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Contribution from the Bureau of Biological Survey
HENRY W. HENSHAW, Chief

Washington, D. C. ▼ April 17, 1915

BIRD MIGRATION

By

WELLS W. COOKE, Assistant Biologist

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INTRODUCTION.

The mystery of bird migration has proved a fascinating subject for speculation and study from earliest times. Long ago it was noticed that birds disappeared in fall and reappeared in spring, but, not knowing where they spent the intervening period, many fanciful theories were advanced to account for their disappearance, as hibernation in hollow trees or in the mud of streams or ponds. Within the century stories were current of whole flocks that were seen to disappear beneath the waves of the Mediterranean to winter in its depths. With later years, however, has come a fuller knowledge of migration, especially of the particular region in which each species passes the cold season, and more definite information in regard to the routes followed in the spring and fall journeys. But fuller knowledge has served to increase rather than to lessen interest in the subject. More persons to-day are watching birds and noting their times of arrival and departure than ever before. Indeed, the Biological Survey has received migration notes from more than 2,000 different observers,

NOTE.—This bulletin discusses the subject of bird migration. Of interest to nature students and to investigators of the economic relation of birds to agriculture.

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showing how widespread is the recent development of this important phase of nature study.

The Survey has been collecting data on bird migration for more than 25 years. Investigations by its field naturalists extending over the North American Continent from Panama to the Arctic Circle have resulted in voluminous notes, and in addition assistance of ornithologists throughout the country has been enlisted, so that each year reports are received in spring and fall from hundreds of experienced observers. Lighthouse keepers also have supplied valuable information concerning the destruction of birds at their lights. The facts gathered—over 500,000—from these various sources form the largest amount of data on bird migration ever collected in this country and permit broader and safer generalizations than have hitherto been possible.

A knowledge of the times of migration of birds is essential as a basis for intelligent study of their economic relations and is equally necessary in formulating proper legislation for bird protection—two subjects which form important parts of the work of the Biological Survey.

CAUSES OF MIGRATION.

For more than 2,000 years the phenomena of bird migration have been noted; but while the extent and course of the routes traversed have of late become better known, no conclusive answer has been found to the question, Why do North American birds migrate? Two different and indeed diametrically opposite theories have been advanced to account for the beginnings of these migrations.

According to the more commonly accepted theory, ages ago the United States and Canada swarmed with nonmigratory bird life, long before the Arctic ice fields advancing south during the glacial era rendered uninhabitable the northern half of the continent. The birds' love of home influenced them to remain near the nesting site until the approaching ice began for the first time to produce a winter—that is, a period of inclement weather which so reduced the food supply as to compel the birds to move or starve. As the ice approached very gradually, now and then receding, these enforced retreats and absences—at first only a short distance and for a brief time—increased both in distance and duration until migration became an integral part of the very being of the bird. In other words, the formation of the habit of migration took place at the same time that changing seasons in the year replaced the continuous semitropical conditions of the preglacial eras.

As the ice advanced southward the swing to the north in spring migration was continually shortened and the fall retreat to a suitable winter home correspondingly lengthened, until during the height of the glacial period birds were for the most part confined to Middle and South America. But the habit of migration had been formed, and when the ice receded toward its present position the birds followed it northward and in time established their present long and diversified migration routes.

Those who thus argue that love of birthplace is the actuating impulse to spring migration call attention to the seeming impatience of the earliest migrants. Ducks and geese push northward with the beginnings of open water so early, so far, and so fast that many are caught by late storms and wander disconsolately over frozen ponds and rivers, preferring to risk starvation rather than to retreat. The purple martins often arrive at their nesting boxes so prematurely that the cozy home becomes a tomb if a sleet storm sweeps their winged food from the air. The bluebird's cheery warble we welcome as a harbinger of spring, often only to find later a lifeless body in some shed or outbuilding where the bird sought shelter rather than return to the sunny land so recently left.

As a matter of fact, however, only a small percentage of birds exhibit these preseasonal migration propensities. The great majority remain in the security of their winter homes until spring is so far advanced that the journey can be made easily and with comparatively slight danger; and they reach the nesting spot when a food supply is assured and all the conditions of weather and vegetation are favorable for beginning immediately the rearing of a family of young.

If, however, a longing for home is considered the main incentive to their northward flight, there arises the question as to why birds desert that home so promptly after the nesting season is over. Data recently collected at the Florida lighthouses by the Biological Survey show that southward migration begins at least by the 10th and probably as early as the 1st of July. Indeed, most birds start south as soon as the fledglings are able to shift for themselves. The orchard oriole, the redstart, and the summer warbler of central United States and the nonpareil of the South all begin their southward journey early in July, long before the fall storms sound a warning of approaching winter and when their insect menu is particularly varied and abundant.

According to the opposite migration theory, the birds' real home is the Southland; all bird life tends by overproduction to overcrowding; and, at the end of the glacial era, the birds, seeking in all directions for suitable breeding grounds with less keen competition than in their tropical winter home, gradually worked northward as the retreat of the ice made habitable vast reaches of virgin country. But the winter abiding place was still the home, and to this they returned as soon as the breeding season was over. Thus, in the case of the orchard oriole mentioned above, many individuals that arrive in southern Pennsylvania the first week in May leave by the middle of July, spending only 2½ months out of the 12 at the nesting site.

Whichever theory is accepted, the beginnings of migration ages ago undoubtedly were intimately connected with periodic changes in the food supply. While North America possesses enormous summer supplies of bird food, the birds must return south for the winter or perish. The overcrowding which would necessarily ensue should they remain in the equatorial regions is prevented by the spring exodus northward. No such movement occurs toward the corresponding southern latitudes. South America has almost no migratory land birds, for bleak Patagonia and Tierra del Fuego offer no inducements to these dwellers of the limitless forests of the Amazon.

The conclusion is inevitable that the advantages of the United States and Canada as a summer home and the superb conditions of climate and food for the successful rearing of a nestful of voracious young far overbalance the hazards and disasters of the journey thither. For these periodical trips did not just happen in their present form; each migration route, however long and complex, is but the present stage in development of a flight that at first was short, easily accomplished, and comparatively free from danger. Each lengthening of the course was adopted permanently only after experience through many generations had proved its advantages.

RELATION OF MIGRATION TO WEATHER.

It may safely be stated that the weather in the winter home has nothing to do with starting birds on the spring migration, except in the case of a few, like some of the ducks and geese, which press northward as fast as open water appears. There is no appreciable change in temperature to warn the hundred or more species of our birds which visit South America in winter that it is time to migrate. It must be a force from within, a physiological change warning them of the approach of the breeding season, that impels them to spread their wings for the long flight.

The habit of migration has been evolved through countless generations, and during this time the physical structure and habits of birds have been undergoing a process of evolution in adaptation to the climate of the summer home. In spring and early summer climatic conditions are decidedly variable, and yet there must be some period that has on the average the best weather for the birds' arrival. In the course of ages there have been developed habits of migration, under the influence of which the bird so performs its migratory movements that on the average it arrives at the nesting site at the proper time.

The word "average" needs to be emphasized. It is the average weather at a given locality that determines the average time of the bird's arrival. In obedience to physiologic promptings the bird migrates at the usual average time and proceeds northward at the usual average speed unless prevented by adverse weather. Weather conditions are not the cause of the migration of birds; but the weather, by affecting the food supply, is the chief factor which determines the average date of arrival at the breeding grounds. After the bird, in response to physiological changes, has started to migrate, the weather it encounters en route influences that migration in a subordinate way, retarding or accelerating the advance by only a few days, and having usually only slight effect upon the date of arrival at the nesting site.

Local weather conditions on the day of arrival at any stated locality are minor factors in determining the appearance of a given species at that place and time. The major factors in the problem are the weather conditions far to the southward, where the night's flight began, and the relation which that place and time bear to the average position of the bird under normal weather conditions. Many, if not most, instances of arrivals of birds under adverse weather conditions are probably explainable by the supposition that the flight was begun under favorable auspices and that later the weather changed. Migration in spring usually occurs with a rising temperature and in autumn with a falling temperature. In each case the changing temperature seems to be a more potent factor than the absolute degree of cold.

The direction and force of the winds, except as they are occasionally intimately connected with sudden and extreme variations in temperature, seem to have only a slight influence on migration.

DAY AND NIGHT MIGRANTS.

Some birds migrate by day, but most of them seek the cover of darkness. Day migrants include ducks and geese (which also migrate by night), hawks, swallows, the nighthawk, and the chimney swift. The last two, combining business and pleasure, catch their morning or evening meal during a zigzag flight that tends in the desired direction. The daily advance of such migrants covers only a few miles, and when a large body of water is encountered they pass around rather than across it. The night migrants include all the great family of warblers, the thrushes, flycatchers, vireos, orioles, tanagers, shorebirds, and most of the sparrows. They usually begin their flight soon after dark and end it before dawn, and go farther before than after midnight.

Night migration probably results in more casualties from natural causes than would occur if the birds made the same journey by day; but, on the other hand, there is a decided gain in the matter of food supply. For instance, a bird feeds all day on the north shore of the Gulf of Mexico; if, then, it waited until the next morning to make its flight across the Gulf in the daytime it would arrive on the Mexican coast at nightfall and would have to wait until the following

morning to appease its hunger. Thus there would be 36 consecutive hours without food, whereas by night migration the same journey can be performed with only a 12 hours' fast.

Migrating birds do not fly at their fastest. Their migration speed is usually from 30 to 40 miles an hour and rarely exceeds 50. Flights of a few hours a night, alternating with rests of one or more days,

FIG. 1.—Distribution and migration of the bobolink, reedbird, or ricebird (*Dolichonyx oryzivorus*). Of late years the bobolink has been extending its range into newly irrigated districts of western United States (indicated on the map by small encircled areas). Here we can witness the process of a growth in the length of a migration route. So far those individuals, which have added a thousand miles to the route and range into western Nevada, return over the old route and show no tendency to shorten the trip by a direct flight across New Mexico to the Gulf coast of Texas. (See p. 37.)

make the spring advance very slow, averaging for all species not more than 23 miles a day, but with great variations of daily rate among the different species. The exact number of miles which a particular bird makes during one day's journey has not yet been determined, and can not be ascertained until the tagging or banding of birds by means of metal rings is carried out on a far more extensive scale than has yet been possible. If migration were a steady

movement northward with the same individuals always in the van, numerous careful observations might make it possible to approximate the truth; but instead of this, most migrations are performed somewhat after the manner of a game of leapfrog. The van in spring migration is composed chiefly of old birds, and as they reach their nesting places of the previous year they remain to breed. Thus the vanguard is constantly dropping out and the forward movement must depend upon the arrival of the next corps, which may be near at hand or far in the rear. Moreover, in our present state of knowledge we can not say whether a given group of birds after a night's migration keeps in the van on succeeding nights or rests and feeds for several days and allows other groups previously in the rear to assume the lead. It is known that birds do not as a rule move rapidly when migrating in the daytime, but from the meager data available it may be inferred that the speed at night is considerably greater. During day migration the smaller land birds rarely fly faster than 20 miles an hour, though the larger birds, as cranes, geese, and ducks, move somewhat more rapidly. The result of timing nighthawks on several occasions gave a rate of 10 to 14 miles an hour, the former being the more usual speed. This slow rate results from the irregularity of the flight, caused by the birds' capturing their evening and morning meals en route. In the evening the flight lasted about an hour and a half and in the morning about an hour. Thus a distance of approximately 30 miles would be traveled by each individual during the morning and evening flights.

Night migrants probably average longer distances in most of their flights, and this is known to be the case with some species. The purple martin, during the spring of 1884, performed almost its entire migration from New Orleans to Lake Winnipeg during only 12 nights—an average of 120 miles for each night of movement—and some late migrants, like the gray-cheeked thrush, must make still greater distances at a single flight. That most of them can fly several hundred miles without stopping is proved by the fact that they make flights of 500 to 700 miles across the Gulf of Mexico.

DISTANCE OF MIGRATION.

The length of the migration journey varies enormously. A few birds, like the grouse, quail, cardinal, and Carolina wren are nonmigratory. Many a bobwhite rounds out its full period of existence without ever going 10 miles from the nest where it was hatched. Some other species migrate so short a distance that the movement is scarcely noticeable. Thus, meadowlarks are found near New York City all the year, but probably the individuals nesting in that region pass a little farther south for the winter and their places are taken by migrants from farther north. Or part of a species may migrate and

the rest remain stationary, as in the case of the pine warbler and the black-headed grosbeak, which do not venture in winter south of the breeding range. With them fall migration is only a withdrawal from the northern and a concentration in the southern part of the summer home—the warbler in about a fourth and the grosbeak in less than an eighth of the summer area. In the case of the Maryland yellow-throat, the breeding birds of Florida are strictly nonmigratory, while in spring and fall other yellow-throats pass through Florida in their

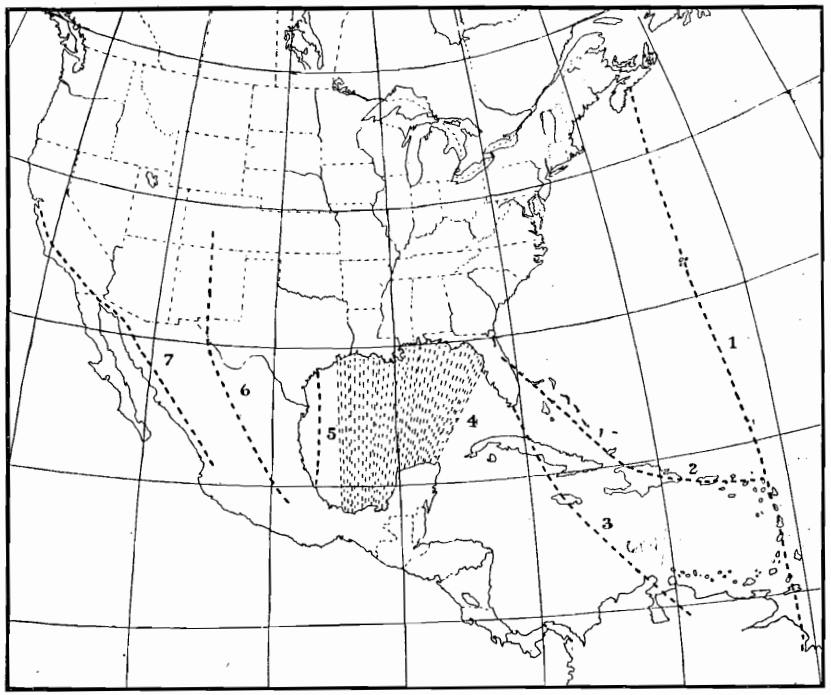


FIG. 2.—Principal migration routes of North America. Most migrants use route No. 4, though this necessitates a flight of 500 to 700 miles across the Gulf of Mexico. A few traverse the more direct route No. 3, and still fewer, route No. 2. Only water birds make the 2,400-mile flight along route No. 1, from Nova Scotia to South America. (See p. 11.)

journeys between their winter home in Cuba and their summer home in New England.

Another variation is illustrated by the robin, which occurs in the middle districts of the United States throughout the year, in Canada only in summer, and along the Gulf of Mexico only in winter. Probably no individual robin is a continuous resident in any section; but the robin that nests, let us say, in southern Missouri, spends the winter near the Gulf, while his hardy Canada-bred cousin is the winter tenant of the abandoned summer home of the southern bird.

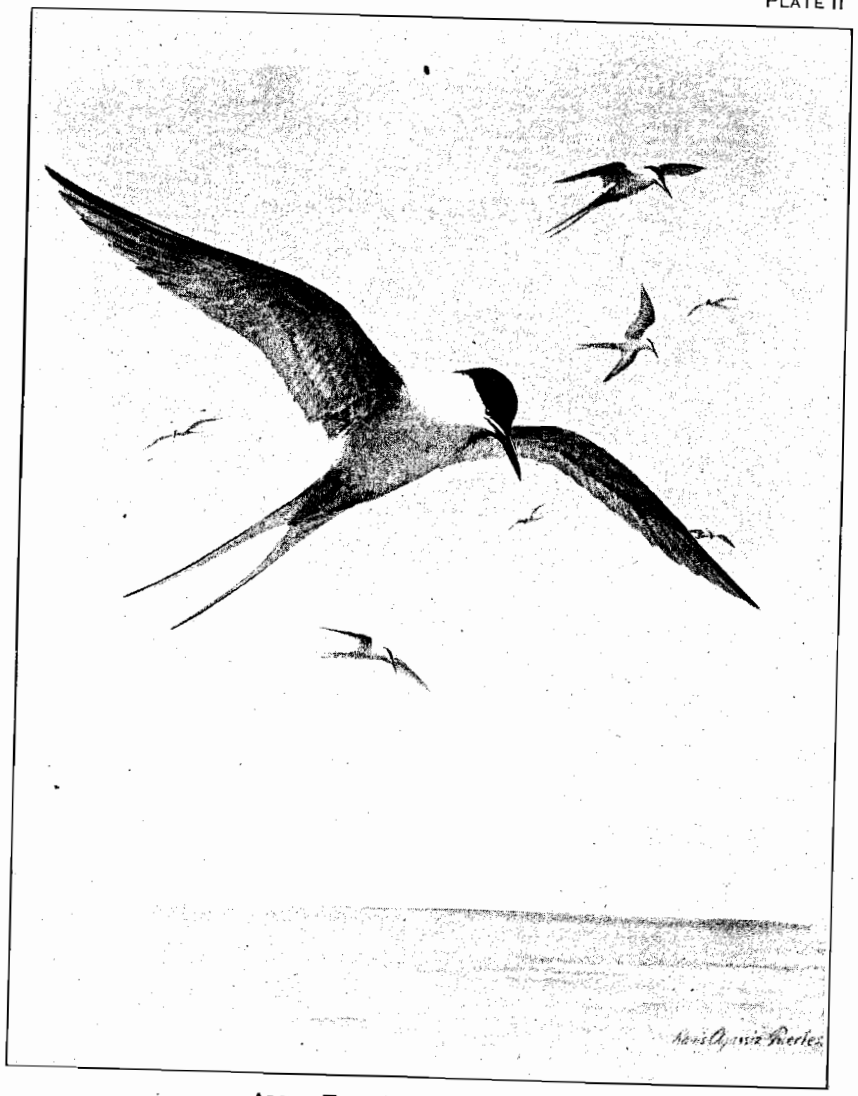
Most migratory birds desert the entire region occupied in summer for some other district adopted as a winter home. These two homes

Bul. 185, U. S. Dept. of Agriculture. PLATE I

BOBOLINK (DOLICHONYX ORYZIVORUS).

[Upper figure, male; lower, female.]

Bul. 185, U. S. Dept. of Agriculture. PLATE II



ARCTIC TERN (STERNA PARADISÆA).

are separated by very variable distances. Many species from Canada winter in the United States, as the tree sparrow, junco, and snowflake; others nesting in northern United States winter in the Gulf States, as the chipping, field, Savannah, and vesper sparrows, while more than a hundred species leave the United States for the winter and spend that season in Central or even in South America. Nor are they content with journeying to northern South America, but many cross the Equator and pass on to the pampas of Argentina and a few even to Patagonia. Among these long-distance migrants are some of our commonest birds; the scarlet tanager (Pl. IV) migrates from Canada to Peru; the bobolinks (fig. 1 and Pl. I) that nest in New England probably winter in Brazil, as do purple martins, cliff swallows, barn swallows, nighthawks, and some thrushes, which are their companions both summer and winter. The black-poll warblers that nest in Alaska winter in northern South America, at least 5,000 miles from the summer home. The land bird with the longest migration route is probably the nighthawk, which occurs north to Yukon and south, 7,000 miles away, to Argentina.

But even these distances are surpassed by some of the water birds, and notably by some of the shorebirds, which as a group have the longest migration routes of any birds. Nineteen species of shorebirds breed north of the Arctic Circle, every one of which visits South America in winter, six of them penetrating to Patagonia, a migration route more than 8,000 miles in length.

The world's migration champion, however, is the arctic tern (fig. 3 and Pl. II). It deserves its title of "arctic," for it nests as far north as land has been discovered; that is, as far north as the bird can find anything stable on which to construct its nest. Indeed, so arctic are the conditions under which it breeds that the first nest found by man in this region, only 7½° from the pole, contained a downy chick surrounded by a wall of newly fallen snow that had been scooped out of the nest by the parent. When the young are full grown the entire family leaves the Arctic and several months later they are found skirting the edge of the Antarctic continent.

What their track is over that 11,000 miles of intervening space no one knows. A few scattered individuals have been noted along the United States coast south to Long Island, but the great flocks of thousands and thousands of these terns which range from pole to pole have never been noted by an ornithologist competent to indicate their preferred route and their time schedule. The arctic terns arrive in the far north about June 15 and leave about August 25, thus staying 14 weeks at the nesting site. They probably spend a few weeks longer in the winter than in the summer home, and this would leave them scarcely 20 weeks for the round trip of 22,000 miles. Not less than 150 miles in a straight line must be their daily

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FIG. 3.—Distribution of the arctic tern (*Sterna paradisæa*), the champion long-distance migrant of the world. It breeds as far north as it can find land on which to build its nest, and winters as far south as there is open water to furnish it food. The extreme summer and winter homes are 11,000 miles apart, or a yearly round trip of 22,000 miles. (See p. 9.)

task, and this is undoubtedly multiplied several times by their zigzag twistings and turnings in pursuit of food.

The arctic tern has more hours of daylight and sunlight than any other animal on the globe. At the most northern nesting site the midnight sun has already appeared before the birds' arrival, and it never sets during their entire stay at the breeding grounds. During two months of their sojourn in the Antarctic the birds do not see a sunset, and for the rest of the time the sun dips only a little way below the horizon and broad daylight is continuous. The birds therefore have 24 hours of daylight for at least eight months in the year, and during the other four months have considerably more daylight than darkness.

ROUTES OF MIGRATION.

The shape of the land areas in the northern half of the Western Hemisphere and the nature of the surface has tended to great variations in migratory movements. If the whole area from Brazil to Canada were a plain with the general characteristics of the middle section of the Mississippi Valley, the study of bird migration would lose much of its fascination. There would be a simple rhythmical swinging of the migration pendulum back and forth, spring and fall. But much of the earth's surface between Brazil and Canada is occupied by the Gulf of Mexico, the Caribbean Sea, and parts of the Atlantic Ocean, all devoid of sustenance for land birds. The two areas of abundant food supply are North America and northern South America, separated by the comparatively small land areas of Mexico and Central America, the islands of the West Indies, and the great waste stretches of water.

The different courses taken by the birds to get around or over this intervening inhospitable region are almost as numerous as the bird families that traverse them, and only some of the more important routes will be mentioned here. (See fig. 2.)

ISLAND ROUTES.

Birds often seem eccentric in choice of route, and many do not take the shortest line. The 50 species from New England that winter in South America, instead of making the direct trip over the Atlantic involving a flight of 2,000 miles, take a somewhat longer route that follows the coast to Florida and passes thence by island or mainland to South America. What would at first sight seem to be a natural and convenient migratory highway extends from Florida through the Bahamas or Cuba to Haiti, Porto Rico, and the Lesser Antilles and thence to South America (see fig. 2, route 2). Birds that travel by this route need never be out of sight of land; resting places are afforded at convenient intervals and the distance is but little

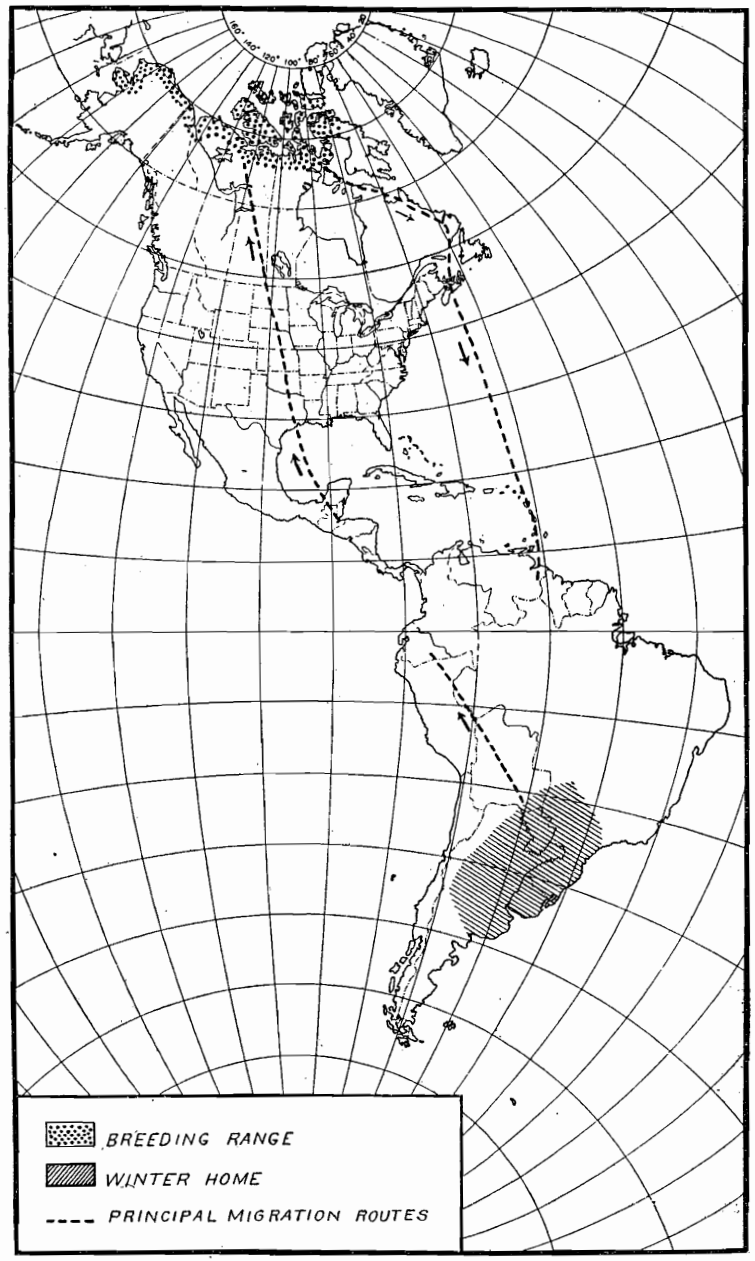

FIG. 4. Distribution and migration of the golden plover (*Charadrius dominicus*). In fall it flies over the ocean from Nova Scotia to South America, 2,400 miles—the longest known flight of any bird. In spring it returns by way of the Mississippi Valley. Thus the migration routes form an enormous ellipse, with a minor axis of 2,000 miles and a major axis stretching 8,000 miles from Arctic America to Argentina. (See p. 17.)

longer than the water route. Yet beyond Cuba this highway is little used. About 25 species continue as far as Porto Rico and remain there through the winter. Only adventurers of some six species gain the South American mainland by completing the island chain. The reason is not far to seek—scarcity of food. The total area of all the West Indies east of Porto Rico is a little less than that of Rhode Island. Should a small proportion only of the feathered inhabitants of the Eastern States select this route, not even the luxuriant fauna and flora of the Tropics could supply their needs.

A still more direct route, but one requiring longer single flights, stretches from Florida to South America via Cuba and Jamaica (see fig. 2, route 3). The 150 miles between Florida and Cuba are crossed by tens of thousands of birds of some 60 different species. About half the species take the next flight of 90 miles to the Jamaican mountains. Here a 500-mile stretch of islandless ocean confronts them, and scarcely a third of their number leave the forest-clad hills for the unseen beyond. Chief among these is the bobolink (Pl. I), which, now well fattened on fall seeds, is so full of strength and energy that the 500-mile flight to South America on the way to the waving pampas of southern Brazil seems a trifle. Indeed, many bobolinks appear to scorn the Jamaican resting point and to compass in a single flight the 700 miles from Cuba to South America. With the bobolink is an incongruous company of traveling companions—a vireo, a kingbird, and a nighthawk that summer in Florida; the chuck-will's-widow of the Gulf States; the two New England cuckoos; the gray-cheeked thrush from Quebec; the bank swallow from Labrador; and the black-poll warbler from far-off Alaska. But the bobolinks so far outnumber all the rest that the passage across the Caribbean from Cuba to South America may with propriety be called the "bobolink route." Occasionally a wood thrush or a tanager joins the assemblage, but the "bobolink route" as a whole is not popular with other birds, and, though many traverse it, they are but a fraction of the multitudes of North American birds that spend the winter in the southern continent.

GULF ROUTES.

The main-traveled highway is that which stretches from northwestern Florida across the Gulf, continuing the southwesterly direction which most of the birds of the Atlantic coast follow in journeying to Florida (see fig. 2, route 4). A larger or smaller percentage of nearly all the species bound for South America take this roundabout course, quite regardless of the several-hundred-mile flight over the Gulf of Mexico.

The birds east of the Allegheny Mountains move southwest in the fall, approximately parallel with the seacoast, and apparently keep

this same direction across the Gulf to eastern Mexico. The birds of the central Mississippi Valley go southward to and over the Gulf. The birds between the Missouri and the edge of the plains and those

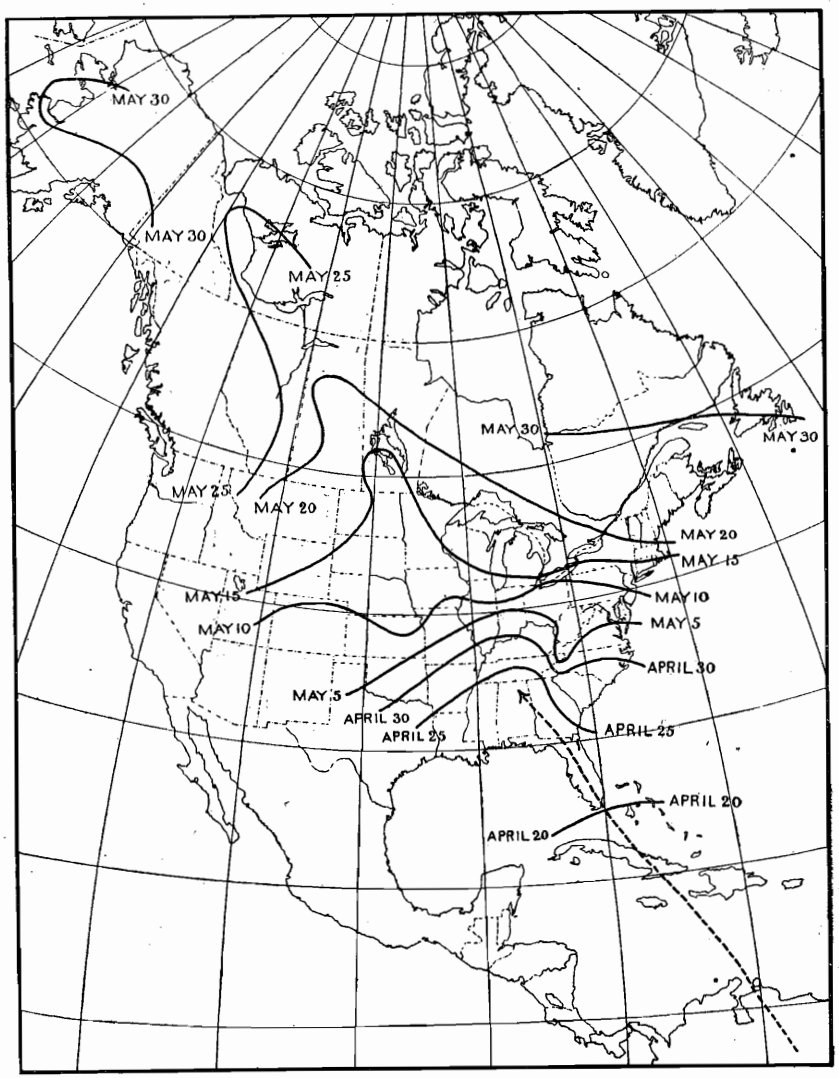

FIG. 5.—Migration of the black-poll warbler (*Dendroica striata*). This is a night migrant and flies directly across the West Indies in contradistinction to the cliff swallow (fig. 6), which is a day migrant and flies around the Gulf of Mexico (see p. 19). The heavy solid isochronal lines show the places at which birds arrive at the same time. As birds move northward, these lines are farther apart, showing that the birds are moving faster; from April 30 to May 10, the average speed is about 30 miles a day, while from May 25 to May 30 it is more than 200 miles a day. (See p. 43.)

of Canada east of the Rocky Mountains move southeastward and south until they join the others in their passage of the Gulf. In other words, the great majority of North American birds bound for a

winter's sojourn in Central or South America elect a short cut across the Gulf of Mexico in preference to a longer land journey by way of Florida or Texas. In fact, millions of birds cross the Gulf at its widest part, which necessitates a single flight of 500 to 700 miles. It might seem more natural for the birds to make a leisurely trip along the Florida coast, take a short flight to Cuba, and thence a still shorter one, of less than 100 miles to Yucatan—a route only a little longer and involving much less exposure. Indeed, the earlier naturalists, finding the same species both in Florida and in Yucatan, took this probable route for granted, and for years it has been noted in ornithological literature as one of the principal migration highways of North American birds. As a fact, it is almost deserted except for a few swallows, some shorebirds, and an occasional land bird storm driven from its accustomed course, while over the Gulf route night after night for nearly eight months in the year myriads of hardy migrants wing their way through the darkness toward an unseen destination.

To the westward a short route (see fig. 2, route 4) stretches a few hundred miles from the coast of Texas to northern Vera Cruz. It is adopted by some warblers, as the Kentucky, the worm-eating, and the golden-winged, and a few other species, which seek in this way to avoid a region scantily supplied with moist woodlands.

OTHER ROUTES.

Still farther west are two routes (see fig. 2, routes 6 and 7) which represent the land journeys of those birds from western United States that winter in Mexico and Central America. Their trips are comparatively short; most of the birds are content to stop when they reach the middle districts of Mexico and only a few pass east of the southern part of that country.

The routes as outlined on the map must not be considered as representing distinctly segregated pathways with clearly defined borders. On the contrary, they are merely convenient subdivisions of the one great flightway which extends from North to South America. There is probably no single mile in the whole east and west line from northern Mexico to the Lesser Antilles which is not crossed each fall by migrating birds. What is meant is that the great bulk of both species and individuals cross the Gulf to eastern Mexico, while to the eastward their numbers steadily diminish.

The map of the migration routes (fig. 2) shows route No. 1 that has not yet been described. It extends in an approximately north and south line from Nova Scotia to the Lesser Antilles and the northern coast of South America. Though more than a thousand miles shorter than the main migration route, it is not employed by any

land bird. But it is a favorite fall route for thousands of water birds, notable among which is the golden plover.

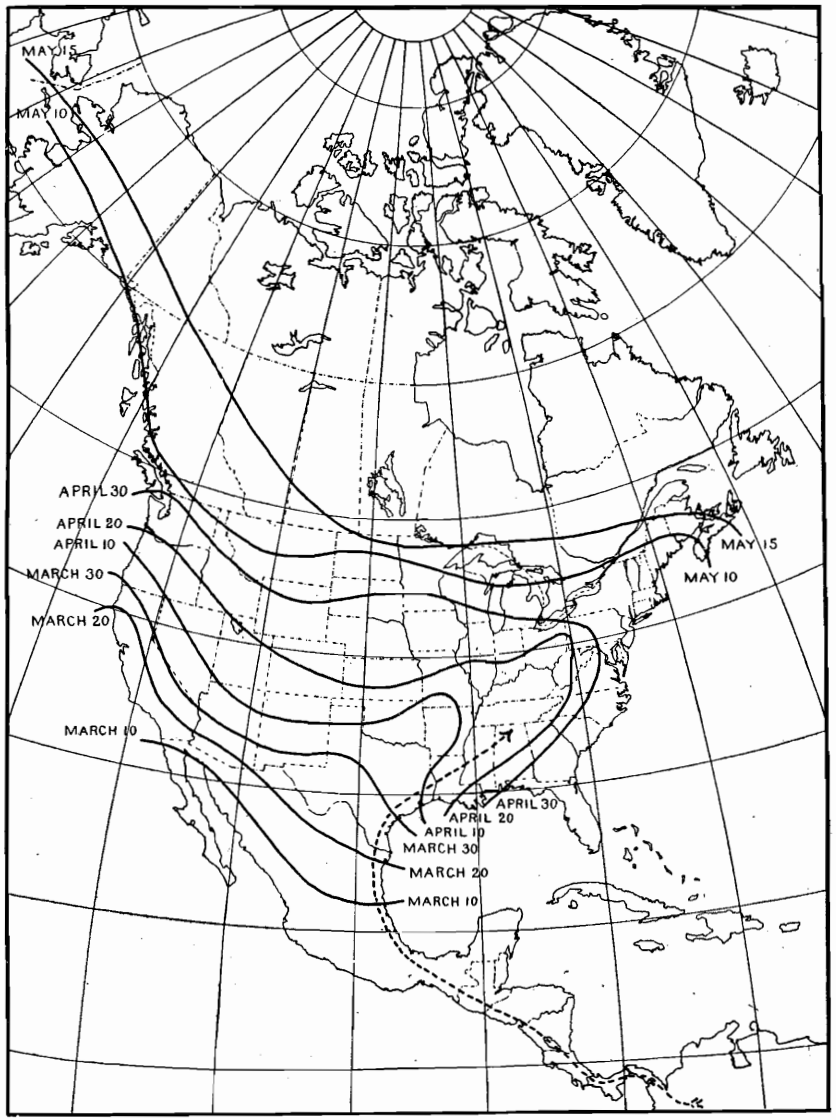

FIG. 6.—Migration of the cliff swallow (*Petrochelidon lunifrons*). This is a day migrant, feeding on the wing; hence it keeps near land and journeys around the Gulf of Mexico, instead of flying across it as is done by the black-poll warbler (fig. 5) which migrates at night. (See pp. 19 and 26.)

The journey of this plover is wonderful enough to be given in detail. Its most striking characteristics are a single flight of 2,400 miles—the longest known flight of any bird—and an elliptical migration route following different paths for the spring and the fall

migration (see fig. 4). In the first week of June the golden plover arrive at their breeding grounds on the "barren grounds" above the Arctic Circle far beyond the tree line. While the lakes are still icebound they build their shallow nests in the moss only a few inches above the frozen ground. As soon as the young are old enough to care for themselves fall migration is begun by a trip to the Labrador coast, where the plover fatten for several weeks on the abundant native fruits. Thence a short trip across the Gulf of St. Lawrence brings them to Nova Scotia, the starting point for their extraordinary ocean flight due south to the coast of South America, their objective point. In fair weather the birds fly past Bermuda without stopping, and many flocks do not pause at the first of the Antilles but keep on to the larger islands and sometimes even to the mainland of South America, accomplishing the whole 2,400 miles without pause or rest. How many days are occupied in the trip may never be known. Most migrants fly at night and rest in the day or vice versa, but the plover fly both night and day. After a short stop on the northern coast of South America they resume their journey and travel overland to the pampas of Argentina. Here they remain from September to March (the summer of the Southern Hemisphere) free from the domestic responsibilities of their northern summer home. The native birds of Argentina are at the time engrossed in family cares, but no wayfarer from the north ever nests in the south.

After a six months' vacation here the plover start back to the Arctic, but by an entirely different route. They cross northwestern South America and the Gulf of Mexico, reaching the United States along the coasts of Louisiana and Texas. Thence they move slowly up the Mississippi Valley and by early June are again at the nesting site on the Arctic coast. The round trip has taken the form of an enormous ellipse, with a minor axis of 2,000 miles and a major axis stretching 8,000 miles from Arctic America to Argentina.

The golden plover of the Atlantic Ocean, though often flying 2,400 miles continuously, could make intermediate stops if they so desired. Sometimes, when storm driven, they seek the nearest land and not infrequently appear at Cape Cod and Long Island. Some flocks stop for longer or shorter periods at Bermuda and on the islands of the Lesser Antilles. To the golden plover of the Pacific, however, no such convenient harbors of safety are available. Their flight of approximately equal length (2,000 miles) takes them across an islandless sea from Alaska to Hawaii. No matter what storms are encountered, when once they are started over the ocean they must continue to the end or perish. It seems incredible that any birds can lay a course so straight as to attain these small islands in midocean, 2,000 miles from the Aleutian Islands on the north, 2,000 miles from

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California on the east, and 3,700 miles from Japan on the west. And yet year after year golden plover in considerable numbers fly in fall

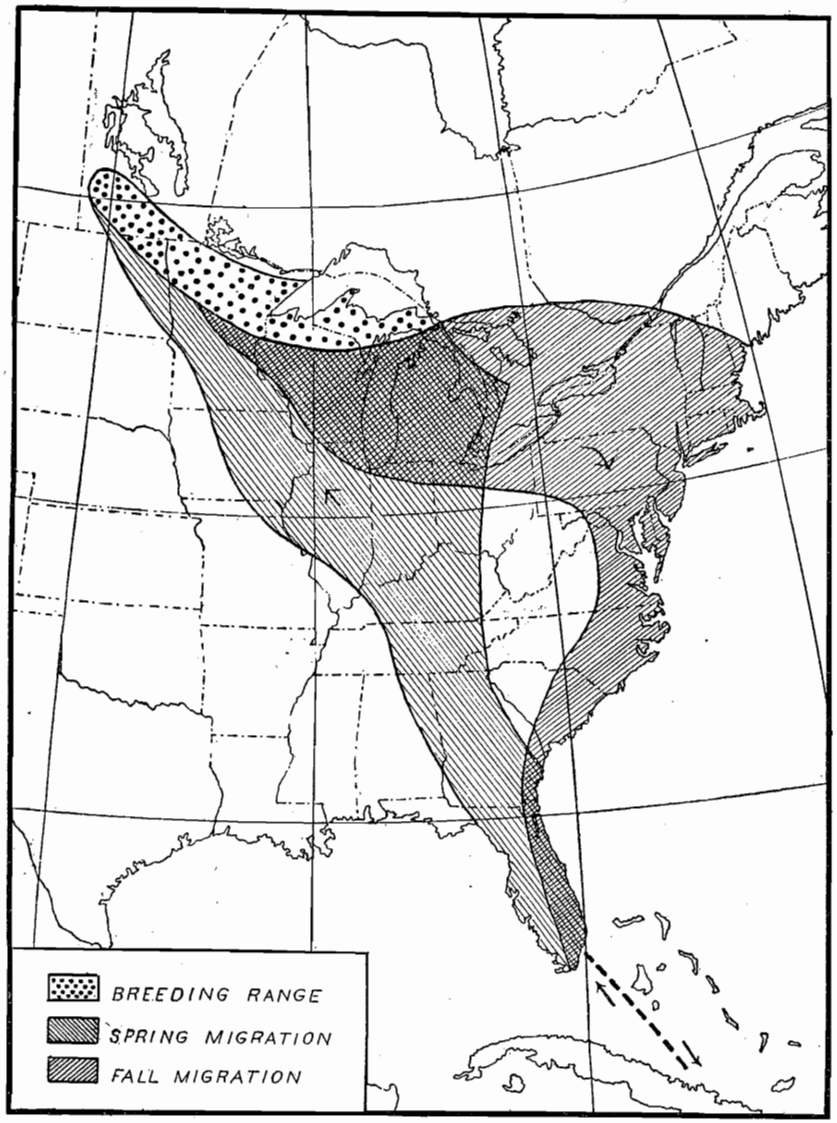

FIG. 7.—Breeding range and migration routes of the Connecticut warbler (*Oporornis agilis*). Breeding in northern United States and southern Canada, it migrates east in fall to New England, then follows the Atlantic coast to Florida and across the West Indies to the winter home in South America. In spring after its return to Florida it crosses the Allegheny Mountains and passes up the Mississippi Valley to its summer home. (See p. 21.)

from Alaska to Hawaii, spend the winter there, and the next spring wing their way back again to nest in Alaska.

DIRECT AND CIRCUITOUS MIGRATION ROUTES.

All black-poll warblers winter in South America. Those that are to nest in Alaska strike straight across the Carribbean Sea to Florida and northwestward to the Mississippi River (see fig. 5). Then the direction changes and a course is laid almost due north to northern Minnesota in order to avoid the treeless plains of North Dakota. But when the forests of the Saskatchewan are reached the northwestward course is resumed and, with a slight verging toward the west, is held until the nesting region in the Alaska spruces is attained.

Cliff swallows in South America are winter neighbors of the black-poll warblers. But when in early spring nature prompts the swallows which are to nest in Nova Scotia to seek that far-off land, situated exactly north of their winter abode, they begin their journey by a westward flight of several hundred miles to Panama. Thence they move leisurely along the western shore of the Caribbean Sea to Mexico (see fig. 6), and, still avoiding any long trip over water, go completely around the western end of the Gulf. Hence as they cross Louisiana their course is directly opposite to that in which they started. A northeasterly flight from Louisiana to Maine and an easterly one to Nova Scotia completes their spring migration. This circuitous route has increased their flight more than 2,000 miles.

Why should the swallow select a route so much more roundabout than that taken by the warbler? The explanation is simple. The warbler is a night migrant. Launching into the air soon after nightfall, it wings its way through the darkness toward some favorite lunch station, usually one to several hundred miles distant, and here it rests and feeds for several days before undertaking the next stage of its journey. Its migration consists of a series of long flights from one feeding place to the next, and naturally it takes the most direct course between stations, not avoiding any body of water that can be compassed in a single flight.

The swallow, on the other hand, is a day migrant. It begins its spring migration several weeks earlier than the warbler and catches each day's rations of flying insects during a few hours of slow evolutions, which at the same time accomplish the work of migration. Keeping along the insect-teeming shores, the 2,000 extra miles thereby added to the migration route are but a tithe of the distance the bird covers in pursuit of its daily food.

The cliff swallow spends the winter in Brazil and Argentina and breeds from Mexico to Alaska. Writing 10 years ago concerning it, the author made the following statement:

> It would be expected to reach the United States in spring first in southern Florida and Texas, later in the Rocky Mountains, and finally on the Pacific coast. As a matter of fact, the earliest records of the bird's appearance in spring come from northern

central California, where it becomes common before the first arrivals are usually noted in Texas or Florida. The route the species takes from Brazil to California is one of the yet unsolved migration puzzles.

Since the above was written much additional information has been obtained on the movements of this species, and now it is possible to

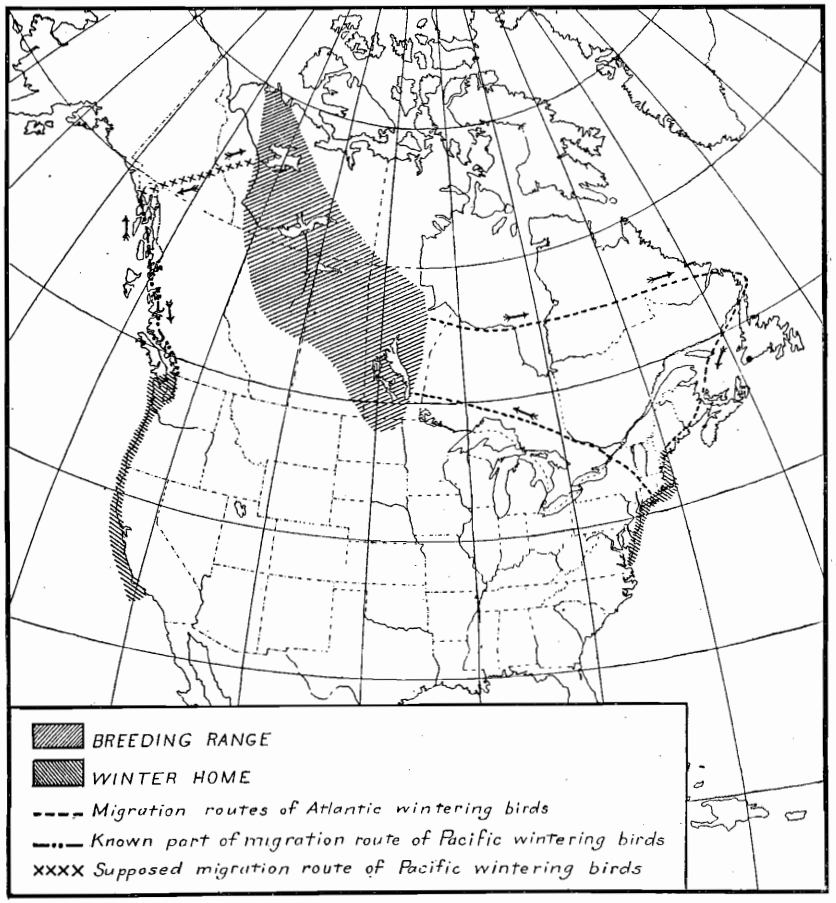

FIG. 8.—Distribution of the white-winged scoter (*Oidemia deglandi*). Birds wintering on the Atlantic coast follow an elliptical migration route, passing eastward in fall to the Labrador coast and returning the following spring by a route from Long Island Sound northwestward directly to the breeding grounds. Birds wintering on the Pacific coast are known to migrate spring and fall along the coast between Washington and southern Alaska, but where they cross the mountains can only be surmised, for they have never been noted anywhere on the 500-mile strip between the Pacific Ocean and the Mackenzie River, and apparently this part of the migration route is accomplished at a single flight. (See p. 21).

solve this migration puzzle. It is now known that the cliff swallows go around the Gulf of Mexico instead of across it. The isochronal lines on the migration map show that the birds advance along the Pacific coast of Mexico faster than along the Gulf side, so that on March 20, when the van has not quite reached the lower Rio Grande of Texas, it is already far north in California.

Bul. 185, U. S. Dept. of Agriculture. PLATE III

WHITE-WINGED SCOTER (OIDEMIA DEGLANDI).

[Lower, figure, male; upper female.]

SCARLET TANAGER (PIRANGA ERYTHROMELAS).

[Upper figure, male; lower, female.]

ECCENTRIC MIGRATION ROUTES.

The normal migration route for the birds of eastern North America is a northeast and southwest course approximately parallel with the trend of the Atlantic coast; the birds breeding in the interior take a line of flight parallel in general with the course of the three great river valleys—those of the Mississippi, the Red, and the Mackenzie—that form a highway rich in food supplies between their winter and summer homes. Many birds, however, follow migration routes widely differing from the normal. One of the most extreme exceptions is that of the marbled godwit. Formerly a common breeder in North Dakota and Saskatchewan, some individuals on starting for their winter home in Central America took a course almost due east to the Maritime Provinces of Canada and thence followed the Atlantic coast to Florida and continued southward; others went in the opposite direction, traveling westward to southern Alaska and southward along the Pacific coast to Guatemala. Thus birds which were near neighbors in summer became separated nearly 3,000 miles during migration, to settle finally in close proximity for the winter.

The Connecticut warbler, choosing another eccentric course, adopts different routes for its southward and northward journeys (see fig. 7). All the individuals of this species winter in South America, and so far as known all go and come by the same direct route between Florida and South America across the West Indies; but north of Florida the spring and fall routes diverge. The spring route leads the birds up the Mississippi Valley to their summer home in southern Canada; but fall migration begins with a 1,000-mile trip almost due east to New England, whence the coast is followed southwest to Florida. The Connecticut warbler is considered rare, but the multitudes that have struck Long Island lighthouses during October storms show that the species is at least more common than would be judged from spring observations, and also how closely it follows the coast line during fall migration. The breeding of the Connecticut warbler offers a fruitful field of investigation for some bird lover during a summer vacation, for there undoubtedly is a large and as yet undiscovered breeding area in Ontario north of Lakes Huron and Superior. Incidentally this route of the Connecticut warbler is a conclusive argument against the theory that migration routes always indicate the original pioneer path by which the birds invaded the region of their present summer homes.

Another species having an elliptical migration route is the white-winged scoter (fig. 8 and Pl. III). This duck breeds near fresh water in the interior of Canada and winters entirely on the ocean along the Atlantic and Pacific coasts of the United States. From its summer home west of Hudson Bay individuals that are to winter on the Atlantic travel 1,500 miles almost due east to the coast of the most

eastern part of Labrador; thence they cross the Gulf of St. Lawrence and follow the New England coast to their winter home, which extends from southwestern Maine to Chesapeake Bay, with the center of abundance off Long Island and Massachusetts. In spring

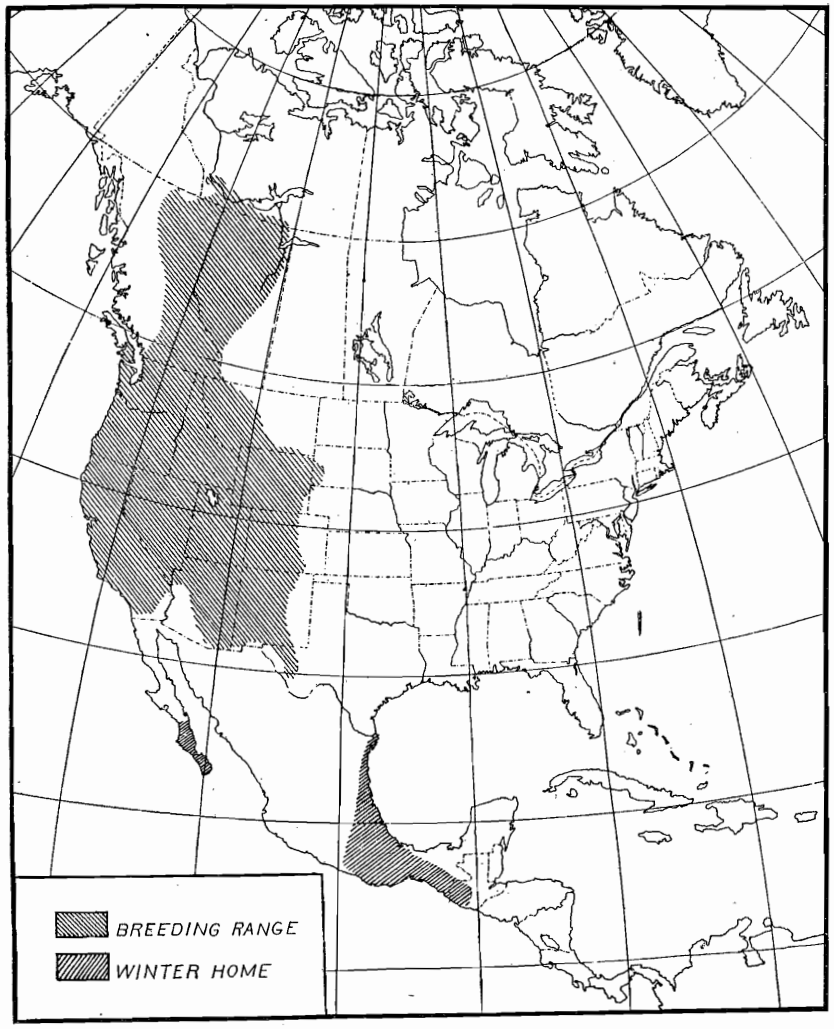

FIG. 9.—Breeding and wintering ranges of the western tanager (*Piranga ludoviciana*). It would be supposed that the birds nesting in the northeastern part of the breeding range would reach their summer home by the most direct route, through western Texas and along the eastern foothills of the Rocky Mountains. The next map (fig. 10) shows that they take a peculiarly circuitous route. (See p. 23.)

the birds return to their breeding grounds by an inland route traversing the valleys of the Connecticut, Hudson, and Ottawa Rivers. Individuals that winter along the Pacific coast from Washington to southern California are known to pass by thousands up and down the coast as far north as that coast has a generally north and south

trend; but as soon as the coast line turns westward near the northwestern point of British Columbia the birds disappear and are not known anywhere in the 500-mile strip between the Pacific coast and the Mackenzie Valley. Apparently this region is crossed at a single flight from the salt water of the coast to the fresh-water summer home on the great lakes of the Mackenzie Valley.

A migration route entirely different from any thus far mentioned is that of the western tanager, or Louisiana tanager, as it was formerly called. From its winter home in Guatemala (see fig. 9) it enters the United States about April 20; another 10 days and the van is in central New Mexico, Arizona, and southern California, marking an approximately east and west line (see fig. 10). The next 10 days the easternmost birds advance only to southern Colorado, while the western have reached northern Washington. May 10 finds the line of the van extending in a great curve from Vancouver Island northeast to central Alberta and thence southeast to northern Colorado. It is evident that the Alberta birds have not reached their breeding grounds by way of the eastern slope of the Rocky Mountains, a route which would naturally be taken for granted by anyone examining a map of the winter and summer homes. On the contrary, these Alberta breeders must have come by way of the Pacific coast to southern British Columbia and then crossed over the main range of the Rocky Mountains, which at this season (May 20) are still cold and partly covered with snow.

Still another strange migration route, probably unique, is that of the Ross snow goose (see fig. 11). This species breeds on the Arctic islands north of Mackenzie and in fall migration it travels up the valleys of the Mackenzie and Athabaska Rivers in company with thousands of other waterfowl bound for their winter homes on the coasts of eastern United States and the Gulf of Mexico. But on reaching the northern boundary of the United States the Ross goose parts company with its traveling companions, and while they continue south and southeast along the usual migration route it turns to the southwest, crosses the main range of the Rocky Mountains, and settles for the winter in California.

WIDE AND NARROW MIGRATION ROUTES.

The shape of North America tends to a converging of the lines of migration toward the Gulf of Mexico, and consequently the east and west breadth of the migration route just south of the United States is usually less than the corresponding breadth of the breeding territory. The extent to which migration routes contract varies greatly with different species. The redstart represents one extreme (see fig. 12), where the lines of migration are carried far eastward to include the Bahamas and the Antilles, while they also extend southwestward

into Mexico. Thus the migrating hosts present a broad front with an east and west extension of 2,500 miles from Mexico to the Lesser Antilles.

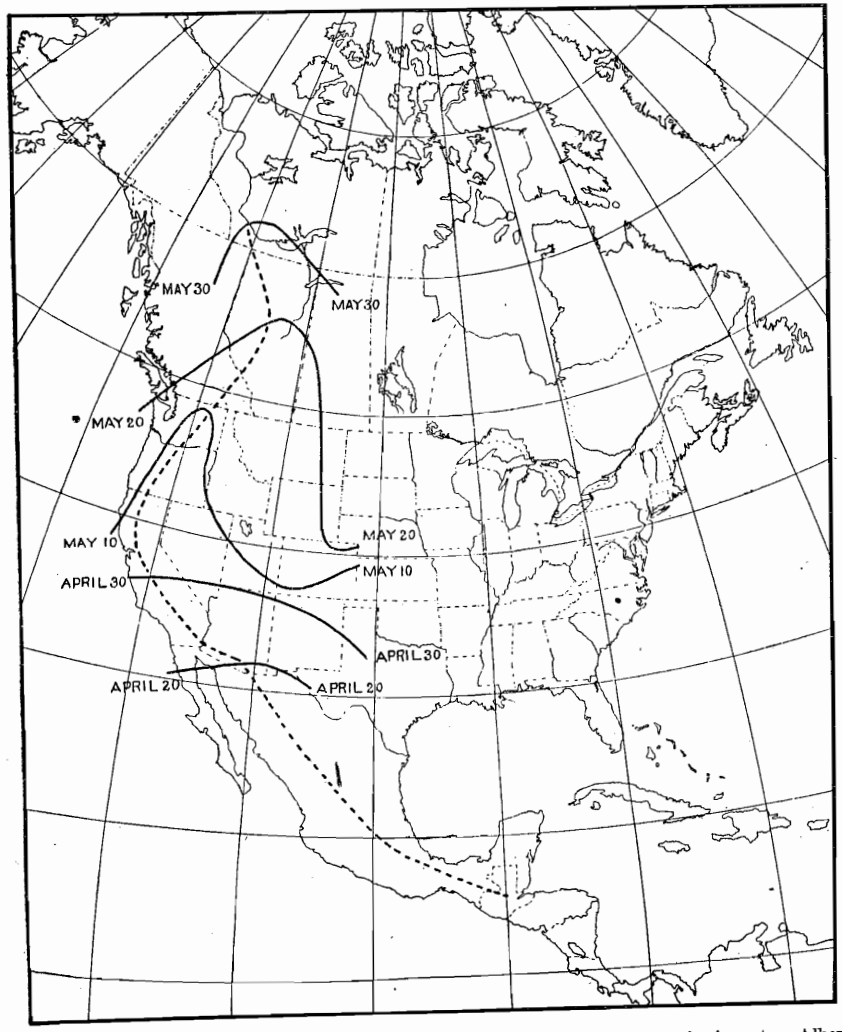

FIG. 10.—Migration of the western tanager (*Piranga ludoviciana*). The birds that arrive in eastern Alberta May 20 can not have come by way of Colorado and Wyoming, as would be expected (see fig. 9), for on this date the van of migration along the eastern foothills of the Rocky Mountains has only just reached northern Colorado. The isochronal lines of migration point to the conclusion that these birds migrate north through California and then cross the Rocky Mountains of British Columbia to Alberta, though at this season (May 20) these mountains are largely covered with snow. (See p. 23.)

The opposite extreme, a narrow migration route, appears in the case of the rose-breasted grosbeak (see fig. 13). The breeding range extends from Nova Scotia to central Alberta, 2,500 miles, and the migration lines converge until the grosbeaks leave the United States along 800 miles of the Gulf coast from western Florida to central Texas.

The case of the bobolink is typical of many species nesting in North America and wintering entirely in South America (see fig. 1). The summer home extends from Cape Breton Island to Saskatchewan, 2,300 miles, and the migration lines converge toward southeastern United States and then strike directly across the West Indies for South America. In this part of their journey the migration path contracts to an east and west breadth of about 800 miles, and a very large percentage of the birds restrict themselves to the eastern half of it. In South America the region occupied during the winter has about one-fifth the breadth and one-third the area of the breeding range.

The route of the scarlet tanager is an extreme example of narrowness of the path traveled twice a year between winter and summer homes (see fig. 14). The breeding range extends 1,900 miles from New Brunswick to Saskatchewan. The migration range is contracted to 800 miles from Florida to Texas as the birds leave the United States. The migration lines continue to converge until in southern Central America the limits are not more than 100 miles apart.

SLOW AND RAPID MIGRATION.

The black-and-white warbler presents some interesting phases of migration. It winters in Central America, Mexico, the West Indies, and the peninsula of Florida (see fig. 15). Ordinarily it would not be possible to distinguish the spring migrants in Florida from the wintering birds, and the advance of migration could not be noted until the migrants had passed north of the winter range, but records of black-and-white warblers striking lighthouses of southern Florida indicate the beginning of the birds' northward migration flight from Cuba. This occurs on the average on March 4, and the birds do not appear in southern Georgia beyond their winter range on the average until March 24. Thus a period of 20 days is taken for the van of migration to move 400 miles across Florida, an average rate of 20 miles per day. This rate is about the slowest of all North American birds and is only slightly increased throughout the whole spring migration up the Atlantic coast to Nova Scotia (see fig. 16), where the birds arrive about May 20, having averaged less than 25 miles a day for the whole 77 days after leaving Cuba.

Migration along the western border of the range is fully as slow as along the Atlantic coast; on the average, the first arrive at Kerrville, Tex., March 9 and in northern North Dakota May 10, having traveled 1,300 miles in 60 days, or 22 miles a day. Thence the speed is more than doubled to the northwestern limit of the range in the Mackenzie Valley. (See fig. 16.)

Incidentally it may be remarked that the black-and-white warbler is one of the very few migrants which arrive in Texas and Florida before they appear at the mouth of the Mississippi. The van of most species reaches southern Louisiana earlier than southern Texas.

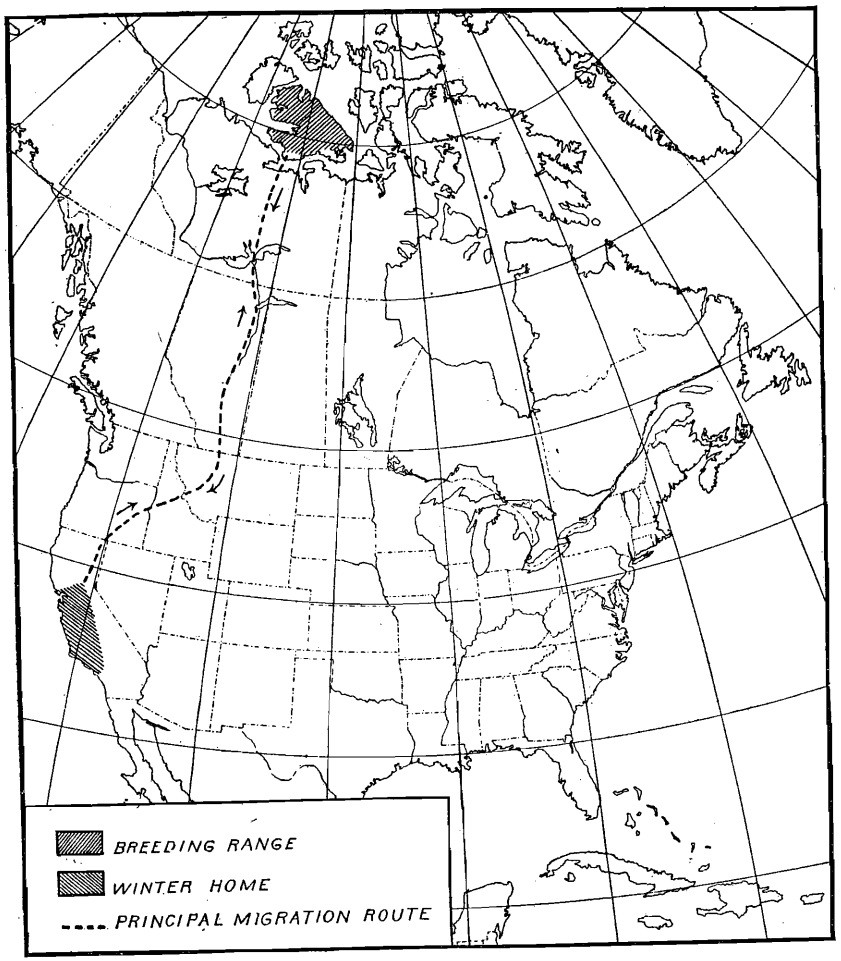

FIG. 11.—Distribution and migration of the Ross snow goose (*Chen rossi*). This is apparently the only species that breeds on the Arctic islands, migrates south in fall through the Mackenzie Valley, and when it reaches the United States, instead of passing south and east to the Mississippi Valley, turns westward, crosses the Rocky Mountains, and winters in California. (See p. 23.)

The cliff swallow is another species with a slow migration schedule (see fig. 6). It must start northward very early, since by March 10 it is already 2,500 miles from the winter home and yet averages only 25 miles a day for the next 20 days while rounding the western end of the Gulf of Mexico. It more than doubles this rate while passing up the Mississippi and Ohio River valleys. The crossing of the Alleghenies comes next, and there are only 200 miles of progress

to show for the 10 days' flight. By this time spring has really come east of the Alleghenies, and the swallow travels 60 miles a day to its summer home in Nova Scotia. It is to be noted that the swallow works up to high rates of speed only when it is traveling on the diagonal, and that except during the 10 days spent in crossing the mountains each 10 days' travel covers approximately 5 degrees of latitude.

One of the best examples of rapid migration is that of the gray-cheeked thrush. This bird remains in its South American winter home so long that it does not appear in southern United States until late April—April 25 near the mouth of the Mississippi and April 30 in northern Florida (see fig. 17). The last week in May finds the bird in extreme northwestern Alaska, the 4,000-mile trip from Louisiana to Alaska having been performed in about 30 days, or about 130 miles a day.

Generally the later in the season a bird migrates the greater is its average speed, but not necessarily the distance covered in a single night. The early migrants encounter much bad weather and after one night's migration usually delay several days before making the next flight. The later migrant finds few nights too unfavorable for advancing, so that short flights taken on successive nights greatly raise the average migration speed.

HOW BIRDS FIND THEIR WAY.

How do migrating birds find their way? They do not journey haphazard, for the familiar inhabitants of our dooryard martin boxes will return next year to these same boxes, though meanwhile they have visited Brazil. If the entire distance were made overland, it might be supposed that sight and memory were the only faculties exercised. But for those birds that cross the Gulf of Mexico, and more especially for the golden plover and its ocean-crossing kindred, something more than sight is necessary. Among day migrants sight probably is the principal guide, but it is noticeable that these seldom make the long single flights so common with night migrants.

Sight undoubtedly does play a part in guiding the night journeys also. On clear nights, especially when the moon shines brightly, migrating birds fly high and the ear can scarcely distinguish their faint twitterings; if clouds overspread the heavens, the flocks pass nearer the earth and their notes are much more audible; and on very dark nights the flutter of vibrant wings may be heard but a few feet overhead. Nevertheless, something besides sight guides these travelers in the upper air. In Alaska a few years ago members of the Biological Survey on the Harriman expedition went by steamer from the island of Unalaska to Bogoslof Island, a distance of about 60 miles. A dense fog shut out every object beyond a hundred yards. When the steamer was halfway across, flocks of murres, returning to

Bogoslof after long quests for food, began to break through the fog-wall astern, fly parallel with the vessel, and disappear in the mists ahead. By chart and compass the ship was heading straight for the

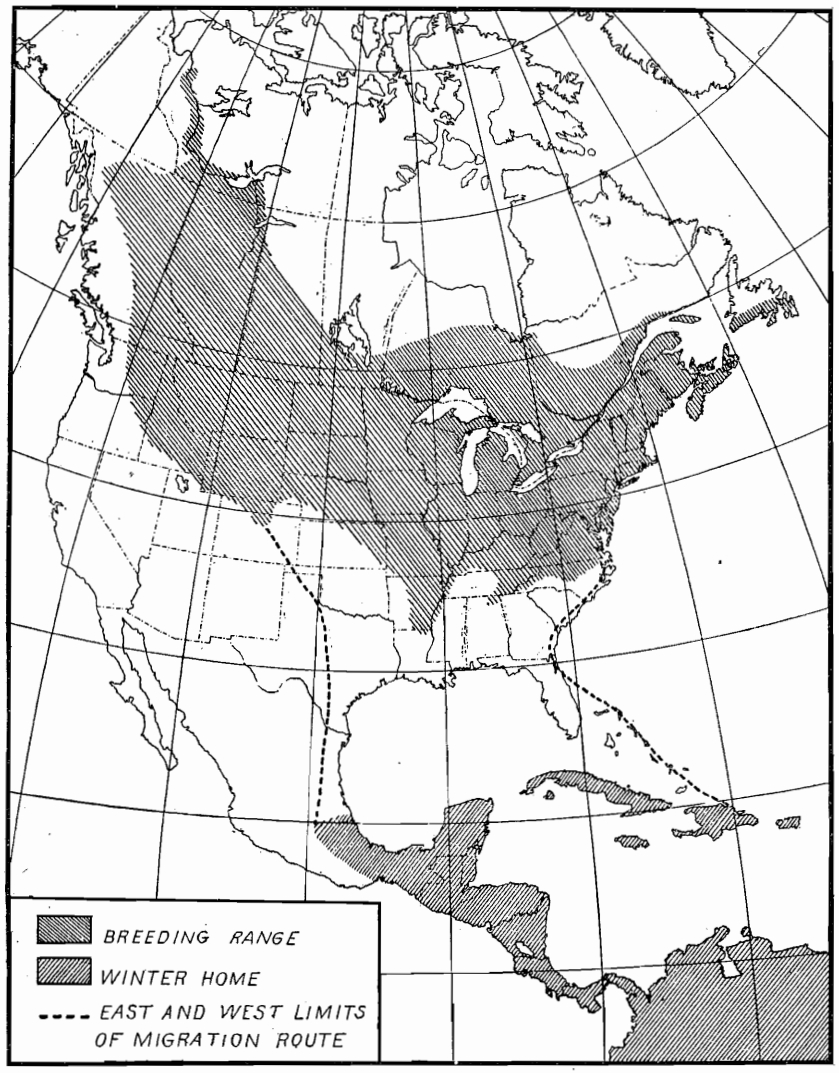

FIG. 12.—Distribution and migration of the redstart (*Setophaga ruticilla*). An example of a wide migration route. Redstarts cross all parts of the Gulf of Mexico and pass from Florida to Cuba and through the Bahamas, so that their migration route has an east and west width of more than 2,000 miles. (See p. 23.) The opposite of this (a narrow migration route) is shown by the distribution map of the rose-breasted grosbeak, fig. 13.

island, but its course was no more exact than that taken by the birds. The power which carried them unerringly home over the ocean wastes, whatever its nature, may be called a sense of direction. We recognize in ourselves the possession of some such sense, though

imperfect and frequently at fault. Doubtless a similar but vastly more acute sense enables the murres, flying from home and circling wide over the water, to keep in mind the direction of their nests and return to them without the aid of sight.

But even the birds' sense of direction is not infallible. Reports from lighthouses in southern Florida show that birds leave Cuba on cloudy nights, when they can not possibly see the Florida shores, and safely reach their destination, provided no change occurs in the weather. But at fickle equinoctial time many flocks starting out under auspicious skies find themselves suddenly caught by a tempest. Buffeted by the wind and their sense of direction lost, these birds fall easy victims to the lure of the lighthouse. Many are killed by the impact, but many more settle on the framework or foundation until the storm ceases or the coming of daylight allows them to recover their bearings.

A favorite theory of many American ornithologists is that coast lines, mountain chains, and especially the courses of the larger rivers and their tributaries form well-marked highways along which birds return to previous nesting sites. According to this theory, a bird breeding in northern Indiana would in its fall migration pass down the nearest little rivulet or creek to the Wabash River, thence to the Ohio, and reaching the Mississippi would follow its course to the Gulf of Mexico, and would use the same route reversed for the return trip in the spring. The fact is that each county in the Central States contains nesting birds which at the beginning of the fall migration scatter toward half the points of the compass; indeed, it would be safe to say all the points of the compass, as some young herons preface their regular journey south with a little pleasure trip to the unexplored north. In fall most of the migrant land birds breeding in New England move southwest in a line approximately parallel with the Allegheny Mountains, but we can not argue from this that the route is selected so that mountains will serve as a guide, because at this very time thousands of birds reared in Indiana, Illinois, and to the northwestward are crossing these mountains at right angles to visit South Carolina and Georgia. This is shown specifically in the case of the palm warblers. They winter in the Gulf States from Louisiana eastward and throughout the Greater Antilles to Porto Rico; they nest in Canada from the Mackenzie Valley to Newfoundland. To migrate according to the "lay of the land," the Louisiana palm warblers should follow up the broad open highway of the Mississippi River to its source and go thence to their breeding grounds, while the warblers of the Antilles should use the Allegheny Mountains as a guide. As a matter of fact, the Louisiana birds nest in Labrador and those from the Antilles cut diagonally across the United States to summer in central Canada. These two routes of palm warblers

cross each other in Georgia at approximately right angles. It is possible to trace the routes of the palm warblers because those nesting to the east of Hudson Bay differ enough in color from those nesting farther west to be readily distinguished even in their winter dress.

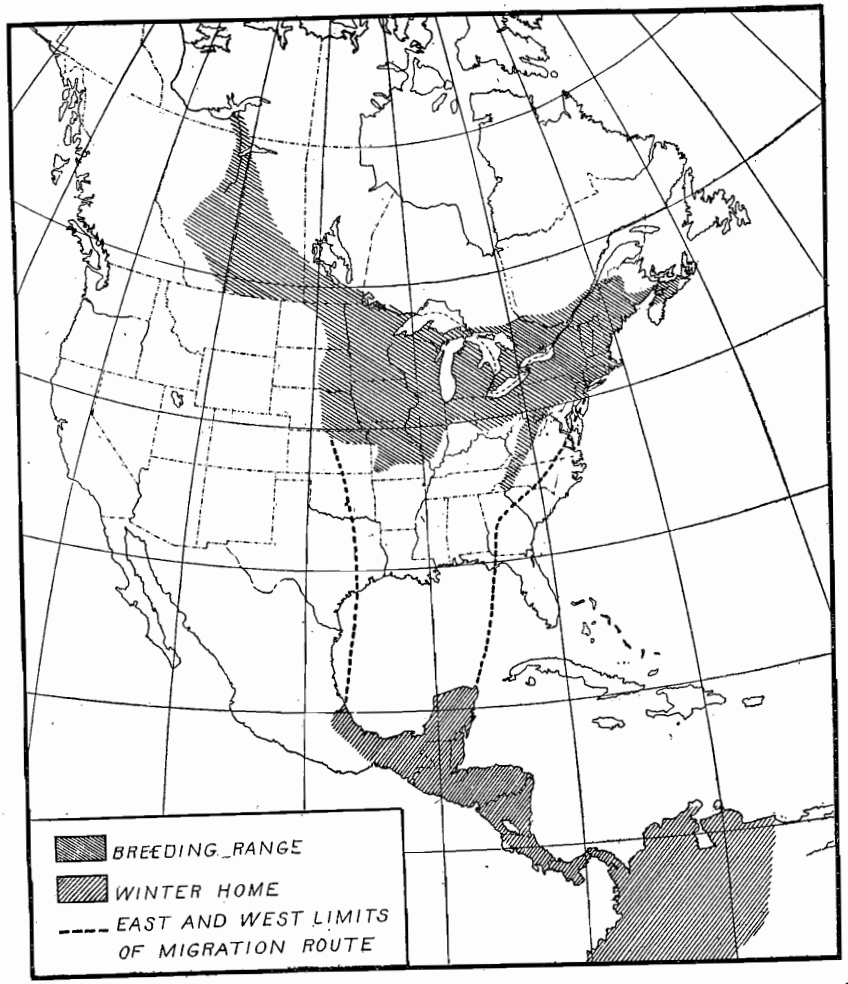

FIG. 13.—Distribution and migration of the rose-breasted grosbeak (*Zamelodia ludoviciana*). An example of a narrow migration route. The breeding range has an east and west width of 2,500 miles, while in migration the birds converge until they leave the United States along a line of the Gulf coast only 800 miles wide. (See p. 24.) The opposite of this (a wide migration route) is shown by the distribution map of the redstart, fig. 12.

It must always be remembered, however, that from a common ancestry these two groups of palm warblers came to differ in appearance because they gradually evolved differences in breeding grounds and in migration routes and not that they chose different routes because they were subspecifically different.

The truth seems to be that birds pay little attention to natural physical highways except when large bodies of water force them to deviate from the desired course. Food is the principal factor in determining migration routes, and in general the course between summer and winter homes is as straight as the birds can find and still have an abundance of food at each stopping place.

MIGRATION AND MOLTING.

It is interesting to note the relation between migration and molting. Most birds care for their young until old enough to look out for themselves, then molt, and when the new feathers are grown start on their southward journey in their new suits of clothes. But the birds that nest beyond the Arctic Circle have too short a summer to permit such leisurely movements. They begin their migration as soon as possible after the young are out of the nest and molt en route. Indeed, these Arctic breeders are so pressed for time that many of them do their courting during the period of spring migration and arrive at the breeding grounds already paired and ready for nest building, while many a robin and bluebird in the middle Mississippi Valley has been in the neighborhood of the nesting site a full month before it carries the first straw of construction.

Various peculiar changes of plumage are presented by certain species during migration. The young golden plover are white breasted as they fly over the Atlantic Ocean in fall. This has given place to jet black as they cross the Gulf of Mexico in spring. The bobolink (Pl. I) goes south in fall obscurely marked with buff and olive; he returns next spring the well-known black and white denizen of the marshes. The scarlet tanager (Pl. IV) performs his fall migration in a suit of uniform greenish yellow known to only a small number of his human friends, who welcome him as an old acquaintance when he returns the next spring in his striking black and scarlet.

CASUALTIES DURING MIGRATION.

Migration is a season full of peril for myriads of winged travelers, especially for those that cross large bodies of water. Some of the water birds making long voyages can rest on the waves if overtaken by storms, but for the luckless warbler or sparrow whose feathers become water-soaked an ocean grave is inevitable. Nor are such accidents infrequent. A few years ago on Lake Michigan a storm during spring migration forced to the waves numerous victims, as evidenced by many subsequently drifting ashore. If such mortality could occur on a lake less than 100 miles wide, how much more likely even a greater disaster attending a flight across the Gulf of Mexico. Such a catastrophe was once witnessed from the deck of a vessel 30 miles off

the mouth of the Mississippi River. Large numbers of migrating birds, mostly warblers, had accomplished nine-tenths of their long flight and were nearing land, when caught by a "norther," with which most of them were unable to contend, and falling into the Gulf they were drowned by hundreds.

During migration birds are peculiarly liable to destruction by striking high objects. The Washington Monument, at the National Capital, has witnessed the death of many little migrants; on a single morning in the spring of 1902 nearly 150 lifeless bodies were strewn

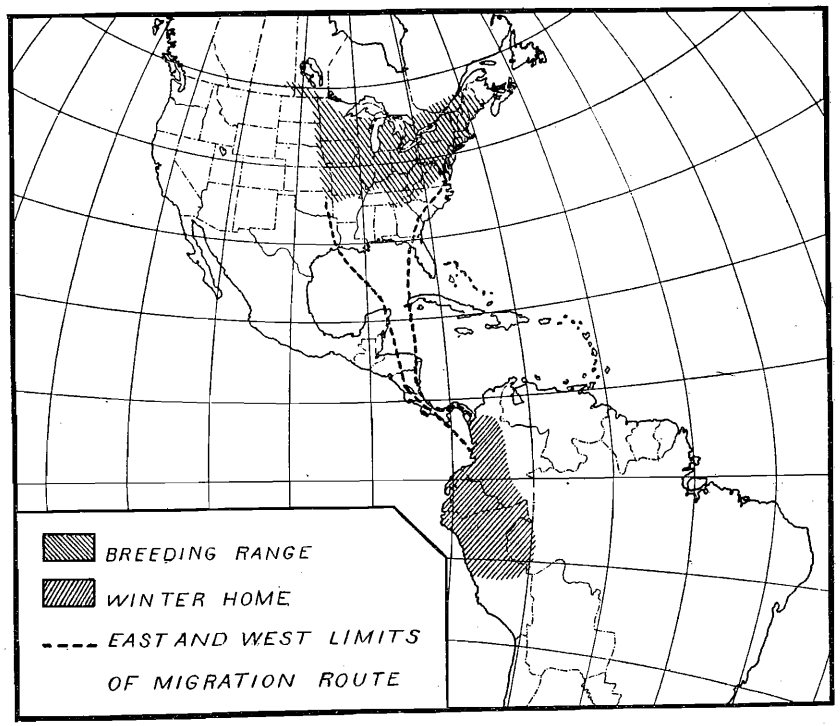

FIG. 14.—Distribution and migration of the scarlet tanager (*Piranga erythromelas*). An example of an extremely narrow migration route. The breeding range has an east and west extension of 1,900 miles. The migrating lines converge until in southern Central America the limits are not more than 100 miles apart. (See p. 25.) For a less narrow and a wide migration route see figs. 13 and 12, respectively.

around its base. As long as the torch in the Bartholdi Statue of Liberty in New York Harbor was kept lighted the sacrifice of bird life it caused was enormous, even reaching a maximum of 700 birds in a month.

Every spring the lights of the lighthouses along the coast lure to destruction myriads of birds en route from their winter homes in the South to their summer nesting places in the North. Every fall a still greater death toll is exacted when the return journey is made. Lighthouses are scattered every few miles along the more than 3,000 miles

of coast line, but two lighthouses, Fowey Rocks and Sombrero Key, cause far more bird tragedies than any others. The reason is twofold—their geographic position and the character of their lights. Both lights are situated at the southern end of Florida, where countless thousands of birds pass each year to and from Cuba; and both are lights of the first magnitude on towers 100–140 feet high. Fowey Rocks has a fixed white light, the deadliest of all. A flashing light frightens birds away and a red light is avoided by them as would be a danger signal, but a steady white light looming out of the mist or darkness seems like a magnet drawing the wanderers to destruction. Coming from any direction they veer around to the leeward side and then flying against the wind strike the glass, or more often exhaust themselves like moths fluttering in and out of the bewildering rays.

ARE BIRDS EXHAUSTED BY LONG FLIGHT?

During the spring migration of 1903 two experienced ornithologists spent the entire season on the coast of northwestern Florida, visiting every sort of bird haunt. They were eminently successful in the long list of species identified, but their enumeration is still more remarkable for what it does not contain. About 25 species of the smaller land birds of the Eastern States were not seen, including a dozen common species. Among these latter were the chat, the redstart, and the indigo bunting, three species abundant throughout the whole region to the northward. The explanation of their absence from the list seems to be that these birds, on crossing the Gulf of Mexico, flew far inland before alighting and thus passed over the observers. This would seem to disprove the popular belief that birds under ordinary circumstances find the ocean flight excessively wearisome, and that after laboring with tired pinions across the seemingly endless wastes they sink exhausted on reaching terra firma. The truth seems to be that, endowed by nature with wonderful powers of aerial locomotion, many birds under normal conditions not only cross the Gulf of Mexico at its widest point but even pass without pause over the low swampy coastal plain to the higher territory beyond.

So little averse are birds to an ocean flight that many fly from eastern Texas to the Gulf coast of southern Mexico (see fig. 2, route 5), though this 400 miles of water journey hardly shortens the distance of travel by an hour's flight. Thus birds avoid the hot, treeless plains and scant provender of southern Texas by a direct flight from the moist, insect-teeming forests of northern Texas to a similar country in southern Mexico.

That birds are not exhausted by their long flights will be evident upon consideration of the origin of these protracted journeys. All migratory movements must have begun with changes of location

which were very slight, whether over land or water. From this short migration benefit accrued to individuals or to their posterity. Migration became a fixed habit, and the distance covered gradually—very gradually—increased as each succeeding extension proved advantageous. It is not to be supposed that every attempted

FIG. 15.—Summer and winter homes of the black-and-white warbler (*Mniotilta varia*). A very slow migrant. The isochronal lines of migration indicating the rate of speed are shown in figure 16. (See p. 25.)

extension was successful; in fact, it is more probable that only a small part of the experimental pioneer routes were permanently adopted. Moreover, it must be borne in mind that the time occupied in the establishment of present migration habits and routes is to be measured by geologic ages, and there is no reason to suppose that changes took place during these ages any faster than they do

now. Therefore when one of these experimental routes proved detrimental it was abandoned.

In this connection it may be well to consider the actual amount of energy expended by birds in their migratory flights. Both the soaring and the sailing of birds show that they are proficient in the use of several factors in the art of flying that have not yet been mastered either in principle or practice by the most skillful of modern aviators. A vulture or a crane, after a few preliminary wing beats, sets its wings and mounts in wide sweeping circles to a great height, overcoming gravity with no exertion apparent to human vision even when assisted by the most powerful telescopes. The Carolina rail, or sora, has small, short wings apparently ill adapted to protracted flight, and ordinarily when forced to fly does so reluctantly and alights as soon as possible. It flies with such awkwardness and apparently becomes so quickly exhausted that at least one writer has been led to infer that most of its migration must be made on foot; the facts are, however, that the Carolina rail has one of the longest migration routes of the whole rail family and easily crosses the wide reaches of the Caribbean Sea. The humming bird, smallest of all birds, crosses the Gulf of Mexico, flying over 500 miles in a single night. As already noted, the golden plover flies from Nova Scotia to South America, and in fair weather makes the whole distance of 2,400 miles without a stop, probably requiring nearly if not quite 48 hours for the trip.

Here is an aerial machine that is far more economical of fuel—i. e., of energy—than the best aeroplane yet invented. The to-and-fro motion of the bird's wing appears to be an uneconomical way of applying power, since all the force required to bring the wing forward for the beginning of the stroke is not only wasted, but more than wasted, as it largely increases the air friction and retards the speed. On the other hand, the screw propeller of the aeroplane has no lost motion. Yet less than 2 ounces of fuel in the shape of body fat suffice to force the bird at a high rate of speed over that 2,400-mile course. A thousand-pound aeroplane, if as economical of fuel, would consume in a 20-mile flight not the gallon of gasoline required by the best machines but only a single pint.

EVOLUTION OF MIGRATION ROUTES.

It has already been stated that each of the present migration routes, however long, has probably been of slow growth from an originally short flight. In the case of many routes it is easy to trace the probable steps in evolution. Thus the route across the Gulf of Mexico, from the mouth of the Mississippi to Campeche, at the end of the glacial era was undoubtedly a trip by land through Texas. As the land now the Eastern States arose from the ocean or

was freed from the overlying ice cap, the tendency would be for the migration route at its northern end to turn and be extended eastward to enter the new and as yet uncrowded districts. The route at this stage would be a half circle, and a tendency would soon develop to shorten some of the curve through Texas by a short flight over the western end of the Gulf of Mexico. This short flight would

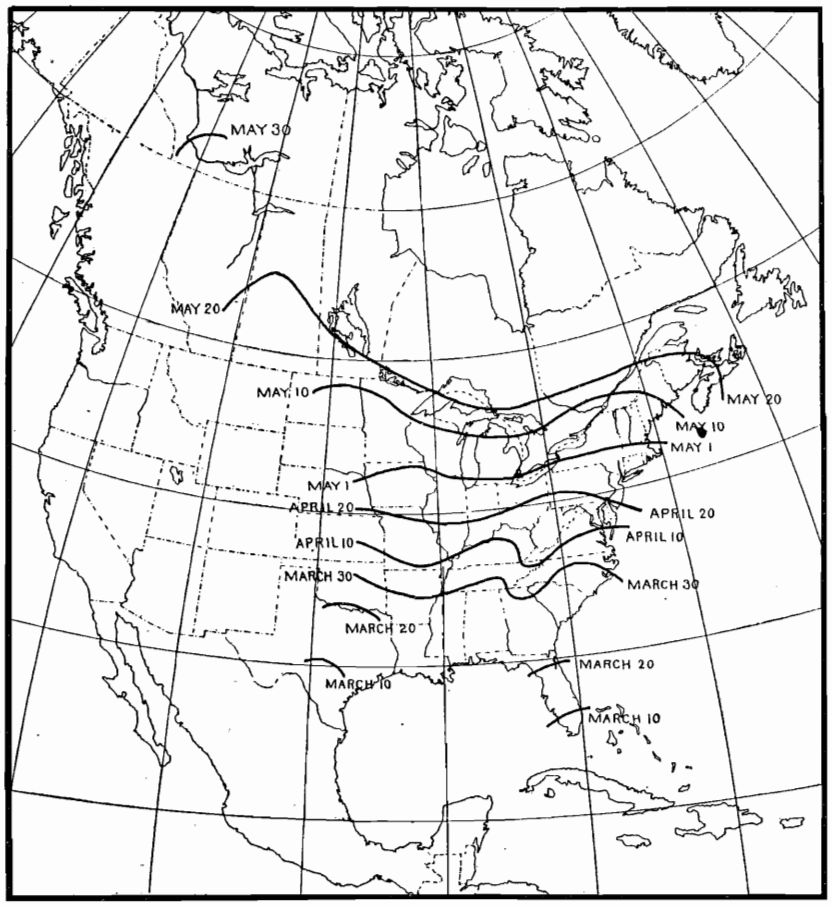

FIG. 16.—Isochronal migration lines of the black-and-white warbler (*Mniotilta varia*). An example of a slow and uniform migration. Isochronal lines indicating the advance of the van during each 10-day period of spring show an average speed of about 20 miles a day in March in Florida and about 25 miles a day for the whole trip to southeastern Canada. (See p. 25.) The opposite (a rapid migration) is shown by the gray-cheeked thrush (fig. 17).

gradually be lengthened and its points of arrival and departure at the mainland carried eastward until eventually the curve would be replaced by a straight flight across the Gulf.

Some migration routes have been so recently developed that they still plainly show their origin. The red-eyed vireo, a striking example, is a woodland bird and as such is essentially an inhabitant of the

States east of the Great Plains; but an arm of the breeding range extends northwestward to the Pacific coast in British Columbia (see fig. 18). It is evident that this is a late extension of the range, that it has taken place by a westward movement from the lower Missouri Valley section, and that the nesting birds of Washington and British Columbia retrace in spring and fall the general route by which they originally invaded the country.

The origin of this vireo's route is also indicated by the isochronal lines shown in figure 19. On March 20 the vanguard is just entering the United States from the winter home in South America. Northward progression is fairly uniform for the next 5 of the 10-day periods, carrying the birds to eastern Nebraska, southern Michigan, and southern New England. But then a change becomes evident. The eastern birds continue their lines of flight and pass almost directly to their summer homes. Some of the western-born individuals, however, begin to turn at a wide angle from their previous course and proceed on a long northwestward slant to the Pacific. It is especially to be noted that as these individuals change their course they quicken their speed until they travel on the average more than twice as far a day as their eastern brethren.

In the case of the bobolink the evolution of a new extension of the migration route is now occurring before our very eyes. By nature a lover of damp meadows, the bobolink was formerly cut off from the Western States by the intervening arid region. But with the advent of irrigation and the bringing of large areas under cultivation, little colonies of nesting bobolinks are beginning to appear here and there almost to the Pacific. Some of these colonies are shown by encircled areas on the map in figure 1, and the probability is that the not distant future will witness a large increase in the number of bobolinks west of the Rocky Mountains.

NORMAL AND ABNORMAL MIGRATION.

The relative position of the northern and southern groups of individuals of a species during the two yearly migrations is one of the obscure points that late investigations help to elucidate. The supposition is that in the case of species which adopt what may be called normal fall migration, birds which nest farthest south migrate first and proceed to the southern end of the winter range; those that breed in the middle districts migrate next and occupy the middle of the winter range; and, finally, those of the northern part of the breeding range migrate last and remain farthest north for the winter. In other words, the migration is a southward movement of the whole species during which the different groups of individuals or colonies retain in general their relative positions. This has been commonly believed, but only of late has it been clearly proved for any particular species.

An example or two will make this clear. The black-and-white warbler breeds from South Carolina to New Brunswick (see fig. 15). In the southern part of its range it nests in April. New Brunswick, however, is scarcely reached by the earliest birds before the middle of May (see fig. 16), as the species occupies about 50 days in crossing

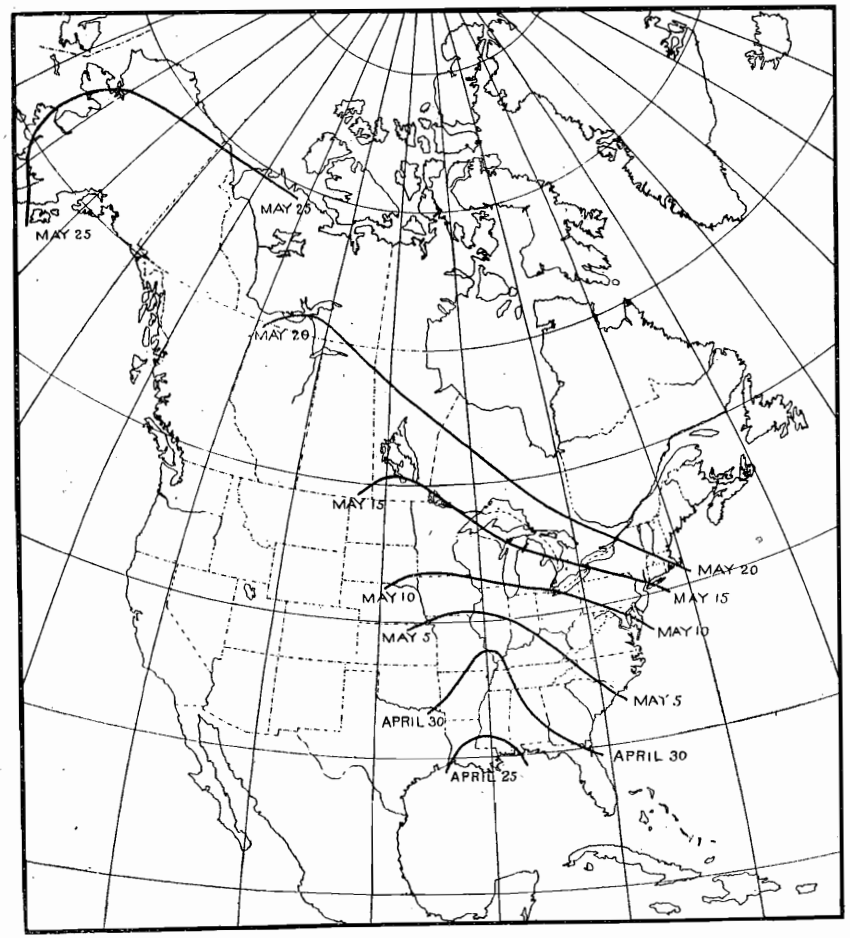

FIG. 17.—Isochronal migration lines of the gray-cheeked thrush (*Hylocichla aliciæ*). An example of rapid migration. The whole 4,000 miles from Louisiana to Alaska is passed over in about 30 days, or about 130 miles per day. The last part of the route the speed is several times what it is in the central Mississippi Valley. (See p. 27.) For an example of the opposite, a slow migration, see the black-and-white warbler (fig. 16).

the breeding range. It is probable that 60 days is about the shortest possible time in which such a bird could build a nest, rear its young, molt, and be ready for the return journey; and if so, then no New Brunswick black-and-white warbler is ready to start south before the middle of July, and 50 days for the trip would bring the earliest migrants to the Gulf States in September. Yet both old birds and

young of the year have been seen by the middle of July at Key West, Fla., 500 miles south of the breeding range; on August 10 in Costa Rica; and on August 21 on the northern coast of South America. These dates point to the conclusion that early migrants south of the United States could not have been birds from the northern part of the range, but must have been those from the southern part.

Black-throated blue warblers reach Cuba in fall just about the time other migrants of the species appear in North Carolina. The inference is that the arrivals in Cuba are the birds that nested in the southern Alleghenies, while those appearing in North Carolina are from the latitude of northern New England or beyond. Redstarts and summer warblers arrive on the northern coast of South America so early (August 27 to September 2) as to indicate that they represent the southern breeding birds. Indeed, these representatives of the species are seen in South America just about the time the earliest of the northern breeding birds reach Florida.

Recent investigations have shown also that many species of birds do not follow this "normal" order of migration. The most southern-bred Maryland yellow-throats are almost nonmigratory, residing throughout the year in Florida; those breeding in the middle districts migrate only a short distance; while those from Newfoundland go to the West Indies, passing directly over the winter home of their fellows in the South. The red-winged blackbirds of the middle of the range in northern Texas are almost stationary, but are joined in winter by migrant red-wings from the remote Mackenzie Valley. The palm warblers of the interior of Canada in the course of their 3,000-mile journey from Great Slave Lake to Cuba pass through the Gulf States early in October. After the bulk have passed, the palm warblers of the Northeastern Provinces come slowly to the Gulf States and settle there for the winter, content with only a 1,500-mile trip. Some of the blackpoll warblers that pass in spring through Florida proceed northeast 1,000 miles to breed in northern New England, while others, traveling northwest more than 3,000 miles, summer in Alaska. Among the Maryland yellow-throats nesting in western Pennsylvania are undoubtedly individuals that during the winter are scattered in the Gulf States, the West Indies, and even Central America. These examples show that no invariable rule, law, or custom exists in regard to the direction or distance of migration.

The winter distribution can not certainly be determined from the summer home, nor does it positively indicate that home. The statement can be made still stronger. Each species is composed of many small groups, each of which in regard to summer and winter home and route of migration is a law unto itself, and the knowledge of these facts with regard to one group offers little or no basis for

judgment in regard to members of other groups. Thus, although a certain general tendency is observable, each species presents a separate problem, to be solved for the most part only by patient, painstaking observation.

FIG. 18.—Distribution and migration of the red-eyed vireo (*Vireosylva olivacea*). An example of a lately extended breeding range and migration route. It is evident that the species has only recently invaded Washington by an extension almost due west from the northern Mississippi Valley, and that it still migrates spring and fall along the route originally traversed in this extension. (See p. 37 and also fig. 19.)

RELATIVE POSITION DURING MIGRATION.

Spring migration has its own special features, and no such synchronous movement then occurs as has been described as "normal migration" in fall. With many birds, probably the majority of land birds, the first individuals of a species to appear at a given locality are old birds that nested there the previous year; these are followed by others that nested in the region just to the north; and the last to appear are those whose homes are in the most northern part of the breeding range. The above statement applies only to old birds; in what order or at what time young of the previous year migrate has not yet been discovered. If, then, for any species, the southern-nesting birds lead the van in both fall and spring migrations and the rear guard in each case is composed of northern-breeding birds, it follows that some time between October and April a transposal of their relative positions occurs, and that the more southern birds pass over those whose migration farther north is delayed by winter still holding sway in their summer dominions. Just when and where this transposition occurs is a problem of migration reserved for future solution. Nor is it yet settled whether northern-bred birds remain strictly within their winter range until after their more southern congeners have passed by, or whether they begin an early migration so slowly as soon to be overtaken and passed by their more impetuous cousins.

Still later in spring another transposition occurs. The northern birds pass across the southern part of the breeding range, where the southernmost birds are already busy with their domestic duties. Spring migration seems, therefore, to be for most species a game of leapfrog, the southern birds first passing the northern and the northern passing them in turn.

RELATION BETWEEN MIGRATION AND TEMPERATURE.

The Canada goose is typical of what may be called regular migration. This bird fulfills the popular notion of bird migration, i. e., it moves northward in spring as soon as the loosening of winter's fetters offers open water and a possibility of food. It continues its progress at the same rate as spring, appearing at its most northern breeding grounds at the earliest possible moment. The isotherm of 35° F. (see fig. 20) seems to be the governing factor in the rate of spring migration of the Canada goose and, as shown on the map, the isotherm and the vanguard of the geese are close traveling companions throughout the entire route. Moreover, the isochronal lines representing the position of the van at various times are approximately east-and-west lines during the whole migration period.

But this so-called regular migration is performed by a very small percentage of species, the great majority choosing exactly the opposite course—to remain in their winter homes until spring is far advanced and then reach their breeding grounds by a migration much more rapid than the northward advance of the season. The summer

warbler is a good example of this usual habit. Some summer warblers that return to the Great Slave Lake region to breed after spending the winter in Central and South America arrive at their nesting grounds when the average daily temperature is about 47° F. According to the movements of the Canada goose, these summer warblers might be expected to pass up the Mississippi Valley and on to their

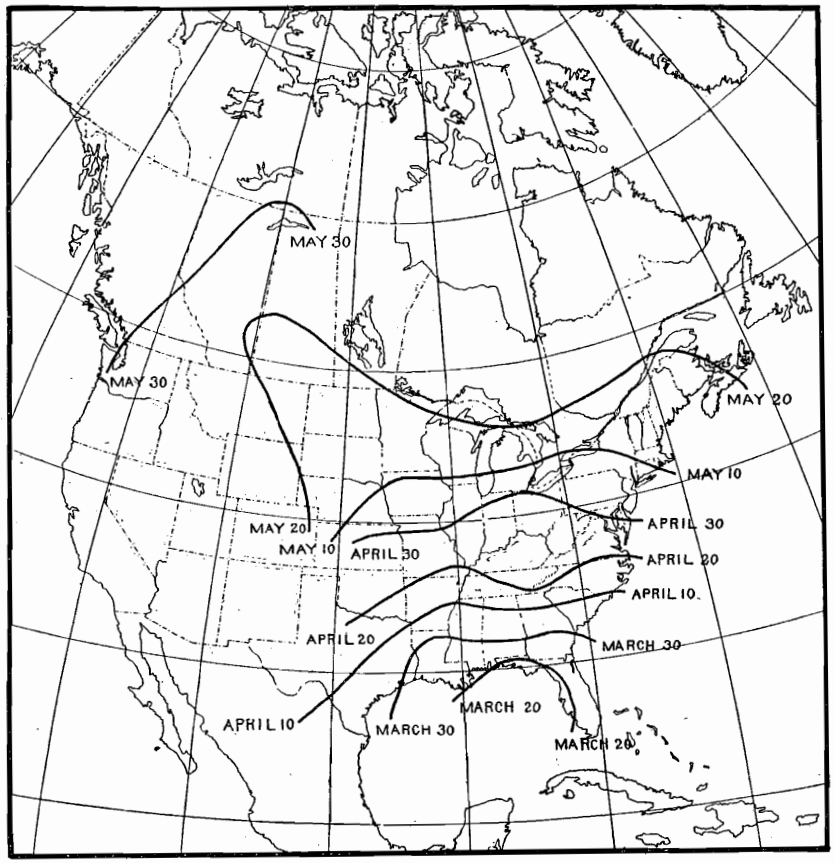

FIG. 19.—Isochronal migration lines of the red-eyed vireo (*Vireosylva olivacea*). An example of a recently extended migration route. The birds which are to nest in New England advance along the Atlantic coast in approximately a straight line and at a fairly uniform speed, while those which are to nest in Washington advance up the Mississippi Valley at about the same speed until eastern Nebraska is reached, when they turn sharply to the northwest and more than double their speed as they journey along this recently extended route to the far northwest. (See p. 37 and also fig. 18.)

summer homes at the same time as the northward-moving temperature of 47° F. But if this were so they would never leave the United States, for the average temperature of the coldest month of the year at New Orleans is 54° F. As a matter of fact, the summer warblers of Great Slave Lake are probably too well content with the warm, humid, insect-laden air of the south to brave the arctic blasts before

necessity compels. They linger in the Tropics so late that when they reach New Orleans, April 5, an average temperature of 65° F. awaits them. They now hasten. Traveling north much faster than the spring does, they cover 1,000 miles in a month and find in southern Minnesota a temperature of 55° F. In central Manitoba the average temperature they meet is 52° F., and when they arrive late in May at Great Slave Lake they have gained 5 degrees more on the season. Thus during the whole trip of 2,500 miles from New Orleans to Great Slave Lake these birds are continually meeting colder weather. So fast do they migrate that in the 15 days from May 11 to 25 they traverse a district that spring requires 35 days to cross. This outstripping of spring is habitual with all species that leave the United States for the winter and also with most northern birds that winter in the Gulf States. Careful examination of migration records of each species of the Mississippi Valley shows only six exceptions—Canada goose, mallard, pintail, common crow, red-winged blackbird, and robin.

The robin as a species migrates north more slowly than the opening of the season; it occupies 78 days for its trip of 3,000 miles from Iowa to Alaska, while spring covers the distance in 68 days. But it does not follow that any individual bird moves northward at this leisurely pace. The first robins that reach a given locality in spring are likely to remain there to nest, and the advance of the migration lines must await the arrival of other birds from farther south. Therefore each robin undoubtedly migrates at a faster rate than the apparent movement of the species as a whole and does not fall behind the advancing season. This is true of most if not all of the other seemingly slow migrants. Late and rapid journeys of this kind offer certain advantages; fewer storms are encountered, the mortality rate is lowered, food is more plentiful along the way, and the birds reach the nesting site full of energy and in good condition to assume the cares and labors of house building and brood raising.

An extreme example of a late and rapid migration is that of the black-poll warbler (see fig. 5). The birds enter the United States in southern Florida April 20, when the average temperature there is 72° F. Ten days later the van has reached the central Mississippi Valley, where the temperature is 60° F., and the birds continue to advance faster than the progress of spring until at the time they reach their Alaska breeding grounds on May 30 they find there an average temperature of only 45° F.

VARIATIONS IN SPEED OF MIGRATION.

The immense variation in the speed with which migrants travel different parts of the broad bird highway extending from the Gulf to the Arctic Ocean by way of the Mississippi and Mackenzie Valleys is a recent determination of special interest. The black-poll warbler

furnishes one of the best examples (see fig. 5). Wintering in north-central South America and migrating in April across the West Indies to Florida, some individuals pass on northwest to the Mississippi Valley, north to Manitoba, northwest to the valley of the Mackenzie, and thence almost due west to western Alaska. From the Gulf of Mexico to Minnesota a fairly uniform average speed of 30 to 35 miles a day is maintained; southern Indiana and Missouri are reached the first week in May, southern Iowa early in the second week, and southern Minnesota is entered by the middle of the month. Then

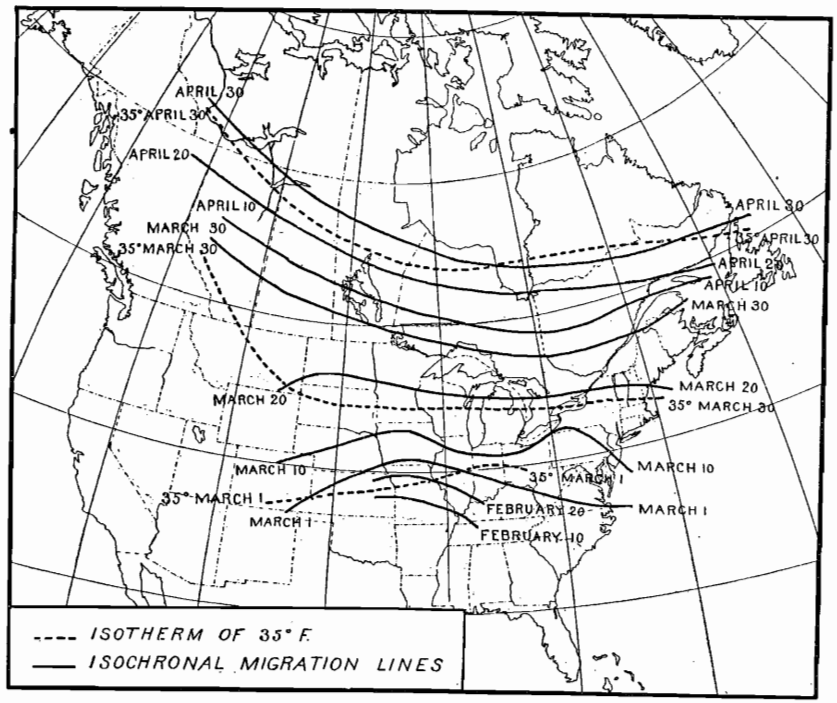

FIG. 20.—Migration of the Canada goose (*Branta canadensis*). An example of migration keeping pace with the advance of spring. The earliest Canada geese arrive in central Illinois when the average temperature is about 35° F., and they reach their most northern breeding grounds at about the same temperature, having advanced northward at approximately the same rate as the advance of spring. (See p. 41.)

comes a "spurt"; within another week the black-polls appear in the central part of the Mackenzie Valley, and the following week they arrive in northwestern Alaska, many individuals undoubtedly averaging more than 200 miles a day during the latter part of the journey. Thirty days are thus occupied in traveling the 1,000 miles from the Gulf of Mexico north to southern Minnesota, and scarcely half that time in traversing the remaining 2,500 miles northwest to Alaska. The directions of migration are emphasized because the change of direction is intimately connected with the great increase of speed, as will be explained.

A similar increase of speed is shown by many other species. The average speed of migration from New Orleans to southern Minnesota for all species is close to 23 miles a day. Sixteen species maintain a daily average of 40 miles from southern Minnesota to southern Manitoba, and from this point 12 species travel to Lake Athabaska at an average speed of 72 miles a day, 5 others to Great Slave Lake at 116 miles a day, and 5 more to Alaska at 150 miles a day.

The reason for these remarkable differences is very simple: The speed increases as the birds move northward because the advance of the season is more rapid in the northern interior than on and near the southern coast. The farther removed a district is from the ocean the greater the extremes of its temperature. At New Orleans the average daily temperature of January is 54° F., and that of July is 82° F., while at Winnipeg, Manitoba, the corresponding average temperatures are: January, −7° F.; July, 66° F. Hence during the period the temperature at New Orleans is rising 28 degrees, that at Winnipeg rises 73 degrees. Consequently as a given isotherm moves north during spring in the Mississippi Valley it continually increases its rate of advance. The isotherm of 35° F., corresponding to the commencement of spring migration, advances north at the rate of 3 miles a day from January 15 to February 15, 10 miles daily during the next month, and 20 miles daily during the following month.

But an additional explanation must be sought for the wonderfully quickened speed with which birds pass northwestward from Minnesota to the Mackenzie Valley. Along the eastern foothills of the Rocky Mountains isotherms travel north faster than at corresponding latitudes farther east. From February 15 to March 15 the isotherm of 35° F. (the line of spring) passes along the foothills from New Mexico to northern Colorado at the rate of 12 miles a day. During the next month, under the influence of the Chinook winds, its rate of northward progress is increased to 40 miles a day, so that by April 15 it has reached Lake Athabaska. Spring has come with a rush in this western interior country. The result is that during the height of the migration season, from the middle of April to the middle of June, the southern end of the Mackenzie in Saskatchewan has just about the same temperature as the Lake Superior region 700 miles farther south.

These conditions, coupled with the diagonal course of birds across this region of fast-moving spring, necessarily exert a powerful influence on bird migration. The robin's average temperature of migration is 35° F.; that is, the bird puts in an appearance soon after snow begins to melt and streams to open, but before vegetation has made any marked advance. These conditions occur in the central Mississippi Valley about the middle of February, and it is the first of March before spring and the robins cross northern Missouri and arrive

together in southern Iowa. Thence a whole month is consumed by the birds in their slow progress (13 miles a day) to central Minnesota. Their pace then quickens to keep up with the northward rush of spring, and another 10 days at doubled speed brings them to southern Canada. Here they must make an important choice. To the north and northeast lies a land that awakens slowly from its winter's sleep, and where the sun must wage a protracted warfare against the cold of the ice masses in Lake Superior and Hudson Bay. To the northwest stretches a less forbidding region already quickening under the influence of the Chinook winds.

Most of the robins from Missouri that pass through western Minnesota elect to turn to the northwest, and now they must not only keep pace with the rapidly advancing season but must do so on a long-drawn diagonal. Their daily average rises to 50 miles (four times that in southern Iowa) and later, when the course of the birds bound for western Alaska becomes nearly due west, the rate increases to 70 miles a day—more than six times the speed with which the journey began. The Alaska-breeding robins are the only ones that develop high speed. Robins bound for Newfoundland move leisurely along the Atlantic coast at the proverbially slow rate of the oncoming of spring in New England, and, scarcely exceeding 17 miles a day, they finally arrive at their destination the first week in May, when their Alaska-bound relatives are already 1,200 miles farther north.

An interesting migration route is that of the robins nesting in southern Alberta, which arrive too early to have come from the south and southeast; hence they must have come from the southwest, though this route has necessitated their crossing the main range of the Rockies while the mountains were still in the grasp of winter. Robins remain all winter on the Pacific coast, north to southwestern British Columbia, which has about the same winter temperature as St. Louis, 700 miles farther south. Hence the wintering robins of British Columbia are already far north at the advent of spring and do not need any hurried migration to reach Alberta on time, so that they average only 8 miles a day, the slowest rate for the species. It may fairly be asked, How do we know that the Alaska robins have come all this long distance from the central Mississippi Valley, instead of the far shorter distance from British Columbia? It happens that the robins of the two sides of the continent slightly differ in color and in pattern of coloration. Birds of the western style are not known north of southwestern Saskatchewan, central British Columbia, and southeastern Alaska, while the whole country to the northward is occupied by birds whose characteristics prove that they came from the southeast.

It does not necessarily follow that any individual bird makes all these changes in its speed of migration. The flight of the individual can not be traced or timed under the present system of obtaining records, and in the above statements it is meant that the general advance of the van of the birds is marked by these great changes in speed. It is quite likely that the first robins which reach central Minnesota at an average speed of 13 miles a day stop there and nest, and it is possible that those which continue the advance to southern Mackenzie at an average speed of 40 miles a day are individuals that have waited later in the winter home and have covered the whole distance at the higher rate.

That individual birds do increase their daily rate of progress as they proceed northward seems probable from the records of the gray-cheeked thrush (see fig. 17). The earliest migrants of this species travel from southern Louisiana to northern Iowa (1,000 miles) in about 15 days, or over 60 miles a day. As at this time they are passing over a country in which they do not breed, there is no reason to infer that the same birds do not keep continually in the lead. Hence 60 miles a day may be considered the actual average speed of individuals forming the van of this species. Two weeks later the earliest gray-cheeked thrushes appear in northwestern Alaska, 3,000 miles from Iowa, and it seems unreasonable not to conclude that the same birds that averaged about 60 miles a day as they moved north in the lower Mississippi Valley have greatly increased this speed as they continued their journey northwestward and finally westward to Alaska.

THE UNKNOWN.

Interest in bird migration goes back to a remote period; marvelous as were the tales of spring and fall movements of birds, as spun by early observers, yet hardly less incredible are the ascertained facts. Much has been learned about bird migration in these latter days, but much yet remains to be learned, and the following is one of the most curious and interesting of the unsolved problems. The chimney swift is one of the most abundant and best-known birds of eastern United States. With troops of fledglings catching their winged prey as they go and lodging by night in tall chimneys, the flocks drift slowly south joining with other bands, until on the northern coast of the Gulf of Mexico they become an innumerable host. Then they disappear. Did they drop into the water or hibernate in the mud, as was believed of old, their obliteration could not be more complete. In the last week in March a joyful twittering far overhead announces their return to the Gulf coast, but their hiding place during the intervening five months is still the swift's secret.

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