WEATHER AND SPRING MIGRATION

BY GEORGE G. WILLIAMS

MANY ornithologists tend to ignore and to belittle the rôle of weather in bird migrations. Thus, Wetmore (1927) remarked that "weather conditions have little if anything to do with the migrations of birds"; and Lincoln (1939) wrote: "While it is true that there are important general relationships between migration and climate, it may also be said that the state of the weather at any certain point has little if anything to do with the times of arrival of migratory birds at that point."

One of the few articles showing an awareness of the direct effects of weather on migration is by Captain Neil T. McMillan, of Eastern Air Lines, which was published originally in 'Bird-Lore' (1938) and republished the next year in the 'Annual Report of the Smithsonian Institution.' But even this stimulating article deserves re-examination, and the entire problem, like so much else customarily taken for granted in bird migration, needs to be re-studied.

HEIGHT OF MIGRATION

Captain McMillan and a few other writers believe that migrants habitually fly at tremendous heights. The birds are said to take advantage of favorable currents assumed to exist in the upper air. However, Wetmore (1927) summarized the experience of aviators flying in the First World War: "It is exceptional in flying to meet with birds above an altitude of 5000 feet, and the bulk of migration is performed below a height of 3000 feet from the earth." According to recent newspaper dispatches, investigations by the United States Civil Aeronautics Administration have shown that more than two-thirds of all collisions between birds and airplanes occur below 2000 feet, and virtually none above 6000 feet.

For meteorological reasons alone birds might be expected to avoid high-level flying: (1) the temperature of the air normally decreases by at least 3.5° F. for every thousand feet of altitude. Therefore, birds flying north with the warm weather in spring would place themselves in cold weather by ascending much more than 3000 feet; (2) in North America the winds of high altitudes tend to shift from the south to the west, or even northwest, in spring. These winds would not only be of little benefit to migrants bound north, but might actually impede their flight or carry those birds traveling along the Atlantic flyway far out over the sea; (3) winds at very high altitudes are usually much

stronger than those lower down, and birds, especially night migrants, do not generally fly in strong winds.

LANDING AT NIGHT

A good deal has been written about the physiological, seasonal, diurnal, and even meteorological factors influencing the beginning of a migratory flight, but the problem of landing has been ignored. Yet this problem, for a bird migrating through darkness hundreds or thousands of feet above the earth, is obviously vital. Therefore, the question arises—Can night migrants over land areas always see well enough in the darkness to land safely whenever they wish?

We can never know, except from indirect evidence, how well any bird can see, but some of this indirect evidence follows:

A. Domestic fowls and most caged wild birds, when disturbed on a dark night, flutter about and blunder into objects that they would avoid in the daytime. Apparently they do not see well in darkness.

B. After spring thunderstorms at night, birds are not infrequently found dead on the ground the next day (Glass and Peterson, 1946). Sometimes hail may have killed the birds (Gates, 1933), but more often there was no hail. Apparently the death of the birds resulted from one of the following circumstances: (1) the rain drove them close to earth where they plunged blindly and fatally against some tree or building; or (2) they sought to make a crash landing in order to escape the storm and "cracked up" in the darkness; or (3) unwilling to land, they flew on through the storm till they dropped dead of exhaustion. This last explanation, however, seems the least plausible; birds would probably drop to earth before dying of exhaustion, at least they have been observed countless times dropping exhausted into the sea, and yet being quite thoroughly alive (Buckley, 1945; Dufresne, 1947). I have never examined a bird found dead after a thunderstorm at night without finding injuries suggestive of a collision. Moreover, I have never found, or heard of, any dead birds on the ground after a simple thunderstorm in the daytime. We may conclude, then, that many migrants have difficulty in seeing how to land safely on dark nights.

C. In the sensational Lapland Longspur disaster of 1904, the migrants, having launched themselves on a night flight, were overtaken by a wet snowstorm while they were aloft. The next morning many living and many dead birds were found on the ground. "There were still many live longspurs a week after the diaster, with broken legs and wings and various other injuries . . . Doctor Lowe, the village doctor, examined many dead longspurs and found fractured and indented skulls . . . broken necks, wings and legs and ruptured

lungs and intestines" (Terres, 1948). In other words, the longspurs had evidently collided with the ground, or some other solid object, in trying to land. Presumably, they had attempted or had been compelled by sodden wings to seek refuge on the ground, had been unable to see how to land safely in the darkness, and had cracked up.

Scores of such examples might be cited, but they would all point to the same conclusion—that most species migrating on dark nights cannot land safely in the darkness.

From this conclusion we may draw the following inference—once the typical migrant has launched himself on a migratory flight, high up in the darkness, he must stay aloft till the coming of dawn or the rising of the moon affords him enough light to land. If sudden bad weather catches him aloft in the darkness, he can do nothing but endure it, run before it, risk dashing himself against the unseen earth below him, or take the even greater risk of dropping blindly into water or mud in a place without shelter and with nocturnal enemies.

TAIL WINDS

In the article already mentioned, Captain McMillan declares flatly that "It is the air that goes places and the birds go with it," but this seems to be an aviator's habitual enthusiasm for his element; the observations of other ornithologists do not bear him out.

Almost everyone has seen hawks, swallows, or other day migrants pressing forward in the face of opposing winds; Sutton (1945) records them flying into the teeth of a hurricane. In the last three years I have made many telescopic observations of birds flying across the moon's face and have noticed that four or five successive birds crossing in as many minutes may be traveling in four or five different directions. All of them could not possibly be traveling with a tail wind. Furthermore, though some of the night migrants in the Houston-Galveston region fly north or northwest in spring, the vast majority of them travel northeast or north-northeast. Yet, the prevailing spring winds of the area are from the south and southeast. Moreover, the birds normally continue their predominantly northeasterly direction no matter what the wind direction may be at any particular hour.

It may happen, of course, that a spring migrant may fly with a tail wind, but this is only a coincidence. In general, birds depend upon their wings, not the wind, to get them places.

STRONG WINDS

Day migrants sometimes travel when a strong wind is blowing, but I have repeatedly observed, by means of the telescope, that night

migration ceases completely in spring when a strong wind is blowing. Even when the wind is from the southern quadrant, virtually no birds ride with it if it is strong. Knowing that migrants must have difficulty in landing on dark nights, we can understand their reluctance to travel with strong winds, even when the winds are going their way. A bird flying through the darkness and not being able to land until dawn might be carried by a strong wind far beyond its intended destination; or if the wind shifted slightly, it might be borne many miles off course, or even far out to sea, before morning. Strong winds coming up suddenly while migrants are aloft in the darkness and unable to land must be considered one of the chief hazards of migration.

TEMPERATURE

The trend of modern ornithology away from the old anthropomorphic interpretation of bird behavior is wholly admirable. On the other hand, the simplified mechanistic point of view sometimes violates common sense. For example, Terres (*loc. cit.*) said that the longspurs were driven forward against the storm by an irresistible migratory urge, "cold and mechanical, as implacable as death . . ." There was "no desire to run before the storm. In the fierce drive of migration there is no reason, and the wild heart had become the slave of the mysterious will." One has only to look out at one's own chicken yard, when a sudden thunderstorm comes up, to see birds "run before the storm." The same is true of Mockingbirds feeding on the lawn and sparrows in the street. In the Gulf Coast region of the United States in spring there is never a passing cold front, or even thunderstorm, that does not precipitate a multitude of migrants that remain hopping about trees and bushes until the weather has bettered. The migratory urge in these birds is not "cold and mechanical, as implacable as death."

To be sure, increasing day-lengths, gonadal development, and an innate migratory habit affect migrations, but weather conditions affect them too. Of course, there are calendar limits within which each species advances into any region in spring, but these limits may be flexible by as much as three or four weeks.

We may understand why these limits are flexible by examining specific migratory data.

A. March of 1945 was incredibly warm over the entire United States east of the Rockies; in the northeastern part of the country it was the warmest March in more than 150 years. Reference to 'Audubon Field Notes' (1945) covering that spring shows the effect of this warm weather on migration. From Boston, Griscom (p. 29)

reported: "The early April migrants [*i. e.*, those normally expected early in April] appeared *in some numbers* on dates without precedent in history . . . Even a few stragglers of species normally arriving in May were reported." From New York, Nichols (p. 31) reported: "Those birds which normally arrive prior to the middle of April were present this year about ten days earlier than average." From Toledo, Mayfield (p. 34) reported a series of arrivals that were "significantly early" and "earliest on record." From Evanston, Illinois, Smith and DuMont (p. 35) reported: "Practically all waterfowl arrived from one to two weeks early"; and they mention other species arriving remarkably early. From Houston, Williams (p. 40) reported: "Nearly all the birds due in March showed up from a week to a month early."

B. On the other hand, in that same spring of 1945, the last two weeks of April and the first two of May were abnormally cold. Griscom reported two-thirds of the birds due in the April period as being "*exceptionally late*," and the entire migration "decidedly late by May 10." Mayfield reported: "After the middle of April almost every arrival was late." Smith and DuMont reported: "With May and March reversed, early migrants arrived earlier and the late ones later, with all observers reporting extreme dates." From Jefferson City, Missouri, Cunningham (p. 37) reported: "Warm weather early in the season seemed to speed up the northward movement of early migrants, while cool, wet weather in May retarded the movements of later migrants."

C. Following the lead of the late Wells W. Cooke, modern writers have had much to say about the correlation of spring arrival dates with *average* temperatures. But a cursory examination of 'Audubon Field Notes' for any spring would show that, in North America, the spring migrations in general proceed in a series of spurts or rushes correlated with *maximum* temperatures. Table 1 shows how plateaus of high temperatures for the spring of 1944 were almost invariably accompanied by waves of spring arrivals in Minnesota. The only reason the spring of 1944 in Minnesota was selected, instead of some other spring somewhere else, was that more distinct waves occurred there in a short time than is usually the case.

It will be noted from the table that, with one exception, every distinct plateau of temperature is associated with bird waves, and that no waves occurred except in conjunction with distinct plateaus. The exception is the May 7 to 10 period. A huge rain in that period, with tremendous floods in Minneapolis, is doubtless responsible for the lack of migrants, and of observers outdoors to see them.

The conclusion we may draw from these few examples, as well as

TABLE 1

CORRELATION OF RELATIVELY HIGH TEMPERATURES WITH WAVES OF SPRING ARRIVALS IN MINNESOTA, 1944.

April		April		May	
1	27°	16	33°	1	70°*
2	32°	17	56°*	2	75°
3	34°	18	62°*	3	56°
4	37°	19	58°*	4	35°
5	29°	20	46°	5	39°
6	63°*	21	53°	6	46°
7	62°*	22	47°	7	63°
8	60°	23	44°	8	61°
9	63°*	24	41°	9	64°
10	51°	25	46°	10	66°
11	51°*	26	57°	11	64°*
12	59°	27	69°*	12	74°*
13	62°	28	68°*	13	75°*
14	42°	29	70°	14	79°*
15	38°	30	71°*	15	85°

Temperatures are daily maxima for Minneapolis
Asterisks indicate waves of birds

from many additional data for which there is no room here, is that the advance or retardation of migrants in spring is influenced by temperature on a day-to-day basis. This conclusion is at variance with the opinions of those many ornithologists who stress average calendar dates, average seasonal temperatures, or even average daily temperatures as controlling factors; but, I do not believe that the facts normally substantiate these opinions. In any event, and this is my main point here, we must conclude that, under certain circumstances at least, most birds may and do adjust their *daily* migratory behavior to *daily* conditions of temperature.

REVERSE MIGRATION

I have tried to show that spring migrants may advance or halt their journeys according to daily conditions of temperature, but do they ever retreat in spring before an advancing cold front? Here are some facts that may help us answer the question:

A. At about 5 p. m. on March 10, 1948, near Houston, Texas, I saw several large flocks of curlews (probably Hudsonian) flying rapidly south-southeast. Two hours later, a very severe and unseasonable cold front struck Houston from the north-northwest and brought freezing weather the next day. It would seem that the curlews had been retreating before the advancing cold front.

B. I was fortunate enough to be studying migrations through a telescope in Houston on the night of May 1, 1947, when a mild cold front arrived in the region. When observations commenced at 7:50 that evening, what little wind there was, was southerly. Yet I noted

that a good many birds were heading west or southwest. At 8:30 light, scattered clouds began to pass, going south, though the wind at the surface remained southerly. At 9:30, a brisk north wind struck and from that time until observations ceased at 11:10 p. m., over half the birds seen were flying fast toward the west or southwest. Presumably the birds, which normally would have been heading north or northeast at that time of year, were retreating before the cold front.

C. In the early spring of 1934, I heard geese flying north over my home in Houston at about 8:30 on a warm, clear evening. Then, at about 11:30 p. m. I heard geese flying south through the cloudy weather that had developed. At about 1 a. m. a cold front struck, bringing a stiff north wind and lower temperature. There seems no doubt that here, too, was a retreat before cold weather.

It is just possible that some birds may be able to foresee bad weather under some conditions, and may retreat before cold weather actually arrives. This is a ticklish question that I do not wish to insist on too much, but there is some evidence for it, and it needs to be investigated further. Two examples follow:

D. Lewis (1938) was the first to call attention in print to a southward migration in spring of many species on Pelee Island, Lake Erie. At the annual meeting of the Wilson Ornithological Club, November 29, 1947, Mr. W. W. H. Gunn, of the University of Toronto, read a paper on "Reverse Migration over Lake Erie" in which he pointed out that reverse migrations in spring in the region mentioned are quite common. Gunn's paper referred to the weather only in general terms, and Lewis's paper described the weather on the day of the reverse migration (May 12, 1937) as balmy, with southerly winds. On the next day after Lewis made his observation, however, the entire region several hundred miles north of Lake Erie was in the grip of a severe and unseasonable blizzard. Perhaps a low-pressure area that had passed through the region the previous day had warned the birds of what was coming. The birds retreating southward would have struck the north shore of Lake Erie, would have been reluctant to cross the water, would have followed the shore southwestward into the funnel of Pelee Peninsula (Gunn's theory), and then would have crossed the lake eventually, after all. Future investigations of the Pelee phenomenon should include information about the weather *subsequent* to observations.

E. In late afternoon on March 22, 1947, in Houston I saw several large flocks of Ring-billed Gulls, *Larus delawarensis*, many Bank Swallows, *Riparia riparia*, and a few Chimney Swifts, *Chaetura pelagica*, and Purple Martins, *Progne subis*, migrating *southeastward*

into a brisk and warm southeast wind. The first warm wave of the spring had surged up from the south a day or two previously, had occupied all the Gulf States, and had ascended the Plains States as far as northern Nebraska. At the same time, however, a cold front was just entering the northwest corner of the United States. But this cold front did not reach Houston till about 40 hours after I had seen the birds migrating southeast. It is impossible that they could have gone northward, met the cold front, raced southward again and reached Houston that far ahead of the front. A more credible explanation is that the barometer was taking a rapid plunge only about 250 miles northwest of Houston on March 22, and that the northward-migrating birds ran into this area of lowering pressure, sensed its warning, and retreated gulfward at once.

Whether or not birds can ever foresee bad weather, there is enough evidence at hand to show that they are not always driven northward, ever northward, in spring by an undeviating and irresistible migratory urge. Faced by an advancing cold air-mass, spring migrants may turn aside from their course, or reverse it.

AIR-MASSES

The concept of vast air-masses differing from one another in temperature, humidity, origin, and speed of movement, and reacting with one another as they flow here and there about the world, is fundamental in modern meteorology. Whether these air-masses and their movements have any effect on bird migration is a problem that has been virtually ignored in American ornithology. The present brief paper cannot begin to solve this problem, but it may suggest some of the possibilities inherent in the meteorological approach to studies of migration.

Anyone may observe the almost "insidious" effects of a slowly moving air-mass by watching sky-writing. The great letters in the sky may not change their conformation, but within a few minutes they usually drift far away from their original position. In the same way, the position of a bird high over the earth could likewise be affected by the drift of the air-mass in which the bird happened to be flying, unless the bird were somehow able to keep a direct course despite the drift of the air-mass.

Just how birds manage to keep on course is a matter about which thousands of pages have been written. To review these pages here is out of the question, but the general conclusion of most students is that visibility of some sort is necessary for most birds, if they are to navigate successfully. Even the Yeagley theory (1947) of homing

and orientation requires, as Davis (1948) points out, that birds have visible landmarks to help them guide their flight.

Consider what happens on a night when migrants are aloft. If there is a moon, or even clear starlight, or some faint afterglow from the sunset or pre-glow from the dawn, the birds may be able to see the earth below them. They will certainly be able, as any aviator will testify, to make out shorelines and large rivers, and may be able, according to some theories, to navigate by reference to the moon or other heavenly bodies. However, suppose the sky becomes overcast quite quickly, as often happens at the edge of an advancing weather front, and the earth below and the sky above are blotted from view. What course will the birds then take?

If it is true, as stated above, that visibility is necessary for successful navigation, birds flying through the darkness under an overcast sky will not be able to keep a direct compass-course. Being suspended in the ocean of moving air, they will not even know whether, or which way, this ocean is moving, unless they have visible guide-points to help them. A flying bird is, as McMillan (1938) pointed out, "essentially a part of the wind . . . Even if he rides a hurricane spinning at well over a hundred miles an hour, the bird will feel not an ounce more pressure or have a single feather ruffled."

Accordingly, if the air-mass in which migrants are flying on a dark and overcast night should shift its direction, the birds would be unaware of the shift. Unconsciously they would change the absolute compass-direction of their own flight. Thus, if a bird were flying northeast on a dark night and the air-mass in which he was flying changed its direction from south to northwest, the absolute compass-direction of the bird's flight would change to east or, depending on the relative speeds of bird and wind, to east-northeast or east-southeast.

Suppose birds migrating at night under an overcast sky met a cold front moving in a different direction from their flight, and perhaps bringing with it rain or snow or temperature low enough to discourage migration. The birds would be caught in a dilemma; they could not see how to land safely on the earth below them, and yet they could not continue flying with sodden wings through rain or snow, or they might not want to push on in the face of steadily dropping temperatures. The only thing left for them would be to run before the wind, or with it, and try to out-distance its approaching bad weather. Before morning came, and the birds could see how to land, or before a region of milder temperature was reached, the birds might have retreated hundreds of miles off-course.

In short, the entire pattern of migration might be drastically altered

by the movements of air-masses. All that would be required for such drastic alteration would be an overcast sky and a shift in the wind's direction, particularly if the shift were accompanied by rain, snow, or sharply falling temperatures. Since meteorological conditions such as these are the almost invariable accompaniments of cold fronts, and since cold fronts normally sweep across the United States once or twice a week throughout each spring, finding illustrative examples of the way the principle works is easy. The following examples are no better or worse than dozens of others that could be listed:

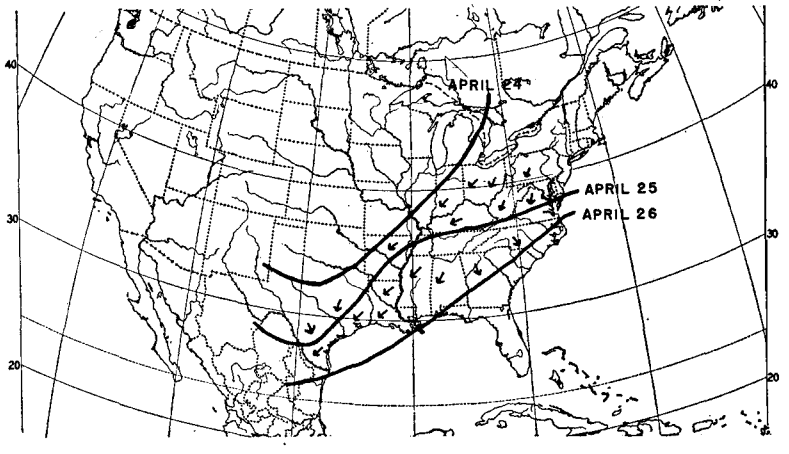

FIGURE 1. Map to show how advancing cold front (April 24–26, 1947) with extraordinary sweep of northeast winds brought Black-poll and Cape May Warblers to Texas coast. Heavy black lines indicate position of cold front on successive days; arrows show wind direction.

A. *Two rare warblers in Texas.*—The Black-poll Warbler, *Dendroica striata*, and the Cape May Warbler, *Dendroica tigrina*, normally migrate in spring through the eastern United States, and are extremely rare along the Texas coast. On April 27, 1947, however, J. M. Heiser and I saw two black-polls on Galveston Island, and other observers saw two more on the same date on the western shore of Galveston Bay. Furthermore, on this same date Mrs. Hagar saw a Cape May Warbler at Rockport, Texas, about 180 miles down the coast from Galveston. Until this time I had never seen a Black-poll Warbler on the Texas coast, and McKay (near the head of Galveston Bay) had seen it only once. Neither McKay nor I have ever seen a Cape May Warbler, and Mrs. Hagar has seen it only one other time.

What caused the presence of rare warblers on April 27, 1947? Weather maps afford an answer. On April 23 and 24, there had been

summer temperatures as far north as New York, Pennsylvania, and Ohio, with southerly winds extending all the way from Florida. This was perfect weather for migration in the eastern United States, but on the night of April 24–25 a cold front crept across the states mentioned and brought freezing temperatures, snow, and cold rain.

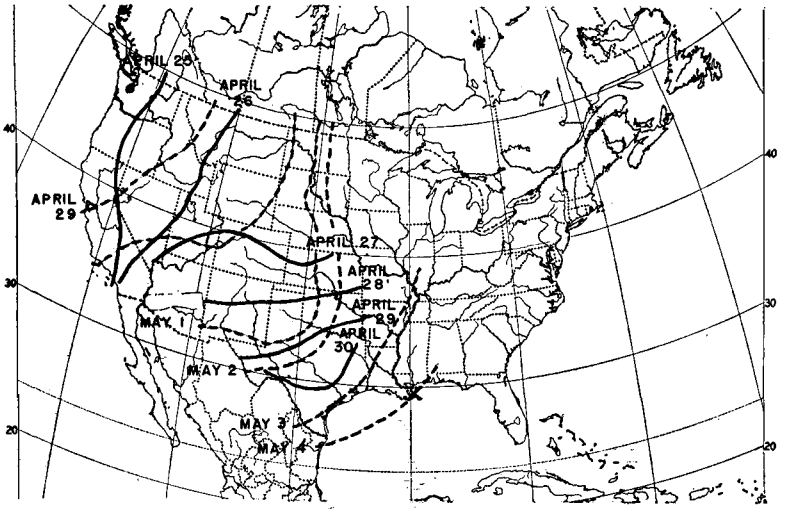

FIGURE 2. Map to show the advance of two cold fronts (solid lines, April 25–30, 1946; broken lines, April 29–May 4) that brought many western species to the Texas coast.

At the same time a northeast wind began blowing. The rain and cold pushed down across all the southern states on April 25 and 26, and the northeast wind continued blowing through the southern states on the 26th, and through Texas till the 27th (Fig. 1). This was very unusual weather; cold winds usually come into Texas in spring from the north or northwest, not from the northeast. This was the only time between April 15 and May 30, 1947 (the migration season) when this sort of weather prevailed. It seems probable that the Black-poll and Cape May Warblers had been migrating through the northeastern part of the country, had met the cold front with its bad weather and obscured sky, had retreated from it in the night, and had been borne down into Texas by the northeast winds.

B. *An invasion of western birds.*—On April 25, 1946, a series of cold fronts started moving east from the Pacific coast (Fig. 2). The first of them entered Texas from the northwest on April 28. It was almost immediately overtaken by another cold front from a more

westerly direction; the combined fronts reached the Texas coast on the afternoon of May 3 and were followed by northerly squalls till May 5. There were rains, cloudy skies, and falling temperatures throughout the period.

As these fronts approached and arrived, a truly remarkable number of western species showed up along the lower Texas coast. They included, at Corpus Christi: the Ash-throated Flycatcher, *Myiarchus cinerascens*, and Rufous-crowned Sparrow, *Aimophila ruficeps*, on April 30; Beardless Flycatcher, *Camptostoma i. imberbe*, Western Flycatcher, *Empidonax difficilis*, and Virginia's Warbler, *Vermivora virginiae*, on May 1; Rufous Hummingbird, *Selasphorus rufus*, on May 2; the rare Lucifer Hummingbird, *Calothorax lucifer*, on May 3; Broad-tailed Hummingbird, *Selasphorus platycercus*, and Violet-green Swallow, *Tachycineta thalassina*, on May 5; and at Rockport, on a bay 25 miles north of Corpus Christi, White-tailed Kite, *Elanus leucurus*, White-throated Swift, *Aëronautes saxatalis*, and Hepatic Tanager, *Piranga flava*, on May 5. Fred M. Packard tells me that he is positive he saw a Bohemian Waxwing near Corpus Christi on May 5; though at first glance the record seems incredible, the presence of this northwestern bird here with all the other western birds at this time seems quite natural.

C. *Green-tailed towhee in Massachusetts.*—Though this paper is primarily concerned with spring migration, the presence of a Green-tailed Towhee, *Chlorura chlorura*, at Northampton, Massachusetts, on December 31, 1946 (Eliot, 1948) tempts an explanation. This particular bird was seen by hundreds of New England observers, and even had its picture in 'The Auk.' On December 27 to 29, 1946, occurred a vast, almost continent-wide phenomenon of weather that the U. S. Weather Bureau considered remarkable enough to deserve a series of special studies in its weather maps. What happened is suggested in Figure 3. A low-pressure area, with a pronounced cold front extending southward from it, developed in the central plains states on December 27, and moved eastward, southward, and even westward. Winds of a force up to 35 miles per hour rotated about the area. At the same time, squalls developed along the cold front, and the temperature dropped steeply behind it. On the morning of December 29, southern Texas was as cold as northern Pennsylvania and was growing colder but, ahead of the cold front, warm southwest winds continued to blow steadily for three days. A bird caught ahead of the cold front, unable to turn westward or southwestward because of the cold, and confused by the rain, squalls, and cloudy skies, would almost certainly have surrendered to the southwest

winds and moved northeast. This is undoubtedly what happened to the Green-tailed Towhee.

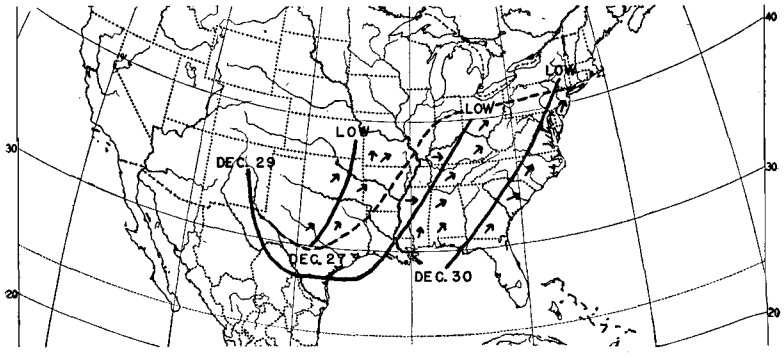

FIGURE 3. Map to show the unusual weather conditions (December 27–30, 1946) that brought a Green-tailed Towhee to New England. Broken line indicates the freeze-line of the morning of December 29.

SUMMARY

Birds flying at night may become pawns of the weather. They may advance, retreat, or veer off at an angle from the direct course; they may be borne far off-course by moving air-masses catching them aloft on dark nights; they may flee for hundreds of miles before an advancing cold front, and they may reach, or be borne to, unaccustomed places before dawn comes and they can see how to land, or are safe from inclement weather. Considering the frequency of advancing cold fronts in spring, it is likely that most spring migratory flights do not proceed in a direct south–north line, or in any straight line; there are probably few spring seasons in which most birds that breed in the northern United States or Canada do not have to alter their course at some time, retreat in the face of bad weather, suffer dissemination indiscriminately over the continent, seek refuge in unfamiliar areas, and return to their regular course along abnormal routes.

If this conclusion is sound, several familiar ornithological methods and hypotheses are open to criticism: (1) the assumption that spring migrants invariably arrive from a southerly direction is unwarranted; the migrants may arrive from a northerly direction, or any other; (2) the belief that forces dependent upon day-lengths, gonadal development, and inherited migratory habit drive migrants forward undeviatingly toward a goal is not sound; (3) when a spring migrant "arrives in the midst of a snow storm," or any other bad weather, he

has not necessarily been fighting his way obstinately into the bad weather; instead, he may have been retreating from it when it overtook him and forced him to seek refuge on the ground; (4) the first arrival dates and the average arrival dates of a species in any region may tell very little about the schedule of the species, but only something about the weather; (5) the drawing of isochronal lines across a map to indicate simultaneous arrival dates of a spring migrant, and then measuring the south–north distance between the lines in order to determine the bird's migration speed, may have some significance, by the mere law of averages, if carried out over a great many springs, but it has no real significance if it involves only one or two seasons, for the migrant may not have traveled from south to north but from southwest to northeast, or on some other diagonal, and may have tacked and veered back and forth across even this diagonal; (6) the Yeagley theory, if I understand it, fails to explain how migrants can find their way back to their correct course and destination after being hurried hither and thither by the weather, sometimes hundreds of miles off-course, through a whole series of electromagnetic and gravitational gridworks.

LITERATURE CITED

BUCKLEY, JOHN L. 1945. Land birds at sea. Auk, 63: 440.

DAVIS, LEVERETT, JR. 1948. Remarks on: 'The physical basis of bird navigation.' Journ. Appl. Physics, 19: 307.

DUFRESNE, FRANK. 1947. Bobolink on the Gulf of Mexico. Auk, 64: 138.

ELIOT, SAMUEL A., JR. 1948. Green-tailed towhee at Northampton, Massachusetts. Auk, 65: 301–302.

GATES, WM. H. 1933. Hailstone damage to birds. Science, 78: 263–264.

GLASS, BRYAN P., AND PETERSON, RANDOLPH L. 1946. Notes on bird mortality during nocturnal thunderstorms near College Station, Texas. Condor, 48: 96.

GRISCOM, LUDLOW *et al.* 1945. Audubon Field Notes: Spring Migration. Aud. Mag., 47 (Sect. II): 29–43.

GRISCOM, LUDLOW *et al.* 1947. The Changing Seasons: a Summary of the Spring Migration. Aud. Field Notes, 1: 147–168.

LEWIS, HARRISON F. 1939. Reverse migration. Auk, 56: 13–17.

LINCOLN, FREDERICK C. 1939. The migration of American birds. (Doubleday, Doran and Co., New York), p. 52.

MCMILLAN, NEIL T. 1938. Birds and the wind. Bird-Lore, 40: 397–406.

SUTTON, GEORGE MIKSCH. 1945. Behavior of birds during a Florida hurricane. Auk, 62: 603–606.

TERRES, JOHN K. 1948. Bird of tragedy. Aud. Mag., 50: 90–95.

WETMORE, ALEXANDER. 1927. The migrations of birds. (Harvard Univ. Press, Cambridge), pp. 48, 52.

YEAGLEY, HENRY L. 1947. Preliminary study of a physical basis of bird navigation. Journ. Appl. Physics, 18: 1035–1063.

The Rice Institute, Houston, Texas, December 3, 1948.