# Flight Tracks of Homing Pigeons Measured with GPS

Karen von Hünerbein and Wolfgang Wiltschko

(*Zoologisches Institut, Johann-Wolfgang von Goethe University of Frankfurt*)

Eckhard Rüter

(*Rüter EPV Systeme GmbH*)

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Flight paths of homing pigeons were measured with a newly developed recorder based on GPS. The device consists of a GPS receiver board, a logging facility, an antenna, a power supply, a DC-DC converter and a casing. It has a weight of 33 grams and works reliably with a sampling rate of 1 Hz for an operating time of about three hours, providing time-indexed data on geographic positions, ground speed and altitude. The devices are fixed to the birds with a harness, and the data are downloaded when the bird is re-captured. The measured flight paths show many details: for example, initial loops flown immediately after release and large detours flown by some pigeons. Three examples of flight paths are presented from a release site 17·3 km northeast of the home loft in Frankfurt. Mean speed in flight, duration of breaks and total length of the flight path were calculated. The pigeons chose different routes and have different individual tendencies to fly loops over the village close to the release site.

KEY WORDS

1. Animal Navigation. 2. GPS. 3. Trials.

1. INTRODUCTION. Homing pigeons are able to return to their home loft from places where they have never been before, but their mechanism of navigation is not yet completely understood (Schmidt-Koenig, 1991; Wiltschko, 1992 and Wiltschko, 1994). For this reason, it may be helpful to record the flight paths of homing pigeons, in order to correlate them with physical factors that are assumed to be involved in their navigation and with the topographical structure of the area. To achieve this, a GPS flight recorder – specifically designed for homing pigeons – was developed to measure flying positions accurately and record homing flight paths (Hünerbein *et al*., 1997).

The technical reason for developing a new type of flight recorder is that the other methods used so far for measuring the flight paths of birds – like ARGOS, conventional radio tracking, the use of aircraft and magnetic direction recording devices – have major disadvantages. These either have a short range, low resolution in time and space and lack accuracy, or a lot of effort and manpower are needed to carry out measurements, or there are high operating costs. A detailed comparison of different navigation systems can be found in former publications (Hünerbein *et al.*, 1997; Hünerbein and Müller, 1998). The current, operational version of the GPS flight recorder is described in the following Sections, and three flight paths recorded by the device are discussed.

## 2. GPS FLIGHT RECORDER.

The following conditions affect how the flight paths of pigeons can be measured:

(a) the birds are rather small, 300–500 g, and should not be burdened with more than 10 percent of their body weight,
(b) Orientation experiments are performed within a medium range of 10–200 km,
(c) The pigeons move fast, with an average speed of 70 km/h,
(d) They return to the home loft within 0·3–24 hours after release,
(e) Pigeons' backs have free access to the sky as long as they fly. Thus satellites can be received with no obstruction.

A big advantage of pigeons in contrast to other animals is that they return to their home loft on their own and can easily be re-captured, so data can be logged and need not be retransmitted.

Thus the most important requirements of the tracking device are: high accuracy, frequent position fixes, low weight, small size, long range availability of position determination and low impact on the pigeons' behaviour. The most difficult requirement to meet was the low weight. The Global Positioning System (GPS) was chosen because of its worldwide availability, its high accuracy of position fixes and because the position fixes are independent of one another. Un-augmented GPS accuracy was 100–300 m before 1 May 2000 and is now 10–30 m after the deliberate degradation of the system – the Selective Availability – was switched off. This accuracy is inherent in the system and cannot be changed by a user.

## 3. DESIGN OF THE GPS RECORDER.

The GPS recorder (shown in Figure 1) measures the position of the pigeon during flight and records these positions in an internal memory. The GPS recorder consists of a GPS patch antenna, a hybrid GPS receiver board, a datalogger, a power supply, a DC-DC converter, a connector and a display of status. It has a weight of 33 g and a physical size of $8{\cdot}5 \times 4 \times 1{\cdot}5$ cm. The GPS recorder has a sampling rate of 1 Hz and operates for approximately 3 hours. The time of operation is limited by the capacity of the lithium battery. The device operates at 3·3 V and constantly needs 167 mA.

At the end of the pigeon's flight, the position data are downloaded to a computer. Then the flight paths, or parts of them, can be calculated and displayed on a map. Data protection in case of power failure is achieved, because the positions are stored on a flash memory. Data can be downloaded as NMEA (standard defined by the National Marine Electronics Association, USA), in a company-owned format or as ASCII text. NMEA data are converted by a Visual Basic program to allow processing by standard PC software.

The effectiveness of the device was first demonstrated in trials at the release site Obermörlen (Hünerbein *et al.*, 2000), where seven complete and two incomplete flight paths were recorded. The incomplete flight paths were due to pigeons taking long breaks and exceeding the time of operation of the GPS recorder.

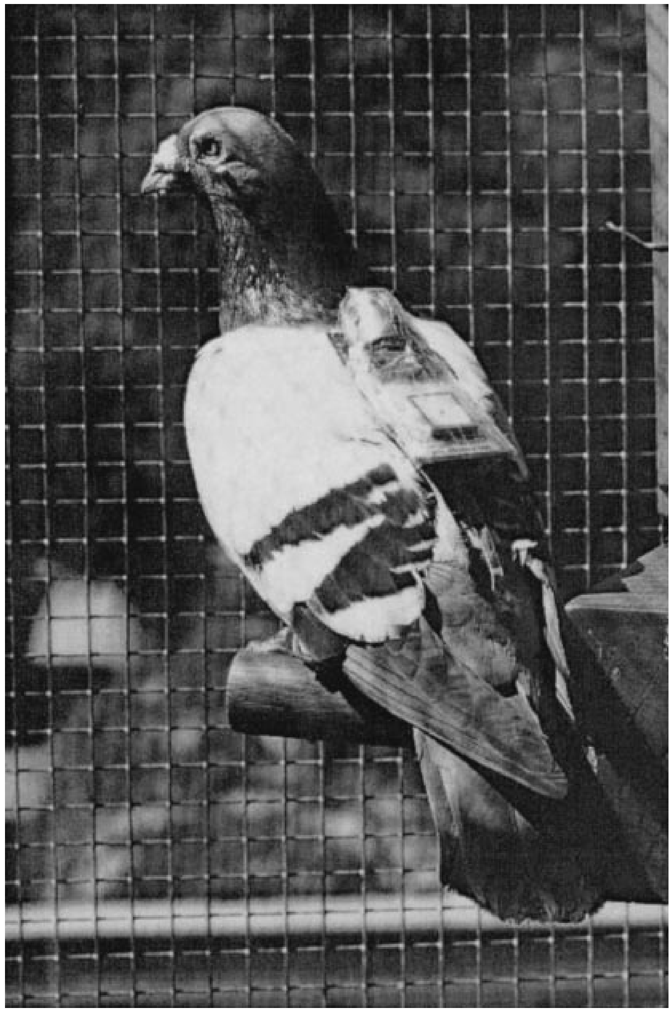

Figure 1. Pigeon in a flying cage carrying a GPS recorder.
(Picture first published in *Galileo's World*, Summer 2000.)

4. DISCUSSION OF THE GPS RECORDER. The main aim of developing a GPS recorder sufficiently miniaturized to put on homing pigeons, have them fly with it and obtain accurately measured flight paths, has now been achieved.

The major advantages of the GPS device are the high sampling rate, the large number of positions that can be stored and the technology of GPS with an accuracy of position of 10–30 metres. These properties lead to a high spatial and temporal resolution of the flight paths. The two major disadvantages of the device are the weight and the residual magnetic field. The weight is about 10% of the pigeons' body weights and is likely to cause the pigeons an additional effort in their homing flight. However, in the three examples presented in this paper, the homing times of Pigeons A-C were within the range of medians of the control sample (16–27 min). The residual magnetic field of the device was about 3% of the Earth's magnetic field. Since it has been shown in previous studies that very small differences in field intensity of about

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0·2 % can make a difference in the pigeons' initial orientation (Wiltschko *et al.*, 1986), this possible influence must be taken into consideration in future studies with the GPS recorder. However, in the examples of flight paths shown here, the initial orientation does not appear to have altered when compared to previous years (see below).

Another disadvantage of the GPS recorder is the short time of operation of three hours, which is due to limited battery capacity. This capacity can only be increased by adding a heavier battery or by lowering the sampling rate, which would reduce the temporal resolution. An increase in weight is not acceptable, since the present weight already represents the maximum pigeons should carry.

5. BIOLOGICAL EXPERIMENTS. The flight paths described here were produced in Spring 2000. Adult, experienced pigeons were used. The birds had been trained for two months carrying a harness and weights from 8–35 g. The pigeons were released from sites with increasing distances and different directions to their home loft to get them used to carrying the equipment. During the experiments, control pigeons carrying nothing at all were also released. The primary experiments were performed from the release site Büdesheim 17·3 km north east of Frankfurt (home direction 231°) under sunny conditions in a slightly hilly terrain. The skyline of Frankfurt is visible from the ground. GPS flight recorders were switched on before the test to allow acquisition of satellites before take-off, to acquire a first fix and to check whether the GPS recorders were operating correctly. The flight paths described consist of 952, 1089 and 1562 recorded positions excluding the periods before take off and after landing. The number of positions per flight path depends on the individual pigeon's homing time. Homing times of GPS pigeons and control pigeons were determined in the traditional way, by a person at the release site and a person at the loft.

6. DATA ANALYSIS. Several software systems were used to measure or calculate different parameters of the flight paths.

TOP 50 – a map system containing maps of the area around Frankfurt am Main – is capable of displaying GPS data and measuring distances between points on the map (© DASA Aerospace). This system was used to determine the maximum lateral deviation from the beeline and the distance from release site at the point of maximum lateral deviation.

WINTRACK is a software for analysis of tracks of different animals and for displaying tracks (© David Wolfer) and was used to determine the length of flight paths from the sum of distances between each pair of position values. Langrech is a software for calculating values from GPS tracks of homing pigeons (© by Karen von Hünerbein) and was used to calculate mean speed of flight, time in flight and the number and duration of breaks

7. EXAMPLES OF FLIGHT PATHS.

7.1. *Pigeon A*. Pigeon A's flight path is approximately S-shaped; the first part of the flight is located left of the beeline in the direction of flight. The pigeon flew one small loop over the village of Büdesheim (Figure 5) and two small loops upon arrival at the loft; there were no loops in the major part of the homing flight after the initial stage. The majority of the flight path was above human settlements. Pigeon A's time of flight was 15 minutes; no time was spent in breaks.

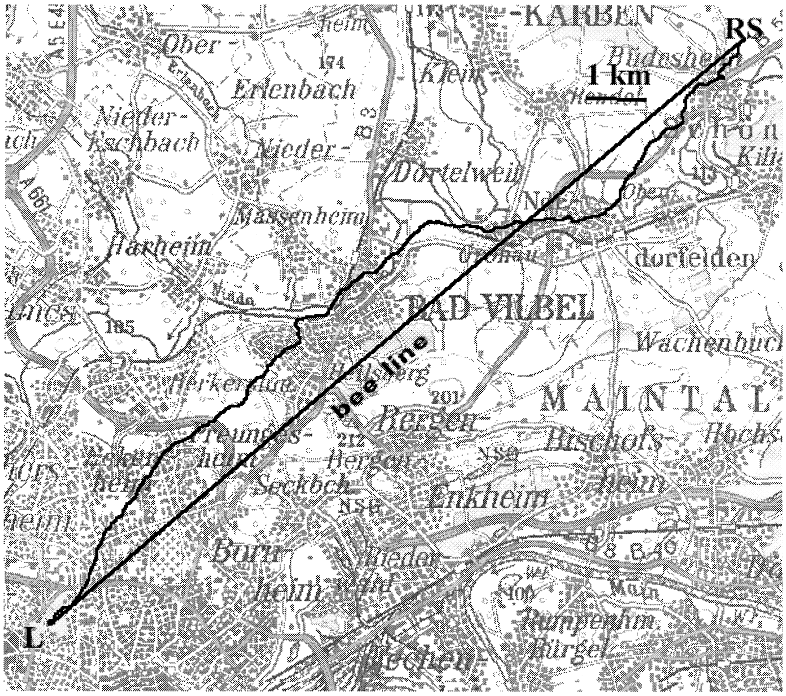


Figure 2. Flight path of Pigeon A (RS = release site, L = Loft).
(Map: Copyright © Bundesamt für Kartografie und Geodäsie, Frankfurt am Main, 2001.)

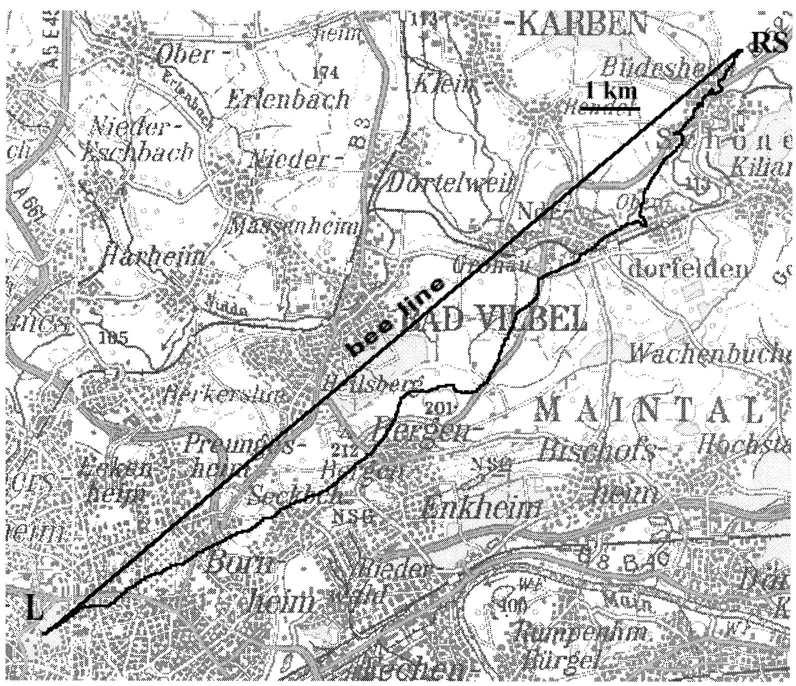


Figure 3. Flight path of Pigeon B (RS = release site, L = Loft).
(Map: Copyright © Bundesamt für Kartografie und Geodäsie, Frankfurt am Main, 2001.)

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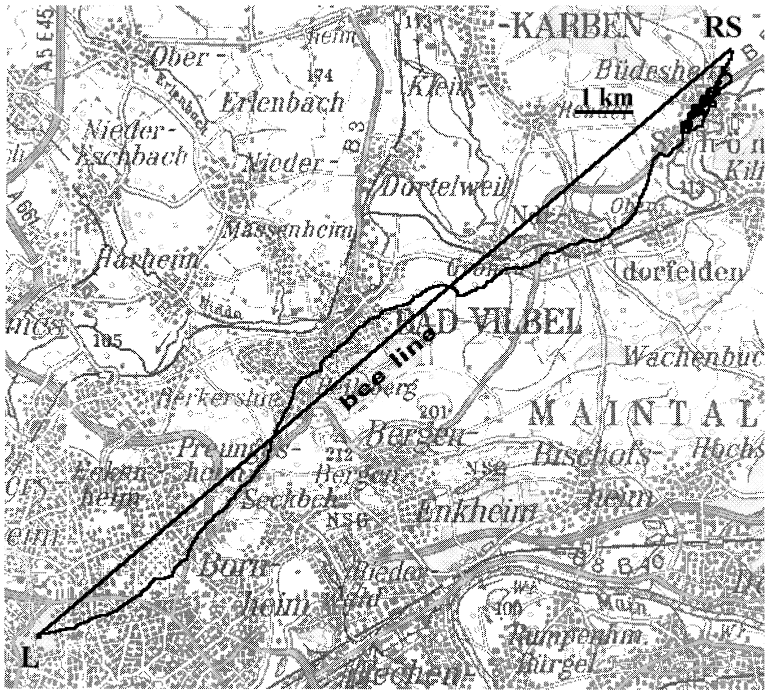



Figure 4. Flight path of Pigeon C (RS = release site, L = Loft).


7.2. *Pigeon B*. Pigeon B's flight path is approximately bow-shaped, the first part of the flight is located left of the beeline in the direction of flight. Pigeon B flew three small, closed loops (Figure 5) over the village of Büdesheim, one open loop over Oberdorffelden and no loops in the latter part of the flight. In the middle of the flight, it flew parallel to the road B521 for 2·5 km. Then it took a westward turn, possibly to avoid a hill North of Bergen-Enkheim. After the bend around the hill, the rest of the flight path was quite straight towards home. The length of Pigeon B's flight path was 20·3 km compared to 17·3 for the most direct route. The mean speed was 65·8 km/h. Pigeon B came home within 18 min with no time spent on breaks. Compared to Pigeon A, the mean speed was lower and the homing time longer, even though the length of flight path was almost identical.

7.3. *Pigeon C*. Pigeon C's path is approximately 1·5 times S-shaped; the first part of the flight is located left of the beeline seen from the release site. The pigeon flew many, extensive loops over Büdesheim (see also Figure 5) and one small loop upon arrival at the loft, but in the major part of the homing flight there were no loops. Pigeon C's length of the flight path was 28·4 km compared to 17·3 of the most direct route. The mean speed was 64·2 km/h. Pigeon C came home within 26 minutes, with no time spent on breaks. Compared to Pigeons A and B, the mean speed was lower and the homing time much longer. The length of the flight path was 8 km longer than the length of the two other pigeons. Since Pigeon C made no large detour en route, the increase in the length of flight path must be due to the extensive loops flown over Büdesheim in the initial part of the flight. Since it did not spend time in breaks, much of the increase in homing time must also be due to the loops flown in the first part

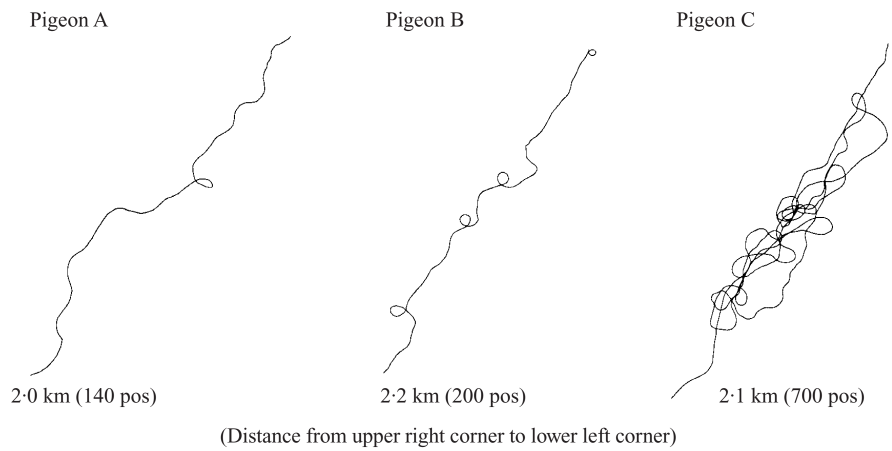



Figure 5. Magnification of the first 2 km of the flight paths: loops flown by the 3 different pigeons. The release site is in the upper right corner of the track. Tracks made visible by WINTRACK (Wolfer, 1993).

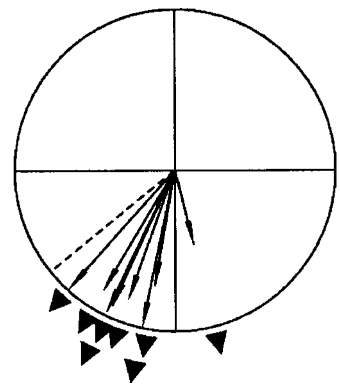
Table 1. SURVEY OF THE THREE FLIGHT PATHS (* CALCULATED WITH WINTRACK).

| | Pigeon A | Pigeon B | Pigeon C |
|---|---|---|---|
| Number of positions/complete track | 952 | 1089 | 1562 |
| Homing time | 15 min | 18 min | 26 min |
| Mean speed in flight | 74·9 km/h | 65·8 km/h | 64·2 km/h |
| Breaks | 0 | 0 | 0 |
| Length of flight path* | 20·4 km | 20·3 km | 28·4 km |
| Shape of flight path | S | Bow | 1·5 S + loops |
| Crossings of the beeline in the middle of the path | 1 | 0 | 2 |
| Vanishing bearing | 220° | 215 ° | - |
| Max. lateral deviation from beeline | 1·2 km | 1·7 km | 1·2 km |
| Distance from the release site at point of max. lateral deviation | 6·9 km | 8·1 km | 3·8 km |

of the flight. The lower mean speed in flight of 64·2 km/h compared to 74·9 km/h of Pigeon A would only account for an increase in homing time of about 3 min assuming the same length of flight path. But its homing time was 11 minutes longer than that of Pigeon A (Table 1).
The homing times of control pigeons ranged from 16–27 min.

8. FLIGHT PATHS. All three flight paths are similar in the very first part of their flight; the pigeons departed about 10–15° counter-clockwise of the home direction. In previous years, a release site bias has been observed in Büdesheim that varied between 166° and 222° among adult pigeons. It was located to the left of the homing direction as seen from the release site (Figure 6) (Wiltschko *et al.*, 1986).

The deviation to the left in the initial stage of the flight path that can be seen in all three pigeons is therefore consistent with the observations of bias in previous years. In the latter stages of the flight, there are individual differences in the route chosen



Each arrow represents the mean vector of a group of adult control pigeons in one experiment. The length of the vector represents the *scatter*, the longer the vector the smaller the scatter. Triangles point in the *mean direction* of the mean vector. The *home direction* is indicated by the broken line.

In the years 1981 – 1993, the mean direction of the vanishing bearings was always left of the home direction as seen from the release site.

Figure 6. Bias of adult control pigeons at Büdesheim in previous releases.

and in the tendency to fly loops. All the flight paths shown here have a rounded, bow or S shape; the pigeons did not fly on straight lines nor on the beeline, although they stayed quite close to the beeline. The loops were mainly flown over the village of Büdesheim closest to the release site in home direction.

The many loops flown by Pigeon C resulted in a major increase of homing time and an increased length of flight path. A reduced mean speed in flight also caused some increase in homing time. However, all three homing times (15, 18 and 26 min) were in the range of the homing times of control pigeons (16–27 min).

## 9. CONCLUSIONS.

These results illustrate the potential of the GPS-based technique to yield a wealth of data on the behaviour of animals en route. The new flight recorder will help to close a gap in biotelemetry, so that now a large number of new species can be tracked over medium distances as long as they can be re-captured. At present, the GPS recorder is suitable for animals with a weight of above 0·5 kg, but further attempts will be made to decrease the weight of the recorder in the future. The GPS recorder should find a wide range of applications in behavioural and conservation studies.

The three flight paths shown here are similar to each other in the initial stage, which seems to correspond to the release site bias observed in previous years. Increases in homing times seem to be due to loops flown and a lower mean speed. The homing times of the three pigeons carrying GPS were consistent with homing times of the control pigeons.

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## REFERENCES

DASA Aerospace. (1998). TOP 50, 2.0. software.

Hünerbein, K., Wiltschko, W., Müller, R. and Klauer, B. (1997). A GPS-based flight recorder for homing pigeons. *Conference Proceedings of the GNSS 97*. Ed.: Deutsche Gesellschaft für Ortung und Navigation) April 21st-25th, 1997. Bonn. Volume II: 561–570.

Hünerbein, K. and Müller, R. (1998). Development of a GPS flight recorder for birds. *Conference Proceedings of the European Telemetry Conference 98*. Arbeitskreis Telemetrie e.V. (ed.), Braunschweig: 86–98.

Hünerbein, K., Hamann, H. J., Rüter E. and Wiltschko, W. (2000). A GPS-based system for recording the flight paths of birds. *Naturwissenschaften 87*: 278–279.

Kenward, R. E., Pfeffer, R. H., Al-Bowardi, M. A., Fox, N. C., Riddle, K. E., Bragin, Y. A., Levin, A. S., Walls, S. S. & Hodder, K. H. (in press). New techniques for demographic studies of falcons. *Journal of Field Ornithology*.

Schmidt-Koenig, K. (1991). Über Karten und Kompasse bei Brieftauben. Verh. Dtsch. *Zool. Ges. 84:* 125–133.

Wiltschko, W., Nohr, D., Füller, E. and Wiltschko, R. (1986). Pigeon Homing: The use of magnetic information in position finding. G. Maret, J. Kiepenheuer, N. Boccara (eds.) Biophysical Effects of Steady Magnetic Fields. *Proceedings of the Workshop Les Houches*. France, Springer Verlag, Berlin: 154–162.

Wiltschko, R. (1992). Das Verhalten verfrachteter Vögel. *Die Vogelwarte 36:* 249–310.

Wiltschko, R. (1993). Pigeon homing: release site biases and their interpretation. *Proceedings of RIN 93. Orientation and Navigation – Birds, Humans and Other Animals*. Oxford 1993, Paper No. 15.

Wiltschko, W., Wiltschko, R. (1994). Avian orientation: multiple sensory cues and the advantage of redundancy. Davies, M. N. O. and Green, P. R. (eds.). *Perception and Motor Control in Birds: 95–119*. Springer Verlag, Berlin, Heidelberg.

Wolfer, D. (1993–2000) WINTRACK. Software. University Irchel, Zürich, Switzerland.