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Time of nocturnal departures in European robins, *Erithacus rubecula*, in relation to celestial cues, season, stopover duration and fat stores

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To identify the mechanisms of control of temporal schedule of nocturnal migratory flights in small songbirds in nature, we studied the time of departure in a medium-distance nocturnal migrant, the European robin, on the Courish Spit (southeastern Baltic coast) using radiotelemetry. Exact measurements of departure time in 100 birds (58 in autumn and 42 in spring) showed no fixed time window of nocturnal departures during Evening Nautical Twilight. Take-offs occurred throughout the night and even during Morning Astronomical and Nautical Twilight Periods. Departure time showed no significant difference between clear skies and overcast conditions, and significantly differed between the seasons. The median departure time shifted significantly towards sunset during shorter nights in spring as compared to autumn. In both seasons (1) European robins initiating flight after short (1–2 days) stopovers showed no significant differences in departure time between individuals with small and large fuel stores at arrival; and (2) departure time was significantly related to stopover duration: the longer the birds stayed, the earlier they departed in relation to sunset. Only in spring and after longest stopovers, all departures occurred within a short time window soon after sunset.

Keywords: departure time; European robin; *Erithacus rubecula*; nocturnal migration; stopover duration; take-off

Migrating birds differ in their lifestyle, size, aerodynamic characteristics and behaviour, and the diel pattern of their flight activity. However, the duration and timing of migratory flights are poorly understood (Alerstam 1990; Berthold 2001). Numerous small songbirds fly during the night and make stopovers of varying duration to refuel (Dolnik 1975, 1995; Alerstam & Lindström 1990). The commonly accepted model of temporal schedule of flights over land assumes for these birds: using the period of sunset as the main reference point; simultaneous take-off during Evening Nautical Twilight Period; flight during several hours; landing after midnight; no inter- or intraspecific variation (Moore 1987; Kerlinger & Moore 1989). Deviation from this basic pattern (except of departure period) may occur when migrants have to cross large expanses of water or deserts (Moreau 1972; Kerlinger & Moore 1989; Alerstam 1990; Biebach 1990; Martin 1990) or face unfavourable flight conditions (Biebach et al. 2000).

It is assumed that the fixed time window of nocturnal departures soon after sunset is adaptive and allows the birds to use multiple cues to select a flight direction (Emlen 1980; Moore 1987; Able 1989, 1993; Helbig 1991; Sandberg 1991). Such cues include calibration of magnetic and celestial compasses, based on sunset direction, skylight polarization pattern and stars (Able 1993; Able & Able 1995; Wiltschko et al. 1998; Cochran et al. 2004; Muheim et al. 2006). Departure soon after sunset

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also allows migrants to use favourable atmospheric conditions during this time of day, that is, low temperature and reduced turbulence of wind, for powered flight (Kerlinger & Moore 1989).

A careful analysis of literature, however, shows that the current concept of the fixed time window of nocturnal departures is based on surveillance radar data that 'have focused on the starting time for the main exodus of migrants at dusk, and at the variation of this starting time between days' (Åkesson et al. 1996). In contrast, methodologically more reliable telemetric data showed that in most species studied a varying proportion of individuals may depart much later than Evening Nautical Twilight Period (Cochran et al. 1967; Åkesson et al. 1996, 2001; Moore & Aborn 1996; Bolshakov & Chernetsov 2004). Using telemetric data, it is assumed that the timing of nocturnal flight initiation in passerine migrants varies between species, latitudes, seasons, and individuals (Åkesson et al. 2001). Unfortunately, the available telemetric data are limited to several songbird species from the Old and New World and, with one exception, suffer from small sample size (Table 1). Together with scarce data on flight duration (Cochran 1987; Wikelski et al. 2003; Cochran & Wikelski 2005) and time of landing (Bolshakov 1981; Bolshakov et al. 2002, 2003a, b) it hampers the analysis of control mechanisms of temporal schedule of flight in passerine nocturnal migrants and principles of organization of migration.

In this study, we investigated natural migratory flight initiation in medium-distance nocturnal migrants, European robins, *Erithacus rubecula*, by radiotelemetry. Our aims were

(1) To obtain direct data on departure time in a large sample of migrants and to test the hypothesis that nocturnal passerine migrants depart on migration during a limited time period shortly after sunset, and that certain astronomical situations trigger departures.

(2) To investigate the influence of celestial orientation cues by comparing departure times under clear and overcast skies.

(3) To compare departure times in spring and in autumn.

(4) To test the importance of fuel stores for departure time. Fuel stores are known to influence flight versus stopover decisions (Dolnik 1975, 1995) and possibly flight schedule.

(5) To test the relationship between departure time and duration of preceding fuelling periods at stopover.

METHODS

Study Area, Study Species and Selection of Birds

European robins were mist-netted at a stopover site on the Courish Spit (southeast Baltic coast, Russia 55°09′N, 20°51′E) in spring and autumn 2002–2003 in the framework of a long-term trapping project (Chernetsov & Titov 2000). In the study area most European robins are transient migrants which breed in the Baltic countries, Finland and NW Russia and spend their winter in southwest and south Europe (Payevsky 1973; Bolshakov et al. 2001).

In autumn, European robins were radiotagged between 2 September and 20 October (69 hatching-year birds), in spring between 1 and 30 April (47 birds in their second calendar year and five older individuals). In both seasons, the following criteria for selecting birds were met based on the aims of the study.

(1) We radiotagged the birds that were initially captured on the first day of a rise in numbers of European robins at stopover after a migratory pause. As European robins migrate exclusively by night, it allowed us to assume that the birds had just arrived to the study site after at least one migratory flight during the previous night. It has been shown by seniority analysis that the bulk of European robins initially captured during a wave of nocturnal migration when a high number of captures occurs, had indeed just arrived (Chernetsov & Titov 2000). Arrival date was known for 119 birds out of 121. All birds were ringed at first capture, then a proportion of them were

Table 1. World telemetric data on take-off time in passerine nocturnal migrants

Species	Region	*N**	Season	Source
Hylocichla spp. (3 species)	N. America	18 (18)	Spring	Cochran et al. 1967
Catharus ustulatus	N. America	1 (1)	Spring	Cochran 1987
Turdus philomelos	Europe	2 (2)	Spring	Åkesson et al. 1996
Turdus philomelos	Europe	8 (4)	Autumn	Åkesson et al. 1996
Turdus merula	Europe	1 (1)	Autumn	Åkesson et al. 1996
Erithacus rubecula	Europe	1 (0)	Autumn	Åkesson et al. 1996
Luscinia luscinia	Europe	3 (2)	Autumn	Åkesson et al. 1996
Acrocephalus scirpaceus	Europe	38 (29)	Autumn	Åkesson et al. 2001
Piranga rubra	N. America	17 (0)	Spring	Moore & Aborn 1996
Catharus minimus	N. America	5 (5)	Spring	Cochran et al. 2004
Catharus ustulatus	N. America	5 (5)†	Spring	Cochran et al. 2004
Ficedula hypoleuca	Europe	4 (3)	Spring	Bolshakov & Chernetsov 2004
Acrocephalus schoenobaenus	Europe	12 (12)	Spring	Bolshakov & Chernetsov 2004
Erithacus rubecula	Europe	45 (42)	Spring	This study
Erithacus rubecula	Europe	62 (58)	Autumn	This study

*Number of birds whose departure time was known exactly is given in parenthesis. For the remaining birds, only the period of night is known.
†In one individual, take-off time was known for four consecutive nocturnal flights.