once and many of the islands twice. We visited portions of the mainland shore also. We landed at many nest locations to count eggs or nests, although rocky shores and rough water prevented us from looking at all nests. We took detailed notes on numbers and behavior of gulls and terns, on location of the nests, numbers of eggs, availability of unused habitat, and on other bird species.

On Eagle Island Harris examined 50 clutches of eggs for cracks and breakage that might be associated with shell thinning caused by DDT or other hydrocarbon chemicals. On Gull Island we collected 15 herring gull eggs for shell measurements and pesticide analysis.

Using a set of U. S. Geological Survey maps we located all marshes of half an acre or more in size. During June we thoroughly explored all of these by canoe. We found no gulls nesting in marshes; the only common terns present, foraging in the marshes near Duluth-Superior, belonged to the Duluth tern colonies.

During the second half of June we surveyed by motor boat and canoe the remaining areas of mainland shoreline, from the Michigan to the Minnesota state lines. At this time, almost all gull eggs had hatched and most of the young were two or more weeks old. In May the adults incubate their eggs almost constantly, but when the chicks are half-grown the parents do not always remain close to the nest itself. The definite presence and exact location of lone nests may be very difficult to determine. Therefore, we carefully examined new areas of shoreline that we suspected might contain nests, visiting these locations at least twice.

On June 22, Harris visited common tern colonies in Washburn and in Ashland. He counted adults, nests, eggs, and newly hatched young. On June 25 and 26 we visited the Superior-Duluth area and briefly surveyed the shorelines of the harbor. We landed at the Port Authority and Sky Harbor tern colonies in Minnesota to count nests, eggs, and young.

During the last days in June and the first half of July we revisited almost all gull nests in the Apostles to determine nest success or failure and to count young. The counting of gull young presented rather different problems at the lone nests and small colonies than at the large colonies. At single nests and small colonies we theoretically could determine reproductive success by finding all young at the location, and dividing that figure by the number of nests present to obtain the number of young per nest. Unfortunately, it was impossible to know whether we were finding all young. The chicks run or swim many yards; because of their speckled coloration they can easily be overlooked in vegetation or among rocks. We visited most lone nests two to four times. At some we could find the chicks easily; others we knew had failed either because the adults had left the area or because there were no places where the young could hide and elude our searches. But some lone nests and most of the small colonies were on loose piles of rock; we saw half-grown chicks slip into the crevices, like mice, and totally vanish.

Our counts of young therefore were incomplete. For each nest however, we did collect data on substrate, height above water, distance up to the forest floor (where applicable), and accessibility to ground predators.

All studies we have examined on herring gull reproductive success reported results from colonies of a hundred or more pairs. Here the difficulties lie not so much in the availability of hiding places as in the large numbers of chicks that must be pursued and counted. In most studies, only a portion of the colony was being observed, and the study area chicks had to be kept separate from or at least distinguished from other chicks. Most students attempt to band all young chicks. They then recover the bodies of those that die, thus indirectly discovering how many are surviving,or they attempt to recapture all living chicks (see Paynter, 1949; Harris, 1964; Kadlec and Drury, 1968; Keith, 1966). Paludan (1951) was able to follow the fortunes of the chicks in his study area because natural features denied them access to the rest of the colony.

Such methods can provide detailed data on chick survival. But they involve extensive searches through the colony. Judging from the confusion we caused by our visits to Gull Island, we believe that some bodies and some live chicks must be overlooked. But more importantly, visits to the colony can contribute substantially to the mortality that is being studied.

Some observers have supplemented data obtained from brief visits to the colonies with notes taken from observation blinds (Kadlec et al., 1969) or have counted chicks from a blind as a check on survival figures (Emlen, 1956; Brown, 1967). We used blind observations exclusively to obtain reproductive success figures for Gull Island.

We chose two locations on Gull Island; one, a partly vegetated site with 20 nests, and the other on the open rocky beach, with 55 nests. We counted and mapped all nests. Then one of us hid in a blind and counted the chicks when they returned. During an observation period of 12 or more hours, all chicks will return to their parents' territories. With this method disturbances are minimized, although probably our presence in the colony still caused a few chick deaths. The one problem with the method involves abandoned nests. We assumed that most of these failed; but in a one-day visit there is no way to determine whether some of the nests represent second nesting attempts by a single pair. During earlier observations of the partly vegetated site, we saw one pair build a second nest and move their young chicks from one nest to the other! The problem of determining renestings can be avoided by visiting the location during the egg stage and marking the nests to be observed later. Early visits to our partly vegetated site allowed us to detect the one renesting attempt. At our open site, we believe that at most two or three of the successful nests represented renestings.

In mid and late July we made two visits to each of the three Wisconsin common tern colonies, counting all nests and eggs. As the colonies were small, we obtained counts of young by searching each colony thoroughly and checking the water for swimming young. At the Ashland breakwater colony, some chicks may have successfully hid from us under the rocks. We missed few if any chicks at the other two colonies.

Between July 14 and 18 we returned to the Duluth-Superior area. We thoroughly examined the entire Wisconsin shoreline, including bays, marsh areas, the lower Nemadji River, and up the St. Louis River 1/2 mile beyond Mud Lake. We surveyed most of the Minnesota side of the harbor, although we may have missed some single nesting pairs or small colonies. On that side we located four nesting locations for common terns, and three for ring-billed gulls. We present our data for these colonies because of their proximity to the study area, although the information we collected in Minnesota is less complete than our Wisconsin data.

We do not believe we overlooked any ring-billed gull or common tern colonies. But because of the extensive area of our study, we may have missed a small number of lone herring gull nests. Pairs which begin nesting early may have failed and left the location before we reached that part of shoreline. We did not visit a few parts of the shore after the third week in May; very late starting pairs may have been absent from their territories at that time. Pairs failing in a first attempt may have renested without our detecting them. Allowing for early failures, late attempts, and renests, we believe our totals for lone nests of herring gulls are probably within 5, certainly within 10, of the actual number of pairs that made nests and laid eggs in our study area.

IV. RESULTS OF THE SURVEY

A. THE HERRING GULL

In 1974, a total of approximately 1,010 pairs of herring gulls nested on the Wisconsin shore of Lake Superior. All but 31 pairs nested in the Apostle Islands. The gulls were concentrated in thirteen colonies ranging in size from two pairs on Long Island to 580-90 pairs on Gull Island (see Figure 2). These colonies are listed in order of decreasing size in Table I.

Critical nest areas for the species can easily be identified. The vast majority of nests were found in the two largest colonies. Gull Island, only three acres in size, is located off the northeast end of Michigan Island. It is composed of pebbles and boulders rising in a ridge on the north side but low and flat elsewhere. Vegetation covered less than half the island with sparse grasses or no vegetation elsewhere. The gulls entirely occupied the open portions of the island, with nests also under many bushes adjoining open areas. Nests were five to 15 feet apart, with territories smallest on the wide beach at the island's west end. On May 30 we counted 599 gull nests, 10-20 of which were ring-billed (see Section IVB).

Eagle Island held the second largest colony. Only at this colony did we fail to make an exact count of nests. Based on a sample count of slightly under one-fifth of the shoreline and on three counts of adults, we estimate 250 $\pm$ 25 nests were present. The island is 28 acres in size, rising to a height of 21 feet above low water level. Ledges of rock line all shores except on the southeast, where clay banks rise from the lake instead. The gulls nested all around the island on the steep shoreline. The interior of the island is relatively flat and for the most part thickly vegetated with pine, hemlock, cedar, and various deciduous trees. A small number of nests lay at the very edge of the forest above the ledges. We found none inland. The closest nests lay 10 to 15 feet apart.

The next largest two colonies on Otter and Hermit Islands were occupied by 45 and 28 pairs of herring gulls. Unlike the Eagle and Gull Island colonies, these sites were on islands large enough to support mammalian predators. The nests lay on inaccessible cliff ledges or on piles of talus rock between the cliffs and the lake. Because

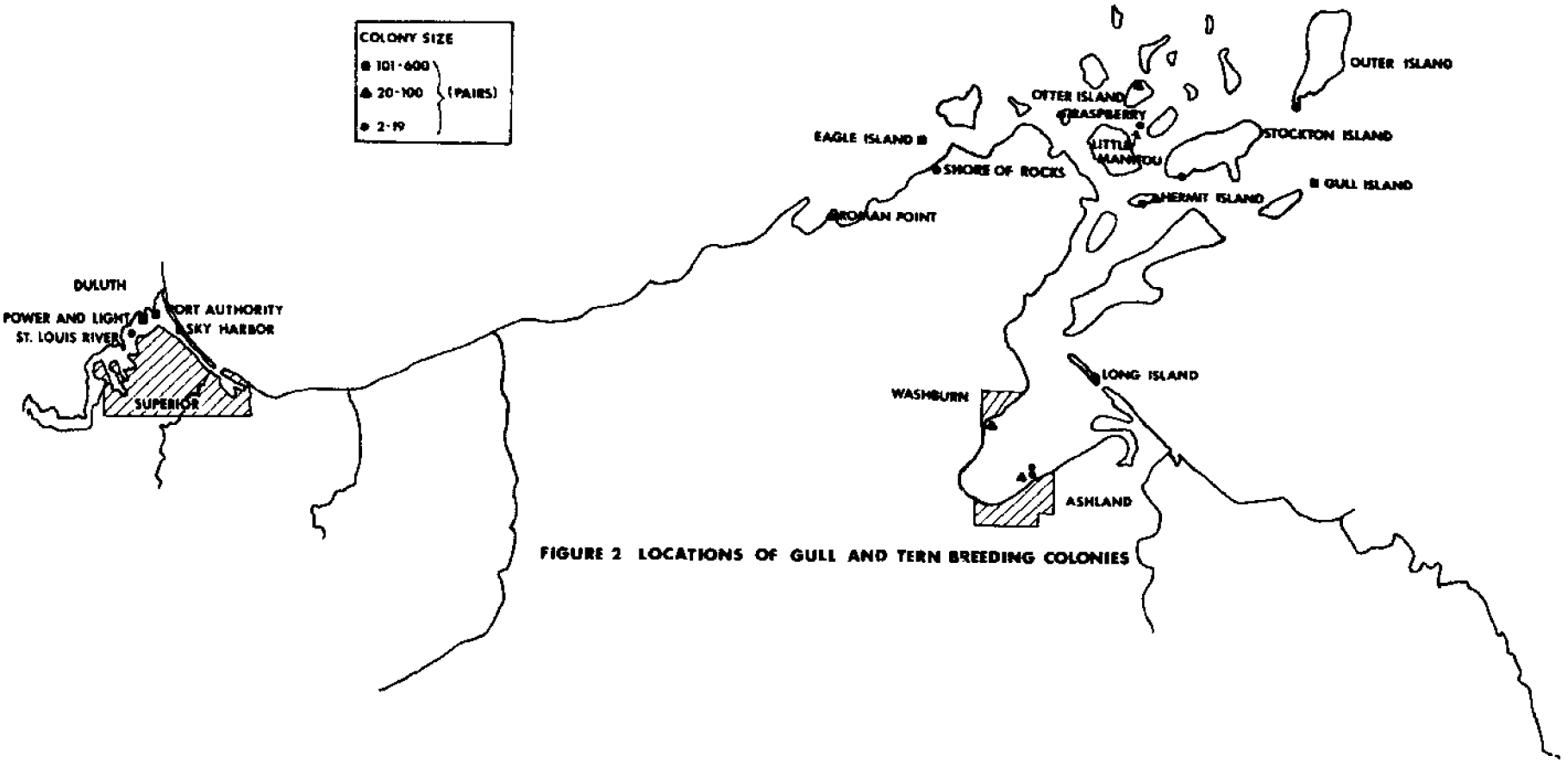

FIGURE 2 LOCATIONS OF GULL AND TERN BREEDING COLONIES

Table 1. Herring Gull Colonies on the Lake Superior Shoreline in Wisconsin

Location	Size	Terrain Description
Gull Island	580-590 pairs	low, rocky island
Eagle Island	250 ± 25 pairs	ledges and bluffs on all sides of small island
Otter Island, north side	45 pairs	cliff shoreline
Hermit Island, east end	28 pairs	cliff shoreline
Outer Island, south tip	18 pairs	sandy beach
Ashland breakwater	15 pairs	narrow line of boulders in bay
Little Manitou Island	10 pairs	very small island of rocks
Hermit Island, south side	7 pairs	small cliffs and rocky shore
Roman Point, mainland	7 pairs	cliff shoreline (nests widely scattered)
Shore of Rocks, mainland	7 pairs	cliff shoreline (nests scattered)
Stockton Island, southwest side	6 pairs	cliff shoreline
Raspberry Island, northwest side	3 pairs	rocky shore
Long Island, south end	2 pairs	sandy beach

of the colony sizes and because the presence of the gulls contributes to the attraction and uniqueness of these two tall shorelines, these locations should also be considered critical areas for the species.

The Otter Island colony was scattered along roughly a mile of shoreline on the north side of the island, where cliffs rise as high as 45 feet above water. Most of the nests lay among littered rock at the cliff base. Twenty-six nests lay on 2 talus heaps, with nests as close as 7 to 10 feet apart. Other nests had been built on inaccessible ledges on the cliff, while 12 lay at the cliff top, at the edge of the forest. Several of the cliff top nests were probably renests; we found 53 nests at Otter, but estimate that only 45 represented different pairs.

The Hermit Island colony was located along 100 yards of broken cliff on the south side of the east end of the island. Most nests were at the cliff base, but some lay on ledges. Only one of the 28 pairs of gulls had constructed its nest at cliff top, 35 feet above water.

The nine other herring gull colonies in the study area occupied varied types of shore, as can be seen from Table I. The two mainland colonies, at the Shore of Rocks (also called the Squaw Bay Cliffs) and at Roman Point are spread along tall cliffs.

Thirty-five pairs of gulls nested singly in the Apostles and at two locations on mainland cliffs. In addition, three other pairs occupied sites through the nesting season although we could find no evidence of nests or young. The following islands had one or more lone nests: Sand, Bear, Devil's, Rocky, North Twin, Cat, Outer, Oak, Manitou, Basswood, Hermit, Madeline, and Michigan (see Figure 3). All nests were located directly on the shoreline. The Rocky Island nest lay on a private pier. The other 34 nests occurred in four types of locations. Twelve were on cliff ledges from 2 to 25 feet above water. All of these sites were totally or relatively inaccessible to land mammals. Similarly inaccessible were 6 nests on tops of isolated boulders. Ten nests on rocky boulders or ledges along the shore were to varying degrees accessible. Three nests lay on or at the bases of steep clay bluffs, while 3 others were at the forest edge above ledges or cliffs. These last six all were easily accessible. With the exception of one lone pair on Manitou, which may or may not have had a nest, no gull pairs occupied low shorelines of sand or pebbles or a marshy or wooded edge.

We found no herring gull colonies in Duluth. One pair nested in the Port Authority common tern colony. We saw a second nest on top of a buoy in the harbor.

Our difficulties in finding young limit what we know about reproductive success. Seventy-five nests on Gull Island contained 1.19 young per nest. These young averaged nearly four weeks in age. Probably about

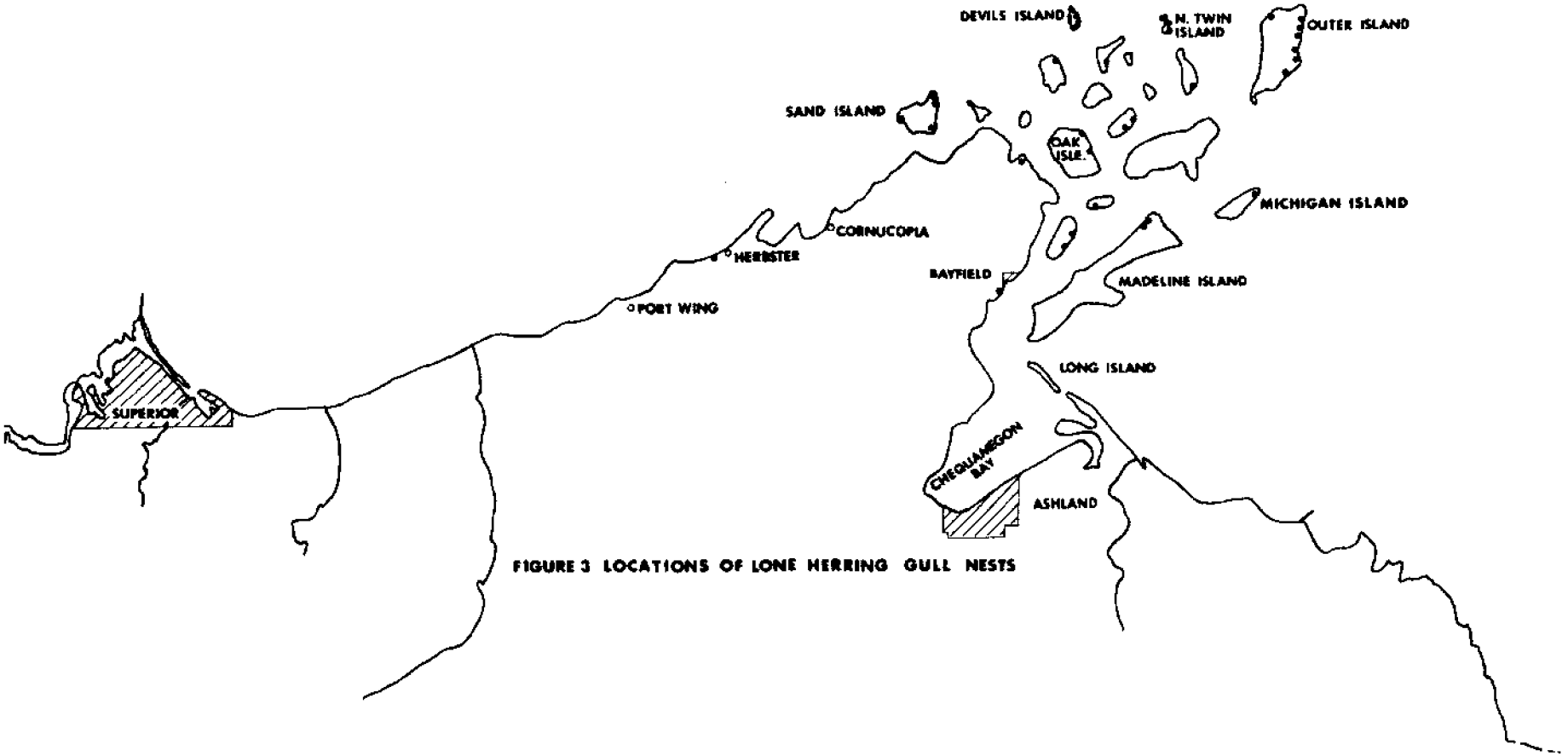

FIGURE 3 LOCATIONS OF LONE HERRING GULL NESTS

one chick per breeding pair fledged. Ludwig (1966), on the basis of immature and adult mortality rates and on other herring gull population characteristics, estimated that a fledging rate of 0.67 young per nesting pair would maintain a stable population. The reproductive success we observed is indicative of an increasing population.

Of our sample, the 20 nests at the partly vegetated site appeared more successful (1.65 young per nest, with an average age of 3 weeks) than the 55 open beach nests (1.00 young per nest, with an average age of over 4 weeks). We believe this differential success is principally due to differing vegetative cover rather than to an abnormally high chick mortality in the fourth week. The effects of cover on chick survival deserve more study, with larger nest samples.

The Otter colony, both the Hermit colonies and the Raspberry Island colony were carefully searched for chicks. Because of the many hiding places, we do not believe we discovered all the young. We did find between 0.5 and 0.7 young per nest at the 4 colonies, a minimum estimate of success; the gull pairs at these locations therefore were raising sufficient young to maintain at least a stable population.

Little Manitou Island,composed entirely of rocks, is only 25-30 feet across and rises 15 feet above the lake. Here bursting waves sent spray onto the highest windward rocks. On June 27, only 4, 2½-week-old chicks survived from the 10 nests.

Several colonies failed totally or almost totally. Three visits to the Stockton Island colony failed to discover any chicks. The nests on beaches at Outer and Long Islands had no young. As these nests were poorly constructed and as we found eggs only in one of them, these may not have represented serious nesting attempts. The colony on the Ashland breakwater lay vulnerable to winds and waves; here we found only 1 young, about 6 weeks old.

Nests at the most successful colony, on Roman Point, all lay on inaccessible ledges. There were houses above several of the nests. We counted 15 young in 6 nests, with a warm, unbroken egg being incubated in the seventh nest.

We can say little about the success of the lone nests — results for 15 of the 35 were uncertain. Thirteen of the remaining 19 nests failed. As 5, possibly all 6, of the most accessible nests (on clay slopes or at the forest edge) failed, we believe accessibility to ground predators strongly influenced nest success.

The herring gull is now using almost all the ideal nest habitat available in the study area. With the exception of Long Island (to be discussed in Section IV D) there are no unused small islands present on the Wisconsin shore suitable for colonies. The larger islands all

support a variety of predatory mammals (Jackson, 1961; Stadnyk et al., 1974). Many but not all cliff locations have at least lone pairs. More uninhabited shoreline exists with boulders or rock ledges, but this represents less ideal habitat with dwindling chances of reproductive success as accessiblity to predators increases.

Reproduction in the study area appears more than sufficient to maintain present numbers of gulls. The breeding population instead appears to be limited by habitat availability. As a result, some adults are using poor locations for nests. The extent to which adults unable to obtain good nest territories do not breed or else emigrate to other areas is unknown.

The Wisconsin shoreline supports a substantial number of non-breeding gulls. The majority are in adult or near adult plumage. Some of these move singly or in groups throughout the area; some loiter near the nest colonies. Thirty to fifty adults were present at all our visits to Little Manitou, where only 10 pairs nested. Local residents told us this island has gradually been reduced in size, because of wave action, and particularly in recent years because of high water levels. The extra adults may be those that in recent years nested on the island but can no longer obtain territories.

Concentrations of non-breeders remained in several areas throughout the summer. By far the largest numbers of these were at Superior harbor and dump. We generally saw between 50 and 250 near Port Wing, Herbster, Cornucopia, Washburn, Ashland, and Long Island. Man-provided food sources — garbage or fish remains — attracted the gulls to all of these locations except Long Island. We estimate that 800-1000 non-breeding gulls, perhaps more, summered in the study area from Port Wing to Chequamegon Bay.

After the nesting season from August 14 to 18 Harris visited harbors and dumps from Port Wing to Ashland to count all gulls present. In New England Kadlec and Drury (1968) used gull counts to obtain adult-immature ratios as an indicator of the age structure of the gull population. But the numbers of adults and immatures Harris could find were too small to provide a measure of the actual ratio of immatures to adults among all herring gulls summering in the study area.

B. THE RING-BILLED GULL

We found ring-billed gulls nesting at one location on the Wisconsin shoreline. On the southwest point of Gull Island, entirely surrounded by herring gulls, we observed 26 adults and 6 chicks on July 8. At this late date we did not want to venture close to the group for an exact count because our approach would have sent the chicks running among the predatory herring gulls. We estimate that between 10 and 20 pairs of ring-billed gulls nested in this small area among the herring gulls.

Additional nesting habitat for this species is quite limited. The larger Apostle Islands have predators that make their sandy beaches unsuitable. Long Island, under proper management, could provide a good site for a colony.

We found ring-billed gulls nesting at three locations in Duluth. One pair with two eggs nested at the Port Authority tern colony. With the common tern nests on two small islands (see Section IV C.) in the St. Louis River were 4 ring-billed nests, 2 on each island. On the north island we found 1 bad egg and one chick. We discovered no young on the south island, although a half-grown chick and two fledglings swam 200 feet to the south.

We discovered a large colony on a narrow peninsula on the Minnesota shore of the St. Louis River, at the Minnesota Power and Light Company stacks and tank. The gulls occupied the outer two-thirds of the point where the vegetation became less thick. The point rose as high as 4 feet above the water, with drift litter, large and small rocks, and some saplings but a larger area of open ground. We counted a total of 790 ring-billed gull chicks. Many of these already had fledged. Young ring-billeds outnumbered adults present. Because of the age of the young and the density of territories, we did not land to count nests, but estimate that between 475 and 550 pairs bred here.

This is by far the largest ring-billed colony recorded for Minnesota. The huge power plant and the surrounding barren ground successfully insulated the peninsula from mainland predators, providing an unusual but suitable location for the gulls. A similarly situated colony has been reported near Rogers City, Michigan (Southern, 1967). To our knowledge

ring-billed gull chicks have never before been reported from the Duluth area. Given the highly successful reproduction of the Minnesota Power and Light adults, ring-billed gulls will probably continue to nest in Minnesota in greater numbers than formerly.

During the breeding season we saw no more than 5 or 10 ring-billed gulls away from Gull Island in the Apostle Islands-Ashland area. Duluth had a much larger number of non-breeders, probably over 100. On July 22, however, 350 ring-billed gulls (327 in adult plumage) were resting on Long Island, and the following day 70 ring-billed including 2 fledglings were perched on the Ashland breakwater. On July 24, Matteson counted 121 ring-billed gulls near the Washburn tern colony. It is possible that all these gulls came from the Duluth and Gull Island colonies, but perhaps other unknown colonies occur along Lake Superior near but not within the study area.

C. THE COMMON TERN

We found common terns nesting at three locations within the study area and at four locations in Duluth (see Table II). All three Wisconsin colonies occupied marginal locations. A total of 56 pairs attempted nesting, but raised almost no young.

The largest colony, with 24 pairs, lay on a small man-made island directly off the Washburn boat landing. Most of the island is steep-sided, of mortared stone, so that while tern chicks may leap from land into the water, they can only regain land on the island's northwest side. The top of the island is level, and portions are thickly vegetated. Terns nested on exposed mortar and stone, or in areas of thin grass. About 24 pairs attempted to nest here, some of them constructing second nest scrapes after initial failures. Three young fledged from the colony. On July 12, many adults still were attending unhatched eggs. By July 24, most adults had left the colony; Matteson saw no young and only 2 warm, unbroken eggs out of 10 eggs remaining.

We believe the chief reason for the nesting failure was human disturbance. The colony lay so close to the Washburn boat landing that all boats leaving or returning would pass near the island. On July 12 two boys splashed out to the island in inflated tire tubes and examined all the "gull" nests. Shortly after a scuba diver paddled by. In future years thickening vegetation will increasingly limit the area suitable for tern nesting.

The Ashland pier colony lay at the end of a dismantled pier just east of the ore dock. This odd island consists of heavy beams supported by poles 6 to 7 feet above water to form a square about 70 by 70 feet that surrounds a low man-made island heavily overgrown with saplings, grasses, and raspberries. The terns nested on the beams on the west, north, and east sides of the square. Eggs or young had very little protection from wind or rain. While some eggs lay in depressions where the wood had rotted, others singly or in threes balanced on pencil-wide cracks in the wood; still others must have rolled off into the water. Twenty pairs of terns attempted nesting. On June 22 we found one newly hatched chick. On our two July visits we could find no young at all.

Table II. Common Tern Colonies on the Lake Superior Shoreline in Wisconsin and at Duluth

Location	Size	Young Present
Washburn	24 pairs	3 fledglings
Ashland pier	20 pairs	no young
Ashland breakwater	12 pairs	1 fledgling
Port Authority	160 pairs	no count, many young present
Sky Harbor	at least 10 pairs	no count
Minnesota Power & Light	10 pairs	3 fledglings, and 2 halfgrown
St. Louis River - 2 islands	10 - 15 pairs	3 young

Failures were due to the exposed location of the nests and to human disturbance. On several occasions we observed boats moored to the beams; people would fish from their boat while the terns screamed overhead. The less exposed middle of the island probably has little potential for nesting. Even if the vegetation were removed, tern chicks would not have access in and out of the water.

We found the third Wisconsin tern colony on Ashland's island breakwater, several hundred yards northeast of the pier colony. About a dozen pairs of terns attempted nesting here, laying their eggs in hollows on the bare stone. The breakwater offers very little shelter from either weather or waves. Little vegetation is present. Many of the hollows in stone used as nest scrapes had filled with water. We observed one young nearly fledged.

Such low reproductive success, perhaps only 4 chicks for 56 pairs, is certainly insufficient to maintain this breeding population. We believe the terns used these poor colonies because they could not find better locations. Only two other places on the Wisconsin shore appear highly suitable. The first, Gull Island, is entirely occupied by the larger herring gulls.

Long Island, the second possible location, protects Chequamegon Bay on its northeast side. Probably it once had nesting terns. David Bradley of Washburn (personal correspondence) observed terns on a sandy point on the west of the island for many years. Recent high water levels on Lake Superior have flooded the site. Bratley believed that the evicted terns may have moved 5 miles to establish the Washburn colony, first occupied in 1971. At least 2 young were raised on the island that year. In 1972, he observed 10 young. In 1973, the adults were present but no nesting occurred. Whether Long Island terns established the 2 Ashland colonies at the same time is unknown. Local residents told us adult and young terns had been on the pier colony in 1973.

Few common terns were present in the study area away from the colonies during the next season. In May, when we observed scattered terns throughout the Apostles, migration was still at its peak; then over a hundred gathered at both Ashland and Washburn, and many fished off Cornucopia (according to local residents); the Duluth-Superior harbor attracts up to several thousand terns in mid May (Green and Janssen, in press).

From mid June to mid July we observed no terns in the Apostles, except for a flock summering at Long Island. Here we found 30-50 adults on May 30, but only 25 on June 20 and 6 on July 22. One common tern briefly visited Port Wing on June 25. From the Middle River west terns come from Duluth foraging, a distance of about 13 miles.

We found no common terns nesting in Superior, Wisconsin, but in Duluth they occupied four locations. As in 1972 and 1973, the majority

nested near the Port Authority, an odd mainland location distant from human activity and isolated by highways. We counted 150 nests, scattered widely on several hundred square yards of sand. The middle area of the colony had no vegetation. Most nests lay where sparse grasses or scattered willow shoots grew — but many of these areas were not inhabited. We did not make any counts of young, although many were present in July and we believe the colony was quite successful.

On the ground with the tern nests we found 1 herring gull, 1 ring-billed gull, and 1 piping plover nest (with a second pair presumably nesting).

We observed at least 16 adult terns at the small Sky Harbor Airport on Minnesota Point. This mainland colony was protected from disturbance by its proximity to the runway, where no trespassing was allowed. We counted 8 scrapes and 2 additional young probably from scrapes we couldn't locate, for a total of at least 10 nesting pairs. We found 7 young and 10 eggs on June 26. This site has held more nests in past years but is becoming less suitable due to increasing vegetation (Henry Roberts, personal communication).

On July 18 we located 10 nest scrapes on the mainland just north of the ring-billed gull colony at the Minnesota Power and Light Company. These scrapes lay on piles of ash and scrap from the Power Company's furnaces, 15 to 20 feet from the water and 4 to 6 feet above its level. The terns had no vegetation or cover, except inland from the colony site where trash had been piled. At least 20 adult terns were present with 3 fledglings and 2 half-grown chicks. Other chicks may have hidden in the trash.

Like the ring-billed colony, this colony was protected by the Power Plant and barren ground. The nests were 10 to 20 feet apart; additional area was available for nests.

To the south of this colony in the St. Louis River, common terns nested on the 2 small islands that the ring-billed also inhabited. At least 19 adults were present on July 18, and we estimate 12 to 16 scrapes had been made, perhaps some of these renests.

Both islands, and 3 others to the southwest that had thick growths of bushes and small trees, were man-made. The northern of the two had a brick shore and mortared stone in its middle. The rest of the northern island was choked with nettles. We found 4 scrapes — 2 empty, 2 with clutches of 3 eggs — in the limited open space, and 4 dead young.

The south island was very low. On a limited area of open shore we found 5 nests, with a total of 2 warm and 2 bad eggs. The rest of the island supported a tangle of grasses and annual flowers. Nine bad eggs lay hidden in grasses. The only open spot in the middle was a shallow pool of water; 8 eggs had fallen in, perhaps displaced by the adult terns

as they had struggled through the vegetation.

The soil was damp and dark. We believe that in May the vegetation had been low or sparse enough to encourage nesting, but the plants quickly grew until at 2 or 3 feet in height they had literally closed off the nests from the terns. We did find three live young crouched in the grasses.

During the fall of 1974, much of the sand at the Port Authority colony was removed or covered. Beginning in 1975 buildings will be erected over much of the site. With the loss of what was by far their best location, the future of Duluth terns in uncertain. The St. Louis colonies are unsuitable and the Sky Harbor location becoming increasingly overgrown. Some pairs may settle at the barren Power Company colony. On the Wisconsin side of the harbor, the only possible location is Barker's Island, where terns once nested. Some parts are still open, although subject to heavy disturbance. Perhaps terns will discover a new location on the Minnesota side, which we examined less thoroughly.

The Superior-Duluth terns and Ashland-Washburn terns, separated by over 100 miles of shoreline, require independent management approaches. The Ashland-Washburn colonies are at present inadequate. It is possible that with changing conditions along the shoreline, new sites may become available. But otherwise, if terns are to remain in the Chequamegon Bay area, the present locations must be improved or the terns encouraged to return to Long Island.

D. LONG ISLAND — NEW NEST LOCATION FOR THE PIPING PLOVER

The piping plover has been placed on Wisconsin's list of Animals with Changing Status. This species formerly bred on Lake Michigan and elsewhere in Wisconsin. By the 1970's it had disappeared from all known nesting locations except Barker's Island at Superior (Wisconsin DNR, 1973). This site also was abandoned in 1972 and 1973 (Samuel Robbins, personal communication). It was not known whether pairs still nested elsewhere on the Lake Superior shoreline.

We looked at all portions of the shoreline during our gull and tern survey. The piping plover nests in areas of dry sand (Bent, 1929). Most of the beaches we saw appeared too narrow to suit the plover. Some of these we did not search, but we hiked along many of the larger ones and scanned others through binoculars from our boat. We found only 4 piping plovers, 2 together on the sandy south end of Long Island and 2 on the north end of Chequamegon Point, separated from Long Island by a narrow channel of water.

We saw all 4 birds on June 20 and 21. On July 22, Matteson revisited the area. The Long Island pair still was present, and one adult repeatedly attempted to lure Matteson away from one area with a broken wing act. He may have found the scrape, although he saw no eggs or young. There were no piping plovers present on Chequamegon Point that day.

It is unlikely that piping plovers summered elsewhere on the Superior shoreline. We examined in vain the largest beaches including the south tips of Outer and Cat Islands, the southeast of Stockton Island, along Bark Bay, at Port Wing, and the beaches on the outer side of Chequamegon Point and continuing east. We fear that the one, possibly 2, pairs that attempted nesting are Wisconsin's last breeding piping plovers. The species should be placed on the state's Endangered Species list.

The 408-acre Long Island is a unique area in Wisconsin but its suitability as a nesting area has been threatened. While rising water levels may have washed out the terns' colony location, the entire south end of the island is sandy, and many portions have that mixture of open

ground and beach grass that terns prefer. A tern flock summered in this area, as well as many herring gulls. But except for the 2 poorly constructed gull nests, neither species attempted to nest.

Although Long Island is remote from inhabited parts of the mainland — marshes nearly sever Chequamegon Point from other parts of the shore — boaters visit it with increasing frequency (David Bratley,personal comm.). People and their dogs walking through the dunes will disrupt any nestings. At the time of our visits, the tracks from motor bikes and other vehicles ran over all areas of sand.

In at least the last 2 summers mammals on the island have discouraged tern nesting and may have caused failure for the piping plovers. In 1973, the island's owner released 4 pigs to summer on the island. In 1974 pigs were not present, but we discovered a fox den with gull bodies and feathers about its entrance. While Long Island is not so far off Chequamegon Point as to be physically inaccessible to mainland mammals, the low sand flats and narrow water channels off the point as well as the sandy and marshy terrain on the point itself make visits to the island by predators unlikely. Probably the fox crossed over to the island when the lake was frozen.

The sandy end of Chequamegon Point suffers similar human disturbance. As it is not separated from mainland predators, it hasn't the same potential for a tern colony. The piping plover, however, nests on the mainland in many parts of its range.

Long Island, in addition to its nesting plovers and potential for a tern colony, may be attractive to Caspian terns Hydroprogne caspia also. This large relative of the common tern nests in island colonies on the lower Great Lakes (Ludwig, 1962). On May 30, 22 Caspians roosted on Long Island. At least 8 still remained on June 20 and 21. Under special management of the island for common terns, this species also might nest.

In Section VI A we will suggest measures necessary to protect Long Island as nest area. But the island itself is unique in Wisconsin and still retains its undisturbed appearance. The location has scenic, educational, and scientific values.

The island breaks all waves from the northeast so that Chequamegon Bay on the southwest side is protected and often calm. Sand is deposited on or eroded from various parts of the shore. The narrow northern 2/3 of the island presents a varied cross section. On the northeast shore jack pines stand; but the sand gradually washes away so that the outermost trees topple and upend their roots. Inland a narrow deciduous forest grows, until the ground dampens at the edge of a similarly long and narrow bog, containing sphagnum mosses and pitcher plants. On the

bog's southeast side the ground rises into bushes; the land slopes again in a sand and driftwood beach to the shallow bay.

While the island should not be disturbed by human visitors during the nest season, it could be visited in early spring and from late August through the fall and winter. It is also a significant resting area for migrating birds, particularly shorebirds (David Bratley, personal communication).

V. HUMAN ACTIVITIES AFFECTING GULLS AND TERNS

A. RECREATION AND DEVELOPMENT

By the year 2000 leisure time days will increase by 63% over present numbers (Rosner, 1973). Projected numbers of tourists travelling to the Bayfield Peninsula alone by 1985 are 740,000 to 1,000,000 — an increase of 600,000 to 800,000 over 1973 figures for a county whose population is about 12,000 (Matteson et al., 1973). A prime attraction will be the Apostle Islands. Around 80% of the tourists will be water recreationists. Of these, 12% will hike and camp on the islands. Since the islands with the most nesting gulls are small, the numbers of potential hikers present a managerial problem.

Dramatic increases in fishing, hiking and boating are expected. Between Duluth-Superior and Ashland there are many small craft facilities, with the largest in Duluth-Superior and the next largest in Bayfield. The boating season is only five months long. Since one cannot go too far without refueling, boat use may be heavily concentrated among the islands themselves. If this should happen the high level of water quality of the area may be threatened. Much more significantly, nest colonies will be increasingly subjected to human disturbances.

Tourism is expected to revive an economy suffering from low productivity in agriculture, forestry and mining. Second home development seems to be rising exponentially although there are serious water pollution problems associated with such development (Matteson et al. 1973). There are two paper companies located along the Wisconsin shoreline. One is in Ashland (The American Can Company) and the other is located in Superior (The Superior Fiber Products Company). Both contribute substantially to oxygen depletion locally though their impact has been somewhat reduced due to improved primary treatment systems. Other areas of development include small-scale agriculture and ongoing highway construction projects. Both contribute, though to a lesser degree, to water quality problems through runoff and red clay erosion.

In the Duluth-Superior harbors, along portions of the St. Louis River and to a lesser extent in Chequamegon Bay, concentrations of industrial wastes have been found. These waters carry coliform concentrations, trace metals, phenols, thermal additives, oxygen-consuming substances, suspended matter and toxic materials (U. S. Dept. of the Interior, 1970). The effects of certain of these pollutants on gulls and terns have not been studied.

The Corps of Engineers dredges approximately 10 million cubic yards annually from Great Lakes harbors. They have been active in the Duluth-Superior harbor in recent years, dredging over 6 million cubic yards there in 1968. In the past they have deposited their dredged materials in authorized open waste dumping areas. However, the sludge may, in addition to clean lake sand, contain oil and grease, dissolved solids, nutrients and toxic materials. In 1968 the Federal Water Pollution Control Administration carried out sediment-analysis tests and found unacceptable levels of oil, grease, phosphorous and chemical oxygen demand in portions of the Duluth-Superior and Ashland harbors (United States Department of the Interior, 1969). Presently the Corps may dispose of dredged materials in open water only if upon inspection the materials are found to be non-polluting (Jerry McKersie, personal comm.).

While gull and tern populations may be directly affected, chemical pollutants are more likely to harm the fish populations on which gulls and terns depend for food. Most fish are highly sensitive to deteriorating water quality. Toxic chemicals accumulate in the fish and may cause mortality or reproductive failures (U. S. Dept. of Interior, 1969). The water ecosystems of Lake Superior are characterized by a retention time of pollutants of four hundred years. In comparison, the retention times for Lakes Erie and Ontario are less than twenty years (Lake Superior Project, 1972-1973).

B. FISH AND THE FISHERIES

General

On Lake Superior fish are the principal article in the diets of gulls and terns. As such the status of the lake's fish species is a significant factor in contributing to breeding success. Historically, the major fish species have had to endure the combined effects of extensive overfishing, polluted waters, predation from the sea lamprey Petromyzon marinus, and increased competition for food from introduced species (McCown, 1973). Accordingly, since 1956 the Lake Superior fisheries have been in a depressed state with the notable exception of the Apostle Islands area which has been recovering in recent years (Ronald Poff, personal communication).

The status of the major fish species in the Apostle Islands area with the exception of the lake herring is presently very good and is continuing to improve due to successful stocking efforts begun in 1952 (Ronald Poff, personal communication). Since almost all gull colonies studied were located among the islands the stability of the major fish species in this area suggests that food scarcity should not be a problem to breeding populations in future years.

Wisconsin's total number of licensed commercial fishermen on Lake Superior has sharply declined in numbers over the past seven years due to the limited entry concept established by the Department of Natural Resources in 1967. The regulation limiting issuance of licenses was instituted to prevent overfishing. In 1966 there were a total of 72 licensed commercial fishermen. In 1973 the total had dropped to 19 — 12 full-time licensed fishermen and 7 part-time (King and Swanson, 1973). With the decline in numbers of fishermen, fish offal, a prime food source for gulls and terns, has become less available.

The Major Fish Species

The lake trout is ubiquitous in Lake Superior from deep water to offshore shoals to tributary rivers (Lawrie and Rahrer, 1973). Hatchery-reared lake trout have been stocked in the Apostle Islands since 1952. Peak stocking efforts reached in 1964 have been cut in half and the numbers of lake trout naturally have declined. However, the number of native spawners in an area determines population stability. Nowhere else in the Great Lakes have the percentages of native lake trout returning to traditional spawning grounds been as high as the 85% recently recorded for the Apostle Islands area (Ronald Poff, personal communication).

The Lake whitefish is restricted to inshore shallow water habitats and is found in the Apostle Islands at depths from less than 18 to 64 meters (Lawrie and Rahrer, 1973). The whitefish population in the Apostle Islands is recovering slowly from its low levels of abundance experienced during the decade of intense lamprey predation between 1956 and 1967. A peak in numbers was reached in 1971 and 1972 mainly due to the success of a high spawning population in 1966 (King and Swanson, 1973).

The lake herring is found throughout a wide range of bathymetric depths ranging from 5 to 165 meters (Dryer and Bell, 1964). Since 1949 the numbers of herring in Lake Superior have diminished steadily due primarily to overfishing (Lawrie and Rahrer, 1973) and to competition for food with the increasing chub population and with the introduced smelt population (Anderson and Smith, 1971).

Though there are five species of chub in Lake Superior, 95% of chubs harvested in Wisconsin waters are Coregonus hoyi (King and Swanson, 1973). The chub harvest in Wisconsin waters increased from 394,000 pounds in 1972 to 430,000 pounds in 1973. However, the health of the chub population is being closely watched since 1972-1973 figures are lower than 1970-1971 figures (King and Swanson, 1973).

Historically, apart from the lake trout and the three corregonines, only three other species have been abundant enough to yield quantities approaching 250,000 pounds annually in Lake Superior. They are the lake sturgeon, the walleye and the smelt (Lawrie and Rahrer, 1973).

Since 1920 annual yields of sturgeon have exceeded 10,000 pounds only three times. Sturgeon are taken in the shallow waters of estuaries and adjacent inshore areas and have declined over the years due to overfishing and pollution of waters from woody allochthonous materials (Lawrie and Rahrer, 1973).

Walleye inhabit the warmer waters of shallower large bays and island regions and are mostly absent from the open lake. They can often be found in rivers. Walleyes have not been an important species in United States commercial fishing since the turn of the century. In Canadian waters they seem to be declining due to water pollution (Lawrie and Rahrer, 1973).

Smelt immigrated from the lower Great Lakes to Lake Superior and were first recorded as being present there in 1930. Commercial fishing yielded 45,000 pounds in 1952 and until 1961 the United States yield rose exponentially at a rate of almost 40% per year. Since then, total Lake Superior yields have fluctuated around 1,404,000 pounds annually. Dryer et al., (1965) reported that the smelt has supplanted the chub as the principal food of the Lake Superior lake trout population.

The alewife is the most abundant fish species in Lake Michigan and Lake Huron and a main food source for gulls on both lakes. However, the cold water temperatures of Lake Superior may be detrimental to the alewife. The species generally inhabits shallow inshore waters and on Lake Superior temperatures can be unstable here due to upwellings and seiches. Temperature variation could be as much as 10 or 12 degrees C. over a 24 hour period. Consequently the alewife might experience sizable temperature shocks resulting in mortality (Stanley and Colby, 1971). The alewife is not abundant in Lake Superior (Lawrie and Rahrer, 1973).

C. SOLID WASTE

Solid waste in the form of putrescible, land-disposed materials has often created a scenic and sanitary problem in Wisconsin Lake Superior communities but has provided gulls food to complement a regular fish diet. Since 1969, however, solid waste disposal sites and operations have been upgraded resulting in improved solid waste management (The Natural Resources Council of State Agencies, 1973).

Solid waste disposal operations in the four county area are administered by the Department of Natural Resources under N. R. 151 of the Wisconsin Administrative Code in accordance with Sections 144.43 and 144.4 of the Wisconsin Statutes. State supervision was minimal until the advent of the sanitary landfill method of solid waste disposal in 1951. In 1962 the state established a licensing program, and licensing and inspection began in the spring pursuant to adoption of solid waste disposal standards.

Presently significant variances or exemptions from a full sanitary landfill status are afforded local units of government depending on applicability of state standards to their situation.

There are three types of solid waste sites: the open dump, the modified landfill site and the sanitary landfill site. The open dumps are required to be covered tri-annually during spring, summer and fall. Modified landfill sites are to be covered monthly except during the winter months (December through March) when they do not have to be covered at all. Sanitary landfill sites must be covered daily with no burning allowed (Thomas Sy, personal communication).

A total of about 23 solid waste disposal sites are within foraging distance of nesting gulls in the study area. All 23 are no more than 14 miles away from the lake water but by far the largest number are only one mile or less away. Fifteen of the sites are classified as "modified"; the remaining eight are split evenly in classification as either "sanitary" or "open". The impact of the site classification system upon feeding gulls should be minimal in future years as the amount of available edible materials is substantial even at "sanitary" sites. Additionally, the amount of waste materials in the future will be increasing in proportion to both increased resident and tourist populations.

D. WATER LEVELS

Water levels in the Great Lakes can critically affect nesting gull and tern habitat. Ludwig (1962) reported that common tern colonies on Lakes Michigan and Huron experienced low breeding success due to seasonal fluctuations in the water levels of the lakes.

In addition to endangering nesting habitat, water levels can cause serious erosion to the red clay bluffs along the shoreline of the mainland and shores of the islands and along the tributary streams where red clay deposits are especially abundant (Lake Superior Project, 1972-1973). The result is the discharge of many tons of sediment annually to the lake from the most severely eroded and high-sediment producing area in the Lake Superior basin: the four-county study area. Aquatic life is affected by the reduction in depth of light penetration and in the settlement of solids on the lake bottom.

Since 1922, in the interests of both navigation and electrical power generation, outflow from the lake has been controlled at Sault Ste. Marie, Ontario by the U. S. Army Corps of Engineers. Because of the political power around the lower Great Lakes where extensive shoreline damage has occurred, the water levels of Lake Superior in 1973 were raised to their legal maximum level of 602 feet above mean sea level established by the U. S. and Canadian governments. The result, especially along the south shore, was to cause continued erosion damage and to create greater damage whenever strong northeast winds rolled waves up to the 603 or 604 foot level (Milwaukee Journal, 1973). Litigation is presently pending on the matter, involving the Northern Environmental Council and the U. S. Army Corps of Engineers. The present level of Lake Superior is 601.8 feet.

The water levels on Lake Superior historically have been subject to long-term and seasonal variations. Seasonal variation, however, rarely exceeds half a meter (Lee, 1971) and mean annual levels for the period 1860-1913 and 1941-1967 were 600.19±0.66 feet and 600.58±0.56 feet, respectively. (Lawrie and Rahrer, 1973). The highest level recorded since 1860 has been 602.68 feet in August 1876. The lowest level recorded since 1860 has been 598.3 feet in 1926.

Lake Superior gull and tern nest habitat may not be as extensively affected as similar habitat on the lower lakes, where water level fluctuations are greater; but because Superior water levels have been essentially stable, a matter of inches in height can have adverse consequences to sensitive areas.

E. POLLUTANTS

We did not observe any evidence of reproductive failures caused by chemical contamination in the three study species.

Anderson (1970) reported that in 1967 14 herring gull eggs from the Knife Island colony in Lake Superior contained an average of 616.0 ppm lipid DDE and 595.6 ppm lipid PCBs (equivalent to 44.9 ppm DDE and 43.4 ppm PCBs wet weight), lower than the levels found in Lake Michigan eggs in 1967 and much lower than the 1964 levels — when 9 eggs averaged 202 ppm wet weight DDE — which caused reproductive failure (Keith, 1966). The Knife Island eggshells were 7% thinner than pre-1946 shells. Whether DDE has ever caused widespread reproductive failure on Lake Superior is unclear. On June 15, 1968, Alexander Sprunt IV (personal correspondence) observed what he believed to be abnormally frequent egg breakage and high chick mortality on Gull Island in the Apostles.

In 1973, herring gull eggs from the north shore of Lake Superior contained much lower DDE and PCB concentrations than the 1964 Lake Michigan eggs — composite samples of 4 or 5 eggs held from 15.9 to 33.9 ppm wet weight DDE and from 40.6 to 64.1 ppm PCBs (Ryder, 1974).

On May 24, 1974, about 5 days before the first eggs in the colony would hatch, we closely examined 48 clutches of eggs from Eagle Island for breaks, dents, or fine hairline cracks in the shells. Thirteen nests held at least one egg with some degree of cracking. Of 125 eggs examined, 17 eggs (13.5%) had damaged shells. Twelve of these had faint hairline cracks and 2 had faint star cracks which did not affect egg viability. Two others had dents in the shell, and one egg was broken open. Lake Michigan eggs in 1974 at a similar stage of incubation had considerably more shell fractures (Raymond Faber, personal communication).

In some nests we observed egg-sized or smaller rocks with depleted clutches of 1 or 2 eggs. This suggests abnormal adult behavior at the nest. One nest of the 48 nest sample had 1 rock; on Gull Island on May 30, 11 gull nests of 599 examined held 13 rocks.

Embryos in the 15 eggs we collected from Gull Island were on average half developed. Raymond Faber of the Department of Wildlife Ecology at the University of Wisconsin, measured the eggshells. The shell thickness index (see Ratcliffe, 1967, for an explanation of this measure of shell thinning) averaged 1.61, a -6.9% change from the shell thickness index for pre-1946 eggs. This degree of thinning closely approximates thinning for the Knife Island eggs, although DDT use in the Lake Superior watershed has decreased. These eggs are now being analyzed for chemical residues. We believe that at present levels, the pollutants will not affect herring gull reproduction.

Ryder (1974) analyzed herring and ring-billed gull eggs from the north shore of Lake Superior for mercury. Levels in the 2 species were roughly comparable, for the composite egg samples ranging from 0.40 to 0.75 ppm wet weight.

Ryder (1974) reported that ring-billed gull eggs contained significantly lower DDE and PCB levels than did herring gull eggs. Eggshells showed no thinning when compared with pre-1946 eggshells. On the basis of our observations, data on contamination in the herring gull, and the relatively clean waters of Lake Superior we do not believe that ring-billed gull reproduction in the study area, nor common tern reproduction, are presently affected by chemical contamination.

VI. RECOMMENDATIONS

A. FOR THE MANAGEMENT AND PROTECTION OF GULLS AND TERNS

Because there are only limited areas available for nesting sites and because pairs gather in colonies to nest, both gulls and terns are highly vulnerable to human disturbance and habitat loss. As development and recreational use of the Lake Superior shoreline increase, it will be important to protect suitable nest colony sites for both herring gulls and common terns.

All the large herring gull colonies are located within the Apostle Islands National Lakeshore. Therefore the National Park Service's recreational development and wildlife management policies will determine the future of the species on Wisconsin's Lake Superior shore. The two largest colonies, occupying Gull and Eagle Islands, absolutely must be protected from all human disturbance. Fortunately these islands are small and difficult to approach, so that their suitability for other use is limited. No boats should be allowed to land at either island or approach within 100 yards of the shore during the breeding season — from early April until the end of August. Access at other times might be permitted, but no piers or buildings should be constructed, nor should changes in the vegetation be permitted. Such rules would also protect the heron rookery on Eagle Island.

We have also identified the Otter and Hermit Island colonies as critical areas for the species. No disturbances should be allowed near the colonies during the nest season. Any piers, buildings, or campsites constructed on Otter Island should be far away from the colony. We recommend that trails not be created through the dense undergrowth to the cliff tops over the nest ledges — frequent frightening of the adults and reproductive failure would result. Hermit Island is smaller than Otter. Piers or trails should not be placed anywhere on the island if their presence would make disturbance of the colonies by hikers likely.

Trails to cliff areas without gull colonies would offer park visitors similar scenic views, for example on the northeast end of

Stockton, the west side of Sand Island, or portions of the east side of Outer.

Because Hermit and Otter Islands are centrally located in the Apostles group, because the colonies on vertical rock faces are easily viewed from boats, and because they occupy striking rock formations, these locations have special educational values. The tour boat presently circling the islands comes so close to the large Hermit colony that the adults are disturbed. But a tour boat could pass at a greater distance while still allowing a look at the colony. Interpretation by boat guides could complement a photographic display located in the mainland portion of the park, about herring gulls, among the most characteristic wildlife of the lakeshore.

The Shore of Rocks colony on the mainland cliffs at the west end of the National Lakeshore enhances the value of the spectacular red and gray cliffs. But people walking above the cliffs will threaten the existence of the colony. If a trail must be constructed here, its impact can be considerably reduced if in the immediate colony area it does not follow the cliff tops but runs back some distance through the forest, with one or two spur trails providing access to specific look-out points.

Special management of these 5 colonies should protect Wisconsin's Superior gull population from increasing recreational use of the Apostle Islands.

While gull management should consist of protecting present colonies, the future of common terns at existing sites is threatened in both the Ashland and Duluth areas. In Duluth the main 1974 colony site will no longer be available for nesting. In the past the terns have always found new colony sites, but with increasing human development of the area it is uncertain whether or not sufficient habitat remains for the terns to relocate and nest. It would be possible to remove vegetation from parts of Harbor Island or the Sky Harbor Airport. There are two main difficulties with this solution: first, finding persons willing to organize and perform the work involved, and second, obtaining permission to remove the vegetation. Many people are not sympathetic to tern nesting needs and consider bare ground an eyesore.

Most of the recent tern colony sites in Duluth-Superior have been created by the dredging activities of the U. S. Army Corps of Engineers. The Corps presently has plans to begin disposing sludge at a new site. Additional tern habitat may thus by chance be created. But if the terns do not discover a new nest location, strenuous

efforts should be made to alter existing locations or to influence Corps dredging operations so that a new site will become available. It would be unfortunate for the city to lose its terns, which last summer could be seen foraging through every corner of the harbor.

The Ashland and Washburn colony sites are at present inadequate; terns are not successfully reproducing. The Ashland breakwater colony cannot be improved. The feasibility of special management for the pier colony should be investigated. At the least, human disturbance should be minimized by designating the island a wildlife area and prohibiting boat docking during the nest season. But the site will remain marginal unless the vegetation can be removed from the island's center, and access to and from the water can be created.

The Washburn Island is more suitable for a colony. Again disturbance must be minimized. Some vegetation should be removed from the island.

Because of their locations and size, neither of these sites will ever be ideal. Long Island, however, has greater potential. Several steps can be taken to allow terns to successfully nest. First, human disruptions must be stopped. During the entire breeding season, from early April until the end of August, no visitors should be permitted on the island. Boaters, picnics, all-terrain vehicles, and hikers are incompatible with tern colonies. Secondly, pigs, foxes, and other large mammals should be kept off the island. Foxes now there should be removed. Each spring any predatory mammals that have crossed over from the mainland should be trapped and released elsewhere. These measures would also protect the rare piping plover.

Management of this nesting habitat can best be accomplished through state action, with the DNR either working out agreements with Long Island's present owner, or else purchasing the land.

The measures suggested above for the herring gull and common tern will also protect the present and potential ring-billed gull population. In addition, the ring-billed gulls' colony by the Minnesota Power and Light Company should be protected from disturbance.

The piping plover should be placed on Wisconsin's Endangered Species list.

While chemical pollution does not now threaten gulls or terns in the study area, use of hydrocarbon pesticides, PCBs, and mercury might easily have deleterious effects. These substances should not be released into the environment.

B. FOR FOLLOW-UP STUDIES

Extensive surveys repeating the 1974 study should be run at 5-year intervals to determine changes in numbers or distribution of the study species and the effects of human activity. Such changes will provide warning that other disturbances of the lakeshore ecosystem may be occurring. The appendices to this report have been prepared primarily for use in follow-up surveys.

Residents and visitors in the area should particularly notice the nesting or presence of ring-billed gulls; these records should be reported to the Wisconsin DNR or the Wisconsin Society for Ornithology so that the status of this species can be annually determined.

The future status of the common tern is so precarious that its nest colonies should be surveyed every breeding season. Without annual data, the success of active management programs cannot be known, nor can protection efforts be adjusted so that the species will continue to nest in the Duluth and Ashland areas.

VII. SUMMARY

During the summer of 1974 we surveyed nesting herring and ring-billed gulls and common terns along the entire Wisconsin shoreline of Lake Superior, including offshore islands and marshes adjacent to the lake. We also investigated human activities on Lake Superior that might affect these bird populations.

A total of approximately 1,010 pairs of herring gulls nested on the Wisconsin shoreline. They were concentrated in 13 colonies, with all but 31 pairs nesting in the Apostle Islands. The vast majority of gulls occupied two small islands — Gull Island, with 580-590 pairs, and Eagle Island, with 250 ± 25 pairs. The next largest colonies, of 45 and 28 pairs, were on shoreline cliffs at the north side of Otter Island and at the southeast end of Hermit Island.

Thirty-five pairs of herring gulls nested singly in the Apostles and at two locations on mainland cliffs. Three additional pairs occupied sites through the season although we could find no evidence of nests or young.

A sample of 75 nests on Gull Island was highly successful, containing 1.19 chicks per nest. These young averaged nearly 4 weeks in age.

At the other colonies and at the lone nests we had great difficulty searching for young. While some colonies produced at least enough young to maintain stable gull numbers, the Stockton, Outer, and Long Island colonies as well as the Ashland breakwater colony completely or almost completely failed. Success at the lone nests was uncertain. Most nests highly accessible to mammalian predators failed.

Overall herring gull reproduction in the study area appeared more than sufficient to maintain present numbers of gulls. As almost all ideal nest areas were used in 1974, availability of breeding habitat rather than reproductive success probably limits herring gull numbers in this area.

We found ring-billed gulls nesting at one location on the Wisconsin shoreline, on the southwest point of Gull Island. There we observed 26 adults and 6 chicks entirely surrounded by herring gulls, and estimate that between 10 and 20 pairs bred.

We discovered ring-billed gulls nesting at 3 locations in Duluth, Minnesota. One pair nested at the Port Authority tern colony. There were 4 nests on 2 small islands in the St. Louis River. A large colony occupied a peninsula at the Minnesota Power and Light Company. We counted 790 young, many of them fledged, and estimate that between 475 and 550 pairs bred.

Ring-billed gulls have not previously been reported nesting at any of these 4 locations. The species appears to be extending its breeding range into the study area.

We found common terns nesting at 3 locations in Wisconsin — at an islet off Washburn, and off Ashland at the end of a pier now largely dismantled and at an island breakwater. All 3 colonies occupied marginal nest habitat. The low reproductive success, perhaps only 4 chicks for 56 pairs, is certainly insufficient for maintaining these breeding colonies.

At Duluth, common terns bred at 4 sites. Ten pairs nested on barren ash heaps by the Minnesota Power and Light Company. At least 10 pairs nested at the Sky Harbor Airport on Minnesota Point; vegetation now covers most of this deteriorating habitat. Between 10 and 15 pairs bred on two small islands in the St. Louis River, where quickly growing vegetation caused most nests to fail. The largest and most successful colony covered an area of sand dredged from the harbor and deposited near the Port Authority. We counted 160 nests; many young were present in July. Because of building construction this site will no longer be available to the terns.

Long Island is the one location in the Ashland-Washburn area with high potential for a common tern colony, although human disturbance and a resident fox made the island unsuitable in 1974. One pair of piping plovers attempted nesting there, with a second pair possibly breeding on the end of Chequamegon Point. The species probably nests nowhere else in Wisconsin.

Fifteen herring gull eggs collected from Gull Island had shells 6.9% thinner than the average shell thickness for pre-1946 eggs, probably due to DDE and PCB residues in the adult gulls. Contents of the eggs are now being analyzed for chemical contaminants. We did not observe any evidence of reproductive failures caused by pollutants in the 3 study species.

Because there are only limited areas available for nesting sites, both gulls and terns are highly vulnerable to human disturbance and habitat loss. As development and recreational use of the Lake Superior shoreline increase, it will be important to protect suitable nest colony sites.

As all large herring gull colonies are located within the Apostle Islands National Lakeshore, the National Park Service's recreational development plans will determine the future of the species on the Wisconsin shoreline. Visits to Gull and Eagle Islands between early April and the end of August should be prohibited. Portions of Otter and Hermit Islands near the colonies should be closed to people, with no construction of piers, buildings, or trails. We recommend that the Shore of Rocks colony on the mainland also remain free from human disturbance.

If common terns are to continue nesting in the study area, the Washburn and Ashland pier colonies must be protected from disturbance, and the physical sites improved for the terns. If the Duluth terns do not find a new location for a large colony, formerly or presently-used sites should be improved by removing vegetation or else the U. S. Army Corps of Engineers should be persuaded to adjust their dredging operations to create additional habitat.

The ring-billed gull colony by the Minnesota Power and Light Company should not be disturbed.

If human visits to Long Island are prohibited during the nest season and mammalian predators removed each spring, the island may provide an excellent colony site for common terns. These measures would also protect the piping plover, which ought to be placed on Wisconsin's endangered species list.

Common tern and ring-billed gull colonies should be surveyed annually so that population changes can be detected. We recommend that the entire breeding census be repeated at 5-year intervals.

LITERATURE CITED

Anderson, D.W. 1970. Chlorinated Hydrocarbons: Their Dynamics and Eggshell Effects on Herring Gulls and Other Species. Ph.D. Thesis: University of Wisconsin, Madison. 168 pages.

Anderson, E.D. and L.L. Smith, Jr. 1971. Factors affecting abundance of lake herring (Coregonus artedii Lesueur) in western Lake Superior. *Transactions of the American Fisheries Society*, 100:691-707.

Bent, A.C. 1929. *Life histories of North American shore birds*. Part 2, U.S. National Museum Bulletin 146. Government Printing Office, Washington, D.C. 412 pages.

Brown, R.G.B. 1967. Breeding success and population growth in a colony of herring and lesser black-backed gulls Larus argentatus and L. fuscus. *Ibis*. 109: 502-515.

Dryer, W.R. and John Bell. 1964. Life history of lake herring in Lake Superior. *U.S. Fish and Wildlife Fisheries Bulletin*. 63:493-530.

Dryer, W.R., L.F. Erkkila and C.L. Tetzloff. 1965. Food of lake trout in Lake Superior. *Transactions of the American Fisheries Society*. 94: 169-176.

Emlen, J.T., Jr. 1956. Juvenile motality in a ring-billed gull colony. *Wilson Bulletin*. 68: 232-238.

Green, J.C. and R.B. Janssen. In press. *Minnesota birds*. University of Minnesota Press, Minneapolis.

Harris, M.P. 1964. Aspects of the breeding biology of the gulls Larus argentatus, L. fuscus and L. marinus. *Ibis*. 106: 432-456.

Jackson, H.H.T. 1961. *Mammals of Wisconsin*. University of Wisconsin Press, Madison. 504 pages.

Kadlec, J.A. and W.H. Drury. 1968. Structure of the New England herring gull population. *Ecology*. 49: 644-676.

Kadlec, J.A., W.H. Drury, Jr. and D.K. Onion. 1969. Growth and mortality of herring gull chicks. *Bird-Banding*. 40:222-233.

Keith, J.A. 1966. Reproduction in a population of herring gulls (Larus argentatus) contaminated by DDT. *Journal of Applied Ecology.* 3 (Supplement): 57-70.

King, G.R. and B.L. Swanson. 1973. *Progress report of fish management on Lake Superior.* Wisconsin Department of Natural Resources, Division of Forestry, Wildlife and Recreation, Madison. 39 pages.

Lake Superior Project. 1972-1973. *Environmental Decisions: Policies and Guidelines for the Lake Superior Region, Part 1: The Year's Work in Review 1972-1973.* Madison. 98 pages.

Lawrie, A.H. and J.F. Rahrer. 1973. *Lake Superior: a case history of the lake and its fisheries.* Technical Report Number 19, Great Lakes Fisheries Commission, Ann Arbor, Michigan. 69 pages.

Lee, P.J. 1971. *Multivariate analysis for the fisheries biology.* Fisheries Research Board of Canada Technical Report 244. 181 pages.

Ludwig, J.P. 1962. A survey of the gull and tern populations of Lakes Huron, Michigan and Superior. *The Jack-Pine Warbler.* 40: 104-119.

_____. 1966. *Herring and ring-billed gull populations of the Great Lakes 1960-1965.* Publication Number 15, Great Lakes Research Division, University of Michigan. Pages 80-89.

Matteson, R.E., J.L. O'Leary, T.G. Squire, Lelyn Stadnyk and C.E. Twining. 1973. *The impact of the Apostle Islands national lakeshore on Bayfield County.* Sigurd Olson Institute of Environmental Studies, Ashland. 121 pages.

McCown, B.H. 1973. Resource Characteristics and Man's Use of the Lake Superior Region. Thirteen pages in Environmental Decisions: Policies and Guidelines for the Lake Superior Region, Part 2: Staff Papers 1972-1973. Lake Superior Project, Madison. n.p.

The Milwaukee Journal. November 15, 1973. *On Wisconsin.* Anonymous, D.B. Albert, Milwaukee.

Natural Resources Council of State Agencies. 1973. *Managing Wisconsin's Natural Resources.* Madison, 114 pages.

North Central Field Committee. 1965. *Apostle Islands National Lakeshore: A Proposal.* U.S. Department of the Interior. 28 pages.

Paludan, Knud. 1951. *Contributions to the breeding biology of Larus argentatus and Larus fuscus.* Ejnar Munksgaard, 6, Norregade, Copenhagen. 142 pages.

Paynter, R.A., Jr. 1949. Clutch-size and the egg and chick mortality of Kent Island herring gulls. *Ecology.* 30: 146-166.

Ratcliffe, D.A. 1967. Decrease in eggshell weight in certain birds of prey. *Nature.* 215: 208-210.

Rosner, M.H. 1973. Leisure Time Budgets: Implications for the Tourist Industry in the Lake Superior Region. Fourteen pages in Environmental Decisions: Policies and Guidelines for the Lake Superior Region, Part 2: Staff Papers 1972-1973. Lake Superior Project, Madison. n.p.

Ryder, J.P. 1974. Organochlorine and mercury residues in gulls' eggs from western Ontario. *Canadian Field-Naturalist.* 88:349-352.

Southern, W.E. 1967. Dispersal and migration of ring-billed gulls from a Michigan population. *The Jack-Pine Warbler.* 45: 102-111.

Stadnyk, Lelyn, R.L. Verch and B.A. Goetz. 1974. *Stockton Island survey: an ecological survey and environmental impact study of Stockton Island, Apostle Islands national lakeshore.* Ashland, Northland College. 71 pages.

Stanley, J.G. and P.J. Colby. 1971. Effects of temperature on electrolyte balance and osmoregulation in the alewife (Alosa pseudoharengus) in fresh and sea water. *Transactions of the American Fisheries Society.* 100: 624-638.

United States Department of the Interior. 1969. *An Appraisal of Water Pollution in the Lake Superior Basin.* Federal Water Pollution Control Administration PL 84-660. 107 pages.

_____. 1970. Water-oriented Outdoor Recreation in the Lake Superior Basin. Bureau of Outdoor Recreation, Ann Arbor, Michigan. n.p.

_____. 1971. *Apostle Islands National Lakeshore, Wisconsin, Master Plan.* 30 pages.

Wisconsin Department of Natural Resources. 1973. *Endangered Animals in Wisconsin.* Madison. 28 pages.

Zube, E.H. and H.H. Dega. 1964. *Wisconsin's Lake Superior shoreline.* Wisconsin State Department of Resource Development. 42 pages.