Ornis Hungarica 2018. 26(2): 222–231.
DOI: 10.1515/orhu-2018-0030

Migratory movements of Peregrine Falcons *Falco peregrinus*, breeding on the Yamal Peninsula, Russia

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Received: October 30, 2018 – Revised: November 11, 2018 – Accepted: December 21, 2018

This is a contribution submitted to the Proceedings of the World Conference on the Peregrine Falcon in Budapest in September 2017.

Sokolov, V., Sokolov, A. & Dixon, A. 2018. Migratory movements of Peregrine Falcons *Falco peregrinus*, breeding on the Yamal Peninsula, Russia. – Ornis Hungarica 26(2): 222–231. DOI: 10.1515/orhu-2018-0030

Abstract We describe the migration pathways of 12 Peregrine Falcons *Falco peregrinus calidus* breeding on the Yamal Peninsula, Russia. Overall, we tracked 30 complete (17 autumn and 13 spring) and 5 incomplete seasonal migration routes. Winter ranges extended from the Atlantic coast of southern Portugal in the west to Kish Island in the Arabian Gulf in the east, and from Krasnodar in southern Russia in the north to South Sudan. Eight birds were tracked to their wintering sites, with migration pathways ranging from 3,557 km to 8,114 km, taking 14 to 61 days to complete. Birds spent an average of 190 days in their winter ranges (range 136 to 212 days, N = 14), and departure on spring migration took place in April. The home ranges used by wintering Peregrines were varied including coastal habitats, agricultural landscapes, savannah, desert and an urban city. Departure from breeding areas took place in September with birds returning in May. Peregrines exhibited a high degree of fidelity to their winter ranges, with four birds tracked over three successive migrations until the 2012 breeding season.

Keywords: migration pathway, birds of prey, range fidelity

Összefoglalás Oroszországban, a Jamal-félszigeten költő vándorsólymok *Falco peregrinus calidus* közül 12 egyed vonulási útvonalát írtuk le. Összesen 30 teljes (17 őszi és 13 tavaszi) és 5 részleges vonulási útvonalat követtünk. A telelőterületek nyugaton Portugália atlanti partjaitól, keleten a Perzsa-öbölben található Kish-szigetig, valamint északon az oroszországi Krasznodarszktól, délen Dél-Szudánig terjedtek ki. Nyolc madarat követtünk a telelőterületéig, ezek vonulási útvonala 3557–8114 km között változott, amit 14–61 nap alatt tettek meg. A madarak átlagosan 190 napot töltöttek telelőterületükön (136–212 nap, n = 14), majd a tavaszi vonulást áprilisban kezdték meg. A telelő vándorsólymok költőterülete változó volt, beleértve tengerparti, mezőgazdasági, sivatagos és szavannás élőhelyeket, valamint egy várost. A költőterületet a madarak szeptemberben hagyták el, és májusban tértek vissza. A vándorsólymok jelentős hűséget mutattak a telelőterületük iránt, amit 4 – a 2012-es költési időszakig 3 vonulási szezonon keresztül követett – madár bizonyít.

Kulcsszavak: vonulási útvonal, ragadozómadár, területhűség

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Introduction

Holarctic Peregrines *Falco peregrinus* breeding at northern latitudes are migratory, including *F. p. tundrius* and northern populations of *F. p. anatum* in the Nearctic, and *F. p. calidus* along with northern populations of *F. p. peregrinus* and *F. p. japonensis* in the Palearctic (White *et al.* 2002, 2013, 2018). In contrast to the Nearctic, little is known about the northern distribution limits of wintering Peregrines across the Palearctic. The Eurasian breeding range of the *F. p. calidus* subspecies extends from the Kanin Peninsula eastwards through Russia to Arctic Yakutia, where they intergrade with *F. p. japonensis*/*harterti* (White *et al.* 2013).

It has long been known that migratory Peregrines from Northern Eurasia can spend the winter in Europe and North Africa (Cramp & Simmons 1980), sub-Saharan Africa to the Eastern Cape (S33.73, E26.42 (Hd.dd); Jenkins & Stephenson 1999), the Middle East (Jennings 2010), Central Asia (Dementiev & Gladkov 1952), the Indian subcontinent (Naoroji 2006) and South-East Asia (White & Bruce 1986), reaching as far south as Christmas Island (S10.5, E105.66) (Carter & Silcocks 2010). However, relatively little data exists on the connection between breeding and wintering areas for migratory Peregrines in Eurasia. Ganusevich *et al.* (2004) successfully tracked two adult females from their breeding ranges on the Kola Peninsula, Russia to wintering areas in Western Europe, while Peregrines from the Taimyr Peninsula wintered in Central Asia (Eastham *et al.* 2000). More recently, systematic tracking of Arctic Eurasian Peregrines has shed further light on migratory connectivity, with birds wintering in SE Asia originating from breeding regions in northern Yakutia (Dixon *et al.* 2012), those wintering in the Indian Sub-continent originating from the Khatanga Gulf region (Dixon *et al.* 2017), while those reaching the Middle East and Arabia came primarily from the Yamal, Gydan and western Taimyr Peninsulas (Sokolov *et al.* 2016).

In this study, we describe the multi-annual migration movements and wintering locations of *F. p. calidus* Peregrines deployed with satellite-received transmitters at their nest sites on the Yamal Peninsula, Russia.

Methods

This study is based on data received from Peregrines breeding in the low-shrub tundra zone of the Yamal Peninsula, Russia (N 68.22, E 69.15), in an area of maritime valleys, low hills and tundra marshes with patches of willow thickets within a network of lakes, rivers and streams. Peregrines used river or lake sand cliffs up to 40 m high as nesting sites (see details in Sokolov *et al.* 2014).

In June 2009, we fitted 18g solar PTTs (Microwave Telemetry Inc., MD, USA) to 10 adult Peregrines (9 females and 1 male; including a breeding pair) at nine breeding territories within a 78 km^2 polygon. In August 2010, we fitted similar PTTs to two juvenile males prior to fledging; these were the offspring of two females deployed with PTTs in the previous year. All PTTs were attached to the birds by a Teflon ribbon backpack harness. The Teflon ribbon strand was attached at its midpoint to the anterior anchor of the PTT and the two ends were tied with a flat-knot to crossover the sternum, with the trailing ends attached to the posterior anchor points of the PTT. The PTT was mounted high along the dorsal midline with space to fit two fingers under the PTT unit (see Dixon *et al.* 2016).

We received telemetry data from the Argos satellite tracking system (CLS, France). We used the Douglas Argos Filter Algorithm ('DAR' filter) designed to retains points, which correspond to a realistic rate of movement and which do not form tight angles (Douglas *et al*. 2012, Wikelski & Kays 2017). We only included Argos data of ≥ LC1, removing duplicate timestamps, and set a maximum realistic movement speed between locations as 100 km/h, while the internal angle between successive locations was set at 15°.

We defined the start of migration as the first day the bird began continuous movement towards the north or south. In two cases, birds moved to a staging area prior to initiation of long-distance migration. Arrival at winter and breeding ranges was defined as the first day the Peregrines movements became localized. Average speed of migration was calculated as the whole distance from start to end divided by duration, while average flight speed during migration was calculated as the distance between successive location points divided by time between such locations. We did not calculate migration speeds for birds which stopped transmitting during migration. We identified stopover sites when birds travelled less than 50 km between two subsequent locations.

Results

Overall, we tracked 30 complete (17 autumn and 13 spring) and 5 incomplete seasonal migrations by 12 (9 adult females, 1 adult male and 2 juvenile males) Peregrines from breeding sites within 200 km^2 on the Yamal Peninsula of the Russian Arctic *(Figure 1)*. Four birds were followed over 3 years covering three complete autumn and spring migrations.

Typically, Peregrines departed on autumn migration during September, taking from two weeks to two months (mean = 25 days) to cover distances from 3,000 km to 8,500 km to reach their wintering areas *(Table 1)*. Spring migration from the wintering areas started in April and birds arrived at their breeding sites in May. On average, Peregrines spent 190 days in the wintering area and 117 days in the breeding area. The autumn departure dates of four

Table 1. Dates of the migration events for the Peregrine Falcons in 2009–2012
1. táblázat A vándorsólymok vonulásának dátumai 2009–2012 között

Seasonal event	N	Mean	Median	SD	Range
Autumn departure	20	14 of Sept	13 of Sept	9	28 Aug – 28 Sep
Arrival at winter range	17	11 of Oct	11 of Oct	18	17 Sept – 26 Nov
Spring departure	14	19 of Apr	23 of Apr	8	4 – 29 Apr
Arrival at breeding range	13	16 of May	15 of May	5	10 – 28 May
Duration of autumn migration (days)	17	26.8	24.5	11.7	14 – 61
Duration of spring migration (days)	13	25.8	23	8.4	14 – 47
Speed of autumn migration (km/day)	17	222.6	215.43	57.5	0.4–1072.6
Speed of spring migration (km/day)	13	239.6	214.6	77.8	0.6–1205.2

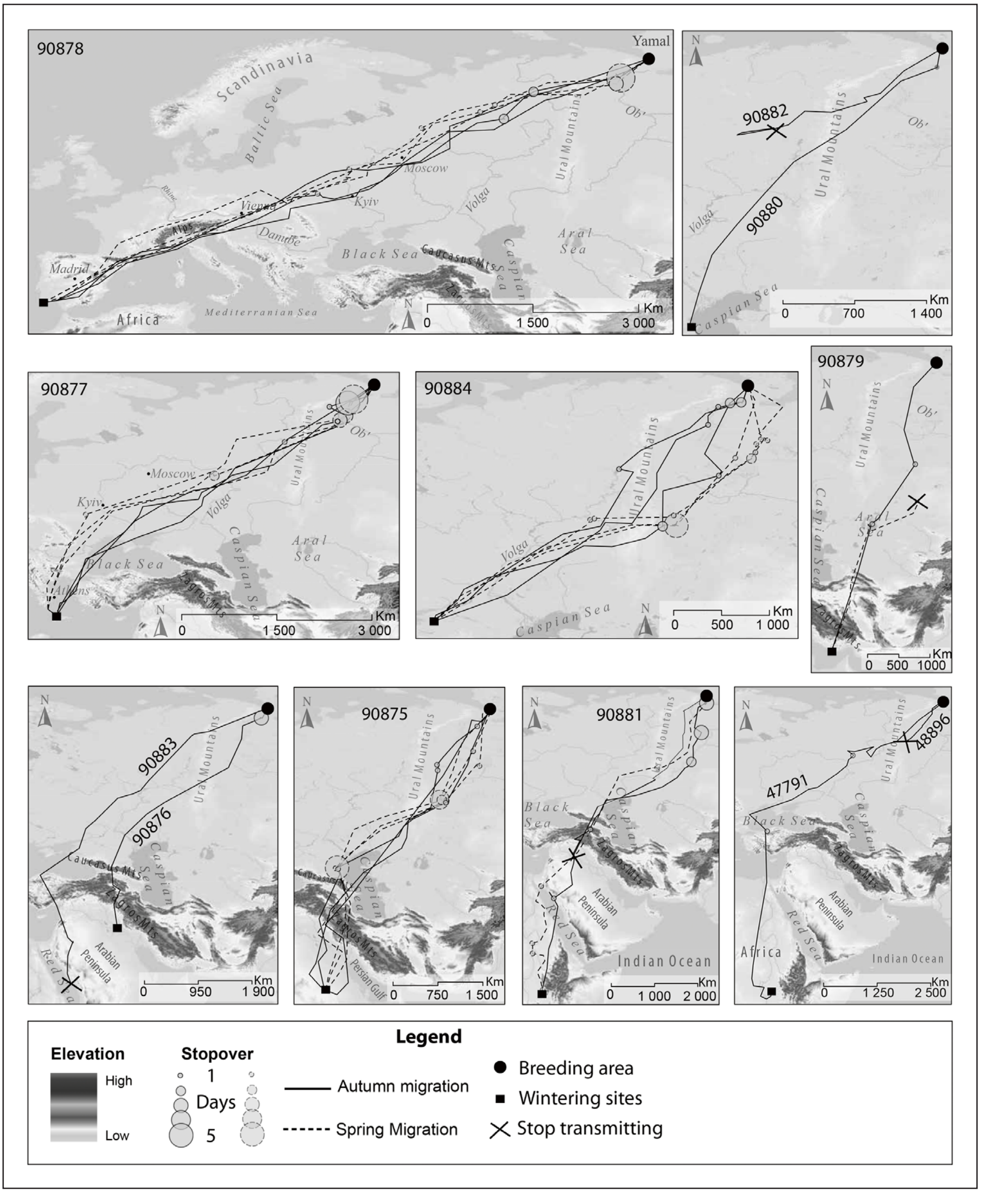

Figure 1. Migration of Peregrine Falcons breeding on the Yamal Peninsula. Number is ID of different birds. 90876 and 90883 are male and female respectively from a breeding pair. Juvenile male (47791) is a fledgling of 90884, whilst juvenile male (48896) is a fledgling of 90878

1. ábra A Jamal-félszigeten költő vándorsólymok vonulási útvonalai. A számok a különböző egyedek azonosítói: 90876 és 90883 egy párt alkotó hím és tojó. A 47791-es fiatal hím a 90884-es fiókája, illetve a 48896-os hím a 90878-as fiókája individual birds differed across three consecutive years by an average of 6.9 days (median = 6 days, range 1–14 days), while the corresponding difference for departure on spring migration was 3.3 days (median = 3.5, range 0–7).

The average daily distances travelled were 223 km and 240 km during autumn and spring migrations, respectively. The maximum travel distance detecting during one day (24 hours) was 1,072 km on autumn migration and 1,205 km during spring. The lower Ob River basin, 180 km south of the breeding area, was a regularly used utilized stopover area during both autumn and spring migrations *(Figure 1)*. We also identified stopover sites in the Ural Mountains for two birds (90884, 90875) and the western coast of the Caspian Sea for another (90880). All autumn migration routes exhibited longitudinal displacement to the west by 20° to 95°, and all distances travelled were longer than the Great Circle distance *(Table 2)*.

We localized 9 wintering ranges of Peregrines, extending from 8˚ W (Faro, Portugal) to 54˚ E (Kish Island, Arabian Gulf) in longitude and from 46˚ N (Krasnodar, Russia) to 6˚ N (Junqali, Sudan) in latitude *(Figure 1)*. All the winter ranges were situated SW of the breeding area, with a mean bearing of 225° and a mean great circle distance of 4,987 km *(Table 2)*. Three of the wintering ranges were on the Atlantic, Mediterranean and Arabian Gulf coasts, whilst a fourth was within 20 km of the Caspian Sea coast. The five others were situated in inland territories at least 100 km from the coast *(Figure 1)*.

Peregrines wintering at inland sites in Krasnodar, Russia (N 46.08, E 39.46), Dagestan, Russia (N 43.98, E 47.09) and Saudi Arabia (N 25.9, E 45.01) occupied ranges that encompassed mainly agricultural land, the wintering ranges of an adult and juvenile in South Sudan encompassed savannah (N 6.09, E 34.36; N 7.64, E 32.76), whilst a male wintering in Baghdad, Iraq (N 33.31, E 44.35) occupied a wholly urban range. The three coastal wintering ranges differed in character; in Portugal (N 37.09, E 8.38) the coast comprised urban areas, Mediterranean scrub and a saline lagoon, in Crete (N 35.50, E 24.17) the range encompassed islets and a rocky coastline backing on to Mediterranean scrub, agricultural land and an airport, whilst in the Arabian Gulf the Peregrine range encompassed urban areas, an airport and plantations on Kish Island (N 26.57, E 53.93), as well as rocky hillside of the adjacent mainland.

Table 2. Migration metrics for tracked Peregrines
2. táblázat A nyomonkövetett vándorsólymok vonulási adatai

Bird ID	Number of full migrations	Great Circle distance (km)	Mean migration path in autumn / spring (km)	Bearing
47791	1	7447	8554	220
90875	6	4983	5247 / 5330	212
90876	1	4190	4485	215
90877	6	4556	5048 / 5037	241
90878	6	5698	6366 / 6470	275
90879	1	4742	4978	200
90880	1	2967	3082	216
90881	2	7342	8114 / 8073	218
90884	6	2954	3557 / 3600	229

The breeding pair that we tracked would have occupied widely separated winter ranges; the male established a winter range in Baghdad, Iraq, whilst his mate stopped transmitting during her autumn migration 1,185 km to the SW on the Red Sea coast of Saudi Arabia. Individual Peregrines showed fidelity to their winter ranges and all four females that still had functioning PTTs were tracked back to the same winter locality in Saudi Arabia, Crete, Portugal, and Krasnodar in successive years.

Losses during autumn migration

All Peregrines deployed with PTTs in 2009 departed their breeding sites on the Yamal Peninsula, but two PTTs stopped transmission during autumn migration. One female (90882) started migration on 28 September, covering about 1,100 km in a SW direction over 11 days, but then location signals were received for a further 3 weeks from a localized area, probably stationary, on the border of the Perm and Komi regions ca. 190 km SE of Syktyvkar, Komi, Russia (N 61.34, E 54.35) before transmission ceased. The second female (90883) departed on 21 September and covered around 5,600 km before transmission ceased on 20 October close to Yanbu, Saudi Arabia on the Red Sea Coast (N 24.37, E 37.92); this being a well-known falcon trapping area (see also Dixon *et al.* 2011, Sokolov *et al.* 2016).

The PTT on one female (90881) stopped transmission during autumn migration in 2010; after departing from the breeding area on 22 September the last signal was received on 18 October around 4,200 km south ca. 30 km southwest of Al Qa'im, Syria (N 34.1, E 40.81).

A juvenile male (48896) departed its natal area in August 2010, this being the offspring of female 90878. After travelling ca. 1,000 km in a week, the bird reached an area close to Serov, Sverdlovsk Region, Russia (N 59.5, E 60.81). Signals were received from a localized area until early October, and briefly resumed again in spring 2011 indicating that the PTT was stationary.

Losses in wintering ranges

The PTTs on two birds, a male (90876) and a female (90880) stopped transmitting when they were in their winter ranges. The male wintering range was located in Baghdad, Iraq (see also Dixon *et al.* 2013) and after arrival on 20 September 2009 transmissions were received until 02 January 2010. The female occupied a winter range in an agricultural landscape on the Caspian coast in Dagestan, Russia, arriving on 22 September 2009 and transmitting location data until 07 January 2010.

A juvenile male (47791), the offspring of female 90884, reached its wintering area in South Sudan in early November 2010, having travelled ca. 8,500 km, but the PTT stopped transmitting signals within a week.

Losses on spring migration

One PTT stopped transmitting during spring migration in 2010. Female (90879), that wintered on Kish Island, Iran started spring migration 04 April, returning along a broadly similar pathway as the autumn migration to reach the coast of the Aral Sea, from where it deviated course, moving SE and then NE to reach an area ca. 80 km northwest Karsakbay, Kazakhstan (N 48.18, E 65.93) when signals came from a localized area ca. 2,600 km from the winter range, probably stationary, until the end of May 2010.

Losses in the breeding area

One PTT (90877) stopped transmitting in the breeding area in late June 2012 and when the nesting territory was checked on 20 June we did not find any Peregrines breeding and there was no sign of the female with the transmitter.

In summer 2012, we re-trapped the remaining three birds at their nesting sites and removed the PTTs (90875, 90878, 90884).

Discussion

Timing, duration and speed of migration

Our data confirm previous observations about the timing of autumn migration of Peregrines breeding in Arctic Russia. Prior to our study, it was known that Peregrines (ssp. *calidus*) disappeared from their breeding ranges on the Yamal Peninsula in September to early October (Paskhalny & Golovatin 2009), while five females, one adult and four juveniles, deployed with PTTs at nest sites on the western Taimyr Peninsula departed during September (Eastham *et al*. 2000). On the Kola Peninsula of Russian Lapland, four female Peregrines (ssp. *peregrinus*) were tracked via satellite and departed their breeding areas in September but only two were tracked to their wintering ranges, both arriving in October after migrations that lasted 15 and 26 days (Ganusevich *et al*. 2004). The timing of autumn and spring migration

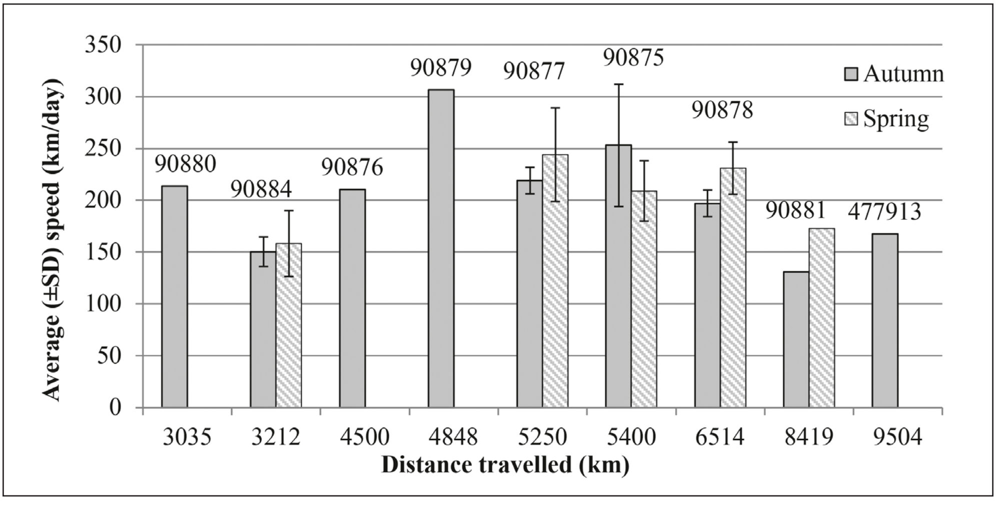

Figure 2. Average speed (±SD) of migration for individual Peregrine Falcons
2. ábra A vándorsólyom egyedek átlagos vonulási sebessége (±szórás)

of satellite-tracked Peregrines breeding in the eastern Taimyr region was also similar to that recorded in the present study, as was the separate migration pathways taken by breeding pairs (Dixon *et al.* 2017).

There was individual variation in speed between autumn and spring migration, but no general differences were apparent in terms of migration distance *(Figure 2)*.

Migration routes

Peregrines breeding on the Yamal Peninsula migrate over a broad front with a westerly displacement, and the birds tracked via satellite reached southerly wintering areas in Western Europe, Africa and the Middle East. Major geographical migration barriers along the migration routes comprised the Mediterranean Sea, Black Sea, Caspian Sea, Red Sea and Persian Gulf, the mountain range of the Caucasus and deserts of the Arabian Peninsula and Central Asia. It was notable that Peregrines whose winter range lay beyond the major sea barriers avoided long sea crossings or took routes that circumvented them. The migration routes taken by Peregrines in North America also appeared to be influenced by coastlines, indicating that long-distance sea crossings can be a barrier to migration (Fuller *et al.* 1998). In contrast, as previously described for the Himalaya (Dixon *et al*. 2017), the mountain chain of the Caucasus was not a barrier to Peregrine migration, and three birds travelling west around the Caspian Sea crossed these mountains to reach more southerly wintering destinations.

In contrast to the adults, which were likely to be returning to winter ranges occupied at least one year previously, juveniles were making their first migrations to unknown winter quarters. Juveniles departed the breeding region around the same time as adults, approximately 20 days after fledging, but not at the same time or along the same migration path as their satellite-tagged parent. One juvenile male (47791) was tracked to its wintering area in South Sudan *(Figure 1).* This bird migrated independently of its female parent, which wintered in Krasnodar, Russia, on a bearing with a difference of 9° and travelling 4,500 km further. The other juvenile male (48896) initiated migration two days after its female parent (90878), which wintered in Portugal, but although we were only able to track this young bird for a distance of *ca*. 1,000 km, the direction of migration differed by 68°.

The main stopover site for birds departing from and arriving to the Yamal Peninsula was the Lower Ob River, a site where large numbers of waterfowl and waders can congregate during the autumn and spring migration periods (Krivenko & Vinogradov 2008). There was one instance on spring migration when a bird (90877) in 2010 flew from the stopover area on the Lower Ob River 180 km to its breeding area on 15 May, only to return after 7 days, presumably because of unfavorable conditions in the breeding area. Another stopover site was an area with many lakes in the Chelyabisk and Kurgan region in the southern Ural Mountains, a region known to hold large numbers of waterfowl and waders during seasonal migration (Tarasov & Lyakhov 2016). A third stopover location identified on the western coast of Caspian sea has previously been recorded as a stopover or wintering site for Peregrines (Lipsberg 1982), where they can hunt waterfowl wintering here (Dementyev & Gladkov 1952).

Wintering locations

Peregrines occupied discrete ranges in their wintering areas, spending more time there (*ca*. 6 months) than in their breeding ranges (*ca*. 4 months) and those tracked over multiple migrations returned to the same winter range in successive years. Fidelity to winter ranges contrasts with the observation of breeding dispersal in the same birds, where 33% of females dispersed to new breeding ranges up to 40 km away (Sokolov *et al.* 2014). All winter ranges were within the breeding distribution of resident Peregrine populations, encompassing the subspecies *brookei* in the Mediterranean, *peregrinus* in Russia, *pelegrinoides* in the Middle East and *minor* in Africa. When establishing wintering ranges, birds may face intraspecific competition from local resident Peregrines as well as other migrants, although we do not know the extent to which these ranges are occupied exclusively by individuals nor if they are defended against conspecifics.

The wide diversity of habitats used by wintering Peregrines in this study is notable, reflecting the adaptability of the species. This plasticity in habitat selection, together with the broad front migration to widespread winter locations across at least two continents, means that migratory Peregrines from our study population are not particularly susceptible to geographically localized threats outside the breeding area.

Acknowledgements

This study was funded by the Environment Agency Abu Dhabi. We thank HE Mohammed al Bowardi and HE Majid al Mansouri for their interest and support, International Wildlife Consultants Ltd. The study was performed within the framework of state contract with the Institute of Plant and Animal Ecology, Ural Branch, Russian Academy of Sciences and partly supported by the Russian Foundation for Basic Research (project no. 18-54-15013).

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