BREATHING OF BIRDS IN FLIGHT

By JACK T. TOMLINSON

Very little work has been done on the breathing of birds in flight. In view of the difficulties inherent in recording breathing under flight conditions, it is not surprising that earlier investigations employed simulated flight conditions. The best review of the literature is found in Salt and Zeuthen (1960).

In an attempt to approach the "natural" condition of flight, we allowed birds to fly essentially "free" but encased their bills in a thin rubber balloon and monitored the breathing with the aid of a motion picture camera (Tomlinson and McKinnon, 1957). This is also subject to criticism as being "unnatural," of course, as is the method of radio telemetry developed by Lord, Bellrose, and Cochran (1962) for a duck. The Mallard Duck (*Anas platyrhynchos*) in the latter experiment was allowed free flight and unimpaired air intake but had its body encircled with a metal band coupled to a radio transmitter.

We have found that pigeons (Tomlinson and McKinnon, 1957) breathe a complete cycle every wing-beat. Lord, Bellrose, and Cochran (1962) showed that Mallard Ducks breathed every second wing-beat, with an indication that occasionally there are three wing-beats per breath.

The present study involves a Western Gull (*Larus occidentalis*) and representatives of three species of ducks: a Lesser Scaup (*Aythya affinis*), a Pintail (*Anas acuta*), and a Mallard.

The method of study consisted of applying balloons of appropriate size over the bill and nares. In all cases the bird could breathe from the corners of the mouth. Although the birds repeatedly tried to remove the balloons, they flew what appeared to be normal flights without obvious anoxia. Flights without balloons appeared identical to the observer. The birds were tethered with a light cord to prevent escape, although no control over flight direction was used. This allowed for a fairly natural flight but made analysis difficult in many cases.

A Bolex H16Rex, 16 mm. motion picture camera, was set at 64 frames per second (slow motion) although the actual speed varies downward to around 60 frames per second, depending on the spring tension, temperature, and other factors. Photographs were taken upon takeoff and for the duration of the flight, a period which rarely lasted more than 4 or 5 seconds. Thus, figures of wing-beat and breathing frequency will be higher than for birds in cruising flight. The number of usable flights was reduced by difficulties in focus and framing together with the tendency of the bird to fly away from the photographer or to turn its head occasionally and obscure the balloon. Flights in which the balloon was clearly visible for more than one second were selected for frame-by-frame analysis. These analyses are summarized in figure 1.

In addition to the birds analyzed in figure 1, flights of a Red-tailed Hawk (*Buteo jamaicensis*) were photographed. It made 13 wing-beats in 2.4 seconds without a breath registering on the balloon. It landed very shortly thereafter and breathing was clearly visible with the bird on the ground. It is my opinion that the bird was not breathing during this time in flight.

From these limited data several tentative conclusions can be drawn. It appears that as the weight increases from gull to ducks and within the ducks, the number of beats per breath increases. The breathing tends to be less ordered in the larger birds, with inhalations and exhalations coming at different parts of the wing-beat cycle. In the

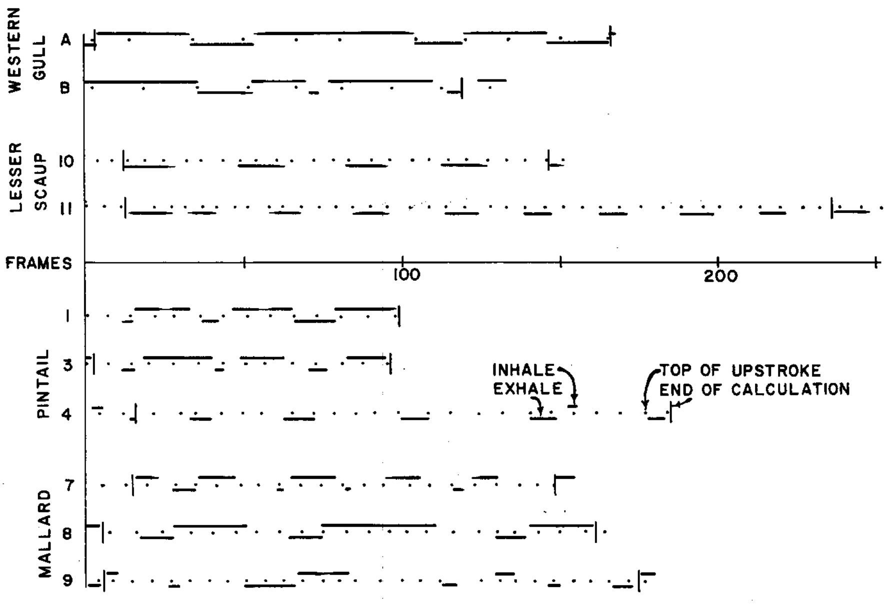

Fig. 1. Graph illustrating the breathing of birds in flight. Broken lines above rows of dots indicate inhalations; broken lines below rows of dots indicate exhalations; wing-beats are shown as rows of dots, each dot representing the top of the upstroke of the wing. The end of each calculation is shown by a vertical line.

pigeon under the same conditions, the inhalation was on the upstroke and exhalation on the downstroke.

Attempts to use the "balloon method" on birds smaller than a pigeon have failed due to insufficient amount and pressure of air and the inertia of the balloon. Attempts are being made to study the respiration of smaller birds using the transmitter method

TABLE 1

WING BEATS IN RELATION TO BREATHING RATES

	Weight in grams	Beats	Breaths	Beats per breath	Length of flight in seconds	Beats per second	Breaths per second
Western Gull	520	10	3	3.33	2.56	3.90	1.17
		8	3	2.67	1.89	4.23	1.59
Totals and averages:		18	6	3.00	4.45	4.04	1.35
Lesser Scaup, ♀	497	23	4	5.75	2.09	10.99	1.91
		37	9	4.11	3.48	10.62	2.58
Totals and averages:		60	13	4.85	5.58	10.76	2.33
Pintail, ♂	785	14	3	4.67	1.53	9.14	1.96
		13	3	4.33	1.48	8.76	2.02
		23	5	4.60	2.64	8.71	1.89
Totals and averages:		50	11	4.55	5.65	8.84	1.94
Mallard, ♂	1255	20	5	4.0	2.08	9.62	2.41
		22	3	7.3	2.63	10.29	1.90
		27	3	5.4	2.42	9.08	1.24
Totals and averages:		69	13	5.31	7.13	9.68	1.82

of Lord, Bellrose, and Cochran (*op. cit.*) or using strain gauges or phonograph pick-up crystals.

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