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SHORT REPORT

Diet of non-breeding Bonelli's Eagles *Hieraaetus fasciatus* at settlement areas of southern Spain

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Capsule Birds at dispersal areas consumed more rabbits than adult territorial eagles.

Bonelli's Eagles *Hieraaetus fasciatus* are long-lived raptors with deferred reproduction (about two to four years in females and three to five years in males) and a rate of low fecundity (typically one or two chicks per pair per year, Cramp & Simmons 1980, Real 2004, Sæter *et al.* 1996). Before recruiting to the breeding population, young eagles undergo juvenile dispersal (Newton 1979, Greenwood & Harvey 1982, Clobert *et al.* 2001). During this period, the movements of non-adult birds are confined largely to 'juvenile dispersal areas', which in the case of Bonelli's Eagles are geographically distinct from natal territories (Cheylan *et al.* 1996, Real *et al.* 1998, Alcántara *et al.* 2001, Mínguez *et al.* 2001, Real & Mañosa 2001, Cadahía *et al.* 2005).

Within dispersal areas, the highest concentrations of eagles are found in just a few settlement areas, typified by a high abundance of the staple prey and an absence of breeding territories (Mañosa *et al.* 1998, Bautista *et al.* 2004). Food availability in these areas can strongly influence the survival and subsequent fitness of young individuals (Gadgil 1971, Horn 1983, Clobert *et al.* 2001). Dispersal areas appear to be key to the long-term stability of Bonelli's Eagle populations (Ferrer & Penteriani 2001, Real *et al.* 2001, Ferrer *et al.* 2002, Bautista *et al.* 2004). Thus, successful conservation of this species depends upon knowledge of Bonelli's Eagle ecology in dispersal areas. However, while much is known about the diet of breeding Bonelli's Eagles (Palma *et al.* 1984, Real 1987, Rico *et al.* 1990, Leiva *et al.* 1994, Martínez *et al.* 1994, Gil-Sánchez 1998, Gil-Sánchez *et al.* 2000, 2004, Iezekiel *et al.* 2004, Palma *et al.* 2006, Moleón *et al.* 2007), little is known about diet in dispersal areas, despite the fact that non-breeders account for an estimated one-third of the total Bonelli's Eagle population (Real & Mañosa 1997). This aspect of dietary ecology has been neglected not only for this species, but for most medium and large raptors (Gargett 1990, Ferrer 1993a, Watson 1997, Ferguson-Lees & Christie 2001).

The Andalusia region of southern Spain supports the largest population of Bonelli's Eagles in Europe (Balbontín *et al.* 2003, Real 2004, Gil-Sánchez *et al.* 2005, Muñoz *et al.* 2005), with about 321–347 breeding pairs (35% of the European breeding population, Moleón 2006). There are six juvenile dispersal areas in this region, the most important of which is in Cádiz province in the southwest of Andalusia (Consejería de Medio Ambiente 2006). This area supports many young birds from other parts of Andalusia (Balbontín *et al.* 2000, Consejería de Medio Ambiente 2006), as well as from elsewhere in the Iberian Peninsula (Alcántara *et al.* 2001, Real 2004), and is an important area for the conservation of the western Mediterranean population of Bonelli's Eagles (Muñoz *et al.* 2005, Consejería de Medio Ambiente 2006). The high density of eagles and the presence of communal roosting sites in this area (Consejería de Medio Ambiente 2006, J. Bautista unpubl. data) make it well suited to an investigation of non-breeding diet. We present here the first data on the diet of non-breeding Bonelli's Eagles in a juvenile dispersal area, and make comparisons with the diet of territorial birds.

The non-breeding study area comprised two groups of settlement areas situated in the middle (three settling areas, about 44 km^2, 36°33′N, 5°55′E) and the

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south (four settling areas, about 52 km^2, 36°17′N, 5°55′E) of the Cádiz juvenile dispersal area. The habitat is characterized by patches of Mediterranean scrubland within a matrix of non-irrigated crops. The area is used primarily for arable and pastoral farming, and small-game hunting.

Food pellets were collected from under Bonelli's Eagles communal roosting sites in two winters (2003/04 and 2004/05). The studied roosting sites (two in the middle area and three in the south) consisted of isolated groups of *Eucalyptus* spp. surrounded by cereal crops. Analysis of pellets is the most frequently used and reliable method for studying and comparing the diet of this species (Real 1996, Gil-Sánchez *et al.* 2004). Samples were collected between November and early February, when the maximum number of Bonelli's Eagles visit the study area (Consejería de Medio Ambiente 2006, authors' unpubl. data). In this area, non-breeding Bonelli's Eagles always used the same trees for roosting, and did not accept other raptors; this prevented doubts about the origin of pellets. Each prey species identified in one pellet was counted as one individual.

Because of the absence of breeding pairs (due to the lack of appropriate nesting cliffs) in the dispersal area (Bautista *et al.* 2004, Balbontín 2005), we studied the feeding habits of territorial birds from pellets in the neighbouring breeding population of Granada (37°20′N 3°45′E, Gil-Sánchez *et al.* 2004). Pellets from four Bonelli's Eagle territories yielded a minimum of 20 prey items each. Samples were collected at adult roosting sites during the same season and years that we collected samples from young eagles at their roosting sites.

For the presentation and analyses of the diet data, prey items were grouped in the following seven categories: Rabbits *Oryctolagus cuniculus*, other mammals, Red-legged Partridge *Alectoris rufa*, pigeons *Columba* spp, corvids, other birds and reptiles. All diet comparisons were tested by means of a chi-squared test and assumed $P < 0.05$.

Forty-two 2-km line transects were carried out between late October and November 2003 to determine Rabbit, Red-legged Partridge and Common Pheasant *Phasianus colchicus* abundances. Twelve transects were located within the central juvenile dispersal areas, ten transects within the southern dispersal areas, and 20 transects within 5 km (value from the mean half-distance between neighbouring pairs for all Granada's population, Gil-Sánchez *et al.* 2004) of the nests in three of the four breeding territories we studied. Surveys were stratified by habitat, and prey counts were performed during dawn and dusk, the main activity periods of eagles. Rabbit density was calculated from a linear regression given by Palomares *et al.* (2001) (census band width 10 m), while Partridge and Pheasant abundances were obtained by truncating the sampling distance to within 20 m of the transect in order to minimize the effect of differences in visibility between habitats (Gil-Sánchez *et al.* 2004).

A total of 179 pellets from the Cádiz juvenile dispersal area yielded a minimum of 267 prey items. The prey taken most frequently by young Bonelli's Eagles was Rabbit (61% of items), followed by Red-legged Partridge (21.7%), other birds (9.8%) and other mammals (5.6%). Pigeons were taken only occasionally (1.9%), and neither corvids nor reptiles were found (Fig. 1). Within the southern settlement areas, Pheasants comprised most of the 'other birds' category (64% of 'other birds' category and 9.8% of the total diet). Diet composition differed between groups of settlement areas ($\chi^2_4 = 15.52$, $P < 0.01$), with Rabbits being more frequently eaten in the central areas, and consumption of other birds more frequent in southern areas (Fig. 1). As young eagles can move between settling areas, differences in diet composition were associated with site rather than individual preferences.

A total of 208 pellets, yielding 270 prey items, were obtained from the breeding territories. There were significant differences in diet between dispersal and territorial sites ($\chi^2_6 = 127.16$, $P < 0.0001$), mainly due

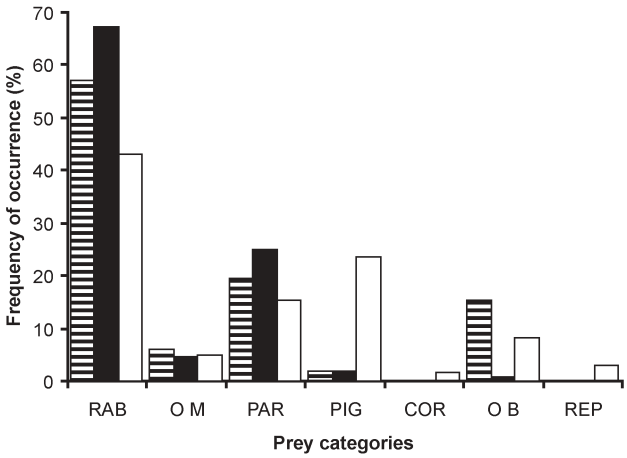

Figure 1. Winter diet composition of Bonelli´s Eagles in Andalusia, southern Spain. Striped bars, southern settling areas (*n* = 163 prey items); black bars, central settling areas (*n* = 104); white bars, breeding territories (*n* = 270). RAB, Rabbit; O M, other mammals; PAR, Red-legged Partridge; PIG, pigeons; COR, corvids; O B, other birds; REP, reptiles.

to the lower consumption of Rabbits in the breeding range (43%), and the greater importance of pigeons as secondary prey for territorial birds (23.7%, Fig. 1).

Densities of Rabbits were 19–30 times higher in the settlement areas than in the breeding territories, while densities of Red-legged Partridges were 12–13 times higher (Fig. 2). Pheasants were restricted to the southern settling areas, with a density of about 2.54 individuals per hectare.

Rabbit featured more prominently in the diets of Bonelli's Eagles in the dispersal area than in breeding territories but, overall, it was the most important prey item for both age groups of eagles. Although sample size was small (three data points), Fig. 2 suggests an association between Rabbit abundance and its consumption by Bonelli's Eagles, which may indicate a functional response. Rabbit was the most frequently consumed prey even in the breeding territories, where the density of this prey was medium to low, indicating that Rabbit is an essential prey for this raptor in Andalusia. This finding seems to be true elsewhere in western Europe: a positive relationship exists between Bonelli's Eagle reproductive success and Rabbit abundance in several sites in northern Spain (Real 1991, Fernández *et al.* 1998) and southern France (Cheylan 1981).

Partridges did not constitute a higher proportion of the diet in dispersal areas than in breeding territories, despite being more abundant in the former than in the latter. The fact that Partridges were preyed on less than Rabbits, despite being at similar densities, could suggest that Rabbits are easier to catch, or that they are more profitable energetically. If they were easier to catch, we would observe a higher proportion of Rabbits in young than in adult eagles' diet, due to a difference in capture success between age classes. However, the Rabbit-to-Partridge ratio in diet was similar between dispersal and breeding ranges (Fig. 2), contradicting this hypothesis.

Pheasants released for hunting usually suffer high predation pressure in release pens (Kenward 1977, Kenward *et al.* 1981, Snyder 1985, but see Kenward *et al.* 2001), probably because they are much easier for predators to catch than wild prey. Therefore, the availability of large numbers of Pheasants in the southern settlement areas of Cádiz (see densities of Pheasants given above) could have had an impact on the number of Rabbits and Partridges ingested by eagles.

The proportion of Rabbits was higher in dispersal areas than in the studied breeding territories. One of the highest proportions of Rabbit in the diet of breeding Bonelli's Eagles in Andalusia and elsewhere in

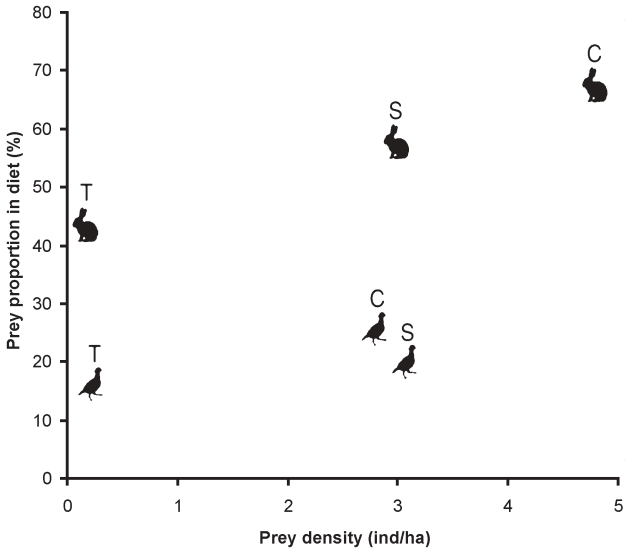

Figure 2. Relationship between Rabbit and Partridge abundances (individuals per ha) and their proportion (%*n*) in the diet of Bonelli´s Eagles in the Cádiz juvenile dispersal area and the neighbouring territories. C, Central settling areas; S, southern settling areas; T, breeding territories.

western Europe is found in Granada (Gil-Sánchez *et al.* 2004), so that differences between young and adult diets should be higher between the Cádiz dispersal area and other breeding places. This difference between diets could be due principally to the fact that non-breeding eagles do not need to hold and defend exclusive territories (Newton 1979) and may explore large regions (young Bonelli's Eagles can fly several hundred kilometres from natal territories, Real *et al.* 1998, Alcántara *et al.* 2001, Mínguez *et al.* 2001, Real & Mañosa 2001, Cadahía *et al.* 2005) searching for areas with a higher availability of the most profitable prey (Ferrer 1993b, Ferrer & Harte 1997). Rabbit densities in dispersal areas are so high that the inexperience of foraging young birds (Newton 1979) could be largely compensated.

Some studies have previously pointed out the influence of Rabbit availability in the regulation of some vital stages in non-adult Bonelli's Eagles, particularly the length of the post-fledging period (Mínguez *et al.* 2001) and the selection of settlement areas by juvenile birds (Mañosa *et al.* 1998, Balbontín 2005). However, the association between Bonelli's Eagles and Rabbits in the dispersal areas may at the present time be functioning as an ecological trap. Rabbit viral haemorrhagic disease (RHD) and myxomatosis outbreaks (Villafuerte *et al.* 1995, Fenner & Fantini 1999, Virgós *et al.* 2007) have decimated Rabbit populations in most

areas. High Rabbit densities in Andalusia are currently confined to areas with a relatively high level of human influence (Bautista *et al.* 2004, Farfán *et al.* 2004). This presents a problem for Bonelli's Eagles, as the pressures exerted by humans cause high mortality of non-adult birds (Ferrer & Penteriani 2001, Real *et al.* 2001, Ferrer *et al.* 2002, Bautista *et al.* 2004). These pressures are mainly small-game hunting, leading to elevated levels of raptor persecution, and a high density of power lines resulting in a high risk of electrocution (Sánchez-Zapata & Calvo 1999, Bautista *et al.* 2004). Hence the dispersal areas in southern Spain could be acting as population sinks.

The survival of non-territorial birds is key to the stability of Bonelli's Eagle populations (Real & Mañosa 1997, Ferrer & Penteriani 2001, Ferrer *et al.* 2002, Carrete *et al.* 2002, 2005). Conservation planning for the recovery of this threatened species should therefore take into consideration the management of Rabbit-rich habitats in juvenile dispersal areas. In particular, programmes favouring the stability of Rabbit populations (e.g. enhancing low-intensity farming systems supported under the Common Agricultural Policy agro-environmental regulations, Bignal & McCracken 1996), as well as measures to mitigate direct persecution and electrocution on power lines, in these areas (Real *et al.* 2001) should be encouraged.

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