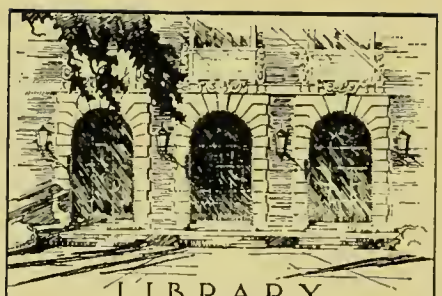
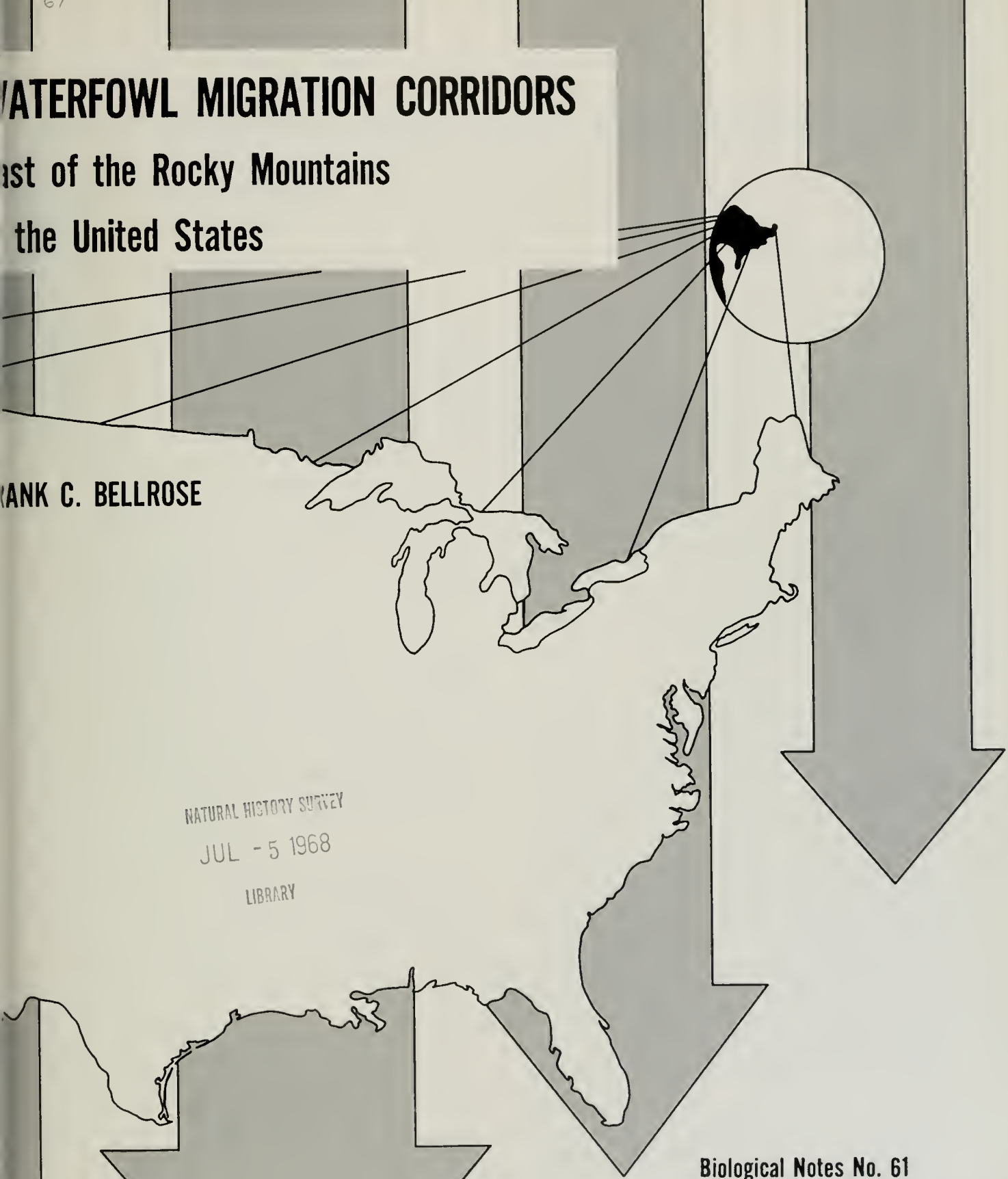


/ATERFOWL MIGRATION CORRIDORS

ıst of the Rocky Mountains

the United States

ANK C. BELLROSE



Biological Notes No. 61

ILLINOIS NATURAL HISTORY SURVEY

URBANA, ILLINOIS JUNE, 1968

STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
NATURAL HISTORY SURVEY DIVISION

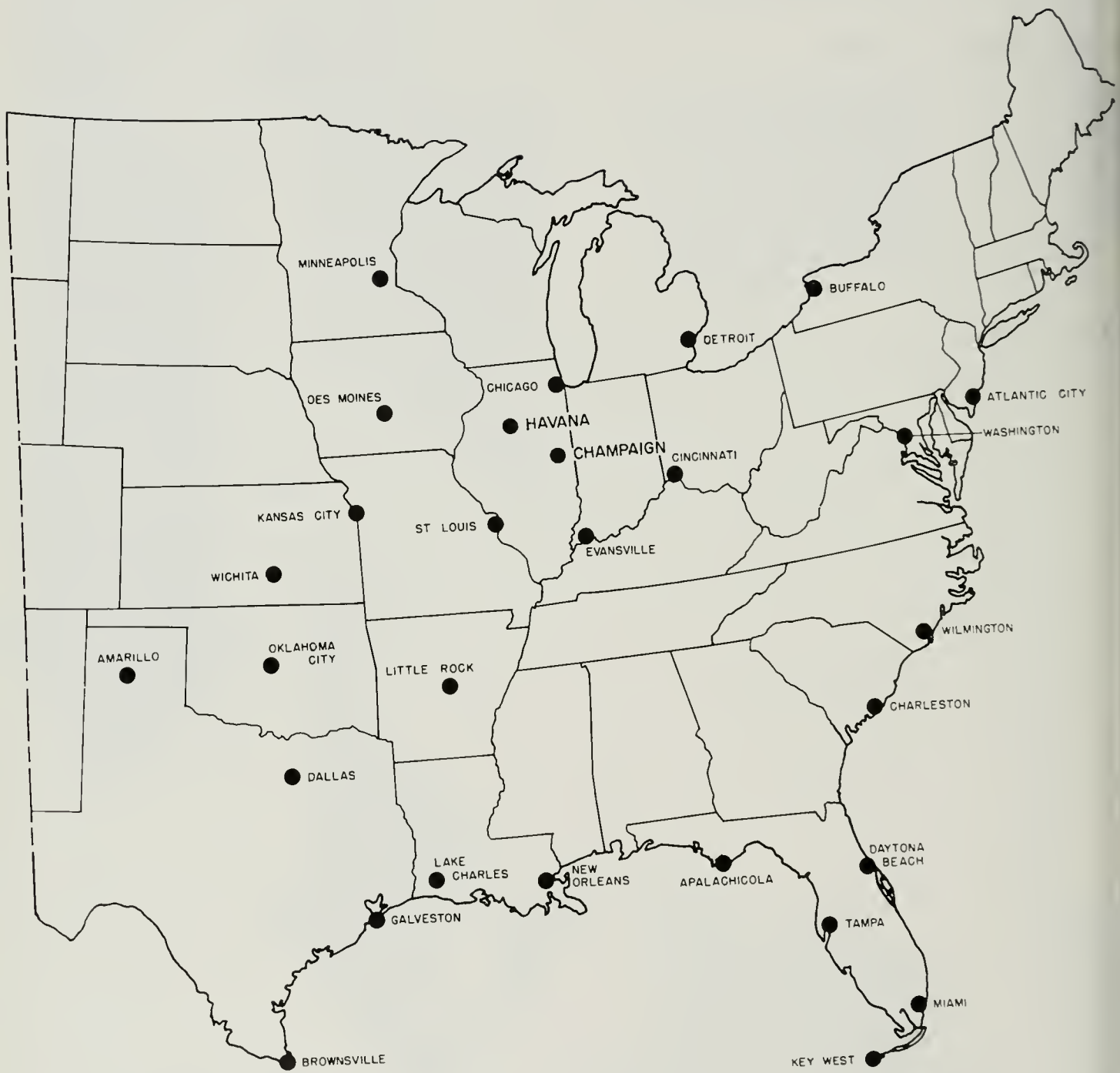


Fig. 1.—Locations of U.S. Weather Bureau and Illinois Natural History Survey radar stations used in obtaining data on waterfowl migration corridors.

Waterfowl Migration Corridors East of the Rocky Mountains in the United States

FRANK C. BELLROSE

It has been over three decades since Frederick Lincoln (1935) defined and mapped the four waterfowl flyways of North America. Since then maps of the flyways with their attendant routes have been published innumerable times, in most instances almost without modification from the original presentation. Lincoln based his flyway maps entirely upon data resulting from bandings of waterfowl before 1935.

Although a tremendous amount of banding data has been obtained since Lincoln initially mapped the waterfowl flyways of North America, no attempt has been made to update the maps of routes within the flyways. Numerous papers showing waterfowl bands recovered from bandings of particular species in given states have provided evidence that flyway routes as outlined by Lincoln are in need of revision.

Recently I was requested to prepare a report, *Establishing Certain Parameters of Hazards to Aircraft by Migrating Birds in the Mississippi Flyway,* for the Bureau of Sport Fisheries and Wildlife (Bellrose 1967). Part of the report was devoted to establishing the migration paths of waterfowl within the Mississippi Flyway and across this flyway to the Atlantic Coast. Waterfowl biologists who saw various drafts of the maps suggested improvements and extensions of the regions covered. Consequently, this project grew to include all areas of the United States east of the Rocky Mountains.

The greatest quantity of available data pertained to the Mississippi Flyway, the next largest quantity to the Atlantic Flyway, and the smallest quantity to the Central Flyway. Therefore, I believe the material is likewise most sound for the Mississippi Flyway, next for the Atlantic, and least sound for the Central Flyway.

The maps represent an attempt to show myriads of migration paths with clarity. A presentation of all the details available on the flight routes of waterfowl would result in maps either approaching incomprehensibility or drawn on such a large scale as to limit reproduction.

I prefer to refer to the mapped patterns of waterfowl movement as "flight corridors" rather than routes. I believe a route represents a path only a mile or two wide which waterfowl follow consistently from year to year. Each corridor, on the other hand, consists of a web of routes, some of which may cross or crisscross within a single flight corridor. The corridors do not have sharp boundaries; rather there may be gradual changes from the center of a flight corridor to its margins in the numbers of waterfowl using it. If the adjacent corridor has a greater abundance of waterfowl, then the number of birds increases from the center toward the margin. On the other hand, if the adjacent corridor has fewer birds, the number decreases from the center to the periphery.

Because numerous sources of data which had no common denominator were used, the presentations of flight corridors are my interpretation of the available data. Unquestionably the maps can be improved as more information becomes available. Therefore, this paper is presented as an interim report. A detailed analysis of the findings on bird migration from radar surveillance is in preparation.

METHODS

This paper is based upon seven kinds of information sources from which waterfowl migration patterns and magnitudes of passage were deduced:

1) recoveries of bands from waterfowl

2) visual sightings of waterfowl in migration by ground observers

3) visual sightings of waterfowl in migration from light aircraft

4) radar surveillance of waterfowl in migration

5) periodic waterfowl censuses conducted in Illinois, 1938–1966; in all states of the Mississippi Flyway, 1954–1956; and in several states of the flyway, 1954–1966

6) reports on the annual winter inventory of waterfowl by states in the Atlantic, Mississippi, and Central flyways, 1960–1966

7) review of the material prepared for this report and consequent suggestions for improvement by the Technical Committee of the Mississippi Flyway Council and by waterfowl biologists in the Atlantic and Central flyways

Band Recoveries

Band recovery data are the most important information source from which to deduce waterfowl migration patterns, because these data are more extensive than other kinds and deal with identifiable population elements. The principal disadvantage in using band data for this purpose is that they are discontinuous; that is,

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recoveries occur in relation to the distribution of hunting areas and numbers of hunters. Frequently waterfowl stop in tremendous numbers on large water areas, such as Lake Michigan, where there is little or no hunting. Other waterfowl cross nonstop over hundreds of miles of terrain devoid of suitable habitat, such as the Appalachian Mountains. Moreover, bands attached to ducks at a northern station and recovered far down the flyway do not necessarily show the deviations from a straight line which the birds may have taken to reach the point of recovery. Nevertheless, in this paper the judicious interpretation of band data forms the principal base for determining the migration paths of waterfowl.

Often a point of confusion in using waterfowl banding data *per se* to map migration paths arises from a wide dispersal of recoveries. This occurs for some species more frequently than for others. In this respect redheads, lesser scaups, and canvasbacks are most notorious among ducks; however, even such a strong homing species as the Canada goose has been banded in one flyway and later killed in another. This creates the impression that some species of waterfowl do not move along well defined routes of migration but scatter over broad regions of the continent.

However, I believe that these "misplaced" waterfowl have indeed migrated along well defined routes of travel for the species. It seems apparent that the transfer of individuals from one flight route to another within a flyway or to routes in other flyways occurs because they are carried along by larger assemblages of migrating waterfowl. Especially on the breeding grounds, where waterfowl gather on staging areas before departing in migration, it is likely that birds which ordinarily use a given flyway route may be captivated by a flock or assemblage of birds using a different route.

Anyone who has watched departing flocks of migrating waterfowl and flocks in actual migration is aware of the diversity of orientations among members of some flocks. Small groups may break away from large groups and head in entirely different directions, or they may separate from large flocks only to recombine and continue in one direction. This separating and sometimes recombining among migrating flocks of waterfowl suggests to me that one population element may at times influence the migration behavior of other elements. When flocks combine into migratory assemblages on staging areas, a small segment of a population may change flight routes and even flyways, thus accounting for a wider dispersal of bands than would seem warranted by the distribution of flight routes.

Both published and unpublished material on recoveries of bands attached to waterfowl were carefully reviewed. In addition, I analyzed band recoveries from over 100,000 mallards at five locations in Illinois and those made at the Squaw Creek National Wildlife Refuge in northwest Missouri. Band recovery data on Canada geese recently compiled by the Migratory Bird Population Center, Bureau of Sport Fisheries and Wildlife, were also examined.

Visual Sightings by Ground Observers

For the past 10 years the Technical Committee of the Mississippi Flyway Council has assisted me in recording the visual sightings of waterfowl throughout the flyway. During a 20-year period with the assistance of numerous cooperators I have recorded the passage of waterfowl through Illinois.

Visual sightings reveal details of diurnal flight routes not evident from banding analysis. They are especially useful in determining routes used by Canada and blue and lesser snow geese, species which migrate diurnally more often than do most other species of waterfowl.

Visual Sightings from Aircraft

From a light aircraft I have observed flocks of ducks and geese in migration on numerous occasions during the 20 years I have been making weekly censuses of waterfowl in Illinois. On several occasions I have followed migrating flocks of ducks and geese for over 50 miles.

Many pilots, particularly of light aircraft, report migrating flocks of waterfowl to the nearest FAA station. These reports, called Pireps, are sent by teletype to other stations on the regional circuit. For 5 years I have collected Pireps on waterfowl sightings in the north-central United States as received by the FAA station at Burlington, Iowa. These reports are most valuable for plotting the lines of flight of Canada and blue and snow geese and, to a lesser extent, ducks.

Actually following migrating flocks of waterfowl with a light airplane provides details of flight routes used more precisely than other methods described here. I have used this procedure on numerous occasions in Illinois.

Radar Surveillance

Radar surveillance of waterfowl migration proved to be valuable in determining the direction and magnitude of movement. Because radar can "see" at night and through clouds not laden with water droplets, it provided information obtainable by no other technique. The principal disadvantages of radar are that it rarely allows the observer to identify waterfowl species, and the records are geographically discontinuous.

Dr. Richard Graber and I employed an APS-42A radar at Havana and Champaign, Ill., and a mobile unit in Illinois, Indiana, Iowa, and Missouri during the waterfowl migration periods, 1960-1964. In addition I had the cooperation (1963–1965) of U.S. Weather Bureau WSR-57 radar surveillance of waterfowl migrations at 27 stations (Fig. 1).

The Illinois Natural History Survey's small radar provided a window on the passage of waterfowl which extended only 4 miles, but WSR-57 radar furnished a window on waterfowl passage that usually extended 40 miles and occasionally up to 100 miles.

Periodic Waterfowl Censuses

Estimates of waterfowl populations were made periodically throughout the Mississippi Flyway during the au-

tumn, 1954–1956, under the coordination of the Technical Committee of the Mississippi Flyway Council. In Illinois I have made waterfowl censuses from a light aircraft over much of the state, 1946–1966. Several states, notably Missouri, Tennessee, and Louisiana, have made periodic waterfowl censuses from 1954 through 1966.

Data on the distribution of waterfowl populations within these states provided information from which to deduce much about the magnitudes of waterfowl migrations.

Winter Inventory

The distributions of waterfowl populations at the time of the winter inventories in early January provided information on the ultimate destinations of waterfowl moving through the Mississippi, Atlantic, and Central flyways during the fall migration. The sizes of the various waterfowl population elements on wintering areas compared with the sizes of the same population elements on important migration areas provided the principal means of determining the magnitudes of movement along the migration corridors.

Review of Material

The Technical Committee of the Mississippi Flyway Council has twice reviewed late "editions" of the flyway maps. Some representatives of the Atlantic and Central flyway committees have also reviewed them, as has the Migratory Bird Population Center of the Bureau of Sport Fisheries and Wildlife.

Besides these groups, a host of persons—refuge managers, game agents, game biologists—have reviewed various drafts of the maps and have made numerous suggestions toward improving their validity.

Species Groupings

The most meaningful presentations of waterfowl migrations were obtained by using four categories: dabbling ducks, diving ducks, Canada geese, and blue and lesser snow geese.

Migration corridors used by diving ducks are quite distinct from the corridors used by dabbling ducks. Therefore, I have separated these two groups. Flight corridors of Canada geese are in some regions nearly the same as but in other regions quite distinct from those of the blue and snow geese, and so they are shown separately.

I considered showing separate flight corridors for each of the more numerous species of ducks, but there are many similarities in their migration corridors among those species of dabbling ducks and among those species of diving ducks whose breeding grounds are on the northern Great Plains. The eastern-breeding black duck is an exception, but its migration corridors are so distinct as to be evident on the map for dabbling ducks. It appeared more practical to group species of dabbling ducks and to group diving ducks than to present each species separately. Important differences in the movements of species within the two groups are discussed in the text.

Population Estimates

Three types of population figures were used to estimate the magnitudes of waterfowl passage.

1) Figures presented for populations heading south down the flyways into the United States are based upon winter inventory data, 1959–1966, to which 25 percent has been added to compensate for hunting and other mortality.

2) Peak population figures at rest areas along each corridor are the averages of maximum numbers of waterfowl observed during the fall over a period of years. Because of migration turnover, peak populations of waterfowl usually represent only from one-fourth to one-half of the numbers of waterfowl actually passing through an area.

3) Based upon the distribution of waterfowl habitats and known waterfowl concentrations, the winter inventory data for each state, 1960–1966, were broken down by regions of the state so that the population densities of migration corridors could be indicated as precisely as possible.

All population data should be considered relative rather than definitive. Population data are only approximations of species abundance in the various migration corridors. Maps of migration corridors are based upon population densities and species composition.

FALL MIGRATION PATTERNS

In the past decade duck populations have been depressed by drought and unseasonable temperatures on the breeding grounds. Mallards and pintails have suffered more than other species. Yet, each fall, 1960–1966, about 17,500,000 ducks, excluding the blue-winged teal and the sea ducks, have migrated down flight corridors in the United States east of the Rocky Mountains. The largest portion, about 12,275,000, entered the geographical confines of the Mississippi Flyway from the northern Great Plains, and 2,475,000 of them continued across the Mississippi Flyway to the Atlantic Flyway. Almost 4,500,000 ducks moved south along corridors terminating on wintering grounds of the Central Flyway.

Although most of these ducks originated their southward passage from the northern Great Plains, many started in the Yukon and the Northwest Territories of Canada and some even in Alaska. In addition to the nearly 17,000,000 ducks migrating from or through the northern Great Plains, about 650,000 black ducks moved south from Ontario, Quebec, New Brunswick, and northern states from Wisconsin eastward.

In spite of their depressed populations mallards and pintails made up half of the typical fall flight, with mallards composing about 40 percent. Scaups, the most abundant of the diving ducks, composed about 15 percent of the usual fall flight in the three flyways.

Because flight corridors used by ducks often transcend flyways, I have found it expedient to discuss the passage of each group of ducks from breeding grounds to winter-

ing grounds according to the migration corridors they use. The discussion begins with the westernmost corridors, because of their proximity to the breeding grounds, and proceeds eastward. The flight corridors of geese, however, are discussed from east to west.

Dabbling Ducks

Western Plains Corridor. — The westernmost migration corridor for dabbling ducks that breed on the Great Plains commences in eastern Alberta and western Saskatchewan (Fig. 2). It slopes south-southeast along the eastern edge of the Rocky Mountains to the lower Texas coast and the northern portion of the gulf coast of Mexico. It might be termed the Western Plains Corridor.

An approximation of the dabbling ducks using this corridor is 1,500,000, made up as follows: mallards, 550,000; pintails, 450,000; baldpates, 200,000; green-winged teals, 125,000; gadwalls, 90,000; and shovelers, 30,000.

Some mallards winter almost at the northern end of this corridor near Malta, Mont., where usually about 2,000 stay during the cold months. Up to 15,000 mallards also winter along the Yellowstone River of Montana where it runs through this corridor and on east into the next one. One hundred thousand mallards winter just east of the Front Range in northern Colorado, with an additional 30,000 along the Arkansas River in the southeastern part of that state. Other thousands winter farther east in the area embraced by the adjacent corridor. By far the largest concentration of wintering mallards in the Western Plains Corridor occurs in the Texas panhandle where about 300,000 usually concentrate.

The Texas panhandle is also an important wintering ground for several other species: pintails, 160,000; green-winged teals, 90,000; baldpates, 60,000; gadwalls, 15,000; and shovelers, 8,000.

About 600,000 dabbling ducks continue southward in this corridor to winter along the lower Texas gulf coast and the upper Mexican gulf coast. Most of these are pintails, numbering almost 75,000 on the Texas coast and 187,000 on the Mexican coast (Saunders 1964:259). Other important dabbling ducks wintering in this area are: baldpates, 108,000, of which about 105,000 occur on the Mexican coast; gadwalls, 62,000, of which 56,000 are on the Mexican coast; 19,000 green-winged teals; and 17,000 shovelers.

Mid-Plains Corridor. — Immediately east of the Western Plains Corridor lies the Mid-Plains Corridor. It extends from western Saskatchewan to the Texas coast between Galveston Bay and Corpus Christi.

About 700,000 dabbling ducks migrate along this corridor. Mallards predominate, numbering, at the start of the hunting season, about 500,000. Pintails are next in abundance with 110,000, followed by 40,000 green-winged teals, 18,000 baldpates, 15,000 gadwalls, and 7,000 shovelers.

Mallards, about 10,000 of them, winter in this corridor as far north as Fort Peck, Mont. Along the North Platte River, in western Nebraska and eastern Wyoming, nearly 75,000 mallards winter, while almost 125,000 congregate along the South Platte and Republican rivers in northeastern Colorado. Lake McKinney and the Cimarron River in southwestern Kansas are the wintering areas of about 125,000 mallards. A rough estimate is 50,000 mallards wintering in this corridor in Texas, largely in the northern part of the state: only about 7,000 mallards reach the Gulf Coast where this corridor terminates. Almost all of the other species of dabbling ducks using this corridor winter along the Texas coast.

Eastern Plains Corridor.—The easternmost Great Plains corridor extends from central Saskatchewan across eastern Montana and western South Dakota to the gulf coast of eastern Texas and western Louisiana. It is termed the Eastern Plains Corridor.

Almost 3,000,000 dabbling ducks head down this corridor in the fall. About 1,000,000 are mallards, 600,000 are pintails, 460,000 are gadwalls, 400,000 are green-winged teals, 300,000 are baldpates, and 225,000 are shovelers.

Mallards in this corridor winter as far north as the hot springs adjacent to the Black Hills of South Dakota, where 20,000 stay. Farther south about 40,000 winter along the Platte River in central Nebraska and 14,000 in the Harlan County Reservoir area in the southern part of that state. In this corridor in Kansas about 45,000 mallards winter, 20,000 at the Quivira National Wildlife Refuge and Cheyenne Bottoms, and 25,000 at the Jamestown Management Area. Almost 160,000 mallards winter on artificial reserviors in Oklahoma. A rough estimate of 45,000 is made for mallards wintering in eastern Texas, north of its gulf coast, and only 4,000 for the Gulf Coast. The largest concentration of mallards using this flight corridor winters in Louisiana; nearly 400,000 are concentrated along the coastal marshes adjacent to rice fields in the western part of the state.

Practically all of the other dabbling duck species, about 1,500,000 birds, winter in the coastal marshes between Galveston Bay, Texas, and Vermilion Bay, La. About 10 percent of these ducks winter in east Texas and 90 percent in western Louisiana.

Missouri River Corridor. — The Missouri River has a pronounced effect on migrating waterfowl. It attracts ducks because it offers rest areas and food and a guideline in migration. Almost 1,500,000 dabbling ducks appear to use this extremely narrow corridor, creating a great density of passage.

The Missouri River Corridor extends from northwest North Dakota along the river course to Kansas City, Mo. Most of the ducks leave the river there, apparently because it turns abruptly eastward. The main branch of the corridor continues southeastward to eastern Louisiana, while a subbranch extends southward to western Louisiana.

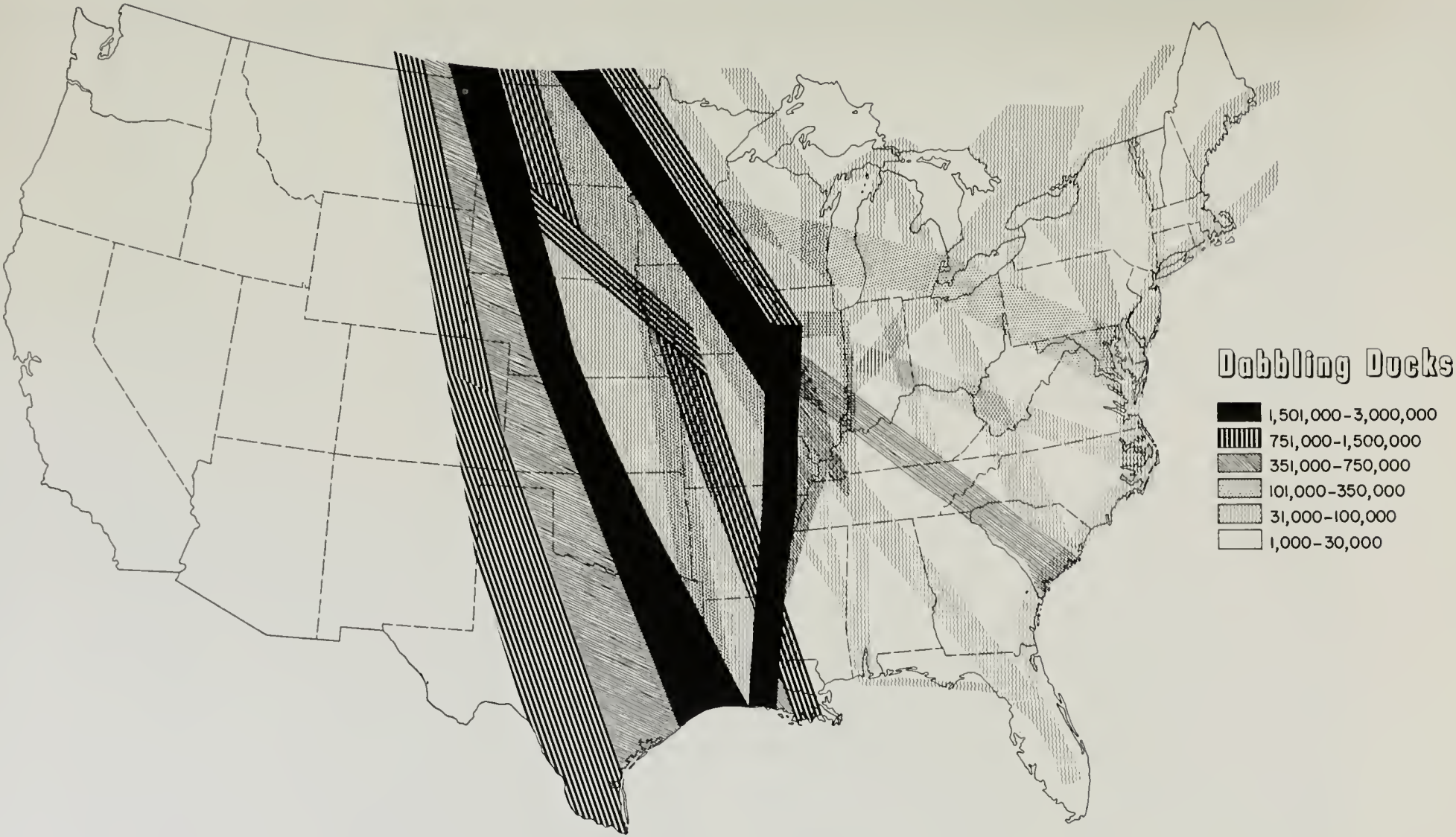

Fig. 2.—The migration corridors used by dabbling ducks during their fall migrations

Mallards migrating along the Missouri River Corridor number about 1,100,000 along with 150,000 pintails, 100,000 green-winged teals, 50,000 baldpates, and 50,000 gadwalls.

Mallards in the Missouri River Corridor winter in numbers as far north as the Fort Randall Reservoir and Lake Andes, S. Dak. About 250,000 stay there. At the Squaw Creek National Wildlife Refuge in northwest Missouri the wintering mallard population usually averages about 200,000. About 11,000 winter on the Platte River in Nebraska near its confluence with the Missouri River. In eastern Kansas about 20,000 winter on the Marais-des-Cygnes Management Area and nearly 100,000 winter on the Neosho Management Area.

Probably not more than 300,000 of the 1,100,000 mallards wintering in Arkansas arrive by this corridor. However, most of the 150,000 mallards wintering on the Holla Bend National Wildlife Refuge near Russellville, Ark., use this corridor. Others also arrive there by flying directly south from the Swan Lake National Wildlife Refuge in north-central Missouri.

Available evidence suggests that most of the 55,000 pintails, 23,000 gadwalls, 18,000 baldpates, 18,000 green-winged teals, and 13,000 shovelers which winter in southeast Arkansas arrive by this corridor. Others of these species migrating down this corridor probably use the western branch to reach coastal marshes in western Louisiana.

Mississippi River Corridor. — The next corridor, the Mississippi River Corridor, starts on the Manitoba border in central North Dakota and stretches southeastward to the Mississippi River in southeast Iowa and northeast Missouri. From there it extends eastward to the Illinois River valley. At this point the corridor changes direction to the south to terminate on the gulf coast of Louisiana.

Because of its narrowness, this corridor has the greatest density of dabbling duck passage of any migration corridor east of the Rocky Mountains. The upper section, from Manitoba to the Mississippi River, is followed by almost 2,500,000 dabbling ducks of which, 2,000,000 are mallards, 200,000 are pintails, 125,000 are baldpates, 70,000 are green-winged teals, 50,000 are gadwalls, and 20,000 are shovelers.

The lower section of the Mississippi Migration Corridor, from western Illinois southward, is used by smaller numbers of waterfowl because of the corridors which stem from it. These corridors extend southeastward to terminate in North Carolina, South Carolina, and Florida.

The northernmost concentrations of mallards wintering in this flight corridor are on the Mississippi River near New Boston, Ill., and on the upper Illinois River. About 25,000 winter near New Boston and 60,000 on the Illinois River above Peoria. Other concentrations of wintering mallards are: lower Illinois River near Havana, 140,000; Mississippi River, Hannibal, Mo., to Alton, Ill., 200,000; southern Illinois, 150,000: southeast Missouri, 40,000; Reelfoot Lake, Tenn., 50,000; northeast Arkansas, 400,000; Stuttgart, Ark., area, 300,000: eastern Mississippi, 60,000; Louisiana (by this corridor), about 200,000, some at Catahoula Lake but most in the southeastern part of the state.

Most of the other species of dabbling ducks migrating along the Mississippi Corridor through the Iowa-Illinois-Missouri area winter on the southeast Atlantic Coast. Details of the corridors used to reach specific wintering areas will be described later.

Mid-Prairie Corridor.—A corridor used by far fewer ducks is shown paralleling the Mississippi Corridor to the west and south. This is the Mid-Prairie Corridor. It is estimated that 250,000 dabbling ducks use this route in similar proportions by species to the species using the Mississippi Corridor. Two of the most important stopping places on this corridor are the Fountain Grove Wildlife Area and the Swan Lake National Wildlife Refuge in north-central Missouri; there mallards usually reach a peak of 75,000 during the fall.

Mid-Minnesota Corridor. — To the north and east of the Mississippi Corridor a corridor extends from eastern Manitoba to the upper Mississippi River south of Minneapolis. This is termed the Mid-Minnesota Corridor; it is followed by about 760,000 dabbling ducks. Most of the mallards, about 600,000. follow the general course of the upper Mississippi southward: however, at the peak of migration nearly 100,000 land to feed on the Upper Mississippi River National Wildlife and Fish Refuge between Red Wing, Minn., and Rock Island, Ill. From the upper Mississippi River the bulk of the mallards move both south to the upper Illinois River valley and southeast to northwestern Indiana.

Chesapeake Bay Corridor. — However, an estimated 65,000 mallards. 35,000 baldpates, and 25,000 pintails move eastward from the upper Mississippi River to eastern Wisconsin, especially the Horicon National Wildlife Refuge. This corridor then continues eastward to encompass the marshes of Lake Erie from Monroe, Mich., to Sandusky Bay, Ohio. From the Lake Erie marshes it is a nonstop flight of about 400 miles to Delaware and Chesapeake bays, where most of these ducks winter.

North Carolina Corridor. — From north-central Illinois a corridor followed by 65,000 dabbling ducks extends southeastward to wintering grounds in northern coastal North Carolina. It is used by approximately 35,000 pintails, 18,000 mallards, 8,000 baldpates, and 2,000 gadwalls.

South Carolina Corridor. — The largest flight corridor for dabbling ducks to the Atlantic Coast is used by about 400,000 birds. It extends from west-central Illinois on the Mississippi River to the coast of South Carolina. The approximate species composition is 140,000 mallards, 125,000 pintails, 70,000 baldpates. 40,000 gadwalls, and 25,000 shovelers.

Mid-Florida Corridor. — The most southern corridor extends southeast from southern Illinois on the Mississippi River to central Florida. Most of the ducks using this corridor proceed no farther than the Cross Creeks and Tennessee national wildlife refuges, Tenn., and the Wheeler National Wildlife Refuge, Ala., where 300,000 mallards have wintered in recent years. About 35,000 pintails, 25,000 baldpates, and 5,000 mallards continue southeastward to Florida.

Mobile Bay Corridor. — Flight corridors extend from the north and northwest to wintering grounds in the Mobile Bay delta area of Alabama. About 35,000 dabbling ducks winter in the Mobile delta area, including almost equal numbers of baldpates (8,500), pintails (8,000), and gadwalls (7,000), with lesser numbers of green-winged teals, mallards, and black ducks. Formerly mallards wintered in greater numbers in the Mobile delta area, but in recent years increasing numbers have stopped for the winter at the Noxubee National Wildlife Refuge in eastern Mississippi. About 60,000 mallards winter at the Noxubee Refuge along with 3,000 baldpates, 2,600 green-winged teals, 1,500 black ducks, and 1,300 gadwalls.

Black Duck Corridors. — A corridor extends across western Lake Superior and south-southeast through eastern Wisconsin to northeastern Illinois and northwestern Indiana. About 25,000 black ducks and 10,000 mallards use this corridor as far as southeastern Wisconsin, where, at the Horicon National Wildlife Refuge, additional mallards join the passage south.

Other corridors extend southward through western and eastern Michigan. A total of approximately 150,000 black ducks and 50,000 mallards follows these corridors. The western corridor divides in southwestern Michigan, one branch swinging southwest to the Kankakee and Willow Slough management areas of Indiana, and the other branch turning south-southeast to the TVA lakes in eastern Tennessee. The easternmost corridor in Michigan continues south-southeast to the coastal marshes of South Carolina.

A corridor followed almost entirely by black ducks extends southwestward from eastern Ontario, across the west end of Lake Erie to the confluence of the Wabash and Ohio rivers, and on south to the Arkansas River in eastern Arkansas. Perhaps 35,000 black ducks use this path.

Of the approximately 50,000 black ducks which winter in South Carolina, Georgia, and Florida, most reach these states by a corridor extending south from eastern Ontario to coastal South Carolina and thence down the coast to Florida.

A most important corridor for migrating black ducks extends from eastern Ontario across central New York to Chesapeake Bay. From the distribution of band recoveries, I estimate that three-fourths of the 100,000 black ducks wintering from Chesapeake Bay, Md., south through Pamlico Sound, N. C., arrive by this corridor.

About one-third of the 60,000 black ducks wintering in New Jersey appear to arrive by the corridor which extends from western Quebec down the Lake Champlain and Hudson River valleys. Probably half of New Jersey's wintering population of black ducks arrives by the corridor running down the Atlantic coast. This corridor channels about 150,000 black ducks southward, including the black ducks wintering up the coast from New Jersey. In addition, the bulk of the 80,000 green-winged teals wintering along the Atlantic Flyway use this coastal corridor from the Maritime Provinces of Canada to reach their principal wintering grounds in southeastern South Carolina, where about 60,000 congregate.

Diving Ducks

About 4,200,000 diving ducks migrate south into the United States east of the Rocky Mountains. Slightly over 60 percent of these divers are scaup ducks, mostly lesser scaups. Redheads are second in abundance, composing almost 20 percent; canvasbacks and ring-necked ducks each form about 7 percent of this population.

Western Plains Corridor. — Not only are the densities of diving duck passage along migration corridors different from those of dabbling species, but the migration corridors are arranged somewhat differently (Fig. 3). The Western Plains Corridor of the diving ducks extends along the east flank of the Rocky Mountains from eastern Alberta to the upper gulf coast of Mexico.

Rough approximations of the diving ducks following the Western Plains Corridor are: lesser scaups, 50,000; redheads, 15,000; and canvasbacks, 5,000. Most of the redheads using the lower half of this corridor originate from breeding grounds in the Great Salt Lake basin of Utah.

Mid-Plains Corridor. — The Mid-Plains Corridor for diving ducks extends from western Saskatchewan to the lower Texas coast between Aransas Pass and Brownsville. About 150,000 lesser scaups and 5,000 canvasbacks follow this corridor. Radar at Brownsville, Texas, indicates that most of these ducks proceed south along the Gulf Coast to winter in Mexico. Only 8,000 scaups and 2,000 canvasbacks winter along the Aransas Pass-Brownsville stretch of coast.

Eastern Plains Corridor. — The Eastern Plains Corridor for diving ducks differs in directional axis from that of the dabblers. This corridor extends almost north-south from western Manitoba and eastern Saskatchewan to the Texas coast below Matagorda Bay. Of the 450,000 divers using this corridor fully 95 percent are redheads. Indeed, almost three-fourths of the redheads in North America fly along this corridor to reach their wintering grounds on the Laguna Madre along the Texas and Mexican coast. About 15,000 lesser scaups and 6,000 canvasbacks join the 425,000 redheads using this corridor.

East Texas Corridor. — Between the Eastern

Fig. 3.—The migration corridors used by diving ducks during their fall migrations.

Plains Corridor and the Missouri River Corridor is a small, wedge-shaped corridor used by about 55,000 divers in migration from lakes in the eastern Dakotas to the Texas coast between Sabine Lake and Matagorda Bay. Practically no redheads migrate along this corridor, but about 50,000 lesser scaups, 4,000 ring-necked ducks, and 2,000 canvasbacks use it.

Missouri River Corridor. — The Missouri River Corridor for diving ducks enters North Dakota farther east than its counterpart for dabbling ducks. It extends through the Waubay Hills of northeastern South Dakota to the vicinity of Kansas City, Mo., where the corridor divides three ways: one branch continues almost straight south to the gulf coast of western Louisiana, the second branch swings southeasterly to lakes Pontchartrain and Borgne in eastern Louisiana, and a third branch follows the Missouri River eastward across Missouri.

Above Kansas City, Mo., this corridor is used by about 175,000 lesser scaups, 50,000 ring-necked ducks, 2,000 redheads, and lesser numbers of canvasbacks. Perhaps 30,000 of the lesser scaups turn eastward at Kansas City along with about 5,000 ring-necked ducks. It seems probable that the remaining population of lesser scaups, some 145,000, divides about equally between the south and southeast branches of the corridor. The remaining 45,000 ring-necked ducks follow the south branch to the Lacassine National Wildlife Refuge in southwestern Louisiana. Most of the canvasbacks and redheads follow the southeast branch to southeastern Louisiana.

Prairie Corridor. — Between the Missouri River and Mississippi River corridors is a smaller flight corridor used by perhaps 20,000 lesser scaups and 5,000 ring-necked ducks to pass from southwestern Minnesota across central Iowa, Missouri, and Arkansas to the Louisiana coast.

Mississippi River Corridor. — The diving duck corridor most comparable to the Mississippi River Corridor for dabbling ducks enters the United States farther east in northwestern Minnesota from lakes Manitoba and Winnipeg in Manitoba. This corridor divides in central Minnesota, one branch taking an east-southeast direction, the other branch continuing south-southeast to where the Mississippi River borders southern Iowa.

The key concentration point of the more westerly branch of this corridor is the Mississippi River's Keokuk Navigation Pool, which includes the 30 miles between Dallas City, Ill., and Keokuk, Iowa. Peak populations of diving ducks in this area (1960–1966) averaged 320,000 lesser scaups, 31,000 ring-necked ducks, and 22,000 canvasbacks. Probably twice these numbers pass through this area in the fall.

Also included in this corridor are lakes of the Illinois River valley, which lie about 100 miles east of the Mississippi River. At one time diving duck populations were higher in the Illinois valley than in the Mississippi valley. Pollution of the water diminished the food supply (Mills *et al.* 1966), resulting in a tremendous decline in the number of diving ducks in the Illinois valley. During the fall migration peak numbers now include only 13,000 lesser scaups, 12,000 ring-necked ducks, and 2,000 canvasbacks.

From this west-central area of Illinois, the Mississippi Corridor divides into two branches; the larger branch extends directly south to the Louisiana coast, and a smaller branch extends southeastward to Florida.

As judged from the direction taken by departing flocks, the branch which stretches toward Louisiana is followed by about 500,000 lesser scaups, 30,000 ring-necked ducks, and 30,000 canvasbacks. No more than 50,000 of the 500,000 lesser scaups winter north of the Gulf Coast, primarily along the lower Mississippi River; the rest winter off the coast of Louisiana, largely east of Grand Chenier and west of Marsh Island. About 10,000 ring-necked ducks go no farther than southeastern Arkansas, and 5,000 stop in central Louisiana, especially at Catahoula Lake. The remaining 15,000 ring-necked ducks winter in southeastern Louisiana, particularly in the Mississippi River delta.

About 7,500 canvasbacks winter on the Mississippi River just south of the Keokuk Navigation Pool and north of Alton, Ill. Farther south, in southeastern Arkansas, western Mississippi, and northeastern Louisiana, old oxbow lakes of the Mississippi River provide wintering areas for about 10,000 canvasbacks. Another 10,000 canvasbacks go on to winter on Wax Lake southwest of Morgan City, La.

West Florida Corridor. — The flight corridor from west-central Illinois southeastward, terminating in Florida, is followed by about 100,000 lesser scaups, 25,000 ring-necked ducks, and 10,000 canvasbacks. The first wintering area of significance for these ducks is Reelfoot Lake, Tiptonville, Tenn., and the Tennessee National Wildlife Refuge near Paris. About 3,500 scaups, 10,000 ring-necked ducks, and 2,000 canvasbacks winter on these areas. Except for those using a subbranch to Mobile Bay, most of the remaining ducks fly on to Florida.

Mobile Bay Corridors. — The subbranch extending south-southeast from Reelfoot to Mobile Bay, Ala., is used by about 7,000 ring-necked ducks, 4,500 scaups, and 3,500 canvasbacks. Most of these ducks winter in the Mobile Bay area, but about 5,000 of the 7,000 ring-necked ducks stop to winter at the Noxubee National Wildlife Refuge in eastern Mississippi.

A small flight corridor extending south from northeastern Illinois is followed by about 12,000 ring-necked ducks. Some winter at the Tennessee National Wildlife Refuge, and others continue south to the Mobile delta area.

Now we must return to Minnesota to pick up the pattern of diving duck passage to the east. The principal corridor extends east from central Minnesota across central Wisconsin to lakes Poygan, Butte des Morts, Winneconne, Winnebago, Mendota, and Michigan.

South Carolina Corridor. — From southeastern Wisconsin a corridor extends to coastal South Carolina. About 35,000 ring-necked ducks and, perhaps, several thousand lesser scaups follow this corridor.

Mid-Florida Corridor. — Radar observations at Chicago point to a large south-southeasterly departure of lesser scaups from along the Illinois and Wisconsin shore of Lake Michigan. As many as 250,000 have been known to concentrate there during the fall migration, but unknown is the proportion migrating east as opposed to south-southeast. Perhaps one-third of this population migrates southeast to Florida. Probably the bulk of the 70,000 ring-necked ducks which winter in Florida also use this corridor. An additional 15,000 ring-necked ducks reach Florida largely by way of a corridor extending from the eastern part of Michigan's upper peninsula south along the Indiana-Ohio border, across eastern Kentucky and Tennessee, and through central Georgia.

Southern Michigan Corridors. — From eastern Wisconsin the main flow of diving duck passage, other than that of the ring-necked duck, is east to east-southeast across Michigan to the Saginaw Bay and Lake St. Clair-Detroit River-Lake Erie areas.

Diving ducks congregate on Saginaw Bay to the extent that peak numbers include 22,000 lesser scaups, 22,000 redheads, and 7,000 canvasbacks. One hundred miles to the south peak populations of 380,000 lesser scaups, 260,000 canvasbacks, and 42,000 redheads have been recorded on Lake St. Clair, the Detroit River, and western Lake Erie by the Michigan Department of Conservation (1954–1958). More recent aerial surveys over Lake Erie have revealed several hundred thousand diving ducks spread as far east as Long Point, Ontario. About 8,000 scaups, 6,500 canvasbacks, and 2,000 redheads winter in the Detroit River area, but at least 700,000 diving ducks fly on from Lake Erie to wintering grounds in the Atlantic Flyway.

Central Ohio Corridor. — A flight corridor extends southward from Lake Erie to Florida. Radar observations of diving ducks moving south past Columbus, Ohio, and band recoveries from lesser scaups and redheads point to a passage of over 100,000 divers along this corridor. Most of the 75,000 redheads which usually winter in Florida stay on the upper west coast. It appears that practically all of these ducks arrive by this corridor.

During the fall of 1966 unusually large numbers of redheads appeared on Lake Erie. Subsequently, in the midwinter waterfowl population survey, 200,000 redheads were found on Apalachee Bay, Fla. The absence of an unusually large concentration of redheads during the fall along the Atlantic Coast implies that these birds flew directly south from Lake Erie to Apalachee Bay, Fla. About half of the 11,000 canvasbacks wintering in Florida also appear to use this corridor when flying south from Lake Erie.

About 358,000 scaups, almost all lesser scaups, wintered in Florida, 1960–1966. Major concentrations were: 200,000 on the Indian River, Oak Hill to Vero Beach; 60,000 on interior lakes, largely between Palatka and Orlando; 40,000 on Tampa and Sarasota bays and Charlotte Harbor. The lesser scaups wintering on the Indian River reached that area along four flight corridors: the Atlantic Coast from Chesapeake Bay, the Central Ohio from Lake Erie, the Mid-Florida from Lake Michigan, and the Mississippi River from west-central Illinois. For lesser scaups wintering elsewhere in Florida the corridors other than the Atlantic Coast are the principal passageways.

Ring-necked ducks winter largely in peninsular Florida lakes from Lake City south through Lake Okeechobee.

Chesapeake Bay Corridors. — The principal passage of diving ducks to the Atlantic Coast occurs along a corridor from Lake St. Clair, the Detroit River, and Lake Erie to Chesapeake Bay. At least 250,000 lesser scaups, 130,000 canvasbacks, and 50,000 redheads use this corridor.

Other corridors channel smaller numbers of diving ducks to Chesapeake Bay. One corridor extends southeast from Saginaw Bay, Mich.; another extends east from Saginaw Bay to the Central Lakes region of New York and then south-southeast to Chesapeake Bay.

At peak population in the fall about 13,000 diving ducks are found in the Central Lakes region of New York (including the major and minor Finger Lakes, Oneida Lake, and Montezuma Marsh) (Benson *et al.* 1957:200). The population turnover in the fall is probably several times this number, for an average of 5,000 redheads and 4,000 canvasbacks winter there, and censuses show that many thousands pass through on the way to wintering grounds on the Atlantic Coast.

Atlantic Coast Corridor. — From Chesapeake Bay tens of thousands of diving ducks migrate south along the Atlantic Coast, some as far as Florida. About 100,000 canvasbacks remain to winter in Chesapeake Bay along with 60,000 lesser scaups and 40,000 redheads. Almost 14,000 canvasbacks, 8,000 lesser scaups, and 6,000 redheads winter on Albemarle and Pamlico sounds, N. C. Along the coast of South Carolina and Georgia about 40,000 lesser scaups and 4,000 canvasbacks winter, but only 400 redheads stay there.

In addition to the corridor extending south-southeast from the Central Lakes region of New York, a corridor continues eastward to the Atlantic Coast. This is followed by an estimated 25,000 lesser scaups, and 7,000–10,000 canvasbacks.

Long Island Sound Corridor. — I have somewhat tentatively placed corridors for the passage of scaups, almost entirely greater scaups, from Lake Winnipegosis, Manitoba, across the northern reaches of Lake Superior and Georgian Bay, to the eastern end of Lake Ontario.

From the Lake Ontario–St. Lawrence River area the corridor continues southeast to Long Island Sound. Another corridor apparently brings greater scaups from Alaska and the Northwest Territories of Canada via the west coast of James Bay to Lake St. Francis (near Montreal), Lake Champlain, and Long Island Sound. The mapping of these corridors is based upon bandings of greater scaups on Long Island Sound by the New York State Conservation Department and upon field observations of duck flights over New York state.

Winter inventory estimates, 1960–1966, show that 225,000 scaups stayed between Boston and Delaware Bay. Most of these are greater scaups, according to Dirck Benson, New York State Conservation Department. He reported (personal communication) that the proportion of greater to lesser scaups varies from 6:1 in the New York City area to 10:1 off the coasts of Massachusetts, Connecticut, and Rhode Island.

It seems evident that sizeable numbers of greater scaups move from Long Island Sound southward along the Atlantic Coast as far as Florida. Small numbers of greater scaups also appear to migrate along other corridors in the company of lesser scaups to reach the southeast Atlantic Coast and the Gulf of Mexico.

Canada Geese

More than any other species of waterfowl, Canada geese have radically altered their migration routes during the past decade. This great change in migration habits has resulted from this species' rapid adaptation to newly created waterfowl refuges and feeding grounds. Since they are still in the process of evolving new migration corridors, probably this analysis of migration paths will be outmoded in a few years.

Airplane pilot and ground observer reports were especially useful in plotting migration corridors used by Canada geese. Radar observations from Buffalo; Washington, D. C.; Detroit; Cincinnati; and Evansville, Ind., also aided materially in mapping Canada goose flight routes. There were several wintering populations about which the evidence was conflicting as to the paths followed from staging areas at Hudson and James bays. Banding data suggested rather involved, circuitous routes, while observation reports suggested more direct paths. Perhaps, it was speculated, Canada geese traveled both the direct corridors (Fig. 4) and the circuitous corridors. However, the observed flight corridors were across terrain devoid of suitable habitat, and therefore, band recoveries would be few or wanting.

Because band recoveries often reflect a shift in the wintering grounds of a particular banded sample, they must be interpreted with caution. There is an intermixing of Canada goose wintering populations on staging areas at James and Hudson bays. It appears that geese that usually visit one wintering ground are frequently carried along by population elements bound for a different wintering area. Thus, band recoveries may not always reflect the flight course used by a given Canada goose population passing from a particular breeding area to a particular wintering area.

Each fall about 1,300,000 Canada geese (winter inventory plus 25 percent hunter kill, 1960–1966) leave Canada east of the Rocky Mountains for wintering grounds in the United States. The largest number, 600,000, head for wintering grounds in the Atlantic Flyway; the next largest number, 475,000, head for wintering grounds in the Mississippi Flyway; and 250,000 use routes within the Central Flyway. Because the flight corridors of Canada geese generally fall within the established flyways, these flight corridors are discussed flyway by flyway. Canada goose corridors are also dealt with from east to west, because those in the east are closest to the breeding grounds.

Atlantic Flyway. — The largest passage of Canada geese, about 500,000, crosses central and western New York en route to wintering grounds along the shores of Delaware Bay, Chesapeake Bay, Back Bay, Currituck Sound, Albemarle Sound, and Mattamuskeet Lake. The most important single flight corridor is one across the central part of Lake Ontario and the Finger Lake region of central New York. The second most important corridor skirts the east end of Lake Ontario, passes over Oneida Lake, and proceeds south to Delaware and Chesapeake bays. The third most important corridor crosses the west end of Lake Ontario with most geese migrating south-southeast to Chesapeake Bay. Radar and visual observations indicate that a branch of this corridor extends straight south from Buffalo to Gadde's Pond, N. C., and the Carolina Sandhills and Santee national wildlife refuges, S. C. Band recoveries show a passage of geese from Chesapeake Bay to Gadde's Pond, Carolina Sandhills, and Santee. This population totals about 25,000 Canada geese, and it is impossible to ascertain relative numbers using the two corridors.

Small migratory movements of Canada geese occur across eastern New York, but the only significant corridor, used by perhaps 4,000 birds, is one along Lake Champlain and the Hudson River to New Jersey. A very small corridor used by about 2,000 Canada geese extends south over Tupper Lake in the west-central Adirondacks to the Delaware River valley.

A corridor used by about 10,000 geese extends from the Jack Miner Bird Sanctuary, near Kingsville, Ontario, southeast to Chesapeake Bay. A small corridor used by only a few thousand geese extends from Mosquito Creek Reservoir in northeastern Ohio and Pymatuning Reservoir in northwestern Pennsylvania to Chesapeake Bay.

About 30,000 Canada geese use a corridor that extends along the Atlantic Coast from Maine to the Pea Island National Wildlife Refuge near Nags Head, N. C. As this goose population proceeds southward, various

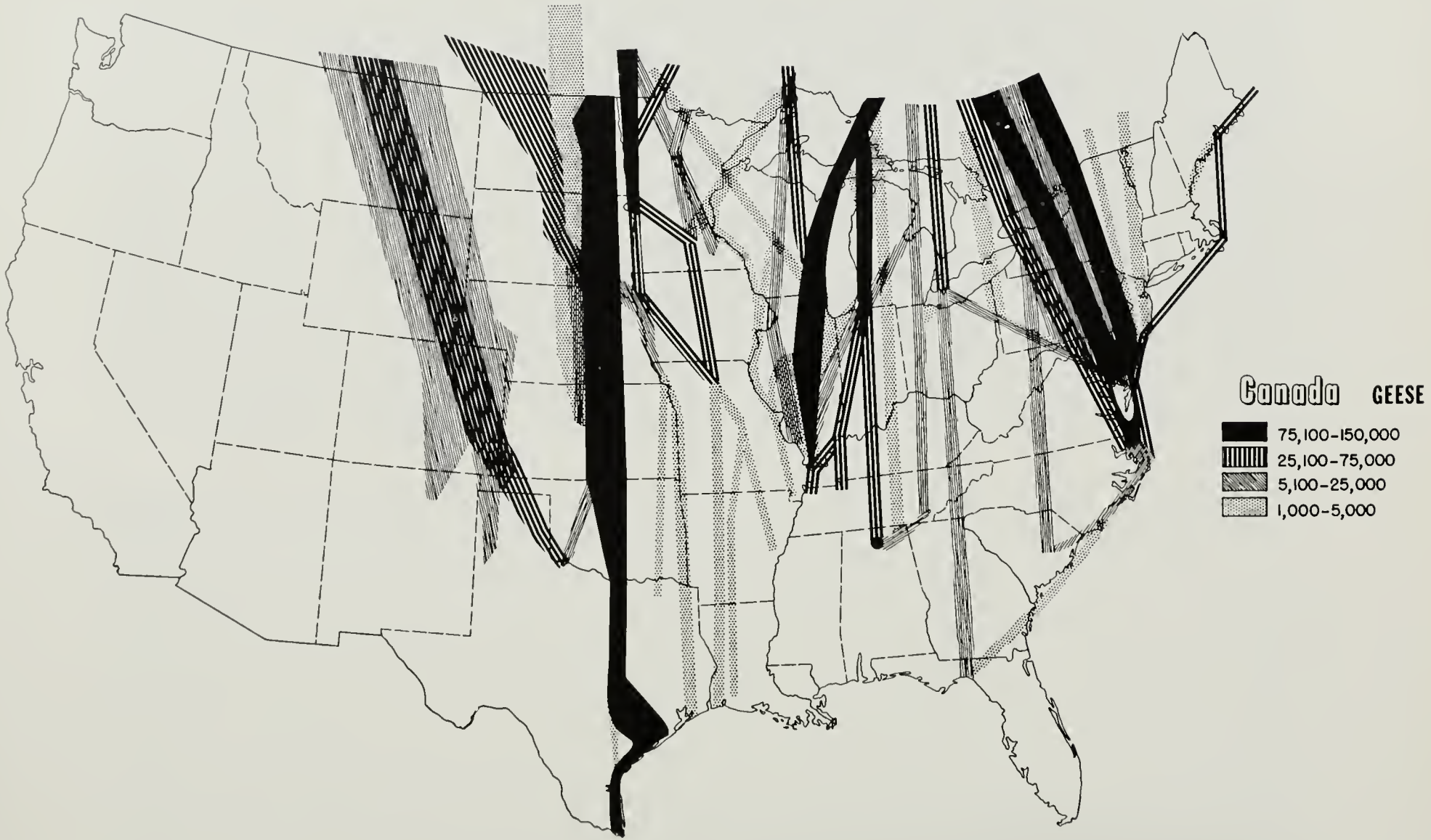

Fig. 4.—The migration corridors followed by Canada geese during their fall migrations.

elements drop off to winter at Great Bay, N. H., 2,000; Plymouth Bay, Mass., 1,000; Monomoy National Wildlife Refuge, Mass., 6,000; Long Island, 2,800; Brigantine National Wildlife Refuge and adjacent coastal areas of New Jersey, 4,500; and Pea Island, N. C., 10,000.

Mississippi Flyway. — The main migration corridor for Canada geese in the Mississippi Flyway extends down the west shore of Lake Michigan to the Horicon National Wildlife Refuge about 50 miles northwest of Milwaukee. About 150,000 Canada geese use this corridor. Upon departing from Horicon most of the geese fly slightly west of south, between the Fox and Rock rivers, and on south for 400–450 miles to three waterfowl refuges in southern Illinois located near Carbondale, Ware, and Cairo.

Another important corridor extends down the east shore of Lake Michigan. According to a study by Wilson and Weiss (1961:4), it is used by about 90,000 Canada geese. Wilson and Weiss's computations show that about 28,600 geese stopped at the Swan Creek Marsh near Fennville in southwestern Michigan, indicating that the bulk of the migrants passed without stopping.

In southwestern Michigan the Lake Michigan Corridor divides three ways. One branch swings southwestward to join the corridor in eastern Illinois extending to the Crab Orchard National Wildlife Refuge near Carbondale. A second branch extends south-southwest to the Wabash River in Indiana and follows it south to its mouth, where some flocks of geese head due south for Kentucky Lake, Tenn., and other flocks continue along the Ohio River to the Horseshoe Lake State Wildlife Refuge near Cairo, Ill. Almost 20,000 of these geese continue southward along the Mississippi River to Reelfoot Lake, Tenn. The third branch extends almost straight south from southwestern Michigan, passing over Indianapolis, Ind., and slightly east of Nashville, Tenn., to the Wheeler National Wildlife Refuge in Alabama, where about 40,000 geese winter.

A small flight corridor enters central Michigan via the Straits of Mackinac. It extends south near Petoskey and Battle Creek, Mich., and Fort Wayne, Ind.; continues east of Louisville, Ky.; and terminates at Guntersville Lake near Scottsboro, Ala. A Canada goose population of 3,000–5,000 follows this flight corridor.

A third corridor extends through eastern Michigan south to the Shiawassee National Wildlife Refuge and Saginaw Bay, where it divides. One branch, used by 10,000–15,000 Canada geese, extends to the southwest, skirts Lake Michigan, and terminates at the Crab Orchard National Wildlife Refuge near Carbondale, Ill. At the peak of migration as many as 4,000 of this group stop at the Willow Slough Wildlife Area in northwestern Indiana. The other branch continues due south, through western Ohio and near Cincinnati, to the Hiwassee Wildlife Area north of Chattanooga, Tenn., where about 5,000 geese winter. Some geese continue along the Tennessee River to Scottsboro, Ala., and the Wheeler National Wildlife Refuge at Decatur, Ala.

A fourth flight corridor extends southward from James Bay across the west end of Manitoulin Island and down Lake Huron to a refuge near Pontiac, Mich., and the Jack Miner Bird Sanctuary near Kingsville, Ontario.

This corridor divides there, one branch extending south-southwest to the Lake Erie marshes of Ohio and Grand Lake near Celina, Ohio. About 4,000 winter at Grand Lake and 1,500 on the Lake Erie marshes. Pilot reports and sightings from the ground indicate that another branch extends due south from the Jack Miner Sanctuary along the Scioto River valley through central Ohio and across the Great Smoky Mountains to areas near Tallahassee, Fla., including the St. Marks National Wildlife Refuge. Band recoveries tell another story. They show the flight corridor extending from Jack Miner's to Chesapeake Bay, going south along the Atlantic Coast to Georgia, and then swinging southwestward to the Tallahassee area. About 7,500 Canada geese winter in that area, but it is difficult to determine the relative magnitudes of passage along the two corridors.

West of the large Lake Michigan corridor, a small corridor extends southwest through Wisconsin to the Necedah National Wildlife Refuge in the west-central part of that state. In continues south to the Mississippi River and across country to the Louisa unit of the Mark Twain National Wildlife Refuge near Muscatine, Iowa. From the Louisa refuge some flocks of geese continue south along the Mississippi River to a point northwest of St. Louis where they leave the river to proceed south-southeast to the Mingo National Wildlife Refuge in southeast Missouri. From 5,000 to 7,000 Canada geese stop at the peak of migration at the Necedah Refuge, and peak numbers at the Louisa refuge are from 1,000 to 2,000. About 5,000 winter at the Mingo Refuge.

Another small corridor reaches the upper Mississippi River via the north shore of Lake Superior and the St. Croix River. It follows the Mississippi to the Spring Lake National Wildlife Refuge, Savanna, Ill. From there it extends south to the lower Illinois River. About 2,000 geese follow this corridor.

A small corridor used by about 6,000 giant Canada geese runs southeast from their Manitoba breeding ground in the region between Lake Manitoba and Lake Winnipeg to their wintering ground at Silver Lake in Rochester, Minn. Another population of about 4,000 giant Canada geese migrates southeastward from the Whiteshell Provincial Park region of southeastern Manitoba to its wintering grounds on the Rock Prairie area near Beloit, Wis.

In addition to those using the Great Lakes corridors, the largest passage of Canada geese in the Mississippi Flyway moves south through western Minnesota and Iowa and eastern South Dakota to the Swan Lake Na-

tional Wildlife Refuge in north-central Missouri (Vaught & Kirsch 1966:21). The Red River provides a corridor to the Big Sioux River. About at its confluence with the Missouri River the geese turn from south to southeast and proceed across country to the Swan Lake Refuge.

Another branch of this corridor follows the Minnesota River from Big Stone Lake to near Mankato, Minn., where it turns almost due south to the Swan Lake Refuge. The importance of the Minnesota River to migrating Canada geese is shown by the fact that on the Lac qui Parle Refuge on that river from 7,000 to 12,000 geese have stopped in the past 2 years.

From 1960 to 1966 an average of 65,000 Canada geese have wintered at the Swan Lake National Wildlife Refuge, Mo., while about 8,000 have migrated farther south to winter at the White River and Holla Bend national wildlife refuges in Arkansas and in western coastal Louisiana.

Central Flyway. — Migration patterns of small Canada geese in the Great Plains have been reported by Ryder (1955), Marquardt (1962), Rutherford (1965), and MacInnes (1966). In addition, I have studied the geographic distribution of these geese as indicated by winter inventories and reports of fall populations based on coordinated censuses made along their flight paths. Indirect recovery data from bandings of Canada geese at the Sand Lake National Wildlife Refuge, S. Dak., 1952–1964, were also used in this analysis.

In addition to the small Canada geese, which nest in the Arctic, larger forms, nesting farther south, use the same flight corridors. Other flight corridors are not presented because of lack of information.

Of the two principal Canada goose corridors in the Central Flyway the easternmost was termed the tall-grass prairie route by Marquardt (1962:48–49) and the westernmost the short-grass prairie route. About 150,000 Canada geese (1961–1967) moved south from Manitoba in the region between Lake Manitoba and Lake Winnipeg down the eastern Great Plains Corridor. The first large gathering, from 12,000 to 20,000, occurs in the vicinity of Devils Lake, N. Dak. Farther south about 18,000 Canada geese concentrate at the peak of migration on the Sand Lake National Wildlife Refuge in South Dakota. From 500 to 1,500 stop in Nebraska, mostly along the Missouri River. About 5,000 gather in Kansas, largely at the Kirwin and Quivira national wildlife refuges and the Cheyenne Bottoms Wildlife Area. Just south of the Kansas border, at the Salt Plains National Wildlife Refuge in Oklahoma, about 18,000 Canada geese are found at the height of migration.

Across Oklahoma to the south the Tishomingo and Hagerman national wildlife refuges on Lake Texoma are the focal points for aggregations of about 28,000 Canada geese. Most of these small Canada geese continue southward to the Texas coast, the bulk of the migrants reaching it between Galveston and Matagorda bays. From there a sizeable number of geese move along the Gulf Coast as far south as Tampico, Vera Cruz, Mexico.

About 40,000 small Canada geese winter along the Texas coast and 5,000 along the Mexican coast. On Lake Texoma in northern Texas about 12,000 geese belonging to this population winter, largely on the Hagerman National Wildlife Refuge. Others, about 16,000, winter as far north as the Salt Plains National Wildlife Refuge in northern Oklahoma.

The westernmost of the Great Plains flight corridors for Canada geese extends from southeastern Alberta and southwestern Saskatchewan to the panhandle of Texas. A population totaling about 100,000 of these geese enters the United States to fly almost nonstop down this broad corridor complex to western Nebraska and southeastern Colorado. In the fall of 1966 about 10,000 were observed on the North Platte River in Nebraska and 48,000 in southeastern Colorado, largely on Eads, Blue, Lake Meredith, Henry, John Martin, Horse Creek, and Two Buttes reservoirs. On the average 35,000 remain to winter on these reservoirs, while about 33,000 winter farther south—5,000 in northeastern New Mexico, 8,000 at Buffalo Lake and Muleshoe national wildlife refuges in the Texas panhandle, and 20,000 at the Waggoner Ranch and Winchester Lake near Vernon, Texas. In recent years 5,000 have wintered as far north as the North Platte River in western Nebraska.

A population of perhaps 50,000 Canada geese, referred to as the Western Prairie group, migrates from the Saskatchewan River delta and other areas in Saskatchewan and Manitoba to the Fort Randall Reservoir on the Missouri River in southern South Dakota. About 28,000 occur there and on nearby Lake Andes at the peak of the fall migration; almost 18,000 winter there.

From the Fort Randall Reservoir two principal corridors are used by Canada geese migrating farther south. One corridor follows the Missouri River to the Squaw Creek National Wildlife Refuge in northwest Missouri, where, at the height of the fall flight, about 8,000 geese are found. The wintering population numbers about 4,500 Canada geese. Another 7,000 migrate farther southward to winter on the Gambill Refuge near Paris, Texas, and in southeast coastal Texas.

The other corridor, followed by about 15,000 geese, extends almost straight south from the Fort Randall Reservoir to the Cheyenne Bottoms Wildlife Area and the Kirwin and Quivira national wildlife refuges in Kansas. About 7,500 winter in these areas, and smaller numbers continue to the Salt Plains and Tishomingo national wildlife refuges in northern and southern Oklahoma, respectively. About 3,500 geese of this population winter at these two refuges, while several hundred continue south to the Texas coast to winter near Tivoli.

Almost 6,000 Canada geese nest in the Great Plains of the United States and Canada. These birds breed in numerous scattered colonies from southeastern Saskatche-

wan to central Nebraska. Most migrate only short distances along dispersed lanes of travel.

Blue and Lesser Snow Geese

Each October from 400,000 to 450,000 blue and lesser snow geese migrate through the Mississippi Flyway to reach their wintering grounds on the coastal marshes of Louisiana (Fig. 5). An additional 300,000 migrate across the Great Plains to winter along the Texas coast. Of the two principal contingents of these geese the eastern departs from southern James Bay and the western contingent from Hudson Bay between York Factory and Cape Henrietta Maria (Cooch 1955:171).

There is some variation in the migration pattern of these geese from year to year. During the last 15 years there have been 2 years, 1955 and 1959, when unusual numbers of blue and lesser snow geese appeared east of their customary flight lanes. As many as 500 blue and lesser snow geese appeared in early November, 1955, in the Lake Erie marshes of Ohio and 2,200 in the interior of that state. At the same time 4,000 were found on TVA reservoirs in Tennessee, 1,400 on TVA reservoirs in Alabama, and 1,200 in Mississippi.

The easternmost flight corridor, customarily used by small numbers of blue and lesser snow geese, runs from the south end of James Bay slightly west of south to the Lake Erie marshes of Ohio; there it turns southwestward across Indiana along the White River to the Wabash River, where it turns due south to Mobile Bay, Ala. From there the corridor turns south-southwestward to the Mississippi River delta. About 10,000–15,000 blue and snow geese follow this corridor, according to the Alabama Department of Conservation. An offshoot of this corridor is used by about 1,800 blue and snow geese which winter at the Wheeler National Wildlife Refuge, Decatur, Ala. In recent years small numbers of blue and snow geese have been observed migrating down the Chattahoochee River on the border of Alabama and Georgia.

A somewhat larger number of blue and lesser snow geese use a corridor that extends through Saginaw Bay, Mich., southwestward to the Wabash River. This corridor then follows the Wabash to its confluence with the Ohio River, follows the Ohio to the Mississippi River, and the Mississippi to its delta southeast of New Orleans.

The number of blue and lesser snow geese stopping at Saginaw Bay has varied from 700 in 1955 to 2,100 in 1956. Few stop elsewhere along this route, but many flocks are seen and heard passing down the Wabash River.

A flight corridor of approximately the same size enters Michigan east of Sault Ste. Marie. It proceeds south-southwest across Michigan, across the northeast corner of Indiana (where it passes over the Willow Slough Wildlife Area), and along the Kaskaskia River in Illinois to the Mississippi River. There it usually cuts due south across country to pick up the Mississippi again near Reelfoot Lake, Tenn.

The only consistent stopping place for blue and lesser snow geese on this corridor is the Willow Slough Wildlife Area near Morocco, Ind. Numbers resting and feeding there have averaged at their peaks about 3,600, 1954–1960.

Another corridor enters Michigan west of Sault Ste. Marie, running southwestward across Grand Traverse Bay and southern Lake Michigan. (Numerous pilots have reported these geese at 5,000–10,000 feet over the southern end of the lake.) Upon reaching the west side of Lake Michigan, it turns south-southwestward to the Kaskaskia River which it follows to the Mississippi River.

As with the migration corridors of Canada geese, the blue and lesser snow goose corridors immediately to the west of Lake Michigan are followed by more geese than are those to the east. Of the Wisconsin corridors, the one probably used by the largest number of blue and snow geese follows the Lake Michigan shore about to the Illinois border, where the corridor turns southwest to the upper Illinois River.

A large corridor also extends along the west side of Green Bay to Lake Winnebago, where its direction changes from south-southwest to almost due south, passing over the Horicon Marsh National Wildlife Refuge (where from a few hundred to several thousand geese stop) to the upper Illinois River valley.

Of all the corridors coming from James Bay, the farthest one to the west appears to extend south-southwest across the center of Lake Superior to the Keweenaw Peninsula of Michigan. There it apparently divides, one branch continuing south-southwest to central Wisconsin where it turns southward to reach the Mississippi and Illinois rivers. This branch brings at least 12,000 blue and lesser snow geese to the Mississippi River along the borders of Iowa and Missouri, and 10,000 to the Illinois River valley between Banner and Meredosia (based on peak numbers from censuses of 1954–1966). The other branch arrives at the Illinois River valley near Bureau and is used by at least 6,000 blue and snow geese.

Seldom are more than a few hundred blue and lesser snow geese observed above Dubuque, Iowa, either on the Mississippi River or migrating down it. Thus, it is apparent that most of these birds observed south of Dubuque and above St. Louis in the Mississippi River valley use this Central Wisconsin Corridor. About 10,000 geese using this corridor winter near the mouth of the Illinois River at Grafton, Ill.

This corridor continues in two branches slightly west of south through west-central Illinois and along the adjacent reach of the Mississippi River to recombine near Ste. Genevieve, Mo. It continues in the same direction across the southeast corner of Missouri and northeast

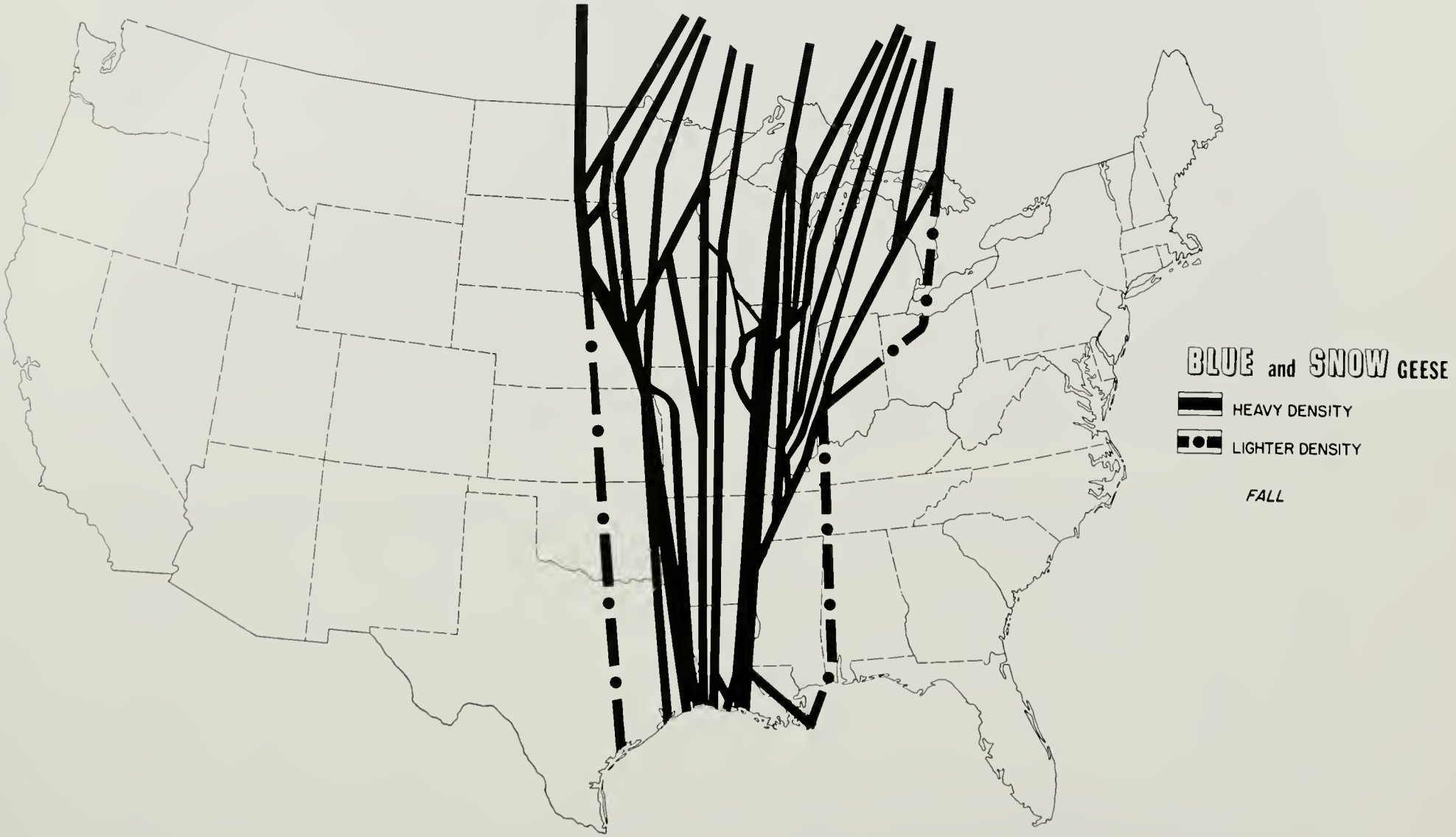

Fig. 5.—The migration corridors followed by blue and lesser snow geese during their fall migrations from staging areas on Hudson and James bays to the Gulf Coast.

corner of Arkansas to return to the Mississippi River near Rosedale, Miss. There this flight corridor is joined by one which results from the merger of several smaller corridors between the mouth of the Ohio River and Memphis, Tenn.

At this juncture this corridor probably accommodates the passage of about 150,000 blue and lesser snow geese. The corridor approximates the course of the Mississippi River, but splits about where the Louisiana border extends east of the river. One branch continues along the river to the Mississippi delta; the other branch heads directly south to Marsh Island on the coast.

The group of flight corridors used by blue and lesser snow geese west of Lake Superior appears to stem from Hudson Bay. A corridor, used by relatively small numbers of blue and snow geese, crosses the western tip of Lake Superior, proceeds over the Mississippi River near Winona, Minn., and continues south over Little Rock, Ark., and Alexandria, La., to the Gulf coastal marshes. Few of these geese stop en route, and so it is difficult to approximate the magnitude of this flight.

A second corridor, farther west, enters the United States near Ely, Minn., and divides near Duluth. One branch extends south over the Crex Meadows Wildlife Area, Wis., to the Swan Lake National Wildlife Refuge in north-central Missouri. The other branch extends south-southwest along the Minnesota River to Mankato, Minn., where it turns slightly east of south to pass over Des Moines, Iowa, on its way to the Swan Lake Refuge. There it recombines with its easterly branch. An average peak fall population of 8,000 blue and lesser snow geese occurred at the Swan Lake Refuge, 1954–1960, but probably two to three times this number passed through the area during the entire migration period.

A third corridor from Hudson Bay extends southwest over Sioux Lookout, Ontario, enters the United States near International Falls, Minn., and continues to the vicinity of Leech Lake, Minn., where it turns southward to pass over Spirit Lake, Iowa, and reach the Squaw Creek National Wildlife Refuge in northwest Missouri.

A fourth corridor extends south-southwest over Quibell, Ontario, crosses the United States-Canadian border near Rainy River, Ontario, and continues in the same direction to Lake Traverse and Big Stone Lake on the South Dakota-Minnesota border. There the corridor turns south to follow the Big Sioux and Missouri rivers to the Squaw Creek Refuge. A branch of this corridor extends to the Tewaukon National Wildlife Refuge in the southeast corner of North Dakota. It turns south there extending over the Waubay Hills of South Dakota to reach the Missouri River near Yankton, S. Dak. From 1956 to 1964 peak numbers of blue and lesser snow geese at the Tewaukon Refuge during the fall averaged about 9,000.

A fifth corridor extends south-southwest from Hudson Bay over Kenora, Ontario, and along the west shore of Lake of the Woods to the Sand Lake National Wildlife Refuge in northeastern South Dakota. The sixth corridor reaches the Sand Lake Refuge from the region between Lake Manitoba and Lake Winnipeg in Manitoba via the Devils Lake region of North Dakota and the James River.

Peak numbers of blue and lesser snow geese at the Sand Lake Refuge have averaged about 60,000 during the fall, 1954–1964. Not only is the population turnover probably two to three times this number, but numerous flocks bypass the refuge.

From the vicinity of Sand Lake National Wildlife Refuge flight corridors stretch southward across Nebraska, central Kansas, and Oklahoma to the Texas coastal plain. About 300,000 blue and lesser snow geese winter on the coastal plain of Texas (1963–1967), most (170,000) between Galveston and Corpus Christi. Only 5,500 winter between Corpus Christi and Brownsville. On the upper coastal plain, between Galveston and the Louisiana border, about 125,000 winter. Most of these geese probably arrive by flight corridors from the Squaw Creek National Wildlife Refuge in northwest Missouri.

The bulk of the blue and snow geese which funnel into the Squaw Creek Refuge come from the Sand Lake Refuge. However, other flight corridors reach Squaw Creek through the Waubay Hills of northeastern South Dakota and by way of Lake Traverse and Big Stone Lake on the western border of Minnesota. Peak populations at Squaw Creek average 55,000 geese (1954–1961), with probably two to three times this number passing through the region. The number passing through is indicated by the census of the fall of 1960 when at one time 130,000 blue and lesser snow geese were on the Squaw Creek Refuge. During late November, 1967, 120,000 blue and snow geese were estimated at the De Soto Bend National Wildlife Refuge on the Missouri River near Omaha, Nebr.

An average of 18,000 blue and lesser snow geese winter at Squaw Creek; indeed, in January of 1966, 48,000 were recorded. However, the bulk of the blue and snow geese move south from Squaw Creek to winter on the coastal plains of eastern Texas and western Louisiana.

SPRING MIGRATION PATTERNS OF BLUE AND LESSER SNOW GEESE

Much less is known about the flight corridors used by waterfowl migrating northward in the spring than is known about the corridors used in fall migrations. Band recoveries are few, not many observers are in the field, and there is much less interest in observing the northward migration of waterfowl because hunting is not involved.

However, circumstantial evidence indicates that some of the pintails migrating through California in the fall migrate northward through the western basin of the

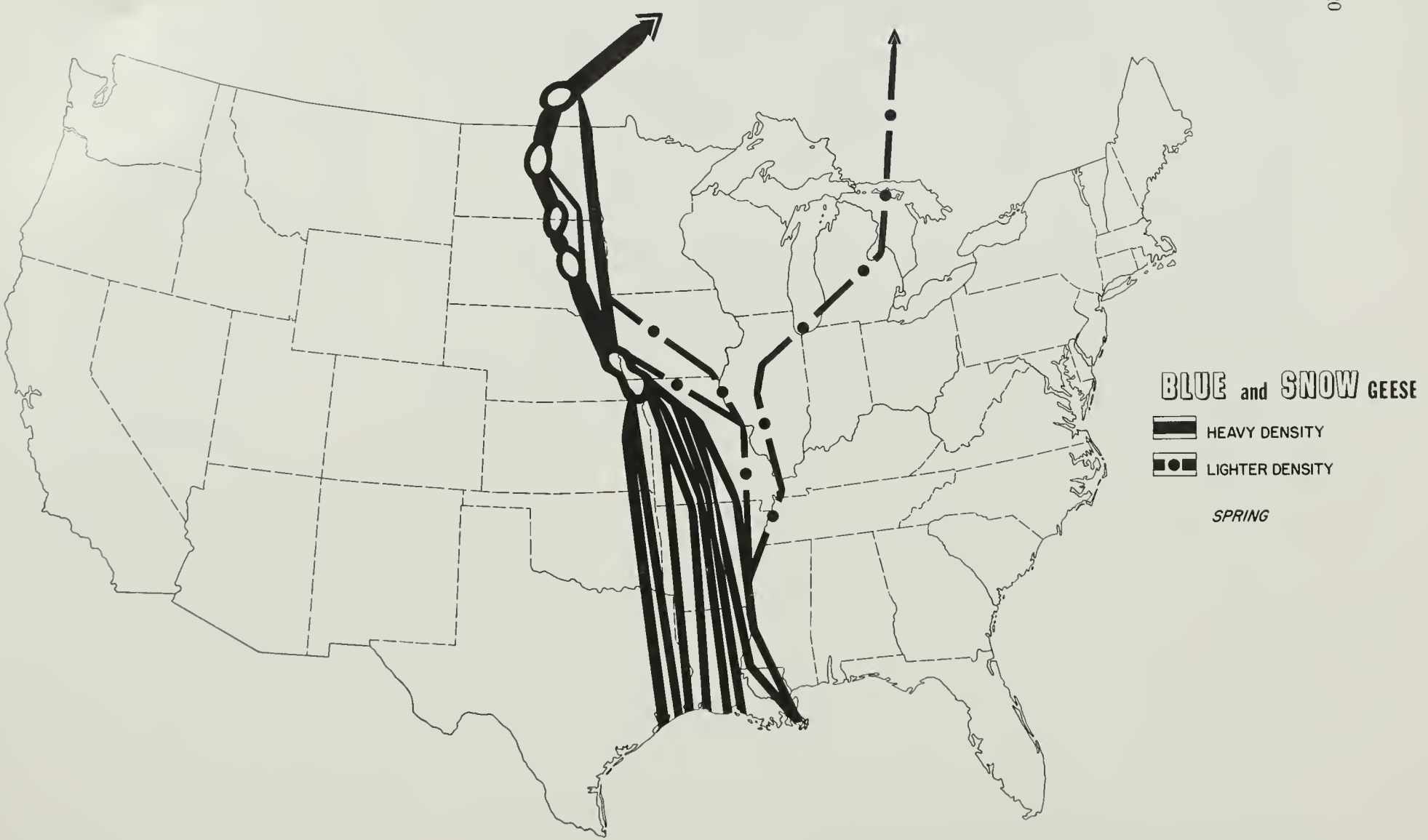

Fig. 6.—The migration corridors followed by blue and lesser snow geese during their spring migrations from the Gulf Coast to southern Canada. The areas enclosed by heavy lines between northwestern Missouri and southern Manitoba are important concentration and feeding areas.

Mississippi River in the spring (Aldrich *et al.* 1949:13–16). Radar surveillance of early spring migration of ducks indicates a pronounced northeastward movement throughout the interior of the southern and central United States. Since this is not the reverse of a comparable fall passage, it suggests that some species of ducks use one migration corridor in the fall and another in the spring. Findings from radar surveillance of spring waterfowl movements will be presented in detail in a later report.

Here I wish to describe only the spring migration of blue and lesser snow geese because it is well known and is so utterly different from the fall migration. What makes it unusual is the shift of the eastern contingent of geese westward to the Missouri River (Fig. 6).

Numerous flight corridors extend slightly west of north from points of concentration between Galveston, Texas, and the delta of the Missisippi River. As the corridors from eastern Louisiana proceed north, they turn more westward, especially in southern Missouri.

Most of the spring flight corridors focus on the Missouri River in the vicinity of the northwest Missouri and southeast Iowa borders, particularly at the Squaw Creek National Wildlife Refuge. By early March the concentration of blue and snow geese at Squaw Creek alone amounts to 200,000–250,000. Additional thousands of geese are scattered over other areas in that general region.

As the snow and ice melt in the Missouri River valley, these geese gradually move northward to the vicinity of Onawa, Iowa. From there a small branch corridor continues northward to Big Stone Lake and Lake Traverse on the Minnesota-South Dakota border. A secondary branch extends north over the Waubay Hills of South Dakota to the Tewaukon National Wildlife Refuge in southeastern North Dakota.

The bulk of the population, however, continues north-northwest from Onawa, Iowa, to the Sand Lake National Wildlife Refuge northeast of Aberdeen, S. Dak. In those springs when the ice is late leaving the Sand Lake Refuge, the geese stop about midway between Onawa and the Sand Lake Refuge in the area of De Smet, S. Dak.

Between 200,000 and 500,000 blue and snow geese stop to feed in the vicinity of the Sand Lake Refuge in the spring. Peak numbers are usually reached April 10–15. From 15,000 to 20,000 form a peak at the Tewaukon Refuge, usually about mid-April.

From Sand Lake most of this population continues up the James River valley to rest and feed in the area about Devils Lake, N. Dak. As the weather permits, they proceed northeastward to agricultural fields and water areas northwest of Winnipeg, Manitoba.

In addition to the flight corridors already described (used by 90 percent or more of the blue and lesser snow geese migrating in the spring) a small corridor follows the Mississippi River. Usually the geese using this corridor number about 5,000–15,000. They leave the river between Hannibal, Mo., and Burlington, Iowa, flying northwestward and apparently bound for the principal concentration of the species along the Missouri River.

Occasionally a small passage of blue and lesser snow geese occurs on the Illinois River. Apparently these birds leave the Illinois River near Bureau and head northeastward to Saginaw Bay, Mich. Prior to the spring of 1967 this group numbered only a few hundred. However, on March 15, 1967, an estimated 7,000 appeared in the lower Illinois River valley. On March 17 these geese moved up the valley to Clear Lake near Pekin, Ill. They departed Clear Lake the night of March 18–19. Michigan Department of Conservation biologists reported that an estimated 5,000 blue and snow geese were at Fish Point, Saginaw Bay, Mich., on March 24, and on March 28 they counted 6,400. Unknown are the exact days of arrival and departure.

The conclusion that the flock of geese at Saginaw Bay was the one that left Clear Lake is based upon the unusually large number of geese east of the Mississippi River in the spring of 1967, the similarity in estimates of the number of birds in the flock, the compatability of dates when the geese were last noted on the Illinois River and first detected at Saginaw Bay, and the absence of any flock of blue and snow geese of comparable size in Wisconsin even though biologists were alerted to watch for this flock.

SUMMARY AND DISCUSSION

Waterfowl in migration cover the breadth of the United States east of the Rocky Mountains. However, there are great differences in the densities of their passages over the country. Evidently the differences in densities of waterfowl in passage stem from the productivity and locations of the breeding grounds from which the migrations originate, the distribution of favorable habitats en route to the wintering areas, the locations and carrying capacities of the wintering grounds, and the evolutionary processes by which species reduce competition with each other. Species of waterfowl with similar food preferences appear to reduce competition by concentrating on different wintering areas (Weller 1964:99).

The migration corridors outlined in this paper represent passageways, each connecting a series of waterfowl habitats extending from the breeding grounds to the wintering grounds. The directions taken by corridors between waterfowl habitats have been deduced from band recoveries, radar surveillance, and visual sightings from the ground and from aircraft. Population estimates on migration rest areas and winter areas of concentration provide a means of determining comparative densities of passage by species.

Migration corridors differ from flyways in being smaller and more precisely defined as to species and population elements using them. I consider the fly-

ways as proposed by Lincoln (1935) to be primarily geographical and secondarily biological. Migration corridors, on the other hand, are primarily biological and secondarily geographical.

It is evident from this presentation that many flight corridors which cross a large section of the Central Flyway terminate on wintering grounds in the Mississippi Flyway. Likewise it is evident that most migration corridors leading to wintering grounds in the Atlantic Flyway first cross the Mississippi Flyway.

The migration corridors of prairie-nesting dabbling ducks tend to slope in a general northwest-southeast direction. Population elements from the eastern part of the prairie breeding grounds tend to winter on the eastern and northern fringes of the principal wintering grounds. As the prairie breeding grounds occur farther and farther west, the ducks using them tend to winter either farther and farther down the Atlantic Coast to Florida or farther and farther west and south along the Gulf of Mexico.

Unlike dabbling ducks, a large proportion of the diving ducks nesting on the Great Plains of Canada migrate east from Alberta and western Saskatchewan to eastern Saskatchewan and Manitoba before entering the United States. Therefore, their flight corridors in the United States do not slope toward the east as greatly as do those of dabbling ducks. An important exception, of course, is the large eastward passage of divers through the Great Lakes region to the northeast Atlantic Coast.

Migration corridors of ducks become increasingly complex from west to east. Those on the Great Plains are relatively simple and are shown on the basis of densities of passage and changes in species composition. The pattern of migration corridors in the Midwest becomes more complex because corridors end in wintering areas in both the Mississippi and Atlantic flyways. Important wintering grounds east of the Great Plains receive migrating ducks from two, occasionally three, and rarely, four corridors. The more corridors leading to wintering grounds, such as those in Florida, the greater the difficulty in appraising relative densities of passage in those corridors.

The flight corridors of Canada geese are more directly along a north-south axis than are those of most ducks. Consequently, the corridors of Canada geese fall within specific flyway boundaries more readily than do those of most duck species. The black duck is an exception, for its migration corridors also fall quite well into either the Mississippi or Atlantic flyways as a result of its easterly breeding grounds.

Within the last decade we have witnessed the development of hunting regulations governing the take of waterfowl for each of the four flyways. Regional adjustments have been made in the hunting regulations to bring waterfowl production and kill into greater balance between broad regions of the United States. As waterfowl management becomes more and more refined, it will become feasible to manage the kill on smaller regional bases than the present flyways. The migration corridors outlined in this paper provide bases for considering regional units smaller than flyways.

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APPENDIX

The common and scientific names of waterfowl referred to in the text are:

Geese	
Canada Goose	*Branta canadensis*
Lesser Snow Goose (Blue Goose)	*Anser caerulescens*
Dabbling Ducks	
Mallard	*Anas platyrhynchos*
Black Duck	*Anas rubripes*
Gadwall	*Anas strepera*
Pintail	*Anas acuta*
Green-winged Teal	*Anas carolinensis*
Baldpate	*Mareca americana*
Shoveler	*Spatula clypeata*
Diving Ducks	
Redhead	*Aythya americana*
Ring-necked Duck	*Aythya collaris*
Canvasback	*Aythya valisineria*
Greater Scaup	*Aythya marila*
Lesser Scaup	*Aythya affinis*

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