How fast does the Common Swift *(Apus apus)* fly? Chronological bibliography

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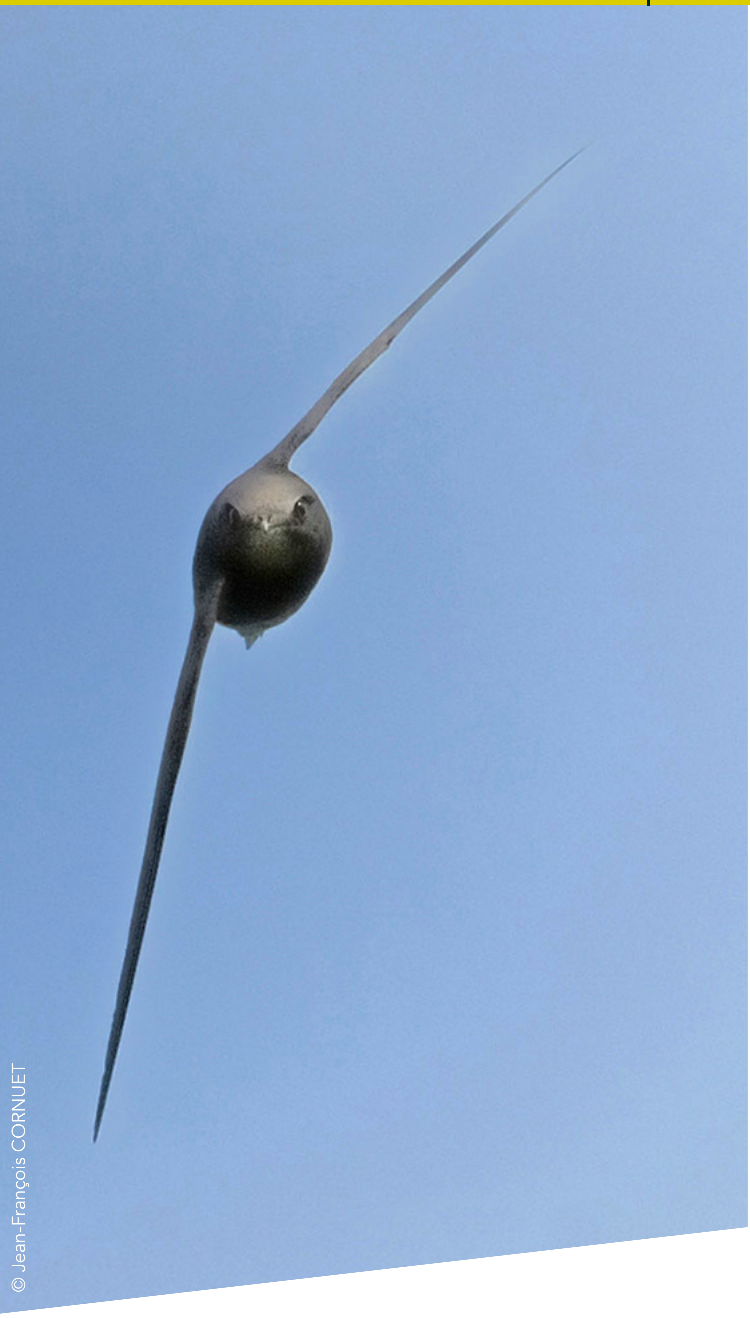

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Abstract

The Common Swift is renowned for its rapid flight. It is commonly said to be able to fly at speeds of 200 km/h or more. This chronological bibliographical summary begins with the first measurements published in 1947 by Emil WEITNAUER, one of the great pioneers in the study of this species. He manually clocked swifts at over 200 km/h above a breeding colony.

From 1955 onwards, WEITNAUER used radar to track the swifts' high altitude flights. These radars were to be used by other research teams, whose publications included data on flight speeds during migration. Gradually, the experimental conditions for these measurements were refined.

As early as the 1970s, researchers were building optical devices such as ornithodolites to measure flight speeds. Then, from the 2010s onwards, video camera systems provided

continuous data on the flight of a single individual (3D trajectory, speeds and accelerations).
The discussion in this bibliographical summary attempts to explain why the initial speed data published by WEITNAUER almost 80 years ago are still used in articles on the Common Swift.

Introduction

The starting point for this bibliographical study was the watching of a videoconference on the Common Swift organized for World Swifts Day on June 7, 2021.
The video, entitled "**Zoom sur le Martinet noir**" ("Zoom on the Common Swift") was put online on July 6, 2021 on the Youtube channel "Paris nature", managed by the Direction des Espaces Verts et de l'Environnement of the City of Paris.
The videoconference is hosted by Frédéric JARRY of Maison Paris Nature. The main characteristics of the Common Swift's biology and the measures to be taken to favour its populations are presented by two speakers:

- Ghislaine FERRÈRE of the Bleu Martinet association;
- Philippe MAINTIGNEUX of the LPO (Ligue pour la Protection des Oiseaux = French League for Bird Protection).

Philippe MAINTIGNEUX comments on the slide below concerning flight speed:

> "Once it's in the air, it has amazing flying capabilities. So it has top speeds in excess of 200 km/h, current speeds that are between 40 and 100 km/h with cruising speeds that can reach 80 km/h."

When I saw this slide, I began a bibliographical search to find out where these speed data came from, which I had already read in popular articles, books and websites.

1. Measuring flight speed using stopwatches

Two authors have published the results of their measuring flight speed of swifts by manual timing. Using fixed visual cues, they defined paths of known lengths along which they timed swifts on the wing. As the observation sites were above a colony, the birds practised a variety of flights: foraging, swooping...

1.1 (1947) Emil WEITNAUER

In 1947, Emil WEITNAUER published a long paper on his observations on the breeding of the Common Swift in his Oltingen colony (Switzerland): : "Am Neste des Mauerseglers, *Apus apus*". On page 178 he discusses the problem of speed and flight performance

1.1.1 Matérials and methods

Emil WEITNAUER writes:

"In the course of countless observations of their aerial activities, I have had many opportunities to admire their agility in flight. So it's not surprising that I dared to measure their flight speed.

There are two routes that my swifts take most often during their flights.

1. From the ridge of the neighbouring house (which runs parallel to the school building) to the school building via the nesting sites.

2. Over the high stepped gables of the vicarage (which is at right angles to the church), through the tower.

I measured these distances, set up with the stopwatch 80 and 140 metres away from them and, when the swifts were flying low over the ridge or gabled roof, measured their speed".

1.1.2 Results

Emil WEITNAUER writes:

"If they flew calmly without flapping their wings, I measured 5 to 7 m/s (18 to 25 km/h).

If the swifts are covering distances as they usually do when hunting insects over fields, I obtained an average speed of 17 m/s (around 60 km per hour) with 100 measurements. But if they follow each other closely, I often measured 20 to 30 m/s (72 to 108 km/h) in 100 measurements. However, over short distances of 20 to 50 m, they also reached 40 m/s (144 km/h) and 60 m/s (216 km/h) (max. around 200 km per hour) in their swooping flight.

In good weather, I was able to determine a flight time of 15 hours at the time of feeding of the young using bird and nest observations. At 17 m/s, this gives a daily performance of 918 km. Cf. A. Schifferli (1942)". (**Table 1**)

1.1.3 Discussion

Emil WEITNAUER writes:

"I'm aware that my measurements with rudimentary tools cannot be error-free. But I did get an indication of their flying speed. - Let's hope that a reader with better measuring equipment will be able to obtain accurate measurements - not only their agility, but also their speed of flight is astonishing".

In the abstract on page 182, he identifies two main speeds:

"Flight speed measurements showed around 60 kilometres per hour for insect hunting, and around 200 kilometres per hour for diving.".

Even though Emil Weitnauer took 100 measurements, he is aware that they are open to criticism.

The most problematic measurement is that of the speed of nose-down flights for at least 2 reasons:

1. with a more or less diving trajectory, it is very difficult to have visual reference points to evaluate the distance covered;

2. the faster birds fly, the more error-prone manual timing can be: a dive flight of 110 m at 200 km/h is covered in 2 s!

Subsequent work on measuring Common Swift flight speeds will have two major differences:

1. the wind speed at the time of measurement will always be taken into account in order to distinguish between the speed of the bird in relation to the ground (groundspeed) and the speed of the bird in relation to the air (airspeed);

2. measurements will be made mainly on horizontal flight, i.e. self-propelled flight, where the airspeed reflects the swift's muscular capacities. In diving flight, on the other hand, the bird largely uses the force of gravity, converting potential energy into aerodynamic work.

Table 1.
The speeds of the different types of Common Swift flight, measured using a stopwatch according to WEITNAUER (1947).

Gliding flight	Horizontal foraging flight	Horizontal pursuit flight	Diving and aerial games
5 - 7 m/s (18 - 25,2 km/h)	Average : 17 m/s (61,2 km/h)	20 - 30 m/s (72 - 108 km/h)	40 - 60 m/s (144 - 216 km/h)

1.2 (1968) Hans OEHME

In 1968, Hans OEHME continued his work on the aerodynamics of bird flight by publishing a paper on the flight of the Common Swift: "Der Flug des Mauerseglers *(Apus apus)*".
For his calculations he needs an mean speed of the level flapping flight of the Common Swift.

1.2.1 Matérials and methods

To obtain level paths, he timed swifts flying 80 to 130 metres in the 'corridors' of a city's streets. He measured 41 flights.

1.2.2 Results

OEHME presents its measurement results in **Table 2**.

1.2.3 Discussion

Unlike WEITNAUER, OEHME raises the question of airspeed, which he solves simply by making measurements when the wind speed is zero. He writes:

> "Airspeed: It is difficult to determine airspeed correctly, as it is not groundspeed that is required, but the bird's own airspeed. Measurements can therefore only be taken when the wind is stationary".

The table shows that the speeds range from 11 m/s (39.6 km/h) to 28 m/s (100.8 km/h).
For his further calculations, OEHME uses the speed of 16 m/s (57.6 km/h) found in 13 of the 41 measurements.
He considers 16 m/s (57.6 km/h) to be the "normal airspeed" of level flapping flight (self-propelled flight) of the Common Swift (**Table 3**).
OEHME does not specify the behaviour of birds flying in street "corridors": prey capture, social behaviour (chasing, screaming parties...).
OEHME does not quote WEITNAUER's paper published 21 years earlier, he prefers to make his own measurements. This is understandable when one reads the work of OEHME, who was as much or more (?) a physicist than a naturalist.
Furthermore, OEHME used slow-motion film footage (80 fps) of swifts on the wing to analyse, for example, the movements of the wings during flapping flight. He can therefore associate his speed measurements with slow-motion images taken at the same locations and times.
Although OEHME and WEITNAUER use the same methodology -timing of swifts in flight over a specific distance - it is difficult to compare their results because their research aims and methods are different.

On the gliding flight, OEME writes on page 290:

> "Gliding speeds had to be determined over shorter distances (40-50 m) and are therefore more uncertain. They were between 8 m/s and 14 m/s (28.8 and 50.4 km/h)".

Table 2.
Flight speeds of the Common Swift, measured using a chronometer by OEHME (1968).

Speed (m/s)	11	14	15	16	17	18	19	21	22	25	26	28
Speed (km/h)	39,6	50,4	54,0	57,6	61,2	64,8	68,4	75,6	79,2	90,0	93,6	100,8
Flight numbers (41)	1	2	7	13	6	1	2	2	1	4	1	1

Table 3.
Speeds of the different types of flight of the Common Swift, measured with a stopwatch according to OEHME 1968.

Gliding flight	Horizontal foraging flight	Horizontal pursuit flight	Diving and aerial games
8 - 14 m/s (28,8 - 50,4 km/h)	11 - 28 m/s (39,6 - 100,8 km/h) Average speed : 16 m/s (57,6 km/h)		Unmeasured speed

1.3 French-speaking authors who agree with the speed of 200 km/h, published by WEITNAUER in 1947

1.3.1 (1951-1973-1980) Paul GÉROUDET

In the 1951, 1973 and 1980 editions of his book *Les Passereaux, tome 1, du Coucou aux Corvidés.* Delachaux et Niestlé, Neuchâtel-Paris, Paul GÉROUDET writes in the chapter relating to the Common Swift:

> "The aerial performance of the Common Swift is well known, although its speed has sometimes been exaggerated; WEITNAUER (1947) clocked 22 km per hour in a quiet glide, 60 km per hour in a hunting flight over meadows, and 200 km per hour in a vertiginous chase, but over short distances."

In 1951, 1973 and 1980, GÉROUDET validated the speed measurements published in 1947 by WEITNAUER, including the speed of 200 km/h.

1.3.2 (1994) Lionel FRÉDÉRIC

In 1994, in his monography entitled *Le Martinet noir*, Lionel FRÉDÉRIC writes :

> "Weitnauer (1947) clocked the Common Swift at 20 km/h in gliding flight, 60 km/h in foraging flight and 200 km/h in hunting flight. However, this extreme speed is only achieved over short distances".

This author, by repeating almost literally the sentence written by GÉROUDET in 1951, validates the speed measurements published in 1947 by WEITNAUER, including the speed of 200 km/h.

1.3.3 (1998) Paul GÉROUDET and Michel CUISIN

In 1998, in the latest edition of Paul GÉROUDET's works, updated by Michel CUISIN, we can read:

> "Although sometimes exaggerated, the aerial performance of the Common Swift shows remarkable control of the flight for a bird of its size. The maximum speed reached over short distances during high-speed chases does not exceed 60 m/sec. (216 km/h), but during insect foraging, measurements by Weitnauer (1947) gave 11 to 28 m/sec. (40 to 100 km/h), only 5 to 14 m/s during the gliding periods".

The speed of 216 km/h for pursuit flights published by WEITNAUER 1947 is taken over and validated again.
The speeds for foraging flight (40 to 100 km/h) are those published by OEHME 1968 and not by WEITNAUER in 1947.

For gliding flight, it is a synthesis between the data of WEITNAUER 1947 (minimum: 18 km/h) and OEHME (maximum: 50.4 km/h).
These different data are in fact those published in 1980 in volume 9 of Glutz von Blotzheim, U. N. & Bauer, K. M. *Handbuch der Vögel Mitteleuropas* (Akademischer, Wiesbaden, 1980).

1.3.4-2000-2001-Pierre DÉOM

In his well-documented work on the Common Swift, Pierre DÉOM writes about the speed of diving flights on page 12:

> «And if I tell you that swifts have been clocked at speeds of 160 kilometres per hour in diving flight, will you believe me? For a few seconds, some can even reach 200 kilometres per hour !»

For the 200 km/h, the author uses and validates WEITNAUER's timed data from 1947, but without specifying that this speed referred to diving flights.

1.3.5 (2019) Gérard GORY

In *OISEAU MAG*, the LPO's spring 2019 nature magazine, n°134 page 47, Gérard GORY writes:

> "The particular morphology of this bird gives it great skill and speed in flight. Its good visual acuity, slender wings that propel it to speeds well in excess of 100 km/h, and the ability to turn within a short radius make it a formidable hunter.
> The Common Swift flies around obstacles and reaches speeds of up to 200 kilometres per hour. It is probably one of the fastest birds".

For the 200 km/h, the author uses and validates WEITNAUER's timed data from 1947, but without specifying that this speed referred to diving flights.

1.3.6 (2021) Philippe MAINTIGNEUX

As mentioned in the introduction, during the video conference on the Common Swift on 7 June 2021 and in the video posted on Youtube on 6 July, "*Zoom sur le Martinet noir*", commenting on a slide, Philippe MAINTIGNEUX said:

> "Once it's on the wing, it has amazing flying capabilities. So it has top speeds of over 200 km/h, current speeds of between 40 and 100 km/h with cruising speeds of up to 80 km/h. This means that for the birds that live in Paris, we think that some of them will feed as far as the Fontainebleau forest. At 80 km/h, it is quickly reached, we are not going to say that it is a walk, but almost".

The author uses speeds without specifying the types of flight concerned.
For the 200 km/h, the author uses and validates WEITNAUER's 1947 timed data, but without specifying that this speed referred to diving flights.

1.4 Authors who exclude the speed of 200 km/h, but validate some of the other timed data of WEITNAUER (1947) and OEHME (1968)

1.4.1 (1972) Bruno BRUDERER and Emil WEITNAUER

In 1972, in a paper entitled "Radar tracking of day and night flight of swifts *(Apus apus)*" both authors use tracking radar (go to Part 2.1). When they deal with the flight speed, they present the data of WEITNAUER (1947) and OEHME (1968) in graphical form.

> "Measurements of flight times between two house gables (cf. WEITNAUER, 1947) show that the flight profile of the swift in rapid descending flight certainly allows such high speeds, but also show that the speed of normal horizontal flight is generally less than 50 km/h. Optical measurements by OEHME (1968), also shown in Figure 1 (in red), confirm these results".

Two important remarks on this graph which WEITNAUER co-authored in 1972:

1. All flights above 100 km/h measured by WEITNAUER in 1947 are diving flights.

2. These diving flights do not exceed 165 km/h on the histogram. There is no longer any question of 200 km/h.

1.4.2 (1980) Emil WEITNAUER

In 1980, in his monography on the Common Swift (*Mein Vogel*), Emil WEITNAUER, in a short chapter on flight speeds (page 84), repeats almost literally the sentences written with Bruno BRUDERER in 1972, including the graphic illustrations (**Figure 1**).

Always in 1980, volume 9 of Glutz von Blotzheim, U. N. & Bauer, K. M. *Handbuch der Vögel Mitteleuropas* (Akademischer, Wiesbaden, 1980) was also published.

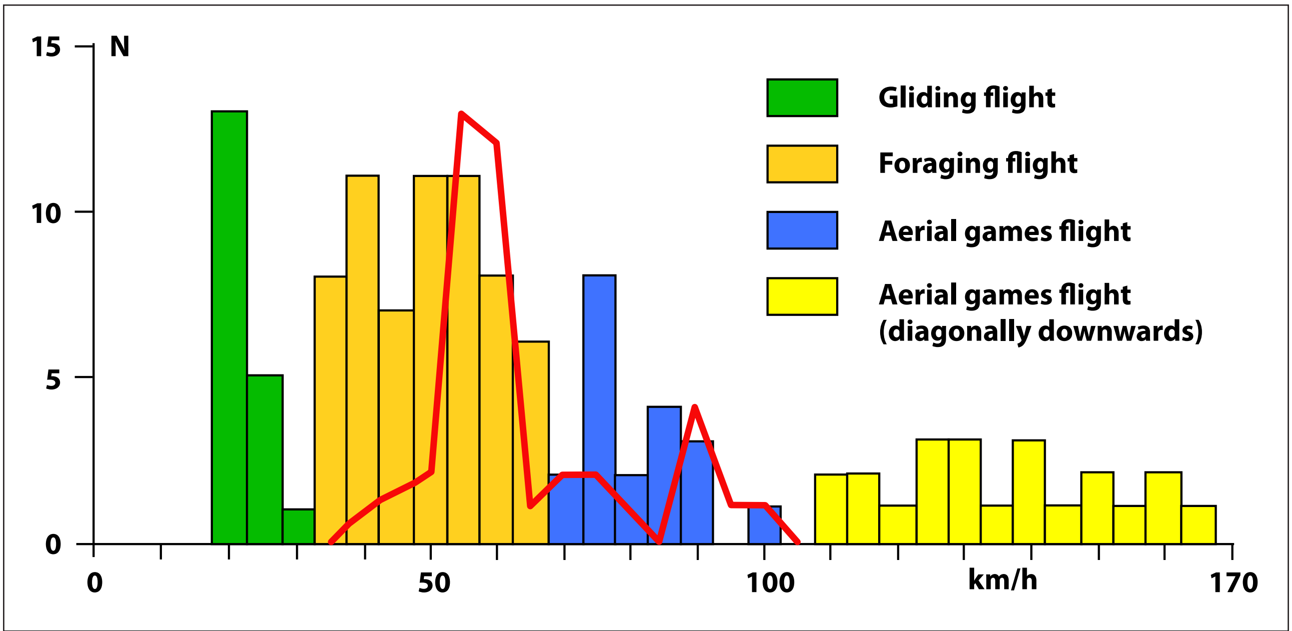


Figure 1. (from BRUDERER & WEITNAUER 1972)
Flight speeds of swifts measured optically in daylight, according to the measurements of WEITNAUER in 1947 (histogram) and OEHME in 1968 (red curve).

On page 697 this sentence can be found:

"In gliding flight 5-14 m/s, in powered flight 11-28 m/sec are usually achieved, in flying games up to 40-60 m/sec(WEITNAUER 1947, OEHME 1968 b)".

These data correspond to a "synthesis" between the data of WEITNAUER (1947) and OEHME (1968).

For gliding flight : 5 m/s (18 km/h) is the minimum for WEITNAUER (1947); 14 m/s (50.4 km/h) is the maximum for OEHME (1968).

For level foraging flight : 11 - 28 m/s (39.6 -100.8 km/h) are the data from OEHME (1968).

For diving-display flight : 40 - 60 m/s (144 - 216 km/h) are the WEITNAUER (1947) data.

1.4.3 (2001) Bruno BRUDERER and Andreas BOLDT

In 2001, in a paper entitled "Flight characteristics of birds: I. Radar measurements of speeds" both authors present an annotated list of flight speeds of 139 species of the Western Palearctic, mainly in migratory flight. All measurements were taken with the same tracking radar and corrected for the influence of wind with wind measuring balloons tracked by the radar (go to Part 2.3).

On page 192, the authors write about the Common Swift:

"Oehme (1968) noted most speeds of diurnal flights in the range of 15-17 m/s, values which are in the same range as those reported by Bruderer et Weitnauer (1972) for hunting and display flights, but not for migratory flights".

These two authors use the same time data as in 1972.

1.4.4 (2009) Per HENNINGSSON *et al.*

In 2009, in a paper entitled "Flight speeds of swifts *(Apus apus)*: seasonal differences smaller than expected" the authors compare the night-flying behaviour of the Common Swift across seasons.

The birds were tracked with tracking radar from the University of Lund in southern Sweden during spring night migration, summer night roost flights and autumn night migration (go to Part 2.5).

The authors write about the published high speeds:

"Swifts are known to be able to fly at high speeds; records of up to 28ms^{-1} exist (Oehme 1968 ; Bruderer & Weitnauer 1972)".

It is interesting to note that the maximum value retained in the earlier timed data is that of OEHME (100.8 km/h) and not the higher values of WEITNAUER (up to 200 km/h in 1947).

1.4.5 (2014) Bernard GENTON and Marcel JACQUAT

In 2014, in the book *Martinet noir : entre ciel et pierre (Common swift: between sky and stone)*, both authors provide information on flight speeds on several occasions.

Thus on pages 27, 28 and 29 they write about types of flight:

"**Foraging**: many sharp turns, laterally and altitudinally between 40 and 60 km/h

Drinking: gliding on the surface of a fairly calm water, about 35 km/h

Migration: fairly straight, about 90 km/h

Roosting: gliding between 20 and 30 km/h (Weitnauer, 1980)".

These speed data are based on both literature data (mainly WEITNAUER 1947; 1980) and observations made by the authors in the wild.

On the subject of nest access flight, the authors quote the data of Van Arkel (1997):

Page 29:

> "**Cavity diving,** sometimes from a high altitude, then resource for braking and entry at about 70 km/h to the nest, practised by the breeders (speed measured by van Arkel in 1997)".

Page 93, Bernard GENTON adds:

> "As time goes by, the entry path becomes more precise and fluid; finally, nest penetration takes place with ease; in some individuals it is achieved at high speed and seems to be a constitutive part of flight. Van Arkel (1997) indicates that when access to the cavities is clear: "the Common Swift arrives in front of its nest hole at a speed of 70 km/h".

This data from Van Arkel is problematic as the material and measurement method have never been published. It is quite possible that in the diving flight to the nest cavity the swift flies at 70 km/h because in 2015 deMARGERIE *et al.* (go to Part 5.) measured a speed of 22.9 m/s (82.44 km/h) in such a diving flight. However, it seems unlikely that the bird is still at this high speed at the nest entrance itself. It would be necessary to make precise measurements of speed over the last 2 metres before the nest entrance. The Common Swift appears to be able to accelerate and brake abruptly over short distances.

On page 94, concerning duet flights by young pairs, Bernard GENTON states:

> "While these vibrating duo flights are likely to reappear sporadically in the future, they are now transformed into long, playful, high-speed aerial circuits, during which the pair follow each other at close range (barely 40 cm apart and probably at well over 100 km/h) over the colony's neighbourhood".

Although Bernard GENTON suggests the probability of flight speeds well in excess of 100 km/h, at no time does he quotes or validates WEITNAUER's "200 km/h" (1947).

1.4.6 (1956-2018) Two "cautious" authors, David LACK and his son Andrew LACK

In 1956, David LACK published his famous monograph on the Common Swift, entitled *Swifts in a tower.*

In chapter 10, he devotes about fifteen pages to the swift's flight. He states at the beginning of the chapter:

> "The analysis of its flight is a technical subject which I have no studied at first hand and what follows is a summary of the work of others in so far as I understand it".

About the flight speed of the swift, he writes:

> "Swifts are generally claimed to be the fastest of all birds in level flight, but it is hard to be sure, as they rarely fly as rapidly as they can. A Dutch worker has estimated that, when feeding, swifts often fly at only 25 miles an hour, being passed by starling or pigeon, but that they sometimes move at 40 miles an hour and may increase up to 60 miles an hour if extended. A pilot in the First World War thought from his air-speed indicator that swifts in unhurried flight near to him were moving at 68 miles an hour. The swift's highest speed on a short burst has never been measured. One taken from a church tower at Tournai in Belgium and transported by aircraft returned from London airport in four hours, at an average speed of 37 miles an hour, a remarkable achievement even if it flew directly back, and also showing that the bird can orientate itself with accuracy".

It is surprising that David LACK does not mention the measurements and results published by Emil WEITNAUER, especially since he refers to the 1947 article followed by the mention (flight-speed).

I think that David LACK does not validate Emil WEITNAUER's methodology when he writes :

> "The swift's highest speed on a short burst has never been measured".

He prefers to give examples of speeds that seem more realistic from another dutch worker (H. J. SLIJPER, 1948) for foraging flight (40 km/h)

In 2018, Andrew LACK, David's son, supervised the re-edition of his father's book (1956). He added a chapter 19 entitled "Swift in a tower – Sixty two years on" in which he summarises the main findings on swifts since 1956.

On the subject of flight speeds, he writes:

> " On a more prosaic note, we have now some accurate measurements of what that speed is from Professor Anders Hedenstrom and his co-workers from Lund University in Sweden. During migration or on feeding flights, swifts will normally fly at around 10 m s^{-1} (22 mph) but during 'screaming parties' in particular, they can fly much faster than that. Using two high speed cameras, placed 1,400 mm apart on a beam, they recorded swifts flying at speeds of 11.9-31.1 m s^{-1} (26.6-69.6 mph) with an average of 20.9 m s^{-1} (46.8 mph) in screaming parties on a calm clear day at a local colony. At the same time these birds were actually rising upwards in the air at an average of 4.0 m s^{-1} (9 mph). These are only short bursts, but powered flight of these astonishing speeds has never been accurately recorded in any other bird. It is certainly possible that other swifts may be able to fly faster than our swift but this needs confirmation using accurate methods of measurement; speeds such as the 47 m s^{-1} (105 mph) mentioned for the white-throated needletail swifts are almost certainly exaggerations".

Like his father, Andrew LACK does not mention the timed speed measurements of WEITNAUER (1947) and OEHME (1968).

REVIEW

The **Table 4** shows that all the French-speaking authors (GÉROUDET, CUISIN, FRÉDÉRIC, DÉOM, GORY, MAINTIGNEUX) quote the high speed data (200 km) published by WEITNAUER (1947). The fact that as early as 1951, GÉROUDET validated the data of WEITNAUER (1947) may also explain this choice.

WEITNAUER with BRUDERER in 1972, then alone in his monograph *Mein Vogel* of 1980 lowers the maximum speed from 216 km/h to 165 km/h; but it remains at 216 km/h in the "Glutz" of 1980.

Other authors (BRUDERER, BOLD, HENNINGSSON) prefer to quote OEHME's 1968 data, rather than WEITNAUER's 1947 data.

From 1956, WEITNAUER used radar to track swifts at altitude. He also measured flight speeds.

Table 4.
Timed speed measurements made by WEITNAUER **in RED** and OEHME in GREEN and their use in subsequent publications by various authors.

	Gliding flight	Horizontal foraging flight	Horizontal pursuit flight	Diving and aerial games
1947 WEITNAUER	5 - 7 m/s (18 - 25,2 km/h)	average speed : 17 m/s (61,2 km/h)	20 - 30 m/s (72 - 108 km/h)	40 - 60 m/s (144 - 216 km/h)
1951 GÉROUDET quoting WEIT-NAUER (1947)	6,1 m/s (22 km/h)	16,6 m/s (60 km/h)	55,5 m/s (200 km/h)	
1968 OEHME	8 - 14 m/s (28,8 - 50,4 km/h)	11 - 28 m/s (39,6 - 100,8 km/h) average speed : 16 m/s (57,6 km/h)		
1972 WEITNAUER & BRUDERER in a graph using data from WEITNAUER (1947)	5,5 - 8,3 m/s (20 - 30 km/h)	9,7 - 18,0 m/s (35 - 65 km/h)	16,6 - 27,7 m/s (60 - 100 km/h)	30,5 - 45,8 m/s (110 - 165 km/h)
1972 WEITNAUER & BRUDERER in a graph using data from d'OEHME (1968)		11 - 28 m/s (39,6 - 100,8 km/h) average speed : 16 m/s (57,6 km/h)		
1980 WEITNAUER in "*Mein Vogel*" BAUER & BRUDE-RER 1972	5,5 - 8,3 m/s (20 - 30 km/h)	9,7 - 18,0 m/s (35 - 65 km/h)	16,6 - 27,7 m/s (60 - 100 km/h)	30,5 - 45,8 m/s (110 - 165 km/h)
1980 WEITNAUER & SCHERNER in GLUTZ VON BLOTZHEIM & BAUER quoting WEITNAUER (1947) et OEHME (1968)	5 - 14 m/s (18 - 50,4 km/h)	11 - 28 m/s (39,6 - 100,8 km/h)		40 - 60 m/s (144 - 216 km/h)
1994 FRÉDÉRIC quoting WEIT-NAUER (1947)	5,5 m/s (20 km/h)	16,6 m/s (60 km/h)	55,5 m/s (200 km/h)	
1998 GÉROUDET & CUISIN quoting WEITNAUER (1947) et OEHME (1968)	5 -14 m/s (18 - 50,4 km/h)	11- 28 m/s (39,6 - 100,8 km/h)		60 m/s (216 km/h)
2000 DÉOM				44,4 - 55,5 m/s (160 - 200 km/h)
2001 BRUDERER & BOLD quoting OEHME (1968)		average speed : 16 m/s (57,6 km/h)		
2009 HENNINGS-SON quoting OEHME (1968)			maximum 28 m/s (100,8 km/h)	
2019 GORY			55,5 m/s (200 km/h)	
2021 MAINTIGNEUX		11,1 - 27,7 m/s ; (40 - 100 km/h) top speed > 55,5 m/s (200 km/h)		

2. Measuring flight speeds using radars

With the use of radar, measuring of flight speeds changes scale. Ground timing is done optically over colonies with the variety of social flights associated with breeding.
Radar displays mainly provide indirect observations of birds flying aloft day and night for night roosting or migration. As technical progress has been made (surveillance radar, then tracking radar), the identification of birds and the measurement of flight parameters (altitude, speed, etc.) have become increasingly precise.

2.1 (1955-1960) Emil WEITNAUER uses a surveillance radar

Since his 1947 article on the Common Swift's breeding, WEITNAUER has been particularly interested in the nocturnal aerial activity of swifts.

2.1.1 (1956) The first WEITNAUER data with a radar

In 1956, in a paper entitled "Zur Frage des Nächtigens beim Mauersegler V. Beitrag", WEITNAUER presents his first results obtained with the help of radar and aircraft at Zurich's Kloten airport during four nights in the summer of 1955 (28 June, 8 ,11, 18 July).
WEITNAUER states:

> "1. The radar used is a surveillance radar.
> 2. The various echoes appear as points of light on the screen.
> 3. However, we don't yet know how large and dense a group has to be to produce an echo, and the radar gives no indication of the number or type of birds, so we can only conclude from the way the dot is moving that it is a bird.
> 4. Unfortunately the altitude cannot be read on the surveillance radar we use".

About speed, he writes:

> "Calculating the speed of the flying clouds on the basis of the time data in the illustrations would not give a clear result, as we do not know whether the swifts are ascending or descending during their flight. Furthermore, we do not know their flight altitude, which is why wind cannot be taken into account. Nevertheless, the illustrations show that many flights probably move quite quietly (circling?) during the night and sometimes remain stationary. The speeds readable on the 'screen' were generally between 15 and 40 kilometres per hour, but from time to time a dot would pass by at 60-100 or even 160 km/h".

The above speed data will be partially corrected in a later publication (Bruderer & Weitnauer, 1972).

2.1.2 (1960) An initial review of WEITNAUER

En 1960, in a new article entitled "Über die Nachtflüge des Mauersegle, *Apus apus*", WEITNAUER reviews his research into the nocturnal flying activities of the Common Swift. He also took the opportunity to review the current state of knowledge on the subject.
In addition to observations in and over the colony, since 1950 (Weitnauer, 1952), flights in a small aircraft have confirmed that swifts spend the night flying high above the ground.
From 1955 onwards, a surveillance radar at Zurich airport was used to monitor nocturnal flights at altitude (Weitnauer, 1956).
From 1959, in addition to live observation using radar, the radar screen was filmed so that the swifts' nocturnal movements could be monitored and analysed in greater detail.

Certain technical improvements in radar enabled WEITNAUER to write:

> "A special radar device also enabled us to take altitude measurements. In fine weather, with layers of warm air reaching high altitudes, the swifts climbed as high as 3,000 m above the ground. I can give the following information on the speed of swifts during their night flights, which however date back to the migration period: On the night of 6 to 7 August 1959, I followed ten echo points over a distance of 5 nautical miles (9.25 km). Speeds varied from 71.120 to 87.120 kilometres per hour, with an average of 80 kilometres per hour".

The above speed data will not be related to Common Swifts in a later paper (Bruderer & Weitnauer, 1972).

2.2 (1972) Bruno BRUDERER and Emil WEITNAUER use a tracking radar

2.2.1 Matérials and methods

In 1972, in a new paper entitled "Radarbeobachtungen über Zug und Natchflüge des Mauerseglers *(Apus apus)*", both authors use a tracking radar which has many advantages over the search radar used by WEITNAUER from 1955:

> "1. individual targets (birds) can be searched, selected and then tracked automatically;
> 2. bird species are identified with confidence;
> 3. flight parameters (path, bird speed, wind speed...) type of flight (flapping or gliding) and flapping frequency are recorded.
> 4. wind speed is measured using radar tracked balloons to calculate the actual air speed of the birds".

The data are mainly from the spring migration period 1971 (28 April-20 May: 160 individuals) and from 2 nights at the beginning of the autumn migration period 1970 (28-30 July: 39 individuals). The observations were supplemented by radar monitoring of swifts in daylight.

2.2.2 Results and discussion

In the analysis of their results, BRUDERER and WEITNAUER write:

> "WEITNAUER (1956) showed, on the basis of observations made using the Kloten surveillance radar, that swifts only fly at a speed of 15-40 km/h in night flight. The new measurements taken using target-tracking radar confirm these results, with 88 non-migratory birds showing an average speed of 23.5 km/h and extreme values of 10 and 42 km/h respectively (**Figure 2**).
> It is difficult to determine the speed of migrating swifts using surveillance radar, as radar does not allow targets to be recognised. Today, we assume that the high speeds of certain light spots moving in a straight line, which WEITNAUER (1956 and 1960) interpreted as possibly being migrating swifts, are rather due to migrating waders or other bird species migrating earlier in the year. In our material, we were unable to find any bird with a swift flight pattern that had a speed greater than 60 km/h. The average speed of 29 swifts considered to be migratory was 40 km/h (11.11 m/s)" (**Figure 2**).

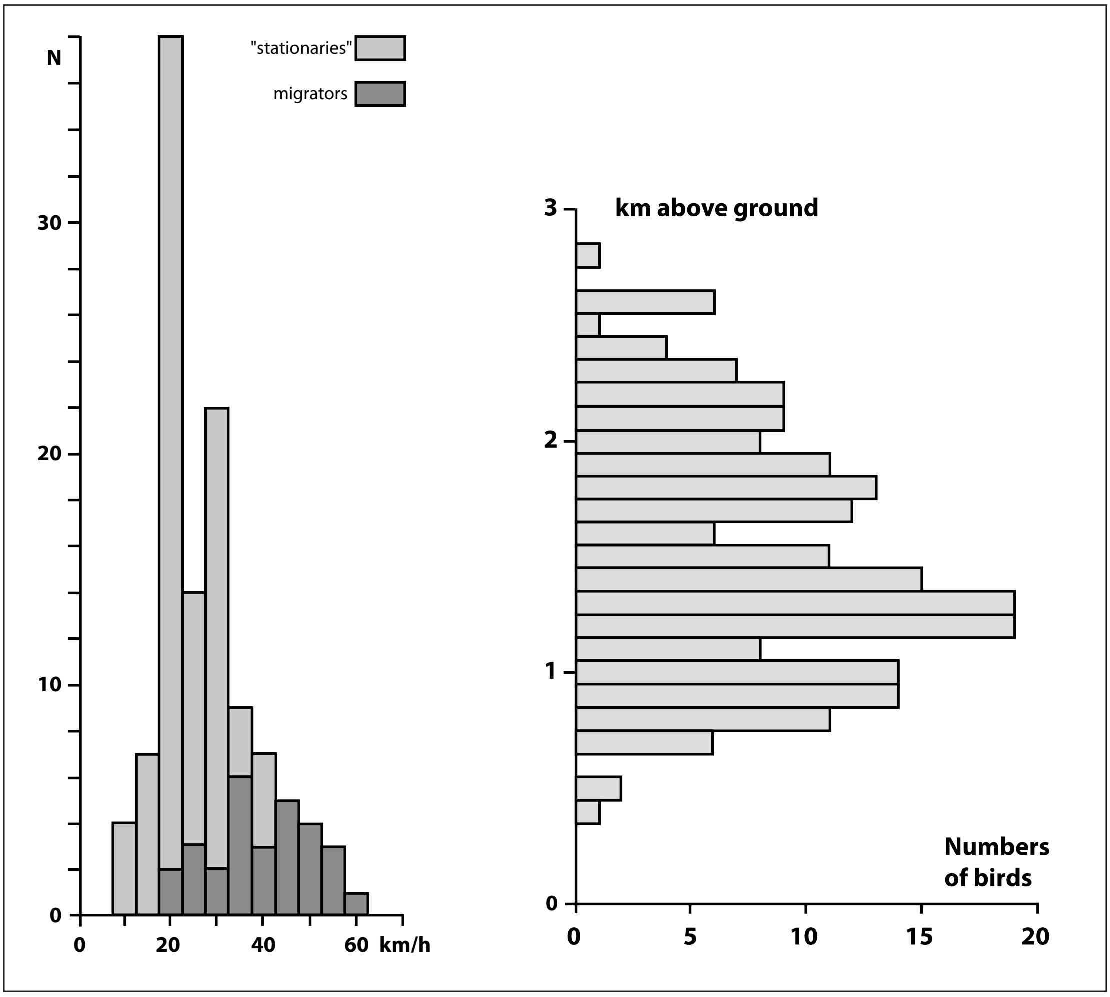


Figure 2. (from BRUDERER & WEITNAUER, 1972)
On the left: flight speeds of night-flying swifts measured with tracking radar.
On the right: altitude distribution of swifts in spring 1971 and on two nights in late summer 1970.

2.3 (2001) Bruno BRUDERER and Andreas BOLDT use a tracking radar

In 2001, in a paper entitled " Flight characteristics of birds: I. Radar measurements of speeds " both authors present an annotated list of flight speeds of 139 species of the Western Palearctic, mainly in migration.

2.3.1 Materials and methods

All measurements were taken with the same tracking radar and corrected for the wind influence with wind measuring balloons tracked by radar..

2.3.2 Results and discussion

Both authors write about the Common Swift:

> "The flight speed is highly variable, depending on the actual behaviour. Bruderer and Weitnauer (1972) showed that speeds measured during roosting flights (likely to correspond to low values of *Vmp) vary around 6.4 m/s, while migratory speeds (probably **Vmr) vary around 11 m/s. The mean value of the present data (11.1/10.6 m/s) comprises about five times more (mainly migrating) individuals than the 1972 data set. Two released birds show only a slightly reduced speed (10.3/9.2 m/s)"
>
> *Vmp : characteristic speed associated with a minimum power ("flapping flight"). Vmp is independent of the wind
>
> **Vmr : speed associated with a minimum energy per unit distance. Vmr is a function of wind direction and speed.

They confirm earlier results (Bruderer & Weitnauer, 1972) on the speed of nocturnal roosting flight (6.4 m/s = 23 km/h) and on the speed of migratory flight (11 m/s = 40 km/h).

2.4 (2001) Johan BÄCKMAN et Thomas ALERSTAM use a tracking radar

In 2001, in a paper entitled "Confronting the winds: Orientation and flight behaviour of roosting swifts, *Apus apus*", both authors test the hypothesis that swifts are adapted to minimise energy expenditure during the nightly roosting flight and during a compensatory return flight if they are moved by the wind.

2.4.1 Materials and methods

The measurements are made at night with a tracking radar in Lund (Sweden) between 4 July and 5 August 1999.

2.4.2 Results and discussion

Both authors write:

> "The true airspeed was, on average, 9.3m/s (table 1), which is faster than the value of 6.5m/s reported by Bruderer & Weitnauer (1972). The reason for this discrepancy is not entirely clear, but could, at least partly, be due to differences in the methods used to calculate the flight track. In our study we used 10-s intervals for speed calculations (based on five 2-s readings), while Bruderer & Weitnauer (1972) measured flight distances from a paper printout".

Both authors partly attribute the divergence of their results from those of BRUDERER and WEITNAUER, 1972 to a possible methodological difference in the calculation of flight paths.

2.5 (2009) Per HENNINGSSON *et al.* use a tracking radar

In 2009, in a paper entitled " Flight speeds of swifts *(Apus apus)*: seasonal differences smaller than expected" both authors compare the nocturnal flight behaviors of the Common Swift according to the period and activity.

2.5.1 Materials and methods

Birds were followed from the University of Lund in southern Sweden during spring night migration, summer night roosting flights and autumn night migration. Flight speeds were compared with predictions from theories of flight mechanics and optimal migration.

2.5.2 Results and discussion

Results are presented in the **Table 5**.
Both authors write:

> "Bruderer & Weitnauer (1972) studied the spring migration and summer roosting flights of swifts. In that study, the mean air speed was found to be 11.1ms–1 during migration and 6.4ms–1 during summer roosting flights, a finding that has been generally quoted in support of adaptive speed adjustment according to flight mechanical theory. In this study, we find a less pronounced difference in flight speed between spring and summer. The difference in results between the two studies can, at least partly, be attributed to a difference in methodology; (i) spring migration was studied during night in this study and during day by Bruderer and Weitnauer, (ii) positions were logged every second in this study compared with every 20th second in the study by Bruderer and Weitnauer. Mean flight speeds during spring in the two studies are similar (10.6 compared to 11.1), suggesting that flight speeds are similar between night and day. During roosting flight, the birds typically fly along a very irregular path at very low ground speed, constantly orienting themselves towards the wind (Bäckman & Alerstam 2002). This circuitous track in combination with a lower position recording rate may have resulted in an underestimate of the length of the true flight path and thereby also the actual flight speed (Bruderer & Weitnauer,1972). On migration, the flight path is straight and the speed estimate is therefore accurately estimated also by recording one position every 20th second".

Table 5.
Ground and air speeds of Common Swifts on pre- and post-nuptial night migration flights and on summer night roosting flights, from Henningsson *et al.*, 2009.

	Pre-nuptial nocturnal migration (May)	Nocturnal roosting (July)	Post-nuptial nocturnal migration (August)
Sample	n = 176	n = 311	n = 150
Average groundspeed	11,5 m/s (41,4 km/h)	6,4 m/s (23,0 km/h)	8,8 m/s (31,7 km/h)
Average airspeed	10,6 m/s (38,2 km/h)	9,0 m/s (32,4 km/h)	9,2 m/s (33,1 km/h)
Average altitude	980 m	1335 m	1374 m

3. Measuring flight speed using ornithodolite

As early as the 1970s, researchers sought to develop optical devices (double theodolites) inspired by surveyors' devices to determine the bird's position in space at each moment from the ground in order to establish the birds' paths and calculate the parameters of their flight (altitude, speed, etc.).

In 1982 then in 2013, PENNYCUICK improved the method, to which he gave the name "Ornithodolite".

But it seems that it was not until 2016 that this technique was used to measure the speeds of swifts in flight.

In 2017, Susanne ÅKESSON and Anders HEDENSTRÖM published a paper entitled "Adaptative airspeed adjustment and compensation for wind drift in the common swift: differences between day and night".

3.1 Materials, methods and results

> " The Ornithodolite consists of Vectronix Vector 21 Aero bin¬oculars (7 x 42 magnification) with three built-in sensors (a laser range finder, a magnetic compass and an elevation angle sensor). When tracking a bird the Vector buttons are pressed to store time-stamped readings of distance, azimuth and elevation angles directly to a computer file. Each reading of a bird (or flock of birds) is called an 'Observation' of the bird's timed position in space with the observer in the origin, and a series of two or more observations of the same target is called a 'Run', which is used to calculate mean ground speed, vertical speed and track direction. Wind measurement is necessary to calculate airspeed and heading direction. We used a Gill Windsonic anemometer mounted on a 5 m mast in an unobstructed location near the Ornithodolite, which transmitted the reading to the computer at 1 s intervals via a pair of wireless modems (Haccom UM-96). Wind speeds above 15 m above the ground surface were measured by tracking the path of released helium-filled balloons with the Vector".

On the location, periods and swifts observed, the authors specify:

> "Observations of migrating common swifts were made at Ottenby on the island of ~Oland in the Baltic Sea, off the east coast of southern Sweden.
>
> The data were subdivided into spring migration (15-30 May), summer weather movement (8 July 2015) and autumn migration (26 July-12 August)" (**Table 6**).

Table 6.
Ground and air speeds of Common Swifts during pre- and post-nuptial diurnal migration flights and during summer meteorological diurnal flight, according to ÅKESSON et HEDENSTRÖM, 2017.

	Pre-nuptial diunal migration (May)	Summer meteorological diurnal flight	Post-nuptial diunal migration
Sample	n = 56	n = 29	n = 47
Average groundspeed	10,96 m/s (39,45 km/h)	5,62 m/s (20,23 km/h)	5,92 m/s (21,31 km/h)
Average airspeed	13,87 m/s (49,93 km/h)	11,22 m/s (40,39 km/h)	11,70 m/s (42,12 km/h)
Average altitude	35,5 m	31,6 m	52,4 m
Maximum altitude	81 m	100 m	310 m

3.2 Discussion

The authors write:

"Spring migration airspeeds were higher than those during summer weather movements and autumn migration, which is in agreement with previous observations (Henningsson *et al.*, 2009). Higher flight speeds during spring migration are consistent with predictions of time minimization and higher overall migration speed (Åkesson *et al.*,2016; Åkesson, Klaassen, Holmgren, Fox, & Hedenström, 2012; Hedenström & Alerstam, 1998). Flight speeds during summer weather movement and autumn migration were very similar, suggesting these movements are moulded by similar criteria. The higher airspeed in spring was obtained by more continuous flapping flight over flap-gliding, but irrespective of season a high flight speed was related to higher incidence of flapping flight".

4. Measuring flight speed using 2 video cameras

In 2010, in a paper entitled "How swift are swifts *Apus apus*" Per HENNINGSSON, Christoffer JOHANSSON and Anders HEDENSTRÖM measured the flight speed of common swifts during screaming parties.

4.1 Matérials and methods

The speed measurements were made using two video cameras mounted on a beam on a tripod. The distance between the two cameras was 1400 mm and their relative angle difference to the beam was 7.0°. The frame rate was set at 200 Hz (200 fps).
After calibration of the two cameras, the comparison of the stereo images obtained with each of them allowed the calculation of the birds' speeds.
This study is based on the flight paths of 25 sequences of swifts in flight during screaming parties, filmed during one day at the end of June 2008. The average length of the filmed trajectories was 1.95 m, and the trajectories were straight as the birds flew past the colony.
One day, 29 June 2008, with clear skies and quiet winds was chosen as the experimental day in order to minimise the effects of weather and wind on the flight behaviour of the birds.

4.2 Results

The authors write:

> "On average the birds flew with a horizontal speed (Vh) of 20.9 ms^{-1} (+/- 5.1 ms^{-1}, n = 25) ranging from 11.9 ms^{-1} to 31.1 ms^{-1} (112 km/h)"

4.3 Discussion

The authors write:

> "The main focus of this study was the flight speeds of swifts during the special flight behavior referred to as 'screaming flight'. During these flights the birds appear to push themselves to perform at their maximum,

> perhaps as some sort of display involving demonstration of flight strength towards other individuals. The results show that the birds do fly at high speeds during 'screaming parties', on average 20.9 ms-1, which is roughly twice as fast as the average speed recorded on for example spring migration (Bruderer et Weitnauer 1972, Henningsson *et al.* 2009). The maximum speed recorded in this study was 31.1 m/s (112 km/h), which is the highest yet recorded for a swift in self-powered flight (non-diving, cf. Oehme 1968, Bruderer et Weitnauer 1972)".

In 2010, it is the first time that speeds of some of the fastest Common Swift flights are measured with a rigorous methodology: self-propelled horizontal flights whose speeds are measured with high frequency stereo cameras.

Let us compare these results with those published by WEITNAUER and OEHME.
In 1947, WEITNAUER writes:

> "But if they follow each other closely, I've often measured 20 to 30 m/s (72 to 108 km/h) in 100 measurements".

If we assume that this flight type corresponds to screaming parties, the speed range (72 to 108 km/h) is higher than the 2010 average of 75 km/h. This difference can be explained by differences in the methodologies:

1. the manual timing in WEITNAUER 1947 and the recording system with high frequency stereo cameras in HENNINGSSON et al. 2010;
2. the consideration of wind speed in 2010;
3. the possible impact of the characteristics of the measured chase flights (length, level path or not...) on the flight speed of the birds.

In the graph (**Figure 1**) published in 1972 by BRUDERERER AND WEITNAUER, all flights with a speed greater than 100 km/h measured by WEITNAUER are diving flights.

In 1968, OEHME did not specify the flight type he was timing in the street "corridors". His primary objective was to obtain an average speed of movement in self-propelled level flight.

In the table of results of his measurements (**Table 2**), it can be assumed that the 9 measurements between 75.6 and 100.8 km/h may correspond to screaming parties.

5. Measuring flight speed using rotational stereo videography

In 2015, Emmanuel de MARGERIE *et al.* published an paper entitled "3D tracking of animals in the field using rotational stereo videography" where they present a new tracking method.
In 2018, applying this method to the foraging flight of the Common Swift, Emmanuel de MARGERIE, Cécile PICHOT and Tyson L. HEDRICK published an article entitled "Gliding for a free lunch: biomechanics of foraging flight in common swifts *(Apus apus)*."

.

5.1 Materials and methods (2015)

The authors write:

> "The general principle of our method is to measure the position of an animal through its spherical coordinates, relative to the stationary observer (Fig. 1A). An angle measuring base (AMB), similar to a theodolite, records azimuth (a) and inclination (i) angles while the observer frames the moving animal in a viewfinder. Supported by tacheometer (or total station), but works at a higher sampling frequency (up to the video frame rate). Moreover, the embedded video record of the animal is used to extract additional behavioural data that can be combined with the tracking data.
> There are two expected limits to this tracking method. First, the animal must remain visible during its movement; hence, the method only applies to terrestrial and aerial paths in open environments. The second limit results from the stereo-image-based distance evaluation: as uncertainty in terms of the distance measure increases quadratically with distance from the observer (Cavagna *et al.*, 2008), the range of the tracking device will be finite, restricting precise tracking to a given radius around the observer".

5.2 Materials and methods (2018)

The authors write:

> "Here, we quantified swift flight trajectories by rotational stereo videography (RSV), which uses a camera and telephoto lens with a set of mirrors to combine views from two vantage points into one image, all mounted on an instrumented pivot to track individual birds during flight (de Margerie *et al.*, 2015)
> Common swifts, *Apus apus* (Linnaeus 1758), were recorded at the Beaulieu University Campus in Rennes, France during six sessions between 17 June and 9 July 2015. Recordings were conducted between 09:00 h and 13:00 h from the second-floor balcony of a campus building using RSV (Fig. 1) with a DMC-GH4 camera (Panasonic, Osaka, Japan) and 200 mm f/4 Ai lens (Nikon Inc., Tokyo, Japan)
> Local wind speed and direction in the horizontal plane were recorded by releasing and tracking a helium-filled balloon once per hour"

5.3 Results

By limiting ourselves to the mean speeds according to the flight type (flapping and or gliding), we can build the **Table 7**.

These speeds were measured and calculated only during **foraging flights over the colony.**
However, the authors mention another interesting fact:

> "Highly swept wings were also repeatedly observed when the bird dived toward its nest at the end of a foraging flight, attaining equivalent airspeeds up to 22.9 m/s (82,44 km/h)".

Table 7.
Average airspeeds of Common Swifts in flapping and/or gliding foraging flight from de MARGERIE, PICHOT ET HEDRICK, 2018.

	Flapping flight	Gliding flight	Flapping and gliding flight
Sample	n = 72	n = 73	n = 73
Average airspeed	10,1 m/s (36,4 km/h)	9,5 m/s (34,2 km/h)	9,7 m/s (35,0 km/h)

5.4 Discussion

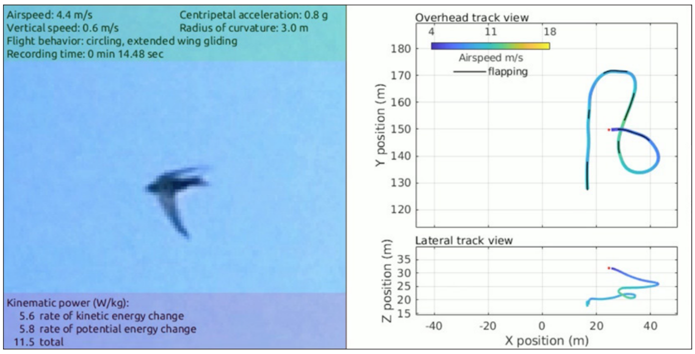
1. **For gliding,** the authors compared their results with those obtained by various authors in wind tunnels.
They write:

> "The values measured from freely behaving wild birds are similar to those from wind tunnels with the best agreement among the studies in the minimum sink rate and maximum lift to drag ratio, but slightly more variation in the exact speeds at which those were reached. Our free-flight results typically show the slowest maximum duration speed and a greater range between the maximum duration and maximum range speeds, suggesting a slightly more varied performance envelope than was revealed by wind tunnel studies involving fewer birds".

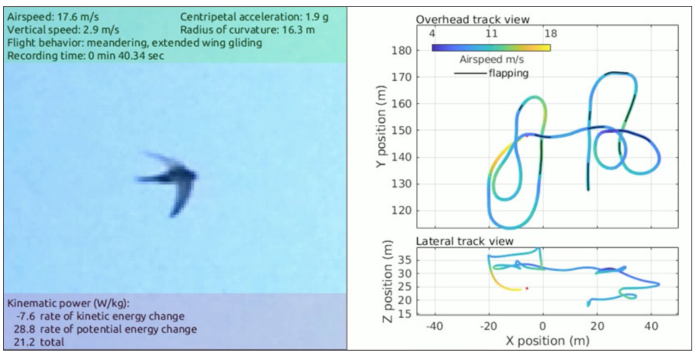
2. **For diving toward the nest**, this is the first data (22.9 m/s = 82.44 km/h) obtained with a precise methodology.

A video with commentary is included with the paper :
https://movie.biologists.com/video/10.1242/jeb.186270/video-1

This video shows the continuous evolution of the parameters along the trajectory of a mainly foraging flight.
Over the 68 seconds of the video, the instant speed of the bird in relation to the air (Airspeed) changes 370 times. The mean speed is 10.10 m/s (36.36 km/h) with a minimum value of 4.4 m/s (15.84 km/h) and a maximum value of 17.6 m/s (63.36 km/h).



Minimum airspeed: 4,4 m/s (15,84 km/h) during prey catching



Maximum airspeed: 17,6 m/s (63,36 km/h) during foraging

6. General discussion

Four main rigorous methodologies have thus far made it possible to measure certain average and maximum speeds of Common Swift flights.

Tracking radar (since 1972) is the tool best suited to measuring the flight parameters of swifts at altitude during nocturnal roosting flights and diurnal or nocturnal, prenuptial or postnuptial migratory flights.

The ornithodolite (2017), the stereo system with 2 video cameras (2010) and the VSR or rotational stereo videography (2018) are equipment and methods that are suitable for measuring the flight parameters of swifts passing within sight of a terrestrial observer. They are beginning to provide information on the various diurnal flights: close to the ground migration flights, foraging flights and social flights (screaming parties).

None of these methods is simple to implement. Reading the scientific articles that describe them shows that they each require solid skills in physics, mathematics and computing, not forgetting a certain skill on the part of the operator for the methods that require continuous monitoring of the swift in the air.

If we take into account only recent measurements of mean air speeds obtained using these rigorous methodologies, we can construct the **Table 8**.

Table 8.
Average airspeeds of common swifts in different types of flight

	Average airspeeds	Publication
Foraging flight in the colony	10,1 m/s (36,4 km/h)	Hedrick, T., Pichot, C. and de Margerie, E. 2018
Flight during screaming parties in the colony	20,9 m/s (75,2 km/h)	Henningsson, P. et al. 2010
Nocturnal summer roosting flight at altitude	9 m/s (32,4 km/h)	Henningsson, P. et al. 2009
Nocturnal pre-nuptial migratory flight at altitude	10,6 m/s (38,2 km/h)	Henningsson, P. et al. 2009
Diurnal pre-nuptial migratory flight at altitude	no data	
Diurnal pre-nuptial migratory flight close to the ground	13,9 m/s (49,9 km/h)	Hedenström, A., and Åkesson, S. 2017
Nocturnal post-nuptial migratory flight at altitude	9,2 m/s (33,1 km/h)	Henningsson, P. et al. 2009
Nocturnal post-nuptial migratory flight close to the ground	no data	
Diurnal post-nuptial migratory flight close to the ground	11,7 m/s (42,1 km/h)	Hedenström, A., and Åkesson, S. 2017

This bibliographical study, which is certainly incomplete, shows us that measuring the flight speeds of the Common Swift is a difficult task. It is first necessary to specify what we want to measure and how.

1. Groundspeed or airspeed.

Groundspeed is what we are used to seeing on the speedometer of a motor vehicle. It is also the speed we perceive when we see a bird moving across the sky. This is the speed measured by WEITNAUER in 1947 above his colony.

Measuring a bird's airspeed means calculating its own speed in relation to the mass of air in which it is moving. Its calculation therefore takes into account the wind speed, which must be measured at the same time as the groundspeed. On long migratory flights with strong tailwinds, the groundspeed can be twice as high as the airspeed.

As early as 1968, OEHME was aware of this problem, which he resolved simply by choosing to carry out his measurements in calm weather with no wind. Subsequently, other researchers continued to measure the wind either using anemometers close to the ground or by radar or video tracking of balloons at altitude.

2. Speed of the bird along a horizontal path.

To establish the bird's muscular performance, speed must be measured along a horizontal path. This is what OEHME called "self-propelled flight" in 1968.

In fact, in flight with a path inclined downwards, right up to diving flight, the bird uses the force of gravity to a large extent, converting potential energy into aerodynamic work.

3. Precise nature of the flight whose speed is to be measured.

The nature of a flight may be easy to identify: foraging flight with visible captures, group flight such as screaming parties, etc.

The nature of the flight may be more difficult to identify: in July at high altitude and at night, it is necessary to be able to distinguish on the radar screen between local birds in roosting flight and those actively migrating, etc.

4. Use of a precise measurement method, which must be presented in detail in the publication.

On this methodological point, WEITNAUER's publication (1947) is imprecise. For example, he did not indicate the exact distance over which he measured his time. This is all the more important as the speeds measured are very high (200 km/h).

These problems are well known in competitive sport for sprint races such as the 100 m, where the speeds measured do not exceed 37.5 km/h: "the International Association of Athletics Federations now specifies that times are only approved if fully automatic timing has been used, if the favourable wind speed is less than 2.0 m/s and if there has been no doping".

WEITNAUER was a great ornithologist and his research on his favourite bird is a remarkable contribution to our knowledge of the biology of the Common Swift.

This bibliographical study is not a "malicious" criticism of either the work on speed published by WEITNAUER in 1947 or the authors who quoted him and thus validated his data.

Among them, GÉROUDET and GLUTZ VON BLOTZHEIM published reference works on European ornithology which have served as reliable bibliographical resources for many authors.

Let's go back to the initial question of this study: why in 2024 do some authors still consider that the Common Swift is capable of flying at more than 200 km/h? Quite simply because reliable authors such as GEROUDET and GLUTZ VON BLOTZHEIM have validated this 200 km/h speed.

Let's summarise the evolution of the literature on the subject of 200 km/h in 8 key dates:

1947 - WEITNAUER

In his first paper on swifts, "Am Neste des Mauerseglers Apus apus", published in 1947, WEITNAUER mainly describes the reproduction of the Common Swift. Of the 50 pages of the paper, only 2 pages are devoted to swift speeds and flight performance. Various speeds are measured, including the famous 200 km/h.

At the end, he admits in all honesty:

> I'm aware that my measurements with rudimentary tools cannot be error-free. But I did get an indication of their flying speed. - Let's hope that a reader with better measuring equipment will manage to get accurate measurements - not only their agility, but also their speed of flight is astonishing.

1951 - GÉROUDET

In 1951, in the first edition of LA VIE DES OISEAUX *Les Passereaux, tome 1, du Coucou aux Corvidés.* GÉROUDET quoted and validated the timing data of WEITNAUER (1947). The text will be the same in the various editions of his remarkable books, which are and will remain for a long time to come the bedside books of French-speaking ornithologists.

1956 - LACK

Unlike GÉROUDET, in his famous monograph on the Common Swift *(Swifts in a Tower)* LACK does not quote, and therefore does not validate, the data of WEITNAUER, whose 1947 article is nevertheless included in the bibliography of the pages that LACK devotes to the flight.

LACK even writes :

> "The swift's highest speed on a short burst has never been measured".

It is likely that he has problems with WEITNAUER's methodology.

1968 - OEHME

In his study of the flight of the Common Swift "Der Flug des Mauerseglers *(Apus apus)*", OEHME requires an average speed of swift flight. Rather than using WEITNAUER's data, he preferred to carry out his own timing measurements. He added two important conditions: low wind and horizontal path. Out of 41 measurements, he obtained a maximum speed of 100.8 km/h.

1972 - BRUDERER & WEITNAUER

In an paper mainly devoted to radar observations of the migration and night flight of the Common Swift, "Radarbeobachtungen über Zug und Nachtflüge des Mauerseglers, *Apus apus*", the two authors review the speed data obtained by WEITNAUER (1947) and OEHME (1968).

They present this old data in graphical form (**Figure 1**).

It shows more clearly than in 1947 that:

1. the WEITNAUER data above 100 km/h are speeds measured during diagonal downward air games.
2. the histogram of WEITNAUER's data stops at 165 km/h. There is no longer any mention of the 200 km/h of 1947. Was this "correction" made following exchanges between WEITNAUER and BRUDERER?

This 1972 paper marks an evolution in WEITNAUER's 1947 data.

1980 - WEITNAUER in his monograph on the Common Swift

When, in 1980, WEITNAUER published his monograph on the common swift *(Mein Vogel)* under his own name, he confirmed his change of opinion by repeating almost literally the sentences and graphics from the 1972 paper.

1980- WEITNAUER in Vol. 9 of "Glutz"

In 1980, Vol. 9 of Glutz von Blotzheim, U. N. & Bauer, K. M. *Handbuch der Vögel Mitteleuropas* (Akademischer, Wiesbaden, 1980) was also published.

Emil WEITNAUER and Erwin SCHERNER are the authors of the chapter on the Common Swift.

Their monograph is supervised by co-authors GLUTZ VON BLOTZHEIM and BAUER.

Page 697 contains the sentence:

> Gliding generally reaches 5-14 m/sec, powered flight 11-28 m/sec, and flight games up to 40-60 m/sec (Weitnauer, 1947, Oehme, 1968 b).

These numerical data correspond to a "synthesis" between the data of WEITNAUER (1947) and those of OEHME (1968). Unlike WEITNAUER's monograph, the extreme speeds (40 - 60 m/s or 144 - 216 km/h) are quoted and validated by GLUTZ VON BLOTZHEIM & BAUER.

1998 - GÉROUDET & Michel CUISIN

In the latest edition of GÉROUDET's LA VIE DES OISEAUX *Les Passereaux, tome 1, du Coucou aux Corvidés,* revised by CUISIN, the above speed data from the 1980 "Glutz" are quoted and validated.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Conclusion

How should we approach the problem of the speed of Common Swift flights today?
It all depends on the nature of the publication.
In a scientific research paper, the authors who approach or deal with the subject are supposed to be familiar with the evolution of ideas on this complex issue. They know how to make judicious choices in the use of their sources.
In a popularisation publication, it is normal for the majority of authors to place their trust, in good faith, in people whose seriousness and ornithological skills are recognised by the scientific community.
If GÉROUDET, quoting WEITNAUER's timekeeping (1947), has validated since 1951, in the various editions of his books on the Life of Birds, that swifts are capable of reaching speeds of 200 km/h, why should we doubt it today?
If in 1980, GLUTZ VON BLOTZHEIM & BAUER, in the Handbuch der Vögel Mitteleuropas, a reference work on European avifauna, quoted and validated all of WEITNAUER's (1947) measurements, including the speed of 216 km/h, why should we doubt it today?

After reading the various papers and books cited in this study, I'd like to offer a few final thoughts of my own.

1. Only 2 authors have published timings (Weitnauer, 1947 and Oehme 1968) which are still used as references in popular publications today. These 2 authors took their measurements during the breeding season in a colony with different research objectives.
I think that manual timing can give a good overview of speeds up to 100 km/h (the maximum speed measured by OEHME is 100.8 km/h). Speeds above 100 km/h obtained by WEITNAUER are more open to dispute (see the evolution of WEITNAUER's thinking on his data).

2. Only two studies on airspeeds have been carried out using other methods **in a colony:**
2010 - HENNINGSSON et al. measured flight speeds during **screaming parties** considered to be among the swifts' fastest flights.
Minimum speed: 43 km/h
Average speed: 75 km/h
Maximum speed: 112 km/h

2018 - deMARGERIE et al. measured speeds during **foraging flights over a colony.**
Minimum speed: 16 km/h
Average speed: 36 km/h
Maximum speed: 63 km/h
(data from the video published as an example).

3. All the measurements in the other studies cited were made on swifts:

- either at altitude (radar) in nocturnal roosting flight or in migratory flight by day or night ;
- or close to the ground (ornithodolite) during daytime migratory flight.

These studies mainly provide **average speeds of migratory movements.**
Table 4 gives average air speeds of between **30 and 50 km/h**.
We have already noted that during long migratory flights with strong tailwinds, the speed of flight relative to the ground could reach twice the speed relative to the air.

4. I don't know whether a common swift is capable of flying at 200 km/h or more (groundspeed or airspeed) because this 200 km/h has never been measured rigorously. Do we even know whether the swift's body is capable of

withstanding such speeds?

Like other authors (Andrew LACK…), I note that, in self-propelled flight, the fastest speed to date (112 km/h) is that measured by HENNINGSSON et al. in 2010.

5. It is quite possible that swifts are capable of reaching speeds in excess of 112 km/h during diving flight. To find out, we need to develop precise and indisputable measurement methods.

6. For several years, my daily observations over a colony while filming swifts showed me that swifts had extremely variable flight speeds, as they were notably capable of lightning acceleration in their social interactions and masterful braking to enter the nesting cavities.

This analysis comes to a temporary halt, pending new publications of measurements that innovative technologies will make possible in the years to come.


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