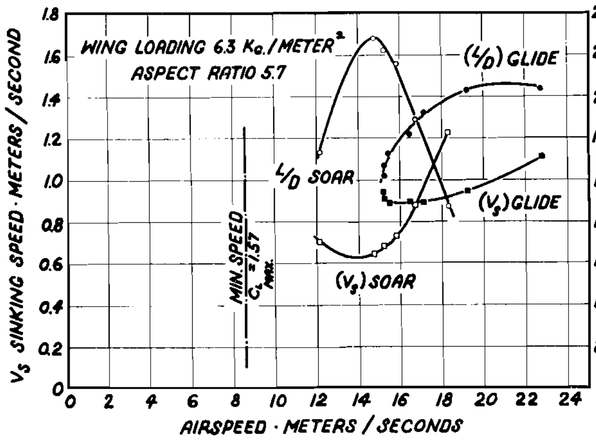

Fig. 6. Velocity polar and glide ratio of black buzzard.

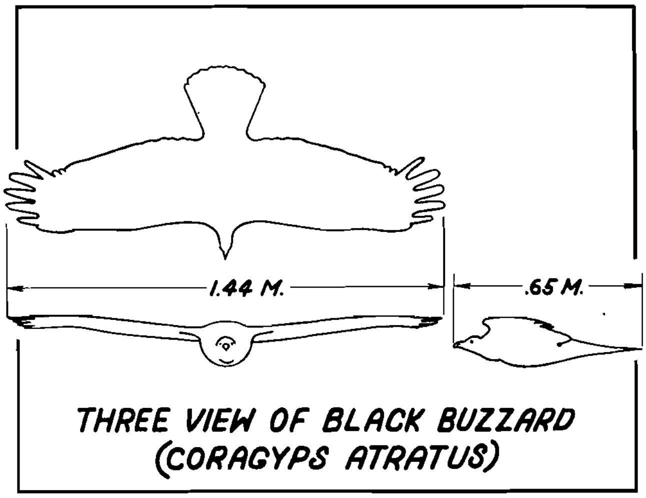

Figure 7.

page. The success in training this bird was due to the skill and understanding of George Carter.

Had this experiment been successful, it would have yielded the sinking speed in function of airspeed, i.e., the speed polar similar to figure 2. But for a landing bird, we would need to observe the mode in which the bird is flying in order to delineate the function of the variable geometry of the slotted wing tip.

Furthermore, the success achieved in training this one bird by Carter clearly supports his contention that it would be possible to train live birds to fly in a windtunnel whose axis could be inclined to the horizon. Thus, the bird would be forced to fly at different gliding angles and at different airspeeds, simply by inclining the tunnel and varying the airspeed so that the bird would remain motionless in the throat of the tunnel. With this method, one could delineate the function of the slotted wing tip as well as derive drag polars for various changes in geometry which the bird would be compelled to make in order to stay in the tunnel.

Since the technique of using trained birds was so dependent on the training of the birds and so time consuming, the comparison method of flying with birds in a sailplane was developed in 1949 (ref. 6), as a refinement of the simple one point comparison test made on the laughing gull in figure 2.

In the comparison method for determining the speed polar and consequently drag polar of a bird in free and natural flight, a sailplane of low sinking speed and low forward speed capability is needed. In addition, the sailplane must be highly maneuverable since the pilot must follow birds having extremely good turning abilities.

Figure 5 shows a sailplane rigged for bird flight research. A small radio transmitter and receiver is carried by which to transmit data to a ground data recorder. The telephoto camera on the windshield is used to record the geometry of the bird. However, the results obtained with this camera were not helpful, in that it was not possible to determine the orientation of the tip feathers from the non-stereoscopic photographs.

In making these measurements, the sailplane was launched by either a ground tow behind an automobile on a long runway or by an airplane tow. When the sailplane reached an altitude where upcurrents were strong enough to support it, the pilot would release and soar in a good upcurrent. Ground observers would scan the skies for buzzards, and when one was found, direct the pilot to the buzzard by radio. When the pilot located the bird, he would descend to the altitude of the bird and then follow it, staying no more than 5 to 10 meters behind it. At 30 second intervals, the pilot would report the airspeed at which he and the bird were flying and the altitude of the bird above the horizon, measuring in wing spans.

Subsequent plots of the altitude of the bird against time yielded, from the slope of this plot, the difference in sinking speed between the bird and the sailplane.

Then, by measuring carefully the sinking speed of the sailplane in the still air of the morning at various airspeeds, one has the speed polar of the sailplane. Adding to this polar the differences in sinking speed between the bird and the sailplane, we arrive at the speed polar of the bird. (Figure 6.)

In this illustration, the two modes of gliding flight yield two different speed polars of the bird. In the soaring mode, the bird flies with open tip slots, while in the gliding mode, he flies usually on a long descent at relatively high speeds with tip slots closed. Also in the latter mode, the bird will introduce an M-shaped sweep back, whereas in the soaring mode, a pronounced sweep-forward of the wing is used. Figure 7 shows the black buzzard in his soaring mode.

Returning to figure 6, we see that at a speed of 17 meters per second, the speed polars cross. Above this speed, the bird chooses the gliding phase, for under this condition his sinking speed is considerably lower than with the tip feathers opened. Below 17 meters per second, the bird finds that he can reduce his sinking speed by opening the tip slots, and thereby increase his glide ratio (L/D). The glide ratio curves represent the distance the bird can fly for each unit loss of altitude. In other words, the black buzzard (*Coragyps*) is capable of gliding 23 miles in still air from an altitude of one mile at his best glide ratio. This remarkable feat is possible at a relatively slow forward speed of 15 meters per second with tips slots open.

An interesting biophysical constant can be derived from the velocity polar of figure 6. If we wish to determine the minimum power required for the bird to maintain level flight, we take the product of the minimum sinking speed of 0.62 meters per second and the weight of the bird. This yields the rate of loss of potential energy which must be