EFFECT OF WIND ON FLIGHT SPEEDS

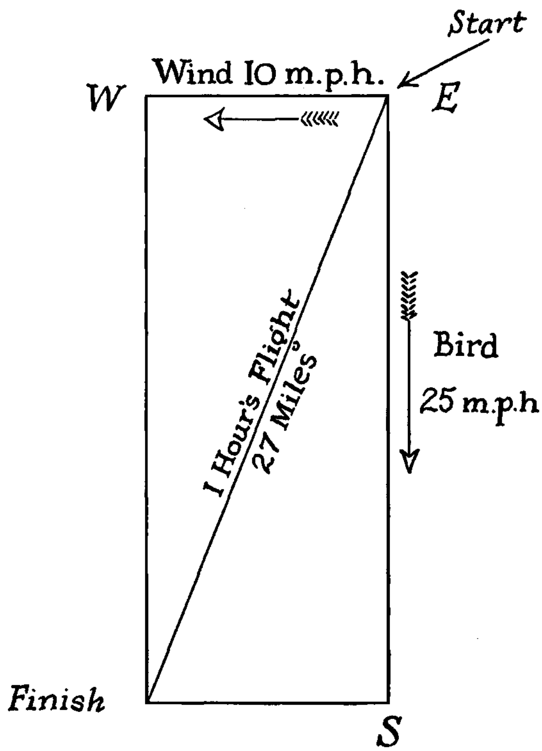
BY FRANCIS H. ALLEN

A CONSIDERABLE amount of data on the flight speeds of birds has been accumulating for some years, especially since the attention of aviators and motorists has been directed to the subject, but a reading of the latest compilation of these data—that made by Miss May Thacher Cooke of the United States Biological Survey and published as a 'Circular' of the Department of Agriculture under date of May, 1937—reveals a lack of certain very material information in most of the records. Few observers seem to have considered the importance of recording the *exact* velocity of the wind and its *exact* direction in relation to the line of flight. These elements are vital factors where ground speeds are concerned, though comparatively unimportant for air speeds. The air speeds recorded by aviators are true indications of how fast the birds were flying at the times of observation, though not of how they were progressing on their journeys. In the case of birds watched from on land, whether from automobiles or otherwise, it is necessarily the actual distance covered in a certain time that is noted; and this distance may be very materially modified by the wind. To ascertain the air speed in such cases—that is, the true speed of the bird—is not a mere matter of adding the velocity of the wind to that of the bird going against it and subtracting it when the bird flies down wind, for that does not take into consideration the vastly greater number of winds that blow from other quarters. I am speaking of birds following a definite course, not simply working farther north or south or east or west in relation to latitude or longitude.

It is a well-known fact that during strong winds birds on migration tend to 'pile up' against such barriers as mountain ranges and the seashore. In the latter case seabirds are swept in from the sea during storms from that quarter, while landbirds during high offshore winds are held along the shore by their natural reluctance to leave the land. But along the shore and in many other places birds fly on definite courses on which it is important for them to govern their flight according to the wind in which they are flying. It is obvious that a slow-flying bird will be reluctant to fly in a strong adverse wind, and even of beam winds any but the gentlest will handicap a slow flyer seriously by tending to blow the bird off its course. Some of the effects of winds blowing from other angles, however, appear to have been very commonly overlooked, though it is all a matter governed by the same law as the composition of forces. A little experimenting with various parallelograms has produced results that have rather surprised me, and it may be worth while to bring them to the attention of others.

Let us assume that a bird on the southward migration is following a coastline that runs due north and south, and that its course calls for its keeping within a definite distance of shore. We may call it a Brown Pelican on the coast of California flying at an air speed of twenty-five miles an hour. Let us assume that a wind of ten m. p. h. arises—what the

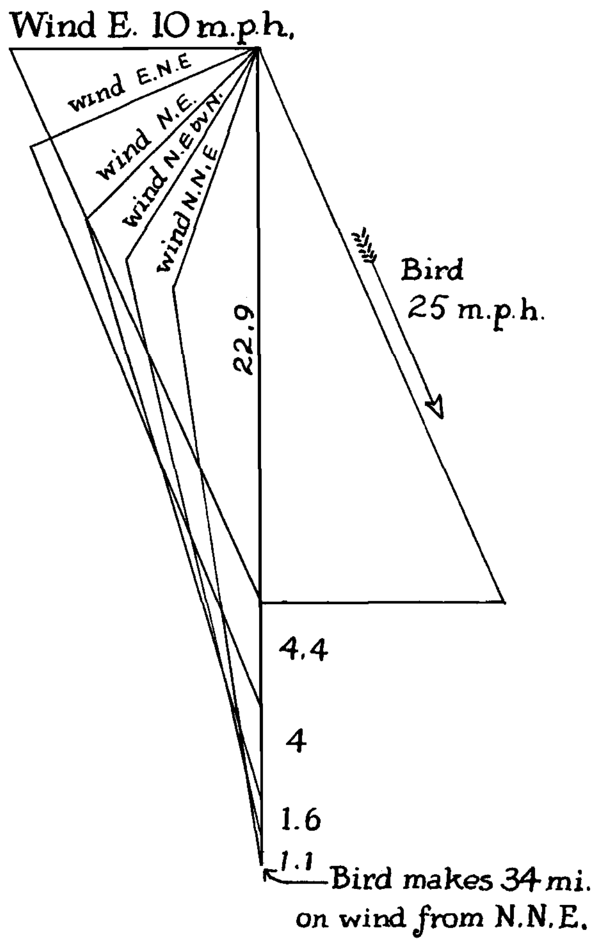
FIG. I
Scale: I in. = 8 miles.



Weather Bureau calls a 'gentle breeze'—and blows from due east. If the pelican were to fly blindly by some internal compass that led it due south, it would find itself after an hour at the end of a diagonal of a rectangular parallelogram twenty-five miles farther south, but ten miles farther west. The bird would have travelled about twenty-seven miles but would be ten miles out at sea (see Text-fig. 1).

But though birds know nothing of parallelograms of velocities, they do know how to hold a course. In this case our pelican would fly about south-southeast to counteract the effects of the ten-mile east wind, and an hour's flight at twenty-five m.p.h. would take it about 22.9 miles on its southward course (see Text-fig. 2). A shift of the wind to east-northeast would speed our bird up to a gain of 4.4 over the 22.9 miles. Another shift to northeast

FIG. 2
Scale: 1 in. = 8 miles



would gain it another four miles. If the wind shifted another point, to northeast-by-north, the bird would gain an additional 1.6 miles; and a further shift to north-northeast would land it 1.1 miles still farther south, making a total of thirty-four miles on its course. If the wind went round to the north and blew steadily from that quarter, the southing would be thirty-five miles; that is, the bird's twenty-five plus the wind's ten. (For convenience, except in the case of the east wind, only half of each parallelogram has been shown in the diagram.)

As it may not be clear to all readers just how the parallelograms, or rather the semiparallelograms, or triangles, are constructed, it may be well to say at the outset that they are drawn in the most mechanical fashion by empirical methods employing the simplest instruments and the most elementary mathematics. I believe, however, that the results are exact enough for all practical purposes. Given a fixed course (in this case due south), a fixed wind speed and wind direction, and a fixed bird speed, one has only to spread the dividers to the exact bird m.p.h. on a scale, place one end at the leeward end of the wind line, and then mark where the other end crosses the line of the north-and-south course. This gives the end of the diagonal of the (complete or incomplete) parallelogram, the direction of the diagonal being, of course, always the same by the terms of the problem. The length of the (vertical) diagonal indicates the ground speed of the bird. It must be emphasized that for the purposes of this demonstration the bird's air speeds are fixed. If the measure of the bird's m.p.h. is not long enough to reach the line of its course from the leeward end of the wind line, it shows that the bird travelling at that speed could not possibly keep its course in that wind, but would be blown farther and farther out to sea. As a matter of fact, no bird's air speed is inflexible, and unquestionably any bird finding itself unable to cope with the wind at its ordinary speed would increase its speed as much as necessary and practicable.

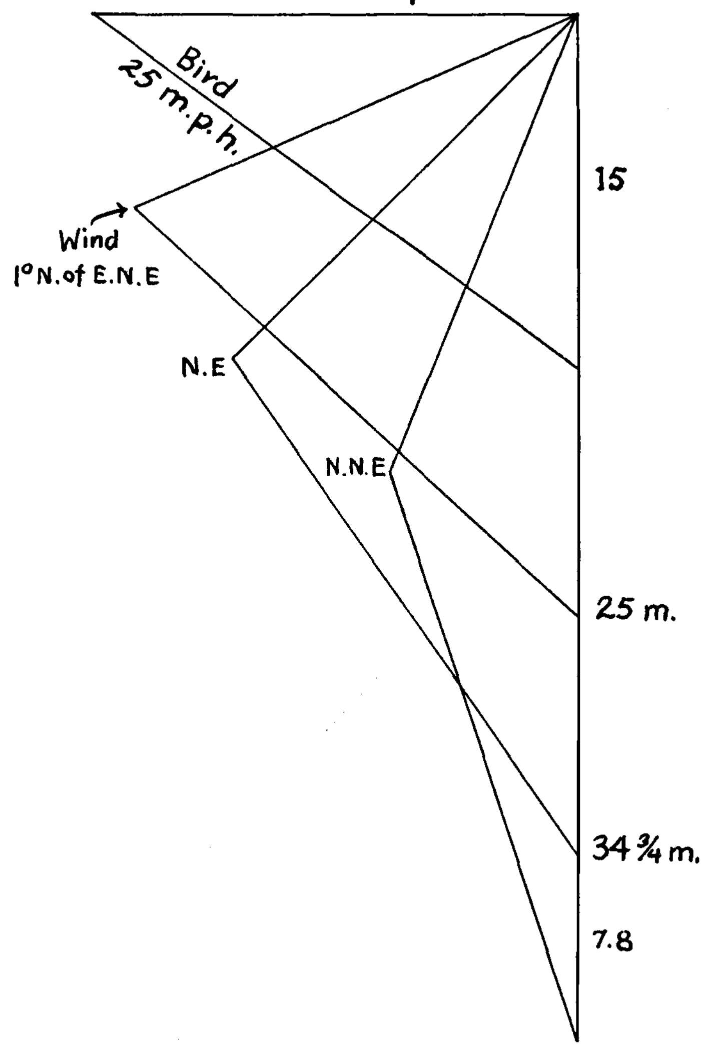
But what we have set out to do at present is to show how the wind affects the ground speeds of birds flying at their normal air speeds. The stronger the wind, the more it hinders a bird when it blows abeam or in that general direction, and the more it helps the bird as it approaches the direction of flight. With a twenty-mile wind—a 'fresh breeze' as the Weather Bureau calls it—the neutral point comes at about one degree north of east-northeast for our twenty-five-mile southward-flying pelican. East of that, the wind would hold the bird back. With the wind abeam, it could make but fifteen miles on its course. On the other hand, if the wind should swing to northeast, the bird could make about 34¾ miles; and if it should swing to the north-northeast, the bird could gain nearly eight miles over that (see Text-fig. 3).

But let us increase our wind to twenty-five miles—a 'strong breeze.' Now our bird could just hold its own in a beam wind by flying directly into it, but of course no bird would fly in such a wind if it felt any urge to keep a course at right angles to the wind. If, however, the wind should swing only a single point, 11¼ degrees, to the north, our southward-bound pelican by

FIG. 3

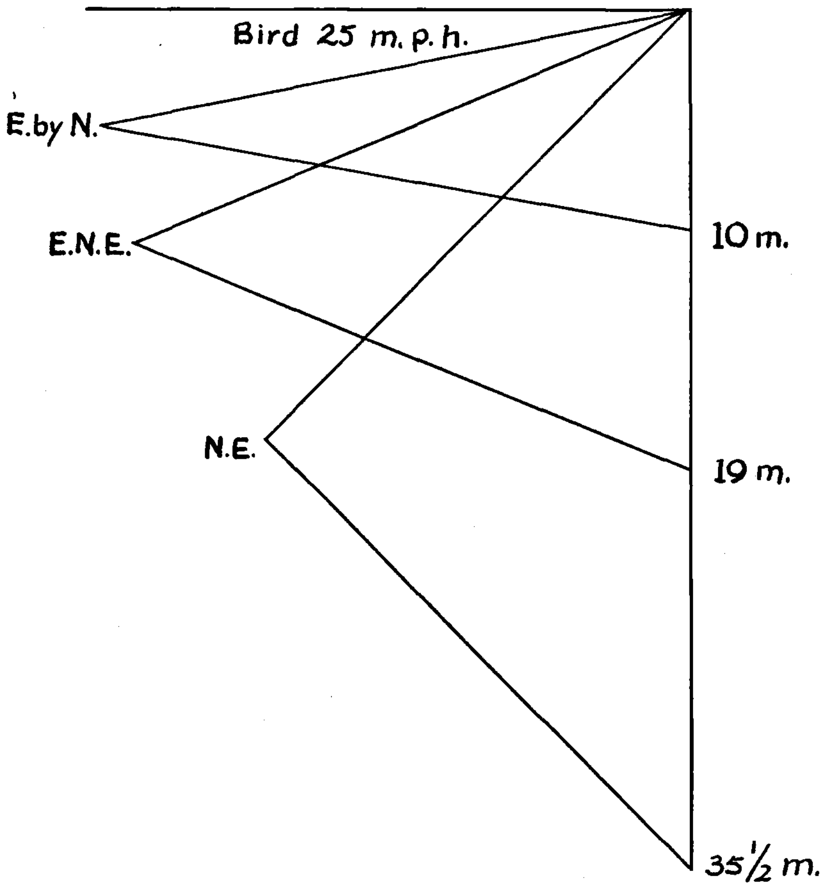
Scale : 1 in. = 8 miles

Wind 20 m. p. h.



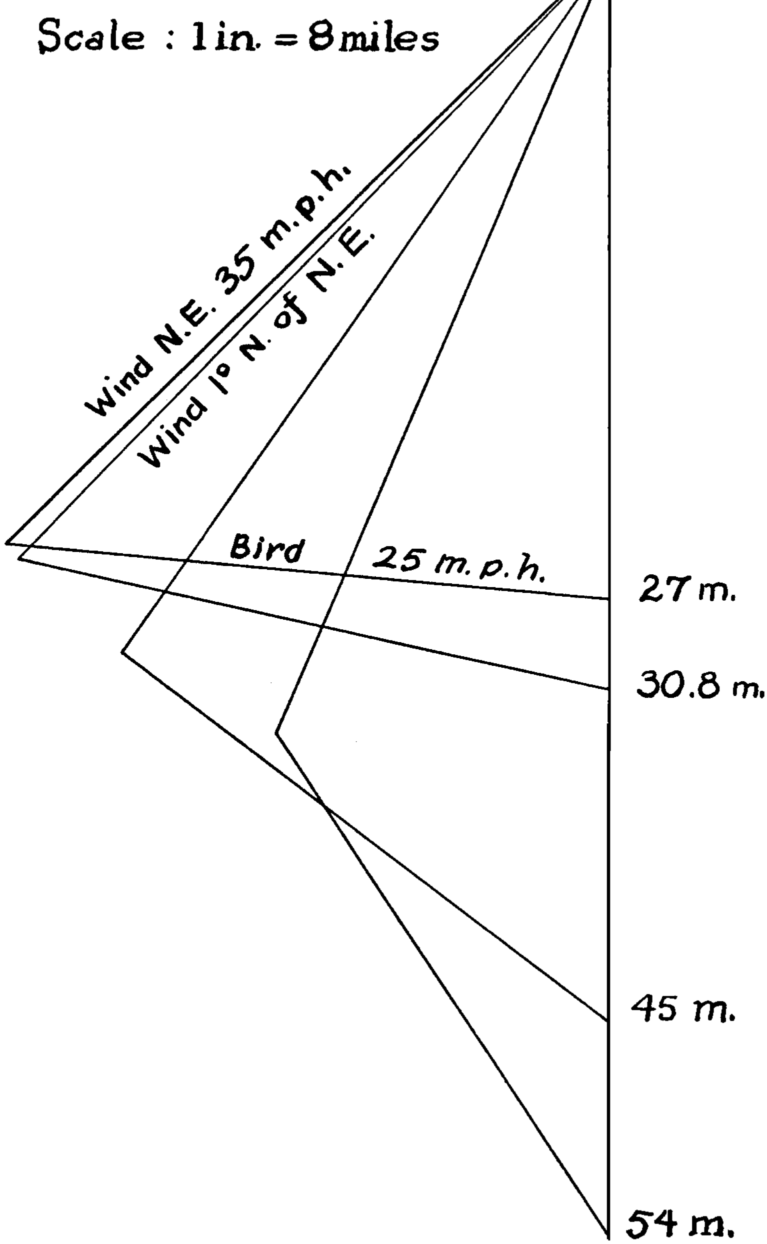
flying at normal speed about ten degrees south of east could gain about ten miles on its course, and that might be worth the effort. An east-northeast wind would net about nineteen miles, and a northeast wind would be distinctly favorable, speeding the bird up to 35½ miles (see Text-fig. 4).

FIG 4
Scale: 1 in. = 8 miles
Wind from E: 25 m.p.h.



When we are considering changes as small as a single point, we must not forget that no strong wind ever blows steadily from one point of the compass. No one who has watched a weather-vane can fail to have noticed that such winds are constantly veering, perhaps as much as a point or even

FIG. 5

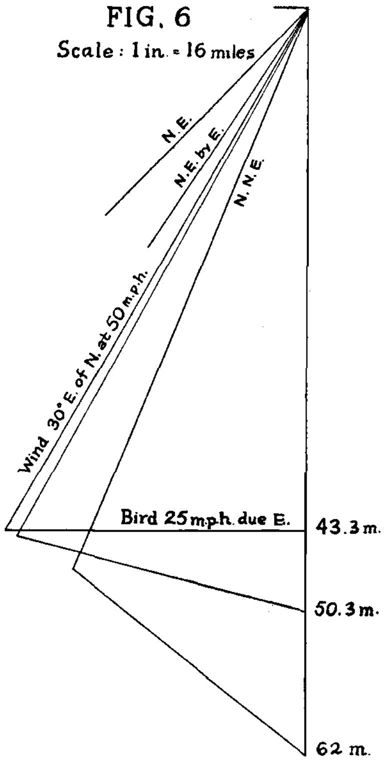

Scale : 1 in. = 8 miles
Wind N.E. 35 m.p.h.
Wind 1° N. of N.E.
Bird 25 m.p.h.
27 m.
30.8 m.
45 m.
54 m.

more, to one side or the other of the mean direction. When we speak of changes of only one point, therefore, we mean changes that *average* a point in one direction in the course of an hour.

If our strong breeze increases to a 'moderate gale' blowing thirty-five m.p.h. from the northeast, our bird by flying a little south of east can keep its course and better its mileage slightly, perhaps by two miles. A shift of a single degree to the north will now speed it up to thirty miles or more,

FIG. 6

Scale : 1 in. = 16 miles



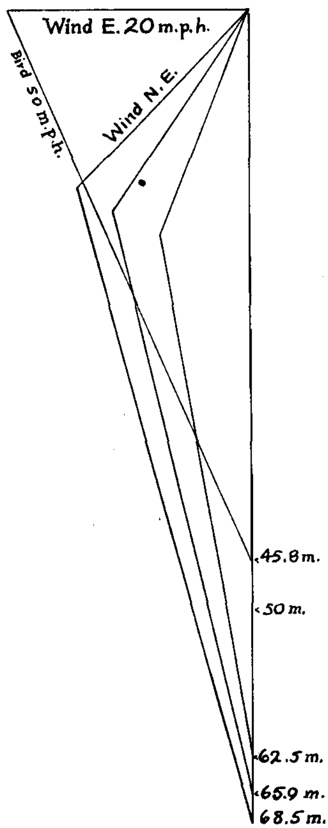
and, as the diagram (Text-fig. 5) shows, a shift to northeast-by-north will add about fourteen miles to the bird's speed, while a further shift to north-northeast will add nine miles more, making the total fifty-four miles an hour.

If the moderate gale increases to a 'strong' one of fifty m.p.h., it will blow our bird out to sea unless it comes from thirty degrees or less east of north. At about N. 30° E. it would take it 43.3 miles on its course. One degree more to the north would add seven miles, and a wind from the north-northeast would carry our twenty-five-mile bird about sixty-two miles (see Text-fig. 6).

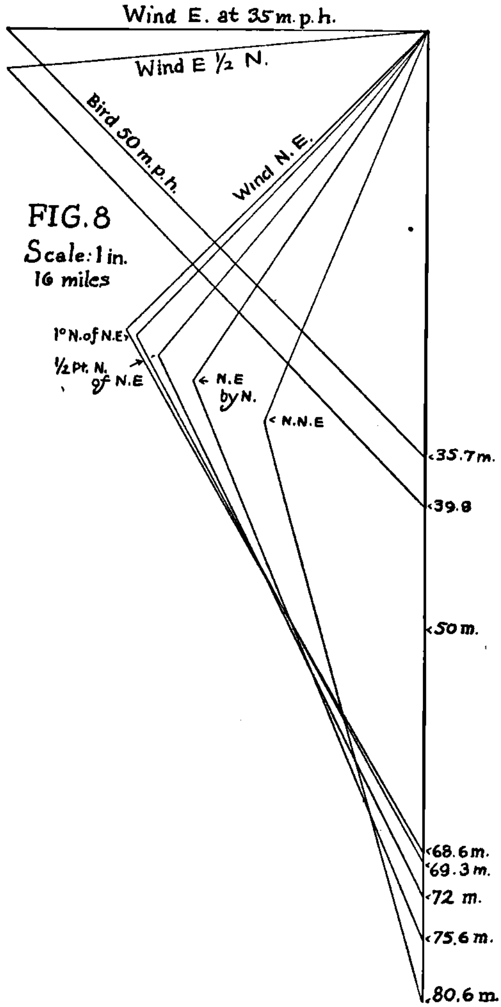
So much for our comparatively slow-flying pelican. Now let us take a faster bird, say a duck with a speed of fifty m.p.h. in a calm. With such a bird a ten-mile wind from any direction can make little difference. At the worst it can reduce the speed only to forty and at best it can increase it only to sixty m.p.h. Ducks, however, being strong-flying birds, may well

FIG. 7

Scale: 1 in. = 16 miles



venture forth in strong breezes. Our diagram (Text-fig. 7) shows that, with a beam wind of twenty m.p.h. from the east, a southward-flying duck would make 45.8 miles an hour. The beam wind would thus hamper it, but a northeast wind of the same velocity would speed it up to 62.5 miles. With a wind due east at thirty-five m.p.h. our fifty-mile duck could hold its course by heading a very little south of southeast and make 35.7 miles. A shift of half a point ($5\frac{5}{8}°$) to the north of east would add a little over four miles to what the bird would make with an east wind. A northeast wind at thirty-five m.p.h. would enable our duck to make 68.6 miles in an hour, and a shift of one degree to the north would give it about two-thirds of a mile more; and so on (see Text-fig. 8).



To see how a fifty-mile wind would affect a fifty-mile bird we have only to double the figures for the twenty-five-mile bird in a twenty-five-mile wind (see Text-fig. 4).

Our diagrams suggest that in a hampering wind a bird heads deliberately in a very different direction from that in which its course would lead it and allows the wind to make the necessary adjustment. It must not be understood that this is what actually happens. We should not expect to see a bird heading straight for shore when its real intention is to parallel the shore. What the bird actually does is to fight every foot of the way and, however this is done, the result is the same as if it steered by compass in the appropriate direction. It is clear, at least, that no more economical way of keeping its course could be devised than by using its full powers of flight in a direction calculated to balance accurately the force of the wind.

As I have said, and as everybody knows, birds' flight speeds are not fixed quantities. We cannot say that *the* speed of the Mallard, for instance, is fifty m.p.h. The air-speed records for this species run from forty-six (plus or minus) to sixty. It should be obvious that even the air speeds of birds are governed by conditions other than their wing power. Meinertzhagen in an often-cited paper in 'The Ibis' for 1921, recorded his conclusion that "birds have two speeds—a normal rate which is used for everyday purposes and also for migration, and an accelerated speed which is used for protection or pursuit, and which in some cases nearly doubles the normal speed." He does not make it clear, however, why he limits his birds to *two* speeds. I think he was intent chiefly on showing that birds possessed a power of considerable acceleration over their ordinary speeds, and had no real intention of asserting that individual birds were actually limited to two fixed speeds. It would seem fairly obvious that even ordinary speeds vary greatly. A pelican feeding would naturally fly in much more leisurely fashion than if it were flying home to its roost, and a small bird flitting from one tree to another could hardly get up the speed it would need for a migration flight. So, too, in the higher speeds, a bird pursued by a hawk would naturally accelerate from fast to faster and faster as the chase became hotter; and would make a greater speed in getting away from a fast hawk than would be needed in escaping from a slower one, because it would be pressed to the limit of its strength. Perhaps for most purposes the most valuable speed records are those that show the very limit of the bird's powers.

Of the 178 records of ground speed—not air speed—listed in Miss Cooke's paper, only twenty-nine make any mention of the wind. Of these, nine report "calm", "still air," or "no wind," and may be taken as valid records for air speed; two say "light air"; five, "wind abeam"; one, "all types of wind"; one, "wind behind"; one, "favoring wind"; one, "gale behind"; one, "strong head wind"; only three give any estimate of the velocity of the wind in m.p.h.; and only one mentions any relative wind direction except ahead, abeam, or behind.

The last-mentioned record, which is also one of the three giving figures for the velocity of the wind, is that of Brown Pelicans by Carl R. Smith published in 'The Gull,' monthly bulletin of the Audubon Association of the Pacific, in September, 1924. This single record is praiseworthy as an attempt to give exact data, but I must call attention to the fact that it is open to serious question. The timing of the pelicans was done at El Pismo Beach near San Luis Obispo, California, when the birds were flying "south, keeping close to shore." We are informed that the prevailing wind on this stretch of the coast is from the northeast, but no statement is made as to its exact direction at this particular point and time. Mr. Smith goes on to say, "Their speed, in practically calm air, reaches 14 miles per hour; in a half-gale, it rises to 16 miles per hour; with the wind blowing at fifty miles per hour, the birds travel at the rate of 22 miles per hour." Now fourteen m.p.h. in a calm seems very slow for a Brown Pelican. Longstreet's record cited by Miss Cooke for four birds with wind abeam (not a favoring wind) is twenty-six m.p.h., and Meinertzhagen cites a record for another species of pelican of fifty-one m.p.h. with a "side wind" of fifteen m.p.h., which at the very least would mean an air speed of fully thirty-six m.p.h. Moreover it is not stated how Smith's wind speed of fifty m.p.h. was ascertained or just what is meant by "half-gale." It is hard to see, at any rate, how his birds could possibly have flown in a fifty-mile gale from the northeast without being blown out to sea even if they could increase their speed to thirty-five miles. A more favorable wind at anything approaching that speed would have taken them much more than twenty-two miles on their course. I am at a loss to account for Mr. Smith's figures and am sorry not to be able to accept Miss Cooke's explanation, which seems to be founded on the now-discredited theory that a wind blowing horizontally has some mysterious lifting power of its own that makes it easier for a bird to fly against it than with it. It is only fair to quote Miss Cooke's exact words for the benefit of readers who may not have her paper at hand. She seems to have regarded these strong winds from the northeast as favoring winds—whereas it is clear that, blowing at such speeds they must have been seriously hampering, to say the least—and, to account for the comparatively slight gains in flight speed after so great increases of what might appear to be a favoring wind, she says: "The explanation is that in order for a bird to remain aloft it must rest on a current of air against the under side of its wings, and the current must come from the front, not from behind, the backward tilt of the wings catching this wind. These facts are well recognized in modern aeronautics. Both birds and airplanes must take off and land into the wind. Therefore, if the wind is directly behind, the bird must move its wings faster in order to get the necessary upbearing current or else be blown along by the wind without being able to guide its course." This overlooks the fact that the bird, by its progress through the air, *creates* the current on which it must rest. Otherwise it would be impossible for a bird to fly in a calm. As a matter of fact, for supporting a bird in the air, except for the variations in force and direction of the wind, one way of the wind is as good as another and one velocity of the wind is as good as another. A balloon floats upright in a steady wind as in a calm, and a bird makes the same air speed in a steady wind, whether flying with it, against it, or across it. Whichever way the bird goes, it gets its support from the current of air that it meets and gets no more support from a head wind than from a stern wind, because, being borne along with the wind, the air in which it flies is stationary so far as the bird's movements within it are concerned. Only in landing and in taking off is it important for a bird, as for an airplane, to head into the wind, because then the flier passes from one element to another. (There is also the exception of the hovering bird, which heads into the wind to maintain its position over a particular spot of land or water.) The dislike that birds seem to have for flying with the wind applies, I think—after the first inertia is overcome—only to strong winds, which are accompanied by frequent annoying puffs that ruffle the feathers when they strike them from the rear.

I hope I have shown the importance of fuller and more precise data on wind direction and wind speed in records of the ground speeds of birds. When we consider that a difference of a very few degrees in the direction of a wind may make all the difference between complete frustration and substantial progress for the bird, and that apparently neutral winds become increasingly unfavorable as they increase in strength, we can appreciate the seriousness of the gaps in the published data.

Professor Frederick A. Saunders, of the Physics Department of Harvard University, has been kind enough to read this paper and has helped me with valuable suggestions.

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