# Estimating the Airspeed Velocity of an Unladen Swallow

*Hashing out the classic question with Strouhal numbers and simplified flight waveforms.*

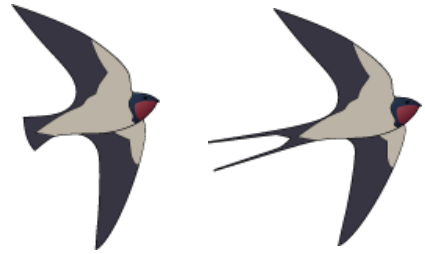
After spending some time last month trying to develop alternate graphic presentations for kinematic ratios in winged flight, I decided to try to answer one of the timeless questions of science: just what *is* the airspeed velocity of an unladen swallow?

## What do you mean, an African or European Swallow?

To begin with, I needed basic kinematic data on African and European swallow species.

Although 47 of the 74 worldwide swallow species are found in Africa,[1] only two species are named after the continent: the West African Swallow (*Hirundo domicella*) and the South African Swallow (*Hirundo spilodera*), also known as the South African Cave Swallow.

Since the range of the South African Swallow extends only as far north as Zaire,[2] I felt fairly confident that this was the non-migratory African species referred to in previous discussions of the comparative and cooperative weight-bearing capabilities of African and European swallows.[3]



South African Swallow (*Hirundo spilodera*)

European Swallow (*Hirundo rustica*)

Kinematic data for both African species was difficult to find, but the Barn or European Swallow (*Hirundo rustica*) has been studied intensively, and kinematic data for that species was readily available.

## It's a simple question of weight ratios

A 54-year survey of 26,285 European Swallows captured and released by the Avian Demography Unit of the University of Capetown finds that the average adult European swallow has a wing length of 12.2 cm and a body mass of 20.3 grams.[4]

Because wing beat frequency and wing amplitude both scale with body mass,[5] and flight kinematic data is available for at least 22 other bird species,[6] it should be possible to estimate the frequency ($f$) and amplitude (A) of the European Swallow by a comparison with similar species. With those two numbers, it will be possible to estimate airspeed (U).

## In order to maintain airspeed velocity, a swallow needs to beat its wings forty-three times every second, right?

Actually, wrong. By comparing the European Swallow with bird species of similar body mass, we can estimate that the swallow beats its wings 18 times a second with an amplitude of 18 cm:

| Species | Body mass | Frequency | Amplitude |
|---|---|---|---|
| Zebra Finch | 13 g | 27 Hz | 11 cm |
| European Swallow | 20 g | ≈ 18 Hz? | ≈ 18 cm? |
| Downy Woodpecker | 27 g | 14 Hz | 29 cm |
| Budgerigar | 34 g | 14 Hz | 15 cm |

Note that even the tiny Zebra Finch flaps its wings no more than 27 times a second while cruising.

If we ignore body mass and look only at bird species with a similar wingspan, we can estimate an average frequency of 14 beats per second and an amplitude of 23 cm:

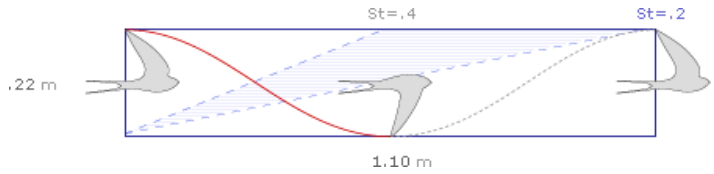
| Species | Wingspan | Frequency | Amplitude |
|---|---|---|---|
| Budgerigar | 27 cm | 14 Hz | 15 cm |
| European Swallow | ≈ 28–30 cm | ≈ 14 Hz? | ≈ 23 cm? |
| Downy Woodpecker | 31 cm | 14 Hz | 29 cm |
| European Starling | 35 cm | 14 Hz | 26 cm |

By averaging all 6 values, we can estimate that an average European Swallow flies at cruising speed with a frequency of roughly 15 beats per second, and an amplitude of roughly 22 cm.

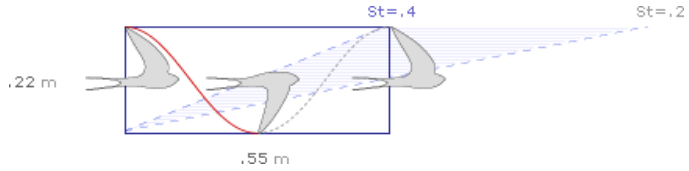
## Skip a bit, Brother

Last month's article on The Strouhal Number in Cruising Flight showed how simplified flight waveforms that graph amplitude versus wavelength can be useful for visualizing the Strouhal ratio (*f*A/U), a dimensionless parameter that tends to fall in the range of 0.2–0.4 during efficient cruising flight.

For a European Swallow flying with our estimated wingbeat amplitude of 24 cm, the predicted pattern of cruising flight ranges from a Strouhal number (St) of 0.2:

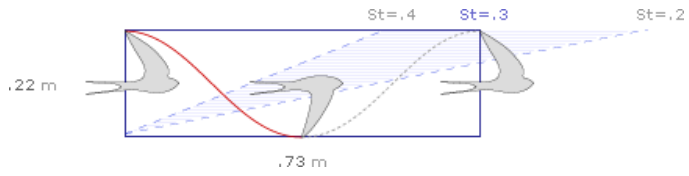



... to a less efficient 0.4:




If the first diagram (St = 0.2) is accurate, then the cruising speed of the European Swallow would be roughly 16 meters per second (15 beats per second * 1.1 meters per beat). If the second diagram (St = 0.4) is accurate, then the cruising speed of the European Swallow would be closer to 8 meters per second (15 beats per second * 0.55 meters per beat).

If we settle on an intermediate Strouhal value of 0.3:




We can estimate the airspeed of the European Swallow to be roughly 11 meters per second (15 beats per second * 0.73 meters per beat).

## Three shall be the number thou shalt count

Airspeed can also be predicted using a published formula. By inverting this midpoint Strouhal ratio of 0.3 (*f*A/U ≈ 0.3), Graham K. Taylor et

al. show that as a rule of thumb, the speed of a flying animal is roughly 3 times frequency times amplitude (U ≈ 3*f*A).[5]
We now need only plug in the numbers:

U ≈ 3*f*A
f ≈ 15 (beats per second)
A ≈ 0.22 (meters per beat)
U ≈ 3*15*0.22 ≈ 9.9

... to estimate that the airspeed velocity of an unladen European Swallow is 10 meters per second.

## Oh, yeah, I agree with that

With some further study, it became clear that these estimates are accurate, though perhaps coincidental.

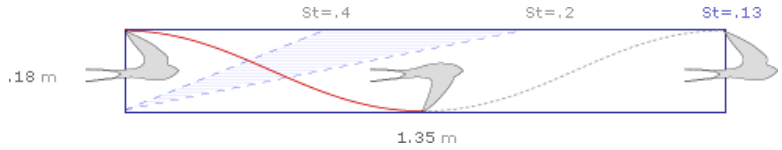
An actual study of two European Swallows flying in a low-turbulence wind tunnel in Lund, Sweden, shows that swallows flap their wings much slower than my estimate, at only 7–9 beats per second:

> "Compared with other species of similar size, the swallow has quite low wingbeat frequency and relatively long wings." [7]

The maximum speed the birds could maintain was 13–14 meters per second, and although the Lund study does not discuss cruising flight in particular, the most efficient flapping (7 beats per second) occurred at an airspeed in the range of 8–11 meters per second, with an amplitude of 90–100° (17–19 cm).

## And there was much rejoicing

Averaging the above numbers and plugging them in to the Strouhal equation for cruising flight (*f*A/U = 7 beats per second * 0.18 meters per beat / 9.5 meters per second) yields a Strouhal number of roughly 0.13:




... indicating a surprisingly efficient flight pattern falling well below the expected range of 0.2–0.4.

Although a definitive answer would of course require further measurements, published species-wide averages of wing length and body mass, initial Strouhal estimates based on those averages and cross-species comparisons, the Lund wind tunnel study of birds flying at a range of speeds, and revised Strouhal numbers based on that study all lead me to estimate that the average cruising airspeed velocity of an unladen European Swallow is roughly **11 meters per second**, or **24 miles an hour**.

## What is the capital of Assyria?

For those looking for additional answers, the four capitals of Assyria were Ashur (or Qalat Sherqat), Calah (or Nimrud), the short-lived Dur Sharrukin (or Khorsabad), and Nineveh.[8] The ruins of all four ancient cities fall within the modern state of Iraq.

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*Thank to everyone who has written in with comments and questions. Responses are posted here, along with a revised estimate from Dr Graham K. Taylor, and some alternate theories.*

November 17, 2003

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