

Brief report

Diet of the Montagu's Harrier *Circus pygargus* nesting in natural habitat in Eastern Spain

Ruben Limiñana, Tamara Javaloyes & Vicente Urios

R. Limiñana, Instituto de Investigación en Recursos Cinegéticos (IREC). CSIC-UCLM-JCCM. Ronda de Toledo, s/n. E-13005 Ciudad Real, Spain. E-mail ruben.lm@gmail.com
T. Javaloyes & V. Urios, Grupo de Investigación Zoología de Vertebrados. Instituto Universitario de Investigación CIBIO, Universidad de Alicante. Apdo. correos 99, E-03080 Alicante, Spain

Received 21 March 2011, accepted 16 August 2011

We describe the diet of the Montagu's Harrier (*Circus pygargus*) population breeding in inland Castellón province (eastern Spain), which exhibits among the highest breeding productivity of European populations of this species. We assessed diet using pellets collected at nests at the end of the breeding season. We recorded the minimum number of items in every pellet for six prey classes (lizards, passerines, small mammals, coleopterans, orthopterans and other insects). We also analyzed between-year relationships in diet diversity and breeding output at the nest level. The most frequently eaten prey were insects, particularly large orthopterans of the family Acrididae. Passerines were also abundant in the diet and contributed more than 50% of the consumed biomass. We found no significant between-year relationship in breeding output and diet diversity at the nest level. Further studies on prey availability in different habitat types would be needed in order to understand how land-use changes affect the Montagu's Harrier population.



1. Introduction

As in other avian groups, food supply is one of the main factors influencing the ecology of raptors (e.g., Newton 1979). The occurrence of adequate prey numbers to fulfill energy requirements may influence the birds' breeding-site selection, and food may also directly affect the breeding output of individuals (Newton 1979). Hence, knowledge of the diet of focal species at a location of interest is crucial for appropriate management and conservation action.

The Montagu's Harrier (*Circus pygargus*) is a medium-sized raptor with a Palearctic distribution (Arroyo *et al.* 2004). The species is included in Annex I of the European Birds Directive (2009/147/EC); hence special conservation action to protect the breeding, foraging and migratory areas of this species should be implemented along its entire distribution. The majority of the European population breed in cereal crops, but some still breed in a variety of natural habitat, including moorlands, scrublands and wetlands (Arroyo *et al.* 2004). One of these populations occurs in inland

Castellón province in eastern Spain (Limiñana *et al.* 2006a, 2006b). There, population numbers have increased from three pairs in the early 1980s up to ca. 170 breeding pairs in 2009. Moreover, the productivity of this population, in terms of reproductive output, is among the highest reported for the species in Europe (Limiñana *et al.* 2006a, Soutullo *et al.* 2006). Breeding output in the Montagu's Harrier is related to food availability (e.g., Butet & Leroux 1993, Arroyo 1998, Salamolard *et al.* 2000, Arroyo & Garcia 2006). Given the high productivity of the Montagu's Harrier population in the Castellón province, it has been suggested that food may not limit the growth of this population (Limiñana *et al.* 2006a). However, until now, a description of the diet of this population – a key element for studying the food-limitation hypothesis – has been lacking.

Montagu's Harriers hunt a wide variety of prey types, from insects to small hares (Terraube & Arroyo 2011). In Spain, birds, especially passerines, are usually the most frequent prey, representing between 10% and 76% of prey of the diet; insects are also frequently consumed, representing between 3% and 79% of prey (Arroyo 1997, Sánchez-Zapata & Calvo 1998, Martínez *et al.* 1999, Corbacho *et al.* 2005). In contrast, mammals and reptiles are a less common component of the diet, representing between 1% and 29% and 1% and 12%, respectively. Nonetheless, the species may show regional specialization, feeding on the most profitable prey types in a given area (Arroyo 1997, Arroyo *et al.* 2004). Identification of the main prey groups may help reveal the mechanisms whereby land-use changes affect the focal species.

Here, we describe the diet of the Montagu's Harrier population breeding in inland Castellón province, in terms of numbers and biomass of items of different prey groups. We also study the relationship between the diet and breeding output (defined here as the number of chicks at nest) of the focal species at the nest level. We hypothesize that when the preferred group of prey is scarce in a given year, harriers should more frequently prey on other items, which in turn should result in higher diversity in the diet (Arroyo & García 2006). We thus predict that diet diversity will be negatively associated with breeding output, as it reflects lower abundance of the main group of prey.

Table 1. Prey groups detected in pellets of Montagu's Harriers from Castellón province, Spain ($n = 232$ pellets). For each group, the occurrence of items in all pellets (%), the total number of items (n), and contribution to the total biomass (%) are shown.

Group	Occurrence	Items	Contribution
Passerines	80.4	193	51.93
Coleopterans	37.4	113	2.03
Orthopterans	30.6	122	10.94
Other insects	36.6	137	2.46
Lizards	29.8	70	12.56
Small mammals	15.8	56	20.09

2. Material and methods

2.1. Pellet collection

We collected a total of 232 pellets during 1997–2006 from Montagu's Harrier nests while ringing chicks, at the end of the breeding season, i.e., from mid-June to mid-July. The study site covered an area of ca. 1,050 km² in which the species nests in sclerophyllous Mediterranean shrubland (Limiñana *et al.* 2006a, 2006b). We used all 232 pellets to describe the diet of the local population (Table 1). However, 96 of these pellets had been stored without a reference to year and nest; hence only 136 pellets were used to analyze the relationship between diet and breeding output (Table 2).

We dissected the pellets in hot water to hydrate prey remains and to prevent their deterioration during analysis (e.g., Marti 1987). We recorded the minimum number of each prey type in each pellet according to the following six prey groups: lizards (Lacertidae), passerines, small mammals, orthopterans (Acrididae), coleopterans and other insects. For lizards, passerines and small mammals, the presence of scales, feathers or fur, respectively, in each pellet were considered to belong to a single prey individual. For insects, the minimum number per pellet was assessed by counting the number of elytra, genitalia or jaws. We did not identify prey to species or genus level due to the fact that only a small proportion of the prey items appeared in the pellets. For passerines, only small body feathers appeared in pellets (beaks or skulls were not found); given the size of the body feathers found, we are confident that only

Table 2. The relationship between diet and breeding output over the 5-years study period for a Montagu's Harrier population in Castellón province, Spain. The number of sampled nests, total number of collected pellets, mean \pm SD number of pellets per nest, mean \pm SD number of prey items per nest, mean \pm SD number of chicks per nest (productivity), mean \pm SD Shannon-Wiener diversity of prey, and mean \pm SD number of prey items per pellet for a given year are indicated.

Year	Nests	Pellets, total	Pellets/nest	Items/nest	Productivity	Diversity	Items/pellet
2002	8	21	2.63 \pm 1.30	9.00 \pm 5.35	3.25 \pm 1.17	1.19 \pm 0.28	3.52 \pm 1.71
2003	6	18	3.00 \pm 2.19	8.17 \pm 5.35	2.83 \pm 1.17	1.09 \pm 0.32	2.84 \pm 0.86
2004	20	56	2.80 \pm 1.58	7.50 \pm 7.27	3.00 \pm 0.92	0.92 \pm 0.45	2.45 \pm 1.44
2005	9	14	1.56 \pm 0.88	5.56 \pm 3.78	2.78 \pm 1.20	1.02 \pm 0.63	3.52 \pm 1.34
2006	10	27	2.70 \pm 2.06	10.40 \pm 9.76	2.80 \pm 1.03	1.15 \pm 0.50	3.50 \pm 1.39

passerines appeared in these pellets, although remains of larger birds were occasionally observed at nests (authors' pers. obs.). Similarly, for small mammals, only fur was found in pellets, and jaws or skulls never appeared. Finally, the total number of prey was converted to biomass to assess the relative importance of each prey group in the diet of the Montagu's Harrier (Terraube & Arroyo 2011). To do that, we adapted weights from Arroyo (1997): lizards = 10 g, passerines = 15 g, small mammals = 20 g, orthopterans = 5 g, and coleopterans and other insects = 1 g.

The use of pellets together with prey remains collected at nests accurately describes the diet of harriers (e.g., Simmons *et al.* 1991, Arroyo 1997). However, pellets alone have also been recently assessed as providing a good indication of consumed prey in the Montagu's Harrier (Trierweiler 2010). Moreover, in our case, we rarely found prey remains at nest, and these were only occasionally collected and stored, thus preventing their use in the analyses together with prey items from pellets.

2.2. Diet and breeding output

We analyzed the relationship between diet and breeding output at the nest level. To do that, we used 136 pellets collected from a total of 53 nests during 2002–2006 (see above). For each nest, we calculated the total number of individuals in each prey group that had been identified in pellets. Using these data, we calculated the diet diversity of each nest using the Shannon-Wiener index (e.g., Arroyo 1997). We also calculated the mean num-

ber of prey items per pellet for each nest. We used pair-specific productivity (i.e., the number of fledglings in each nest) as the measure of breeding output (see also Limiñana *et al.* 2006a). We estimated the productivity of nests for which we had diet data as being the number of ringed chicks; this productivity measure was therefore available only for successful nests. We ringed chicks at the age of 22–28 days, when they are well developed and about to fledge. To test whether productivity was related to diet diversity, taking into account annual variation in productivity, we used a Generalized Linear Model (GLM) with productivity as the response variable, diet diversity (Shannon-Wiener index) as the explanatory variable and year as a factor, modeled using a Poisson error distribution and a log link function. We conducted the statistical analyses in R (R Development Core Team 2009); the significance level was set at $P = 0.05$, and tests were two-tailed.

3. Results

The occurrence of each prey group in pellets, total number of prey items of each category, and the contribution of these items to the consumed biomass are summarized in Table 1. Insects were the most abundant prey (53.8%), but represented only 15.4% of the consumed biomass. Orthopterans were the most frequently encountered insects in the diet, contributing most to the total abundance and dietary biomass (17.7% and 10.9%, respectively). Passerines were also abundant (27.9%), comprising 51.9% of the dietary biomass. Lizards

and small mammals were less abundant (10.1% and 8.1%, respectively), but due to their large size (especially small mammals) they represented a high percentage of dietary biomass (12.6% and 20.1%, respectively).

Productivity did not significantly vary between years during 2002–2006 ($\chi^2_4 = 0.543$, $P = 0.98$). Moreover, the relationship between productivity and diet diversity was not significant ($\chi^2_1 = 0.868$, $P = 0.35$).

4. Discussion

The present study was based on pellets collected at nests. As adults generally feed outside the nest (Arroyo *et al.* 2004), thus, they are likely to reflect the diet of nestlings. Insects, especially grasshoppers, are abundant in the Mediterranean semi-arid landscapes where areas of natural vegetation are interspersed with extensive agricultural areas (e.g., Rodríguez & Bustamante 2008). Agricultural land represents the main land-use type within our study area. Hence, insects are probably abundant and easy-to-capture, explaining why they were the most common prey item in our dataset. In fact, invertebrates are the most common prey of the Montagu's Harrier across its distribution range, especially in the Mediterranean region (e.g., Hiraldo *et al.* 1975, Arroyo 1997, Corbacho *et al.* 2005). Additionally, feeding on insects may represent other advantages for Montagu's Harrier nestlings, such as providing carotenoids, which are crucial for bird physiology and for certain social traits (Sternalski *et al.* 2010).

The high contribution of passerines in the diet of Montagu's Harrier in our study area accords with findings from other southern European populations, in which passerines represent up to 79% of total prey and between 30% and 86% of biomass (e.g., Arroyo 1997, Sánchez-Zapata & Calvo 1998, Martínez *et al.* 1999, Corbacho *et al.* 2005). In our study area, the timing of passerine egg hatching roughly coincides with that of the Montagu's Harrier. Consequently, fledging passerines are likely to be abundant and easy-to-catch (Arroyo 1997). Additionally, although large birds were not observed in pellets, we occasionally observed remains of these birds at the nests and saw parents bring these to the nest (authors' pers. obs.).

Therefore, it may be that large birds also contribute significantly to the overall prey biomass, making birds an even more important component of the diet of Montagu's Harriers within our study area.

We also found lizards to be a common prey item. Although generally, lizards are uncommon in the diet of this species (less than 5%; Arroyo 1997, Martínez *et al.* 1999, Corbacho *et al.* 2005), similar results have been found in southeastern Spain (12% of prey items; Sánchez-Zapata & Calvo 1998). Our results may thus reflect the fact that, within our study area, lizards are commonly found in unpaved roads near nesting sites, and are consequently likely to be relatively easy to catch.

Although small mammals potentially make up a large component of dietary biomass, in our study area they were not commonly found in the diet. This may be related to their availability and abundance within the study area, but alternatively, could be because small mammals are generally crepuscular, whereas Montagu's Harriers are primarily diurnal (Martínez *et al.* 1999). However, in several northern European populations, small mammals are the most abundant prey items, comprising 55.8% of the diet in France (Millon *et al.* 2002) and 60% in the Netherlands (Koks *et al.* 2007).

By contrast, small mammals represent less than 5% of prey in more southern populations (Giacchini *et al.* 1995, Sánchez-Zapata & Calvo 1998, Corbacho *et al.* 2005; but see Martínez *et al.* 1999). In southern Europe, small mammals are generally less abundant than in northern Europe (Hansson & Henttonen 1985) and therefore less profitable in terms of the income/cost relationship of energy (Terraube & Arroyo 2011). Hence, the low percentage of small mammals, found in our study area, is more likely to be due to the latitude of our study area than to the local abundance of mammals or likelihood of capturing these prey. It is also possible however, that, because larger prey are difficult to quantify in studies based solely on pellets (Simmons *et al.* 1991), our results may be biased towards small prey such as insects.

Eggs are commonly found in the diet of the Montagu's Harrier, and can represent up to 10% of total prey items (Corbacho *et al.* 2005), but we found egg remains in only two of the analyzed pellets. This could be due to the fact that eggs are generally taken opportunistically (Arroyo 1997), but

could also be due to the possibility that eggs are difficult to deliver to nestlings, as they have seldom been reported in studies on nestling diet (e.g., Millon *et al.* 2002, Terraube *et al.* 2011). Moreover, as the hatching periods of the Montagu's Harrier and passerines roughly coincide in our study area, eggs can be expected to be uncommon in the diet of nestlings of the former.

In several raptor species, a latitudinal variation in diet composition and diversity has been found, with southern populations showing greater diet diversity (e.g., Korpimäki & Marti 1995, Arroyo 1997, Watson 1997). This geographical trend reflects a general tendency of prey diversity to increase with decreasing latitude (Pianka 1966, Lozano *et al.* 2006). More prey groups are consumed by Montagu's Harriers in Castellón than in more northern areas where the diversity of potential prey for harriers is lower and generally dominated by small mammals (e.g., Millon *et al.* 2002, Koks *et al.* 2007). This lower diversity is associated with a lower density of other prey groups (Terraube & Arroyo 2011). The Montagu's Harrier is a generalist with some geographical specialization in diet, feeding on the most profitable (generally the most abundant) prey in a given area, in terms of the ratio between the energy provided by the prey and the energy used to capture it (Arroyo 1997).

On the other hand, the most profitable prey may vary from year to year, according to between-years variation in abundance of each prey group and hence, Montagu's Harriers may adjust their diet to the most profitable items in a given year. The diet diversity in our study area was relatively high (see Terraube & Arroyo 2011 for a review), and not significantly related to inter-annual variation in breeding output. This finding suggests that food may not limit the species' breeding in our study area (Salamolard *et al.* 2000). It should be noted that productivity values of nests used for food analyses were similar throughout the study period (2002–2006), and we did not include in the analyses nests that failed, because pellets were collected while ringing chicks, i.e., from successful nests only. Both this, and the relatively low sample size to conduct these analyses at the nest level may conceal general patterns of the influence of diet on breeding output at the population level. Hence, these results must be interpreted with caution.

Montagu's Harriers generally hunt in open areas such as herbaceous crops, grasslands and bare ground (e.g., Martínez *et al.* 1999), whereas in our study area, the hunting grounds were mostly cereal crops and open grasslands (Limiñana *et al.* 2011). Recent land-use changes in the Mediterranean region may represent a socio-economic transformation in these areas, negatively affecting traditional farming where harriers feed. Under this scenario, it is important to identify the availability of prey across different habitat types, and a specific target should be to protect high-quality foraging areas for the focal species, i.e., areas hosting the highest numbers of large insects and passerines.

Acknowledgements. We are indebted to Aeropuerto de Castellón for supporting and funding the project on the ecology of Montagu's Harrier in Castellón. Special thanks are due to Servicio de Biodiversidad from Conselleria de Medio Ambiente, Agua, Urbanismo y Vivienda (Generalitat Valenciana) for permissions to carry out the present study. M. Carmen Soria, D. Pavón and C. Torregrosa helped with pellet analyses. P. López, A. Soutullo, B. Arroyo, M. Koivula and two anonymous referees provided insightful comments on early drafts of the manuscript. The present study complies with the current laws in Spain.

Itä-Espanjan niittysuohaukkojen ravinto luontaisessa ympäristössä

Tutkimme niittysuohaukan (*Circus pygargus*) ravinnon koostumusta Itä-Espanjan Castellónin provinssissa. Lajin pesimätulos on alueella Euroopan parhaita. Ravinnon koostumuksen selvittämiseksi keräsimme oksennus- ja ulostepellettejä pesiltä pesimäkauden lopussa. Kirjasimme pellettikohtaisesti minimimäärän saaliseläimiä jaoteltuna liskoihin, varpuslintuihin, pikkunisäkkäisiin ja hyönteisiin.

Analysoimme myös vuosien välisen ravintokirjon ja pesimämenestyksen suhdetta pesätasolla. Yleisimpiä saaliseläimiä olivat hyönteiset, erityisesti Acrididae-heimon heinäsiikat. Myös varpuslinnut olivat yleisiä ja muodostivatkin yli 50 % ravinnon kokonaisbiomassasta. Pesätasolla emme havainneet merkitsevää yhteyttä ravinnon monipuolisuuden ja pesimämenestyksen välillä. Lisätutkimuksissa voitaisiin keskittyä selvittämään eri ympäristötyyppien välisiä saaliin saatavuuseroja,

jotta voitaisiin paremmin ymmärtää, kuinka maan-käytön muutokset vaikuttavat niittysuohaukka-populaatioon.

References

- Arroyo, B.E. 1997: Diet of Montagu's harrier *Circus pygargus* in central Spain: analysis of temporal and geographical variation. — *Ibis* 139: 664–672.
- Arroyo, B.E. 1998: Effect of diet on the reproductive success of Montagu's harrier *Circus pygargus*. — *Ibis* 140: 690–693.
- Arroyo, B.E. & García, J.T. 2006: Diet composition influences annual breeding success of Montagu's harriers *Circus pygargus* feeding on diverse prey. — *Bird Study* 53: 73–78.
- Arroyo, B.E., García, J.T. & Bretagnolle, V. 2004: Montagu's harrier *Circus pygargus*. — In *Birds of Western Palaearctic Update*, vol. 6: 41–55.
- Butet, A. & Leroux, A.B.A. 1993: Effect of prey on a predator's breeding success: a 7-year study on common vole (*Microtus arvalis*) and Montagu's harrier (*Circus pygargus*) in a west France marsh. — *Acta Oecologica* 14: 857–865.
- Corbacho, C., Moran, R. & Villegas, M.A. 2005: The diet of Montagu's harriers *Circus pygargus* in relation to land-use systems in pseudosteppe areas of Extremadura (SW Iberian Peninsula). — *Ardeola* 52: 3–19.
- Giacchini, P., Hedges, C. & Pandolfi, M. 1995: Attività alimentare e dieta di Albanella minore (*Circus pygargus*) in Italia centrale. — *Supplemento alle Ricerche di Biologia della Selvaggina* 22: 245–248. (In Italian)
- Hansson, L. & Henttonen, H. 1985: Gradients in density variations of small rodents: the importance of latitude and snow cover. — *Oecologia* 67: 394–402.
- Hiraldo, F., Fernández, F. & Amores, F. 1975: Diet of the Montagu's harrier (*Circus pygargus*) in southwestern Spain. — *Doñana Acta Vertebrata* 2: 25–55.
- Koks, B., Trierweiler, C., Visser, E.G., Dijkstra, C. & Komdeur, J. 2007: Do voles make agricultural habitat attractive to Montagu's harrier *Circus pygargus*. — *Ibis* 149: 575–586.
- Korpimäki, E. & Marti, C.D. 1995: Geographical trends in trophic characteristics of mammal eating raptors in Europe and North America. — *Auk* 112: 1004–1023.
- Limiñana, R., Surroca, M., Miralles, S., Urios, V. & Jiménez, J. 2006a: Population trend and breeding biology of Montagu's harrier *Circus pygargus* in a natural vegetation site in Northeast Spain. — *Bird Study* 53: 126–131.
- Limiñana, R., Soutullo, A., Urios, V. & Surroca, M. 2006b: Vegetation height selection in Montagu's harriers *Circus pygargus* breeding in a natural habitat. — *Ardea* 94: 280–284.
- Limiñana, R., Arroyo, B.E., Surroca, M., Urios, V. & Reig-Ferrer, A. 2011: Influence of habitat on nest location and reproductive output of Montagu's harriers breeding in natural vegetation. — *Journal of Ornithology* 152: 557–565.
- Lozano, J., Moleón, M. & Virgós, E. 2006: Biogeographical patterns in the diet of the wildcat, *Felis silvestris* Schreber, in Eurasia: factors affecting the trophic diversity. — *Journal of Biogeography* 33: 1076–1085.
- Marti, C.D. 1987: Raptor food habits studies. — In *Raptor management techniques manual* (ed. Pendleton, B.A.G., Millsap, B.A., Cline, K.W. & Bird, D.M.): 67–80. National Wildlife Federation Science and Technical Series No. 10, Washington.
- Martínez, J.A., Lopez, G., Falcó, F., Campo, A. & De la Vega, A. 1999: Hábitat de caza y nidificación del aguilucho cenizo, *Circus pygargus*, en el parque natural de la Mata-Torreveja (Alicante, SE de España): efectos de la estructura de la vegetación y de la densidad de presas. — *Ardeola* 46: 205–212. (In Spanish with English summary)
- Millon, A., Bourrioux, J.L., Riols, C. & Bretagnolle, V. 2002: Comparative breeding biology of Hen Harrier and Montagu's harrier: an 8-year study in north-eastern France. — *Ibis* 144: 94–105.
- Newton, I. 1979: Population ecology of raptors. — T & AD Poyser, London.
- Pianka, E.R. 1966: Latitudinal gradients in species diversity: a review of concepts. — *American Naturalist* 100: 33–46.
- R Development Core Team 2009: R: a language and environment for statistical computing. — R Foundation for Statistical Computing, Vienna. URL <http://www.R-project.org>.
- Rodríguez, C. & Bustamante, J. 2008: Patterns of Orthoptera abundance and lesser kestrel conservation in arable landscapes. — *Biodiversity and Conservation* 17: 1753–1764.
- Salamolard, M., Butet, A., Leroux, A. & Bretagnolle, V. 2000: Responses of an avian predator to variations in prey density at a temperate latitude. — *Ecology* 81: 2428–2441.
- Sánchez-Zapata, J.A. & Calvo, J.F. 1998: Importance of birds and potential bias in food habit studies of Montagu's harriers (*Circus pygargus*) in southeastern Spain. — *Journal of Raptor Research* 32: 254–256.
- Simmons, R.E., Avery, D.M. & Avery, G. 1991: Biases in diet determined from pellets and remains: correction factors for a mammal and bird-eating raptor. — *Journal of Raptor Research* 25: 63–67.
- Soutullo, A., Limiñana, R., Urios, V., Surroca, M. & Gill, J.A. 2006: Density-dependent regulation of population size in colonial breeders: Allee and buffer effects in the migratory Montagu's harrier. — *Oecologia* 149: 543–552.
- Sternalski, A., Mougeot, F., Eraud, C., Gangloff, B., Vilers, A. & Bretagnolle, V. 2010: Carotenoids in nestling Montagu's harriers: variations according to age, sex, body condition and evidence for diet-related limi-

- tations. — *Journal of Comparative Physiology B* 180: 33–43.
- Terraube, J. & Arroyo, B. 2011: Factors influencing diet variation in a generalist predator across its range distribution. — *Biodiversity and Conservation* 20: 2111–2131.
- Terraube, J., Arroyo, B., Madders, M. & Mougeot, F. 2011: Diet specialisation and foraging efficiency under fluctuating vole abundance: a comparison between generalist and specialist avian predators. — *Oikos* 120: 234–244.
- Trierweiler, C. 2010: Travels to feed and food to breed. The annual cycle of a migratory raptor, Montagu's harrier, in a modern world. — PhD thesis, University of Groningen.
- Watson, J. 1997: *The golden eagle*. — T & AD Poyser, London.