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Travels with a Backpack:

Satellite tracking of birds

Man has always dreamed of following birds on their often very distant travels to other continents. Earlier, researchers accompanied birds fitted with small transmitters over considerable distances in small aircrafts and even in vehicles on the ground. Nonetheless, the documentation of the complete annual migration routes - nowadays for several consecutive years - was only made possible by satellite telemetry. With the introduction of GPS technology it is now possible to study not only bird migration, but also many other applications such as behaviour in the breeding, rest and wintering areas. We can now accurately measure and analyse home range size, habitat use, territorial behaviour, daily activity, flight behaviour (height and speed) and so forth. In this article, Christiane and Bernd Meyburg describe the dynamic development of satellite telemetry.

Satellite telemetry (ST) celebrated its 25th anniversary as a research tool on 21 July 2009. On this day, 25 years ago, a Bald Eagle *Haliaeetus leucocephalus* in the USA was the first bird to be fitted with a satellite transmitter (PTT = platform transmitter terminal) weighing 170 g. The device transmitted data for some 8 months until 19 March 1985. Since that time satellite telemetry has gone through a stormy development, especially since the start of the 1990s. This manifested itself in a symposium on Satellite Telemetry in Ornithology run by the authors during the 22nd International Ornithological Congress in Durban (RSA) in 1998.

The Argos system

The core element of ST is the Argos system. It receives the signals sent out by the PTTs via NASA satellites that orbit the earth at an average height of 850 km. The data received from the satellite are redirected from various reception stations across the globe to two centres in France and the USA, where they are analysed in parallel. With the assistance of this system it is possible to track the changes in location of individual birds worldwide permanently over long periods of time. In more recent times mobile telephone networks are used to transmit the data.

From Doppler to GPS locating - a quantum jump

Up until eight years ago the PTTs were located by the Argos system exclusively by means of the so-called Doppler shift. The PTT's frequency appears to change during the approach, overflight and departure of the satellite. This apparent change in frequency permits two fixes to be calculated to the left and right of the satellite's path. It is however not possible for Argos to determine which of the two fixes is correct. Doppler fixes have the great disadvantage that they are accurate to some few hundred meters in only a very few cases (some 1 to 5 %). The researcher must therefore check very critically which fixes can be considered for the evaluation of the results. Some fixes are namely far too inaccurate or indeed completely false. The Argos system also provides an estimate of the individual fixes and divides these into probably accurate and probably inaccurate. As Argos cannot however guarantee this accuracy, it is left to the researcher to decide which fixes to accept and which to discard.

Experience and knowledge of the species concerned are of great importance here. We often discard 80 to 90 % of fixes. The Doppler fixes suffice to study the migration routes and wintering areas reasonably accurately; but detection of small local movements in the breeding area is normally not possible using this method. PTTs with solar power and GPS (Global Positioning System) technology, small and light enough (to begin with 65 g) to be fitted to larger bird species, only became available shortly after the millennium. GPS is a system comprising 24 satellites operated by the US Defense Department which has functioned since 26 June 1993. The fixes are constantly accurate to within a few metres. This enables an exact analysis of the size of the area used by birds during the breeding period, while resting on migration and in winter quarters. Spatial and habitat use can be precisely determined. GPS data on flight height, direction and speed permit conclusions on the behaviour of the birds to be made. Until now it was methodically very difficult, if not impossible, to accurately measure flight height and speed. The data are still transmitted via the Argos system, so that this form of telemetry involves the participation of two different satellite systems. In the meantime GPS enhanced PTTs weighing 45 g, 30 g and 22 g are used. In addition, there are GPS PTTs with battery power weighing 45 g and 105 g. The advantage of GPS ST in comparison to previous ST using Doppler fixes lies not only in the much greater accuracy, but also in the reliability of the fixes. 'Bad' fixes, with which the researcher always had to cope with up until now, have been eliminated.

The long way towards an ideal transmitter

The weakness of the system lies in the transmitters, which for fitting to birds need to be small and light. They need to send signals 100 times stronger than so-called conventional VHF transmitters, where as a rule observers on the ground use hand antennas to receive signals and locate the bird. Of the some 10,000 known bird species, only about 1,500 are large enough to carry even the smallest currently available PTT, weighing just 5 g. In our opinion the weight of the PTT including harness should not exceed 3 % of the bird's body weight. For this reason so-called Geo Data Loggers or Geo Locators are being developed in parallel to the ever smaller and lighter PTTs. The former determine position using sunrise and sunset times. They are markedly cheaper than PTTs but their fixes are very inaccurate. In addition the data are saved and not transmitted so that the bird has to be recaptured. Almost faster than we expected, smaller and smaller solar-powered PTTs were produced enabling the study of even smaller bird species. In 2000, PTTs using Doppler fixes and weighing some 18 g became available, enabling us to fit Honey Buzzards *Pernis apivorus* and Kites *Milvus ssp.* With PTTs as well. The course of the technical development of PTTs used in ST can be divided into three phases. The period during which only battery-powered PTTs with Doppler location were available; the phase when solar-powered PTTs producing Dopple fixes were in use; and the final phase in which PTTs with GPS technology could be employed. The time periods depend on the size of the species concerned. The leading producers in the USA set themselves the objective of devising the most theoretically possible ideal PTT. It should weigh practically nothing, be as small as possible and be capable of transmitting any amount of data for an almost unlimited period of time. At present the components are available to construct PTTs using the Doppler shift weighing 4 g or even 3 g. The leading ST producers in the USA reckon that they can probably produce GPS enhanced PTTs weighing 18 g by 2010 and, by 2011, devices weighing only 12 g.

All the way to Southern Africa with the world's smallest satellite transmitter

The prototype of the smallest solar-powered PTT weighing just 5 g comes very close to this aim. We fitted it for the first time to an adult female Eurasian Hobby *Falco subbuteo* in the German federal state of Brandenburg and successfully recorded the annual migration route. The bird was caught and fitted with the PTT on 9 August 2008 near Berlin. After leaving on migration in the second week of August, and a short rest period on the island of Elba off the west coast of Italy from 6 to 13 September, the bird flew at first in a southerly direction towards North Africa. The falcon held this course more or less until reaching its main wintering area in Southern Angola on 17 October. Over two months later it migrated further in a south-easterly direction and arrived in Zimbabwe on 29 December. On 1 January 2009 it reached the southernmost point of its migration between the cities of Bulawayo and Harare in central Zimbabwe. The distance migrated from the breeding site, not including regional movement in Angola, was up to this point 10,000 km. The Hobby did not linger for long in Zimbabwe and retreated almost immediately to its wintering area in Angola. The bird arrived back at its old breeding site in Brandenburg in May. Interesting data was obtained on the winter habitat used, the home range size in winter and migration speed when crossing ecological barriers (e.g. the Sahara). The West African equatorial rain forest proved to be one such significant ecological barrier. Migration was noticeably rapid here with distances of up to some 580 km flown per day - also partly at night. In order to reach the northern perimeter of the area the bird flew an additional 260 km after sunset on 14 April, and arrived at its night roost clear of the rain forest as late as midnight. On one part of the route, 57 km in length, it flew at an average speed of 34.2 km/h. But even in its wintering area the small falcon showed an eagerness for travel, as witnessed by the recording of 543 different fixes. Of the barely 25 weeks spent in the south the bird never spent as long as a week in the same place up to six weeks preceding return migration. In the wintering period from 16 October 2008 to 7 April 2009, the bird covered a total distance of at least 9,025 km. This calculation is based on the distance between the 76 precise night roost fixes, which amounted to somewhat less than the half of all overnight stops. Within Angola these fixes, usually recorded at an interval of 48 hours, were sometimes more than 300 km apart. This means that the actual distance covered by the bird during wintering was significantly greater. Although well over 5,000 Eurasian Hobbies have been ringed in different European countries over the past few decades, only two rings have been recovered in sub-Saharan Africa. This demonstrates how rapidly the current state of scientific knowledge can be driven forward with the help of ST.

Records on migration - the Lesser Spotted Eagle as a pioneer of migration research

In 2004 solar-powered PTTs with GPS technology, small and light enough to be fitted to medium-sized birds such as the Lesser Spotted Eagle *Aquila pomarina,* became available. Since 2004 we have fitted PTTs to not only a large number of Lesser Spotted Eagles, but also to Greater Spotted Eagle *Aquila clanga* and Osprey *Pandion haliaetus*. The first female Lesser Spotted Eagle fitted by us with a GPS enhanced PTT in Brandenburg provided surprises on the first autumn migration. The bird was not infrequently located at heights of over 2,000 m ASL both on migration and in its wintering area in Namibia. On 36 occasions flight speeds of 80 kph and more were recorded, on 3 occasions it flew over 100 kph with a maximum recorded speed of 114 kph. All high flight speeds were recorded south of the Sahara with a single recording of 80 kph over Israel. A large cluster of high speeds were registered in particular in Namibia, with one each of 103 and 114 kph, and a single occasion where a flight speed of 100 kph was recorded in Tanzania on 9 March 2005 on spring migration. The highest average speed in a single hour was reached by the female Lesser Spotted Eagle on arrival in its wintering area in Namibia on 17 January 2006. In six and a half hours it covered 379 km, an average flight speed of over 58 kph. During this period speeds of 90 - 100 kph were reached on 3 occasions and once 114 kph was measured.

Birds of prey have vast wintering areas

The size of the wintering area of Lesser Spotted Eagles, and other species that have extremely extensive wintering ranges, could be precisely recorded for the first time with the help of GPS tracking. Until now, researchers had little exact idea of the size of the wintering areas required by these birds. The first Lesser Spotted Eagle fitted with a GPS enhanced PTT (No. 41861) from 9 December 2004 to 20 February 2005 used an area of 76,700 km² in Namibia and Botswana. As a comparison Scotland has a surface area of 78.772 km². A total of 963 fixes are available for this period, permitting an analysis of the daily activity, habitat use etc. In the following winter the female arrived in its old wintering area in Namibia as late as 17 January, as it had spent much more time resting in the Congo and Zambia. The area used until its departure on spring migration on 20 February was much smaller on this occasion. The wintering behaviour of this bird could be precisely recorded in 5 consecutive winters by means of thousands of GPS fixes - surely an ornithological first. In the meantime, consecutive wintering periods were recorded for a good number of further individuals. The first Hobby fitted with a PTT to date had a much larger wintering area of over 300,000 km²

Long term telemetry

Long term telemetry of individual birds over several years is required to provide answers to many unanswered questions such as winter quarters philopatry, or faithfulness to or divergence from migration routes in different years etc. Several of the PTTs we fitted sent signals for 5 years and more. The world record is held by a female Greater Spotted Eagle, fitted with a PTT by us in summer 1999, and today (August 2009) is still transmitting fixes after over 10 years. It always winters in the Göksu Delta in Turkey where it has also been observed and photographed. White Storks have also carried PTTs for similar lengths of time, but the devices have been exchanged during the period. A male Greater Spotted Eagle, which was fitted with a PTT a year later and always winters in Sudan, transmitted data for seven years, as did a male Lesser Spotted Eagle from Germany.

Battery or solar power? – A poor outlook for northern states

When we started satellite telemetry in 1992, only battery-powered PTTs existed. These were programmed in such a way so as to prolong battery life for as long as possible. This had the consequence for instance that fixes were received for a few hours only every four or five days. In this way we were able to record the complete autumn and spring migration, as well as the wintering period of a male Lesser Spotted Eagle from Germany, although the fixes along the migration routes were relatively far apart. This is probably the first bird ever for which the aim of documenting a complete annual migration record was achieved. In the majority of cases the batteries fail at the start of spring migration. In many telemetry studies only the autumn migration route was therefore described. We therefore considered it essential to document not only the complete annual migration route, but also to repeat this for several annual routes of the same bird. As this is not possible using battery-powered PTTs, we constantly asked our suppliers to produce solar-powered PTTs. The time was then ripe in summer 1993 when a White-tailed Eagle *Haliaeetus albicilla* nestling in Brandenburg was fitted with the prototype of a solar-powered PTT. As these PTTs became smaller and lighter in a short space of time, we converted to the use of solar-powered PTTs only. Many of these PTTs deliver thousands of fixes for a single bird.

Light - a limiting factor

With sufficient exposure to sunlight the solar-powered PTT can send data permanently and thereby deliver an almost unlimited number of fixes. The researcher soon notices the high Argos data transmission costs in his budget. On the African continent for instance such studies with solar-powered PTTs have practically no technical limit. Projects located further away from the equator are however not so easy to conduct. The PTT that we fitted to a White-tailed Eagle on 14 July 1993 sent back one thousand fixes until 1 August 1994. At this time the PTT was not specially programmed and began to transmit as soon as it was adequately charged but otherwise ceased to send data. The young eagle spent the whole year in Brandenburg and Mecklenburg-Western Pomerania in northern Germany, apart from a short excursion to Poland. This demonstrated that the light conditions in the winter of 1993/94 were inadequate for permanent transmission and the number of fixes sank very considerably. As we were however mainly concerned with migrant species this did not affect us to a great degree and we discontinued fitting PTTs to non-migrant birds. The problem only reoccurred when we conducted ST with Red Kites *Milvus milvus* in Germany and Imperial Eagles *Aquila heliaca* in Slovakia. Other birds that we studied, such as Lesser Spotted and

Greater Spotted Eagles, Osprey, Short-toed Eagles *Circaetus gallicus*, Honey Buzzards and Black Kites *Milvus migrans*, all start migration punctually. Bottlenecks, and thereby gaps in transmission, only occur occasionally during autumn migration in October. For the reasons discussed above spring migration presents a special challenge. In spring 1998 the home migration of a female adult Lesser Spotted Eagle, lasting 64 days, was recorded in textbook fashion. Among other data, the positions of all night roosts along the 10,753 km long route were fixed so that the individual daily flight details could be fully calculated. The eagle had spent the winter in the Kruger National Park in South Africa and in neighbouring Mozambique, some 9,000 km direct flight from its breeding site. It left its winter quarters on 21 February and was directly observed arriving at the nest site at 15.15 hrs GMT on 25 April. On 51 days the bird covered an average distance of 211 km (18 to 406). In between it rested on a total of 13 days, which included a forced stop of four days in eastern Hungary due to bad weather. The flight speed data allowed the time of the bird's arrival at the nest site in Germany to be calculated to within 15 minutes. From the beginning of March on eleven days the eagle covered over 300 km daily in Zimbabwe. On 14 March the bird covered its longest daily flight distance on spring migration of 406 km over Tanzania and Uganda. Migration across the Sahara was not markedly quicker than in other regions. From the beginning of March until arrival at the breeding site flight speed remained relatively constant.

Rarities committees and satellite telemetry

As more and more birds are fitted with satellite tags it is hardly surprising that they - mostly unnoticed - also visit countries where their occurrence is of interest to local rarities committees. In 2008, 3 young Lesser Spotted Eagles fitted with our PTTs passed - unnoticed by field ornithologists - through Switzerland where only six records of individuals have been recorded in more than a century. The passage of a young Greater Spotted Eagle through Germany in 2008 led to queries to the Austrian, German and Swiss rarities commissions as to whether the occurrence recorded by ST could be accepted. Satellite data were accepted to be more reliable than field observations, with no difference being made between GPS and Doppler fixes. Records based on Doppler fixes only should however be checked by an experienced telemetry specialist.

Which transmitter for which species?

Which satellite tags are suitable for fitting to which birds? This is a question we are often asked. The decisive factor is first of all the bird's body mass. In order to minimise impairment to the bird's performance, the PTT including harness should not weigh more than 3 % of the bird's weight. This continues to rule out satellie tracking for small birds. Large and middle-sized birds, which spend a great deal of time in the open and frequent the regions around the equator outside the breeding season, are ideal candidates for ST. Solar-powered GPS tags can be fitted to these species, and a maximum of fixes over a long period of time can be expected. Ideal species in this category are for instance Osprey and Black Kite. The further a species diverges from these criteria makes it more unsuitable for ST study. Satellie tracking of smaller species that winter in northern latitudes is very difficult.

What contribution does satellite telemetry make to species conservation?

In accordance with the old adage "I can only protect what I know", the value of a massive gain in scientific knowledge through ST is obvious. A particularly prominent example is the fitting of a PTT to a young Lesser Spotted Eagle in 2008. The bird was located on 12 October 2008 close to Sharm El Sheik in the south of the Sinai Peninsula. Four days later the bird, together with 26 more young eagles, was found dead in the city's sewage works. This number represents almost half of the Lesser Spotted Eagle offspring that fledge annually in Germany. Investigations set in train by us revealed that large numbers of migrant birds, including many rare birds of prey, are found dead every year here. It is now essential to establish the cause of mortality and to do something about it. It was possible to establish the causes of mortality (electrocution on or collision with power lines, shooting, poisoning, drowning in the sea etc.) of a number of other birds and in some cases to examine the corpses. The Sinai Peninsula is a veritable death trap for large birds of prey, in particular young eagles. The crossing of the Gulf to the African mainland is dangerous for them and they clearly often fail to find the north-western route via Suez. In the case of adult eagles we were repeatedly able to record by satellite tracking the more than 500 km detour via Suez; one young eagle also successfully crossed the Gulf from the southernmost tip of the peninsula.

Rings or transmitters?

In some ringing records publications ST is discussed and it is pointed out that despite this technique ringing is still necessary. This gives the impression that the two methods are in competition with one another. We would like to make it clear that this is far from being the case. On the contrary, both methods complement one another. Whenever possible, when fitting PTTs, we have always fitted the birds with a ring of the responsible ringing centre as well as with a colour ring. There are two main reasons for doing this. The PTT sends data for a limited period only, and some birds manage to remove them by biting through the harness. In such cases we could only identify the bird by ringing and recapture. As recapture is rarely successful we fit colour rings to the birds in order to determine later whether the bird at the breeding site is the one we fitted with a PTT or a new individual.

VHF or UHF telemetry?

VHF telemetry (VHF = Very High Frequency, 30 to 300 MHz), also called conventional or ground telemetry has been available for much longer than ST or UHF telemetry (UHF = Ultra High Frequency, > 300 MHz). In order to make a fix by VHF however, at least two observers on the ground are required as a rule, using Yagi directional antennae and receivers to plot angles. As the margin for error of this plotting is at least 5° the fixes are correspondingly inaccurate if the bird can not be observed directly. VHF and UHF telemetry can however complement each other. Ideally both methods can be employed simultaneously when, for example, the behaviour in the breeding area is to be studied in detail. VHF telemetry is however unsuitable for migration studies. In the USA conventional VHF tags were used in combination with small aircraft to follow birds on migration and this method provided some specific information. The effort involved was however very great and contact was often lost. Such an undertaking in Europe is unthinkable due to the many political borders as well as ecological barriers.

Bernd-Ulrich Meyburg, Christiane Meyburg

What questions about birds can we expect to be answered by the results of satellite telemetry?

Results of migration behaviour

• Course of the route of migrating birds (differences in route of individuals in different years; possible differences in migration behaviour between adult and juvenile birds)
• Navigation and orientation (differences between adult and juvenile birds, conclusions on inherent behaviour and experience)
• Geographical location of the wintering areas
• Separation or cohesion of families during migration
• Questions on the crossing of ecological barriers (water bodies, mountain ranges, deserts etc.)
• Questions as to which structures act as guidelines for bird migration
• Bottlenecks: Do all individuals pass through these points and at what point in time? Is it possible to conduct a comprehensive population count at bottlenecks through direct observation?
• Migration timing
Differences between adult/immature/juvenile birds
Differences between males and females
• Migration duration
- Differing routes on autumn and spring migration
- Dependence on the distance between breeding and wintering areas
- Differences between adult/immature/juvenile birds
- Differences from year to year
• Migration flight speed
- Variation during the complete migration period
- Individual differences
- Length of daily flight
- Actual average speed
- Actual flight speed
- Daily profile of migration behaviour
- Dependence on weather
- Dependence on age of the migrating bird (juvenile, immature, adult)
- Dependence on participation or non-participation of adult birds in the breeding process
- Dependence on the distance between breeding and wintering areas

Rest areas

• Geographical location, size and number of rest areas on migration routes
• Ecological conditions in the rest areas
• Length of stay and behaviour in the rest areas

Results of dispersion und dismigration

• In species with less pronounced migration behaviour

Results of wintering behaviour

• Geographical location of wintering areas
• Size and number of home ranges in wintering areas
• Possible nomadic behaviour
• Wintering area site fidelity in different years
• Behaviour in wintering areas

Are migration and breeding success interdependent?
What are the causes of early or late arrival at the breeding site on spring migration (climatic influences during migration, early or late departure from the wintering area, influence of climate change)?

Behaviour in the breeding and summer stay areas
• Behaviour of non-breeding adults (arrival, territory size, possible nomadic behaviour)
• Behaviour of unsuccessful breeding adults (Retention of the breeding site after brood loss?)
• Behaviour of immature birds (Size of territory used, nomadic behaviour?)

Nest site fidelity and settlement behaviour
• Annual return to the same breeding site or change of breeding site
• Settlement behaviour of first-breeders

Pair fidelity over many years
• Breeding site fidelity?

Whereabouts of immature birds during the breeding season before sexual maturity
• Return to the breeding area / permanent stay in wintering area?
• Size of home range, nomadic behaviour

Mortality on migration
• Resulting from human persecution (Identification of persecution 'hot-spots'
• Resulting from bad navigation
• Other causes of mortality

The fate of individuals released into the wild
(Injured and rehabilitated birds of prey, resettlement programmes etc.)

Relevant references:

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Information on the internet: www.argos-system.org/manual/, www.Raptor-Research.de

Bernd Meyburg's interest in birds of prey began in 1962 and he has fitted satellite transmitters to some 150 individual birds, of 15 different species, since 1992. Christiane Meyburg has participated in almost all bird of prey projects since 1971. Since 1992 she has made a major contribution to the organisation and analysis of the many thousands of telemetry data. All previous publications can be seen or downloaded at www.Raptor-Research.de

Captions

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The GPS fixes in the central part of the male Black Kite's home range with PTT 74988. During its successful breeding stay in summer 2008 (2 April - 25 July) 821 GPS fixes were recorded. The concentration in the vicinity of the nest site is noticeable, as on the some 10 km stretch of the upper River Havel in Brandenburg, its main foraging area. Single fixes are denoted by yellow points; overlapping groups of fixes are darker in colour.

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Adult Red Kite male with a 22 g solar-powered GPS satellite transmitter. The transmitter and antenna are clearly visible. Photo: B.-U. Meyburg. Near Weimar in Thuringia, Germany, 4 June 2009.

The distances between all consecutive night roosts during the whole of the wintering period 2007/2008 demonstrate that the Black Kite with PTT 74988 covered a distance of at least 14,000 km in its winter quarters. It seldom used the same night roost more than once.

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Record of the wintering of a female Lesser Spotted Eagle with PTT 41861 in Namibia and Botswana in the time frame 2004-2009 (9 Dec 04 - 20. Feb 05, 17 Jan 06 - 20 Feb 06, 12 Dec 06 - 3 Feb 07, 25 Nov 07– 29 Jan 08, 26 Nov 08 - 8 Feb 09). The bird was ringed as a nestling in July 2000 in Mecklenburg-Western Pomerania (Germany).

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The complete annual migration route in 2007/2008 of a male adult Black Kite from Brandenburg with PTT 74988 (blue line: autumn migration 26 Jul to 12 Sep 2007; green line: wintering 12 Sep 2007 to 2 Mar 2008; red line: spring migration 2 Mar to 2 Apr 2008).

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Oblique satellite photo of Israel taken in the migration direction of a Lesser Spotted Eagle. Details of time of day, height ASL and flight speed are shown next to the GPS fixes. The Mediterranean Sea can be seen to the right of the picture. The night roost 13/14 October 2005 was near Jerusalem.

The three phases of the technical development of transmitters. The time-frame is related to a medium-sized bird such as the Osprey.

Time frame	**Type of transmitter**	**Comments**
1992 – 1995	Battery-powered transmitter with Doppler fixes	Transmitter life only approx. 1 year when the PTT is programmed to send for only a few hours with a gap of several days. A maximum of 100-150 fixes possible.
1995 – 2003	Solar-powered transmitter with Doppler fixes	Transmitter life of several years (in one case over 10 years); with adequate sunlight thousands of Doppler fixes. Well suited for migration research, but too inaccurate for the analysis of movement within a small area.
From 2003	GPS enhanced transmitter (solar and battery-powered)	Fixes accurate to a few metres. This enables precise analysis of habitat use etc. in the breeding area. Replaces VHF telemetry to a large extent. Flight height, direction and speed also recorded in the 3D version.

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Female Eurasian Hobby with the prototype of a satellite transmitter weighing only 5 g. Photo: B.-U. Meyburg, 9 August 2008

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Young Lesser Spotted Eagle with PTT 83270 and identification ring (AX) clearly visible on the Sinai Peninsula (Egypt) on 12 October 2008. Four days later it was found dead in the Sharm El Sheik sewage works together with 26 other young Lesser Spotted Eagles. Photo: G. Grilli.

Photo page 264: Bernd Meyburg with an ad. female Steppe Eagle *Aquila nipalensis* fitted with satellite transmitter shortly before release in Saudi Arabia. Photo: C. Meyburg.