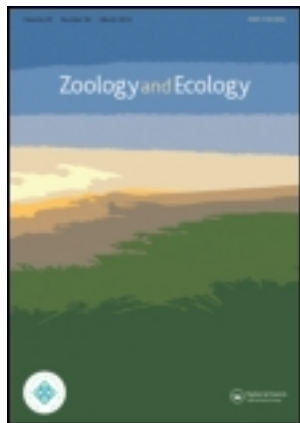


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RESEARCH ARTICLE

Breeding biology of the Montagu's Harrier (*Circus pygargus*) in east-central Poland and implications for its conservation

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In 2005–2011 active conservation and study on the population of the Montagu's Harrier was conducted in the farmland areas of east-central Poland. The population was estimated at 240–270 breeding pairs and its size was stable. The mean clutch size was estimated at 3.71 eggs per breeding pair. The number of fledglings was 1.24 per nest and 2.6 per successful breeding pair. There were no significant differences in sex ratio. The birds nested mainly in winter cereal and rape (70%). Population productivity positively correlated with a high number of nests located in late harvested crops. The pairs breeding in early harvested crops had significantly lower breeding success (10%) than the pairs nesting in winter cereal (>70%), due to losses during farming activities. Protection of broods with fencing had a positive effect on the breeding success of pairs nesting on arable fields. An important factor that had a negative impact on the breeding success of Montagu's Harriers was adverse weather conditions.

2005–2011 metais buvo vykdoma pievinių lingių intensyvi apsauga ir rūšies populiacijos tyrimai rytų centrinės Lenkijos dirbamuose laukuose. Pievinių lingių populiaciją sudarė 240–270 perinčių porų, vidutinis dėties dydis – 3,71 kiaušiniai vienai perinčiai porai, jauniklių skaičius – 1,24 jaunikliai vienam lizdai ir 2,6 jaunikliai vienai sėkmingai perėjusiai porai. Ryškaus skirtumo tarp patinų ir patelių skaičiaus nepastebėta. Paukščiai daugiausiai perėjo žieminių kultūrų ir rapso laukuose (70%). Populiacijos produktyvumas teigiamai koreliavo su dideliu lizdų skaičiumi laukuose, kur derlius nuimamas vėlai. Dėl aktyvios žemės ūkio veiklos perėjimo sėkmė buvo žymiai mažesnė laukuose, kur derlius nuimamas anksti (10%), nei žieminėse kultūrose (>70%). Lizdų aptvėrimas turėjo teigiamą įtaką dirbamuose plotuose perėjusių porų perėjimo sėkmei. Nepalankios oro sąlygos darė didelę neigiamą įtaką pievinių lingių perėjimo sėkmei.

Keywords: Montagu's Harrier; breeding biology; agrocenosis; active conservation; Poland

Introduction

The Montagu's Harrier (*Circus pygargus*) is a long-distance Palaearctic-African migratory raptor species wintering in sub-Saharan Africa (Clarke 1996; Simmons 2000). In Europe it is mostly found in extensive open landscapes. In their natural habitat, as breeding and hunting grounds Montagu's Harriers typically use scrubland, marshes, heather, moors, grasslands and other uncultivated areas. They build nests in high and dense vegetation (Clarke 1996; Cramp and Simmons 1980; Hiraldo, Fernandez, and Amores 1975; Kitowski 2002; Leroux 2004; Limiñana et al. 2006). Since the 1990s, 70–90% of breeding pairs in Western Europe have bred in agricultural habitats (Arroyo, García, and Bretagnolle 2002); however, in Spain and other European countries some populations still breed in their natural habitats (Cramp and Simmons 1980; Clarke 1996; García and Arroyo 2003; Limiñana et al. 2006). The populations breeding in agricultural habitats face substantial human pressure, which leads to high nest losses during farming works.

Between 20% and 70% nests of this ground-nesting species can be destroyed during agricultural activities such as mowing, threshing, and harvesting with large machines (Arroyo, García, and Bretagnolle 2002; Corbacho, Sánchez, and Sánchez 1997; Koks, Van Scharenburg, and Visser 2001; Millon et al. 2002). For this reason, active protection of nests is essential to improve the reproductive output of this species (through lower nestling mortality) and consequently to maintain or increase its population size (Arroyo, García, and Bretagnolle 2002; Corbacho, Sánchez, and Sánchez 1997; Koks and Visser 2002). The Montagu's Harrier is included in Annex I of the European Commission's *The Birds Directive* (2009/147/EC), which lists species that are classified as particularly threatened and in need of special conservation measures. In Poland, it is a scarce or very scarce lowland breeding species, occurring mainly in the eastern part of the country, in the Mazowsze, Podlasie and Lubelszczyzna regions (Tomiałojć and Stawarczyk 2003). In 2007–2009, the

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Polish population was estimated at 3,300–3,550 breeding pairs, with the coverage reaching 30% of the country area (Cenian 2009). Quantitative information about Montagu's Harriers breeding in cereal fields in Poland is extremely limited and remains largely unpublished. The breeding biology of this raptor was studied by Kitowski (2008) and Wiącek (2008), however, only on the populations nesting in saw sedge (*Cladium mariscus*) in the Chełm Calcareous Marshes (*Chełmskie Torfowiska Węglanowe*). It appears, however, that fundamental knowledge of the breeding biology of this species and of processes shaping its abundance is crucial for the effective management and conservation of its population. In addition, colonisation of new habitats (i.e. arable fields) by the species provides the opportunity to explore some adaptive behavioural changes, which can also shed new light on its conservation. In this study, we describe the Montagu's Harrier population inhabiting farmland areas in east-central Poland. Our research aimed at evaluating the effectiveness of brood protection methods applied in various types of crops. Our results should be taken into account when planning conservation actions for the Montagu's Harrier in Poland.

Study area

The study area (Figure 1) was located in east-central Poland (surface 6,260 km²). The area was dominated by farmland, of which over 70% was cultivated and comprised mainly (74%) arable land. Meadows and pastures comprised 18% and 7%, respectively (GUS 2005). Cultivated grassland prevailed in the Bug and the Liwiec River valleys, which were incorporated into the European Natura 2000 network as special bird protection areas, and in the Krzna River valley. Typical of this region were small patches of cultivated grassland, which served as important foraging sites for Montagu's Harriers (Dombrowski 1997). On arable fields the main crops were cereal and potatoes,

and in the recent years corn fields have also been expanded. Typical of the study area were small farms of ca. 8 ha (as of 2010, Agency for Restructuring and Modernisation of Agriculture [ARiMR]). The structure of crops and extensive farming practices favoured the nesting of Montagu's Harriers (Dombrowski 1997).

Material and methods

Data on the breeding biology of Montagu's Harriers were collected in 2005–2011, during implementation of conservation measures for this species. The sites potentially occupied by the birds were searched for in the first twenty days of May, which is the period of their highest detectability (by observation of courtship flights or nest building). Occupation of territories was double-checked in June and July. Since 2008, census counts were performed on ten sample plots (Figure 1). The number of breeding pairs was estimated based on the observed territories and the behaviour of adult birds, applying breeding and nesting criteria after Skikora et al. (2007). The number of sites was evaluated based on the number of loose groups of breeding pairs (semi-colonies) or isolated nests. Nests were searched for between June and July. In order to reduce predation risk, nests were typically visited 2–3 times in the whole breeding season (to find a nest, secure it, ring chicks and take their biometrics). Location of the nests was stored in a GPS device. Clutch size was recorded based on the nests with a full clutch laid (visits in June, when females incubate eggs) or nests with eggs and newly hatched chicks. Chick sex was determined from iris colour and thickness of the tarsus (Arroyo 1995; Clarke 1996).

As a conservation measure, we fenced 96 nests located in cereal, to protect them against predators and agricultural treatments, and monitored the effectiveness of this measure. This was done by surrounding a nest with wire mesh (2 × 2 or 3 × 3 m) and leaving the fenced area unmown (Krupiński 2009). Protection of nests (n = 21) on meadows, in alfalfa, clover or grass crops required leaving a much larger (>5m) unmown area around the nest. Nine nests were secured with an electric mesh fence.

Results

Abundance and habitat use

In 2009–2010 the Montagu's Harrier population on the study area was estimated at 240–270 pairs. Montagu's Harriers' distribution was uneven. Some communes were reported to have higher densities (>10 p/100 km²).

In the southern Podlasie region a majority of Montagu's Harrier nests were observed in winter cereal crops (52%; of which most (41%) were triticale crops). The percent of winter cereal nests was variable and ranged between 26% in 2010 to 82% in 2008. Important nesting habitats were also rape crops (18%) and mead-

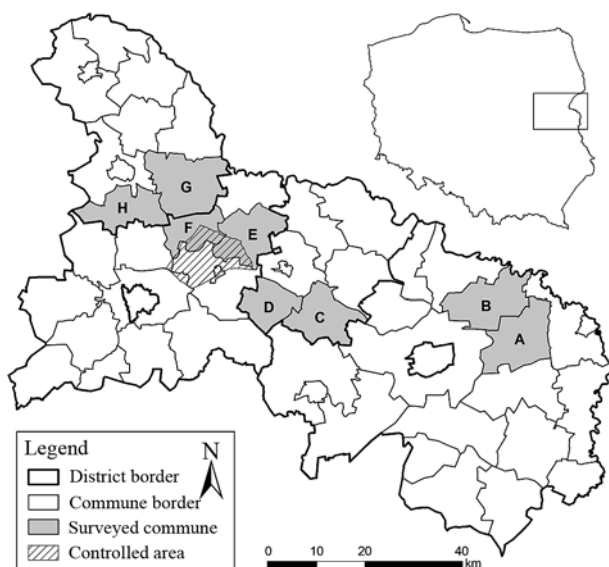


Figure 1. The study area with sample plots.

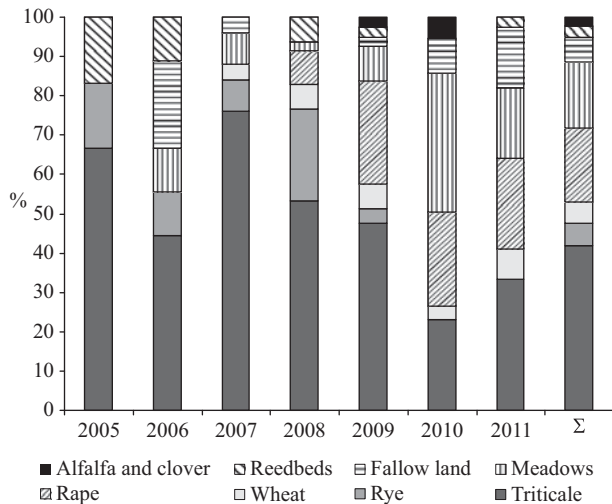


Figure 2. Location of Montagu's Harrier nests ($n = 297$) in the years 2005–2011.

ows (16%) (Figure 2). Most pairs (59%, $n = 183$) had isolated nests. 31% ($n = 43$) pairs formed small groups consisting of 2–3 nests (up to 600 m). Larger semi-colonies of more than four pairs comprised 9% ($n = 16$). The largest colony (14 pairs) was discovered in 2009 in a rape field.

The distance of a nest from the build-up land averaged 290 m ($SD = 234.25$, $n = 150$) and was not less than 28 m. Nests situated up to 300 m from build-

ings comprised 66% ($n = 99$) and nests located up to 400 m from buildings comprised 80% ($n = 120$). The 201–300 m range comprised 19% nests and the 301–400 m range comprised 16% nests. Nests closer than 100 m to and more than 600 m away from buildings both made 6%. The nearest neighbour nest distance (NNND) in the breeding colonies (within the radius of 600 m) was 157 m ($Me = 82.5$ m, $SD = 151.36$, range: 24–589 m).

Breeding biology

The Montagu's Harriers laid 2–6 eggs, 3.71 eggs per breeding pair on average ($SD = 0.15$, $n = 101$). Nests with four eggs prevailed (48.5%, Table 2). The number of fledglings was 1.24 per nest ($SD = 0.82$, $n = 297$) and 2.6 per successful breeding pair ($SD = 0.33$, $n = 142$) on average. The peak of fledging was between 22 and 27 July (Figure 3). Fledged juveniles were observed between 10 July the earliest (2008) and 26 August the latest (2010). The breeding success was 47.8% on average (Table 3).

Nest losses and effectiveness of protection measures

Nest success (at least one fledgling) differed significantly between habitat types, being the highest for wheat and triticale (75.0% and 70.1%, respectively) and the lowest for meadows and reedbeds (10% and 25%, respectively) ($\text{Chi-square} = 179.8$, $df = 7$, $p < 0.0001$). In the case of

Table 1. The number of breeding pairs and sites used by Montagu's Harriers on the monitored areas.

	Number of pairs	Area (km ²)	1996	1999	2006	2007	2008	2009	2010	2011
A	Zalesie commune	147.16	5–6		3–5		2	2–3	2–3	3–4
			5		3		2	3	3	4
B	Rokitno commune	140.82				5	8	2–3	6–7	4–6
						2	3	2	3	3
C	Olszanka commune	87.34				6	3–5	3–5	4–6	1–4
						4	3	4	2	4
D	Huszwle commune	117.61					8–10	5–8	6–8	7
							5	6	5	6
E	Przesmyki commune	117.13					10–11	10–12	8–9	5
							5	6	4	3
F	Paprotnia commune	81.43					5	6	6–7	5–6
							3	5	4	4
G	Bielany commune	109.60					2–4	3–5	8–10	4
							4	3	5	2
H	Repki commune	168.79					7–8	5–6	8–9	8
							6	4	5	5
	Site 'Mordy'	130		9			8–9	8	6–8	7–8
							4	4	4	4

Table 2. Clutch sizes of the Montagu's Harrier in the study area.

	Number of eggs in clutch					Total	Unfertilised eggs
	2	3	4	5	6		
Number of nests	8	30	49	11	3	101	9.6%

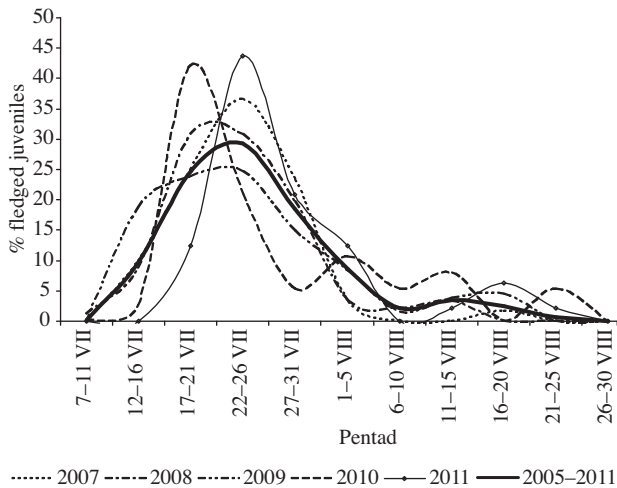


Figure 3. Montagu's Harrier fledging dates (n = 150) in 2005–2011.

nests protected with a fence (n = 96, 91% nest success), located in winter cereal and rape, their nest success was highly significantly different from that of unprotected (40% nest success, n = 99) nests (Chi-square = 59.1, df = 1, p < 0.0001).

The reasons for brood losses were: unknown (51%, n = 155), predation (15%, n = 23), damage by people (24%, n = 37; most frequently at the incubation stage, n = 31), flooding or partial flooding (10%, n = 16). Predation was by mammals (21 nests, of which 14 were plundered by foxes (*Vulpes vulpes*)) and birds (two nests; corvids and the Marsh Harrier (*Circus aeruginosus*)). Most of the unknown losses were probably caused by heavy rainfalls in 2010 and 2011, after which in several cases the Montagu's Harriers that had earlier been known as breeding individuals (following observation of provisioning food to young or nest construction) were not observed any more.

Discussion

Population size

Following a thorough and directed search of the study area in 2008–2010, the population of Montagu's

Harriers was estimated at 240–270 breeding pairs, which was approx. 8% of the Polish population, estimated at 3,300–3,550 pairs (Cenian 2009). In the light of this data, as well as results from the northern part of the Mazowsze region (S. Menderski, pers. comm.), the abundance of the Montagu's Harrier (200–300) reported for the whole Mazowsze region (Tomiałoć and Stawarczyk 2003) appears outdated. Currently, the estimation of 550–800 breeding pairs for this region seems to be more accurate.

The total density of the Montagu's Harrier in the study area (forest coverage 22%) was 3.8–4.3 p/100 km² on average, which makes this bird of prey a scarce and locally moderately common species. These numbers are lower than those observed in the farmland landscape (forest coverage 5%) of the Równina Bielska in the Północne Podlasie region (5–7 p/100 km²) (Pugacewicz 1997). At the same time, they are also much higher than in other regions of Poland, e.g. 0.4–1.3 p/100 km² in Wielkopolska (forest coverage 5%) (Wylęgała 2002), 1 p/100 km² in areas near the city of Kielce (forest coverage 51%) (Polak 2000), or 0–0.6 p/100 km² in the central Małopolska region (forest coverage 15%) (Kajtoch 2009).

Data from the monitored commune and controlled area ('Mordy') indicate relative stability and only minor fluctuations of the local Montagu's Harrier population (Table 1). During the study we also observed that in years with low rodent densities (e.g. 2011) up to 40–50% of pairs did not breed.

Nest habitats

Currently, the main breeding habitat of the Montagu's Harrier in Western Europe is arable fields (Arroyo, García, and Bretagnolle 2002). 70% of populations in France, Germany, and the Netherlands (Salamolard, Leroux, and Bretagnolle 1999; Hölker 1999; Illner 2008; Koks, Visser, Draaijer, and Kleefstra 2002), up to 88–100% in the Czech Republic (Mrlík et al. 2002; Poprach 2006; Suchý 2003), and up to 90% in Spain and Portugal (Ferrero 1995) nest in cereal. The 'cultivated field' population of the Montagu's Harrier in Poland has been developing since the 1990s (Dombrowski 1997; Dombrowski, Gołowski, and Szymkiewicz 2000; Bednorz et al. 2000). Currently, in some regions of Poland, such as

Table 3. Breeding parameters of the studied population of the Montagu's Harrier.

Year	Number of nests	Number of nests with losses	Clutch size (sample size in parentheses)	Breeding success %	Number of fledged juveniles per nest	Number of fledged juveniles per successful nest	Number of fledged juveniles
2005	6	0	3.75 (4)	100	3.00	3.00	18
2006	9	2	3.85 (7)	77.7	2.33	3.00	21
2007	25	8	3.77 (18)	68.0	1.80	2.64	45
2008	47	20	3.78 (14)	57.4	1.80	3.14	85
2009	80	28	3.59 (27)	65.0	1.58	2.28	119
2010	91	77	3.93 (16)	15.3	0.37	2.42	34
2011	39	20	3.46 (15)	48.7	1.23	2.52	48
Total	297	155	3.71 (101)	47.8	1.24	2.60	370

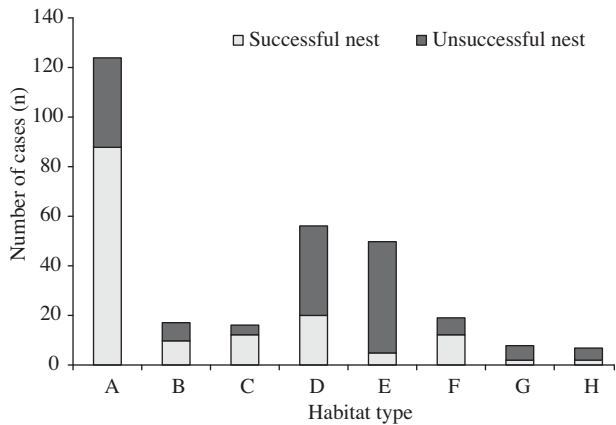


Figure 4. Nest location ($n = 297$) and breeding success of Montagu's Harriers in various habitats: A – triticale, B – rye, C – wheat, D – rape, E – meadows, F – fallow land, G – reedbeds, H – alfalfa and clover.

the Nizina Północnopodlaska (Pugacewicz 1997), over 80% of pairs nest in agrocenoses. In the study area, between the 1980s and the 1990s, the highest number of breeding pairs (46%) was found in river valleys, 38% on farmland fields, and 15% on fish ponds (Dombrowski 1997). Though at that time large farmland areas remained unsearched, even then researchers suspected that the cultivated fields population was the largest. Our study shows that currently in the southern Podlasie region most nests (up to 70%) are located on arable fields, mainly in triticale (41%) or rape (18%). In Western Europe nests are typically placed in winter rye and in wheat crops (Koks and Visser 2002; Illner 2008, 2009; Baum and Baum 2008). Nesting in rape occurs much less frequently. These differences stem most probably from the structure of cereal crops, which is determined by soil richness and the climate, and not from the selection of a particular crop species.

The data from eastern Poland and western Belarus (near the city of Grodno), where in some years up to 100% pairs nested on arable fields (Vintchevski 2006a) show that settlement of arable fields by Montagu's Harriers has also been progressing in Eastern Europe. In our study, we observed that in east-central Poland in the years with low average daily temperature and delayed onset of winter cereal growth a considerable part of the population nested on meadows and in rape crops (Krupiński, Lewtak, and Szulak 2010). This pattern was especially distinct in 2010, when almost 40% of pairs nested on meadows, 26% in rape crops, and only 25% in winter cereal. In that year we observed repeated nesting attempts in cereal crops following the loss of a nest on a meadow.

These results suggest that for the Montagu's Harrier vegetation height at the time of nest site selection is more important than vegetation type. For this reason, this species cannot be said to show preference for a specific type of habitat or to form cultivated field populations (Krupiński, Lewtak, and Szulak 2010). The same conclu-

sions were reached by Vintchevski (2006b), who pointed out that the birds initiate nest building only when vegetation is at least 40 cm high.

Breeding biology

The mean clutch size (3.71 eggs per pair) was similar to the one recorded in the Czech Republic (3.73, Poprach 2006), Western France (2.8–3.8, Butet and Leroux 1993) and the Netherlands (3.89, Koks and Visser 2002). Similar results (3.73 eggs per pair) were observed in pairs with isolated nests built in the saw sedge (*Cladium mariscus*) at the Chelm Calcareous Marshes (Wiącek 2008). Young production did not diverge from the figures obtained by many other authors either (Günther 1990; Hölker 2000; Mrlík et al. 2002; Suchy 2003; Kunstmüller, Skříček, and Hobza 2007; Kitowski 2008) and fell within the range of values typical of this species, i.e. 1–2 young per nest and 2–3 young per successful pair. The fledging peak occurred five days earlier than in Denmark (27–31.07 for 2000–2010, Rasmussen and Clausen 2011). In our study the sex ratio of the population did not significantly diverge from parity (Chi-square = 0.95; $df = 1$; $p = 0.330$, 200:181, 0.524), and therefore we cannot verify the hypothesis by Arroyo (1995), which postulates that there are more male than female hatchlings in the northern populations, and more female than male hatchlings in southern populations.

Nest protection

The breeding success of our Montagu's Harrier population, despite our protection measures, was low (47.8%). This result was mainly due to unfavourable weather conditions (heavy rains and cold temperatures) during egg incubation (2010) and chick hatching (2011). Also, in 2010, following the late onset of winter cereal growth we recorded an unusually high number of pairs (about 40%) nesting on meadows; however, their clutches were usually destroyed during haymaking.

The protection of broods on cultivated grassland areas is extremely difficult. Farming activities (mowing, turning, baling, and hay picking) are carried out in the vicinity of nests in the stage of incubation. The flushing of females leads to mortality of embryos and nest desertion. Another danger can be predation by white storks and corvids foraging on freshly mown meadows. The best protection measure is to delay mowing until the young fledge or at least hatch. Unfortunately, this is not possible to achieve in many cases, and hence only a stripe of unmown field was left around each of the nests. From the conservation point of view, an optimal action would be to leave large meadow patches of at least 10×10 m or the whole parcels unmown, which however means that the farmer should be paid damages for the lost hay. In addition, farmers rarely apply for funding of meadow cultivation from the agri-environmental scheme, where a requirement in the case of farmland bird species protection is that meadows should be mowed late for five years in a row, which is not profitable for farmers.

Good results are achieved by protection of Montagu's Harrier broods on winter cereal or rape fields. Thanks to the late mowing dates in the case of these crops, farming works are carried out at the time when chicks are already hatched and the risk of brood desertion is low. The area of vegetation left unmown around the nest can then be much smaller and does not raise objections from farmers (Krupiński 2009). Fencing prevents crushing nests by farming machines, and putting repellents (e.g. naphthalene balls) lowers the risk of brood detection by ground predators (foxes and wild boars). Due to late broods and late harvesting dates (the last ten days of July) up to 60–70% nests on arable fields in some years of the study (e.g. 2011) were in danger and required protection.

Our results show that in some years weather conditions might be the main factor determining the Montagu's Harrier breeding success. The impact of weather can be direct, e.g. nest flooding or high chick mortality, or indirect, e.g. delayed growth of winter cereal, a high number of nests on meadows or a high number of late broods. Therefore, there is a concern that increased frequency of extreme weather events (such as sudden downpours or prolonged rain in the nesting period) combined with other factors, such as landscape changes or strong predation pressure by foxes, can in the long run negatively affect the Montagu's Harrier population under study.

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