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Translation

Migratory and wintering behaviour of the Red Kite *Milvus milvus* in Thuringia (Germany) as revealed by Satellite Telemetry

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Summary

In the period 2002 to 2005, nine Red Kites (two juveniles and seven adults) were fitted with solar-powered satellite transmitters (PTTs) in Thuringia (Germany) which, up to the end of 2008, enabled 2686 fixes to be made by Argos using the Doppler Phenomenon. Most locations were not very precise, but are adequate for studies of migratory behaviour. In total seven autumn migrations to Spain and four return journeys to the breeding area were tracked. Apart from one juvenile, which departed as early as August and required 47 days to reach Spain, migration began in the first half of October. Arrival in spring took place between 5 and 12 March. During migration to winter quarters the birds covered distances of between 1,450 and 2,320 km, for which the adult birds required between 12 to 28 days. Spring migration, taking between 8 to 22 days, was somewhat quicker. An adult female, which was tracked over five migration periods, spent both of the first two winters in the same area in south-west Spain and, in the third migration period, only flew as far as northern Spain. At the end of December a change in winter quarters of over 130 km took place. In the fourth year of the study it spent the winter in its breeding area. In the following year (2008) the female migrated a week earlier than in the first three years to western Spain, where it was found dead in December. Three members of a family (the male and two juveniles) migrated separately and the juveniles sought out different wintering areas. In addition to the telemetry results the transmitters provided further information on the individual identification of the Red Kites. By this means the ousting of a pair from the breeding area by other Red Kites was recorded and a female, monitored over a five year period, had at least four different partners in this time. Of the nine birds fitted with transmitters, there were mortalities of seven kites, of two males and one female in the breeding area, a further male during migration and both juveniles and an adult female in winter quarters. One female is still carrying the transmitter (summer 2009) and, since the transmitter was deployed at the age of three years, has successfully raised young annually for the past seven years. The PTT of the ninth bird has been removed when it was re-trapped.

1. Introduction

Knowledge to date on the migration and wintering behaviour of the Red Kite is based on visual observation of migrating and wintering birds and the evaluation of ring recoveries. Over the past few years Red Kites have increasingly also been marked with individual wing tags. This has made possible the recording of various data on the birds' location on migration routes, in winter quarters or in the breeding area. More detailed information on the course of migration and wintering areas for individuals could however not be obtained using these methods.

From 2001 onwards the progressive miniaturisation in the development of satellite transmitters (PTTs = platform transmitter terminals) enabled the production of solar powered satellite transmitters that were small enough to be fitted to Kites. This provided the opportunity to use this modern satellite telemetry (ST) technology, which had been introduced for research with larger bird species since the start of the 1990s (Meyburg & Fuller 2007), for the Red Kite as well. This enabled the complete annual migration routes of individual birds to be recorded, in some cases over a period of several years.

Telemetry (= far measurement) is the term used to describe the transmission of readings from a sensor at the point of transmission to a distant location. The readings can be collated, recorded and instantly analysed at the receiving station. With ST the data transmission is via the Argos satellite system (Argos 2008). The determination of fixes is made By Argos using the Doppler phenomenon.

In Thuringia, near the city of Weimar, a long term Red Kite programme has been conducted since 1983 (Pfeiffer 1989, 1995, 2000). This programme concentrates on the study of population ecology parameters such as population development, reproduction rates, age at first breeding, age structure of breeding birds, settlement distance etc. In addition to the ringing of young birds, adult Red Kites have been caught and ringed regularly since 1991. Now that the technical means is available, ST has also been used as a research method to provide additional information on the Red Kite, in particular its migration and wintering behaviour.

2. Materials and methods

In the time frame 2002 to 2005 we fitted a total of nine Red Kites with solar powered PTTs. Two different types from different manufacturers were used. The first transmitter type was the 18 g solar transmitter from Microwave Telemetry Inc. (USA), compatible with Argos. It is steered by a microprocessor and has an accumulator that is charged by a solar cell. This enables it to transmit also at night and to receive fixes from the night roost. In addition it has sensors to measure the temperature in the transmitter, the accumulator voltage, a counter for signals transmitted and a simple activity recorder. These four elements of information are broadcast with every transmission impulse. They are principally of interest with regard to the technical analysis of the transmitter status and provide clues as to whether the bird is still alive. Adjustments can be made to the Microwave transmitters during production to set active or passive time intervals. For specific periods of time the transmitter can be programmed to send for several hours and then stop transmitting for one or more days. This mechanism can be use to save energy by restricting transmission time thereby saving data transfer costs.

The other transmitter type was the 20 g solar PTT from North Star Science and Technology (USA). It functions without an accumulator, transmission times are not adjustable and it produces transmission impulses whenever the solar cell produces sufficient energy. This transmitter also sends data on the inner temperature with each signal, and has an activity recorder that saves movement date when a mercury switch is activated. As energy cannot be stored, no fixes can made when the light conditions are inadequate. Outside the summer months therefore the majority of fixes are transmitted only in the middle of the day.

Of the nine Red Kites fitted with transmitters (Tab. 1), seven were adult birds that had all successfully bred that year. We trapped them close to their nests near Weimar at the end of the nestling period. Three were males, the other four females. In addition two juveniles (nest siblings) were also fitted with transmitters. In the text hereafter the individual birds will be referred to by the number allocated in Tab. 1.

The adult birds were trapped by the Dho-gaza method (Bloom et al. 2007). The net was set up at a distance of 50 - 300 m from the nest, as a rule horizontal to the edge of the woods. This enables a selective trapping of the breeding bird which, in the attempt to chase off an Eagle Owl sitting on a perch next to the net, flies into the net and is caught. Sometimes Red and Black Kites (*Milvus migrans*) from other territories and other bird species come to inspect the Eagle Owl. They are however markedly less aggressive towards it and only exceptionally get caught in the net. The net has a 6 cm mesh, is 10 m long, 4 m high and has two pockets. It is strung up on long rubber bands that enable the Red Kite to be caught gently and without injury. We removed the two young birds from the nest shortly before fledging, fitted them with transmitters and replaced them in the nest.

The PTTs are fitted like a rucksack to the back of the birds. They are fastened with Teflon tapes, which run from the loops on the transmitter in front of and behind the wings and are fastened across the breastbone. For additional security we sewed all knots with surgical thread (Meyburg & Fuller 2007).

The antenna, which is 20 cm long and somewhat curved, juts out obliquely upwards and to the rear. It enables a bird fitted with a transmitter to be identified as such from a middle distance. As the territories of the Red Kites with transmitters were far apart, identification of the respective adult bird was possible within the breeding area. One bird was additionally marked with wing tags in order to distinguish it from its partner, which was also fitted with a transmitter.

The complete mass of the transmitter was in all cases less than 2.2 % of the body mass of the trapped bird and therefore only slightly impaired the bird's performance. A special authorisation for the trapping, ringing, fitting with transmitter and wing-tagging was granted by the Thuringian Ministry for Agriculture, Nature Protection and Environment.

In order to be able to correctly assess and interpret the fixes received by the ST, it is necessary to briefly describe the procedure and study the precision of the fixes.

With the precondition that the PTT has sufficient energy to transmit (i.e. the accumulator is adequately charged or sufficient light falls on the solar cell), and taking into account the possible on/off programming, the PTT sends a signal containing diverse data once a minute on a predefined frequency. Five to six Argos satellites, which circle the Earth on a polar orbit at a height of some 850 km, can receive these signals when they are in the line of sight window of the transmitter. The satellites require some 100 minutes for a complete orbit of the Earth. In Central Europe a satellite makes on average some 31 passes through transmitter's line of sight window in a 24 hour period. A satellite comes into the transmitter's window when it is at least 5 degrees above the horizon from the point of view of the bird fitted with a transmitter. The duration of a satellite pass varies between a few seconds and somewhat over 13 minutes. During this period of time the one minute signals from the PTT can be received by the satellite. A fix using the Doppler Effect is only possible when a number of signals are received during a single satellite pass. Depending on the speed at which the distance between the satellite and the PTT increases or decreases, and the flight path of the satellite in relation to the transmitter, the frequency on which the signal is received changes. This change in frequency enables the position of the PTT to be calculated. The arithmetic algorithm thereby provides two possible positions of the transmitter, to the left and right respectively of the satellite's flight path. As a rule, when evaluating the data on the basis of plausibility, it is not too difficult to determine the actual position of the bird, as the two fixes are usually quite some distance apart.

The accuracy of a fix is dependent on many different factors. If only one signal from the PTT is received during a satellite pass, only the information that the PTT was in the satellite's sight window at the time of reception is known. This sight window is approximately equivalent to a circle of some 5,000 km in diameter on the Earth's surface. Details of the precision of a fix are provided by Argos only when at least four transmitted signals are received during a satellite pass. Details of the accuracy of the calculated coordinates can be deduced to a certain degree of probability from the convergence of the individual position calculations. The Argos system provides the fixes in seven accuracy classes, so-called 'location classes' (LC, Tab. 2, Argos 2008). In respect of the numerical LC, 68 % of the fixes are in the declared field of error. The remaining 32 % can be better or worse. More information on ST, the Argos system and experience with their use with birds of prey can be found for example in Meyburg & Meyburg (1996, 2000, 2006, 2007, 2009a) and Meyburg et al. (1996).

All nine PTTs were tested before being fitted to the birds, by positioning them in an outside location in Berlin with precisely known coordinates for several days. This enabled the deviation from the actual position to be established for each individual fix (Tab. 3).

The low number of test fixes in LC 2 and 3 should not be generalised. Nevertheless the proportion of fixes in the permitted area of deviation was markedly under 68 %. For this reason the calculation of distance in the area of error for each LC was assumed to be twice as great, as shown in Tab. 2.

The manufacturers of the transmitters also carried out functional tests of the PTTs in the USA before delivery. As the exact coordinates of the transmitter during these tests is not known, these latter data only served as a comparison of the frequency of fixes for different LC.

In order to analyse the data provided by the Argos system, these are first of all imported into a database. Using a separate interface the data are visually presented using Google Earth, a programme developed by Google Inc. (USA). The migration maps (Figs. 2 - 9) were prepared using the Encarta World Atlas 2001 from the Microsoft Corporation (USA), with subsequent photo editing. Individual LC B fixes were not taken into consideration if they deviated appreciably from the migration route. We interpreted night roosts as positions where several fixes were made in the same area during the hours of darkness. For each individual fix the LC is shown in brackets on the migration maps. If the bird is located in a small area several times within a short space of time, only the most precise fix is shown and marked with a '+' behind the LC details. All times given are coordinated world time UTC (UTC+1 = CET). The calculation of migration distance was made by directly linking the significant location fixes. All distances given are therefore minimum values and actual distances covered can be much greater. As a rule only LC 1 - 3 fixes were used for the calculations. Exceptionally LC 0 fixes were taken when their accuracy was supported by other fixes in the vicinity. If no fixes from night roosts are available for the calculation of daily flight performance, time differences based on an average seven hour migration day are calculated. The estimate of the average daily length of Red Kite migration in hours is based on the daytime time allocation of migrating Red Kites according to Meineke & Gatter (1982) and Hellmann (1990).

In order to familiarise themselves with and to assess the situation of the Red Kite in its winter quarters (habitat, basis of diet, threat potential and general living conditions), Juliane and Thomas Pfeiffer made a trip to North Spain in the period 16.12 to 21.12.2002, where they visited the winter quarters and known night roosts of Red Kites fitted with transmitters in 2002. The maps used by us were kindly made available by the Eros Data Center of the United States Geological Survey and are based on data prepared by the National Oceanographic and Atmospheric Administration (NOAA).

3. Results

In evaluating the data we restricted ourselves to a description of the individual cases as, due to the small number of cases studied, the statistic analysis only permits limited conclusions as far as the population as a whole is concerned.

The nine Red Kites under study were recorded a total of 5,118 times by passing satellites. From these transmissions 2,686 concrete coordinates were provided. Fixes with high precision (LC 1 to 3) were rare. The percentage distribution of the individual fixes is shown in Tab. 4. The comparison between stationary tests in Germany, and tests in the USA of the same PTTs, demonstrates that the distribution of US telemetry results is similar to the test fixes in Germany, but the percentage of more accurate fixes in the USA was higher.

Because of the dependence of the transmitters on solar energy the frequency of fixes shows large seasonal fluctuation (Fig. 1). Of the 'Red Kite years' data input in the evaluation, 5/6 were from females. As the solar array of the PTT on incubating birds is covered by the wings, insufficient energy is available for transmission, despite the height of the sun in the sky in this period. Markedly fewer fixes are therefore recorded in April and above all in May. The transmitters are provided with most energy when flying, in the periods of intensive foraging when young are being reared and during migration. During December and January there were few fixes, all from Spain. No signals at all were received from a Red Kite wintering in the breeding area.

Tab. 5 shows the day on which each transmitter was fitted, the first and last fix for each Red Kite, the duration of the ST in days and the number of fixes recorded in the different precision classes.

To begin with a male Red Kite and two of its offspring (the oldest and youngest of three siblings) were fitted with transmitters in 2002. Of interest in this case was the question as to whether family groups remain together on migration and possibly also in winter quarters. Until the end of July all three young birds were sighted regularly in the immediate vicinity of the breeding site. They were relatively inactive and let themselves be cared for mainly by the parent birds. During this period therefore only fixes from the male are available. The transmitter on the older juvenile bird first began transmitting from 31 July and that of the youngest sibling on 21 August.

3.1. Red Kite 1 (juvenile, oldest sibling)

The oldest sibling was the first to start migration, very early on 22 August. The migration route of this bird could be followed relatively precisely to its wintering area in Spain (Fig. 2). The first fix was from almost 30 km south-west from the nest site at 8:20 hrs UTC. Subsequently the following significant migration events are listed.

- Crossing of the Thuringia Forest low mountain range.
- First night roost near Bad Kissingen, somewhat more than 130 km distant from its birthplace.
- 24.08 - 14.09.2002 - stopover in the area around Tauberbischofsheim (N 49° 37', E 9° 40')
- 15.09.2002 - migration continues in the same direction as previously.
- 15/16.09.2002 - night roost between the Black Forest and the Swabian Alb after a flight of some 140 km.
- 16.09.2002 - arrival in Switzerland where the bird spent at least one week in Central Switzerland.
- 28.09.2002 - flight over the French Massif Central.
- 30.09 - 01.10.2002 - night roost on the northern flanks of the High Pyrenees near Lannemezan.
- 06.10.2002 - crossing of the Pyrenees in the lower western part of the range.
- 11.10.2002 - first fix from winter quarters in the north of the Spanish province of Burgos, where the bird remained subsequently.
- 28.01.2003 - last signal received from the bird. At this point in time it was still in the wintering area.

Details of the duration of migration and the minimum flight distances covered are at Tab. 6. The wintering area is a high plateau at 600 - 700 m ASL, with mostly extensive agricultural use, and surrounded by a mountain chain. Details of the size of the bird's wintering area can only be determined to a limited extent, as from 50 fixes in the area only two were LC 1 and better. One very precise fix (LC 3) on 24.11.2002 was from (N 42° 40‘ 52“, W 3° 29‘ 31“) only 6.5 ± 3.5 km distant from an LC 1 fix on 14.01.2003 (N 42° 39‘ 32“, W 3° 25‘ 8“).

3.2 Red Kite 2 (juvenile, youngest sibling)

The younger juvenile remained in the general vicinity of its birthplace for over a month longer than its older sibling, until at least 1 October 2002. It also migrated across France to Spain. Its migration route was however more direct to the south-west without a detour over Switzerland. On grounds of cost its transmitter was programmed to send for 12 hours followed by 48 hours of inactivity. The migration route (Fig. 3) is therefore much more roughly documented than that of its older sibling. After crossing the Pyrenees, also in close proximity to the Atlantic coast, it flew past its sibling's winter quarters to an area some 50 km south-west of Valladolid. It was located here for the last time on 06.11.2002. A single LC Z signal after a gap of almost 4 months on 27.02.2003 was inconclusive with regard to its location or whether the bird was indeed still alive.

An estimate of the daily flight distance covered is only possible when sufficient precise fixes (LC 1, 2 or 3) are available. As only a few of these classes of fix (as by the other ST Red Kites) are available, an average daily flight performance was calculated for the stretches that lie between such fixes. These results are shown in Tab. 7.

We visited the night roost from 01/02.11.2002 (Tab. 8 - A) some seven weeks later and found a night roost with some 30 Red Kites in a row of poplars on the edge of a cattle farm. Nearby is a waste disposal site, which is now mostly covered up and is being replaced by a modern recycling plant. The exposed part of the site was used extensively for foraging by the Kites. In Spain, waste disposal sites are preferred foraging sites for wintering Red Kites. Their increasing elimination leads to a marked worsening of the food availability of these birds, and thereby a decline in their chances of survival (Hiraldo et al. 1995).

On 18.12.2002, in the vicinity of the last fix, we also found a night roost of 43 Red Kites (Tab. 8 -B), also in a row of poplars along a stream.

3.3 Red Kite 3 (male, parent of Nos. 1 and 2)

This male's transmitter provided only few data suitable for evaluation. Until at least 08.10.2002 the bird remained in the vicinity of the breeding area. Subsequently there were at first only two fixes on 15 and 18.02.2003 from Central France. Up to 31.02.2003 only single PTT signals were received, but these did not permit the location to be determined. In any event the bird did not return to its breeding area. This was occupied in the following spring by a single Red Kite (probably the female from the previous year), which initially drove away all birds of her own species from the small wood where the breeding site was located. The presence of another Red Kite, neither ringed nor fitted with a transmitter, was first tolerated from the end of April. Only as late as the end of May was a bird observed brooding on the nest. This late brood was however unsuccessful.

3.4 Red Kite 4 (male)

The fourth Red Kite fitted with a PTT in 2002 was the first adult bird which could be tracked by ST on both autumn and spring migration. The transmitting interval programming of its PTT (12 hours active, 3 days inactive) was however even more widely spaced than the second juvenile. The exact time of departure is not known. It wintered in North Spain near the border to Portugal, somewhat further west than the two juveniles (Fig. 4). This area is mainly extensively used farmland. Cowherds drive their herds across the countryside, and the few small fields are protected by stone walls.

This Red Kite was located during the winter at four different night roosts (Tab. 8 C - F), between which it alternated from time to time. On 20.12.2002 we visited two of these night roosts, some 19 km apart. As we had quite precise fixes, we were easily able to find them. At roost C at least 70 Red Kites spent the night and at roost D over 100. A third night roost (E) was a further 12 ± 1.5 km distant. Great distances were covered daily in the search for food. On 07.10.2002 the bird was still at its known night roost (LC 1). 4.5 hours later it was located 16 ± 4 km to the north (LC 2). The greatest distance between two precise fixes (both LC 2) in this wintering area was 38 ± 2 km. From 28.10.2003 the male bird stayed in another area some 75 km north-east of the centre of the first wintering area. Here it was located several times at the same fourth night roost (F). The greatest determined distance of a fix from its night roost in this area was 17 ± 4 km.

The last fix from the wintering area was on 21 February 2003. One week later the bird was located several times at a night roost in France. Three nights later another fix at night was recorded. From the estimated migration speed the arrival of the bird in the breeding area was expected from 5 March onwards. On this and the following day only strange Red Kites were observed in the vicinity of the nest site. On 7 March the bird with the PTT was finally sighted at last year's nest site. At this time the first fix was received from the breeding area. On its arrival at the nest site the male uttered loud calls, but no female was present and none was seen on the days following up to 14 March. Onloy on 19 March two Red Kites were observed with typical display behaviour. The pair then settled in a new nest, some 700 m from the previous year's nest site, and successfully reared two offspring. On 29.08.2003 the last signal was received from the PTT. This Red Kite was not sighted again from August onwards and in the following year a different male occupied the territory. It is assumed that the Red Kite came to grief in the breeding area.

3.5 Red Kite 5 (female)

In 2003 we fitted only a single Red Kite with a transmitter. This female reared its young together with a male, also three years old. The male was also caught and wing-tagged. To begin with the transmitter sent relatively precise fixes. On 19.09.2003, after only ten weeks, it failed completely. In the period 15 July to 28 August all 17 LC 1 and better fixes were at most 12 ± 3 km distant from the nest site. The female spent most of this time over the farmland north of the breeding woodland.

The bird was further sighted with its well-sitting transmitter and since then has bred successfully every year. Until at least 2007 it bred with the same partner. As this male lost first one and then the other wing tag during the 2007 breeding season, mate fidelity could not be proved from 2008. In spite of the failure of the PTT, interesting observations could be made due to the individual markings of the two Red Kites. In 2004 the pair bred in the same patch of woodland as the previous year, but this nest was occupied by a different pair in 2005. The female with the inactive transmitter at first roosted at night in a coppice 2 km distant. Its partner with the wing tags arrived from winter quarters as late as mid-April, and the pair bred successfully (3 young) in the coppice after a month's delay. Since then they have always bred at this new site (at least up to 2009 and perhaps beyond that year). The ousting of the pair from the original nest site would not have been detected if both birds had not been clearly identifiable.

3.6 Red Kite 6 (female)

In 2004 three further Red Kites were fitted with PTTs. Female No. 6 was caught again in 2006. It has bred successfully in both years following the fitting of the transmitter. As the transmitter had only sent usable data in the first year on autumn migration to Spain, and later sent fixes only in summer, the PTT was removed. The opportunity was used to examine the bird in order to establish if any harm had been caused by the PTT and its Teflon harness. In particular the area of plumage and skin along which the teflon ribbons run were examined for signs of chafing or other changes. No impairments that may have been caused by wearing the transmitter for a 2 year period of any kind were found.

The autumn migration of this bird (Fig. 5) exhibits one peculiarity. The female crossed directly over the High Pyrenees and did not cross the lower mountains to the west as the other birds in the study. Its wintering area was immediately at the foot of the southern flanks of the Pyrenees.

3.7 Red Kites 7 and 8 (breeding pair)

In addition to the above female No. 6, both partners of a Red Kite breeding pair were also fitted with PTTs in 2004. They reared three offspring which all fledged. In order to tell the pair apart in the breeding area the female was also wing-tagged. After 80 days no fixes were received from the male and it was no longer sighted. The following year the female paired with another male. We assume that the first tracked male died in the breeding area. The female on the other hand was tracked over five winter periods (Fig. 6 – 9, Tab. 6). This enabled us for the first time to establish very different behaviour patterns in different winters for the same individual. In winters 2004/05 and 2005/06 the bird visited the same area in the south of Spain, demonstrating wintering site fidelity. On autumn migration 2004 the bird covered at least 2,320 km, the longest migration route tracked at that stage. Migration lasted some 4 weeks (27-29 days). The Red Kite therefore covered on average a good 80 km daily.

In 2006/07 it wintered in northern Spain, thus reducing its migration distance by almost a third. In addition to its change of wintering area compared with the previous two years, it also sought out new winter quarters within the season. On 23.12.2006 it moved to an area some 130-140 km to the west.

In winter 2007/08 the female wintering remained in the breeding area and was observed regularly in the immediate vicinity of the nest site, where it also roosted at night. It evidently did not use an existing Red Kite night roost some 8 km distant, where 50 Red Kites roosted in autumn and where seven birds were still present in January. A second Red Kite roosted frequently nearby. Until the end of December this was the partner from the previous season (distinguishable by its individual markings). From the end of January another Red Kite was present, easily identifiable because of a broken-off primary until the moult in May. It became the female's partner in the subsequent breeding season.

After its successful wintering in the breeding area, the bird migrated, a week earlier than in 2004-2006, to new winter quarters in western Spain. As the fixes from the beginning of December onwards were received unchanged from a very small area, we assumed that the bird was dead. On the basis of the last coordinates received the carcass was indeed found on 21.12.2008 by Vicente Lopez Alcazar of Spain. The exact cause of mortality is still being investigated by the Spanish authorities. The finder suspects that the bird was shot and died from its injuries.

This female bred in each of the five years during which it carried a transmitter. It bred in the same territory in a total of 3 different nests, which were up to 1.4 km apart. It was proved that it had at least 4 different male breeding partners during this time. Three of the five broods were successful.

3.8 Red Kite 9 (female)

A further female was fitted with a PTT in 2005. Up until 7 November of that year it had still not migrated and remained in the immediate vicinity of the breeding site. After that time only a single signal (LC Z) was received that allows no clear interpretation of events. It was not sighted in spring 2006. It is assumed that the bird died.

4. Discussion

4.1 Discussion of methodology

The ST method, using solar powered transmitters and providing location fixes by use of the Doppler Effect, provides the opportunity to track sufficiently large birds over a long time frame. The location fixing is not accurate enough for studies within a small area. It is however suitable for acquiring information on the course of migration and the stay in winter quarters, and provides much more detailed information on the spatial and temporal movement of birds fitted with transmitters than conventional methods such as ringing or wing-tagging. The provision of energy for the PTTs still remains a problem. Solar cells in comparison to batteries provide a much longer lifespan for the PTTs; but the dependence on a direct light source, especially in winter with a shorter period of daylight and low position of the sun, does not provide sufficient continuous energy. This results in long gaps between fixes. This problem becomes more acute the more northerly the bird spends the winter.

If one compares the precision of the location fixes from the USA with those of Europe (Tab. 4), it becomes evident that much more precise fixes are achieved in the USA. This phenomenon is well-known and is currently under study. The problem is probably interference radiation in the complete Argos frequency range, whereby weaker signals are suppressed. This interference occurs above all in Central Europe and the Mediterranean, but also in China, Mongolia and Japan. The source of this interference is unknown (Howey 2005; Gros & Malarde 2006).

Wearing the transmitters presents a certain physiological burden for the Red Kite. In the authors' experience however it does not lead to any noticeable impairment. Red Kite No. 5, now (summer 2009) nine years of age, is a good example of long term wearing of a PTT and simultaneous successful rearing of offspring. In the seven completed breeding periods during which the bird wore a transmitter it reared to fledging two or three chicks every year.

4.2 Autumn migration

Autumn migration usually began in the second week of October. This point in time lies within the time frame of the known main autumn migration dates of Central European Red Kites (Ortlieb 1989; Hellmann 1990; Gottschalk 1995). One young Red Kite deviated from this mean and migrated in a SSW direction as early as 23 August. From ring recoveries it is known that juveniles can be found at a rather great distances from their birthplace as early as August (Schonfeld 1984; Glutz von Blotzheim et al. 1989). Migration observations at Falsterbo in Sweden (Kjellen 1992, 1994) and the Swabian Alp (Gatter 2000) detected an earlier mean departure on autumn migration of juveniles compared with adult birds. Nachtigall (2008), studying young Red Kites with wing tags, established that on 14 August one bird was already 107 km to the west of its birthplace, but another was only 3 km distant from the nest on 22 September. It is on the one hand therefore not unusual for a juvenile Red Kite to begin autumn migration early; or on the other hand to remain near its birthplace until the typical departure date of the adult birds. The present study also demonstrates that this dissimilar behaviour can also apply to juveniles from the same nest.

In a project conducted by the Hesse Ornithological and Nature Protection Society (HGON), a juvenile Red Kite was fitted with a PTT in 2007 and four adult birds in 2008. On 22.09.2007 the juvenile had already left on migration; the adult birds began autumn migration in the time frame 04 - 13.10.2008 (Gelpke 2009). These data from the study area in Hesse, only some 140 km distant from the area of the present study, correspond to a great extent with our findings.

In 2007 three juvenile Red Kites were also fitted with PTTs in the Franche-Compte region of France. The project had little success however. Only one bird could be tracked during autumn migration to Spain up to the beginning of November 2007. At the end of August and beginning of September the bird was already located south of the nest site area. Actual migration began through the Rhône valley on 18 September (Paul 2008). The behaviour of this bird is very similar to that of Red Kite No. 1.

Red Kites Nos. 1, 2 and 3 broke up as a family at the start of autumn migration at the latest. Schönfeld (1984), when evaluating the ring recoveries of two siblings, also found that they were both recorded on first migration at almost the same time but very far apart. One bird, 160 days old, was found in Spain some 1,713 km WSW from its birthplace; the other, 163 days old, in France 950 km SW of the nest site. Migrating Red Kites sometimes form flocks of more than 50 individuals. Mostly however they migrate in smaller flocks of less than 10 birds (Hellmann 1990, Gottschalk 1995, Gatter 2000). These flocks definitely do not consist of families, but comprise birds migrating at the same time that come together by chance. The separation of the juveniles from their siblings and the adult birds probably occurs at the start of juvenile dismigration, which is some three to four weeks after fledging (Bustamante 1993; Nachtigall 2008). Evaluation of ring recoveries, and observations of Red Kites with wing tags, show that juvenile dismigration usually takes place in a sector between west and south, that is in the direction of the main autumn migration route (Glutz von Blotzheim et al. 1989, Nachtigall 2008). Only exceptionally do Red Kites fly in another direction during this phase. An example of the latter was a nestling with wing tags near Weimar in Thuringia, which was sighted some 130 km further to the east on 31 August.

The first phase of migration of the juvenile Red Kite No. 1 can therefore be interpreted as juvenile dismigration, which later merges into autumn migration. This can explain the 3 week pause from 24 August to 14 September in the same location. Such a long pause on migration was not recorded for any of the other birds studied.

No comment can be made on the cohesion of the breeding pair with PTTs (Nos. 7 and 8) on migration and in winter quarters as the male could only be tracked into the month of September. A breeding pair from the Hesse project evidently migrated separately to the south-west in autumn 2008 (HGON 2009). Our own observations of individually marked breeding pairs indicate that autumn migration, as also arrival in spring, occurs at different times. In the case of a Greater Spotted Eagle (*Aquila clanga*) family fitted with PTTs, the juvenile as well as the adult birds migrated and wintered separately (Meyburg et al. 2005). The same applies in the case of a Lesser Spotted Eagle (*Aquila pomarina*) family (Meyburg unpubl.).

The direction of migration established for the Red Kites fitted with PTTs was in almost all cases to the south-west, in a relatively direct line over France to the Pyrenees. This agrees with the main direction of Central European Red Kite migration established by ringing projects. Only the early starter on migration, juvenile No. 1, flew at first in a more southerly direction as far as Switzerland. At this early stage it could probably not orientate itself on experienced birds of the same species. From Switzerland it then also flew direct to the Pyrenees. In contrast, British birds leave the nest site in different directions (Evans et al. 1999; Newton 2008). Little is known about the few Red Kites that winter in the Balkans (Ortlieb 1989).

Since 1981 passage across the Pyrenees has been systematically observed at different points (Urcun & Bried 1998). In 1990 a marked decline in passage figures was recorded. Passage takes place principally in the Basque country. In the eastern and central Pyrenees only 1 % of migrants on passage are registered. This agrees with the telemetry results. On six occasions passage was recorded in the area of the lower western Pyrenees, and on one occasion a female flew directly over the central area of the mountain range. According to Urcun & Bried (1998), passage in autumn occurs between the start of September to mid-November, mainly during three periods; the end of September, the second week of October and after 20 October. Red Kites therefore migrate across the Pyrenees later than most other birds of prey. One reason for most birds crossing the western foothills of the Pyrenees at low height is undoubtedly because thermals are scarce so late in the year. It could not be determined if the juveniles passed through earlier.

After crossing the Pyrenees the birds with PTTs flew directly to their main wintering area in northern Spain. Only female No. 7 flew in a wide curve over north-west to south-west Spain in the first two years. The areas this bird flew over are also those with the highest density of wintering Red Kites (Cardiel 2006). The areas in central Spain with fewer winter guests were bypassed.

If the first migration stage of juvenile No. 1 is accepted as dismigration, the birds required between 11 and 28 days for actual migration to their winter quarters. The distances covered were dependent on the directness of the migration route and the location of the wintering area. They fluctuated between some 1,450 and 2,320 km. A female Black Kite (*Milvus migrans*) from the same area in Thuringia, fitted with a similar transmitter with Doppler locating, took 28 days in 2004, 16 in 2005 and 19 days in 2006 for the some 6,000 km long stretch to its wintering area in southern Mauritania (Meyburg unpubl.).

4.3 Wintering

Wintering in the breeding country is in the meantime known of in all states with significant Red Kite breeding populations. More than 1,000 individuals winter in southern Sweden, Germany and Switzerland (Hellmann 2002; Schmid & Volet 2004). In France more than 5,100 wintering individuals were counted in January 2009 (Riols 2009). The great majority of Red Kites however spend the winter, as the birds fitted with PTTs in our study, on the Iberian Peninsula. Although some 66,200 - 72,200 birds were counted during a census in 1994, these figures were 10 years later reduced to some 35,000 -36,200 (Cardiel 2006).

Several aspects of Red Kite behaviour in winter have only been studied to a minor extent to date. Using individual marking with wing tags, the use of the same wintering area by individual birds has been established, but there were also individuals that changed their winter quarters the following year (Nachtigall 2008). Female No. 7 demonstrated both types of behaviour in different winters. In addition, an until now unrecorded change of winter quarters over a distance of 130 km in the same winter, as well as wintering directly in the breeding area in Germany in one year were registered. This great variability in the behaviour of a single bird in different winters was surprising. The factors responsible for the different occurrences cannot be established on the basis of this isolated case. Wuttky (1975) considers the availability of food to be the decisive reason for Red Kites migrating from, or remaining in the Hakel (Saxony-Anhalt, Germany) breeding area in winter. This fact is applicable to the wintering of bird No. 7 in the breeding area. In summer 2007 there was a massive increase in the Common Vole (*Microtus arvalis*) population, so that there was plenty of food available in autumn. This was also accessible for the birds in the winter that followed as there was no long term snow cover. Nonetheless in the same district, in the preceeding and subsequent years when female No. 7 migrated to Spain, there were several wintering birds present.

Calculation of the winter home range size was not possible due to too few fixes of adequate precision (LC 1, 2, or 3). The maximum distance between such fixes for the different winter quarters was between 6.5 ± 3.5 km und 38 ± 3.5 km. The lesser value need not be representative, as in any event only two acceptably precise fixes were available for this period. Very large winter home ranges, as was probable in the case of Red Kite No. 4, could be an indication of poor food availability (Blanco et al. 1990, Nachtigall et al. 2003). This could also explain the change of wintering area in January. Studies of winter home ranges of Red Kites have been conducted using VHF telemetry) in different countries. Heredia et al. (1991) recorded areas of 6.6 to 53.5 km² in the Doñana National Park, whereby Spanish breeding birds require smaller areas than the winter guests. In England, Carter & Grice (2000) estimate 19 - 32 km². In the North Harz foothills in Germany Nachtigall et al. (2003) calculated 6.2 - 8 km². Resetaritz (2006) recorded a particularly small winter home range of only 0.4 - 0.8 km², also in the North Harz foothills, for a breeding pair that foraged almost exclusively at a waste disposal site.

It is known that some Red Kites visit different night roosts within their wintering area. Hiraldo et al. (1995) talk of a night roost network, Hellmann (1996) and Resetaritz (2006) use the term roost area, whereby several separate roosts can lie within a roost area. These can be used alternatively or in parallel by the birds.

Red Kite No. 7 did not migrate in autumn 2007 and wintered first with one, and then with another partner in the breeding area. Nachtigall et al. 2003, using ground telemetry for a Red Kite pair in the North Harz foothills, established that breeding partners can stay together over winter if they remain in the breeding area. The birds roosted mainly at the nest site, and only occasionally joined birds at roosts nearby. Hiraldo et al. (1993, 1995) also report that breeding birds from the Spanish population usually roost alone, whereas the winter guests more or less form large night roosts. Juveniles of Spanish breeding pairs only occasionally use these roosts.

4.4. Spring migration

Spring migration was as a rule faster than in autumn. The probable duration was between 8 and 22 days. Arrival in the breeding area was between 5 and 12 March. As with autumn migration, these data correspond to the heaviest spring migration in the Taunus foothills in Hesse (Gottschalk 1995). The spring and autumn migration routes were very similar but not matching.

In contrast to the Red Kites, an adult female Black Kite from Thuringia (central Germany) flew faster on autumn migration than in spring in all the three years of the study. The fastest autumn migration was 17 days (332 km per day). In spring the fastest return migration was 33 days (207 km per day) for the some 6,000 km flight from southern Mauritania (Meyburg unpubl.). For this bird the autumn and spring migration routes were similar but not matching.

The spring migration route of an adult male Black Kite from Brandenburg (northern Germany), which wintered in West Africa and was fitted with a PTT with GPS, was 6,890 km in length. On average the bird covered 215 km per day between departure and arrival. If only days on actual migration are counted, the average daily performance was 242 km. The 627 km long migration route within Germany was covered in only 2 days. Daily flight performance differed considerably. The longest distances covered in a single day were between 554 and 663 km. On three days, from the evening of 20 March to the morning of 24 March 2008, the Black Kite rested in Morocco, and on three further days it covered less than 100 km, probably because it was mainly foraging for food (Meyburg & Meyburg 2009b).

Aebischer (2009) recorded unexpected behaviour on the part of a Red Kite fitted with a PTT in 2004 as nestling in Switzerland. In spring 2004 this bird, after its return from winter quarters on the northern edge of the Pyrenees, flew back to its wintering area and then returned again to Switzerland. The reason for such a double spring migration is unclear.

4.5. Average daily flight distance during migration

Average daily flight distances achieved on migration vary considerably (Tab. 7). In addition to the migration route taken they have a significant influence on the duration of migration. Possible influencing factors are the time spent daily on migration, the direction (autumn or spring migration), and the age of the bird, as well as different meteorological factors. Gatter (2000) established that some of the factors affecting Red Kite migration were different degrees of visibility, cloud cover, the general weather situation and wind direction and speed. Gottschalk (1995), on the basis of direct observation over distances from 0.8 - 4.2 km, calculated an average daily flight performance of 116 km. He recorded an average flight speed of 11.6 kph (4 - 20 kph) for migrating Red Kites. As a comparison, the average daily distances flown for some other medium-sized birds of prey, determined using ST, were as follows: A Short-toed Eagle (*Circaetus gallicus*) covered daily an average flight distance of 234 km on a stretch of 4,685 km from France to Niger (Meyburg et al. 1998). A Lesser Spotted Eagle from Slovakia on several migration flights to Zambia covered 174 km daily over a total distance of 8,629 km (Meyburg et al. 2004b). Two young Egyptian Vultures (*Neophron percnopterus*) managed an average daily flight distance of 123 km on the 3,572 km stretch from France to Mauritania (Meyburg et al. 2004a).

4.6 Causes of mortality

When signals are no longer received from a bird marked with a PTT the causes can be one of the following:

1. The bird has lost the transmitter.
2. The transmitter is defect.
3. The bird is dead.

It is of course within the bounds of possibility that a transmitter is lost, but is considered to be very unlikely during the first few years of wear. Bernd-Ulrich Meyburg in particular has many years of experience in deploying transmitters to birds of prey, some of which have worn them for many years. Additionally, in contrast to some other species of this bird family, Red Kites are not in the habit of chewing or pulling on the properly fitted Teflon harness.

A defect PTT can easily be noticed when the bird is still in the breeding area (see Red Kite 5) or when it returns on spring migration. The situation is more complicated when the transmitter on a juvenile fails to operate, as these tend more or less to dismigration and it is therefore not so easy to identify individual birds fitted with transmitters.

In the majority of cases, when no more fixes are received, we assume that the bird is dead. If the dead bird is lying on the ground on its belly the transmitter continues to broadcast signals. It is then possible to find the carcass as with Red Kite 7. Of Red Kites fitted with PTTs in Switzerland one was found shot in France (Aebischer corresp.), and Gelpke (2009) found an evidently poisoned bird in France, which had been fitted with a PTT in Hesse. Hiraldo et al. (1995) and Vinuela et al. (1999) list the most frequent cause of mortality in Spain as poisoning, electrocution, shooting, collision with overhead wires and road kills. Poisoning seems to be on the increase since the 1990s. During the Red Kite species protection symposium in Schneverdingen (Germany) in 2007, Cardiel and Vinuela reported that from 1990 to 2005 435 cases of Red Kite poisoning had been recorded officially in Spain totalling 44 % of birds where the cause of mortality had been investigated. They estimate that the actual figure of Red Kites poisoned, based on studies of other birds of prey fitted with PTTs during this time frame, to be as many as 14,500 individuals. Red Kites are also poisoned in France and Germany (Hegemann & Knuwer 2005; Berny & Gaillet 2008).

5. Future prospects

Since 2007 GPS solar powered satellite transmitters weighing 22 g, light enough to be carried by a Red Kite, are available. They transmit hourly GPS coordinates, also via the Argos satellite system. This means that the PTTs, when transmitting the GPS data, are additionally located by means of the Doppler Effect. This new technical capability overcomes the somewhat great inaccuracy of the Doppler fixes. One of these new transmitters was fitted to a male Red Kite in summer 2007. As the bird did not migrate in autumn, and almost no data were recorded in winter, it is not taken into account in the present study. The telemetry data, in addition to the study of migration and wintering data, can also be used for a detailed analysis of the spatial and temporal behaviour in the breeding area as the deviation in GPS locating fixes is only a few metres. The questions of energy provision, particularly in the winter months, as well as interference with data transmission between the PTT and the satellite, are still unsolved. GPS solar transmitters are of interest for Red Kite research as their position is transmitted over mobile phone networks and not via satellite. Adequate network coverage exists in the Red Kite's breeding, migration and wintering areas for the occasional transmission of collated data. In addition to an improvement in transmission quality the somewhat high running costs for data reception could also be reduced. Such PTTs are at present only available for much larger bird species.

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TABLES

Tab. 1: ***Overview of the Red Kites fitted with PTTs, their IDs and their programming.***

Red Kite No.	***Year fitted with transmitter***	***Sex/Age***	***Type and programming of the transmitter***	***Transmitter No.***
1	*2002*	*Juvenile, offspring of No. 3*	*Microwave permanent*	*36229*
2	*2002*	*Juvenile, offspring of Nr. 3*	*Microwave 12 hrs on, 48 hrs off*	*36230*
3	*2002*	*Parent of Nos. 1 und 2*	*Microwave permanent*	*36228*
4	*2002*	*Male*	*Microwave 12 hrs on 72 hrs off*	*36233*
5	*2003*	*Female, 3 years old when fitted*	*North Star*	*41503*
6	*2004*	*Female*	*Microwave 1st year: 10 hrs on 24 hrs off subsequently: 10 hrs on 96 hrs off*	*06990*
7	*2004*	*Female, partner of No. 8*	*North Star*	*40868*
8	*2004*	*Male, partner of No. 7*	*Microwave 1st year: 10 hrs on 24 hrs off subsequently: 10 hrs on 96 hrs off*	*06983*
9	*2005*	*Female*	*North Star*	*57030*

Tab. 2: **A*ccuracy classifications for Argos fixes.***

Location class (LC)	***Prerequisites***	***Accuracy of fix***
Z	*1 signal per satellite pass*	*Location fix not possible*
B	*2 signals per satellite pass*	*No details of fix accuracy possible*
A	*3 signals per satellite pass*	*No details of fix accuracy*
0	*≥ 4 signals per satellite pass*	*> 1500 m*
1	*≥ 4 signals per satellite pass*	*> 500 m and ≤ 1500 m*
2	*≥ 4 signals per satellite pass*	*> 250 m and ≤ 500 m*
3	*≥ 4 signals per satellite pass*	*≤ 250 m*

Tab. 3: Results of own tests to check the accuracy of locations in Germany.

Location class (LC)	***B***	***A***	***O***	***1***	***2***	***3***
No. of test fixes	*193*	*107*	*33*	*19*	*7*	*6*
Mean deviation in km	*49.5*	*8.1*	*6.6*	*3.4*	*0.8*	*2.3*
Maximum deviation in km	*511.9*	*91.9*	*65.0*	*17.9*	*3.3*	*6.7*
Minimum deviation in km	*0.33*	*0.26*	*0.64*	*0.31*	*0.10*	*0.25*
Standard deviation in km	*85.8*	*13.1*	*10.2*	*4.3*	*1.0*	*2.5*
Proportion of Argos fixes in field of error in %	-	-	-	*42*	*43*	*17*

Tab. 4: Distribution of the fixes to the different accuracy classifications and a comparison between tests in Germany and the USA.

Location class (LC)	**Fixes of Red Kites with transmitters (n=5118)**	***Test fixes in Germany (n =752)***	***Test fixes in USA (n=254)***
Z	*47.5 %*	*51.5 %*	*19.3 %*
A	*24.6 %*	*25.7 %*	*12.6 %*
B	*11.4 %*	*14.2 %*	*9.8 %*
0	*13.4 %*	*4.4 %*	*26.0 %*
1	*12.1 %*	*2.5 %*	*17.7 %*
2	*0.9 %*	*0.9 %*	*11.0 %*
3	*0.2 %*	*0.8 %*	*3.6 %*

Tab. 5: Transmitter life and number of fixes per transmitter.

Red Kite No.	*Date transmitter fitted*	*First fix*	*Last fix*	*No. of days*	*No. of fixes per LC*							
					Σ	**Z**	**B**	**A**	**O**	**1**	**2**	**3**
1	16.06.02	31.07.02	28.01.03	227	281	156	78	25	15	3	3	1
2	16.06.02	21.08.02	27.02.03	257	94	48	17	14	9	4	2	0
3	08.06.02	09.06.02	31.03.03	297	335	237	85	24	9	0	0	0
4	16.06.02	16.06.02	29.08.03	440	343	193	74	29	28	11	6	2
5	10.07.03	14.07.03	18.09.03	67	307	93	86	48	64	12	3	1
6	19.06.04	20.06.04	24.06.06	736	586	296	134	55	73	20	8	0
7	26.06.04	26.06.04	20.12.08	1639	2465	1097	597	317	381	45	22	6
8	18.06.04	20.06.04	05.09.04	80	216	89	60	16	47	3	0	1
9	19.06.05	19.06.05	27.02.06	254	471	223	126	55	58	7	2	0

Tab. 6: Important migration data for all periods studied.

Migration period and Red Kite No.	*Departure from breeding area*	*Arrival in winter quarters*	*Duration of autumn migration in days*	*Departure from winter quarters*	*Arrival in breeding area*	*Duration of spring migration in days*	*Migration distance in km*
2002/2003 No. 1	*22.08.02*	*7.-11.10.02[1] (7.10.02)[2]*	*47-51 (47)*	*-*	*-*	*-*	*1580*
2002/2003 No. 2	*2.-8.10.02 (8.10.02)*	*2.-6.11.02 (2.11.02)*	*26-36 (26)*	*-*	*-*	*-*	*1720*
2002/2003 No. 4	*5.9.-11.10.02 (7.10.02)*	*23.-26.10.02 (24.10.02)*	*13-52 (18)*	*22.-27.2.03 (26.2.03)*	*7.3.03*	*9-14(10)*	*Spring:1700 Autumn:1640*
2004/2005 No. 6	*11.10.04*	*21.-22.10.04 (21.10.04)*	*11-12 (11)*	*?*	*?*	*?*	*1450*
2004/2005 No. 7	*11.10.04*	*6.-8.11.04 (7.11.04)*	*27-29 (28)*	*18.2.05*	*11.-12.3.05 (12.3.05)*	*21-22 (22)*	*Spring: 2320 Autumn:2070*
2005/2006 No. 7	*20.9.-11.10.05 (10.10.05)*	*?*	*?*	*16.-27.2.06 (26.2.06)*	*10.-11.3.06 (11.3.06)*	*12-24 (14)*	*2070*
2006/2007 No. 7	*10.10.06 21.-*	*29.10.06 (24.10.06)*	*12-20 (15)*	*22.-26.2.07 (25.2.07)*	*5.-6.3.07 (5.3.07)*	*8-13 (9)*	*Spring: 1560 Autumn:1740*
2007/2008 No. 7	*wintered in breeding area*	*-*	*-*	*-*	*-*	*-*	*0*
2008 No. 7	*3.10.08*	*23.-29.10.08 (23.10.08)*	*21-27 (21)*	*-*	*-*	*-*	*1860*

Notes:
1. Where a time frame is shown the exact date is unknown and lies within the dates given.
2. The figures in brackets are estimates of the actual values. The figures in brackets are estimates of the actual departure on migration, arrival or duration of migration. The values are derived from an extrapolation of the previous or subsequent migration flight distances and fixes taken.

Tab.7: Calculation of average daily flight distances during migration (minimum values); from/to: adequately accurate fix during migration with date, time and LC; + = more fixes nearby; Ü = overnight stops.

Red Kite No.	From (LC)	To (LC)	Distance in km	Duration in days	Average daily flight in km
2	20.10.02 20:09 (2)	01.11.02 23:00 (1)	720	12	60
4	Ü 19./20.10.02 (1+)	Ü 22./23.10.02 (0+)	300	3	approx. 100
7	20.2.05 12:10 (1)	10.03.05 12:53 (1)	1300	1.,1	72
7	26.2.07 13:15 (0+)	4.3.07 14:34 (3)	1400	8,2	approx. 170
7	5.10.08 11:05 (1)	17.10.08 13:57 (2)	940	1,4	76
7	5.10.08 11:05 (1)	7.10.08 10:36 (1)	102	1.9	54
7	7.10.08 10:36 (1)	8.10.08 11:57 (1)	117	1.2	approx. 98
7	8.10.08 11:57 (1)	12.10.08 13:10 (1)	300	4.2	71
7	12.10.08 13:10 (1)	14.10.08 14:28 (2)	181	2.2	82
7	14.10.08 14:28 (2)	17.10.08 13:57 (2)	240	2.9	83

Tab. 8: Overview of the night roosts recorded in winter quarters.

Night roost	Red Kite No.	Spanish province	Latitude N	Longitude W	Precision	Duration of stay
A	2	Valladolid	41° 41’ 21“	4° 46’ 40“	exact	1./2.11.02
B	2	Valladolid	41° 21’ 32“	5° 9’ 26“	exact	6./7.11.02
C	4	Zamora	41° 45’ 1“	6° 4’ 3“	exact	5.-13.11.02
D	4	Zamora	41° 44’ 4“,	6° 17’ 5“	exact	30.10.-7.12.02
E	4	Zamora	41° 38’ 39“	6° 0’ 54“	LC 2	9./10.11.02
F	4	Leon	42° 13’ 1“	5° 39’ 36“	LC 2	31.1.-15.2.03
G	6	Saragossa	42° 10’ 19“	1° 10’ 12“	LC 2	22.10.-4.12.04

DIAGRAMS & MAPS

Fig. 1: Frequency of fixes per month. Only continuous periods of 12 months during which the transmitters were active with the same programming have been taken into account. *(Diagram: x = No. of fixes, y = month)*

Fig. 2: Autumn migration of Red Kite 1.

Fig. 3: Autumn migration of Red Kite 2.

Fig. 4: Autumn and spring migration of Red Kite 4.

Fig. 5: Autumn migration of the Red Kite 6 in 2004.

Fig. 6: Autumn and spring migration of Red Kite 7 in migration periods 2004/2005.

Fig. 7: Autumn and spring migration of Red Kite 7 in migration periods 2005/2006.

Fig. 8: Autumn and spring migration of Red Kite 7 in migration periods 2006/2007.

Fig. 9: Autumn migration of Red Kite 7 in 2008.