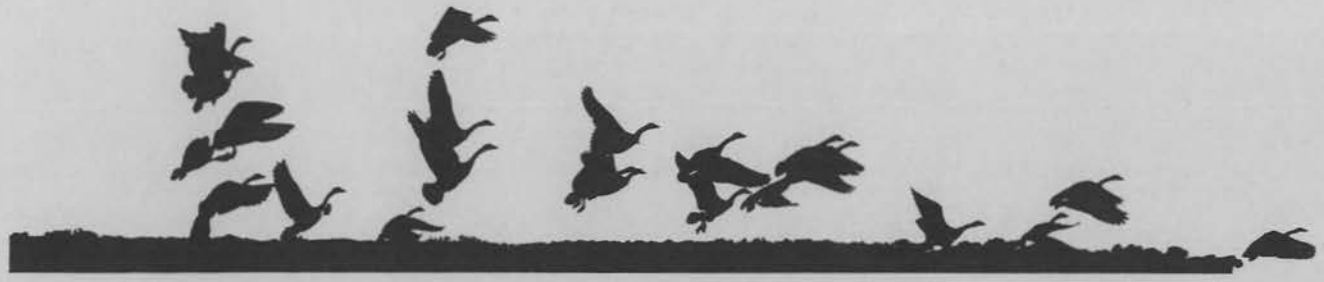
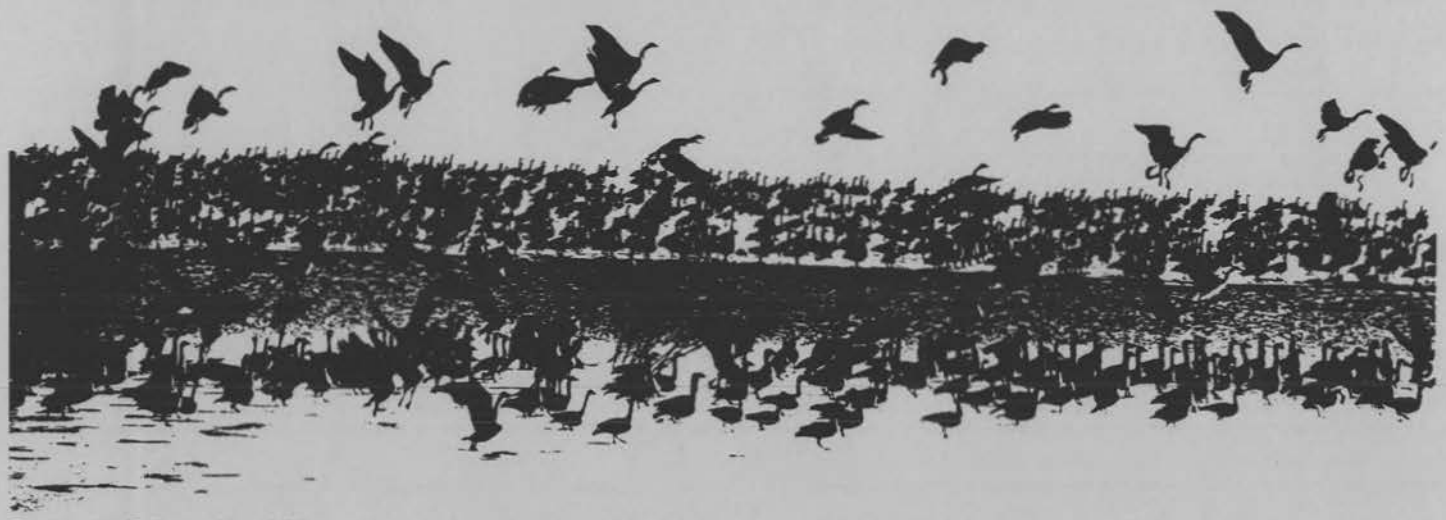


Distribution and Movement of Canada Geese in Response to Management Changes in East Central Wisconsin, 1975-81



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PREFACE

As the Canada goose population around Horicon National Wildlife Refuge increased in the 1960s and early 1970s, problems also increased. Crop depredation, the distribution of geese in the flyway, hunter behavior, and the potential for waterfowl disease all became serious problems for wildlife managers. From 1976-80, the U.S. Fish and Wildlife Service and the Wisconsin Department of Natural Resources implemented a management program to reduce the number of geese and goose-related problems in the Horicon area.

This technical bulletin discusses the distribution and movement of Canada geese within east central Wisconsin and the impacts of that 5-year management program on the distribution.

Several other publications cover related aspects of that research (see Literature Cited section):

Evaluation of Efforts to Redistribute Canada Geese (Rusch et al. 1985) summarizes the effectiveness of management techniques and evaluates their impact on the overall changes in distribution, numbers, survival, and movements of geese in relation to east central Wisconsin as a portion of the range of the Mississippi Valley Population. The evaluation relied on neckband data from about 15,000 geese.

Behavior of Family Groups of Canada Geese in East Central Wisconsin, 1979-81 (Bartelt n.d.*a*) studies 15 family groups. Using radio telemetry, investigators examined family cohesiveness, as well as the impacts of dispersal techniques and hunting.

Response of Canada Geese to Disturbance on Horicon National Wildlife Refuge, 1978-81 (Bartelt n.d.*b*) examines the immediate response of 142 individual geese to dispersal techniques within the refuge.

ABSTRACT

A large segment of the Mississippi Valley Population (MVP) of Canada geese traditionally stops at and around Horicon National Wildlife Refuge (Horicon NWR) between late September and December. As both the MVP and the proportion of the MVP in the Horicon area increased in the 1960s and early 1970s (Craven 1978), problems also increased, including crop depredation, uneven distribution of geese both in Wisconsin and in the flyway, altered hunter behavior, and the potential for waterfowl disease.

From 1976-80, the U.S. Fish and Wildlife Service (USFWS) and the Wisconsin Department of Natural Resources (DNR) implemented a management program to reduce the number of geese and goose-related problems in the Horicon area. From 1975-81, the Wisconsin Cooperative Wildlife Research Unit (WCWRU) and the DNR conducted field research in east central Wisconsin and two additional satellite areas to monitor the distribution and movements of geese and evaluate the management program's progress. The WCWRU work analyzed 25,157 encounters with 8,020 neck-banded geese (banded at Horicon) while the DNR work analyzed 17,774 encounters with 210 radio-marked geese (marked throughout the study area).

Data from the two studies are combined in this paper to address the distribution of geese in east central Wisconsin, the existence of subflocks associated with satellite management areas in east central Wisconsin, and the impact of the management program on goose numbers and distribution.

Despite dispersal efforts through the management program, geese marked at a given area in east central Wisconsin tended to remain in that area during the fall and return to it in subsequent years. Based on radio data, most geese made only 1-2 movements between areas each fall.

Lakes west and northwest of Horicon Marsh (Lakes Area) were very important to geese marked at Horicon NWR, especially those birds from the west side of the refuge. Some geese marked at Horicon NWR did move to satellite areas, but relatively little time was spent on any of these areas except for Grand River Marsh. Hunting recoveries supported the patterns of distribution determined by both neckbands and radios.

Goose populations at Grand River Marsh, the largest of the DNR-managed satellite areas, were highly variable and largely inaccessible for neckband observations; therefore, observations of radio-marked geese were used for analyses. Geese marked at Grand River Marsh used the Lakes Area and Horicon NWR extensively. Eldorado is only 10 miles north of Horicon NWR and feeding areas of geese from Eldorado overlapped those used by Horicon geese. Thus, it was difficult to distinguish between these two areas.

Pine Island and Collins Marsh, two other satellite areas, are both far enough away to avoid major population fluctuations based on events at Horicon NWR. Both areas also had the highest rates of homing in subsequent years after marking.

Movements and distribution of geese in east central Wisconsin were affected by tradition, hunting pressure, refuges and refuge locations, food availability, weather, and dispersal activities. The effects of dispersal activities were local and not as significant in the redistribution of geese as expected. Predispersal patterns of goose distribution were re-established within a year after dispersal ceased.

The Horicon area, Grand River Marsh, Eldorado, and the Lakes Area are too closely related to events at Horicon NWR to allow completely independent harvest management. The areas probably can be manipulated to vary the relative distribution of geese. Pine Island and Collins Marsh can likely be managed independently with minimal impact on goose numbers or distribution at Horicon Marsh.

KEY WORDS: Canada geese, Wisconsin, Horicon Marsh, waterfowl management, habitat manipulation, waterfowl movements, neckbands, radio telemetry.

DISTRIBUTION AND MOVEMENT OF CANADA GEESE IN RESPONSE TO MANAGEMENT CHANGES IN EAST CENTRAL WISCONSIN, 1975-81

by
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INTRODUCTION

The Canada geese (primarily *Branta canadensis interior*) that visit east central Wisconsin during fall and early winter represent a portion of the Mississippi Valley Population (MVP) of Canada geese (Hanson and Smith 1950). These geese traditionally stop at and around Horicon National Wildlife Refuge (Horicon NWR), in an area often described as east central Wisconsin, between late September and December before migrating to wintering areas in southern Illinois and northwestern Kentucky. Craven (1978) used the distribution of hunting recoveries and neckband observations to describe the range of geese banded at Horicon and found that 98% of the recoveries and 99+% of the observations were within acknowledged MVP range boundaries.

Scenes like this were typical near Horicon Marsh during the 1960s and early 1970s when Canada goose populations were at a peak.

EARLY HISTORY OF GEESE IN EAST CENTRAL WISCONSIN

The early history of the MVP was reviewed by Hanson and Smith (1950) and Reeves et al. (1968). Prior to the purchase and development of Horicon NWR by the U.S. Fish and Wildlife Service (USFWS) starting in 1941, very few Canada geese made a stopover in east central Wisconsin. By the early 1950s, the food, water, and sanctuary provided by Horicon NWR began to attract an increasing proportion of the MVP during the fall. By the early 1960s, when the MVP midwinter inventory approached 200,000 geese, the east central Wisconsin peak population reached 100,000 with the majority of geese on or near Horicon NWR (Hunt et al. 1962).

Spectacular concentrations of Canada geese were the primary attraction for thousands of goose watchers in the east central area during the fall.

The peak goose population in east central Wisconsin continued to increase through the early 1970s and the proportion of the MVP represented by the Horicon area peak population also increased during the 1960s and 1970s (Fig. 1). Both increases began to concern wildlife managers by the mid 1960s.

The increasing goose flock created problems in the immediate area of Horicon NWR, where the geese were concentrated. Crop depredation increased (Hunt and Bell 1973), and the quality of hunting deteriorated as the geese attracted large numbers of hunters (Brakhage et al. 1971). Because of these problems, the USFWS began to disperse the goose concentration in 1966 (Reeves et al. 1968). The public and the Wisconsin Conservation De-

Geese are capable of removing corn from ears to a height of about 38 inches. Where snow accumulates, few ears of corn are out of reach of hungry geese.

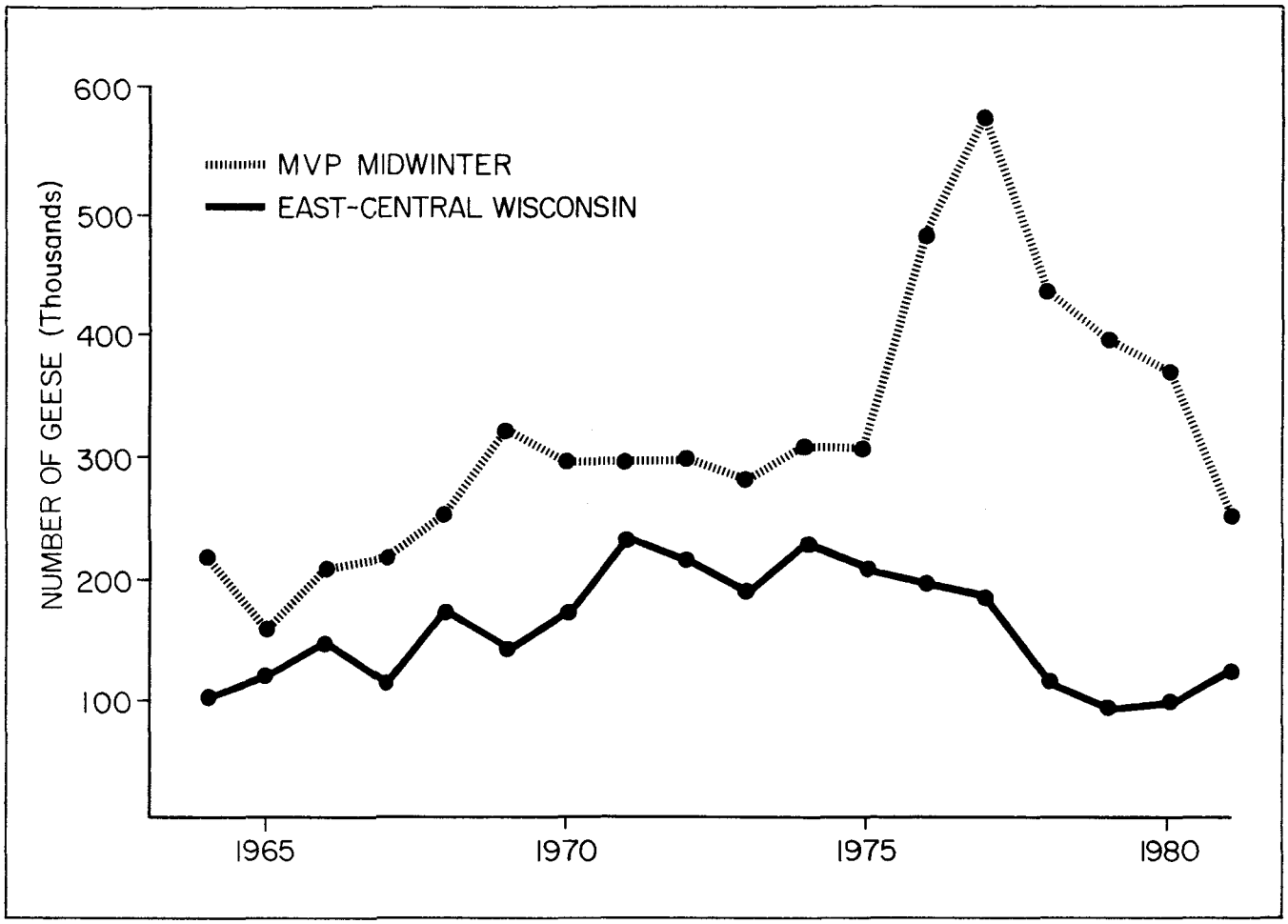


FIGURE 1. *Number of Canada geese in the MVP midwinter inventory and the east central Wisconsin fall peak population.*

partment, predecessor to the Wisconsin Department of Natural Resources (DNR), strongly opposed this effort.

Despite various forms of harassment, the distribution of geese did not change beyond the immediate area, and the local goose harvest was intense (Reeves et al. 1968). From 1966-73, the goose population continued to increase but no effort was made to disperse the flock after the abortive 1966 program. In fact, management on Horicon NWR was designed to hold geese on the refuge by increasing the food supply.

By 1974, the MVP had increased by about 100,000 geese, reaching a midwinter count of about 300,000 (Fig. 1), and the east central Wisconsin population was almost 200,000. Geese remained in east central Wisconsin well into December or even later in some years. It was then apparent to the USFWS and the DNR that the problems of the 1960s were still present and new problems had been added. First, with such a high proportion of the population in one place (Horicon NWR), there was a heightened awareness of the potential for an infectious disease leading to a catastrophe. Second, states south of Wisconsin and Illinois perceived the large goose concentration in Wisconsin and then later in the season in Illinois as limiting their opportunity to share in the goose resource. Third, until the problems of excessive goose concentration in east central Wisconsin could be resolved, further expansion of the MVP was not possible.

THE MANAGEMENT PLAN

In response to the problems, a management plan for east central Wisconsin was developed jointly by the USFWS and the DNR in 1975. The objectives of the 5-year plan (which ran from 1976-80 and is hereafter referred to as the plan) were to: (1) reduce the peak fall goose population to 100,000, (2) reduce goose use days to 5 million, and (3) manage the geese such that 95% of the goose use occurred before 5 December. In response to new data and the acceptance of a 5-year management plan for the entire MVP by the involved states, the goals of the plan were revised upward in 1979 to "emphasize perpetuation" of the Canada geese which stop in east central Wisconsin and to achieve a balanced distribution between Horicon NWR and the surrounding public and private areas that supported significant numbers of geese.

The plan concentrated on the reduction/elimination of food, water, and sanctuary for Canada geese. The specific techniques, their efficacy, and the response of the geese were discussed by Rusch et al. (1985) and in a series of "Goosewatch" progress reports (USFWS and DNR, 1976-80). A summary of the management program activities year-by-year is presented in Table 19.

SUBFLOCKS AND MANAGEMENT OF SATELLITE AREAS

While the local distribution of geese was and remains important to Wisconsin wildlife managers, distribution of geese in response to management changes in Wisconsin also has ramifications for the entire Mississippi Flyway.

Based on data from the first three years of the east central Wisconsin program, Craven (1978) concluded that the geese which used east central Wisconsin were a subflock of the entire MVP. This conclusion was consistent with the findings of Kennedy and Arthur (1974) who identified subflocks within the MVP (including a "Horicon" subflock) based on harvest and inventory data. Craven (1978) also proposed that the east central Wisconsin (or "Horicon" subflock as it was called) might be further subdivided into groups of geese associated with, and faithful to, specific areas.

The potential that management might induce geese to use certain areas and remain faithful to them within and between years motivated the identification and development of DNR-managed satellite areas during the 1960s (Bell 1970). If the distribution and migration of geese on each of these areas was unique, or nearly so, then each area could be managed independently to relieve the problems of large numbers of geese at Horicon NWR. Such subflocks, as proposed by Craven (1978) for east central Wisconsin, were identified by Koerner et al. (1974) in Ohio and in northwestern Wisconsin by Zicus (1981). Raveling (1969*b*) described the fidelity of geese to specific areas of Crab Orchard NWR and speculated that such behavior reflected the continued association of discrete flocks from the breeding grounds. He later supported that hypothesis with data on giant Canada geese in Rochester, Minnesota (Raveling 1979).

RESEARCH TECHNIQUES AND OBJECTIVES

Concurrent with management efforts to disperse the goose flock, two research projects were initiated to evaluate the effects of the management program on the movement and distribution of geese in east central Wisconsin and the Mississippi Flyway as a whole. One conducted by the Wisconsin Cooperative Wildlife Research Unit (WCWRU) at the University of Wisconsin-Madison relied on extensive observations of neck-banded geese, and the other conducted by the Wetlands Wildlife Research Group of the DNR relied on radio telemetry.

The two studies were conducted independently. However, the data were both comparable and complementary and are combined in this paper to present a fuller picture of the distribution and association of geese before, during, and after management changes. Neckband observations provided an extensive sample of large numbers of geese encountered an average of 3 times. The radio telemetry data provided intensive data on relatively few geese encountered an average of 85 times. In combination, the two data sets were used to quantify gross patterns of distribution, movement between different areas, use of field areas for feeding, fidelity to use areas, and the amount of time individual geese spent in each area. In combination, they represent a fuller picture than either study could provide alone.

The specific objectives of this paper are to:

(1) Describe the distribution of Canada geese in east central Wisconsin using (a) aerial counts, (b) neck collar observations, (c) radio locations, and (d) band return data, to determine percent time spent on each area, number of moves per individual, distribution of observations, and distribution of recoveries.

(2) Evaluate the uniqueness and potential for management of geese associated with various satellite areas in east central Wisconsin.

(3) Evaluate the impact of the management program on goose numbers and distribution, and recommend future management practices based on the results of the dispersal program and patterns of goose distribution.

STUDY AREA

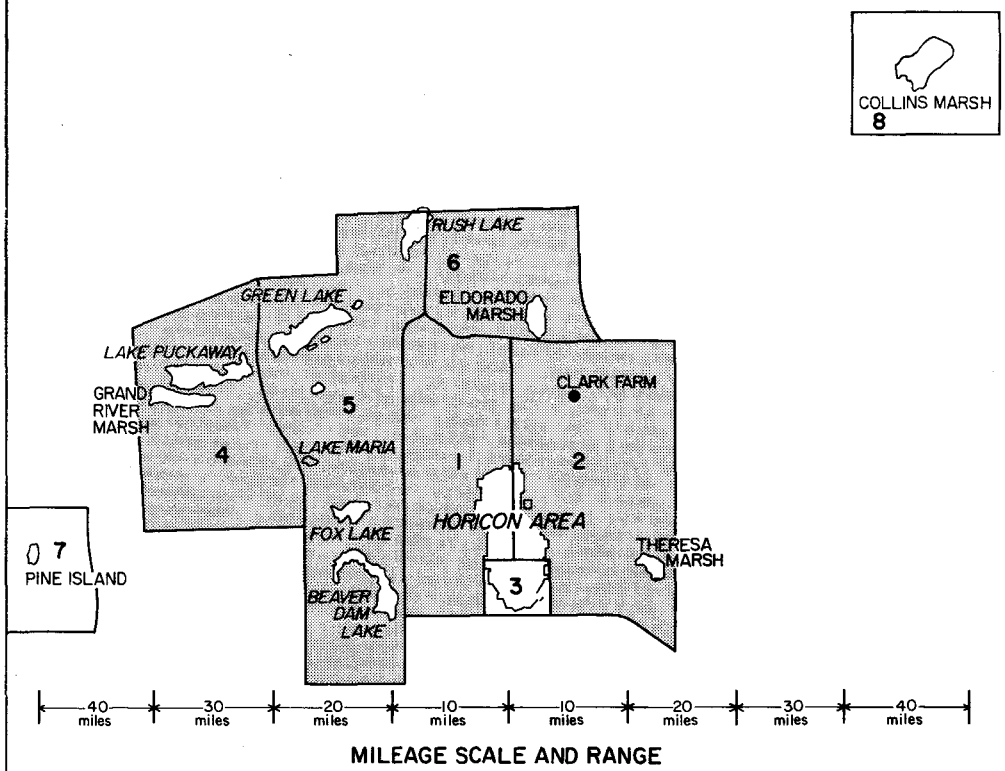
The study area encompassed a 4-county area of about 1,730,000 acres that included the Horicon area (Horicon Marsh and its environs), the Lakes Area west and northwest of Horicon Marsh, and 2 satellite areas (Grand River Marsh and Eldorado Marsh), collectively designated as east central Wisconsin, and in addition, 2 other satellite areas, Pine Island (40 miles west of Horicon Marsh) and Collins Marsh (47 miles northeast of Horicon Marsh) (Fig. 2)*.

*Although Theresa Marsh is a satellite area located in close proximity to Horicon Marsh, it was not included in this study because it was not heavily used by geese at the time our work was begun. Several other areas currently managed for geese were also not included—e.g., Sandhill Wildlife Management Area and Necedah NWR.

The 31,000-acre Horicon Marsh is a shallow basin drained by the Rock River. Water levels are controlled by a dam in the town of Horicon at the southern end of the marsh and by a water control gate in the east-west dike across the marsh delineating federal and state ownerships. The 21,000-acre area north of the dike is managed by the USFWS as Horicon NWR, and is closed to waterfowl hunting. The remainder is managed by the DNR as Horicon Wildlife Management Area (Horicon WMA), part of which is also closed to hunting.

Geese concentrated in the immediate area (10 miles) of the marsh and on DNR or private areas and public lakes within 50 miles of Horicon NWR (Fig. 2). The Horicon and East Central (now Central) Harvest Management Zones established to control the goose harvest are included in the east central Wisconsin study area. The relationship of these various areas and management zones to the segments of east central Wisconsin used for data analysis is discussed in the section on data analysis.

The topography of the area is gently rolling with fertile soil. Dodge and Fond du Lac counties, which include Horicon Marsh, are only 7% and 11% forested, respectively. Agriculture is intensive and is primarily dairy farming. The primary crops are corn, small grains, hay, and vegetables for the canning industry. Lakes are typically shallow and fertile with the exception of Big Green Lake, the deepest inland lake in Wisconsin. The wetlands of the area have been described by Beule (1979). East central Wisconsin has been described by Hunt et al. (1962), Reeves et al. (1968), Green (1968), and LaMarche (1972).



Horicon Marsh = Horicon NWR, under federal management, and the Horicon Wildlife Management Area to the south, under DNR management.

Horicon area = Horicon Marsh (divided into 3 composite segments, East (2), West (1), and South (3)) and surrounding uplands.

Lakes Area = (5) lakes in the uplands west and northwest of Horicon Marsh, including Green Lake, Lake Maria, and Fox Lake.

Satellite areas = goose management areas, including Grand River Marsh (4), Eldorado Marsh (6), Pine Island (7), and Collins Marsh (8).

East Central Wisconsin = ▢ that part of the state associated with the interchange of Canada geese with Horicon NWR. It consists of the Horicon area, the Lakes Area, and 2 satellite areas (Grand River and Eldorado).

Study area (Fig. 2) = east central Wisconsin + 2 additional satellite areas, Pine Island and Collins Marsh.

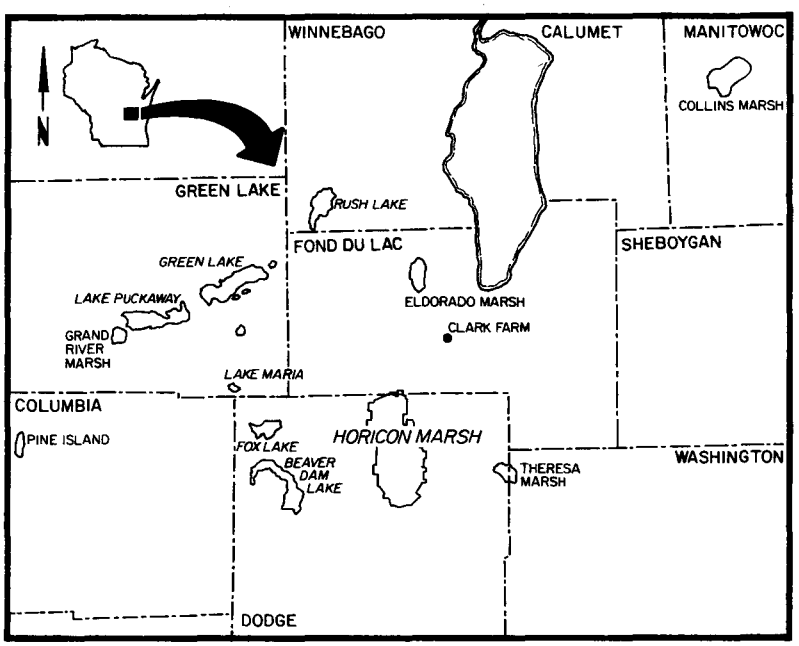


FIGURE 2. *East central Wisconsin study area, showing the 8 units of data analysis.*

METHODS AND MATERIALS

CAPTURE AND MARKING

Data are included in this study from over 15,000 geese neck-banded in Wisconsin and elsewhere in the Mississippi Flyway that were encountered in our study area. Of these, 8,020 were neck-banded at Horicon.

Geese were captured at Horicon NWR and Collins, Pine Island, Grand River, and Eldorado WMA's with rocket nets baited with corn (Dill and Thornsberry 1950). Capture sites at Horicon NWR were distributed around the marsh; however, most of the geese were captured at 2 sites on the east side (Horicon-East) and 1 site on the west side (Horicon-West). From 1975-77, the banding at Horicon NWR was distributed equally between the 2 sides of the marsh and among 3 banding periods—before, during, and after the goose hunting season. From 1978-81, geese became much more difficult to capture, and a larger proportion of the geese were captured at the Horicon-East banding sites. Most geese were captured before and during the hunting season. Banding on state wildlife management areas (WMA) was done in sanctuary areas primarily during the hunting season.

The sex and age of captured geese were determined by criteria described by Hanson (1962). All geese captured from 1975-81 were banded with USFWS legbands and about half of each captured sample were fitted with plastic neckbands during 1975-77 (Craven 1978). From 1978-81, most birds captured were fitted with neckbands. Each neckband bore a unique 4-character code which was legible at up to 500 m to an observer equipped with a 60x spotting scope (Craven 1979).

From 1978-81, a sample of 210 of the captured geese were marked with radio transmitters attached to neckbands as described by Bartelt et al. (1982). Each radio collar transmitted a unique frequency and was color-coded for individual identification. Radio signals were regularly detected from a distance of 2 1/2 miles by a ground-based receiving unit and from a distance of 10 miles by receiving units in aircraft. Radio collars were battery-powered in 1978 and solar-powered in 1979-81. Battery-powered transmitters had a 6-month life expectancy and solar-powered transmitters had a life expectancy of 3 years.

This rocket net yielded a good catch. Catches of up to 300 Canada geese were made but an average catch was less than 100 birds.

OBSERVATIONS OF MARKED GEESE

Neck-banded Geese

A field crew of up to 6 people observed Canada geese wherever geese concentrated in east central Wisconsin. Observations began with the arrival of geese in the fall and terminated with their departure. Observation effort (number of observers and search time) was according to distribution of geese. Observers located geese at least once each week, throughout their assigned segment of east central Wisconsin, but concentrated effort near large aggregations. When flocks were encountered, observers recorded the codes of neck-banded geese and estimated the total number of geese examined during the search for neckbands. They also recorded time and location and described goose associations and activity. A total of 25,157 encounters with neck-banded geese from Horicon NWR were recorded during 1975-81. Encounters were plotted on a square-mile grid and the resultant pattern plots were used as a graphic depiction of the temporal and geographic distribution of geese from a specific banding area.

Radio-marked Geese

Geese equipped with radio collars were located with receivers in mobile units and in aircraft. Up to 5 people were employed each year to locate radio-marked geese on roost sites and in field feeding areas. Observations were conducted 24 hours per day in 1978 and 16 hours per day in 1979-81. Observations began with the arrival of geese in the fall and continued until their departure from Wisconsin. All areas of major goose use except Collins were searched twice per week to determine nighttime roost locations. Collins was searched once per week from aircraft. Other areas were searched once per week from mobile receiving units and once per week from USFWS aircraft. In addition, Horicon and Grand River marshes were searched 5 days per week to detect night roosting patterns within these marshes.

Radio-marked geese roosting at Horicon and Grand River marshes were also followed to field feeding areas. Once a radio-marked goose was detected, the observer recorded the time and location, the frequency of the radio signal, and any goose associations and activity that were observed. Directional bearings from the radio-marked

goose to 2 or more receiver locations were recorded to triangulate the location of the goose. A total of 17,774 encounters with the 210 geese radio-marked in the study area were recorded during 1978-81.

Terminology

We adopted standard band recovery terminology for neckband or radio encounter data. Encounters in the fall of banding are "directs" and encounters in subsequent years are "indirects." We use "fidelity" to describe the strength of the behavior pattern exhibited by a goose or cohort of geese in terms of annual return to a specific satellite area. For several analyses, the sample includes geese marked during the fall under consideration and geese marked in previous years which returned to the area.

AERIAL POPULATION COUNTS

The overall population of geese in east central Wisconsin was counted every year from the air by USFWS personnel. When locating and counting geese, the pilot focused on concentrations of geese rather than scanning the entire area. Counts were made as close to sunrise as possible, before large concentrations of roosting geese dispersed to feed. Surveys were conducted weekly throughout the fall. Because personnel and techniques remained the same from 1975-81, the counts represent useful trends even though biases may exist in the actual numbers.

DATA ANALYSIS

To facilitate the processing of large numbers of observations, the east central Wisconsin area was subdivided into 6 units, which corresponded to areas used as night roosts and the field areas around them (Fig. 2). Horicon Marsh and the surrounding area (Horicon area) was divided into Horicon-West, Horicon-East, and Horicon-South, for research has suggested distinct refuge subflocks associated with banding areas (Raveling 1969*b*, Koerner et al. 1974, and Zicus 1981). Further, Green (1969, 1970, 1971) had done extensive experiments with marked geese around Horicon Marsh and suggested that the marsh be considered as several pieces rather than a whole. However, Green was hindered by a lack of individually identifiable birds. The remaining 3 units were designated as Grand River WMA and its immediate area, the Lakes Area, and Eldorado WMA and its immediate area, as depicted in Figure 2.

Two units, Pine Island WMA and Collins WMA and the surrounding pri-

The neckbands are wrapped around the necks of the geese and fastened with quick drying glue between the layers of the band. No glue was allowed to contact the bird.

A released neck-banded goose is ready to take off.

The neck-banding crew also weighed and measured the geese before releasing them.

One of the planes used by the U.S. Fish and Wildlife Service to conduct aerial goose counts.

vate land used by geese, were outside the contiguous area described as east central Wisconsin, but were included as units for analysis (making a total of 8 units).

The subdivision into 8 units was made on the basis of areas with potential management significance (i.e., lakes, satellite areas, sections of Horicon Marsh), and the assumption that the night roost would be the area most consistently used by geese (Raveling 1966). Although each of these units could support geese independently, their juxtaposition creates continuous goose habitat. The Lakes Area, Grand River WMA, and Eldorado WMA approximate the Central Harvest Management Zone, while the 3 Horicon Marsh units approximate the Horicon Harvest Management Zone.

For the sake of easy reading, the units in this study will be referred to as Horicon, Grand River, Eldorado, Pine Island, Collins, and Lakes Area, unless a particular meaning requires a different label (such as Horicon NWR) (Fig. 2).

MOVEMENT BETWEEN AREAS

Movements between areas were determined for neck-banded or radio-marked geese for which 2 or more encounters were recorded. The mean date (Julian days) between paired encounters of the same goose was used as an estimate of the date of the actual movement. Radio locations used to describe the east-west separation of geese at Horicon Marsh were partitioned based on a north-south line through the center of the marsh. Radio contact was often based on night roost location and a bird roosting west of the line would be depicted as a west side bird even though it might fly out the east side to feed and be very consistent in its patterns. This was not a problem with neckbands since virtually all contact was in fields during the day. Thus neckband and radio telemetry methodologies yield slightly different results for east-west subflock behavior. The distribution of recoveries of leg-banded geese during the hunting season was used to supplement the neckband and radio relocation data.

TIME ALLOCATON AMONG THE STUDY AREAS

The percent of time neck-banded and radio-marked geese spent at each of the 8 areas was calculated for each year. The number of days each individual goose spent in Wisconsin was determined by counting the number of days from its capture or first observation in Wisconsin until the final observation for that bird each year—regardless of where or when that bird had been marked.

If two consecutive observations were on the same area, we assumed the goose was present on that area during all days in the interval of time between the observations. If the observations were on two different areas, 1/2 the number of days in the interval were credited to each area. Marked geese encountered only once contributed 1 day to the area on which they were encountered. The number of days each individual goose was present on an area was summed for all individuals in each year. The percent of time spent on each area was calculated as the total number of days marked geese spent on an area divided by the total days spent on all areas in that year.

All areas were not searched equally for marked geese. To test if this unequal search effort biased the time allocation analysis, only data from days on which all areas were searched were selected from the telemetry data set. The percent of time spent by radio-marked geese on each of the 8 areas was then calculated for this subset of the data with equal sampling. These results from equal sampling were then compared to results of the entire data set. The results of the entire data set were within 7 percentage points of the equal sampling results in all years and for all areas except for geese radio-marked at Grand River WMA in 1979 and 1981. In both of those years the number of geese radio-marked at Grand River and located under the equal sampling scheme was small (7 in 1979, 8 in 1981). The close agreement between the two data sets with different sampling intensities suggest that there was little bias associated with the time allocation analysis.

We suspected that the detection of neck-banded geese was lower on some areas because of differences in topography and land use. Radio-marked geese on the other hand had equal detectability on all areas. The distribution of radio-marked geese agreed closely with the distribution of neck-banded geese. These data suggest that differential detection was not a serious bias.

SEX AND AGE COHORTS

The sex ratio of the annual samples was quite stable (50.7%-57.5% males, $\bar{x}$ = 54.9%), but the age ratio varied from a low of 19.6% immatures in 1977 to a high of 41.1% in 1975 ($\bar{x}$ = 28.3%). The work of Raveling (1969*a*) suggested that the bird's sex was not an important factor in movements. Also, the movement rate for both sexes was virtually identical within all age classes. Thus no analysis was attempted using sex as a variable.

Age, however, may be a factor in movement, especially among members of the unpaired yearling age class. We compared all recognizable age classes—adults, yearlings, and immatures—on the basis of the number of different areas in which individuals of known age were observed within each of the 7 years, 1975-81 (Fig. 3). Adults and immatures behaved in a similar manner ($P > 0.05$) and both groups differed significantly from yearlings ($P < 0.001$) (adults vs. yearlings); ($P < 0.01$) (immatures vs. yearlings). The detected difference makes biological sense but is

very small in absolute numbers (Fig. 3).

We also compared the number of movements per individual and found the same pattern. Adults and immatures were identical and yearlings were slightly higher (0.52 moves/individual for yearlings vs. 0.45 for adults and immatures). The observed pattern was consistent between years. Although the dispersal of yearlings is of significance in Canada goose ecology, we do not feel that the small differences we observed are of management significance in the context of this paper. Because of this, and because yearlings are confounded with adults in the year of banding, age was not considered as a variable in describing movements in this paper. The same patterns and considerations of sex and age factors are assumed in the subsequent discussions of satellite areas.

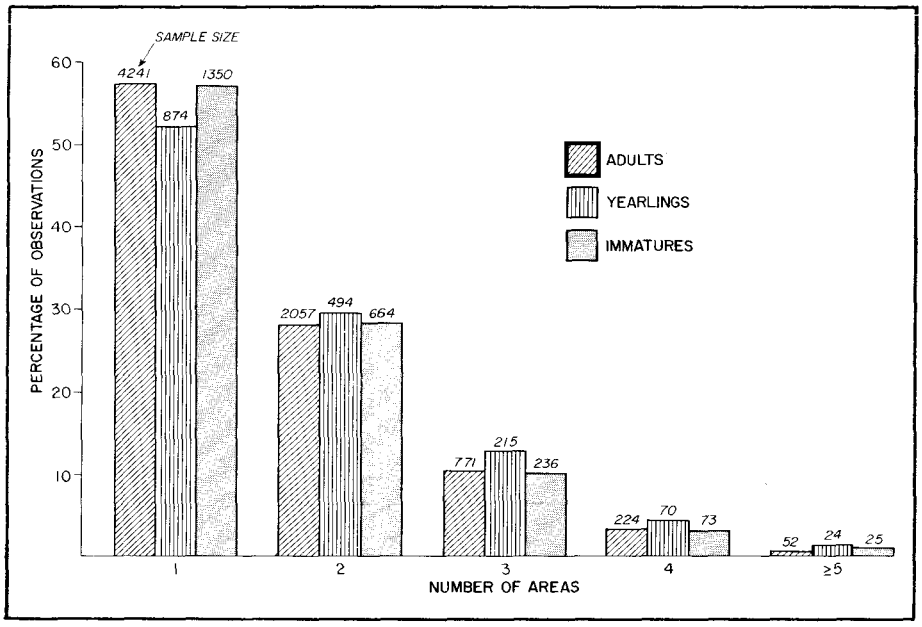


FIGURE 3. *Number of areas in which individual marked geese of different ages were observed within a given year, 1975-81.*

RESULTS

DISTRIBUTION AND MOVEMENT OF GEESE

Horicon National Wildlife Refuge

Although geese are found throughout east central Wisconsin, they concentrate on a series of public lakes, DNR wildlife areas, and Horicon NWR, which provide sanctuary during the hunting season. We neck-banded 8,020 Canada geese at Horicon NWR from 1975-81; 4,187 were neck-banded on Horicon-East and 3,833 on Horicon-West. Similar samples were obtained in each year, except 1978 and 1981 when more geese were marked on the east side. Between 1978 and 1981, 142 geese were marked with radio transmitters; 101 on the east side and 41 on the west side.

Tables 1 and 2 show the number of individual Canada geese neck-banded at Horicon NWR and observed at the various study areas. Tables 3 and 4 show the same data for radio-collared geese.

Fidelity to Areas Within Horicon Marsh. Because the neck-banded geese observed reflected virtually identical proportions of east and west side samples, we feel direct comparisons are possible except as noted (Tables 1, 2). The tendency for birds marked on the east or west side (hereafter called east geese or west geese) to remain on their respective side and return to that banding area in subsequent years is apparent in the number of geese encountered, the total encounters for both neck-banded and radio-marked geese, and the time spent on each area. The radio and neckband data suggest almost identical use patterns in terms of time spent in various areas for both the separate and combined Horicon data (Tables 5, 6). However, as noted, there is some difficulty associated with partitioning geese in either the east or west data for radio telemetry data.

Neckband data suggest that east geese spent about 63.1% of their time within the east area (Horicon-East) while west geese spent about 67.6% of their time in the west area (Horicon-West) (Table 5). These data agree quite well with the distribution of total observations. The mean proportion of total observations of east and west geese in their own area from 1975-81 (shown in Tables 7 and 8) was 72.4% for east birds and 76.3% for west birds. We believe this also supports our contention of similar detectability, at least between these two areas. If the three Horicon areas are pooled, using neckband data, Horicon geese spent 79.6% of their time within the 3 areas (Table 9).

In subsequent years a mean of 38.0% of the original samples marked in the east area were ultimately seen on the east side and 24.6% on the west side (total observations shown in Table 1). For west geese, the figures were 36.6% on the west side and 22.3% on the east side (Table 2). The complement of these percentages represent geese that died in the year of banding, lost neckbands, or were not observed. Of the total Horicon observations, 68.2% (annual range 60-76%) of geese marked in the east area and 65% (annual range 60-76%) of geese marked in the west area were on their own side of the marsh (Tables 7, 8).

The apparent fidelity of these geese to their home area does not mean that they do not move around east central Wisconsin (Table 10). The movement pattern and distribution of observations suggest the importance of the home area, but also demonstrate the number and seasonal variation of movements to other areas (Figs. 4-7). The number of movements per individ-

TABLE 1. *Number of individual Canada geese neck-banded at Horicon-East* and observed at the study areas, 1975-81**.*

Year of Banding	No. Banded	No. Individuals Observed, by Area							
		Grand River	Lakes Area	Horicon-West	Horicon-East	Horicon-South	Eldorado	Pine Island	Collins
1975	711	29/21[a]	93/210	85/204	514/425	127/147	3/18	0/10	0/8
1976	634	22/5	228/62	124/125	338/234	73/54	17/7	6/3	0/15
1977	682	14/7	72/81	141/157	267/210	52/13	13/3	1/7	0/7
1978	840	12/8	70/109	153/231	200/319	2/20	11/1	0/5	0/12
1979	499	5/22	137/80	207/160	288/181	25/18	0/0	10/8	14/4
1980	498	9/11	62/63	144/80	267/127	16/5	0/0	0/4	0/2
1981	323	13/-	52/-	72/-	148/-	3/-	0/-	2/-	0/-

* The east side of Horicon National Wildlife Refuge.
** Does not include duplicate observations of one goose. See Table 7 for total number of observations.
[a] Upper figure indicates number of geese observed in the year of banding (direct); lower figure indicates number of geese observed in subsequent years through 1981 (indirect).

TABLE 2. *Number of individual Canada geese neck-banded at Horicon-West* and observed at the study areas, 1975-81**.*

Year of Banding	No. Banded	No. Individuals Observed, by Area							
		Grand River	Lakes Area	Horicon-West	Horicon-East	Horicon-South	Eldorado	Pine Island	Collins
1975	788	145/41[a]	345/377	287/403	72/239	11/24	7/33	2/8	0/8
1976	760	64/11	447/95	343/276	133/169	9/24	20/22	4/10	2/6
1977	515	10/9	93/58	200/149	91/93	19/13	13/3	1/9	4/2
1978	97	1/2	15/13	22/30	11/24	1/2	0/0	0/1	0/1
1979	500	13/28	206/78	276/193	120/122	20/13	0/0	8/10	2/4
1980	490	11/13	141/178	273/161	92/73	17/7	0/0	1/3	1/1
1981	683	45/-	203/-	341/-	103/-	6/-	0/-	3/-	0/-

* The west side of Horicon National Wildlife Refuge.
** Does not include duplicate observations of one goose. See Table 8 for total number of observations.
[a] Upper figure indicates number of observations in the year of banding (direct); lower figure indicates number of observations in subsequent years through 1981 (indirect).

TABLE 3. *Number of individual Canada geese radio-marked at Horicon-East* and located at the study areas, 1978-81.*

Year of Radio-Marking	No. Marked	No. Individuals Located, by Area**					
		Grand River	Lakes Area	Horicon-West	Horicon-East	Horicon-South	Eldorado
1978	15	3/10[a]	4/1	10/2	14/2	3/1	1/0
1979	27	3/8	5/4	18/6	25/7	3/1	1/0
1980	32	4/6	7/8	8/10	26/10	0/2	0/0
1981	27	8/-	6/-	14/-	22/-	3/-	0/-

* The east side of Horicon National Wildlife Refuge.
** One goose radio-collared in 1979 was located at Collins Marsh Wildlife Management Area and 2 in 1981. One was located at Pine Island Wildlife Management Area in 1979 and 1 in 1980.
[a] Locations in year of marking/locations in all subsequent years.

TABLE 4. *Number of individual Canada geese radio-marked at Horicon-West* and located at the study areas, 1978-81.*

Year of Radio-Marking	No. Marked	No. Individuals Located, by Area**					
		Grand River	Lakes Area	Horicon-West	Horicon-East	Horicon-South	Eldorado
1978	14	1/0[a]	2/0	13/1	11/0	1/0	1/0
1979	6	3/3	4/6	6/6	5/5	2/0	1/1
1980	14	6/5	10/5	11/8	9/5	2/2	0/0
1981	7	3/-	3/-	6/-	4/-	2/-	0/-

* The west side of Horicon National Wildlife Refuge.
** One goose was located at the Pine Island Wildlife Management Area in 1979 and 1 in 1981.
[a] Locations in year of marking/locations in all subsequent years.

TABLE 5. *Comparison of percent of time spent at each study area by Canada geese marked at Horicon-East vs. those marked at Horicon, 1978-81.**

Area Where Marked	Marking Technique	Area of Use: Horicon-East	Eldorado	Horicon-South	Horicon-West	Lakes Area	Grand River	Collins	Pine Island
Horicon-East	Neck-banded	63.1	0.1	0.9	20.7	12.2	2.2	0.4	0.4
	Radio-marked	60.6	0.3	1.6	20.6	12.7	3.5	<0.1	0
Horicon-West	Neck-banded	9.8	0.1	1.2	67.6	18.9	1.9	0.3	0.3
	Radio-marked	21.0	0.2	3.4	48.4	17.0	9.2	0	0.3

* Horicon-East = the east side of Horicon National Wildlife Refuge;
Horicon-West = the west side of Horicon National Wildlife Refuge.

TABLE 6. *Comparison of percent of time spent at each study area by Canada geese marked at Horicon vs. those marked at Grand River, 1978-81.**

Area Banded	Technique	Area of Use: Horicon	Eldorado	Lakes Area	Grand River	Collins	Pine Island
Horicon	Neck-banded	82.5	0.1	15.1	1.6	0.4	0.4
	Radio-marked	83.0	0.3	11.8	4.7	0.2	0.1
Grand River	Neck-banded	31.1	0	21.2	46.5	0	0.2
	Radio-marked	36.6	0.5	25.1	37.8	0	0.1

* Horicon = Horicon National Wildlife Refuge;
Grand River = Grand River Wildlife Management Area.

TABLE 7. *Total number of observations of Canada geese neck-banded at Horicon-East* and observed at the study areas, 1975-81.***

Year of Banding	No. Observations, by Area: Grand River	Lakes Area	Horicon-West	Horicon-East	Horicon-South	Eldorado	Pine Island	Collins
1975	43/21[a]	134/299	103/307	1,304/977	205/53	3/19	0/18	0/9
1976	22/5	385/68	174/180	681/434	88/69	19/7	8/5	0/27
1977	15/7	81/92	188/242	381/372	64/17	13/3	1/9	0/8
1978	12/8	75/135	191/257	241/693	2/29	11/1	0/6	0/12
1979	5/24	208/95	323/272	605/406	37/24	0/0	13/21	19/8
1980	9/12	79/75	232/121	574/262	24/5	0/0	0/8	0/2
1981	13/-	71/-	98/-	288/-	3/-	0/-	5/-	0/-

* The east side of Horicon National Wildlife Refuge.
** Includes duplicate observations of individual geese. See Table 1 for data on individual observations.
[a] Upper figure indicates number of observations in the year of banding (direct); lower figure indicates number of observations in subsequent years through 1981 (indirect).

TABLE 8. *Total number of observations of Canada geese neck-banded at Horicon-West* and observed at the study areas, 1975-81.***

Year of Banding	No. Observations, by Area: Grand River	Lakes Area	Horicon-West	Horicon-East	Horicon-South	Eldorado	Pine Island	Collins
1975	198/43[a]	534/558	497/735	102/399	13/28	7/37	5/12	0/11
1976	69/11	810/103	612/490	199/242	14/38	24/27	6/13	8/11
1977	10/10	105/74	322/267	116/135	24/30	14/3	1/12	6/2
1978	1/2	19/17	29/59	13/51	1/3	0/0	0/2	0/2
1979	14/30	305/103	574/370	190/198	33/18	0/0	19/14	2/7
1980	12/15	180/95	529/325	140/120	21/8	0/0	2/6	2/1
1981	48/-	272/-	640/-	137/-	7/-	0/-	7/-	0/-

* The west side of Horicon National Wildlife Refuge.
** Includes duplicate observations of individual geese. See Table 2 for data on individual observations.
[a] Upper figure indicates number of observations in the year of banding (direct); lower figure indicates number of observations in subsequent years through 1981 (indirect).

TABLE 9. *Average percentage of time neck-banded Canada geese from various banding areas spent on each study area, 1975-81.*

Area Banded	Area of Use: Horicon	Eldorado	Lakes Area	Grand River	Collins	Pine Island
Horicon	79.6	0.4	17.1	2.2	0.3	0.3
Eldorado*	20.7	59.9	15.5	0.4	3.2	0.1
Grand River	23.7	2.4	24.5	48.2	0.5	1.2
Collins Marsh	7.4	0.2	10.8	0.7	80.8	0.2
Pine Island	8.4	0.1	20.1	2.4	0.1	69.0

* Data for Eldorado available only for 1975-79.

TABLE 10. *Percent of time spent on each area by geese marked at Horicon National Wildlife Refuge, 1975-81.*

Year	Horicon	Eldorado	Lakes Area	Grand River	Collins	Pine Island
1975	76.5	0.6	17.5	5.2	0.0	0.2
1976	65.9	1.1	29.7	2.9	0.1	0.3
1977	85.3	1.1	11.9	0.9	0.3	0.4
1978	86.0/94.7*	0.3/0.7	11.4/3.5	1.5/1.0	0.7/0	0.0/0
1979	79.9/84.5	0/0.6	18.4/11.4	0.2/3.6	0.6/0	0.7/0
1980	86.7/76.5	0.03/0.1	12.0/15.9	1.2/7.5	0.01/0	0.1/0
1981	77.2/76.3	0/0	18.5/16.2	3.5/6.6	0.2/0.6	0.6/0.2

* Neckband data/radio data.

ual as determined by radio telemetry suggests that most geese make less than 2 movements between areas each fall (Table 11).

Use of Lakes Area. In the case of Horicon geese (geese marked at Horicon NWR), the Lakes Area is very important to geese from both sides of the marsh, but more so to west geese. East geese spent an average of 12.5% of their time in the Lakes Area compared with 18% for west geese (Table 5). The same pattern is apparent in the number of observations (Tables 7, 8). The proportion of individuals seen in the Lakes Area in the year of banding (directs) varied from 15-59% ($\bar{x}$ = 33.7%) for west geese and from 8-36% ($\bar{x}$ = 17.5%) for east geese (Tables 1, 2). Indirect observation rates for geese from the east or west side in the Lakes Area were not different ($P > 0.05$).

Greatest use of the Lakes Area was in 1976 when a water level drawdown was attempted at Horicon NWR. Variation in use in other years was probably related to temperature and snow depth, which determines how late in the season the lakes and nearby food are available to the geese (Table 12). Decreased use in 1977 was related to heavy snowfall and was reflected in the early mean departure dates reported by Craven (1978). Movement to the lakes typically occurs in late November prompted by the freeze-up of Horicon Marsh. The seasonal change in distribution was evident in the pattern of observations for west geese in October vs. December (Figs. 6, 7) after the shift to the lakes occurred.

TABLE 11. *Average number of detected movements between areas per marked Canada goose, 1978-81.*

Year	Neck-banded Geese	Radio-marked Geese
1978	0.12	0.73
1979	0.37	1.23
1980	0.23	1.74
1981	0.26	1.57

Use of Satellite Areas. There was little use of any of the four satellite areas by Horicon geese based on the time budget (Tables 5, 6, 9). Use of Eldorado, Collins, and Pine Island was very low, while use of Grand River was somewhat higher—about 2% based on neckbands and 3.5-9% based on radios. Because of the superior detection of radio-marked geese at Grand River, we believe the 9.2% figure for Horicon-West, or a Horicon combined average of 6.3%, to be the best estimates of use of Grand River by Horicon geese. Unfortunately, no radio-marked geese were available in the early years of the study when drawdowns, intensive hazing at Horicon NWR, and high goose populations at Grand River occurred. Radio telemetry data in 1978-81 suggest that geese from Horicon which move to Grand River do so in late October or early November and remain there. Given the low rate of movement per individual (about 1.5, Table 11), the November shift to the lakes and some movement across the marsh or to Grand River account for virtually all the movement that occurs.

There is no evidence to suggest that geese in general move freely and repeatedly between areas within a given fall. However, some individual geese made as many as 12 shifts between areas. In all 3 years (1979-81), east geese shifted to Grand River about 1 week later than west birds based on the mean date of movement of radio-marked geese.

Horicon-South includes the DNR-managed Horicon WMA and adjacent private lands. Based on observations of neckbands (Tables 1, 2) it appears that Horicon-East geese are more closely associated with Horicon-South than are Horicon-West geese. Over the 7 years, 298 individual east geese were observed there compared to only 83 west geese. However, the radio telemetry data suggest that there was about twice as much time spent in Horicon-South for west vs. east geese (3.4% vs. 1.6%) (Table 5). The difference can be explained by the difference in the two techniques. Neck-banded geese could only be observed in limited field areas southeast of the Horicon WMA; areas used by geese flying out from the east side of Horicon NWR. Radio-marked geese were located on night roost sites within and near the marsh and provide a more accurate estimate of actual use. Both sets of data demonstrate that there is little goose use of the Horicon-South area. Most of the marsh contained in Horicon-South is a public hunting ground which receives greater hunting pressure than the surrounding private lands. Also, feeding areas were limited within Horicon-South.

Movements of Horicon geese to both Pine Island and Collins were detected within the year of banding and in subsequent years (Tables 1, 2, 3, 4). However, there were only 7 radio-marked geese at either area—1 at Pine Island in 1980 and 1981 and 2 in 1979; 2 at Collins in 1981 and 1 in 1979. Movements of both east and west geese to both areas were infrequent. An apparent peak in movements in 1979 cannot be explained, except as it may be related to intensive disturbance at both Horicon and Grand River caused by an avian cholera abatement program. In the year of banding, from 0-10 east geese (none in 3 years) were observed at Pine Island. No east geese were seen at Collins Marsh except the 14 seen in 1979. For west geese, 0-8 were seen at Pine Island and 0-4 at Collins (none in 3 years) (Tables 1, 2). Apparently, less than 1% of the east and west samples made direct movements to either area in most years. In subsequent years, means of 4-8 individuals from either side of Horicon were ultimately observed at Pine Island or Collins.

Hunting Recoveries. Hunting recoveries occurred in patterns similar to

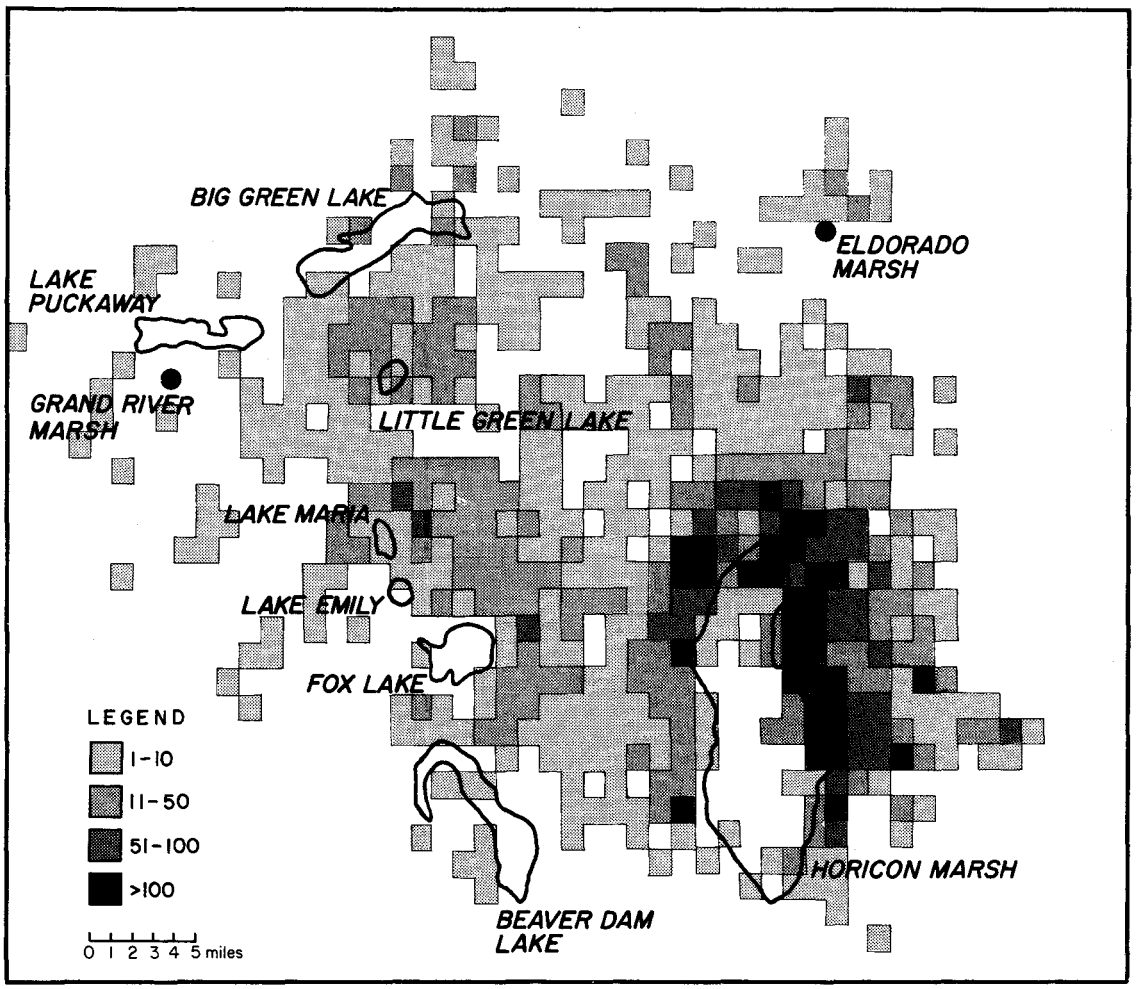


FIGURE 4. *Distribution of observations of Canada geese neck-banded on the east side of Horicon National Wildlife Refuge, 1975-81.*

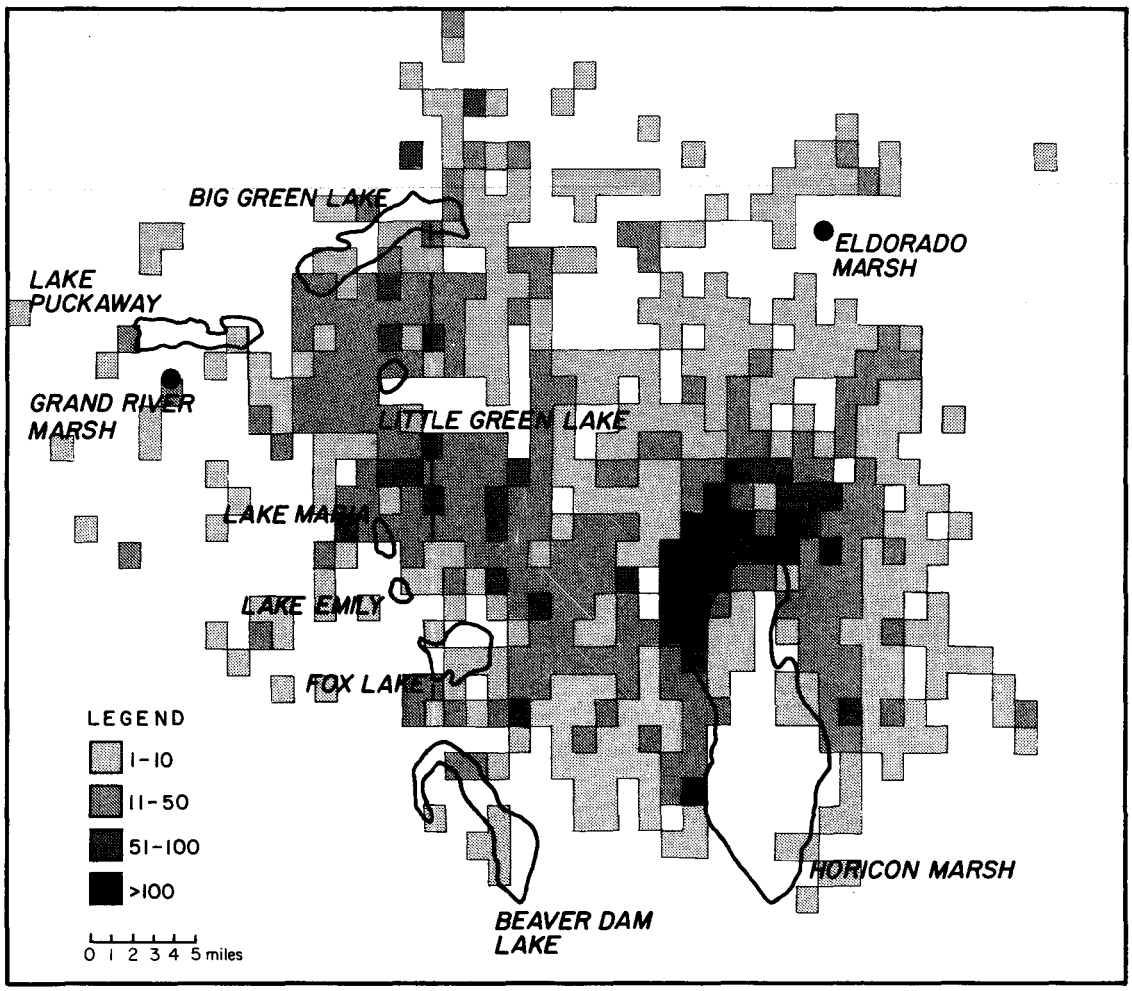


FIGURE 5. *Distribution of observations of Canada geese neck-banded on the west side of Horicon National Wildlife Refuge, 1975-81.*

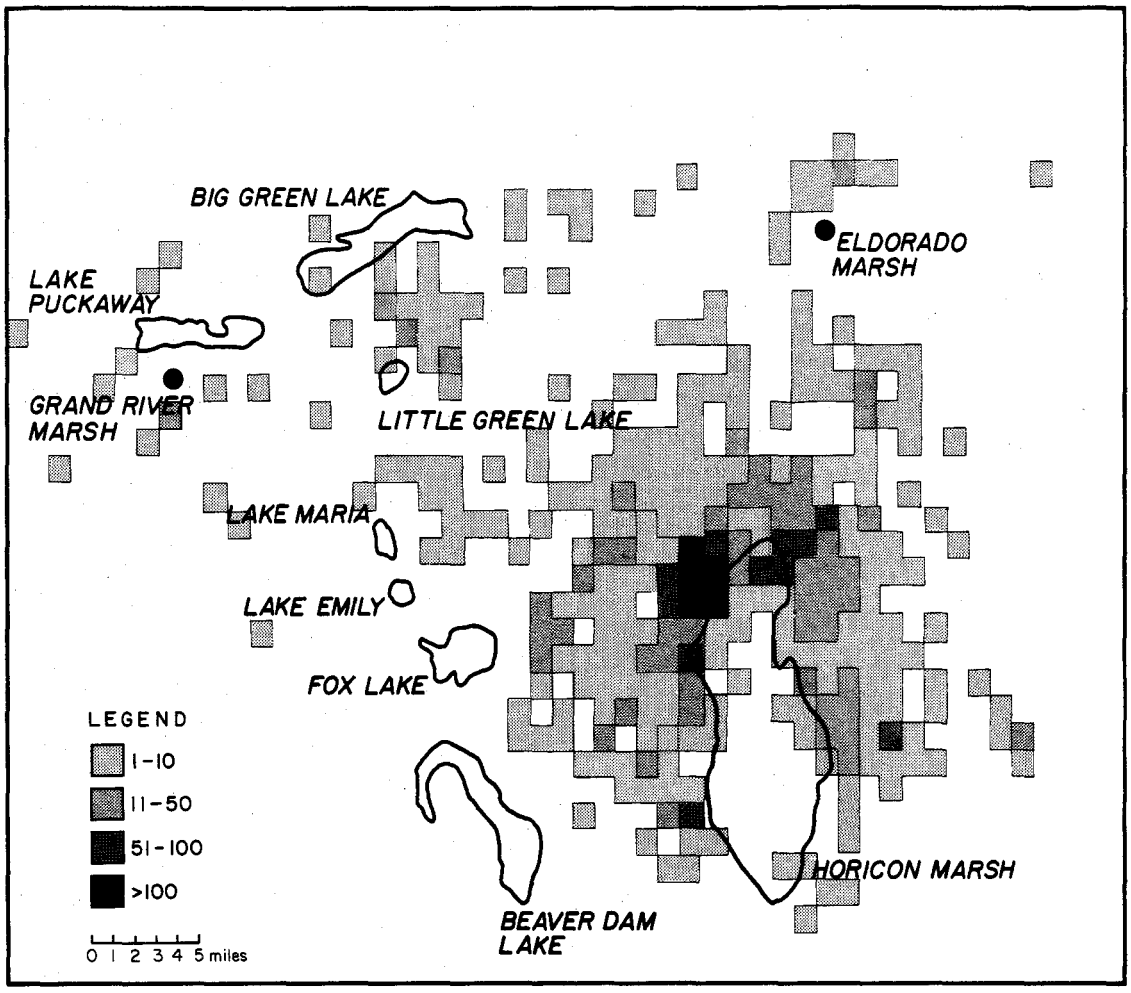


FIGURE 6. *Distribution of observations of Canada geese neck-banded on the west side of Horicon National Wildlife Refuge, October 1975-81.*

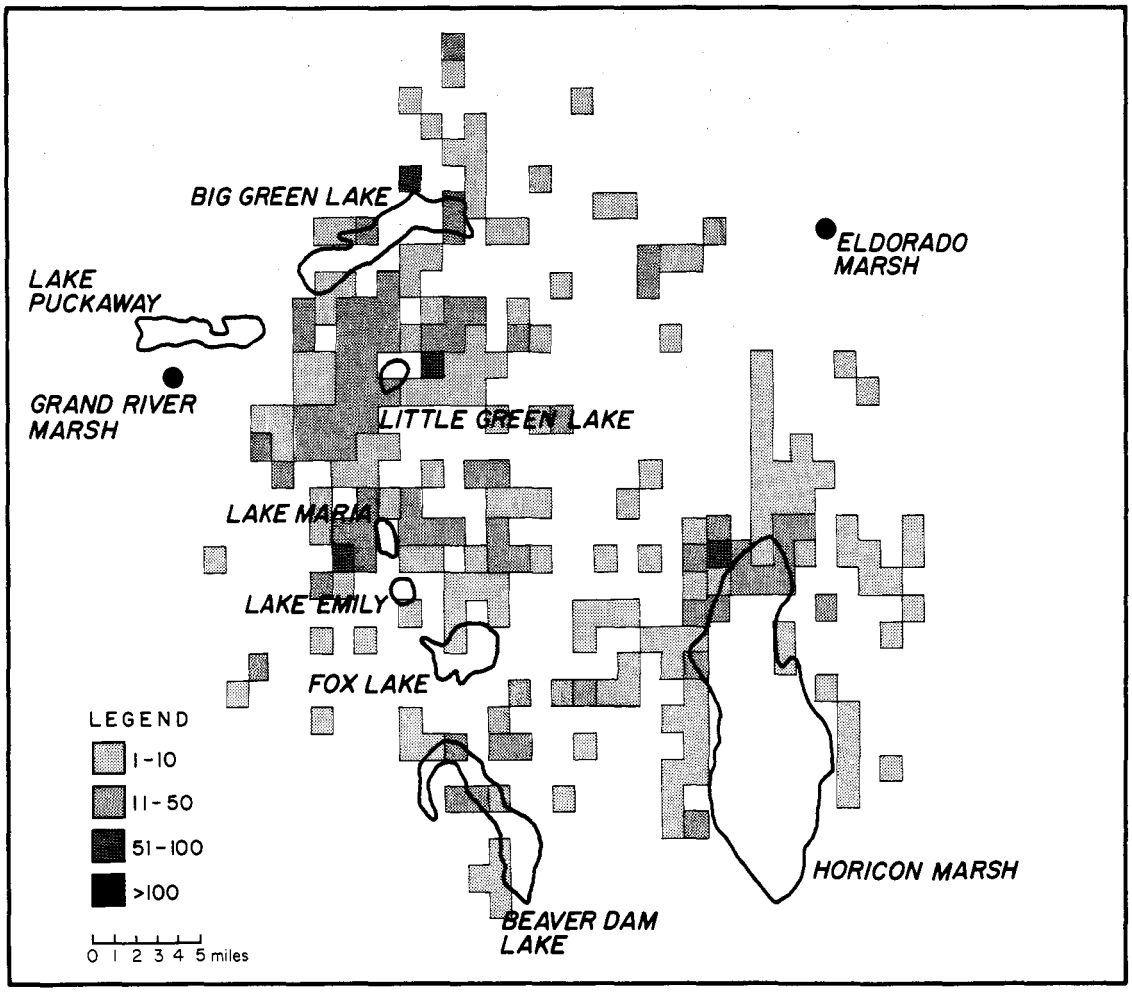


FIGURE 7. *Distribution of observations of Canada geese neck-banded on the west side of Horicon National Wildlife Refuge, December 1975-81.*

TABLE 12. *Monthly weather statistics for Horicon, Wisconsin, 1975-81.*

Year	Month	Average Daily Temperature (F) High	Low	Total Precipitation (inches) Rain	Snow	General Characteristic
1975	Sep	73	42	1.35	—	
	Oct	67	38	0.81	—	Normal
	Nov	47	28	2.78	5.17	
	Dec	29	15	0.36	8.50	
1976	Sep	73	46	0.39	—	
	Oct	56	33	1.47	—	Normal-Severe
	Nov	39	18	—	2.25	
	Dec	23	1	—	6.50	
1977	Sep	70	54	4.31	—	
	Oct	60	39	1.46	—	Severe
	Nov	45	27	2.09	11.0	
	Dec	31	15	2.11	27.0	
1978	Sep	78	55	8.31	—	
	Oct	60	38	1.20	—	Severe
	Nov	46	27	2.17	6.00	
	Dec	30	13	—	27.50	
1979	Sep	77	49	0.19	—	
	Oct	57	38	2.83	—	Mild
	Nov	43	27	1.60	3.50	
	Dec	38	21	1.84	1.00	
1980	Sep	73	51	8.08	—	
	Oct	57	37	1.32	—	Normal-Mild
	Nov	43	28	1.31	0.50	
	Dec	30	15	0.92	9.50	
1981	Sep	70	48	3.48	—	
	Oct	57	37	2.77	—	Normal
	Nov	46	28	1.54	0.50	
	Dec	31	12	0.67	9.50	

* Statistics were recorded on all weekdays and some weekends by the staff of the Wisconsin Department of Natural Resources office at Horicon.

those detected in neckband and radio encounters (Figs. 8, 9). However, the distribution of hunting recoveries must be viewed with some caution. Because many hunters perceive anything near Horicon NWR as "Horicon", some recoveries are reported to the USFWS as simply "shot at Horicon." Given no other information, this recovery is coded with the coordinates of the town of Horicon which is in the southeast block of the four 10-minute blocks which surround Horicon Marsh. Thus this block has an unrealistically high number of recoveries. Recovery data for Horicon geese from that 10-minute block are not included in the analysis.

Direct recoveries for birds from both sides of Horicon Marsh were distinctly concentrated in east central Wisconsin; 214 of 221 (93%) for east geese and 79 of 86 (92%) for west geese. More geese were recovered out of east central Wisconsin in subsequent years; 13% of east geese and 12% of west geese. Omitting the southeast 10-minute block confuses the east-west separation of recoveries. However, even without it, 67% (103 of 154) of east direct recoveries and 46% (61 of 133) of east indirect recoveries were from Horicon-East. For west geese, 93% of the direct recoveries and 53% of the indirect recoveries were from Horicon-West, Grand River, or the Lakes Area. A surprisingly large number of indirect recoveries were reported from the northeast quarter of the Horicon NWR area. However, this may reflect some inaccurate reporting by hunters and subsequent coding within the 10-minute block associated with Horicon NWR. Of the satellite areas, most hunting recoveries of Horicon geese came from Grand River (Figs. 8, 9).

Grand River Wildlife Management Area

The Grand River Wildlife Management Area is located in Green Lake and Marquette counties about 28 miles WNW of Horicon Marsh. At 6,950 acres, with 2,140 acres of water, it is the largest of the four primary satellite areas we examined both in overall size and amount of water. During 1975-81, 1,604 geese were neck-banded and during 1979-81, 56 geese were radio-marked at Grand River WMA (Tables 13, 14).

The goose population at Grand River varied more during the course of the management program than any other area (Fig. 10). Peak populations of 40,000+ in 1977 and 1978 represented all-time record levels. Grand River was located in the direction taken by many geese leaving Horicon Marsh to feed and it provided substantial water and sanctuary. Thus, increased use at Grand River was more likely than at other areas.

Use of Horicon and Grand River. Geese marked at Grand River were encountered throughout east central Wisconsin (Table 13, Fig. 11). Because neck-banded geese at Grand River were difficult to observe, interpretation of the number of neck-banded geese seen at other areas relative to their use of Grand River was difficult. We therefore relied primarily on radio telemetry data to describe the distribution of Grand River geese (Table 14).

The percent of time spent on various areas suggests a tendency of geese to remain at Grand River even though some marked geese were encountered regularly in other areas (Tables 6, 9). Grand River geese typically divided their time between Grand River (48%), the Lakes Area (24.5%), and Horicon (23.7%). Based on neckband data, Grand River geese spent only about 25% as much time in Horicon-East as Horicon-West (4.7% $\pm$ 3.7 vs. 18.8% $\pm$ 15.5). This finding is consistent with the location of the two areas relative to Grand River. The radio telemetry data did not show an east-west difference in use because of the difficulty in partitioning geese to one side or the other, as noted in the Horicon data. Based on the dates when radio-marked geese moved, movements to Horicon tended to occur in late October or early November; about one week earlier to Horicon-West than Horicon-East.

Use of Other Areas. The importance of the Lakes Area to Grand River geese is demonstrated in the time spent there and in the distribution of encounters. The high use of the Lakes Area coupled with the low frequency of movement suggests that individual geese did not make more than 1 or 2 shifts in area during the fall (Tables 6, 9, 11, 13). Movements from Grand River to the lakes occurred from 11 November to 9 December, consistent with late fall use of the Lakes Area. Lakes use was well above mean annual use in 1976 during the drawdown at Horicon (46.3% vs. 24.5%) and again in 1981.

Because few Grand River geese moved to Eldorado or Collins, very little use of these areas was apparent in the time budget (Table 6). In seven years, there were only 2 documented movements of neck-banded geese to Collins and 10 to Eldorado. However, there were more movements of geese from Grand River to Pine Island. From 0-30 individual geese were identified at Pine Island each year (Table 13). Movements to Pine Island occurred between 8 October and 27 October. The lack of observations in 1978 reflected

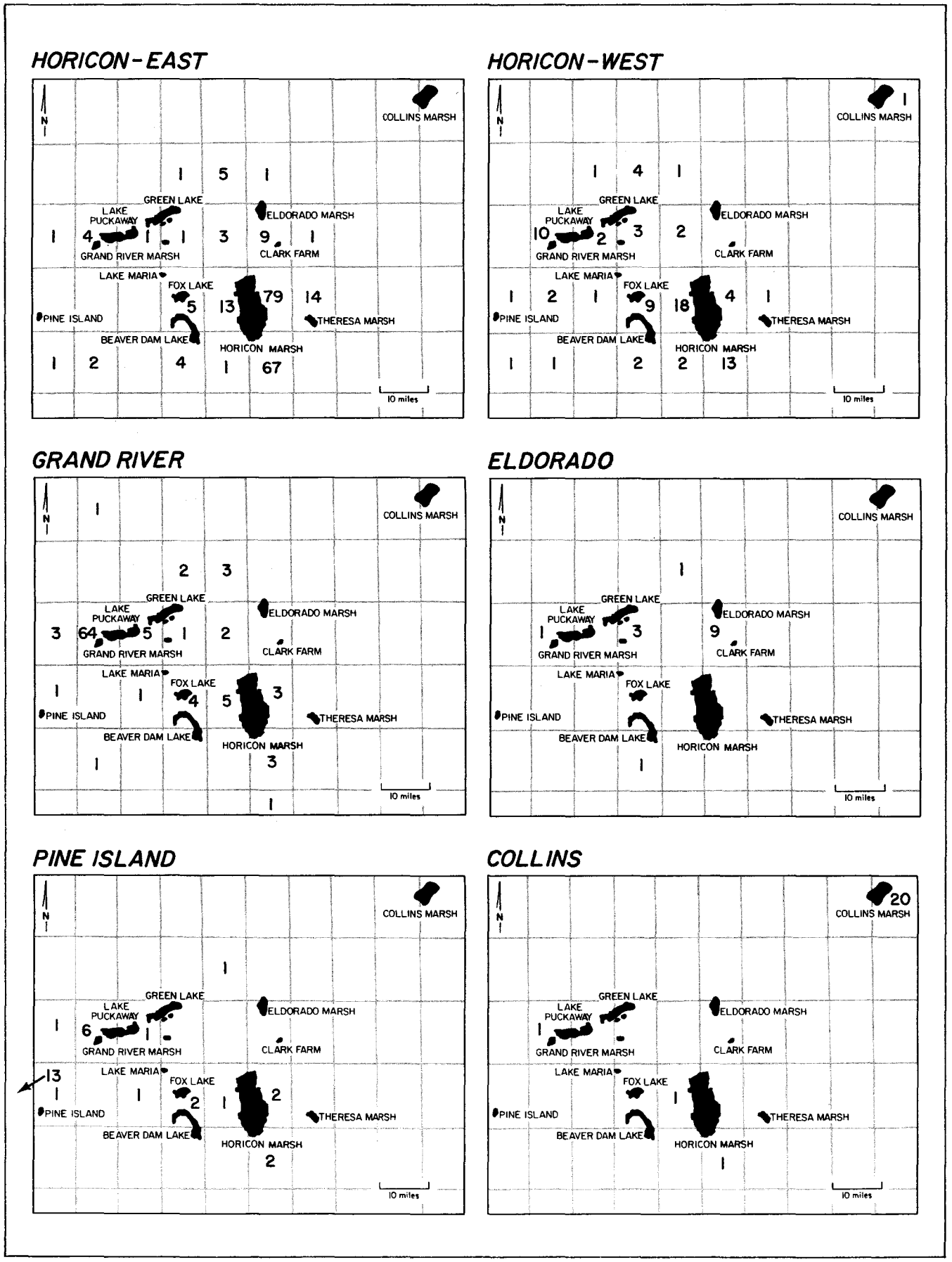


FIGURE 8. *Distribution of direct band recoveries.**

*The number of outliers not shown on these maps are as follows: Horicon-East (7), Horicon-West (7), Grand River (9), Eldorado (2), Pine Island (3), and Collins (2).

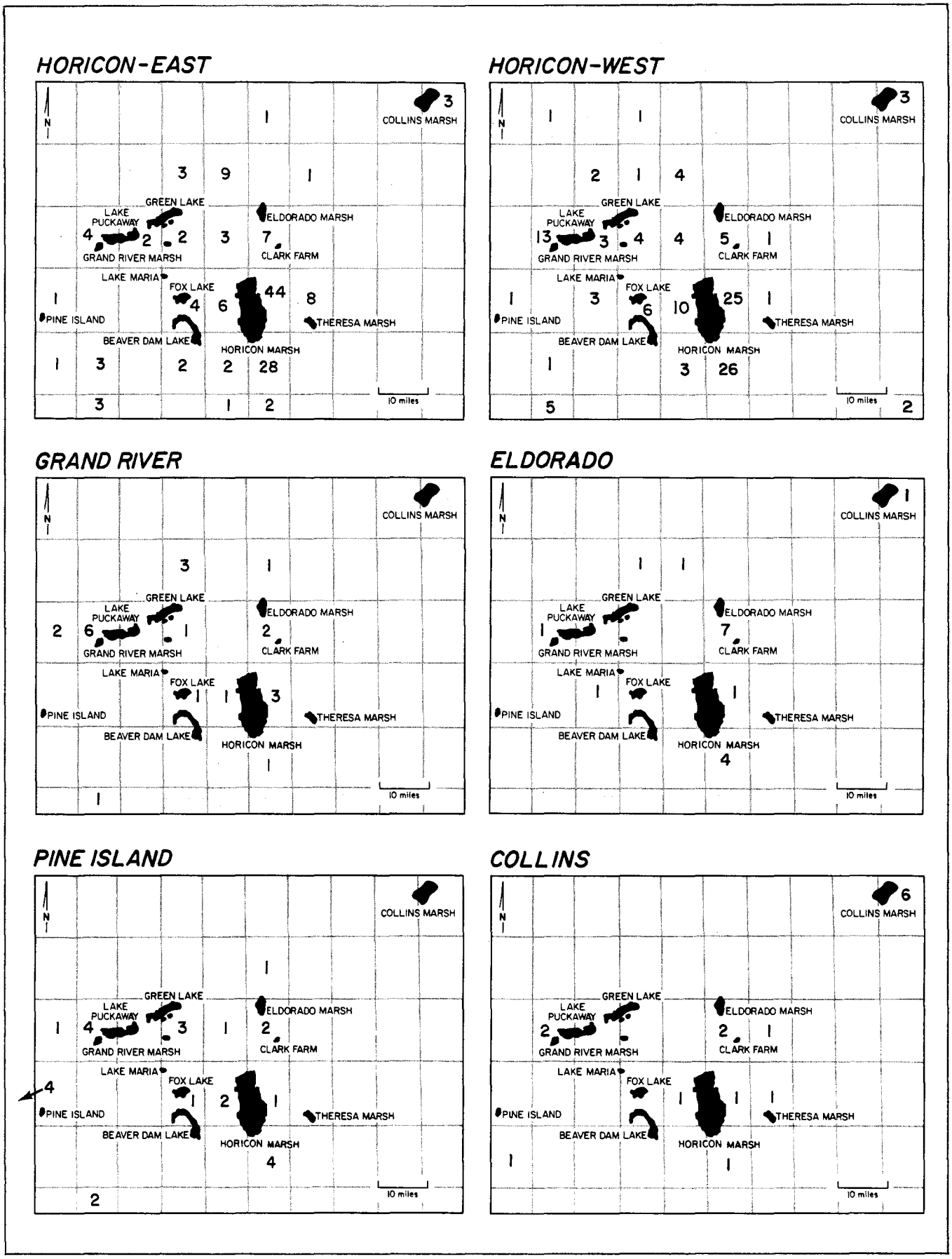


FIGURE 9. *Distribution of indirect band recoveries.**

*The number of outliers not shown on these maps are as follows: Horicon-East (21), Horicon-West (17), Grand River (4), Eldorado (1), and Pine Island (7).

TABLE 13. *Number of individual Canada geese neck-banded at Grand River Wildlife Management Area and observed at the study areas, 1975-81.*

Year of Banding	No. Banded	No. Individuals Observed, by Area							
		Grand River	Lakes Area	Horicon-West	Horicon-East	Horicon-South	Eldorado	Pine Island	Collins
1975	100	10/10*	20/22	18/19	13/13	0/2	0/3	2/7	0/1
1976	99	18/4	44/5	30/21	9/8	0/3	1/0	10/6	1/0
1977	97	10/2	14/5	11/15	4/10	3/0	3/0	3/3	0/0
1978	290	8/5	36/59	42/62	21/73	2/5	6/0	0/8	1/5
1979	246	4/9	73/31	62/38	29/31	5/7	0/0	30/12	0/2
1980	349	83/16	63/40	54/40	46/19	9/4	0/0	13/9	0/1
1981	423	31/-	107/-	77/-	30/-	1/-	0/-	17/-	0/-

* Upper figure indicates number of geese observed in the year of banding (direct); lower figure indicates number of geese observed in subsequent years through 1981 (indirect).

TABLE 14. *Number of individual Canada geese radio-marked at Grand River Wildlife Management Area and located at the study areas, 1978-81.*

Year of Radio-Marking	No. Marked	No. Individuals Located, by Area*					
		Grand River	Lakes Area	Horicon-West	Horicon-East	Horicon-South	Eldorado
1978	0	-	-	-	-	-	-
1979	12	9/5**	5/5	6/5	6/6	0/2	0/0
1980	23	13/8	13/9	11/10	8/7	2/1	1/0
1981	21	18/-	13/-	12/-	10/-	3/-	0/-

* Three geese were located at Pine Island Wildlife Management Area in 1981 and 1 in 1980.

** Locations in year of marking/locations in all subsequent years.

the absence of an observer at Pine Island. The large number of individuals (30) seen at Pine Island in 1979 may be related to the large amount of disturbance present at Grand River as a result of the avian cholera abatement efforts in 1979. Three radio-marked geese were located at Pine Island in 1981 and 1 in 1980 (Table 14).

Hunting Recoveries. The distribution of hunting recoveries supported the pattern of radio-marked and neck-banded goose observations (Figs. 8, 9). The distribution of time spent between Grand River and Horicon correlates well with the observed pattern of direct recoveries; 72 of 109 (66%) direct recoveries were in the immediate Grand River-Puckaway area and the geese spent about 50% of their time at Grand River. Only 11 (10%) were reported from Horicon, and the rest were scattered in the Lakes Area where most goose use occurs after the hunting season. Indirect recoveries did suggest a return to Grand River (8 of 26, 31%); however, the proportion of indirects at Horicon nearly doubled to 19% of the total.

Eldorado Wildlife Management Area

The Eldorado Wildlife Management Area consists of 6,050 acres, including 1,550 acres of water in Fond du Lac County about 12 miles north of Horicon Marsh. Goose use occurs primarily in a 1,060-acre closed area on the north end of the property. Because of its proximity to Horicon, the areas used by geese from Eldorado and Horicon overlap. Geese observed leaving Eldorado to feed typically moved west and southwest into the Rosendale-Brandon-Ripon area—part of the area designated Horicon-West.

In 1975, 1976, and 1978, 294 geese were captured and neck-banded at Eldorado (Table 15). No geese were radio-marked at Eldorado. In 1979, an avian cholera outbreak at Eldorado led to intense disturbance and hazing activity. In 1980, the water levels were reduced to avoid further problems with cholera. Low water and disturbance resulted in low goose use. As with the other satellite areas, Eldorado geese eventually turned up throughout east central Wisconsin (Table 15, Fig. 12).

Use of Other Areas. Horicon area was very important to Eldorado geese; however, most of the observed exchange probably occurred in fields northwest of Horicon Marsh rather than on the marsh itself. Most of the direct observations were associated with Horicon-West and the Lakes Area (Table 15). Eldorado geese spent 59.9% of their time at Eldorado and 20.7% at Horicon (Table 9). Their pattern of use of the Lakes Area was very similar to that of Horicon geese in timing and extent (15.5% vs. 17.1%).

The geese marked in 1975 appeared to be the most faithful to the Eldorado area. Thirty-three of the original 100 (33%) were identified at Eldorado in subsequent years. As noted, overall use of Eldorado declined in 1979-81 because of disease, disturbance, and lack of food. Thus there was diminished opportunity for samples banded in 1976, and especially 1978, to return to the area.

Observations of Eldorado geese demonstrate substantial use of the Lakes Area, Grand River, and Horicon (Fig. 12). In 1976, 52% of the Eldorado sample was identified in the Lakes Area. The mean date for the movement of geese to the lakes was 8 November ($\pm$5.3 days). There were no direct movements to Pine Island or Collins, although 2-5 individuals were identified at each area in subsequent years.

Hunting Recoveries. Hunting recoveries were primarily from the Eldorado area in the year of banding—9 of 17 (53%, Fig. 8). An additional 29% (5 of 17) were scattered throughout the Lakes Area. As indirects, 39% of the recoveries (7 of 18, Fig. 9) were in the Eldorado area and 28% (5 of 18) were reported around Horicon Marsh.

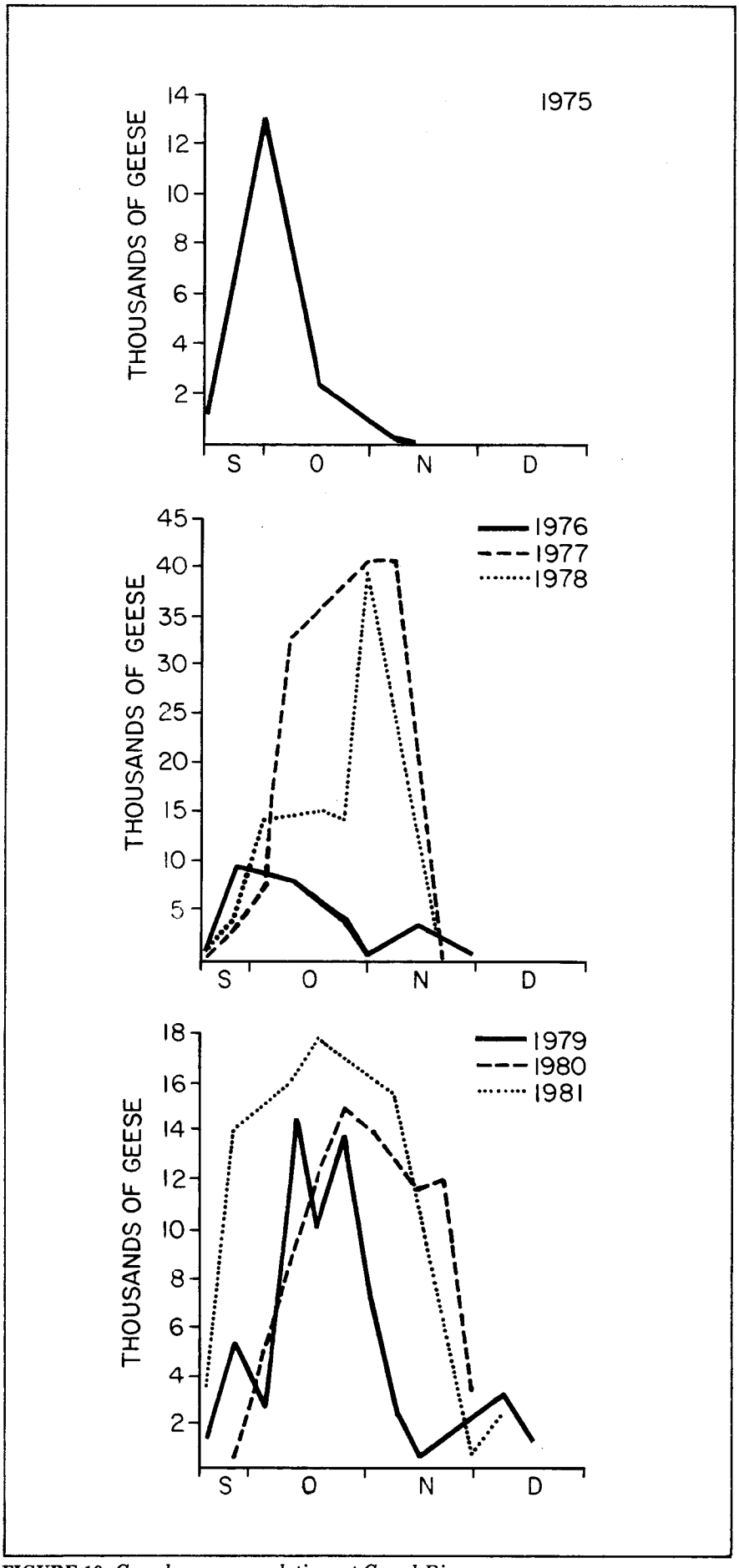


FIGURE 10. *Canada goose populations at Grand River Wildlife Management Area, 1975-81.*

Pine Island Wildlife Management Area

The Pine Island Wildlife Management Area is located along the south bank of the Wisconsin River in Columbia and Sauk counties about 40 miles west of Horicon NWR. Pine Island covers just under 5,000 acres, with only 100 acres of water on the property. From 1975-81, 967 geese were neck-banded at Pine Island (Table 16). No radios were used.

Pine Island was far enough from Horicon Marsh to avoid the large population increases experienced by other satellite areas (except Collins) during the intensive hazing years, 1976-78. In fact, Pine Island experienced below normal populations for those 3 years (Fig. 13). The low populations reflected declining goose use throughout east central Wisconsin (Fig. 14) and increased harvest pressure as quotas were increased. During 1979-81, and particularly in 1980 and 1981, peak populations returned to pre-management program levels.

Fidelity of Geese to Pine Island. The proportion of Pine Island samples of neck-banded geese re-observed at Pine Island in subsequent years compared to other areas did not vary significantly between years and averaged 21% ($P > 0.05$). Even though the fall peak populations at Pine Island represented only about 5% or less of the fall peak population in east central Wisconsin, the tendency for Pine Island geese to return to the area in subsequent years was supported by their on-site re-observation rates relative to those of Horicon geese (Figs. 13, 14). In years after banding, means of 4-8 individuals from either side of Horicon were ultimately observed at Pine Island. In contrast, a mean of 19 Pine Island geese from each sample reappeared at Pine Island. The mean available sample size was only 125 for Pine Island compared with 525 for Horicon-West and 644 for Horicon-East. These data suggest significant, but not absolute, migratory homing by geese to Pine Island.

Use of Other Areas. Neck-banded geese from Pine Island were observed throughout east central Wisconsin in the years of banding and in subsequent years (Table 16, Fig. 15). Very few Pine Island geese were observed at Eldorado or Horicon-South. There were only 3 within-year movements to Collins over 7 years and only 7 individuals were observed at Collins in years after the year of banding at Pine Island. There was significant movement of geese from Pine Island to the Lakes Area and to a lesser extent Horicon within any given year. However, Pine Island geese spent about 69% of their time at Pine Island, the highest per-

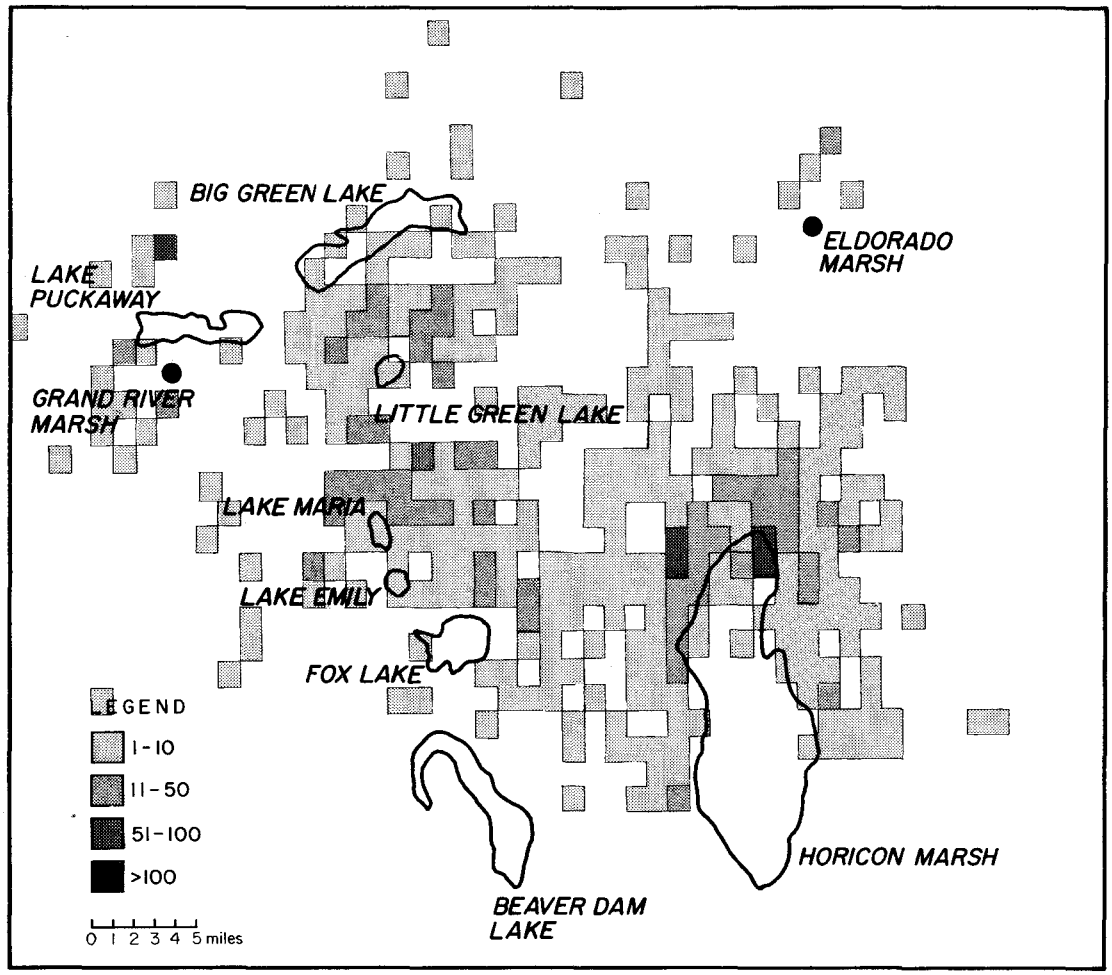


FIGURE 11. *Distribution of observations of Canada geese neck-banded at Grand River Wildlife Management Area, 1975-81.*

TABLE 15. *Number of individual Canada geese neck-banded at Eldorado Wildlife Management Area and observed at the study areas, 1975-81.*

		No. Individuals Observed, by Area							
Year of Banding	No. Banded	Grand River	Lakes Area	Horicon-West	Horicon-East	Horicon-South	Eldorado	Pine Island	Collins
1975	99	18/10*	26/32	18/21	9/27	0/3	1/22	0/4	0/3
1976	95	5/1	52/9	32/17	18/12	2/3	26/8	0/2	0/2
1977	0	-	-	-	-	-	-	-	-
1978**	100	1/1	18/14	18/31	14/46	0/1	15/2	0/5	0/3

* Upper figure indicates number of geese observed in the year of banding (direct); lower figure indicates number of geese observed in subsequent years through 1981 (indirect).
** No geese were banded at Eldorado WMA after 1978.

TABLE 16. *Number of individual Canada geese neck-banded at Pine Island Wildlife Management Area and observed at the study areas, 1975-81.*

		No. Individuals Observed, by Area							
Year of Banding	No. Banded	Grand River	Lakes Area	Horicon-West	Horicon-East	Horicon-South	Eldorado	Pine Island	Collins
1975	100	5/4*	12/16	7/14	5/15	0/1	0/1	39/20	0/0
1976	103	1/2	32/8	6/19	1/14	2/3	1/1	61/18	0/0
1977	119	1/1	12/11	11/36	1/18	3/2	4/1	12/11	1/3
1978	199	7/4	11/48	29/60	7/47	0/7	2/0	1/18	0/4
1979	72	0/1	12/10	13/14	6/10	0/0	0/0	68/20	2/0
1980	158	23/10	43/26	18/27	9/15	1/0	0/0	54/24	0/0
1981	216	14/-	46/-	5/-	4/-	0/-	0/-	96/-	0/-

* Upper figure indicates number of geese observed in the year of banding (direct); lower figure indicates number of geese observed in subsequent years through 1981 (indirect).

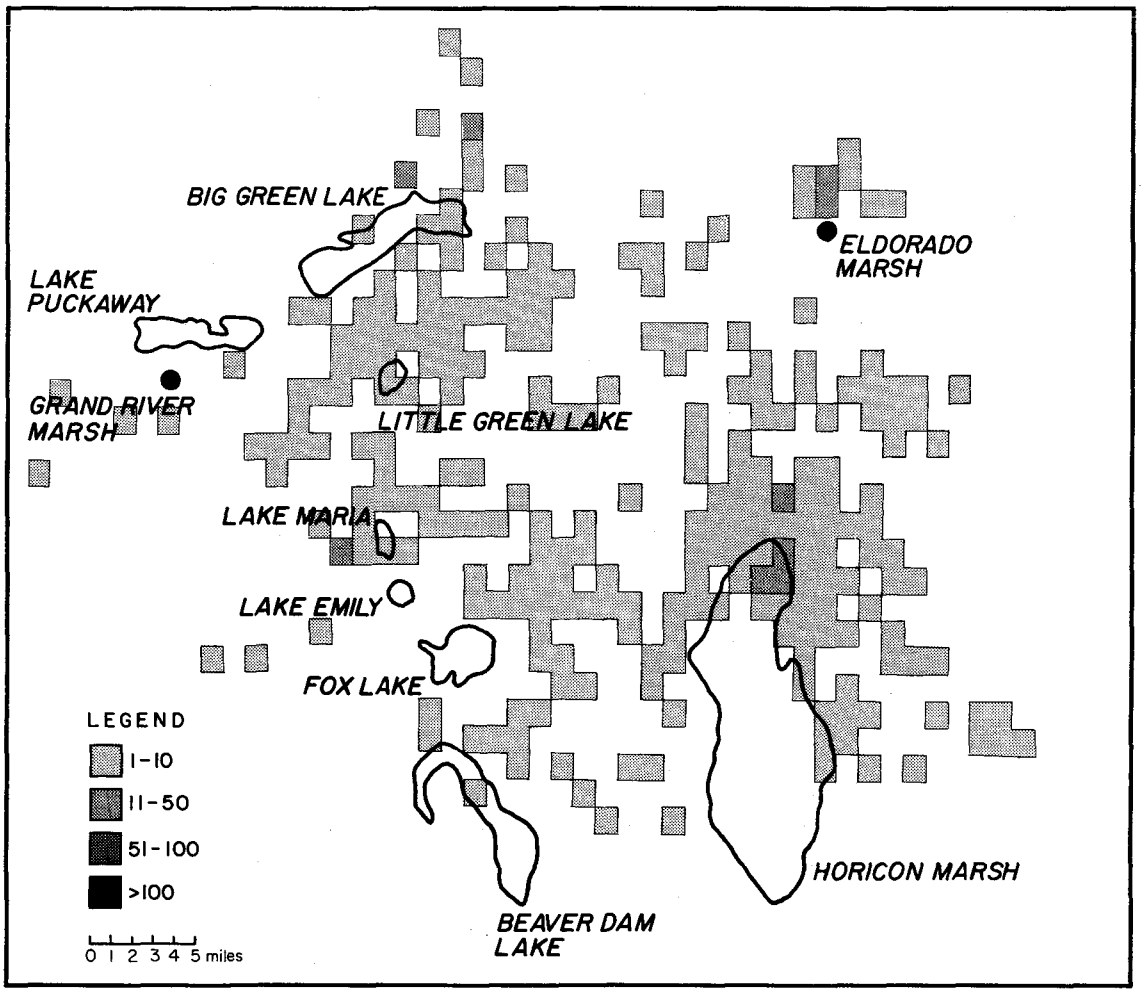


FIGURE 12. *Distribution of observations of Canada geese neck-banded at Eldorado Wildlife Management Area, 1975-81.*

centage of any area other than Horicon and Collins (Table 9). More Pine Island geese were associated with Horicon-West than with Horicon-East; 89 vs. 33 individuals, 170 vs. 119 total observations, and a mean of 16.7% of direct encounters per year vs. 7.2% (Table 16). They also spent more time on the west side than the east side (4.8 vs. 2.9%), consistent with the patterns exhibited by Grand River geese, an area also to the west of Horicon.

Pine Island geese spent 20.1% of their time in the Lakes Area; the highest area of use next to Pine Island itself. Movement to the lakes and Horicon typically occurred in early November. The mean dates of movement from Pine Island to the Lakes Area were 25 October and 3 November in 1976 and 1977 and between 17 November and 25 November in 1979-81. Most observations at Pine Island were during October; mean dates for observations at Pine Island ranged from 16 October to 28 October except in 1980 and 1981 when adequate food supplies probably held geese at Pine Island until late November (P. Kaiser, DNR wildlife manager in Columbia Co., pers. comm. 1981).

Hunting Recoveries. Hunting recoveries of banded geese supported the patterns derived from neckband observations (Figs. 8, 9). Thirty-eight percent of direct recoveries (13 of 34) were in the immediate vicinity of Pine Island; 18% at Grand River and 14% at Horicon. Indirect recoveries suggested some fidelity to the area but not to the degree suggested by observations. Only 12% (4 of 33) of all indirect recoveries were near Pine Island with 21% at Horicon and 12% at Grand River. Pine Island had the highest percentage of indirect recoveries within Wisconsin but outside the area designated as east central Wisconsin (21%).

Collins Marsh Wildlife Management Area

Collins Marsh Wildlife Management Area is located in west central Manitowoc County about 50 miles NE of Horicon Marsh. It has a total area of 4,100 acres, including 1,800 acres of water. Because of the distance from Horicon, the trends in goose use at Collins during 1975-81 were very similar to those at Pine Island (Fig. 13). From 1975-81, 515 geese were neck-banded at Collins (Table 17). No radio transmitters were used at Collins.

Use of Other Areas. Compared to other satellite areas with marked geese, there were very few direct moves documented from Collins to any area in east central Wisconsin (Table 17). Within the year of banding, a mean of 82% of the Collins geese observed were in the immediate area of Collins. Collins geese spent 80.8% of their time at Collins, the highest percentage for any area (Table 9).

The proportion of Collins samples of neck-banded geese re-observed at Collins in subsequent years compared to other areas did vary ($P < 0.05$), with a mean of 22% and a range of only 16-28%. As at Pine Island, the fall peak population at Collins represented only

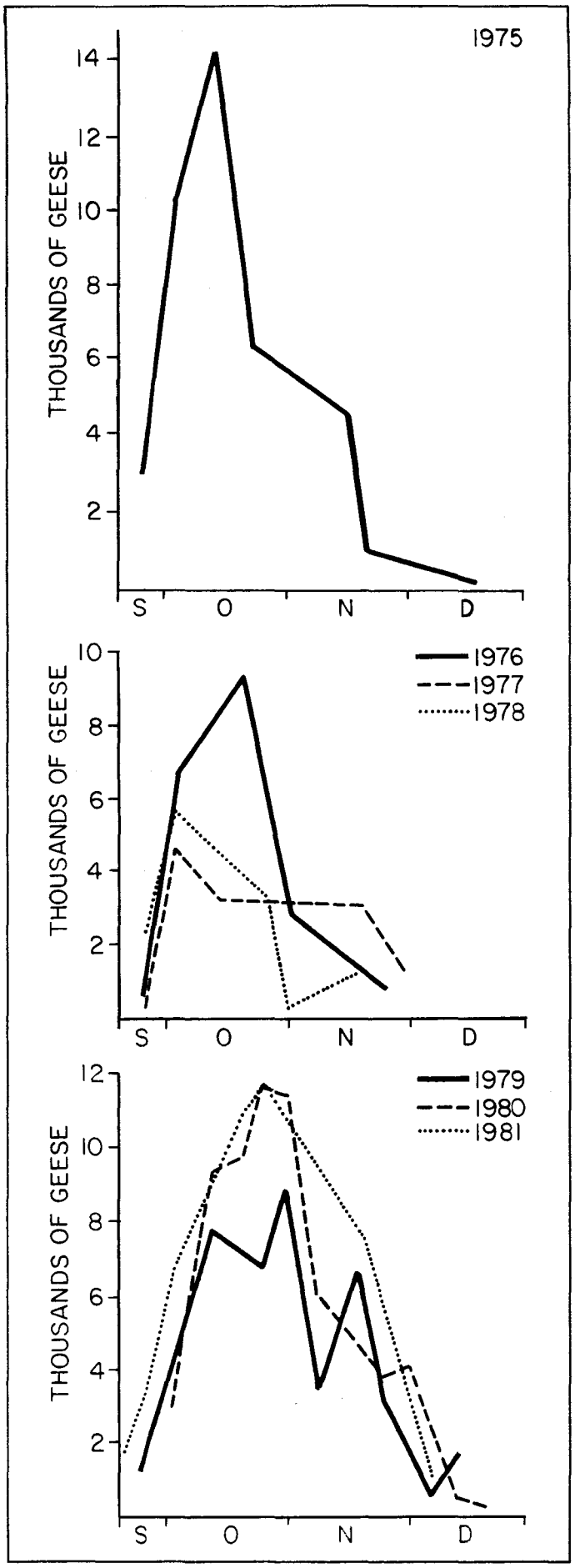


FIGURE 13. *Canada goose populations at Pine Island and Collins Marsh Wildlife Management Areas, 1975-81.*

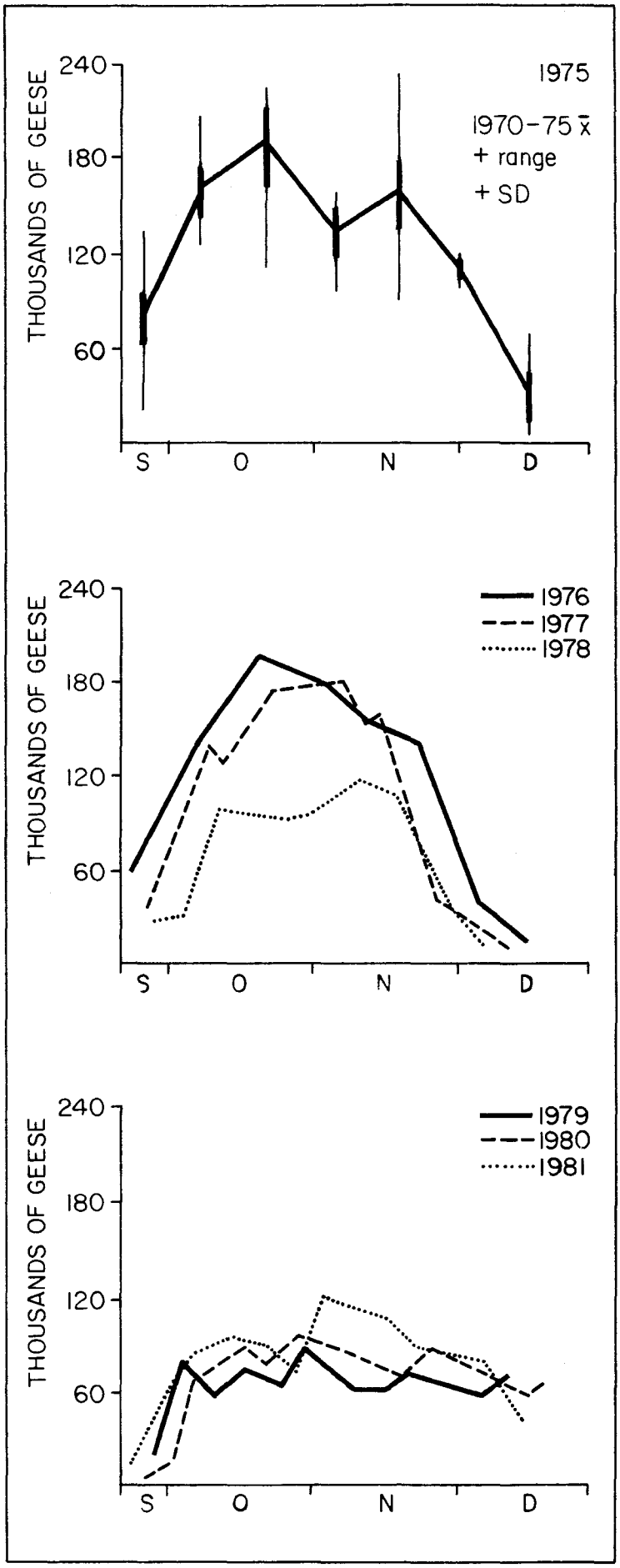


FIGURE 14. *Canada goose populations in east central Wisconsin, 1975-81.*

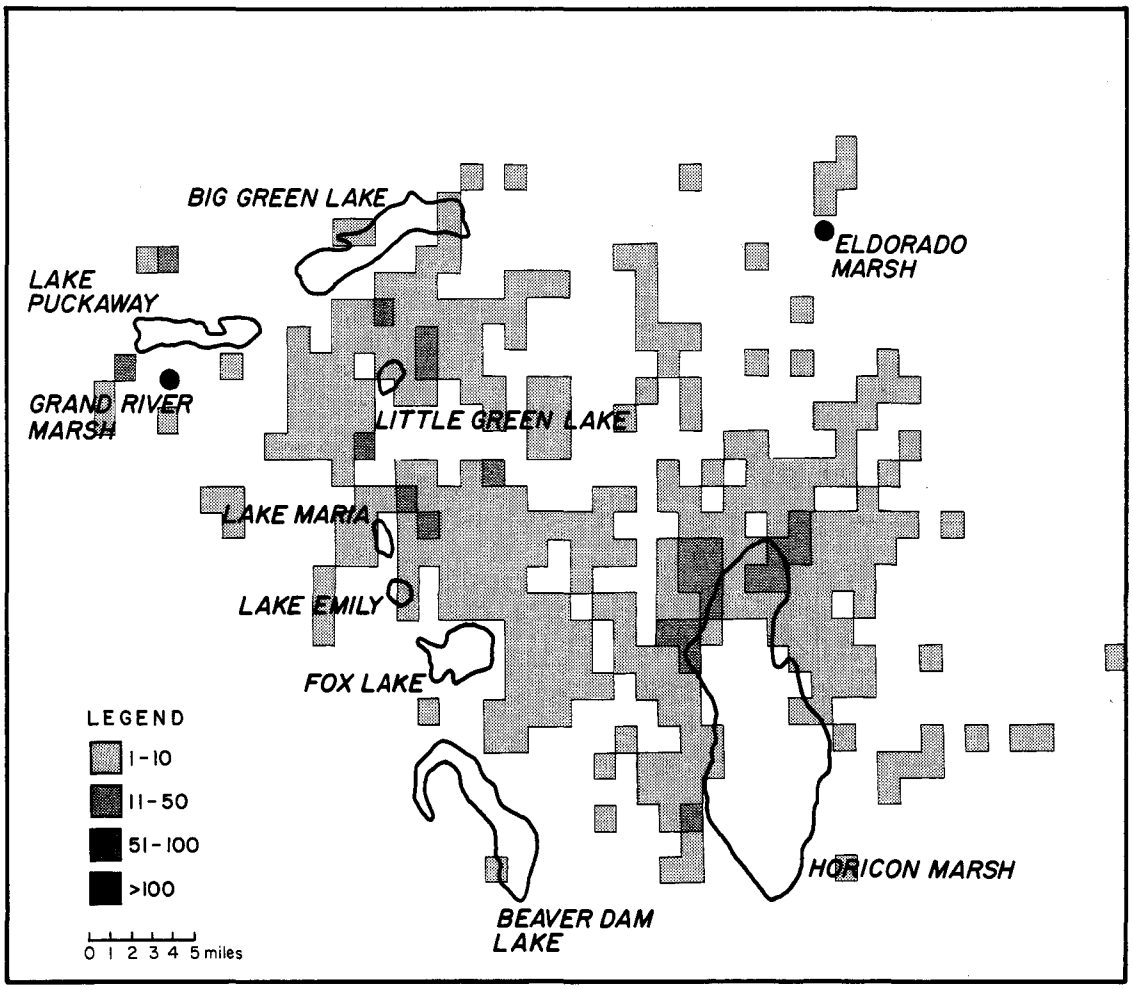


FIGURE 15. *Distribution of observations of Canada geese neck-banded at Pine Island Wildlife Management Area, 1975-81.*

TABLE 17. *Number of individual Canada geese neck-banded at Collins Marsh Wildlife Management Area and observed at the study areas, 1975-81.*

		No. Individuals Observed, by Area							
Year of Banding	No. Banded	Grand River	Lakes Area	Horicon-West	Horicon-East	Horicon-South	Eldorado	Pine Island	Collins
1975	100	4/5*	1/20	1/25	0/30	0/2	0/4	0/0	47/21
1976	100	3/0	20/8	6/17	9/21	0/1	0/3	0/1	73/13
1977	100	1/0	2/8	4/17	3/24	0/2	1/0	0/0	70/15
1978	26	0/0	0/2	0/3	0/5	0/1	0/0	0/0	13/4
1979	119	0/1	4/10	5/20	5/20	0/3	0/0	0/1	102/14
1980	69	0/0	2/6	3/3	4/12	0/1	0/0	0/0	41/9
1981	0	-	-	-	-	-	-	-	-

* Upper figure indicates number of geese observed in the year of banding (direct); lower figure indicates number of geese observed in subsequent years through 1981 (indirect).

5% or less of the fall peak in east-central Wisconsin (Figs. 13, 14). Even so, in years after banding, means of only 4-8 marked individuals from either side of Horicon were ultimately observed at Collins compared to a mean of 13 Collins geese. The mean available sample size was only 86 for Collins compared with 525 for Horicon-West and 644 for Horicon-East. As at Pine Island, these data suggest significant, but not absolute, migratory homing by geese from Collins.

In one case, a juvenile bird marked at Collins in 1975 spent the fall of 1976 at Horicon only to return to Collins for the fall of 1977. There were also several cases of movements from Horicon to Collins and back to Horicon in the same fall. Although Collins is 50 miles from Horicon in a general northerly direction, we do not believe movements from Horicon to Collins are long enough to qualify as reverse migration as described by Raveling (1976). Rather, Collins (and Pine Island) appear to be at the outer limit for local movements from the Horicon area.

Of those Collins geese that did move into east central Wisconsin in the year of banding, all but 9 of 78 (11%) were observed at Horicon or the Lakes Area (Fig. 16). Collins birds spent 7.4% and

10.8% of their time in those 2 areas, respectively. The percentage of time spent was equal for both sides of Horicon. Use of Grand River was concentrated in 1975 and 1976 but amounted to only a trace of time (Table 9). There were only 2 indirect observations at Pine Island, 1 in 1977 and 1 1979, and limited indirect use of Eldorado and Horicon-South.

The chronology and trends of goose use at Collins were very similar to those of Pine Island. The mean dates of observation at Collins were in October, while movements to Horicon and the Lakes Area occurred in the first and second week of November. Food resources within Collins were generally exhausted by 1 November. Prior to that time, geese remained on the refuge area and were difficult to hunt. During November, the geese moved out onto private land to feed and were hunted intensively. Goose hunting pressure, deer hunters within the refuge area, and low food availability combined to push the geese out of Collins by late November.

Hunting Recoveries. Direct hunting recoveries were distinctly centered on Collins (20 of 26, 77%; Fig. 8). There were only 3 direct recoveries (12%) in east central Wisconsin. This does not confirm a lack of movement from Collins to east central Wisconsin because observations suggest that movements tend to occur late in the hunting season. Indirect recoveries did support some migratory homing to Collins (6 of 16, 38%). However, 62% of the indirect recoveries (10 of 16) were in east central Wisconsin around Horicon or Grand River (Fig. 9).

TRENDS IN NUMBERS OF GEESE

This section presents a detailed discussion of numerical trends of geese in east central Wisconsin as they relate to the 1976-80 management/dispersal activities. The USFWS aerial inventory data, which are the basis for these numerical trends, provides an important supporting argument for the observed patterns of goose behavior based on neckband and radio relocations. Since it is likely that managers embarking on similar management plans would have to rely solely on the aerial inventory data to evaluate their management activities, it is useful to present the numerical trends in relation to the 1976-80 management/dispersal activities.

The objectives of the east central Wisconsin management program called for substantial numerical reduction in goose use of east central Wisconsin during 1976-80. The basic ideas were not new, but the techniques and agency support for the program were unprecedented. Initially the distribution of geese between Horicon NWR and the various satellite areas was not addressed. In 1979, with the adoption of the flyway MVP management plan, the basic numerical objectives were reaffirmed and the need for a balanced distribution among the satellites was again identified. This included an upper limit on the amount of acceptable goose use at Horicon NWR.

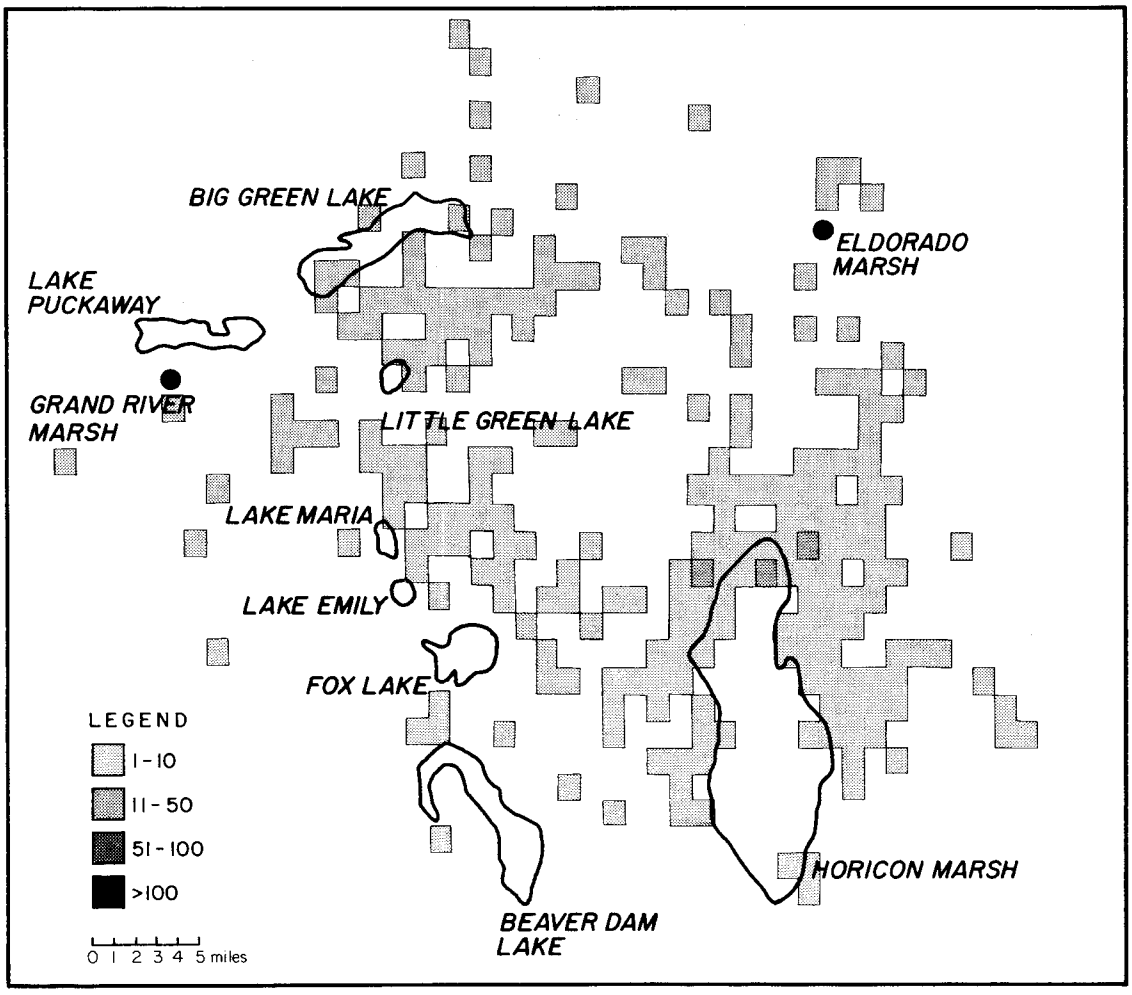


FIGURE 16. *Distribution of observations of Canada geese neck-banded at Collins Marsh Wildlife Management Area, 1975-81.*

The specific management strategies used to obtain the numerical objectives were reviewed for each year of the program (Rusch et al. 1985). An index to the intensity of these activities is presented in Table 18. Although the distribution of geese as determined by aerial counts has been reviewed by Craven (1978) and Rusch et al. (1985), we believe a condensation of these data are necessary to add support and clarification to the results of the studies reported here. The condensation is presented in the following paragraphs.

The migratory pattern and the local distribution of geese in east central Wisconsin prior to the program were discussed by Green (1968) and Craven (1978). Typically, geese arrived at Horicon in late September and increased steadily to peak numbers by the end of October. Migration into the area ended in early November. Some southerly migration to wintering areas occurred throughout October and November, but major movements did not occur until late November and early December (LaMarche 1972, Craven 1978). The freeze-up of Horicon Marsh and the disturbance caused by gun deer hunters in mid- to late November combined to move most of the remaining geese to lakes west and northwest of the marsh (Lakes Area) (Fig. 2) or to Illinois.

In a similar sequence of events, geese on outlying satellite areas either migrated south or moved to the Lakes Area in November when freeze-up and the exhaustion of satellite food resources made the areas unattractive. Weather was a major determinant of the final departure of geese. Freeze-up of the lakes and/or significant snow cover of 5-7 inches, which reduced food availability and roost sites, were required to stimulate the final departure of geese from the area.

The numbers of geese and the chronology of use of various areas of east central Wisconsin are presented in Figures 10, 13, 14, 17. We used 1970-75 mean goose counts as a standard for evaluation of changes for each area.

1975

During 1975, the first year in which we banded and marked geese, no hazing or other major management changes were initiated. Weather was normal (Table 12) and patterns of goose use were typical of the early 1970s. The 4 DNR-managed satellite areas where geese were banded supported peak populations as follows: Collins, 3,950; Eldorado, 5,150; Grand River, 8,500; and Pine Island, 9,400.

1976

In 1976, intensive hazing, coupled with a drawdown of water levels at Horicon NWR and a late summer drought, caused a shift in the distribution of geese in east central Wisconsin (Figs. 14, 17). (For ease of reference to a summary of management activities, see Table 19.) The Horicon area peak

TABLE 18. *Intensity indices for management actions to reduce the number of Canada geese on or near Horicon National Wildlife Refuge, 1975-81.*

	Year							
Management Action	1975	1976	1977	1978	1979	1980	1981	Scoring System
Harvest quota increase	56	56	70	100	70	60	40	Score: 10 per 5,000 geese in quota; see Table 20 for Wisconsin harvest quotas.
Disturbance via upland hunting	0	0	0	0	0	0	0	Score: Disturbance was minimal. (In 1976, refuge area open to small game and bow-and-arrow deer hunting in order to create disturbance on upland sites.)
Hazing via airboat	0	55	100	75	15	0	0	Score: 5 per 100 airboat hours logged; in 1977 and 1978 airboats were used to service 365 exploders (although not hazing directly, the boats functioned as a hazing tool).
Reduction of water	0	50	25	0	0	0	0	Score: 50 for complete drawdown; 25 for partial drawdown.
Elimination of refuge crops/miscellaneous	5	10	10	10	40	20	10	Score: in units of 10, based on subjective appraisal of intensity of effort; miscellaneous includes disease surveillance and trapper activity.
Hazing via aircraft	0	30	18	0	0	0	0	Score: 5 per 10 aircraft hours logged; in 1978 and 1979 a helicopter was used for disease clean-up and surveillance (see text).
Hazing via gas exploders	0	0	20	25	0	0	0	Score: 2 per 1,000 exploder days.
Disturbance via disease abatement techniques	0	0	0	25	25	10	5	Score: in units of 5 based on subjective appraisal of intensity of effort; includes field surveys, carcass pick-up, and localized dispersal activities.
Total Annual Index to Management Intensity	61	201	243	235	150	90	55	

TABLE 19. *Summary of management activities to control Canada goose populations in east central Wisconsin, 1976-80.*

Year	Area	Food Base	Water Level	Dispersal	Hunting	Comments
1976	Horicon	*283 ha left fallow. *219 ha harvested before geese arrived. *73 ha alfalfa left uncut. *All farming agreements terminated. *109 ha of retired cropland seeded for dense nesting cover for ducks.	Drawdown combined with late summer drought significantly reduced water levels and growth of emergent vegetation. Only 364 ha remained flooded.	*Late Sep-early Oct: limited number of flights by fixed-wing aircraft. *18-27 Oct: 57 hrs. of hazing with helicopter. *19 Sep-30 Oct: 1,100 hrs. of hazing with airboats. *Propane exploders, cracker shells, and other scaring devices distributed to farmers with geese in their fields.	*Harvest quota (28,000) unchanged. *Season delayed until 30 Oct to concentrate hunting pressure on segment of flock remaining into late fall.	Hazing occurred during midday and evening when geese were returning to the refuge after feeding on private lands.
	Grand River Eldorado Collins Pine Island Lakes Area	Overall reduction in crops began and reached 30-40% by the end of the program. At Grand River crops were eliminated by 1979.	No change.	Limited hazing at DNR-managed portion of Horicon Marsh, Grand River, and Lakes Area (see comments).		Aircraft used to induce migration in late Nov and early Dec.
1977	Horicon	No crops planted.	Water level returned to normal except for a partial drawdown on the northern end of the National Wildlife Refuge, 3,935 acres flooded.	*Direct aerial and airboat hazing terminated. *Hazing limited to 365 propane exploders. *Airboats logged 2,000 hrs. while servicing exploders between 14 Sep and 21 Nov.	*Upland game and archery deer hunting not permitted. *Quota increased to 35,000 because of substantial increase in the MVP.	*Intense public criticism affected reversal of water management and hazing policy. *Airboat operation and helicopter flight time did function as hazing although described as "servicing exploders". *Peak count of 130,800 (down 23% from 1976) occurred in early Oct, 2-3 weeks earlier than normal. *First major decline in overall goose use of east central Wisconsin occurred in 1977—down 55% from 1970-75 levels.
	Grand River Eldorado Collins Pine Island Lakes Area	Only crops planted were 309 ha on five satellite areas.				*Grand River held 40,000-50,000 geese, compared to pre-program average of 8,500. *In total, all five satellite areas held 36% of the peak Wisconsin population compared to a 1970-75 average of 12%.

TABLE 19. *(cont.)*

Year	Area	Food Base	Water Level	Dispersal	Hunting	Comments
1978	Horicon	No crops planted.	Extremely wet weather led to high water—5,385 ha flooded; approximately twice as much roosting habitat compared to 1977.	*Use of exploders serviced by airboats continued; additional disturbance from fur trappers using small airboats. *Direct airboat hazing allowed if goose count exceeded 50,000. *All hazing activities interrupted from 29 Sep to 26 Oct; airboats and helicopters diverted to clean up of botulism outbreak. *26 Oct to 20 Nov exploder/airboat use returned to 1977 levels.	*Hunting of deer and upland game species resumed. *Record harvest quota of 50,000.	*Major decline in goose numbers at Horicon, east central Wisconsin, and in the MVP. *Horicon peak count declined to 62,300.
	Eldorado Collins Pine Island Lakes Area	Minor reduction in crops at satellite areas.				Satellite areas held 50% of the peak population, but overall use during Oct and Nov was only half that of previous year.
	Grand River				Managed goose hunt conducted but provided only minimal disturbance and hunting pressure.	
1979	Horicon	No crops planted.	3,798 flooded ha.	*Exploder use discontinued in favor of direct hazing by airboats. *Airboats employed 5 Oct to 11 Oct each day prior to sunrise and just after sunset. *Clean up of avain cholera outbreak caused disturbance when airboats and helicopters were used to pick up carcasses.	Harvest quota reduced to 35,000.	*Mississippi Flyway began a 5-year MVP Management Plan; objectives of Wisconsin's 5-year plan were revised accordingly. *Public opposition to airboat hazing had waned. *Peak count was not to exceed 60,000 but reached 70,900.
	Grand River Eldorado Collins Pine Island Lakes Area		Drawdown at Grand River.	Satellite areas frequently searched for sick and dead geese after cholera outbreak.		Number of geese in east central Wisconsin peaked at 94,300—down 25,000 from 1978 and the lowest count since 1960.
1980	Horicon	No crops planted.	Water level normal.	Airboats logged only 70 hrs. in Sep/Oct following a botulism outbreak.	Quota reduced to reflect a continued decline in the MVP.	*Goose numbers began a steady return toward preprogram levels. *Goose use of satellite areas increased very little from 1979-81.
	Grand River Eldorado Collins Pine Island Lakes Area					

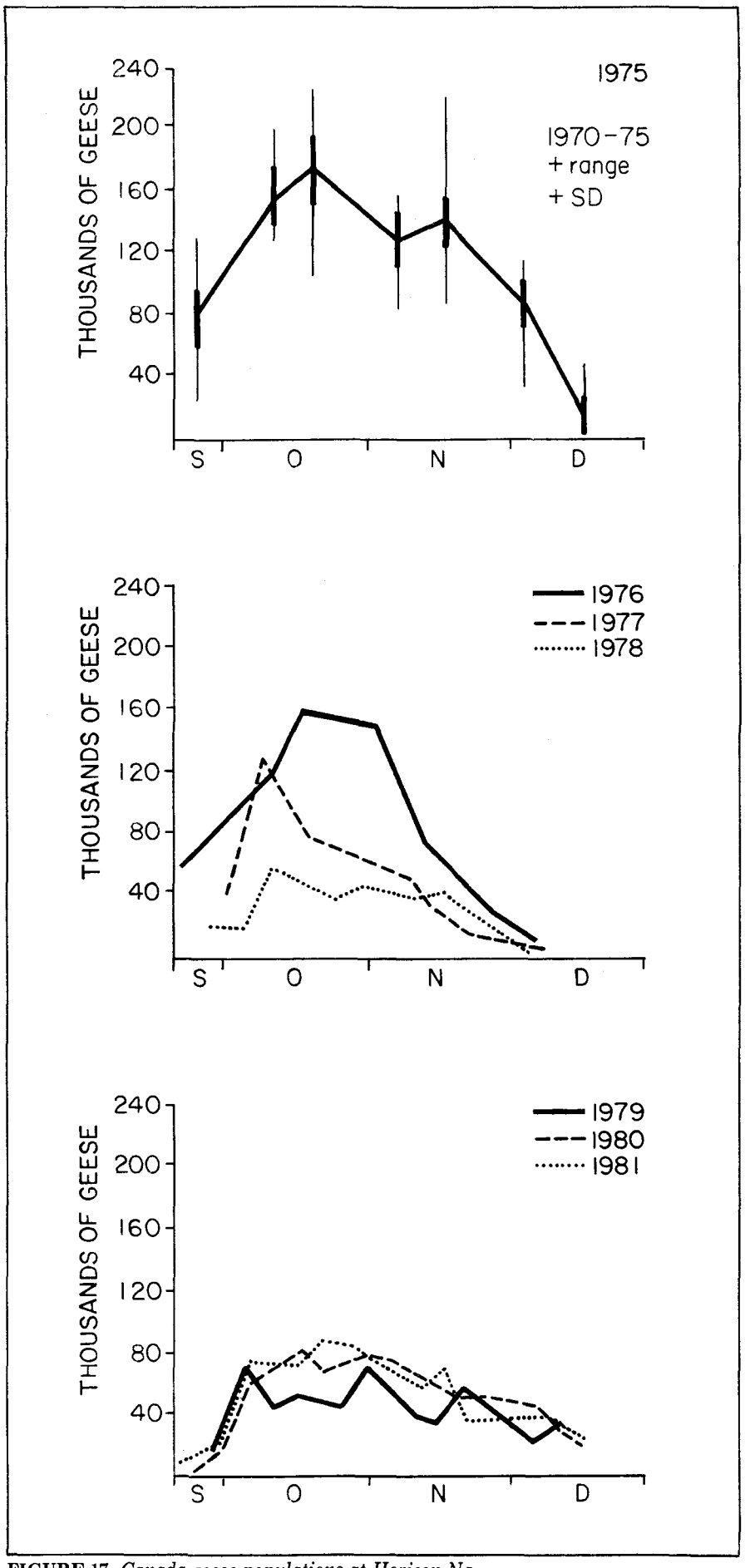


FIGURE 17. *Canada goose populations at Horicon National Wildlife Refuge, 1975-81.*

count was 172,000—comparable to pre-program levels, but goose use days for the refuge declined 30% as many geese left to avoid hazing and find adequate water for roosting. The Lakes Area supported large numbers of geese in October. Despite the change in distribution and a very cold December, overall goose use of east central Wisconsin declined by only 4% from pre-program levels. Satellite area populations were comparable to pre-program levels.

1977

In 1977, geese dispersed from Horicon NWR to surrounding areas in response to disturbance created by propane exploders and airboats (Table 19). The peak count of 130,800 at Horicon occurred in early October, 2-3 weeks earlier than normal. Although satellite areas held record goose populations, overall goose use of east central Wisconsin fell 55% from 1970-75 levels. Heavy snow in November and December contributed to the reduction in goose use. Grand River held 40,000-50,000 geese compared to the pre-program average peak of 8,500. In total, satellite areas held 36% of the peak Wisconsin population compared to a 1970-75 average of 12%.

1978

The apparent increase in the MVP during the winter of 1977-78 resulted in a record harvest quota and subsequent harvest for both Wisconsin and Illinois (Table 20). Disturbance at Horicon in 1978 again resulted in large numbers of geese moving to Grand River (40,000 peak) and the Lakes Area or on to Illinois. Together, satellite areas held about 50% of the peak population for east central Wisconsin. Changes in distribution, high goose harvests, and heavy snow in December depressed goose use to half that of previous years. At this point the numerical objectives of the Horicon plan had been attained (Rusch et al. 1985).

Pine Island and Collins appeared to be beyond the range of disturbance-induced dispersal from Horicon. Populations on both areas were below pre-program levels in 1977 and 1978 (Fig. 13). Even though beyond the efforts of hazing, both areas were subject to the local effects of the increase in the harvest quota.

The drawdown of 1976 converted many wet areas formerly used by geese into dry, cracked hardpan.

Propane exploders, or "gas cannons" such as this one, are a common tool used in goose damage abatement. They were widely used as a source of disturbance to relocate geese on Horicon National Wildlife Refuge beginning in 1977.

Crew aboard one of four airboats used to disperse geese at Horicon National Wildlife Refuge in 1976.

Within 2-3 years after removal of crops from Horicon National Wildlife Refuge, a variety of weeds and native plants reclaimed the former cropfields. Planting and water level manipulation restored many native plant communities on such sites.

1979

With the revision of program objectives in response to some of the data described herein and the MVP management plan adopted in the winter of 1978-79, a numerical objective of 60,000 was set for Horicon NWR. Hazing was restricted to one week in early October 1979 after the refuge population reached 70,900. Harvest quotas were reduced and the east central Wisconsin goose population began a slow recovery from the low counts of 1978 (Table 20). Use days were still down 64% from pre-program levels but there was an increase over 1978.

TABLE 20. *Estimated harvest of Canada geese in Wisconsin and Illinois, 1975-81.**

	Harvest Quota (thousands)			Harvest (thousands)		
Year	Wisconsin	Illinois	Total	Wisconsin	Illinois	Total
1975	28	28	56	66.4	44.9	111.3
1976	28	28	56	45.7	53.7	99.4
1977	35	35	70	89.9	76.6	166.5
1978	50	50	100	85.7	118.7	204.4
1979	35	35	70	62.2	69.0	131.2
1980	30	33	63	57.6	57.7	115.3
1981	20	30	50	39.9	53.4	93.3

* Estimates from unpublished reports that summarized responses to U.S. Fish and Wildlife Service questionnaires sent to purchasers of waterfowl stamps and from tail fan collections.

The east central Wisconsin management program ended in 1980, while the management plan for the overall MVP remained in effect through 1983. There was no hazing activity in either 1980 or 1981. Harvest quotas were further reduced to reflect a continued decline in the MVP (Fig. 1, Table 20). With no disturbance and reduced harvest pressure, goose numbers and distribution continued the steady return to pre-program levels started in 1979 (Figs. 3, 7). However, the rate of increase did not approach the rate of decline experienced in 1976-78. A discussion of the demographic events associated with changes in the MVP, an evaluation of the 5-year Horicon management plan, and the relative importance of emigration and mortality in the population changes witnessed in east central Wisconsin are discussed by Rusch et al. (1985).

DISCUSSION

DISTRIBUTION AND MOVEMENT

The potential for efficient and practical management of the Canada geese in east central Wisconsin during the fall depends on knowledge of the number of geese involved, their distribution throughout the year, and the factors that control numbers and distribution. In this paper, we have attempted to describe the numbers and distribution of these birds during the fall when they are present in Wisconsin. Normal factors that influence goose movements in Wisconsin include hunting pressure, refuges and refuge locations (including Tag Zones), weather (including water availability), food, and tradition. The effects of the dispersal activities were superimposed on these factors.

Hunting Pressure

Hunting pressure tends to concentrate geese on or near refuges. In Wisconsin, the tagging and quota systems limit hunter numbers. Even with the record quota level and subsequent harvest in 1978, gross annual patterns of movement and fidelity were maintained. During fall, Canada geese concentrate in the zones of east central Wisconsin where the goose harvest is regulated by quota. Hunting pressure is relatively light and at certain times of the day, on certain days of the week, or after most goose tags have been filled, the zones become functional refuges relative to areas outside the zones. Thus, changes in zone boundaries can affect goose distribution, particularly the distribution of feeding geese during legal hunting hours. Local movements are influenced to a lesser degree by hunters who occasionally may disrupt feeding or roosting or break up family units (Bartelt n.d.*a*).

Weather Effects

The effects of weather on local movements have been discussed by many authors (Raveling 1969*b*, Koerner et al. 1974, Zicus 1981, and others). In general, temperature, wind, precipitation, and cloud cover affect the timing and duration of local movements but do not change the basic patterns as geese either continue migration or seek alternate open water roost sites.

The freeze-up of roost areas does alter basic movement patterns. Zicus (1981) reported that freeze-up of roosting sites caused major changes in movement patterns at Crex Meadows, as subflocks moved to new roosting or feeding areas or both. The freeze-up of Horicon Marsh and satellite areas causes a shift of geese to the Lakes Area for roosting. Freeze-up and snow cover, as noted previously, induce the final southern departure of geese from Wisconsin. Small pockets of open water below dams or in rivers are not sufficient to hold large numbers of geese. LaMarche (1972) described the 1970 goose migration and how it was affected by various weather parameters.

Feeding Patterns

In the absence of hazing, the only motivation for major off-refuge flights (other than migration) is food. The relationships between crop harvest, the progression of fall, and goose feeding flights are discussed by Green (1970).

Green's use of observation transects on the refuge and at 3-, 5-, and 10-mile intervals from the periphery of Horicon Marsh allowed him to quantify goose use in each general compass heading from the marsh. Geese did forage at greater distances from roost sites as the fall progressed but the distribution of use was asymmetrical around the marsh. Marked geese at Crab Orchard NWR dispersed in all directions to feed (Raveling 1969*b*). At Horicon NWR, the location of open hunting areas and the town of Horicon on the south end of the marsh limited goose use in that general direction. Geese apparently were aware of harvest zone boundaries as they were aware of refuge boundaries. Geese on the east side remained closer to the marsh (maximum distance 9-15 miles) than geese from the northwest corner which flew to the Lakes Area to feed (maximum distance 24-29 miles). The same patterns were apparent in the monthly distribution of our marked geese (Figs. 5, 6, 7) on the same square mile grid system used by Green, even though food was not available on Horicon NWR to the extent that it was during Green's work.

Subflock Behavior

There are differences in the patterns of movement for birds banded in different locations. In general, geese banded in a given area tend to stay in that area during the fall and, to a lesser extent return to it in subsequent years. This was true for all 6 areas where marking was conducted and it may also be true for additional areas that were not sampled. When Horicon-East and Horicon-West were pooled, the degree of fidelity to Horicon was even stronger.

The same pattern has been documented for other goose concentration areas. In Ohio, Koerner et al. (1972) identified two independent subflocks

within a larger flock of geese around Ottawa NWR. Zicus (1981) identified subflocks within the goose flock at Crex Meadows, Wisconsin. Raveling (1969*b*) identified several subflocks at Crab Orchard NWR on the basis of roost and field locations, and speculated that subflocks might represent a continued association of geese from a segment of the nesting grounds. He later documented this for subflocks of giant Canada geese (*B. c. maxima*) at Silver Lake in Rochester, Minnesota (Raveling 1979). Raveling concluded that large flocks of geese regularly contain subflocks which exhibit fidelity to roost sites and flight patterns.

However, Craven and Rusch (1983) could not document stable breeding ground associations through fall and winter and Trost et al. (1981) concluded that geese wintering at a specific refuge in the south were not likely derived from a specific part of the breeding range. Additionally, Bartelt et al. (1984) found geese radio-marked in both Wisconsin and Illinois on the same area of the breeding ground. Thus, we do not suggest that patterns of association detected in east central Wisconsin reflect anything more than migratory homing to areas within a major fall stopover point and a general lack of movement once geese arrive in these areas. Described patterns do not necessarily reflect continued associations of geese from specific nesting areas, nor do they suggest that these associations will maintain any integrity once the geese have left east central Wisconsin.

Area Association

Although the existence of some consistent patterns of goose distribution may appear to be an excellent opportunity for selective management in Wisconsin, there are several associated problems. While the majority of the geese do behave in a predictable pattern, many do not. This may be related to age, broken family units (Bartelt n.d.*a*), individual variation, or other unknown factors. For similar reasons, what appears to be a strong pattern in a given year may deteriorate when the same geese are examined in subsequent years. Second, the geese demonstrated some behavioral flexibility when they moved around east central Wisconsin in response to hazing at Horicon in 1976-78 (Rusch et al. 1985).

We suggest that geese at Horicon, the Lakes Area, Eldorado, and, to a lesser extent, Grand River behave in similar fashion. Selective management changes at any of these areas would likely influence goose use of the others. Green (1970) documented a close relationship between Grand River and Big Green Lake and referred to them and the areas between them as a "complex". The importance of the lakes as a late season roost area was the key link in the association of these areas and still is. However, the subflock concept, as it relates to the opposite sides of Horicon Marsh, for example, makes the selective management of depredation or disease "hot spots" attractive, even though it might impact on overall goose use of the area. A redistribution of geese from the northeast corner of Horicon NWR, for example, would not be nullified by an influx of geese from other areas within a given year.

The detected fidelity of geese to Pine Island and Collins suggests that these areas are less likely to be affected by management changes in the Horicon area. Conversely, management changes concerning habitat or harvest at these areas should have little impact on the numbers or distribution of geese in the Horicon-Lakes-Grand River area within a given year. However, indirect band recoveries suggest that neither of these areas can be considered unique. Harvests at either area are part of the overall Wisconsin MVP harvest and eventually most geese from either Pine Island or Collins spend some time in Horicon, especially during the late fall.

Green (1970) painted and neckbanded geese a decade before this study at Horicon and at the same four satellite areas used in this study. He was able to document movements of Horicon geese to the various satellite areas and all sectors of east central Wisconsin just as we were. He painted geese yellow only in the southwestern portion of Horicon NWR, and these geese were observed in all sectors around the marsh. However, 148 of 179 sections (mile^2) where yellow geese were observed were on the west side. Eighty-three percent of all subsequent observations of all marked geese were on the same side of the marsh as the respective banding site. In 1970, geese were marked at the satellites to document movements in the other direction. Movements were detected; however, a maximum of only 22% of the marked geese were involved.

EFFECTS OF DISPERSAL PROGRAM ON DISTRIBUTION

Various management strategies were implemented to accomplish the goals of the east central Wisconsin management program from 1976-80. Water level manipulation, food reduction on refuges, and several types of hazing were used to change the distribution of geese (Table 18). Aerial counts suggested significant changes in the numbers of geese in east central Wisconsin, most notably in 1976-78. Rusch et al. (1985) suggest that the changes were related more to lower populations overall than changes in distribution. However, some changes in distribution were apparent even though there was no detectable relationship between movement rates of marked geese and an index to the intensity of the management program (Table 18). Furthermore, there were no prolonged changes in the percent of time Horicon-marked geese spent at various areas even though management activities varied greatly between years (Table 19).

The early movement of geese from Horicon to the Lakes Area in 1976 was the first major change in goose use in response to the drawdown and lack of food and sanctuary on Horicon NWR. The next major change was the dramatic, almost 10-fold increase in goose counts at Grand River in 1977 and 1978 with a concurrent decrease at Horicon. Theresa WMA and the Clark Farm also supported higher than normal populations in 1976 and 1978 as did Eldorado WMA in 1976.

What the aerial counts clearly indicated was not apparent in the encounter data for marked geese except for the 1976 use of the Lakes Area (Table 10). The neckband data showed geese spent time at Horicon equal to or greater than the mean level for 1975-81, and there was no indication that Horicon geese spent more time at Grand River. There are several potential explanations. First, geese may have roosted at Grand River to avoid hazing activities but returned to the Lakes Area or Horicon to feed. The aerial count would have placed them at Grand River; field neck-collar observations would have placed them at Horicon or the Lakes Area. Second, the high counts at Grand River may have been inaccurate or the geese involved were not Horicon geese at all, but rather part of an unexplained large increase in the MVP. Third, what were very large proportional increases at Grand River represented only about 20% changes at Horicon. We believe that the first explanation, and to a lesser extent, problems with locating neck-banded geese on roost areas, contributed substantially to our inability to detect the movement.

As noted earlier, movement rates among the large areas used in these analyses did not appear to be strongly correlated with the intensity of disturbance at Horicon. However, the size of the areas selected for analysis may have masked considerable local movement. The immediate disruptive effect of an airboat or helicopter strongly suggested that there was, in fact, signifi-

cant local movement. Bartelt (n.d.*b*) discusses in more detail the effects of dispersal on the local distribution of geese. He found that disturbance changed the local distribution of geese but that the geese returned when the disturbance was removed.

While hazing may not have had an impact on flyway distribution of geese, it did have an immediate, temporary effect on goose distribution within east central Wisconsin at least as determined by aerial counts. This points to the utility of hazing for immediate local dispersal of geese in the case of a disease outbreak.

Hazing did not result in extensive off-refuge crop depredation as some managers feared. Hunt (1983) thoroughly discusses crop depredation in east central Wisconsin. The relative importance of hazing and large increases in the harvest quota and subsequent high harvests of 1977 and 1978 cannot be separated, but hazing may have contributed to the increased vulnerability of geese, as Raveling (1979) and Bartelt (n.d.*b*) suggested.

The basic patterns of fidelity and movement did not change significantly as a result of the management program, suggesting tradition is a more important determinant of goose movements than time-specific management changes. Mortality, primarily due to hunting, apparently reduced the number of geese at Horicon (Trost 1984, Rusch et al. 1985), but the remaining geese exhibited the same behavior patterns that were present with a much larger goose flock.

MANAGEMENT CONSIDERATIONS

This study and the work of Green (1970) suggest that despite changes in goose populations, harvest levels, and levels of hazing, the basic patterns of goose distribution in east central Wisconsin have remained constant over a 10-15 year period. Raveling and Lumsden (1977) concluded that MVP nesting areas in Ontario could support more geese if they could be handled at migration stopover points such as Wisconsin and on wintering areas. Additional geese could be supported in east central Wisconsin in the long-term if new satellite areas are developed, particularly in areas with a minimum of interchange with Horicon, and current population goals are changed. If goose quotas in Wisconsin are to return to pre-management program levels, more geese must be supported within the state than were present in the early 1980s.

The movement of geese described in this study suggests that new satellite areas should be at least 25-30 miles from Horicon NWR. The best direction is difficult to predict, but the homing and movements of geese marked at Collins Marsh suggest that areas north of Horicon would remain most discrete but areas in other directions should certainly be considered. Springvale and French Creek in Columbia County, Killsnake River in Calumet and Manitowoc counties, and White River in Marquette and Green Lake counties should be able to support additional geese.

Refuge areas centered around public lakes, in addition to those already used, or other areas of attractive habitat could also serve to attract and hold geese if sufficient sanctuary is provided. Such areas could help alleviate excessive concentrations around Horicon NWR. Food supplies are apparently more important on some satellite areas such as Pine Island and Collins than at Horicon NWR. This manipulation of food and harvest pressure can determine the numbers of geese and the duration of their use on outlying satellite areas.

Many of the problems that plagued management in east central Wisconsin, such as depredation control, could be diminished or even avoided with a well conceived public relations program on the implications of a local goose concentration in the area of any new satellite development. New wildlife damage legislation passed in 1983 should reduce problems with goose depredation if the county in question is participating in the voluntary program at the time of the problem.

Because of the substantial exchange of geese between Horicon, Grand River, and the Lakes Area, especially between years, the Central and Horicon Harvest Management Zones as they existed in 1981 served primarily to maximize opportunity to hunt by distributing hunters both geographically and temporally, and to hold geese within the zone boundaries during the hunting season. Geese respond to boundary changes by expanding or contracting feeding areas within a single season. As they stood in 1981, the harvest zones encompassed virtually all of the range of the geese roosting at Grand River, Horicon NWR, or the Lakes Area late in the fall.

Manipulation of zone boundaries, addition of new zones, and innovative regulations can best serve to manage hunters, distribute the harvest among hunters, and keep the overall harvest of geese in the Horicon area within limits compatible with future harvest objectives. Adequate zones around new or existing outlying satellites would increase use of these areas, particularly if the bulk of quota harvest is shot in areas such as Horicon NWR where populations may exceed goals. Smaller zones, such as the experimental Theresa zone of 1984, may provide the opportunity to improve the quality of the goose hunt or apply more pressure where crop depredation or disease risk may be excessive.

SUMMARY

Between late September and December, a large segment of the Mississippi Valley Population (MVP) of Canada geese traditionally stops at and around Horicon National Wildlife Refuge (Horicon NWR) in an area often described as east central Wisconsin, before migrating to wintering areas in southern Illinois and northwestern Kentucky. As both the MVP and the proportion of the MVP in east central Wisconsin increased in the 1960s and early 1970s, problems also increased. Crop depredation, uneven distribution of geese in the flyway and in east central Wisconsin, poor hunter behavior, and the potential for waterfowl disease all became serious problems for wildlife managers.

From 1976-80, the U.S. Fish and Wildlife Service (USFWS) and the Wisconsin Department of Natural Resources (DNR) implemented a management program to reduce the number of geese and goose-related problems in east central Wisconsin. The program used disturbance, hunting pressure, water level manipulation, and food reduction as primary techniques to both relocate geese within east central Wisconsin and induce earlier migration out of the state.

From 1975-81, the Wisconsin Cooperative Wildlife Research Unit (WC WRU) and the DNR conducted field research at Horicon NWR and at DNR-managed satellite wildlife areas in east central Wisconsin to monitor the distribution and movements of geese and evaluate the management program's progress. The WCWRU work analyzed 25,157 encounters with over 15,000 neck-banded geese while the DNR work analyzed 17,774 encounters with 210 radio-marked geese. The two studies were complementary and both techniques yielded similar results. Thus, they are combined in this paper.

Geese marked at a given area in east central Wisconsin tended to remain in that area during the fall and return to it in subsequent years. Geese marked at Horicon spent about 65% of their time each fall on the side of the marsh where they were marked, and 65-68% of total observations were on the side of the marsh where the geese had been marked. Based on radio data, most geese made only 1-2 movements between study areas within east central Wisconsin each fall. Lakes west and northwest of Horicon were very important to Horicon geese, especially those birds from the west side of the marsh, which spent 13-18% of their time in the area within 10 miles of these lakes (Lakes Area).

Some Horicon geese did move to satellite areas, but relatively little time was spent on any of these areas except for Grand River Marsh (3.5-9% of total time depending on the year). Aerial counts suggested a major movement of geese from Horicon to the Lakes Area and to Grand River in 1976 and 1977 in response to low water conditions and dispersal activities at Horicon NWR. Only the increased use of the lakes could be detected by neckband observations. No radios were used during those years. Hunting recoveries supported the patterns of distribution determined by both neckbands and radios.

Goose populations at Grand River Marsh, the largest of the DNR-managed satellite areas, were highly variable and largely inaccessible for neckband observations; therefore, observations of radio-marked geese were used for analyses beginning in 1978. Geese marked at Grand River used the Lakes Area and Horicon NWR extensively (25% and 24% of their time, respectively).

Pine Island and Collins Marsh, two other satellite areas, are both far enough away to avoid major population fluctuations based on events at Horicon NWR. Both areas also had the highest rates of homing in subsequent years after marking. Collins geese spent 80% of their time at Collins—the highest percentage for any area. Although Collins geese moved to the Lakes Area or Horicon NWR late in the fall, there were only several instances of geese from other areas moving north to Collins. The fourth satellite area, Eldorado, is only 10 miles north of Horicon NWR. Feeding areas of geese from Eldorado overlapped those used by Horicon geese. Thus, it was difficult to distinguish between these 2 areas.

Movement and distribution of geese in east central Wisconsin are affected by tradition, hunting pressure, refuges or harvest zones, food availability, weather, and dispersal activities. Movements caused by management changes at Horicon NWR, such as reduced water levels and dispersal activities, did not persist in succeeding years. A notable exception was the persistence of increased goose numbers at Grand River WMA after the program terminated. The primary determinant of goose numbers and distribution in east central Wisconsin appears to be hunting pressure moderated by weather patterns and food and water availability within the limits of the number of geese available, i.e., the MVP size. Dispersal activities, such as the use of airboats, did provide rapid, short-term changes in goose use of local areas. These techniques could provide the dispersal necessary for management of disease outbreaks.

Horicon NWR, Grand River, Eldorado, and the Lakes Area are too closely related to allow independent management. The unexplained increase in goose use at Theresa WMA and continued high use of Grand River in the early 1980s suggest that the relative numbers of geese in these areas can be changed through management. Pine Island and Collins can likely be managed independently with minimal impact on goose numbers and distribution at Horicon.

The movement of geese described in this study suggests that new satellite areas should be at least 25-30 miles from Horicon NWR. In addition to planned satellite areas, refuge areas centered around public lakes or other areas of attractive habitat could hold geese, if sufficient sanctuary is provided.

At new satellite areas many of the problems that plagued management in the Horicon area, such as crop depredation control, could be diminished with a well conceived public relations program on the implications of a local goose concentration.

Manipulation of zone boundaries, addition of new zones, and innovative regulations can best serve to manage hunters and keep the overall harvest within limits compatible with future harvest objectives.

The Canada geese in east central Wisconsin are a valuable wildlife resource for the state. The huge goose flocks visible along the northern edge of Horicon NWR in the 1960s and 1970s provided the public with one of the great wildlife spectacles in North America. The problems that led to the East Central Wisconsin Management Program of 1976-80 can be addressed and solved through harvest management, public relations programs, efficient depredation control, disease monitoring, and the development and maintenance of key goose use areas. We concur with Green's philosophy when he said "there is no biological reason why geese cannot continue to concentrate and spend long periods of time in the Horicon area." Whether social or political conditions will overrule biology remains to be determined.

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English-Metric Measure Equivalents

1 mile = 1.609 km
1 acre = 0.405 ha or 4.057m^2

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