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Breeding biology of Montagu's Harrier *Circus pygargus* in north-central Kazakhstan

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Abstract The ecology and conservation status of Central Asian populations of Montagu's Harriers *Circus pygargus* are poorly known. We studied the breeding biology of this species during 3 years in the Naurzum region, north-central Kazakhstan. Most Montagu's Harriers in the study area nested in the forest-steppe transition area, in bushy areas dominated by dogrose *Rosa canina*, which was apparently the nesting vegetation type providing highest and densest nest cover in the study area. Laying occurred from 26 April to 7 June (average 13 May, $n = 49$) and, although it varied significantly between years, was earlier than in western European populations of similar latitude. Mean (±SD) clutch size was 4.44 ± 0.86 (range 2–6; $n = 50$), in the higher range observed for the species. There was no significant interannual variation in clutch size, despite large variations in the abundance of small mammals in the area. Diet was mainly composed of lizards (54.2%, $n = 533$ identified prey in all 3 years), with small mammals (17.1%), passerine birds (14.3%) and insects (13.6%) also being consumed. Mean brood size at the last visit was 2.55 ± 2.10 (range 0–6; $n = 51$). Failure rate was relatively high; the main identified cause of nest failure was predation. We compare the data obtained in this population breeding in natural steppes with breeding parameters from the well-studied western European populations, and discuss the implications for the conservation of this species.

Keywords Breeding biology · Steppes · Kazakhstan · Diet · Conservation

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Introduction

The Montagu's Harrier *Circus pygargus* is a migratory raptor species that breeds from north Africa and west and central Europe across to Russia and central Asia (Cramp and Simmons 1980; Del Hoyo et al. 1994). In Europe, a decade ago, the species had a conservation status of "least-concern" (Tucker and Heath 1994), although this categorisation was mainly based on a very large estimation of the breeding populations in European Russia (Tucker and Heath 1994), possibly unreliable due to the few data available on recent population trends of this species in this part of its distribution range. More recently, it is still considered as "secure" mainly based on a positive trend in the large Russian population, but which has been insufficiently quantified (Birdlife International 2004). In the core areas of western European populations (France and the Iberian Peninsula), it is considered vulnerable or conservation dependent (Millon et al. 2004; Arroyo and García 2008). There is no information about the conservation status or trends of the Asian populations, which are thought to contain a significant part of the global breeding population (ca. 25,000–30,000 pairs; Ferguson-Lees and Christie 2001), although again these estimates are not very precise.

This ground-nesting species traditionally breeds in open landscapes with dense and tall herbaceous plant communities including marshes, lowland heath, rough grasslands and steppes. However, in the western Palaearctic, it has taken to agricultural areas in recent decades, breeding mainly in winter cereal or alfalfa fields. In the late twentieth century, more than 90% of breeders in the Iberian Peninsula nested within cereal crops; the proportion of birds breeding in cereal crops was 70–80% in France, and 40–50% in other western European countries (Arroyo et al. 2003). The change to agricultural habitats was probably catalysed by degradation or loss of natural breeding habitats, but it is likely that this was not the only reason. Indeed, the change from natural to agricultural areas has had a geographic spread (starting in south-west Europe and progressing east and north), and increased rapidly after the first occurrence in each area, more rapidly than the rate of habitat loss (Arroyo et al. 2003).

The Montagu's Harrier is a relatively well-studied species of harrier, with numerous population studies in western Europe in recent decades (review in Arroyo et al. 2004). Most of those studies, however, considered populations breeding in agricultural areas. In such areas, population sustainability depends mainly on conservation measures that reduce breeding losses due to crop harvesting (Arroyo et al. 2002). In contrast, very few studies have been carried out in Montagu's Harrier populations breeding in natural and unaltered habitats (e.g. Limiñana et al. 2006). In particular, there is little information on the breeding ecology of Montagu's Harriers in Asian steppes, despite the apparent demographic relevance of these populations (Ferguson-Lees and Christie 2001). A better knowledge of the breeding ecology of Montagu's Harriers in steppe areas may help improving our understanding of the stability of Montagu's Harrier populations at a global scale.

In this paper, we report on a 3-year study of the density, breeding habitat and breeding parameters of Montagu's Harriers in north-central Kazakhstan. This population breeds primarily in natural vegetation, in a steppe ecosystem partly protected from major anthropogenic modifications or used extensively for grazing. We compare our results with those observed in well-studied populations breeding in natural and agricultural habitats in western Europe, and discuss results in terms of conservation for the species.

Methods

Study area and field methods

The study area was located in and around the Naurzum *Zapovednik* (National Nature Reserve) in the Kostanay Oblast, north-central Kazakhstan (51°N, 64°E). This area is at the juncture of the southern limit of Siberian forests and the northern limit of Eurasian steppes. We regularly checked for breeding harriers along the network of accessible tracks within the area, which totalled 350 km in length, which means, assuming a visibility of 1 km at each side of the transect line, a total surveyed area of ca. 700 km^2. The habitat included a mosaic of dry steppes with feather grass *Stipa* spp. and bunch grasses on the poorer soils, low sagebrush *Artemisia spp*. and other nutrient-rich shrubs and grasses on denser soils. Reeds and phragmites occurred along rivers or in semi-permanent ponds throughout the study area. The area outside the Reserve boundaries was used by humans mainly for sheep, horse and cattle grazing (grazing is not authorised within the Reserve boundaries). Additionally, more than 50% of the steppe outside the Reserve was ploughed for wheat cultivation during the 'virgin lands' program initiated in the 1950s (Katzner et al. 2005), so part of the area was covered by agricultural land (mainly cereal crops). Much of this area turned to fallow in the 1990s, having been neglected since the dissolution of the USSR (Katzner 2003), although we observed a trend for agricultural re-intensification between 2000 and 2007. Finally, interspersed within the steppe matrix, there were three distinct woodland patches (all within the Reserve) dominated mainly by Scots pine *Pinus sylvestris*, birch *Betula spp*. and aspen *Populus spp.* The transition areas between forest and steppe ecosystems were characterised by bushy areas mainly composed by dogrose *Rosa canina* and spirea *Spirea* spp. bushes. Detailed quantitative data on the surface covered by these different habitat types is currently lacking, but based on semi-quantitative observations along our network of tracks, 20% of the monitored area was agricultural land, 60% was unprotected non-agricultural areas (including steppe, riverine habitats, and bushy areas, the latter not covering more than 5% of the surface), and 20% was protected areas (within Naurzum Reserve, including steppe, forest, riverine habitats, and bushy areas, the latter not covering more than 5% of the surface).

On the study area, voles *Microtus ssp* exhibit strong annual fluctuations in abundance like in other more studied vole populations (Zhang et al. 2003; Lambin et al. 2006). Fieldwork took place in June 2000, June 2006 and between April and July 2007. We quantitatively assessed vole abundance in 2006 and 2007 by using an index based on the presence/absence of fresh vole droppings. Twenty-five quadrats (25 cm × 25 cm) were randomly located in 11 (2006) and 25 (2007) randomly selected 1 × 1 km^2 areas spread throughout the study site and sampled for the presence (1) or absence (0) of fresh voles faeces (moist and greenish in colour). Presence/absence scores were then summed across the 25 quadrates in each area (Madders 2003). These sampling showed a mean score of 13.8. ± 7.6 per area in 2006 ($n = 11$), versus 0 ± 0 in 2007 ($n = 25$). We did not quantitatively assess vole abundance in 2000, but, based on data on the breeding success of other raptor species present on the study area and on qualitative observations of voles at night during mammal censuses (Bragin and Katzner, personsal communication; Terraube et al. 2009), we estimated that this year was a high vole abundance year, similar to 2006.

We located harrier nests by following males carrying prey and watching where females landed after a food pass. During the first survey (June 2000), we located 34 Montagu’s Harrier nests of which 16 were visited. In June 2006, we found and visited 26 Montagu’s Harrier nests. During the 2007 field season, 26 nests were also found and visited. Upon the first nest visit, we recorded vegetation type and height at the nest site (in m, averaged from two measures at the edge of the nest). Additionally, vegetation density was categorised as sparse, medium, dense or very dense, by estimating the percentage of plant cover within a 1-m^2 area including the nest. Vegetation height or density were not measured at random points, so it was not possible to evaluate selection of nest sites in relation to vegetation height. However, for comparison, we present data on vegetation heights recorded (with a similar methodology to that described above for Montagu’s Harrier nests) at Pallid Harrier *Circus macrourus* nests across the study area, in order to give an indication of the range of heights of other potentially suitable vegetation available in the area. Pallid Harriers nested in three habitats representative of the main vegetation types in the open habitats of our study area, steppe vegetation (ray-grass or *Artemisia*), riverine habitats (reeds and phragmites) and agricultural areas (set-asides or cereal fields) (Terraube et al. 2009).

For each nest visit, we recorded clutch size or number of nestlings. If the nest contained nestlings, we measured the 8th primary length (in mm) to age nestlings (Arroyo 1995). Laying date was estimated directly if the nest was visited during laying, or by subtracting 30 days from the estimated date of hatching (estimated from nestling age). We calculated relative laying date for each nest as the difference between the laying date for that nest and the average laying date for that year. First year and adult (>1 year old) females were identified from plumage characteristics (see Forsman 1999).

During nest visits, we tried to minimise the length of the stay at the nests and to leave the vegetation as undisturbed as possible, to minimise the risk that human disturbance would make nests more vulnerable to predation. We believe that our nest visits were unlikely to have significantly increased predation rate because of two observations: (1) in 2000, nests monitored at distance without being visited failed at the same rate than visited nests (authors, personal observations); and (2) Pallid Harrier nests on the study area in the same study years (whose nests were visited in the same manner as those of Montagu’s Harriers) had very low predation rates (see Terraube et al. 2009).

The location of all nests was marked with a GPS. Between-nest distances were calculated in Arc View 3.2 from GPS locations. We used data from all the nests located, including those that were not visited. We calculated for each nest the number of breeding neighbours present within 1 km using Arcview 3.2.

To characterise diet, we collected pellets each year at nests or perching sites, and also included observations of prey deliveries at the nest, when we could identify the prey type. Pellets were analysed and their contents were classified as “birds”, “small mammals”, “reptiles” and “insects”. We could not identify all pellet contents to species, but most (95.3%, $n = 37$) small mammals identified were voles. We assessed the minimum number of each prey category per pellet. Data from pellets only were too few (particularly in 2006) to allow Chi-square analyses among years, so we have combined pellets and prey observations at nests. Prey biomass was estimated for each prey type following Arroyo (1995) as 20 g for small mammals, 29 g for birds, 10 g for reptiles, 5 g for insects and 15 g for eggs.

Weather data for the 3 years of the study was obtained through the meteorological station of the Naurzum Nature Reserve (E. Bragin, unpublished data). Available data were average daily temperature for 2006 and 2007, and average temperature for each 10-day period each month for 2000. Additionally, we had access to monthly total rainfall each year. Given that daily temperatures were only available for 2006 and 2007, we only performed statistical tests for those 2 years.

Data analysis

We used generalised linear models (GLM) to test for between-year differences in breeding density, laying date or temperature. Inter-nest distance, laying date or temperature were fitted to models using a normal error distribution. Number of neighbours within a 1-km radius was fitted to models using a Poisson distribution.

We also analysed variations in clutch and brood size in relation to breeding phenology and year using GLM, fitting the response variables to a normal distribution. The initial model included “laying date”, “year” and their interactions as explanatory variables. Non-significant terms were removed sequentially until the most parsimonious model was obtained.

Given that in two of the years monitoring occurred only during a limited time span (1 month), we could not calculate breeding success directly by evaluating the proportion of pairs that start breeding that lead to at least one fledging (the usual procedure in raptor studies; Steenhof 1987). In contrast, and to avoid underestimations, breeding success (i.e. the proportion of nests in which there was at least one fledging) was estimated by modulating the observed failure rate by the "exposure time" (number of days between first and second visit; Mayfield 1975). Nests visited only once were not included in this analysis. This means there were not sufficient data for 2000 to calculate breeding success, and data are only presented for 2006 and 2007.

All tests are two-tailed and data are presented as means ± SD.

Results

Breeding habitat

Surveys to locate harrier nests were conducted in a large variety of habitat types, including steppe, marshland and agricultural areas (see Terraube et al. 2009). For the 67 nests monitored during the 3 years, nest vegetation-type ranged from steppe areas with *Artemisia* patches (5.97%, $n = 4$), to dense reeds on riverine habitats (2.98%, $n = 2$), ray grass (1.49%, $n = 1$), *Spirea* bushes (1.49%, $n = 1$), or berry bushes (4.47%, $n = 4$). However, the majority of nests (83.58%, $n = 55$) were found in dogrose bushes in the forest-steppe transition area. Vegetation height at the nest site averaged 109 ± 33 cm (range 50–200, $n = 64$). For comparison, mean vegetation height at Pallid Harrier nests was 53.63 ± 14.9 cm for nests found in steppe vegetation ($n = 22$), 156.11 ± 62.3 cm for nests found in riverine habitats ($n = 36$), and 30 ± 18.3 cm for nests in agricultural areas ($n = 8$). Vegetation density around Montagu's Harrier nests was classified as very dense in 15% of the cases ($n = 53$), 53% of the nests were situated in dense vegetation, and medium dense in 32% of the cases. No nests were found in sparse vegetation. For comparison, 44% of Pallid Harrier nests appeared in sparse vegetation (mainly in agricultural or steppe vegetation), and 56% in dense vegetation (in riverine habitats) ($n = 75$).

Breeding density

Distance to nearest breeding neighbour averaged 1,031 ± 2,487 m (range 39–15,733 m; $n = 65$ active nest-sites). Average breeding density (number of breeding neighbours present within a 1-km circle around each nest) was 2.75 ± 2.14 (range 0–8, $n = 65$). Average breeding density varied significantly between years (GLM: $\chi_2^2 = 8.46$, $P = 0.015$) with density being significantly higher in 2007 than in 2006 (GLM: $\chi_1^2 = 7.60$, $P = 0.006$). There was also a tendency for density to be higher in 2007 than in 2000 (GLM: $\chi_1^2 = 3.64$, $P = 0.056$).

Breeding phenology

Laying occurred from 26 April to 7 June ($n = 49$; average: 13 May). Mean laying dates varied significantly between years (GLM; $\chi_2^2 = 23.25$, $P < 0.0001$), with laying being almost 2 weeks later in 2007 than in the other years studied (2000: 6 May ± 13 days, $n = 13$; 2006: 7 May ± 8 days, $n = 19$; 2007: 22 May ± 9 days, $n = 17$; Fig. 1a). Mean April temperatures were significantly lower in 2007 than in 2006 ($\chi_2^2 = 7.52$, $P = 0.0061$). More precisely, temperatures of the first and second decades of April were significantly lower in 2007 than in 2006 ($\chi_2^2 = 12.66$; $P = 0.0004$ and $\chi_2^2 = 16.02$; $P < 0.001$, respectively), and also much lower than in 2000 (Table 1).

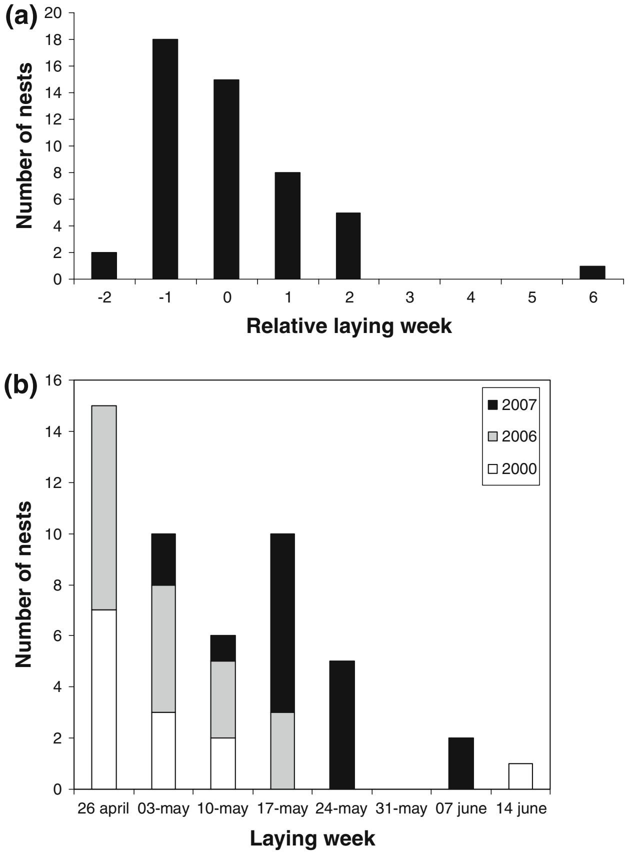

Fig. 1 Frequency distribution of laying dates (**a**) and relative laying dates (**b**) in Montagu's Harrier *Circus pygargus* in north-central Kazakhstan for the 3 years of the study. In Fig. 1b, week 0 is the week of the average lay date in each year

Table 1 Mean temperatures and precipitation levels of the three spring months of the study period (2000, 2006 and 2007)

Year	2000		2006		2007	
	Mean temperatures	Precipitation (mm)	Mean temperatures	Precipitation (mm)	Mean temperatures	Precipitation (mm)
April 1[a]	4.5		5.0 ± 5.3		−2.5 ± 2.7	
April 2	11.6		11.4 ± 4.1		4.2 ± 2.6	
April 3	14		8.0 ± 5.4		10.5 ± 2.1	
April	10 ± 4.9	20.7	8.1 ± 5.2	13.9	4.0 ± 5.9	24.3
May 1	9.9		9.4 ± 4.1		7.0 ± 8.1	
May 2	9.9		15.3 ± 2.4		15.3 ± 3.7	
May 3	14.2		19.4 ± 3.6		20.7 ± 2.7	
May	11.3 ± 2.4	36.8	14.8 ± 5.3	29.6	14.5 ± 7.7	56.4
June 1	17.8		21.8 ± 3.6		12.3 ± 4.5	
June 2	20		25.5 ± 4.5		19.5 ± 5.4	
June 3	25.5		20.0 ± 0.9		24.7 ± 4.8	
June	21.1 ± 3.9	32.9	22.4 ± 4.0	12.1	18.8 ± 7.0	27.9
Vole index	No data		13.8 ± 7.6		0 ± 0	

[a] April 1, 2, 3 refer to the first, second and third decades of April, respectively (same for May and June)

When taking into account annual differences, laying onset extended over 8 weeks (Fig. 1a). However, most (75.9%) clutches each year were laid within a 3-week period (Fig. 1b).

Breeding parameters

Clutch size averaged 4.44 ± 0.86 (range 2–6, $n = 50$). There was no significant variation in clutch size among years and this parameter was not significantly related to laying date (GLM; year: $\chi^2_2 = 0.83$, $P = 0.66$; laying date: $\chi^2_1 = 0.44$, $P = 0.51$), or relative laying date (GLM; relative laying date: $\chi^2_1 = 0.\ 18$, $P = 0.67$).

Mean brood size at the time of the last visit was 2.55 ± 2.10 (range 0–6, $n = 51$). Brood size variation was not significantly explained by year (GLM; $\chi^2_2 = 3.40$, $P = 0.18$) or laying date (GLM; $\chi^2_2 = 0.90$, $P = 0.34$).

The proportion of breeding females that were first year birds was 6.3% ($n = 16$) in 2000, and 11.5% in 2006 and in 2007 ($n = 26$ for each year). This proportion did not differ significantly between years ($\chi^2_2 = 0.41$, $P = 0.82$).

Nest failures

The mean percentage of failed nests over the 3 years of the study was 30%, ranging from 7.69% (of 26 nests) in 2006 to 43.75% (of 16 nests) in 2000, with an intermediate value (38.46% of 26 nests) in 2007. Of the 18 nests failed during the 3 years, 9 failed during incubation and 9 during the nestling period. On most occasions, there were no remains left at the nest, but in 5 nests in 2007, broken eggshells were present, and in 2 nests in 2000, nestling remains were found. In these cases, predation by mammals was the most likely cause of failure.

Mayfield nest success was 65% (95% CI 44.7–85.3%) for 2006 and 20.2% for 2007 (95% CI 2.7–37.7%). Although data for 2000 were insufficient to calculate Mayfield nest success, we know that 7 of the 16 nests visited in 2000 failed, all but one of them in a single colony. In other colonies, the proportion of located nests that were visited was smaller, but we know that they were active at last visit, so overall failure rate may have been lower than that calculated from our own nest visits.

Diet

Combining pellets and observations in all 3 years, lizards formed the main prey category by number (54.18%, $n = 537$ identified prey in total), whereas the percentage of small mammals was 17.13%, birds represented 14.33% and insects 13.59% of all prey. In terms of biomass, birds were the most important prey (38.70%), followed by small mammals (31.30%) and lizards (27.91%). Comparing pellets with observations at the nest, lizards were more frequent at nests (66.6%, $n = 96$ identified prey in nest deliveries) than in the pellets (51.47%, $n = 441$ identified prey in pellets). Insects were never identified at nests, although their frequency in pellets was 16.55%. Percentages of small mammals and birds were similar, regardless of how diet was determined. The overall proportion of each prey type in the diet changed significantly among years ($\chi^2_6 = 37.95$, $P < 0.001$), with birds being more common, and lizards less common in 2000 than in other years (Fig. 3).

Discussion

The main findings of this study were that Montagu′s Harriers in north-Kazakhstan: (1) use dogrose bushes for nesting more frequently than they use other vegetation types; (2) had a diverse diet based on reptiles, passerines and small mammals; (3) had large clutches, suffered relatively high nest failure rates, but appeared nevertheless to have relatively high productivity; and (4) experienced little interannual variation in breeding parameters.

The regular use of dogrose as a nesting habitat, with most (84%) nests found in that vegetation despite it covering less than 10% of the total surface (see "Methods"), was probably associated with the height of that vegetation. It is known that Montagu's Harriers select relatively tall vegetation for placing their nests (Arroyo et al. 2004 and references therein). The steppe vegetation is relatively low throughout the whole breeding season (see "Breeding habitat" for mean vegetation height around Pallid Harrier nests in steppe vegetation), and the reeds or agricultural vegetation are not grown when Montagu's Harriers return to the breeding grounds (authors, personal observatons). Dogrose bushes may thus be the only vegetation in the area that is tall enough at settlement time to be attractive to Montagu's Harriers. This may mean that, in the natural steppes of Kazakhstan, the suitable habitats available for nesting are limited. The observed high vegetation density at Montagu's Harrier nests (as compared to nests of Pallid Harrier) may be a by-product of Montagu's Harriers nesting in Dogrose, usually denser than alternative vegetation, or may indicate that Montagu's Harriers also prefer dense vegetation as a protection from predators (Claro 2000).

Average first egg laying date for the Montagu's Harriers in this population was mid-May. Laying dates are known to vary with latitude (Arroyo et al. 2004). Combining data for the 3 years of the study, laying dates in the Naurzum region were 5 days earlier than expected from the relationship between laying date and latitude in other studied populations (Fig. 2). This difference increased to 15 days if excluding data from 2007, the year when laying was significantly later, most likely because of bad weather conditions (see below). All other studied Montagu's Harrier populations winter in western or central Africa (Limiñana et al. 2007; Trierweiler et al. 2007). The observation that Montagu's Harriers breeding in Kazakhstan breed somewhat earlier (relative to latitude) than western European birds may indicate that they winter in areas that are closer to their breeding grounds than their western European counterparts (or that their spring migration starts relatively earlier), or else that weather conditions on arrival to the breeding grounds in Kazakhstan are more benign than those of western Europe at similar latitudes. Indeed, mean temperatures in Naurzum in April were low (Table 1) in comparison with a same latitude western European site (Rotterdam, mean temperature in April: 8.2°C. http://www.worldclimate.com). But mean temperatures in Naurzum increased quickly and reached a mean of 14.2 ± 4.9°C in May, as compared to an average of 12.5°C in May in Rotterdam. This difference could be related to the strong continental climate characteristic of central Asian steppes, which could explain the earlier laying dates observed in our study population. The likely effect of weather on laying dates is also supported by the fact that laying in 2007 was delayed by 2 weeks. Interannual differences in laying date in a given population might be explained by differences in weather conditions (Sergio, 2003a, b; MacDonald et al. 2004) and/or food abundance (Potapov 1997; Steenhof et al. 1997; Salamolard et al. 2000; Nielsen and Moller 2006). It is unlikely that food abundance was the main reason behind the delay in laying observed in 2007, given that clutch sizes were large and similar to those of previous years. On the other hand, the low temperatures observed in 2007 during the pre-laying period might have delayed laying that year.

The mean clutch size in our study population was among the largest found for this species in western Europe (Table 2). Interestingly, we found no significant interannual variations in clutch size or the proportion of breeding first-year females, despite strong variations in the abundance of one of their prey, voles. This is in contrast to that observed in western European vole-eating populations (Salamolard et al. 2000; Millon et al. 2002; Koks et al. 2007). Montagu's Harriers in the study area had a generally diverse diet, and voles were not the most important part of the diet, even in years of high vole abundance (population outbreaks). This may be related to abundance of other prey: although we could not measure those during this study, it was qualitatively apparent that both passerines and lizards were very abundant in the area (authors, personal

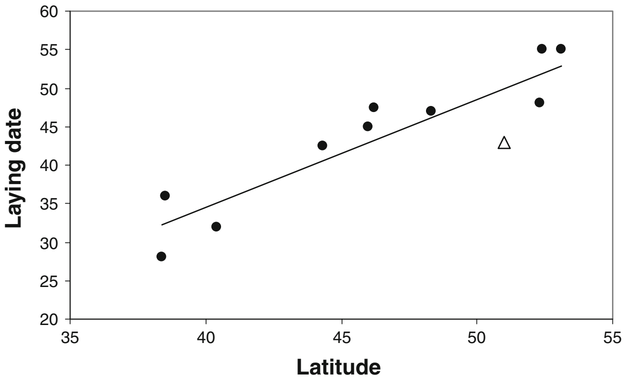

Fig. 2 Relationship between mean laying date and latitude in 11 populations of Montagu's Harrier (western Europe *black dots*, Kazakhstan *white triangle*) (data from Arroyo et al. 2004 and this study)

Table 2 Variations of clutch size of Montagu's Harriers in different parts of Europe and Central Asia (modified from Arroyo et al. 2004)

Location	Clutch size	*n*	Range	References
The Netherlands	4.20 ± 0.80	112	2–7	Bijlsma et al. (1993)
Poland	3.90–4.40	125	2–5	Krogulec and Leroux (1994)
England	4.02 ± 0.07	227	2–10	Underhill-Day (1990)
France, Morbihan	4.27 ± 0.14	29	3–6	Hays (1971)
France, Maine et Loire	3.69 ± 0.19	26	2–5	Cormier (1985)
France, Vendée	3.61 ± 0.17	23	2–5	Cormier (1985)
France, Vendée	3.75 ± 0.80	101	2–6	Arroyo et al. (1998)
France, Charente-Maritime	2.80 ± 0.40–4.39 ± 0.15	200	1–6	Butet and Leroux (2001); Arroyo et al. (1998)
France, Deux Sevres	4.28 ± 1.09	143	2–8	Arroyo et al. (1998)
France, Champagne-Ardennes	3.65 ± 1.01	111	1–6	Millon et al. (2002)
Italy, N. Appenines	3.32	31	–	Faralli (1994)
Italy, Marche	3.8	37	–	Pandolfi and Giacchini (1991)
Italy, Emilia-Romana	3.70 ± 0.80	61	2–5	Martelli and Sandri (1991)
Spain, Madrid	3.93 ± 0.84	215	2–6	Arroyo et al. (1998)
Spain, Ciudad Real	4.30 ± 1.00	120	2–9	Castaño (1997)
Spain, Badajoz	3.48 ± 0.99	98	1–5	Corbacho et al. (1997)
Spain, Castellón	4.34 ± 0.84	266	2–8	Limiñana et al. (2006)
Spain, Cáceres	3.31 ± 0.65	19	2–5	Pérez Chiscano and Fernández Cruz (1971)
Portugal, Evora	3.97 ± 1.04	36	2–6	Claro (2000)
Portugal, Castro Verde	2.82 ± 0.40	11	2–3	Onofre (1995)
North-central Kazakhstan	4.44 ± 0.86	50	2–6	This study

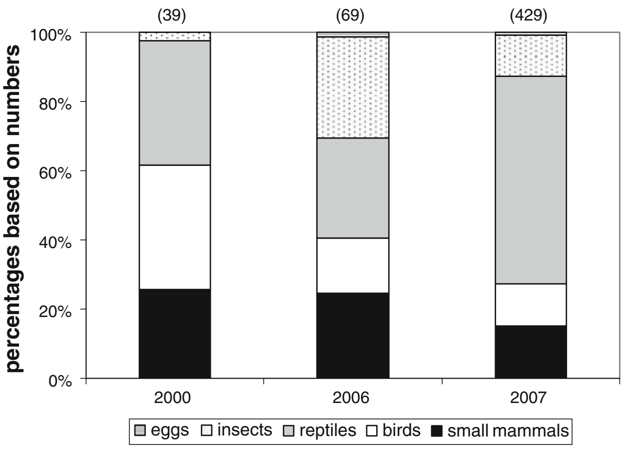

Fig. 3 Diet composition (percentages based on prey numbers) of Montagu's Harriers in the Naurzum region during the study period (2000, 2006 and 2007). Sample sizes (*above columns*) refer to the number of identified prey items

observations). Observed interannual variations in diet could be linked to variations in the abundance of non-vole prey, or to differences in sampling between years (e.g. low sample size in 2000; Fig. 3). Interannual differences in clutch size have nevertheless been observed in generalist populations in western Europe (Arroyo and Garcia 2006; or Castaño 1995), so it is possible that the duration of our study (3 years) was not enough to detect interannual variations, which are expected to be lower in amplitude for generalist than for specialist predators.

Another interesting result was the absence of seasonal decline in clutch size, as reported in many other studies on Montagu's Harrier (Castaño 1995; Salamolard 1998; Millon et al. 2002; Koks et al. 2007), other raptors (Newton and Marquiss 1984; Korpimäki and Wiehn 1998; Mougeot and Bretagnolle 2006) and more generally in bird species (Arnold et al. 2004). A seasonal decline in clutch size is usually related to a difference in the quality of individuals breeding earlier versus later in the season, or to a degradation of environmental conditions, with poorer breeding conditions later in the season (decreased food resources and/or more frequent adverse climatic events). Only one previous study on this species did not find any relationship between laying date and clutch size (Corbacho and Sanchez, 2000). In our study population, this absence of seasonal clutch size decline could be explained by the marked laying synchrony observed in the 3 years of the study, when at least 63.2% of the monitored pairs started laying within a 2-week period (see Fig. 1b). A similar pattern has been observed by Arroyo (1995) in a Spanish population of Montagu's Harriers during years of high breeding synchrony.

Estimates of nest failure rates were higher than in western European populations, when excluding failures due to harvesting activities (Arroyo et al. 2004 and references therein). The most important identified cause of failure was predation. A high predation rate in our study population may be expected, since the predator community of north-central Kazakhstan steppes is very rich. However, it is difficult to discriminate between ultimate and proximate causes of failure, because in most cases no remains were found (so the cause of failure is unknown), and if broken eggshells appeared it was difficult to differentiate whether the nest had been predated, or the eggs had been abandoned and subsequently eaten by scavengers (such as corvids). A combination of poor food supply to incubating females, inclement weather and predation may be involved. Overall, in any case, the Montagu's Harrier population in the Naurzum area appeared to have high nest failure rates, with predation being a non-negligible cause of failure. Predation rates could also be high after fledging, because the Naurzum area supports an extremely high density of eastern Imperial Eagles *Aquila heliaca* that regularly prey on harriers (Katzner et al. 2006). The role of predation on the breeding success of this population needs further research.

Despite relatively high failure rates, it appeared that the Montagu's Harrier population had a relatively high productivity. Unfortunately, fieldwork was only undertaken during a short period during the first 2 years of the study, and there was thus not enough information to evaluate fledging success and productivity for those years. Nevertheless, there were no differences in brood size among years, including 2007 when monitoring was more intense, and the mean brood size at the last visit was in the top range of those observed in western European populations nesting in natural vegetation or when conservation measures to protect nestlings from harvesting activities are in place (2.74 in Castellón, Spain, Limiñana et al. 2006; 1.80 ± 0.21 in Groningen, Netherlands, Koks et al. 2001; 1.83 ± 1.33 in western France, Salamolard et al. 2000; 2.50 ± 1.52 in Extremadura, Spain, Corbacho et al. 1997; 1.90 ± 1.57 in central Spain, Arroyo 1995).

In conclusion, Montagu's Harrier populations breeding in natural steppes of northern Kazakhstan appear to be relatively productive despite high failure rates, which suggest that they may have sustainable dynamics. However, they seem dependent on a relatively scarce habitat (dogrose bushy areas), which may be further depleted if steppe areas are turned into alternative land uses, such as agriculture, or could be sensitive to overgrazing. One of the main threats for steppe habitats in north Kazakhstan is the likely expansion of cereal agriculture in the near future. In our study area, good meteorological conditions and the overall economic growth in recent years has allowed the expansion of the agricultural areas onto adjacent steppe biotopes (Bragin 2003). It is relevant that the most preserved shrubland areas (holding the main breeding colonies of Montagu's Harriers) in our study area were inside a National Nature Reserve, whereas this type of habitat appeared to be more fragmented in grazed and farmed steppe areas. Additionally, climate changes through an increase in fire frequency (as it seem to have been the case in recent years) could further reduce the availability of Montagu's Harrier breeding habitats in our study area. It would be important to determine whether this is the trend in central Asia at large.

It would also be interesting to evaluate the population implications of breeding in agricultural versus natural habitats for the species. Agricultural habitats are widely available, but published data show that at present 60% of nestlings in the Iberian Peninsula and France would die because of harvesting activities if unprotected by conservation measures, and that such a reduction in productivity would make harrier populations unsustainable in the absence of conservation measures (Arroyo et al. 2002). Additionally, the current intensification rate of western Europe agricultural areas has led to important reductions in food abundance (voles and passerine birds; Butet and Leroux 2001; Donald et al. 2001), so food availability might be more limiting in western European areas than in the preserved steppes of Central Asia. Breeding in natural vegetation may lead to higher productivity (e.g. Limiñana et al. 2006), but these populations may be more threatened by habitat disappearance and, as predator communities are more diverse, may suffer higher predation rates during the breeding period. Further research is needed to better understand the dynamics of these different populations and the interplay between breeding habitat selection and availability, breeding success, food availability and predation levels.

Zusammenfassung

Brutbiologie der Wiesenweihe (*Circus pygargus*)
in Nord-Zentralkasachstan

Über die Ökologie und den Bedrohungsstatus zentralasiatischer Populationen der Wiesenweihe *Circus pygargus* ist nur wenig bekannt. Wir haben die Brutbiologie dieser Art in der Naurzum-Region in Nord-Zentralkasachstan über einen Zeitraum von drei Jahren untersucht. Die meisten Wiesenweihen im Untersuchungsgebiet brüteten in der Überganszone zwischen Wald und Steppe in Buschbereichen, die von der Hunds-Rose *Rosa canina* dominiert wurden; dieser Vegetationstyp bot im Untersuchungsgebiet anscheinend die höchste und dichteste Deckung für die Nester. Die Eiablage erfolgte vom 26. April bis zum 7. Juni (Mittelwert 13. Mai, $n = 49$) und erfolgte früher als in westeuropäischen Populationen vergleichbarer geographischer Breite, wenn der Termin auch signifikant zwischen den Jahren schwankte. Die mittlere (±SD) Gelegegröße betrug 4,44 ± 0,86 (Spannweite 2–6; $n = 50$), was am oberen Rand des für diese Art beobachteten Bereichs liegt. Es gab keine signifikante Variation in der Gelegegröße zwischen den Jahren, obwohl die Abundanz kleiner Säugetiere in der Region stark schwankte. Die Nahrung bestand hauptsächlich aus Eidechsen (54,2%, $n = 533$ identifizierte Beutestücke in allen drei Jahren), doch auch kleine Säugetiere (17,1%), Sperlingsvögel (14,3%) und Insekten (13,6%) wurden gefressen. Die mittlere Brutgröße bei der letzten Kontrolle betrug 2,55 ± 2,10 (Spannweite 0–6; $n = 51$). Die Verlustrate war relativ hoch; der ermittelte Hauptgrund für Nestverluste war Prädation. Wir vergleichen die Daten, die in dieser in natürlicher Steppe brütenden Population gewonnen wurden, mit Brutparametern aus gut untersuchten westeuropäischen Populationen und diskutieren die Folgen für den Schutz dieser Art.

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