# 29. Observations on the Flight of Flying-Fishes.

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(Text-figures 1 & 2.)

A point hitherto overlooked in the study of the flight of flying-fishes is that the air is suitable for their flight to very different degrees on different occasions. In this respect their flight resembles that of soaring birds. This statement may be illustrated by the following examples.

## 1. *Flight under unsuitable atmospheric conditions.*

On the 1st June, 1920, at about a quarter of an hour after sunset, the ship on which I was travelling across the Arabian Sea was disturbing groups of small flying-fishes at the rate of one or two groups per minute. The surface of the sea was either glassy or disturbed by ripples too small to be easily visible.

Each fish, on emerging, jumped out of the water so far that, while the body was supported on the outstretched "wings," the end of the tail was still immersed. This organ was thereupon wagged vigorously from side to side, as is usual when starting, thus forming a trail of ripples in the water. After proceeding thus for the unusually long distance of four or five metres, the fish raised its tail from the water and began to glide. The length of the glide made by each fish was, at first, about a metre. Within a few minutes a change was observed. The fishes of each group disturbed by the ship made shorter and shorter glides, until at length each fish fell into the water immediately it ceased to move its tail.

One fish flapped its wings at starting, but made no better glide than the others.

About half an hour previously, in sunshine, the ship had also been disturbing small flying-fishes, which had flown for such distances as are usual. Just before sunset the first symptoms of lessened suitability of the air for their flight were observed. The fishes began to show lateral instability. It may be noted that both vultures and flying-fishes are more apt to show lateral instability late in the afternoon than at other times of the day. The stage of lateral instability shown by the flying-fishes soon passed off and was replaced by one in which the course of each fish, instead of being a horizontal straight line, was undulating. Each fish showed two or three alternations of gain and loss of height before falling into the water. This condition soon changed to that first described.

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In view of these gradual changes in the performances of the fishes, there seems to be no room for doubt that they wished to get away from the neighbourhood of the ship, by air and as quickly as possible, throughout, and that the air was getting progressively less and less fitted for their flight.

On the other hand, it has been observed by me on many occasions that the air remains suitable for the gliding flight of flying-fishes after sunset if wind is present.

2. *Flight under fully favourable atmospheric conditions.*

During the same voyage, in sunshine and in the presence of a light wind, flying-fishes were seen by me to fly at a uniform height above the water till they were out of sight. This was noted on two or three occasions. On a previous voyage I had seen a flight till out of sight under cloud in a monsoon wind. A binocular was used for these observations. Usually the longer flights appear to be between 200 and 400 metres in length. In a flight of this kind the following phenomena may be noticed:—

The fore wings (pectoral fins) are usually in the "flat" position, *i. e.* extended in the horizontal plane. Sometimes the wings are slightly inclined upwards. In this case the outer part of the wing is at a higher level than its base. This may be called the "up" position. Rarely the wings are inclined very slightly downwards. This may be described as the "down" position. This latter disposition, which I was only able to see distinctly on my recent voyage, is probably that used for flight at highest speed, as in slow-speed flight the wings are inclined upwards to a strong degree.

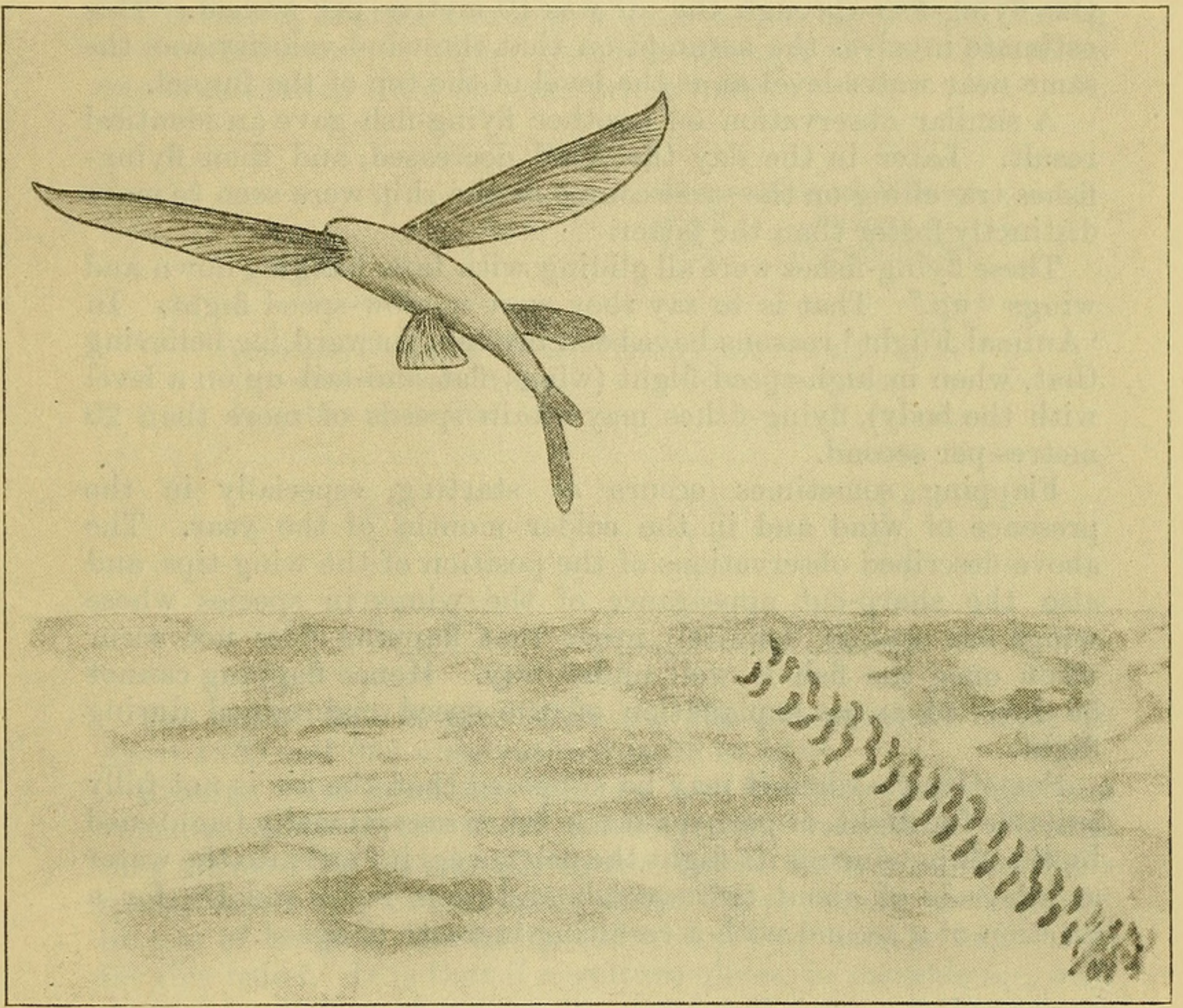
Thus in respect of its wing-disposition the flying-fish resembles the soaring vulture, for vultures have their wings in the "up" position for slow-speed flight and use the "flat" wing disposition for flight at high speed. A further resemblance is indicated by the following very unexpected observation:—

If the flying-fish is very carefully observed the extreme wing-tips, for nearly an inch of their length, may be seen to be bent up forming an angle of perhaps 45 degrees with the rest of the wing. If the sun is not far above the horizon, and if the fish is travelling away from the observer in a southerly (presumably also in a northerly) direction, then the wing-tip furthest from the sun appears thicker than the other. This appearance has been seen by me quite clearly and definitely in flying-fishes of two different species. The appearance seems to be due to the upturned wing-tip being bent round so that it has a negative angle of incidence and hence, when the sun is low, the underside of one wing-tip is seen in shadow. When the sun gets higher the visibility of each wing-tip is reinforced by shadow in this way. But, at best, the upturned wing-tip is by no means easy to see.

The bent-up wing-tips show no appearance of vibration. They appear as if held in their position by a steady force. As I have stated elsewhere ('Animal Flight,' Iliffe and Sons, 1914), the wing-tips of vultures in horizontal soaring flight show the terminal quills bent up as though they were under the influence of a steady force acting from below and behind.

As the fish is emerging from the water an interesting appearance may sometimes be seen. The length of the trail (made by lateral movement of the tail) is generally less than a metre and a half. It may be only half a metre. At the end of the trail in

Text-figure 1.



Flying-fish starting, showing trail of ripples made by movement of tail. Wings up and tail down as in slow-speed flight.

a few observations the fish appeared to make a sudden jump out of the water, gaining height thereby to the extent of four or five inches. Had this appearance of a jump been due to an extra strong stroke by the tail, one would have expected to have seen an extra large ripple in the water. Nothing of the kind was observed. On other occasions, when the jump was not seen and, I believe, did not occur, the trail was observed to get fainter towards its end (text-fig. 1).

### 3. *Speed of flight of flying-fishes.*

During my recent voyage a flying-fish was seen flying on a course parallel with the ship and at the same apparent speed. During eight seconds, timed with a stop-watch, it remained fixed in position relatively to the ship. The latter was travelling through the water at 15½ knots or 7⅝ metres per second. The direction of the real wind was learnt by noting the movement of the waves, that of the apparent wind by the position of the line of smoke from the funnel. From these data it was calculated that the velocity of the wind was 4 metres per second and that of the flying-fish through the air was 10 metres per second. This estimate involves the assumption that the wind-velocity was the same near water-level as at the level of the top of the funnel.

A similar observation on another flying-fish gave an identical result. Later in the day the wind decreased, and then flying-fishes travelling on the same course as the ship were seen to move distinctly faster than the latter.

These flying-fishes were all gliding with tails hanging down and wings "up." That is to say they were in slow-speed flight. In 'Animal Flight' reasons have been brought forward for believing that, when in high-speed flight (wings flat and tail up on a level with the body), flying-fishes may attain speeds of more than 20 metres per second.

Flapping sometimes occurs at starting, especially in the presence of wind and in the colder months of the year. The above-described observations of the position of the wing-tips, and also the sharp-cut appearance of the wings in species whose wings are opaque, definitely prove that flapping does not occur when once the fish is well under way. Hence flapping cannot be invoked as an explanation of the speed maintained during flight.

Sometimes—when it may be supposed that the air is not fully suitable for flight, or perhaps if the fish is exceptionally frightened by the ship—during its flight the fish lowers its tail into the water at intervals of about two seconds and wags it to and fro for a fraction of a second with a resulting increase of speed.

### 4. *Comparison with the speeds attained by vultures in horizontal soaring flight.*

That the speed of flight of flying-fishes is similar to that of soaring vultures when in horizontal flight is shown by the following figures:—

During April 1920, I made several measurements, in Agra, of the apparent speed of vultures with the help of a Souchier telemetre by the method described by me in 'Animal Flight.' Information as to the velocity of the wind in which the vultures were gliding was obtained from measurements made with the help of balloons sent up by Mr. J. H. Field (to whom I owe my thanks) from the Agra Aerological Laboratory. The balloons were sent up at the time I was making my measurements. On one day seven balloons were let off while I was observing. From data thus obtained, it was possible to deduce the speed of the vultures through the air.

Another set of measurements were made by me during the first eight months of the year 1915. In these cases, however, the balloons had been liberated four or five hours before my observations were made. An error is thus introduced into the calculations which, it may be noted, is likely to be less on days of light wind than in stronger winds.

The results of these two sets of observations agree in indicating that vultures soar at higher speeds in stronger winds. The mean speeds calculated from my data are as follows :—

| | Observations made in April 1920. | Observations made in January to August 1915. |
|---|---|---|
| Velocities of wind, in which the vultures were flying, in metres per second. | Mean speed of vultures, in metres per second. | |
| 0–3 | 11·6 | 11·7 |
| 4–6 | 11·8 | 14·1 |
| 7–9 | 15·0 | 17·2 |
| 10–20 | 20·0 | 17·7 |

The above figures are based on 122 observations made in April 1920 and 696 observations made in 1915.

Reasons have been adduced by me for believing that the vultures on which the above measurements were made, were, as they appeared to be, actually in horizontal flight and that their speed, which they can maintain indefinitely, cannot be explained by loss of height. An additional reason may here be mentioned for this belief. It is that if a vulture glides, in soarable air, with even a small loss of height, its speed will very greatly increase beyond the above figures. For instance, in April last a measurement was made of a speed of 42 metres per second in a vulture flying nearly with the wind. The wind had a velocity of only $2\frac{1}{2}$ metres per second at the height at which the vulture was flying. Hence the speed of the bird through the air must have been about $40\frac{1}{2}$ metres per second. As this speed was exceptional and as the bird was travelling in the direction of a place where vultures frequently settle, it was assumed that it was gliding with loss of height, though no loss of height was seen, and it was not included in the calculation of the mean speeds above given.

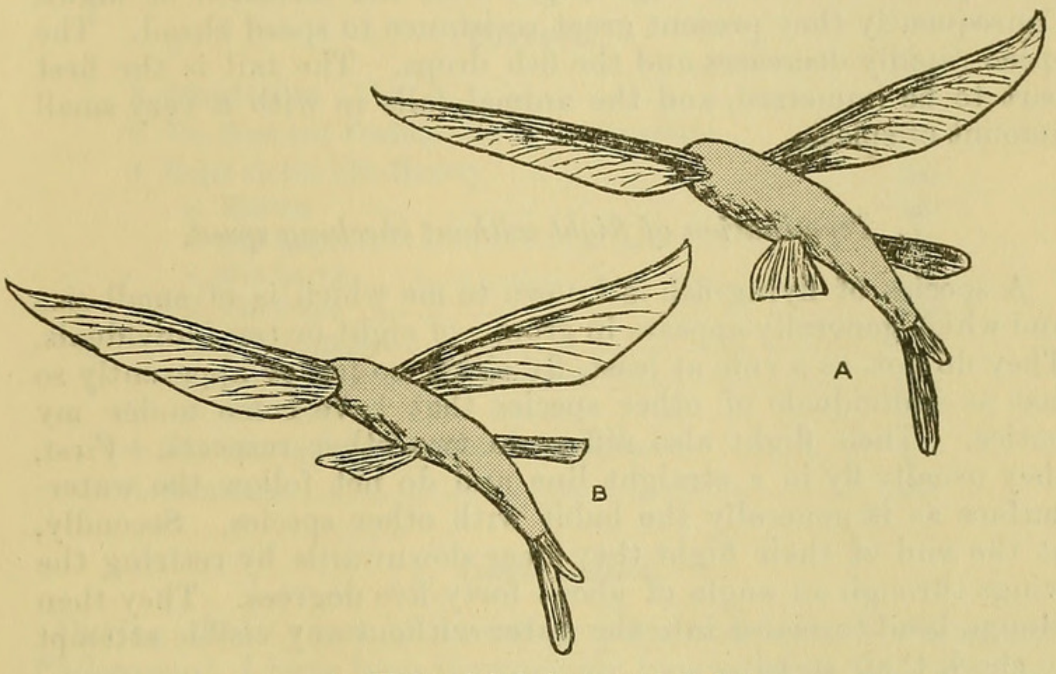
If vultures in soaring flight attain velocities of ten to twenty metres per second and if their velocities tend to increase as soon as they begin to glide downwards, it is obvious that they must possess some means of checking speed. Otherwise they would be unable to land without accident. In 'Animal Flight' two methods of checking speed, one used for high-speed flight, the other used for low-speed flight, have been described. Two analogous methods, for slow and fast speed respectively, employed by flying-fishes have now to be described.

### 5. *Method of checking speed in high-speed flight.*

This method, which depends on changes of position of the hind wings (pelvic fins), has only been followed by me in species whose wings are coloured. It would be quite beyond my powers of observation to see the adjustment in those species whose wings are more or less transparent. Of the species that have yielded most opportunities for these observations may be mentioned one with black hind wings and another whose hind wings have a chocolate-brown colour. The observations about to be described are very difficult to make, and the following account is, to some extent, compiled from glimpses of parts of the adjustment seen on different occasions.

The flying-fish starts its flight with the hind wings directed outwards and backwards and extended in the horizontal plane. At some distance, perhaps 50 metres, from the end of its flight, it may be seen suddenly to lower its hind wings (pelvic fins) so that they point nearly vertically downwards. On my recent voyage, when using a binocular of magnification 10, it appeared to me that, when the hind wings are in the down position, their plane is parallel to the direction of flight. In this position the leading edge only of the hind wing would offer direct resistance to speed ahead. But on a voyage in 1914, when I was using an Aitchison binocular of the very unusual magnification 25, on two occasions the hind wings, when in the down position, appeared to me to be slightly rotated round their long axis so that their hind margins approached each other. On one of these occasions, during part of the flight, one hind wing was less visible than the other. This was probably due to its having been seen end on. When the fish changed its course so that it was travelling directly away from me the two hind wings became equally visible. With the hind wings thus disposed it is obvious that the air passing between them must be, so to speak, entering a funnel, and therefore much resistance would be offered to speed ahead. It is probable that these two dispositions of the hind wings are used successively, for, within about a second of the end of the flight, the two hind wings are suddenly rotated through nearly a right angle round their long axes. The result of this manœuvre is that the plane of the hind wings acquires a position at right angles to the direction of flight. In the first down position the hind wings are not fully expanded. In the last position they are expanded to their greatest extent, thus offering the maximum resistance to speed ahead. On one occasion the adjacent edges of the two hind wings appeared to me to overlap. Almost or quite simultaneously with the full rotation of the hind wings, the tail is lowered and the fore wings are placed in the up position. The tail then touches the water, and the fish falls in with practically no splash.

Text-figure 2.




A. Flying-fish in low-speed flight.

B. Hind wings advanced at end of flight.

In monsoon winds the fish may place its hind wings in the down position and even rotate them almost from the commencement of its flight. If this is done no high apparent speed is attained even in cases in which the fish is travelling at right angles to the wind.

Much practice in observing flying-fishes was needed by me before it was possible to see these adjustments of the hind wings. On my last voyage, in June 1920, I was able to see clearly the full rotation of the hind wings in flying-fishes of three different species.

### 6. *Method of checking speed in slow-speed flight.*

If the flying-fish is making a flight at slow speed, as happens more frequently in the colder than in the hotter months of the year, and as happens usually in the absence of wind, an entirely different means of checking speed is employed and one which is much more easy to observe.

During slow flight the fore wings are strongly inclined up and the tail hangs down. The hind wings, as in high-speed flight, are directed outwards and backwards. Towards the end of the flight the hind wings are somewhat suddenly advanced (text-fig. 2). They still remain extended in the horizontal plane. The effect of this movement is to bring the lift of the wings as a whole further forward in respect of the centre of gravity. The fish consequently rotates round its transverse axis. It is a rotation upwards, *i. e.* the head goes up, the tail down. The angle of incidence of the fore wings is consequently increased to such an extent that their plane assumes a large angle with the direction of flight. Consequently they present great resistance to speed ahead. The speed rapidly decreases and the fish drops. The tail is the first part to be immersed, and the animal falls in with a very small amount of splash.

### 7. *Termination of flight without checking speed.*

A species of flying-fish is known to me which is of small size and which generally appears in groups of eight or ten individuals. They do not, as a rule at least, fly either so far or apparently so fast as individuals of other species that have come under my notice. Their flight also differs in two other respects. First, they usually fly in a straight line and do not follow the water-surface as is generally the habit with other species. Secondly, at the end of their flight they steer downwards by retiring the wings through an angle of about forty-five degrees. They then plunge head foremost into the water without any visible attempt to check their speed.

It is possible that this species is identical with *Exocœtus evolans*. This is the name of a species, or of a group of closely allied species, which differ from other flying-fishes in that their pelvic fins are small and placed far forward. Hence these fins are unfitted to function either for checking speed or for steering in the vertical plane.

It is probable that the frequent shortness of the flights of flying-fishes is often involuntary. My observations indicate that flying-fishes sometimes behave as if they had made a mistaken estimate of the suitability of the air for their flight. On one occasion I noticed that they were starting with their wings disposed for slow-speed flight, that they immediately changed over to the high-speed disposition and then, at once, fell into the water with a splash. On my recent voyage I noted, on one occasion, that flying-fishes were starting with tails up (*i. e.* as in high-speed flight). They then, either at once fell into the water or lowered their tails and flew on. On other occasions when groups of small individuals emerged they all at once fell in with splashing or, in some cases, while the rest splashed in, one or two got away and made flights of normal length.