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Satellite telemetry of Saker Falcons *(Falco cherrug)* in Austria: juvenile dispersal at the westernmost distribution limit of the species

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ABSTRACT—Juvenile Saker Falcons *(Falco cherrug)* frequently travel long distances after leaving their natal areas. Documenting such movements and identifying areas where they make short stopovers and settle temporarily are important for understanding factors that influence the birds' survival and are necessary for conservation. In eastern Austria, at the westernmost limit of the distribution of this species, three juvenile females were fitted with 22g solar ARGOS/GPS PTTs-100 transmitters in 2009 and 2010. The birds left the hacking site at an age of 62-65 days. Between fledging and dispersal, 95% of relocations were confined to an area of 350 m around the hacking site. Before leaving the "natal area", the maximum distances covered were 1.9–3.6 km. The dispersal of the three siblings was abrupt, different and unpredictable. Food availability in the area surrounding the natal site did not appear to influence dispersal behaviour. During their movements, the birds mainly oriented between eastern and northerly directions, and clearly preferred habitats at elevations below 350 m a.s.l. One individual showed only a short-distance movement pattern with mean individual distances of <100 km away from the natal site. It largely remained in an area of 4,458 km² (95% Kernel) (1,503 km² (50% Kernel)) in SW Slovakia for about 3 months. In mid-October she migrated 1300 km south to Sicily for the winter. In contrast, the second individual was very mobile and showed multidirectional and long-distance movement, although she did not range farther than 700 km from the natal area by flying to Ukraine in the east and even reaching the Baltic Sea coast in the north before being killed by a car. The third individual made a round trip heading south to Slovenia, east to Hungary and north to the Czech Republic. In between, she crossed the Alps in eastern Austria and made a temporary stopover in SW Slovakia.

Key Words: *Falco cherrug,* satellite telemetry, juvenile dispersal

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Introduction

The Saker Falcon *(Falco cherrug)* is widely distributed across Eurasia, ranging from central Europe to Mongolia *(Baumgart, 1991; Ferguson-Lees & Christie, 2001).* In eastern Austria, as in the Carpathian Basin, the subspecies *F. c. cyanopus* Thinemann, 1846, reaches the westernmost limit of its regular breeding range. As its absolute breeding numbers are low in all countries, the species is included on all national red lists within its range *(Frühauf, 2005),* and is furthermore protected by international legislation. Due to intensive conservation efforts in parts of the Carpathian Basin, especially in Hungary and Slovakia, where they have been running for many years *(Bagyura et al., 2010),* the European core population is increasing and Saker populations in neighbouring countries are growing. This

is also true for Austria where the current population is around 25-30 pairs and breeding pairs are concentrated in the NE of the country. In recent decades the population has recovered, and is currently stable or slightly increasing *(Gamauf, 1991; Berg, 2000; A. Gamauf* in *Mebs & Schmidt, 2006).* In the open agricultural landscape of the Austrian part of the Pannonian region with its mild climate, Sakers are present throughout the year. Nevertheless, the extent to which Sakers remain in their breeding territories throughout the year or disperse to other regions is still unclear. To date nothing is known about species dispersal, migratory behaviour or space utilization, either for adult falcons or for juveniles. Documenting movements and identifying areas used by this species are important in understanding the factors that influence the survival of the birds. The tendency to disperse is presumably inherent and endogenously controlled, but the actual distances that individuals move are variable and may be influenced by environmental conditions *(Newton, 2008).* Satellite telemetry is a useful tool to address questions of this kind *(Meyburg & Fuller, 2007).* Satellite tracking has revolutionized the study of bird migration and bird life histories. The method has been widely applied to the study of raptors for many years, especially for larger and medium-sized species (e.g. *McGrady et al., 2003; Meyburg et al., 2006; McIntyre et al., 2009*).

Juvenile dispersal, here in the sense of postnatal dispersal or the movement of wandering individuals from their birthplace to their first breeding place, is one of the most important yet least understood features of population ecology and evolution. Many dispersal patterns follow a flow that is polarized along both a specific axis and direction *(Penteriani & Delgado, 2009).*

Mortality in juvenile birds of prey is high, so only a small proportion of birds that hatch reach adulthood *(Newton, 1979).* Loss of young birds can be particularly high during the first weeks of independence. First-year survival is estimated at between 23% and 40-50% in the releative Peregrine Falcon *(Falco peregrinus) (Tordoff & Redig, 1997; White et al., 2002).* For this reason and because of the expense associated with the acquisition and handling of satellite-transmitters, studies have generally focussed on adult birds. However, it is important to obtain more detailed information on dispersal routes, range requirements and locations of young birds because it is possible that these show substantial differences to those of adults *(Hake et al., 2003).* In the case of the Saker Falcon, knowledge of this kind is also relevant to conservation measures.

The project presented here focusses on (1) post-fledging dispersal of Sakers, (2) space-utilization and (3) exploration of temporary environments.

Materials and methods

In the Viennese raptor rehabilitation centre (GVZ-Lobau), 16 captive-bred Sakers from the autochthonous Pannonian population have been released since 2006 using the hacking technique, a training method that helps young falcons to reach their hunting potential by providing them exercise and experience. The hacking platform was located 50 m from the breeding aviary, so that the parents and their juveniles could be in contact with one another. The release site is situated at the border of the Donau-Auen National Park. The closest pair

Figure 1. Tagging a Saker Falcon with a solar ARGOS/GPS transmitter (Photo: *R. Dosedel*)

of wild Saker bred in 2009 about 7 km from the release site. In the course of the project "Born to be Wild", a total of three siblings (females) were fitted with 22g solar ARGOS/GPS PTTs-100 transmitters (Microwave Telemetry, Columbia, Maryland, USA) (Figure 1). We tagged two birds in 2009 and one in 2010, a few days before fledging. The transmitters were mounted as "backpacks", using a 6 mm Teflon ribbon (Bally Ribbon, Bally, Pennsylvania, USA). As the weight of the birds varied between 1040 g and 1200 g, the transmitter comprised 1.8-2.1% of the body weight, well below the 3% conventional guideline value for telemetric studies of birds *(Caccamise & Hedin, 1985; Kenward, 2001).* PTTs were powered by solar energy and transmitted (duty cycle) for 12 hours every 24 to 72 hours. We assume that the dispersal behaviour of released Sakers mirrors that of wild birds, as has been shown to be the case for many different raptors, including falcons (e.g. *Sherrod et al., 1987; Brown et al., 2004; Fremuth et al., 2008; Lindberg, 2009; Stout et al., 2009*).

All birds were also ringed with an aluminium leg band from the Vogelwarte Radolfzell as well as with a coloured leg band. The GPS locations were uploaded via the Argos system of satellites, and were accurate to within a few metres (user manual, CLS/Service Argos,

Bird ID	Weight	Satellite-tagged at	No. of signals	No. of applicable signals (%)	Post-departure tracking period	Dispersal pattern
PTT 93397	1040 g	16-06-2009	582	472 (81.1%)	109 days	unidirectional short-distance movement
PTT 93398	1060 g	16-06-2009	113	90 (79.6%)	46 days	multi-directional long-distance movement out of breeding range
PTT 93401	1200 g	14-06-2010	101	78 (77.2%)	19 days	multi-directional (?) long-distance movement out of breeding range

Table 1. Identification codes, weight, signal quality and duration and dispersal pattern of three juvenile female satellite-tagged Saker Falcons released in the course of a hacking project in eastern Austria

	Cumulative post-departure tracking distance (km)					Straight-line distance from natal/hacking area (km) [1]				
Bird ID	**before leaving hacking site**	**after 1 week**	**after 2 weeks**	**after 3 weeks**	**after 4 weeks**	**before leaving hacking site**	**after 1 week**	**after 2 weeks**	**after 3 weeks**	**after 4 weeks**
PTT 93397	62	259	320	1110	310	2,3	99	83	95	93[2]
PTT 93398	58	2412	?	?		1,9	649	731	?	686
PTT 93401	71	1329	?			3,6	123	218		

Table 2. Movements of juvenile Saker Falcons at the westernmost breeding range in Austria before and up to 4 weeks after leaving the hacking site as determined by satellite tracking (? = incomplete data due to bad weather conditions; [1] maximum distance; [2] similar distance for two more months)

Toulouse, France[1]). We calculated total distance moved during the tracking period as the cumulative tracking distance. However, we recognize that the figures represent minimum estimates as tracking was not continuous and movements were certainly not strictly linear between the locations in the consecutive duty cycles.

All elevation positions (metres above sea level) of PTT fixes were compared with those of random spots. Per locality, 4 random spots were used, each 5 km away from PTT fixes in N (0°), E (90°), S (180°), and W (270°) directions. Home range size was calculated from the fixed Kernel on the certain data set and using the Minimum Convex Polygon (MCP) method (95% isopleth). Core area was calculated by using the 50% isopleth of the same distribution (Animal Movement Arcview Extension 2.0). All statistical analyses were undertaken with the aid of the SPSS 17.0 software package.

As the data from the three Sakers are not homogeneous with regard to the number of signals and the length of the post-departure tracking period, juvenile dispersal is presented at an individual level (Figure 1; Tables 1–2).

[1] *http://www.argos-system.org/manual*

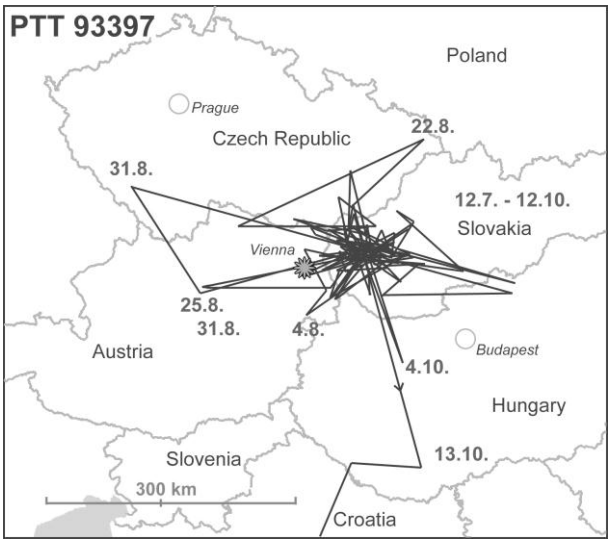

Figure 2. Juvenile dispersal routes of a female satellite tagged Saker Falcon marked PTT 93397

Results

Individual and unpredictable dispersal routes

Saker 1 (PTT 93397; Figure 2) was seen for the last time at its hacking site on the morning of 7 July (age: 64 days). Due to bad weather conditions, no signals were received for several days. Initially the bird did not move very far (Table 2), only flying about 100 km east to SW Slovakia (Trnva district), where she was recorded for the first time on 12 July. During the following three months the core area of her extensive home range was centred in the Trnava valley between the rivers Trnávka and Váh, east of Malé Karpathy Mts (Figure 3). The MCP area used by her was 6,776 km², the 95% kernel area was 4,458 km². The core area extension was relatively large (2,119 km²—MCP, 95% of all locations; 1,503 km²—50% Kernel). The bird moved its centre of activity regularly, sometimes weekly or every other week (mean number of days per centre of activity *11.2 ± 2.3 days; n = 8*). On this more short-term level the home ranges were much smaller (MCP *48.1 ± 22.6 km²;* MCP range 23-74 km²). There was no significant difference between the size of the home range and the number of days the bird used them *(Mann–Whitney U test = 39.4, p = 0.291, n. s.).* The distance between these activity centres varied from 16 km to 41 km. No significant difference was found between the distances and the number of days the home ranges were used *(Mann–Whitney U test = 53.7, p = 0.862, n. s.).* Especially after mid-August, PTT 93397 made longer one-day excursions (Table 3). On one such trip in Austria she even reached the border of the Northern Calcarious Alps. There, and at other localities such as in

Locality	Coordinates	Meters above sea level	Distance (km)	Direction	Date
Austria					
Siegendorf, Burgenland,	47° 46' 29"N, 16° 32' 42"E	188	111	SSW	4 Aug
Neuhofen/Ybbs, Lower Austria	48° 02' 43"N, 14° 52' 16"E	410	275	WSW	25 Aug
SE Neuhofen/Ybbs, Lower Austria	48° 01' 19"N, 14° 53' 26"E	647	297	WSW	31 Aug
Czech Republic					
Vrbice, SW Bohemia	49° 09' 03"N, 13° 40' 58"E	811	352	WNW	31 Aug
Komorni Lhotka, 28 km SE Ostrava	49° 39' 35"N, 18° 32' 39"E	476	105	NNE	22 Aug
Hungary					
Szuha, Bükk, Nagyvisnyó	47° 58' 59"N, 19° 55' 31"E	346	173	ESE	4 Oct

Table 3. The most distant records during one-day excursions of Saker PTT-93397 in 2009 outside its Slovakian core area

S and E Czech Republic and N Hungary, PTT fixes came from higher elevations than the localities she normally used (see below). On the way back from such an excursion the flight speed was 111 km/h (Gänserndorf, Austria – N Bratislava, Slovakia, in 20 minutes); typically, flight speed was 36–51 km/hour. It was not possible to determine with certainty whether the bird visited her hacking site, as was occasionally observed for other birds released in the previous year, which visited their hacking sites until October of the year they were released.

After the sudden onset of winter weather, PTT 93397 left her Slovakian home range on 14 October stopping only for a short time 260 km south, near Pécs, in SW Hungary. Only five days later she was found in W Sicily, c.1200 km SSW from the hacking site and 1300 km from her Slovakian home range. Unfortunately, due to bad weather conditions no signals were received during the migration, so it is not clear which route she took across the Adriatic Sea and how long the crossing took. In Sicily, the transmitter stopped working on 22 October. Surprisingly, sightings of a female 1st-year Saker were reported by an Italian ornithologist (*A. Corso*, pers. com.). His observations in December and mid-January 2010 in the surroundings of Siracusa, SE Sicily, suggested that the bird in question was PTT 93397 and that she was still alive and on the island Although Sicily is very mountainous, all but one location where she was recorded were below 250 m a.s.l.

On 3 March, 2013, PTT 93397 was found in its 5th year electrocuted near Donji Miholjac, NE Croatia, close to Drava River. This location was 302 km (154.1°SSE) away from the releasing site. It cannot be excluded that it settled there for breeding, as the locality was situated inside the breeding range, the bird was already mature and at that time usually breeding starts *(Gamauf & Dosedel, submitted).*

Saker 2 (PTT 93398; Figure 4) left the hatching site three weeks after being tagged on 6 July (age: 65 days). As with her siblings, when she was independent she was repeatedly observed to exhibit kleptoparasitic behaviour, snatching prey items from Kestrels *(Falco tinnunculus)* and Common Buzzards *(Buteo buteo)* and independently hunting voles (*Microtus* sp.). Based on the time between their departures and the bearing of their movements away from the hacking site, the two siblings left the areas where they were released in 2009 independently. Before finally leaving the hacking site, they showed no difference in cumulative tracking distance (km) or mean distance (in a straight line) from the natal/hacking area

Figure 3. Habitat in the core area of Saker PTT 93397 near Bohunice, SW Slovakia (Photo: *A. Gamauf*)

(Table 2), but this changed rapidly afterwards. After the end of a rainy period the bird became very mobile, stopping only for a short time in Trnva district, SW Slovakia, where PTT 93397 chose her core area, and continuing to Starokostiantyniv, Khmel´nyts´ka oblast, W Ukraine. Within two days she covered a distance of >700 km. A further two days later, on 11 July, she was recorded in S Poland, c. 500 km WNW of her easternmost location in Ukraine. During the following days she moved northwards (>700 km from the hacking site). Signals were received from the area W of Gdańsk up to the coast of the Baltic Sea (Słowiński National Park) and including a short trip across the open sea. At the end of July, six weeks after fledging, the bird was killed by a car in Recki, N Poland (close to Gdańsk), about 700 km away from its hacking site. Although she covered a very long distance in total, it is remarkable that she only moved in a radius of around 700+ km from the site of release.

Saker 3 (PTT 93401; Figure 5) undertook her first long trip on 28 June at the age of 62 days. It is remarkable that this journey also led her to the Trnava district, SW Slovakia, where she spent half a day. Presumably the Danube valley functioned as a kind of guideline eastwards into the Carpathian Basin. During subsequent days, under very summery weather conditions, she flew a wide route across W Slovakia and E Austria, where she crossed the Alps at 900-1000 m a.s.l. between Lower Austria and Styria (presumably between Göller 1766 m a.s.l. and Schneealpe 1903 m a.s.l.) 80 km W of the breeding range. This is a region

Figure 4. Juvenile dispersal routes of a female satellite tagged Saker Falcon marked PTT 93398

where no Sakers have been recorded previously. Following the river Mur from the city Bruck/Mur southwards, she finally reached Slovenia (Ptuj). On her return journey she flew northwards through the Little Hungarian Plain and back to her starting point at Komjatice, SW Slovakia. After a short stopover in the Nitra valley, she continued north to NE Czech Republic, from where the last good signals were received (near Kyjovice). A few days later, on 10 July, a single, poor quality signal came east from the city of Ostrava. Despite the help of Czech colleagues *(D. Horal, P.* and *V. Zvolanek)* it was not possible to obtain a final clarification of her whereabouts.

The natural potential of Saker for range extension

Despite being closely related and of the same sex, the three birds behaved very differently. With regard to the directions they flew, the mean post-departure bearing for the three Sakers differed markedly from one another *(Watson U^2 test = 0.73, df =2, P<0.001).* PTT 93397 definitely tended towards the ENE (75%), whereas 52% of all locations of PTT 93398 pointed in N direction, and PTT 93401 dispersed primarily in ENE to ESE directions (Figure 6).

During their juvenile dispersal phase, the three Saker Falcons clearly preferred open plains, basins and hilly areas at low elevations between 100 m and 350 m a.s.l., although the variation was relatively high, especially resulting from occasional excursions outside the core areas. PTT 93397, for example, expanded her range to elevations up to >800 m a.s.l., e.g. in the Northern Calcarious Alps, mountain massifs in eastern Alps and the foothills of the Bohemian Forest. The same behaviour was observed for PTT 93401, who also

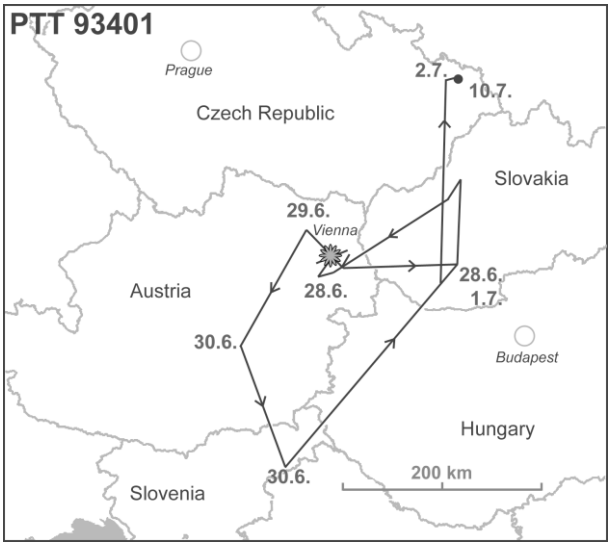

Figure 5. Juvenile dispersal routes of a female satellite tagged Saker Falcon marked PTT 93401

avoided higher ridges and mountain ranges but once directly crossed the alpine massif. Comparing elevations of the PTT fixes with random points, no significant differences were detected for PTT 93397 and PTT 93398. The significant differences for PTT 93401 (*Mann–Whitney U test = 28, p = 0.031;* Figure 7) might result from the relatively low sample size.

Although the wider surroundings of the release site were rich in food sources (Feral Pigeons /*Columba livia* f. *domestica/*, Starlings /*Sturnus vulgaris/*, voles */Microtus* sp./)—which resulted in a high breeding density (e.g. three nests separated by nearest-neighbour distances of 2-3 km)—it had no apparent influence on the start of dispersal or on the movement itself (i.e. it affected neither distance nor direction).

Discussion

Released Saker Falcons from the westernmost limit of the species' breeding range exhibited a wide range of movement patterns. Despite the small sample size, the data show that juvenile Sakers disperse far, outside the closed breeding range in an easterly and northerly direction, e.g. up to Ukraine and the Baltic Sea (Poland). That Poland is visited more frequently than the relatively scarce observations would indicate, was shown by *Sielicki et al. (2009)* and the finding is underlined by another record of an Austrian Saker from June 2009. A 2nd year male hacked at GVZ in the previous year was killed in the southern part of the country (Góra near Pszczyna) by a pigeon breeder. As Sakers prefer lowlands and big river valleys when dispersing, it seems that Austrian birds regularly follow the Moravian

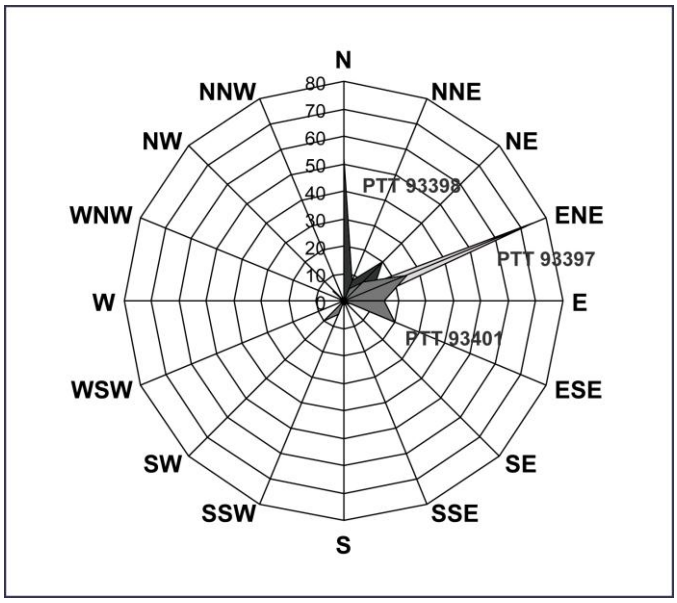

Figure 6. Post-departure direction (% of observations) of three satellite-tagged Saker Falcons from eastern Austria (n=209)

valley in a northerly direction. On the way they pass the Moravian Gap between the Sudety and Beskid Mountains and reach the valley of the Oder River in southern Poland. Three (PTT 93397, PTT 93401, 2nd year male) out of the four birds discussed in this manuscript followed that route (Figure 8).

Topography may play a role in the pattern of dispersal. For example, by following the Drava valley, Sakers could gain access even to inner Alpine areas. Short trips to these areas by Sakers may be the reason that they have been found in these places (records often without details). Among them was a juvenile bird, ringed on the 2nd July 1991 in W Hungary and found one week later on the 9th July in the Klagenfurter Basin, Austria, in a weak condition *(Feldner et al., 2008).* Otherwise, the eastern orientated Danube valley and the Carpathian Basin *per se* play very important role for Austrian Sakers.

Our study confirmed that satellite telemetry is a useful tool to investigate the movements and stopovers of juvenile Sakers at a critical stage of their lives. The results did not only reveal far-reaching dispersal routes, but also highlighted the importance of the Carpathian Basin for Austrian Sakers. The efficiency of satellite tracking technology enables the collection of more precise and reliable information than can be obtained with a small network of observers.

The large distances over which the species roams confirm the potential for gene flow between distant populations, which genetic analyses have proven to occur *(Nittinger et al., 2007). The* ability to expand by means of juvenile dispersal in different directions and over long distances, where even high mountains are not a barrier, requires the ability to settle in suitable habitats outside the closed breeding range. To facilitate this, Sakers are very flexi-

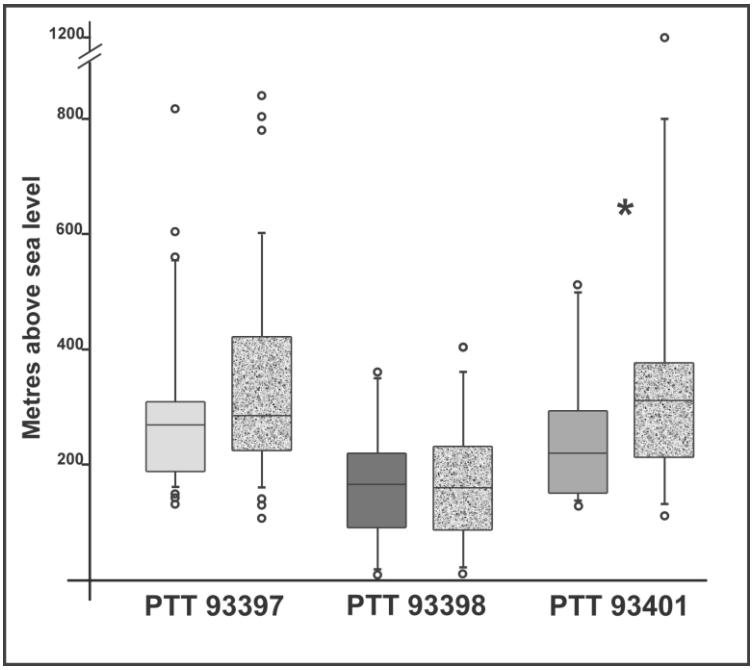

Figure 7. *Box-plots* of metres above sea level of all PTT fixes (left) in comparison with random spots (right) for each of the three tagged Sakers *(* P < 0.05)*

ble hunters and their diet includes small mammals and birds, depending upon the local conditions (*Frey & Senn, 1980; Bagyura et al., 1994;* authors' own data).

An additional key factor in the extension of the species' range is the growing population in the core of its breeding range, the Carpathian Basin. As the population is continuing to grow, especially in the species' Hungarian stronghold *(Bagyura et al., 2009)*, it is perhaps only a question of time before new breeding territories are established outside the present range, perhaps initially N–NW of the current range where dispersal might follow the Danube and Morava valleys as a first guideline. The rather recent records in Saxonia, Germany (1997–2001) and S Poland (1998) should be seen in this light and the historical evidence of "blue-footed falcons" in Germany *(Augst, 1998; Barthel, 2011).* The oldest evidence are dated from the 14th century in Baden-Württemberg (*Gatter & Bizer, 2012*). Other evidence from Hessen and Saxony in the 16th and 17th centuries cannot be dismissed without considering it, either (discussed by *Augst, 1998; Barthel, 2011*) (Figure 8). The fact that these observations did not take place in a climatically warm period but in the "mini ice-age" (c. 1400–1800) is not particularly surprising, as (1) the sightings may relate to relict populations from the former late medieval climatic optimum, and (2) the conditions in the core area of the distribution at that time might have been optimum, allowing the species to spread in a NW direction. (3) Additionally it has to be considered that at that time Germany was largely deforested and often used as pasture land *(Gatter & Bizer, 2012).*

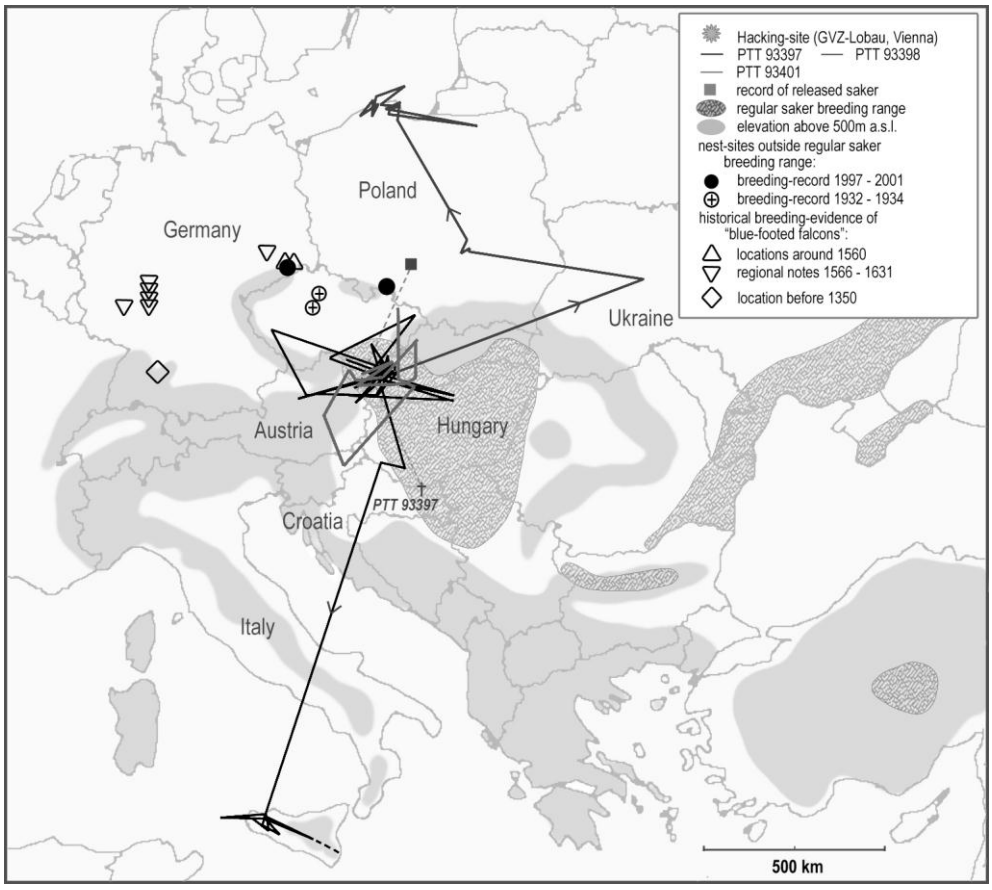

Figure 8. Dispersal routes of three juvenile Saker Falcons at the westernmost distribution limit of the species in connection with current distribution range (after *Mebs & Schmidt 2006*) and historical breeding evidences (after *Augst, 1998; Barthel, 2011* and *Gatter & Bizer, 2012*)

At any rate, young birds from this westernmost portion of the breeding range are especially prone to disperse in increasingly more northerly directions. In contrast, from more eastern populations in the Carpathian Basin of Hungary and Slovakia, only a few out of 43 young Sakers that were fitted with satellite tags visited these regions *(Prommer & Bagyura, 2009; Bagyura et al., 2010).* Birds from that study apparently followed the big valley systems (Danube, Tisza, Drava) that have S to SE orientation on their early dispersal routes instead. It is clearly not possible to predict, apart from initial suppositions *(Huntley et al., 2007),* how the current range of the Saker Falcon will develop as a result of global climate change.

It should be noted that this far reaching dispersal behaviour also represents a potential threat to the Saker, which is associated with agricultural development in central Europe.

Apart from direct persecution (shooting, trapping, poisoning), electrocutions and mechanical accidents (with power lines, cars) are especially noteworthy *(Nagy & Demeter, 2006).* Furthermore, the protected areas are too small to ensure protection of such a mobile raptor.

As Saker Falcons move over large geographic areas and across different international boundaries (seven in this single study) it is obvious that conservation efforts need to address both regional and international issues.

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