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## A STUDY OF THE FLIGHT OF SEA GULLS

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WITH 11 PHOTOGRAPHS AND 2 DIAGRAMS

NO ONE who has traveled on the ferries which ply across San Francisco Bay can have failed to note the sea gulls which follow constantly in their wake. Hour after hour, day by day, sometimes at night even, they may be seen winging tirelessly after the cumbrous boats, sailing high like paper kites, or sporting in the currents of air about the stern, or scuffling noisily for bits of food thrown overboard by the passengers. In the earliest dawn they are on duty, looking like gray specters in the morning mists, and on moonlit nights they are abroad at least until midnight, flapping along like giant bats in the semi-darkness.

Of the many thousands of people who have watched the gulls on the bay and admired their beauty, probably most have thought of their graceful evolutions only as a part of Nature's artistry. But for the ornithologist, the aesthetic is not the sole nor even the principal interest which attaches to them. Rather does he remark the marvelous powers of flight which enable so large a bird to keep aloft for long periods of time without fatigue, and the rapid coordination which permits it to take advantage of every current of the shifting air, and to maintain its equilibrium under the most adverse circumstances of wind and weather.

On account of their large size, easy flight and relatively slow wing movements, the gulls have long been looked upon as peculiarly favorable subjects for studies of avian aeronautics. However, although our knowledge of their flight is rather extensive, as yet it is far from complete. The data assembled by different observers are frequently not in agreement, and, as Hankin (1913, p. 253) has pointed out, two authorities as competent as Maxim and Headley have published statements diametrically opposed. Such contradictory ideas must in most cases indicate, not that the observations on which they rest are incorrect, but only that they are inadequate; a type of behavior which is observed on one or two occasions may be entirely lacking under other circum-

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Fig. 2. The beginning of the stroke.

Fig. 3. The completion of the stroke.

Fig. 4. Wings advanced on the downstroke (left) and retired on the upstroke (right).

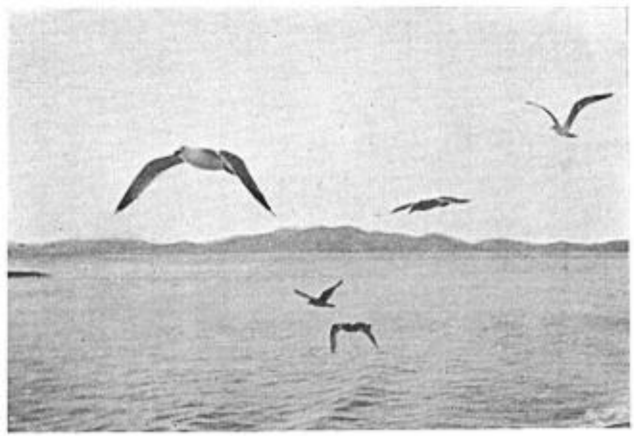

Fig. 5. Five different phases of the stroke.

stances, and it would be a mistake to assume that modes and methods of flight adapted to some particular set of conditions hold true for all.

The writer became interested in some of these problems by watching the maneuvers of gulls about the ferry boats, and he began some months ago to take notes on their behavior with reference to the speed and direction of the wind and other factors, as he had occasion to cross the bay from time to time. The present paper is based on a series of observations covering a period of about nine months, from July, 1921, to March, 1922, during which time the writer has on occasion laid himself open to suspicion of mental aberration by rushing about on the deck of a ferry boat, gazing seaward and skyward, and jotting down notes in a small black book.

The machinery of flight—the structure of wings and feathers and the nice musculature which controls them—has been dealt with in much detail by Headley (1895 and 1912), Hankin (1913), and others. It is sufficient here to note that the wings are strong, rigid and light, that they are curved to offer the maximum resistance on the downward and the minimum on the upward stroke, and that the great wing feathers, by their shape, contribute materially to the action of the muscles and relieve unnecessary strain. It is generally agreed that the muscles and tendons of the wing are so arranged as to operate automatically, the motion which extends the humerus mechanically extending the other units of the wing, even to spreading the flight feathers. (This view has been objected to by Beetham, 1911, p. 435.) It is important also to note that the tips of the flexible flight feathers bend upwards under the strain of any sudden gust (fig. 7), thus allowing the wind to "slide off" from the under surface of the wing and contributing automatically to the maintenance of equilibrium.

Having in mind these few notes on the mechanics of flight, we may go on to consider the bird in action, which has been the major object of these studies. Nothing appears more leisurely and effortless than the flight of gulls. The exertion by which they keep pace with a steamer seems to be little more than an idle flapping, when indeed they are not soaring on almost motionless wings above the boat. But when we come to study more closely just what is taking place, and particularly when we record photographically certain movements that are too quick for the eye, we discover that more energy is being expended than at first seemed to be the case.

The first point to be noticed is that the stroke of the wings is considerably longer than appears to the eye; indeed, each time the pinions are raised they almost meet above the body, and on the downward beat they approach the perpendicular beneath it. This can partially be seen when a bird passes directly on a level with the eye, but can be fully demonstrated only by photographs which catch the wings at their highest and their lowest points. The full sweep of the wings can be seen by a comparison of figures 2 and 3, which indicate respectively the beginning and the completion of a stroke. This is illustrated a little less perfectly by the two birds in figure 4; and in figure 5, by a happy chance, five different phases of the stroke are represented, although neither the full upward nor the full downward extension of the wings is shown. It will be noted by studying the lowest bird in this figure that, on the down stroke, the wing is sharply flexed at the wrist, the forearm being nearly horizontal.

It should be remarked, however, that while the eye tends to underestimate the length of the stroke, the camera somewhat exaggerates it. The wing does not actually describe an arc of nearly 180 degrees, as might be thought from its extreme upward and downward extensions. It is to be remembered that the body of the bird is not moving on a fixed plane, but undulates with each beat of the wings, rising on the downward stroke and falling a little as the wings are raised. This up and down motion appears from Marey's figures (1895, p. 237) to be about equal to the thickness of the body of the bird. Thus when the wings move from the highest to the lowest position of a beat, their tips describe a shorter arc than if the body were fixed. The undulating motion of the body is usually concealed from the observer for lack of a point of reference, or because it is masked by the greater motion of the wings.

From the fact that the wing stroke is as long as we have described, it follows that the beat must also be more rapid than it gives the impression of being. This is found to be true when we undertake to photograph a gull in action. The seemingly leisurely flapping of the wings can rarely be caught

Fig. 6. Rapid movement of the wing tip.

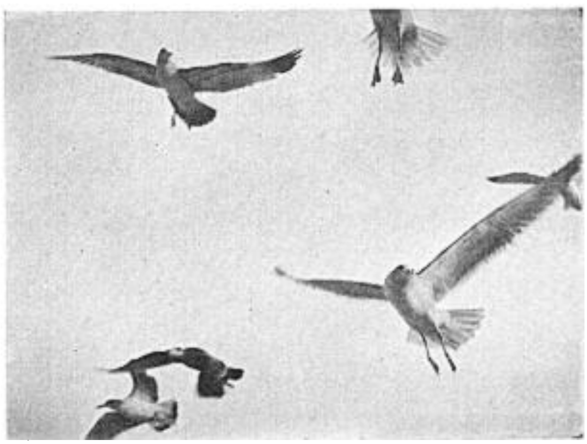

Fig. 7. The use of feet and tail for retarding flight.

by an exposure of less than 1/200 of a second, and often shows movement at even higher speeds than this (fig. 6).

In ordinary flight a gull will average about 120 strokes per minute. This involves a rather slow movement near the shoulder, but one which becomes exceedingly rapid towards the tip of a long wing, as we see in figure 6, and in the case of the lower right-hand bird in figure 7, where the humeri are sharply recorded, but the more rapidly moving tips are blurred.

It is the rapidity of the wing stroke which is the secret of flight, not of gulls alone, but of birds in general. The quick stroke suddenly compresses the resilient air beneath the wing, and this has usually been assumed by theorists to be the means by which the bird is supported; it rides on successive columns of compressed air. Rather, however, should be emphasized the reciprocal of this, that is, that on the downward stroke a momentary vacuum is left above the wing. In other words, the air pressure is removed above but maintained beneath the pinion, so that it is supported theoretically by a force approaching 16 pounds per square inch of surface. Of course, this vacuum is by no means complete and is of very brief duration, but it is obvious that the lifting power of the air beneath is ample to support a much larger bird than a gull on the same wing area.

The displaced air cannot rush in so quickly in the wake of a large wing as in the wake of a small one. This explains why a gull is able to support itself in the air with only two strokes per second, while a sparrow, which really has a greater wing expanse in proportion to its weight than a gull, must take 13 strokes per second (Marey, 1890, p. 100). A large wing is intrinsically a more efficient instrument of flight than a small wing, without reference to the weight of the bird to be supported.

During the beat of the wings there is a certain forward and backward, as well as up and down, motion, so that the wing tip describes an ellipse or, due to the forward movement of the bird, a series of loops (fig. 8). It is possible even that the trajectory of the wing tip is a sort of figure 8, as Pettigrew (1847, pp. 15ff.) has insisted, and Marey (1890, p. 140) has described for the crow; but the presence of a secondary loop cannot be determined by observation, and seems rather doubtful.

Two phases of the loop described by the wing are to be seen in figure 4. The upper bird shows the wings advanced on the down stroke (position A, fig. 8), while the lower bird has them retired on the up stroke (position B, fig. 8).

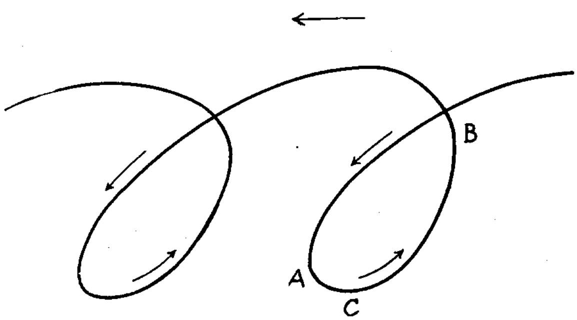

Fig. 8. TRAJECTORY OF THE WING TIP.

Figure 3 shows the wings with the front margins almost vertical, as they would appear at position C, figure 8.

The effect of advancing the wings farther than normal is to rotate the front margins upward, so that the ventral surface is directed anteriorly, thus retarding forward flight. This is well shown in figure 9. These gulls were hovering with almost no forward motion, picking up bits of food from the water without alighting. The advanced wings, depressed tail and lowered feet indicate the efforts to check forward flight.

The feet are ordinarily held close against the under tail coverts in flight (figs. 2, 4, and 6), but may be lowered and even the webs spread out to act as "brakes" in retarding flight. The coordinated use of feet and tail for this purpose is admirably shown in figure 7, especially in the bird only partly included at the top of the photograph.

In rising from the water a further use of the feet becomes evident (fig. 10). A certain forward momentum is necessary before the bird can rise, and a gull may often be seen contributing to the efforts of its wings by kicking vigorously as it leaves the water.

Fig. 9. Hovering over the water with almost no forward movement. Note advanced position of the wings.

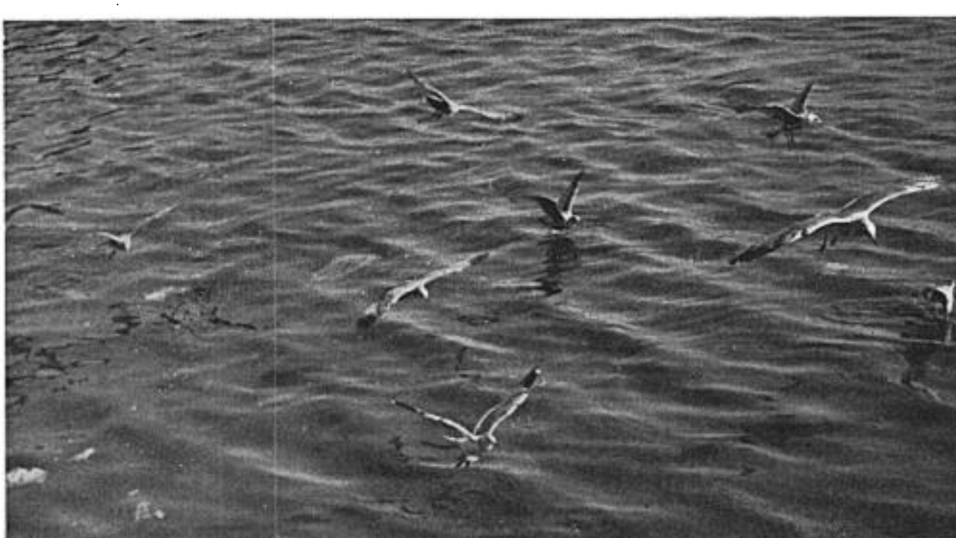

Fig. 10. Rising from the water. Observe positions of feet.

However complicated may be the process of flapping flight, so long as a bird's wings are in motion we are able to understand at least in a measure how it keeps aloft; but what are we to say when we witness a large bird sailing for great distances on almost motionless pinions without loss of altitude, or even steadily gaining altitude with no more effort than the occasional twitch of a wing in making an adjustment to some sudden gust? This is the phenomenon referred to as *soaring flight*, which has ever been a source of wonderment to layman and scientist alike.

While the gulls are not masters of this type of aerial navigation to quite the same extent as the larger hawks and vultures, nevertheless they often give remarkable exhibitions of their powers along this line. It is a common sight to observe a gull travel several miles at a speed of from 12 to 18 knots per hour without a single flap of the wings; and I think it probable that much higher speeds than this would be recorded if there were faster steamers on the bay to serve as a basis of comparison.

Various theories have been proposed from time to time to account for soaring flight, some of which are plausible, while others are rather obviously at variance with the facts.

It has been commonly urged that a soaring bird has gotten into an upward current of air, in which it has only to maintain itself by proper adjustments, retaining its height or ascending according to the force of the rising current and the angle of its wings. In other words, soaring flight is simply a downward glide in an ascending column of air.

It has been objected to this that birds are often seen to soar in the absence of any ascending current, so far as can be detected, and even that they studiously avoid such currents (Hankin, 1913, pp. 19, 63, etc.).

Lilienthal (1911, p. 78) advanced the somewhat surprising theory that the general trend of the wind everywhere is upward at an angle of 3 to 4 degrees to the horizon. The logical difficulties of such a theory are rather obvious, as at this rate we should shortly be living in a vacuum; and Headley (1895, p. 238) has comfortingly demonstrated that the direction of a wind over a level plain is horizontal, although a very slight obstruction may cause a pronounced upward draught.

Opponents of the ascending current theory have proposed numerous other, and often less adequate, hypotheses to account for soaring flight.

Some have postulated a wave-like or pulse-like motion of the air; according to this theory, the bird gains momentum by gliding with the wind in the interim between gusts, and gains altitude by turning to face each freshening breeze (Headley, 1895, p. 246). Others have maintained that small eddies or whirlpools in the air are taken advantage of, the bird meeting them and gaining energy by extinguishing their motion (Hankin, 1913, p. 62). A few have even urged that soaring flight is an illusion, the wings really being in motion, slight, but sufficient to keep the bird aloft. This rather strained hypothesis has probably been suggested by the occasional balancing movements which soaring birds are seen to make.

In the *American Naturalist* for 1886 we find a very remarkable theory advanced by I. Lancaster, which, stated briefly, is this: A properly constructed glider will move in a horizontal direction much more rapidly than it descends vertically. The more the wings are inclined, the greater becomes the horizontal motion relative to the vertical. If the wings are sufficiently inclined, as he assumes to be the case in the soaring bird, theoretically (?) the vertical motion should entirely cease, the pull of gravity causing only horizontal motion. This seems to be a round-about way of stating that a soaring bird is really held up by the force of gravity!

A curious consequence of this theory was that Professor Hendricks (1886) thought it necessary to reply in a subsequent issue of the same journal with several pages of complicated mathematical disproof, demonstrating by various formulae that the effect of gravity would actually be, not to support a soaring bird, but rather to bring it to earth!

A more recent investigator (Hankin, 1913) has discarded all theories having a basis in any known physical laws, and insists, on the grounds, be it said, of much excellent observation, that soaring flight must be referred to some entirely unknown quality of the atmosphere, which he terms "soarability". Of this he postulates two kinds, "sun soarability" and "wind soarability". Neither of these depends upon ascending currents, but rather upon some mysterious transfer of sun (pp. 98, 105, 206) or wind (pp. 278 ff.) "energy" to the soaring bird. Such a theory can hardly be looked upon as doing aught but removing the phenomenon from the realm of possible explanation to that of pure mystery.

It seems at present that the earliest and simplest of these theories, that of ascending currents, is the most plausible. So far as the writer has been able to observe, it is entirely adequate to explain the soaring of gulls. The following extracts from my notes will indicate the basis of this statement:

August 17, 2:20 P. M.—Clear, bright day; stiff west wind. Several gulls observed sporting in current of air deflected upward by ferry slip at Oakland Mole. Would glide west some yards on motionless wings, gradually losing altitude, then rotate wings so as to be caught by breeze and swept back into ascending current, in which they would speedily rise with no visible effort and repeat the performance. This continued about five minutes, until birds were disturbed by coming of a boat.

August 13, 5:30 P. M.—Stiff west wind; several gulls soaring a few yards above and slightly to the leeward of the highest point on Goat Island.

July 29, 10:50 A. M.—Ferry travelling against stiff west wind. Gulls observed at points S, XX, and Y (fig. 11). Those at XX flapped continually. Those at Y took a zig-zag course, alternately flapping and sailing; they would gain momentum by flapping vigorously while in the shelter of the stern, then dive to one side into the wind and sail a moment, quickly losing momentum but gaining altitude. Then, from this increased height, they would dive back into the shelter of the stern, usually adding to their momentum by flapping, and continue across into the wind on the other side, where they would again gain altitude with the loss of momentum. This was repeated indefinitely, like a sort of play.

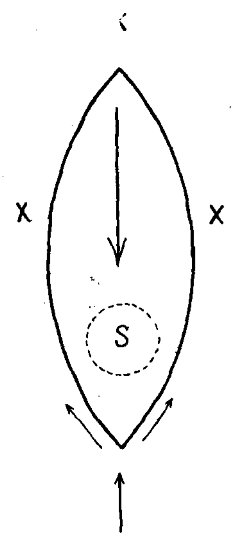


Fig. 11. DIAGRAM OF POSITIONS OF GULLS ABOUT A FERRY BOAT MOVING AGAINST THE WIND.

Several gulls were soaring without effort just above the forward pilot-house. There was scarcely a visible wing movement so long as they remained in the area S (upward draught from bow), but they had to resort to flapping whenever they drifted to one side or the other of this area. (On several occasions a gull has been observed very distinctly to *fall off* this upward current, and drop suddenly somewhat laterally for 10 or 15 feet before righting itself.)

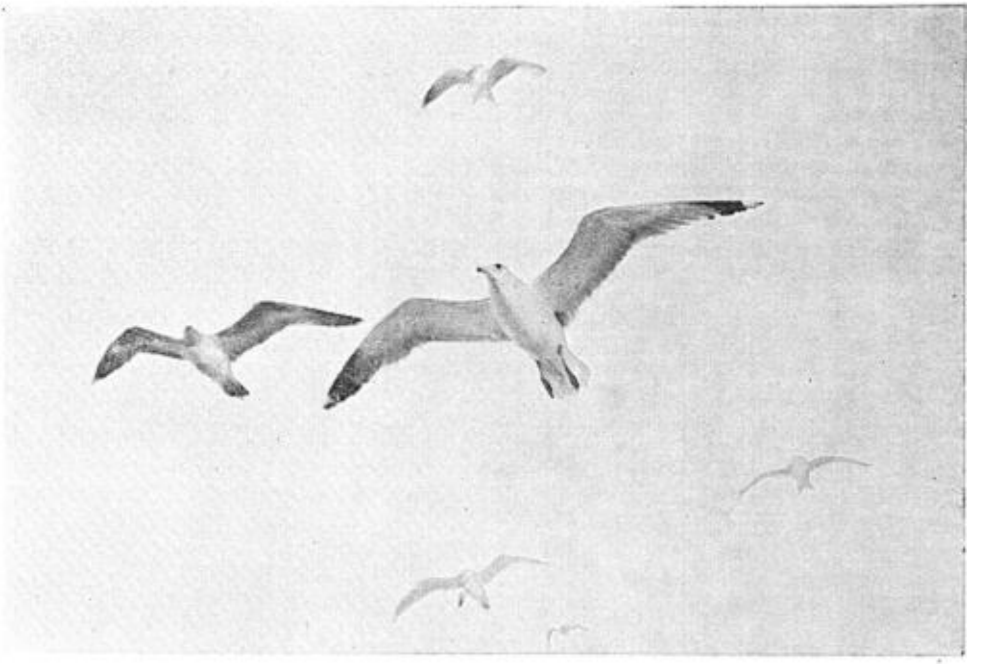

Fig. 12. Typical soaring positions.

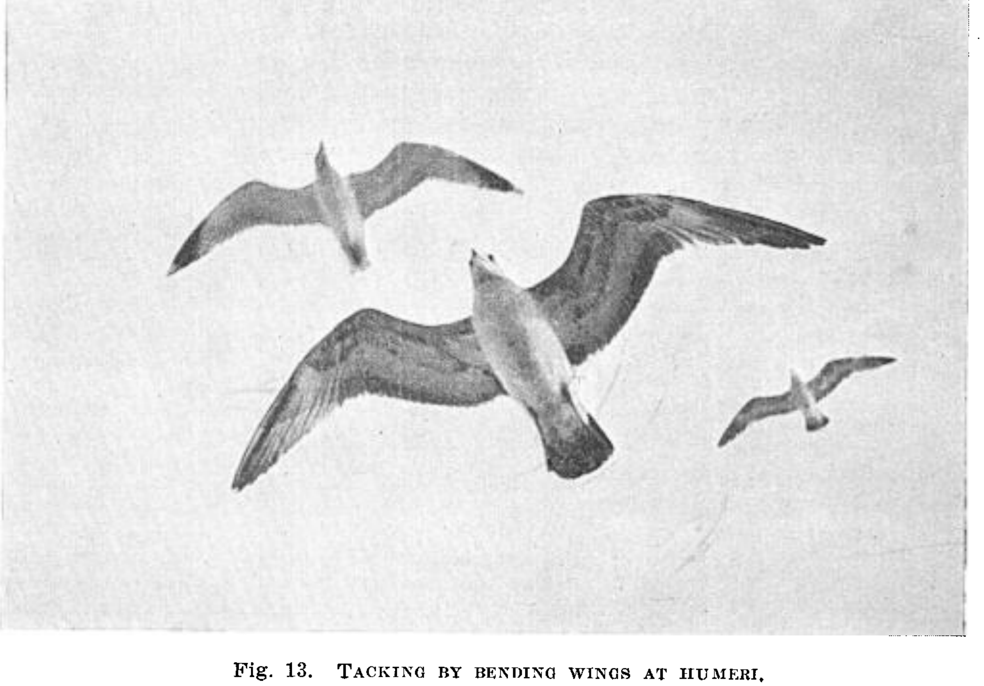

Fig. 13. Tacking by bending wings at humeri.

July 30, 11:40 A. M.—Ferry going west against light breeze. Three gulls soared smoothly just above forward pilot-house, balancing by occasional flick of wing tips.

7:30 P. M.—Ferry going east, with light wind from stern. Several gulls followed, flapping, at a distance. No soaring was attempted.

August 1, 3:20 P. M.—Ferry going west against very stiff wind. Very little soaring attempted, and only for a few moments at a time. One bird alternately flapping and sailing was caught by a sudden gust, almost capsized, and turned completely around. In two or three seconds it righted and began following boat again.

November 6, 2:30 P. M.—Ferry going west; fair wind from starboard. A number of gulls soared over windward side, moving sidewise and forward, with left wing advanced (figs. 12 and 13); that is, the birds were moving with the boat, while facing a point half way between the course of the boat and the direction of the wind.

3:40 P. M.—Ferry going east; wind from port. Birds soared as before, on windward side, but with right wing advanced, as would be expected from reversed direction of flight.

Their method of soaring was carefully observed. They would rise in the upward current at windward side until at a considerable height, then drift forward and laterally, to right or left, with gradual loss of altitude, until they circled back into the ascending current and rose again. Thus their flight was a series of circlings in and out of the ascending column of air, with a steady forward glide to keep pace with the boat. The wings were held nearly motionless, and slightly flexed (fig. 1) to derive the maximum lifting power of the wind.

The chronological order of these excerpts has been intentionally disturbed, in order that they may furnish illustrations respectively of the following points:

1. That gulls take advantage of the air currents deflected upward from buildings, steamers, hill-sides, etc., to indulge in soaring flight.
2. That they have not been observed to soar in the absence of such currents.
3. That the most favorable conditions for soaring about a steamer occur with a moderately brisk wind from the bow, or either side.
4. That a very stiff wind is not favorable to soaring.
5. That the "soarable" position varies with the direction and speed of the wind, and the nature of the object causing the upward draught. Thus, in a moderate wind from starboard, the gulls soared over the windward side of the boat, while in a stiff breeze over the crest of Goat Island, they soared to the leeward of the island. It has been observed also that, with increasing briskness of the wind about the ferry boats, the soarable area tends to move more and more to the leeward. This may explain the confusion which has existed upon the point (Hankin, 1913, p. 253), some observers reporting that gulls soar on the windward, others that they soar on the leeward side of steamers.

In conclusion it should be stated that these data are not intended to furnish an adequate explanation of soaring flight in general, but only of that of the gulls as I have observed it. It is entirely possible that, in the magnificent soaring of eagles and vultures, particularly as seen in the tropics, other factors may enter. Conditions at a height of one or two miles must be very different from what they are at the relatively small heights to which gulls attain.

But if, as some maintain, birds are able to soar in the absence of any *noticeable* upward movement of the air, it is yet entirely possible that such currents may be in operation, due to convection or other causes of atmospheric disturbance with which aeronauts are unpleasantly familiar. The wing of a bird, particularly of a large bird, is, as we have shown above, an extremely efficient instrument, capable of immediate adjustment to derive the maximum advantage from every movement of the air, so that a very slight upward draught may yield it considerable lift.

In any case, it seems wiser to go as far as we can with explanations in terms of known physical laws, rather than to postulate forces of which we know nothing, and which, if they exist, we have little chance of discovering.

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*University of California, July 1, 1922.*

## A NATIONAL BIRD DAY

By ALTHEA R. SHERMAN*

IN *Iowa Conservation* for July-September, 1921, we find a set of resolutions, adopted at the Annual Summer Convention of the Iowa Conservation Association. Among the resolutions, is one that reads as follows: "That we are in sympathy with the movement to make April 3, John Burroughs' birthday, a National Bird Day." Some of us may not be in entire sympathy with such a movement, therefore the present seems the time to voice our objections, and not to say them with flowers.

Those of us, having three hundred and sixty-five days in every year that are more or less bird days, certainly can not object to others having one day

*With the permission of the author this article is reprinted from the **Iowa Conservation,** April-June, 1922. It is so good, and touches on so many questions of the day so directly, that we hereby break our rule not to give space in **The Condor** to matter already printed.—EDITORS.