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Autumn migration and wintering areas of Peregrine Falcons *Falco peregrinus* nesting on the Kola Peninsula, northern Russia

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Four female Peregrine Falcons *Falco peregrinus* breeding on the Kola Peninsula, Russia, were fitted with satellite-received transmitters in 1994. Their breeding home ranges averaged 1175 (sd = ±714) km^2, and overlapped considerably. All left their breeding grounds in September and migrated generally south-west along the Baltic Sea. The mean travel rate for three falcons was 190 km/day. Two Falcons wintered on the coasts of France and in southern Spain, which were, respectively, 2909 and 4262 km from their breeding sites. Data on migration routes suggested that Falcons took a near-direct route to the wintering areas. No prolonged stopovers were apparent. The 90% minimum convex polygon winter range of a bird that migrated to Spain encompassed 213 km^2 (n = 54). The area of the 50% minimum convex polygon was 21.5 km^2 (n = 29). Data from this study agree with others from North America that show that Falcons breeding in a single area do not necessarily follow the same migratory path southward and do not necessarily use the same wintering grounds.

Peregrine Falcons *Falco peregrinus*, particularly those from the far north, migrate very long distances (Hickey & Anderson 1969). Data from ringing schemes in Europe show that most Peregrines from nests in western Russia and the Fennoscandian countries winter from Scotland to the Mediterranean (Ratcliffe 1993, Saurola 1998). Satellite-received transmitters, known as PTTs (Platform Transmitter Terminal), have been used to track a variety of species of birds (Fuller *et al*. 1995, Meyburg & Meyburg 1998, McGrady *et al*. 2003), including Peregrines (Fuller *et al*. 1998, McGrady *et al*. 2002). This technology is particularly appropriate when used to track gross movements of birds over long distances in remote areas (Britten *et al*. 1999). We present data on movements by Peregrines fitted with PTTs on the Kola Peninsula, Russia. Although many Peregrine populations in Europe have recovered from declines linked to organochlorine contamination, populations in eastern Europe, Italy and Spain have seen recent declines (Tucker & Heath 1994). Peregrines from the study area were shown to have relatively high levels of contaminants (Henny *et al*. 1994), and the data from satellite telemetry mapped areas where these Peregrines might be exposed to contaminants (Henny *et al*. 2000). Although Peregrines have been relatively well studied during the breeding season (see Ratcliffe 1993), information on their winter ecology is lacking. This paper details the movements

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of migratory Peregrines breeding in far northern European Russia, and provides some information on winter ranging. A basic narrative and map of the movements of these falcons is found in Henny *et al.* (2000); this paper analyses those movements in more detail.

METHODS

Four breeding adult female Peregrines were fitted with 28-g satellite-received transmitters (Microwave Telemetry Inc., Columbia, MD, USA) on 12–14 June 1994 on the Ponoy River on the Kola Peninsula, northern Russia (Henny *et al.* 1994). This area is characterized by bogs, small lakes and rivers interspersed with elevated, drier forested patches and some cliffs. PTTs were fitted as backpacks (Fuller *et al.* 1995). Russian ringing scheme rings were also fitted.

PTTs were programmed to transmit according to different duty cycle until battery failure. 5698 was programmed to run 8 h on, 93 h off for 20 cycles, then 8 h on, 74 h off; 5700 was programmed to run 8 h on, 126 h off; 5701 was programmed to run 8 h on, 117 h off; and 5710 was programmed to run 8 h on, 98 h off.

Peregrine movements were tracked using the Argos satellite system (http://www.argosinc.com/), which provides location estimates coupled with nominal location accuracy, the 'location class' (LC). Location classes 0, 1, 2 and 3 estimate accuracy (with 68.23% confidence) within > 1 km, ≤ 1 km, ≤ 350 m and ≤ 150 m of the actual location, respectively. Location classes A, B, C and Z contain location estimates deemed by the system to be less reliable. Argos supplies no accuracy estimate with LC A, B or C locations, although they may be accurate (Hays *et al.* 2001). Often Argos will not calculate a location estimate for signals in LC Z. See Britten *et al.* (1999), Vincent *et al.* (2002) and McGrady *et al.* (2003) for more information on Argos system accuracy when tracking wildlife. For all measurements of distance and area, and mapping of general travel paths we used only LC 0, 1, 2 or 3 data; timing of migration was calculated using LC A, 0, 1, 2 or 3.

Initiation of migration was defined as the date that was midway between the last location within 5 km of the nest and the first location estimate > 5 km from the harmonic mean (HM) of the summer locations, after which the falcon did not return. The HM was used because accurate locations of the nest-sites were not available. Distances were measured as great circle distances (GCDs), and the routes taken by falcons were measured by summing the length of flight segments along the migration path, starting with the harmonic mean of summer locations. The overall rate of migration was the sum of the segment lengths divided by the number of days on migration. The wintering period was defined as November–May (McGrady *et al.* 2002). The location of the wintering site was the harmonic mean of location estimates received during the wintering period. Summer range size was the 90% minimum convex polygon encompassing points from the time of fitting falcons with transmitters until the time they left on migration. Winter range size was the 90% minimum convex polygon encompassing points received between November and May. The 90% level was chosen to lessen potential effects of using LC 0 data in the analysis. Area calculations were done within a Lambert equal-area azimuthal projection of the globe.

RESULTS

The amount of data gathered for each bird varied, with data obtained during migration being the most limited (Table 1). On average, LC 0–3 comprised 52.2% (sd = ±0.073) of the data received; LC 2 and 3 (the most accurate locations, see Vincent *et al.* 2002) comprised 6.5% (sd = ±0.052) of the data.

Table 1. Amount and quality of location data for migrant Peregrine Falcons tracked via satellite from the Kola Peninsula, Russia.

ID	Total locations	Total LC 0–3	Total (%) LC 0–3 on breeding grounds	Total (%) LC 0–3 on migration	Total (%) on wintering grounds
5698	121	67	58 (86.5)	5 (7.5)	4 (6.0)
5700	101	41	32 (78)	0 (0.0)	0 (0.0)
5701	105	59	54 (91.5)	0 (0.0)	5 (8.5)*
5710	200	111	56 (50.4)	7 (6.3)	48 (43.3)

*Although these locations were clustered, they were not within our defined 'winter' period, November–May.

Table 2. Areas of summer home ranges of Peregrine Falcons on the Kola Peninsula, Russia, in 1994.

ID	No. of locations	Area (km^2)	Most distant (km) location ≥ 24 h after capture
5698	48	1490	50
5700	30	104	65
5701	48	1550	44
5710	62	1556	204

The mean home range area was 1175 km^2 (sd = ±714, $n = 4$), and these ranges overlapped considerably, especially in the area immediately around all the nest-sites. Some locations in the 24 h after fitting transmitters were relatively far from the centres of the summer territories for all falcons (Table 2), but for three of these the distances from the nest were exceeded later in the summer before migration. The summer home range of 5700 was completely contained within the range of 5698, and more than 50% contained within the ranges of 5701 and 5710.

The Falcons left their nesting areas on migration the throughout September, and three of the four provided information on long-distance migration (Fig. 1). Locations of bird 5700 suggested that she started migration, but either died or lost her PTT soon after. Five locations for this bird were received between 150 and 180 km south-west of the nesting location in September 1994, and then three locations were received from the same general area in May 1995. Once on migration, birds moved south and west rapidly, flying along the Baltic coast. The mean rate of migration was 190 km/day ($n = 2$; Table 3).

In general, Peregrines appeared to migrate along routes that were close to the shortest possible. However, these results must be interpreted in the context of relatively infrequent transmissions, irregular data reception and varying LCs. The data are limited for documenting stopovers of less than 24 h and short

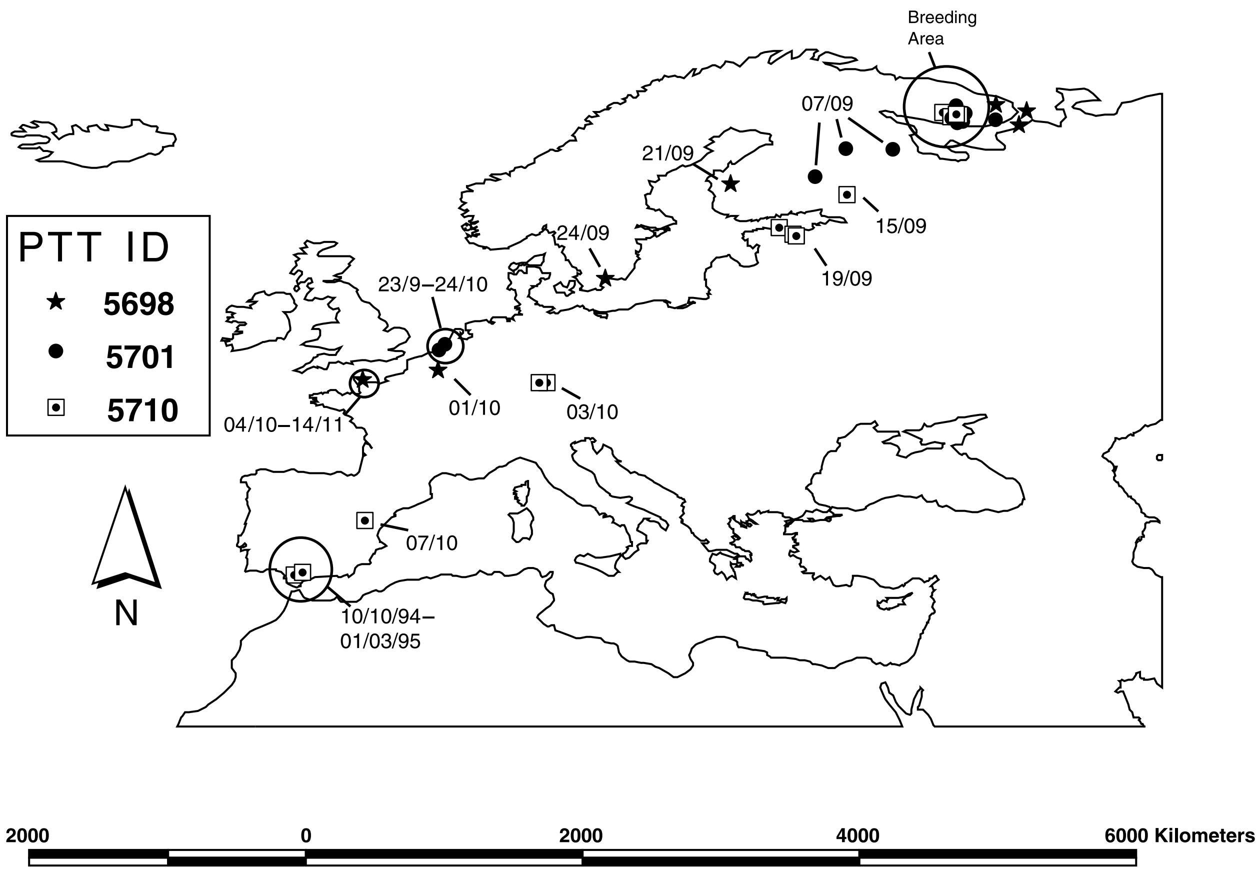

Figure 1. Migration routes and wintering areas of adult female Peregrine Falcons fitted with satellite-receiving transmitters on the Kola Peninsula, Russia, in 1994.

Table 3. Details of migration by breeding adult female Peregrine Falcons marked with satellite-receiving transmitters on the Kola Peninsula, Russia, in 1994.

ID	Monitoring period	Departure date from nesting area	Arrival date on wintering area	Distance travelled (km) (GCD to wintering)	Rate (km/day) of travel	Degrees of latitude crossed (SD/no. of segments)
5698	13 June–14 November	19 September	4 October	3073 (2909)	204 (32.8/n = 4)	17.7
5700	14 June 1994–18 July 1995	30 September	–	–	–	–
5701	14 June–24 October	5 September	–	–	–	–
5710	12 June 1994–1 March 1995	14 September	10 October	4609 (4262)	177 (129.8/n = 5)	29.9

GCD, great circle distance.

deviations from the general migration path. This held true even if we used LC A data. Nonetheless, on 19 September, 5710 deviated from her path toward her wintering area and moved east along the north Estonian coast to the area of the Velikaya River. Given this bird's overall rate of migration, the deviation from the shortest route probably added only about 2 days to the journey.

For birds 5698 and 5710, locations were received into the wintering period. Wintering areas for these two falcons were 1393 km apart and separated by 12.2° of latitude (Table 3). Falcon 5701 may have indeed reached its wintering area on south coastal Holland (51°34′N, 4°57′E), but because no transmissions were received after 24 October, it did not fall within our definition of the wintering period. While actively migrating, the rate of travel for this bird was approximately 165 km/day. The skeletal remains of this bird, still wearing its transmitter, were found in early to mid 1995 on the island of Tholen in Holland at approximately 51°19′N, 4°8′E.

Sufficient locations to estimate winter range size were collected for 5710, which wintered inland in southern Spain (37°16′N, 5°14′W) between the towns of Osuna and Marchena. During the period 1 November 1994 to 1 March 1995, this bird used an area of 213 km^2 (n = 54). The area of the 50% minimum convex polygon was 21.5 km^2 (n = 29).

In the summer following this study, falcon 5710 returned to its breeding territory, was recaptured and the PTT was removed. There was no sign of injury resulting from the transmitter, and at that stage (25 June) this bird had produced four eggs.

DISCUSSION

These data provide the first details of timing and rate of migration of Peregrine Falcons in Europe, and agree with ringing data that show falcons, especially females, from far northern Europe wintering in western Europe, sometimes on the coast (Saurola 1998). Many location estimates (69.6%) were placed in lower location classes (LC = A, B or C) by the Argos system. Lower location classes are caused by factors such as reduced signal quality or limited receptions during a satellite overpass, but are not necessarily inaccurate. Using only LC 0–3 may have reduced the effect of inaccurate location estimates, but also reduced the number of locations for mapping migration and wintering areas. The minor differences between the routes we describe and those reported by Henny *et al.* (2000) for the same birds are the result of our use of only higher quality locations, of which there were fewer.

Summer range values were within those reported by other authors (White & Nelson 1991, Enderson & Craig 1997, Jenkins & Benn 1998), as was the extensive range overlap (Enderson & Craig 1997). The 90% minimum convex polygon was chosen to lessen the effect of inaccurate location estimates, but it also may have excluded accurate locations far from the range centre, and thus underestimated the size of the ranges. That three falcons seemed to move relatively far from the range centres in the 24 h following fitting the transmitter suggests that they may have been affected by capture or tagging. However, the same birds made other, similarly distant, excursions from the nesting area later in the summer. Relatively long-distance excursions from the nesting areas have been noted in other radiotracking studies of Peregrines (e.g. ≥ 79 km, Enderson & Craig 1997; > 80 km, Jenkins & Benn 1998), but the timing of these excursions relative to trapping is not reported. The duration of the excursions was not known, but using Peregrine flight speeds observed by Enderson and Craig (1997) could have lasted as little as 30–120 min. No similar response was noted in radio-tagged Prairie Falcons *F. mexicanus* (K. Steenhof and

M. Vekasy pers. comm.), but Gyrfalcons *F. rusticolus* appear to avoid the nest for some time after capture (K. Burnham pers. comm.). In addition, there was no apparent effect of trapping and radiotagging on breeding success in the year of capture, and the falcon that wandered most widely (5710) reared two fledglings from four eggs (S. Ganusevich unpubl. data). Vekasy *et al.* (1996) could find no measurable effect of smaller harness-mounted radio transmitters on a number of production statistics for Prairie Falcon. At least one and perhaps as many as three of the falcons did not return to breed in the year after tagging. Given that all marked birds were adults and theoretically had a high annual probability of survival, this may point to problems with either the weight of the transmitter or the use of a harness attachment for this species, especially during migration.

In general, the timing and pace of autumn migration were similar to those of Peregrines from northern breeding areas tracked via satellite from the Taymyr Peninsula, Russia, and in North America (Fuller *et al.* 1998, Eastham *et al.* 2000, McGrady *et al.* 2002, W.S. Seegar unpubl. data), and agree with accounts from direct observations (Cramp & Simmons 1980). The routes taken by the falcons were close to the most direct routes to their wintering areas. This finding differs from that of Fuller *et al.* (1998), based on a much larger sample of falcons from across most of North America. Certainly, the low data collection rate in our study probably caused the migration path to be smoothed. However, the relatively smaller water barriers, less extensive coastlines, and less mountainous topography between summering and wintering areas probably affected travel routes in our study less than in the North American study (Kerlinger 1989, chapter 7). Peregrines nesting along the route taken by the falcons in this study are known to migrate along similar paths and to winter in the same locations (Lindberg 1977, Saurola 1977).

These Peregrines did not simply choose to winter in either the closest area or only in areas with an abundance of prey. Our radiotagged falcons flew well south of areas in Europe where Peregrines are known to winter (as far north as 67°N (Schej 1977)). Our falcons also went beyond areas that support large concentrations of potential prey (e.g. shorebirds) for migrating and wintering Peregrines (Smit & Piersma 1989). The migration also did not simply displace the Peregrines a certain distance south because the falcons could have reached the latitudes at which they wintered by a much shorter (~1000 km) route. Their use of relatively direct routes, which were away from traditional concentrations of potential prey, might reflect goal orientation (Berthold 1993) whereby the Peregrines 'knew' the location of their wintering areas and were showing fidelity to them. Peregrine fidelity to wintering sites in Europe is strongly suspected because ringed birds are seen in some wintering localities year after year (P. Lindberg pers. comm.).

Peregrines do hunt while on migration (Rudebeck 1951, Ward & Laybourne 1985), and the detour taken by bird 5701 around 15 September included an area of reed beds in northern Estonia where good hunting opportunities probably existed. This detour also included an area where concentrations of migrant raptors (mostly *Circus* and *Buteo*) have been seen, and whose numbers peak around the time of the Peregrine's passage, although the area of concentration itself appears to provide limited hunting opportunities (J. Shergalin, pers. comm.).

Wintering locations are characterized by concentrations of prey (McGrady *et al.* 2002). Places where we last detected birds 5698 and 5701 are estuarine and support high concentrations of wintering waders (Smit & Piersma 1989). The inland site used by 5710 is agricultural, supports large numbers of feral pigeons *Columba livia* and Red-legged Partridges *Alectoris rufa*, and is known as a wintering area for Peregrines (J. Negro pers. comm.).

Ringing data from Europe show that breeding migratory Peregrines from one area do not necessarily share wintering areas (Saurola 1998, Danish, Spanish and Finnish Ringing Schemes pers. comm. [see Acknowledgements], T. Nygard and P. Lindberg pers. comm.), although few winter recoveries have been made of adult Peregrines for which the nesting location is known. This pattern is supported by our data and agrees with data from North America (Fuller *et al.* 1998, McGrady *et al.* 2002, W.S. Seegar unpubl. data). The same ringing information also shows that there is no link between natal areas and wintering areas. Foreign recoveries of Peregrines ringed as nestlings in Fennoscandia and Russia are mostly from Britain and the Low Countries, but also from as far south as Senegal (Cramp & Simmons 1980, Saurola 1998, T. Nygard and P. Lindberg pers. comm.). Although ringing data are biased because the likelihood of recovery is low and irregular across much of the breeding area and because most are from nestlings, they generally conform with our data from satellite telemetry. As in migratory Peregrine populations in North America (McGrady *et al.* 2002), nest-site fidelity was shown in this study.

Studies in the Americas suggest that wintering Peregrines settle into restricted ranges rather than continually moving to new localities (White *et al.* 1989, McGrady *et al.* 2002). The single bird tracked over winter in Spain used a winter range, the size of which was within the range of areas used by coastal wintering Peregrines in North America (McGrady *et al.* 2002). Despite calculating the size of the winter range as the 90% minimum convex polygon, the use of LC 0 location estimates may have inflated its size, but if they were not included the number of locations would have been reduced from 54 to five.

Globally, there is little information on Peregrines during the non-breeding season. Because some migrant Peregrines spend as much time on wintering grounds as on the summering areas, this lack of information could compromise conservation efforts. Although satellite tracking provides a detailed picture of long-distance movements of Peregrines, studies, including those using very high-frequency telemetry, focusing on non-breeding season habitat use and food habits are needed to provide new information on Peregrine ecology.

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