Appropriateness of Special Protection Areas for wide ranging species: the importance of scale and protecting foraging, not just nesting habitats.

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Short title: SPA effectiveness for ranging harriers.

Abstract. Effective conservation plans and design of Special Protection Areas for protected species should take into account ranging behaviour and foraging habitats, and this is particularly important for wide ranging species. Montagu's harriers (*Circus pygargus*) are ground-nesting semi-colonial raptors typical of agricultural habitats. We studied the foraging behaviour of 14 radio-tracked male Montagu´s harriers, in order to investigate the distance from nests of foraging birds, the extent to which foraging range overlapped with SPA designated for this species, and foraging habitat selection within foraging ranges. Average foraging range size, estimated from either MCP or Kernel 90%, was larger than 100 km^2. Only 19 ± 11% of the foraging ranges were within SPA limits. Cereal (the main habitat used for nesting) was slightly counterselected for foraging, and most prey (64%, n = 117) captured in that habitat were insects. Hunting attempts occurred significantly more frequently than expected in alfalfa, where most prey captured were small mammals (70%, n = 102). Use of this habitat for foraging increased throughout the season. Most prey captured in other habitats (mainly tree crops, shrubs or uncultivated land) were birds (83%, n = 43). SPAs included a higher proportion of cereal, but a lower proportion of alfalfa than areas outside SPAs. Overall, our results show that breeding Montagu´s harriers use an area for foraging much larger than current sizes of most Special Protected Areas for the species, that habitats selected for foraging differ from those used for nesting, and that preferred foraging habitats were less common inside SPAs than outside. Conservation management for this species should aim to protect foraging habitats within a large radius of the colonies, probably requiring measures to be applied outside protected areas. More generally, SPAs designed without including information of ranging behaviour and foraging habitats may be ineffective.

Keywords: agricultural habitats, Special Protection Areas, ranging behaviour, habitat selection.

Introduction

Conservation of wild bird species frequently depends on management and conservation of habitats. For example, in Europe the EC Directive on the conservation of wild birds (79/409/EEC, and 2009/147/EC, henceforth referred to as the Birds Directive) recognises that habitat loss and degradation are the most serious threats to the conservation of wild birds, and requires the Member States of the European Community to identify and classify Special Protection Areas (SPAs) for certain rare or vulnerable species listed on Annex 1 of the Directive. These are intended to safeguard the habitats of the species for which they are selected, with sustainable management of the land in those areas being promoted through measures such as conservation partnerships, financial incentives and legislation. Information about the value of habitats (or habitat preferences as a surrogate) is therefore required to guide conservation and management programmes (Rouquette & Thompson, 2005; Serrano & Astrain, 2005).

Management for conservation of a species should take into account its foraging needs as well as its nesting habitat (Martin & Possingham, 2005). The importance of foraging areas is highlighted in studies that have shown that availability of good foraging areas around nest sites can influence breeding success (e.g. Tella et al., 1998; Rodriguez, Josht & Bustamante, 2006; Amar et al., 2008; Hinam & Clair, 2008), and in many cases, habitats selected for foraging may differ from those selected for breeding (Sergio, Pedrini & Marchesi, 2003). Nevertheless, although the number of studies dealing with foraging habitat selection in birds is increasing recently, they are still relatively scarce, as compared with studies on nesting habitat selection (e.g. Donazar, Negro & Hiraldo, 1993; Tella et al., 1998; Sergio et al., 2003; Amar & Redpath, 2005; García et al., 2006; Arroyo et al., 2009).

Additionally, the criteria used to delimit the boundaries of SPAs are frequently unclear, and sometimes potentially inappropriate. In certain cases (e.g., if no other information exists), the delimitations of the SPAs are based on nest distribution with a certain boundary around the nests, and their sizes are thus dependent on nest distribution. However, some bird species (including most of the raptors) in Annex I of the Birds Directive may range over large areas, so protected areas based solely on nest habitat and distribution may not meet the requirements of the birds they are intended to protect. There have been, however, extremely few studies evaluating the effectiveness of SPAs for providing resources for their target species (but see Martínez et al., 2007, Traba et al. 2007).

In Europe, agricultural areas have the highest number of bird species with unfavourable conservation status (Tucker & Heath, 1994), and there have been a number of agro-environmental schemes to create habitat conditions that are favourable for birds (both within and outside protected areas). The Montagu's harrier (*Circus pygargus*) is one of the most characteristic raptors of agricultural areas in Western Europe, where it nests predominantly within cereal fields (Arroyo, García & Bretagnolle, 2004). As is commonly the case for other species that depend on this habitat (Donald et al., 2000), agricultural intensification and rapid changes of agricultural landscapes and practices are at present the most important threats for this species (Arroyo, García & Bretagnolle, 2003). In the absence of resource-intensive conservation measures, the loss of clutches and broods during harvest operations drastically reduces breeding productivity of Montagu´s harriers nesting in crops (Arroyo, García & Bretagnolle, 2002). The species is thus dependent on active management, and there are currently conservation programmes in many countries and regions, most of which emphasise the protection of nests and nesting habitats (Arroyo et al., 2003). In Catalunya (NE Spain) there have been conservation campaigns for nearly 20 years (Pomarol, 1994; Pomarol, Parellada & Fortia, 1995), and various SPAs have been recently created there that include this species as a target.

The aim of this study was to evaluate the appropriateness of SPAs for foraging Montagu´s harriers breeding within them, in terms of size and habitats provided. Specifically, we addressed the following questions: a) what is the average foraging range size for the species, the location of hunting ranges in relation to SPA limits, or the proportion of capture attempts that occur outside SPA limits?; b) which habitats are selected for foraging, in comparison with those used for breeding? and c) to what extent do SPAs include the selected foraging habitats? We discuss results in relation to the efficacy of SPA networks for wide ranging species.

Materials and methods

Study area

The study was carried out from 2002 to 2004 in and around two Special Protection Areas in the province of Lleida, Catalunya, NE Spain. These were Anglesola (2002-2004), covering 8.5 km^2 and containing 12 pairs in 2004, and Bellmunt (2004), covering 35 km^2 and containing 10 pairs in 2004. Anglesola was created primarily for the protection of Montagu´s harriers. Bellmunt was created for the protection of various steppe bird species of conservation concern, including Montagu´s harriers, and together these two areas hold 25% of the population in Catalunya, and ca. 40% of the pairs in Lleida. Additionally, several other agricultural SPAs exist in the area surrounding these two study areas, with a combined area of more than 200 km^2 (Fig. 1), also holding small numbers of breeding Montagu´s harriers (although they have not been designated for this species).

Habitat availability was evaluated from two different sources. First, we used the local agricultural census of 2003 (for Anglesola) and 2004 (for Bellmunt) (provided by the Department of Agriculture, Hunting and Fishing of the Generalitat de Catalunya). This census is very accurate, and all different crops are differentiated (see Table 2 for a list). These data is provided at the municipality level, but information is not spatially explicit, so we could not include it in a GIS to calculate directly surfaces inside foraging ranges, for example. We summed information from all municipalities where observations of all monitored males in each area had occurred to have an overall idea of the availability of each land use type in each area (calculated as the surface covered by each land use type divided by the total area of all the municipalities considered). Additionally, to evaluate whether habitat composition varied within and outside protected areas, we used the Catalunya Habitat Map (Generalitat de Catalunya. Departament de Medi Ambient i Habitatge, http://mediambient.gencat.net/cat/el_medi/habitats/habitats_cartografia.htm#cd) which was digitised, crossing this information with the SPA limits using ArcView 3.2. This latter data source is spatially explicit, so we could calculate the exact extent in each considered polygon, but was less detailed and, in particular, alfalfa and other irrigated crops such as corn were lumped in the same category (see Table 3 for the categories identified with this source), so we considered it less appropriate for the habitat selection analyses. Overall, land use in Anglesola is dominated by winter cereal crops (representing ca. 50% of total area), the remainder of the land being occupied by a mixture of spring-sown crops (mainly corn), woods, dry orchards (olive and almond trees), irrigated orchards (pear, apple and peach trees), fallow land, pastures and alfalfa fields. In Bellmunt, winter cereal, corn and alfalfa are the most common land uses.

The Montagu´s nests in winter cereal fields in both study areas. The Montagu´s harrier is semi-colonial, forming groups of up to several tens of pairs (most typically, between 3 and 10) nesting close by. Average distance between nests in the study colonies was ca. 500 m (D. Guixé, unpublished data).

Foraging range and foraging distance estimations

Foraging range estimations were based on data from 12 radiotracked males. 11 males were fitted with tail-mount radios (Ag 357 from Biotrack), one of those for two consecutive seasons; one further male was fitted with a TW-3 backpack transmitter (from Biotrack), and also followed during two consecutive seasons, giving data on 14 foraging ranges. Overall, four males were monitored in Anglesola in 2002, five also in Anglesola in 2003, and in 2004 one male was monitored in Anglesola, and four in Bellmunt. Three females were also equipped with transmitters, but the information was not included in this paper, since females hunt little even to feed nestlings (García & Arroyo, 2005), and their foraging ranges are very small, at least in Mediterranean areas (when they hunt, they do it close to the nest; Guixé unpubl. data, and see also Salamolard, 1998; García & Arroyo, 2005; Arroyo et al. 2008).

The Montagu´s harrier hunts mainly by flying in a low and buoyant manner at constantly low speeds, so it is relatively easy to make foraging observations. The prey is usually caught in a stoop, rarely on pursuits (Arroyo et al., 2004), and it is easy to identify capture attempts as birds drop to the ground. We followed marked birds continuously from the nest to a hunting point (i.e., an area where a capture attempt was made, identified as where the bird dropped to the ground for a prey) with a car, using the extensive track network in the study area, and using the radio to relocate the birds if visual contact with them was lost. At each hunting point we reported the crop type. Because the track network was wide and passed through the whole of the study area, we do not think there is a bias in the habitats observed to be used by harriers. We followed each bird once a week on average, aiming to obtain data for two hunting points per monitoring day and more than 40 in total for each monitored bird. Number of points per monitored bird ranged between 20 and 58 (totalling 589), but only one bird had less than 30.

At each hunting point, we also reported whether there was a capture, and the type of prey caught (as bird, small mammal, insect or reptile) when possible. From 382 observed prey captures, 266 could be identified to prey type. There could be biases from this method if most of the unidentified prey belonged to one prey type, or it was easier to identify prey in certain habitats. However, diet as identified from observations was similar to that identified from pellets (Guixé, 2003), and there were no habitat differences in the proportion of unidentified prey, so we believe our results are unlikely to be biased because of the use of this technique.

We calculated several spatial metrics using the GIS programme ArcView 3.2 (and the Animal Movement extension). These included the distance from each hunting point to the nest (in km) and foraging range size (in km^2) for each male, which was estimated using two different techniques: Minimum Convex Polygon (MCP) and Kernel Analysis (Millspaugh & Marzluff 2001; Kenward 2001). For the latter, we calculated 50% and 90% Kernels, as they are frequently used in home ranges studies; they can be thought to illustrate the core (50%) and the global (90%) use of the range, whilst eliminating the impact of outlier locations. Using the Geoprocessing Wizzard in ArcView, calculated the proportion of the hunting observations or foraging range size that lay within the limits of any SPAs.

Statistical analyses

Differences in foraging range size among areas or among years were tested with General Linear Models, fitting the response variables to a normal distribution and using an identity link function. In order to determine the total surface needed for foraging colonial harriers, it was also necessary to evaluate the overlap in foraging areas between neighbouring individuals (otherwise, multiplying the average foraging range size by the number of birds breeding in an area would give overestimated figures).

To estimate habitat selection intensity we used Ivlev’s index (Ivlev, 1961), comparing the proportion of habitats used (as the proportion of hunting points in each habitat type) with those available (as estimated from the agricultural census, see above). As specified above, these data is imprecise because of the lack of spatial resolution, but they reflect the overall availability in the area, so the comparison between both sets of data gives an indication of whether birds use habitats in relation to their availability or not. Ivlev´s index is calculated with the expression IS = (H1/H2-A1/A2) /(H1/H2+A1/A2), where H1 is the number of hunting points in habitat 1, H2 is the total number of hunting points, A1 is the available area of habitat 1, and A2 the total area. IS varies between -1 and +1. Positive values indicate preference, whereas negative values indicate avoidance.

To evaluate the effect of date on foraging distances we used Generalised Linear Mixed Models (GLMM), with distance of each hunting point to the nest as the response variable (normal error distribution and an identity link function). We specified “individual”, “study area” and “year” as random factors, and julian date (with 1 = first may) as a fixed effect. To test the effect of date and distance on habitat selection, we modelled the probability of hunting over each habitat type (alfalfa, cereal or other) where each hunting point was coded as “1” if it corresponded to the habitat in question and “0” if it was a different habitat, using binomial GLMMs with a log link function. These models also specified “individual”, “study area” and “year” as random variables, and julian date (with 1 = first may), distance from the nest and their interaction as fixed effects.

Differences in prey consumed (proportion of birds vs small mammals or insects among the identified prey) between study areas or in relation to habitat were assessed with Chi-square tests.

Results

Foraging range sizes, feeding distances and range overlap

The mean observed distance from the nest for foraging points for all monitored males was 5.8 ± 4.1 km (n = 537). All of the study birds but two were observed foraging more than 10 km (and up to 21 km) away from the nest. On average, only 35 ± 19 % (n = 14) of the hunting points of monitored individuals were within the SPA limits. Foraging distances increased significantly with julian date ($F_{1,523}$= 17.72, P < 0.0001, b = 40.72 ± 9.68).

No significant differences in mean male foraging range size between study areas were found for any of the estimating methods used (Table 1). Similarly, no differences were found between years for any of the estimating methods used (all P > 0.5). Average foraging range size, estimated from either MCP or Kernel 90%, was larger than 100 km^2 (Table 1). On average, only 19 ± 11 % of the Kernel 90% (or 35 ± 31 % of the Kernel 50%, n = 14) was within SPA limits.

In Anglesola, average overlap in the 50% core Kernel areas for neighbouring individuals was 10.40 ± 6.94 km^2 (n = 13), i.e. 55% of the range. Total area used around the colony by all the monitored males was approximately 500 km^2 (Fig. 1). In Bellmunt, average overlap in the 50% core Kernel areas was 5.82 ± 7.81 km^2 (n = 6), i.e. 31% of the range. Total area used around the colony by the monitored males was 718 km^2 (Fig. 1).

Habitat selection and prey in relation to habitat

Comparisons between availability of different crops and the percentage of capture attempts observed on each crop type showed significant selection for alfalfa in both areas (Table 2, Fig. 2). In addition, hunting birds in Bellmunt were observed significantly more frequently than expected over shrubs and uncultivated fields (Fig. 2). Habitat availability was different inside and outside the SPAs (Table 3). There was proportionally more cereal, more shrubs and woodland inside than outside the SPAs in both areas, whereas the opposite happened for irrigated crops, orchards and other habitats.

Foraging distances increased significantly with julian date ($F_{1,523}$= 17.72, $P < 0.0001$, b = 40.72 ± 9.68). In addition, habitat use changed with date. Overall, a higher proportion of hunting observations occurred over cereal early in the breeding period, and over alfalfa later on (Fig. 3). The probability of foraging over alfalfa increased significantly with julian date, but was not affected by distance from the nest not with the interaction between date and distance (Table 4). The probability of foraging over cereal decreased with both julian date and distance from the nest (Table 4). The probability of foraging over shrubs, orchards or woodland did not vary with julian date, but varied with distance from the nest (Table 4).

The most important prey numerically were insects (39.8%, n = 266), with small mammals (34.4%) and birds (22.2%, mainly small passerines and game bird 2chicks) being next in importance. Bird eggs (3.4%), and reptiles (0.4%) were observed only occasionally. The proportion of different prey types did not vary among study areas (X^2_2 = 2.4, P=0.3). In contrast, there was a significant difference in the type of prey captured in relation to habitat (X^2_4 = 171.0, P=0.0001): 70% of prey captured in alfalfa (n = 102) were small mammals; 64% of prey captured in cereal (n = 117) were insects, whereas 83% of prey captured in other habitats (orchards, shrubs or woodland, n = 47) were birds or bird eggs.

Discussion

Our study showed that Montagu´s harriers in Lleida had foraging ranges much larger than the SPAs designated for them, and that their preferred foraging habitats differed from nesting habitat (which was, in fact, counterselected). High-energy prey (small mammals or birds) were mostly captured in habitats other than cereal, the nesting habitat. Further, it showed that preferred foraging habitats were scarcer inside than outside the SPAs. We discuss below these results and their implications for the design of SPAs, and for their effectiveness for protecting wide ranging species.

A first striking result was that Montagu´s harriers in Lleida had very large foraging ranges (more than 100 km^2 according to either MCP or 90% Kernel, 17 km^2 even when evaluating 50% kernel core areas). Range estimates in this study are larger than in the only other published radio-tracking study of home range size in this species (15.87 ± 8.27 km^2, n = 19; Salamolard, 1998), but methods used in the two studies were different. In the latter study, points used for the estimation of range size corresponded mainly to visual observations and/or triangulations (which are more likely to occur close to nests). By contrast, our study only considered points where capture attempt had taken place, and therefore did not consider non-foraging birds or birds travelling to nests, which would on average be observed closer to the nest than birds attempting to catch prey. This may explain why home ranges in Salamolard´s study are smaller than the foraging ranges we calculated. Overlap of foraging ranges of neighbouring males in this study was relatively large (30-50% of the core ranges), but despite this our study showed that a large area is used for foraging around the colonies by breeding Montagu´s harriers.

The SPAs of Anglesola and Bellmunt covered 8.5 and 35 km^2 respectively, areas clearly smaller than those used by the harriers nesting in them. Even when taking into account the whole network of SPAs in the area around the monitored nests, these covered less than 20% of the foraging ranges of the monitored individuals. Additionally, hunting distances increased with date, which may reflect that birds need to travel further distances to acquire enough food to cover the increased demands of older broods, maybe at a time when food supply is low (abundance of passerines has been found to decrease during the later part of the harrier breeding cycle; García & Arroyo, 2005) or depleted around colonies (as found for Lesser

Kestrels *Falco tinnunculus*; Bonal & Aparicio, 2008). This further supports that the area within the SPAs was insufficient to provide males with enough resources for breeding.

Both Catalonian SPAs were particularly small in comparison with other SPAs holding significant (> 5 pairs) populations of Montagu´s harriers in Spain (Table 5). The average size for SPAs designated for Montagu´s harriers was above 330 km^2, but the average population size within SPAs was ca. 30 pairs (Table 5). If the ranging needs found in Lleida apply in other areas, most SPAs would not hold enough resources for Montagu´s harriers breeding in them (e.g., only 10 of 47 SPAs were larger than 500 km^2 and thus holding enough resources for a colony of 10-15 pairs according to our results).

In terms of habitats used for foraging, the strongest preference observed in Lleida was for alfalfa. This crop holds higher diversity and abundance of small mammals (particularly voles) than either cereal or tree crops (Guixé, 2003) and our results showed that most prey captured in this habitat were small mammals. Furthermore, the relative use of this crop increased with date (when energetic needs increase as nestlings hatch and grow), but it was not related to distance from the nest. This suggests that harriers are prepared to travel long distances to reach this food-rich habitat. The use of woodland and tree crops increased with distance from the nest. This is probably related to their availability in relation to nests, because these habitats were particularly uncommon inside the Anglesola and Bellmunt SPAs (Table 3), and thus were not common close to nests. In contrast, shrubs were particularly common inside Bellmunt SPA (thus close to nests), which may explain its selection in that study area.

In contrast, the use of cereal for foraging decreased with distance from the nest, which suggests that it is mostly used opportunistically when travelling to and from other more rich-food areas. Overall, cereal was not positively selected for foraging in any of the study areas and was, in fact, counterselected. This habitat is selected for the location of the nests because it provides cover (Claro, 2000; Arroyo et al., 2004). However, in Lleida it does not contain high densities of birds or small mammals (Guixé, 2003), and most of the prey taken in that habitat were insects, which are not a preferred prey for this species (Arroyo & García, 2006). Captures of insects were most common when nestlings were very small, and most of the captures observed were used for self-consumption (Guixé, pers. obs.). The use of this habitat for foraging decreased with date, suggesting that when the energetic needs were higher, it was less efficient to forage on a habitat providing mostly insects.

This study highlights the importance of rich-food habitats for foraging Montagu´s harriers. In the case of Lleida, these requirements were mainly met in alfalfa crops. Similar results, reinforcing the importance of alfalfa within farmland habitats for this species, have been found in other countries, like western France or the Netherlands, where voles are also important as part of harrier diet (Salamolard et al., 1996; Koks et al., 2007). Non-irrigated alfalfa crops have also been found to be highly selected by many farmland birds (Salamolard et al., 1996; Lane et al., 1999), so they may be a source of overall biodiversity in farmland. However, alfalfa is frequently associated to irrigation schemes, and banning irrigation is often prescribed as an agri-environmental measure in farmland protected areas (Moreno et al., 2010), so care should be taken that, if present within SPAs, agricultural management of alfalfa is compatible with maintenance of biodiversity (Ursua, Serrano & Tella, 2005). It would be necessary to evaluate in each case which is the habitat type that provides both abundant and accessible food for the species.

Problems for the conservation of wide ranging species by site protection

Our study highlights two potential problems of the network of SPAs for protecting wide-ranging species.

Firstly, habitats inside SPAs may not be the most appropriate for foraging for the species they need to protect. SPAs in this study contained higher proportions of cereal (nesting habitat) and lower proportions of alfalfa (foraging habitat) than non-protected surrounding areas. This emphasizes the dichotomy for this and other species between nesting and foraging habitats (Sergio et al., 2003), and the importance of management at the landscape level to contemplate all needs for the species.

Secondly, size of SPAs may be insufficient to provide all resources needed by the protected populations. In Spain, less than 22% of the breeding range of Montagu´s harrier falls within designated SPAs (Traba et al., 2007). Additionally, and as seen by this study, SPAs cover only a fraction of the needs for foraging, so the proportion of the total area needed by breeding Montagu´s harriers in Spanish protected areas may be considerably smaller. Other studies have similarly found that protected areas designated for raptor species do not fulfil their foraging requirements (Martínez et al., 2007). This may, in part, be due to insufficient consideration of the ranging behaviour of such species during the designation of protected areas for them, which may be emphasized when the SPAs are designated for a number of protected species, rather than being single-species oriented (as is the case for many Spanish SPAs). However, even in situations where this information is available, it is likely that the conservation of wide-ranging species will be heavily dependent on the management of foraging habitats outside of protected areas. Given that designation of SPAs needs the compromise and commitment of numerous stakeholders, modifying the limits of existing SPAs is likely to be difficult. Thus, it is extremely important to integrate the management of protected areas with the human activities and land use occurring in their surroundings (Sergio et al., 2005), to enhance the efficacy of the SPA network for conservation of protected species.

Our study perfectly illustrates the latter point. Conservation of Montagu´s harriers breeding in Spanish SPAs must take into account their food supply, which currently derive principally from unprotected areas in the surrounding farming landscape. Increasing the sizes of the protected areas may be difficult, as stated above. Altering land use within the SPAs to increase the availability of preferred foraging habitats (alfalfa or shrubs) may be appropriate to solve this situation, but the effects this would have on the availability of harrier nesting habitat, as well as the consequences on other protected farmland species sharing the SPAs would have to be taken into account. Management habitats for different species may lead to conflicting conservation priorities, which may be reconciled most effectively if management in protected areas is integrated with that occurring in a wider context (Sergio et al., 2005). An effective means of achieving this in farmland landscapes may be through the use of "horizontal" agri-environmental measures (ie., those being low cost, easily and widely applied), or through broadening the eco-conditionality requirements for the Common Agricultural Policy subsidies, to encourage agricultural practices that will maintain and enhance prey populations in the areas adjoining SPAs. However, further thought has to be given to the agronomic, economic and ecological consequences of different agri-environmental measures, to ensure that its application outside protected areas is widely acceptable, economically viable, avoids over-implementation (which would reduce its ecological benefits, Moreno et al. 2010) and can therefore be used as a successful complement to the implementation of a network of protected area to achieve conservation of wide ranging species in farmland.

Acknowledgements

Thanks are due to all the people that have assisted with this project, especially Ferran Broto (for best help with fieldwork in Lleida every year), Fermí Sort, Jaume Bonfil, Francesc Pont and Pau Ferrer, for their valuable help and for the great moments spent together. Manel Pomarol, Lluís Brotons, Gerard Bota, David Giralt, Anna Ponjoan, Montse Raurell, Juan Bécares, Jordi Bas, Santi Mañosa, Joan Martínez and the rural agents of the Noguera and Urgell districts also contributed significantly for the development of the project. We also thank Sean Walls and Ignasi Torre for their recommendations, the Department de Medi Ambient i Habitatge, Regsega and the Centre Tecnològic Forestal de Catalunya for financial and logistic support for the programme, and Juan Carlos Atienza (from the Spanish Society of Ornithology) for information about harrier population sizes in Spanish SPAs. Lluís Brotons, Fabrizio Sergio, Todd Katzner, Steve Redpath, Manuel Morales, Phil Whitfield and Mark Wilson provided many constructive comments that significantly improved earlier versions of the manuscript.

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Table 1. Parameters of home range size and hunting distances of male Montagu´s harriers in Lleida. MPC and Kernels in km^2. Hunting distances in km.

	Anglesola (n = 10)	Bellmunt (n = 4)	All (n = 14)	Differences between areas	
				F	P
MPC	101.5 ± 66.9	201.8 ± 172.2	130.2 ± 110.2	2.67	0.12
Kernel 90%	93.5 ± 66.0	129.9 ± 173.0	103.9 ± 101.1	0.35	0.56
Kernel 50%	16.9 ± 12.2	16.75 ± 23.8	16.9 ± 15.3	0.01	0.98
Median hunting distance	5.4 ± 2.2	5.9 ± 2.1	5.5 ± 2.1	0.17	0.68
Maximum hunting distance	12.9 ± 4.7	13.3 ± 4.4	13.0 ± 4.5	0.02	0.89
% of Kernel 50% within SPAs	39 ± 29	26 ± 37	35 ± 31		
% of Kernel 90% within SPAs	20 ± 13	16 ± 14	19 ± 11		
% of hunting points within SPAs	36 ± 20	32 ± 18	35 ± 19		

Table 2. Proportion of observed trapping attempts in each habitat type, and availability of different habitats in both study areas. N = total number of trapping attempts observed, and total surface of the study areas (km^2).

Habitat	Bellmunt	Anglesola	Availability Bellmunt	Availability Anglesola
Alfalfa	50.8	48.3	17.4	5.0
Cereal	20.6	33.0	31.7	47.8
Dry orchards + vines	0.5	6.5	1.5	9.2
Irrigated orchards	4.2	5.0	5.6	4.4
Shrubs and uncultivated land	13.8	0.8	4.7	4.3
Fallow land	1.1	0.5	3.5	6.4
Corn	1.6	0.5	20.6	8.4
Woodland	6.3	3.0	6.7	7.8
Other	1.1	2.5	8.3	6.7
N	189	400	585	589

Table 3. Availability of different habitats (% of total) inside and outside the SPAs in both study areas.

	Bellmunt				Anglesola			
Habitat	Inside Bellmunt SPA	Inside other SPAs	Outside SPA	Total	Inside Anglesola SPA	Inside other SPAs	Outside SPA	Total
Irrigated herbaceous crops[1]	1.6	2.0	63.5	52.5	20.2	1.0	24.0	19.5
Non-irrigated herbaceous crops[2]	83.5	69.3	25.1	33.7	76.3	73.7	51.9	56.5
Non-irrigated orchards + vines	0.2	1.2	0.2	0.4	3.2	9.6	7.6	7.9
Irrigated orchards	0.1	0.0	4.1	3.4	0.0	0.0	3.9	3.1
Shrubs + uncultivated land	11.5	13.7	2.2	4.1	0.0	6.0	3.0	3.6
Woodland	2.7	13.2	1.4	3.0	0.0	9.4	5.8	6.4
Other[3]	0.4	0.5	3.5	3.0	0.3	0.3	3.9	3.1
Total (km^2)	28.5	78	490	597	8.6	113	464	586

1 Mainly corn, according to data in Table 2

2 Mainly cereal, according to data in Table 2

3 Urban, non arable, blab la.

Table 4. Results of GLMM models explaining the probability of hunting over different habitats in relation to date and distance from the nest. F values of non-significant variables are those obtained before elimination from the model. Parameter estimates are presented for significant variables.

	df	F	P	Parameter estimate
Alfalfa				
Date	1,575	47.15	0.0001	0.05 ± 0.006
Distance	1,521	0.39	0.53	
Date*Distance	1,521	0.39	0.57	
Cereal				
Date	1,522	45.18	0.0001	-0.05 ± 0.007
Distance	1,522	12.98	0.0003	-0.11 ± 0.03
Date*Distance	1,521	0.42	0.51	
Other habitats				
Date	1,522	0.58	0.45	
Distance	1,523	12.87	0.0004	0.098 ± 0.03
Date*Distance	1,521	1.47	0.23	

Table 5. Area (km^2) and harrier population size (number of breeding pairs) of Spanish SPAs with harrier population sizes higher than 5 breeding pairs. N: number of SPAs. Area per pair is the result of dividing the average area by the average harrier population size.

Region	N	Area	Harrier population	Area p. pair
Andalucia	7	193.2 ± 418.1	12.9 ± 4.9	14.9
Aragon	2	189.7 ± 240.9	10.0 ± 0.0	19.0
Castilla la Mancha	2	589.6 ± 682.8	15 ± 7.1	39.3
Castilla y León	23	368.8 ± 314.1	19.3 ± 12.8	19.1
Catalunya	2	21.6 ± 18.5	17.5 ± 3.5	1.2
Extremadura	6	563.2 ± 530.3	85.0 ± 73.9	7.6
Galicia	2	219.0 ± 134	15.0 ± 7.1	14.6
Madrid	1	331.0	70	4.7
Murcia	1	42.9	10	4.3
Valencia	1	19.4	30	0.6
Total	47	332.9 ± 387.3	31.4 ± 46.8	10.6

Figure legends

Figure 1. Total area ranged by foraging Montagu´s harriers (outlined in black) in each of the study areas, in relation to SPA limits (in dark grey). In light grey, highlighted other protected areas in the study area.

Figure 2. Ivlev´s selection index for different habitats in Lleida.

Figure 3. Habitat use (% of hunting points in different habitats) in relation to time in the breeding period.

FIG. 1

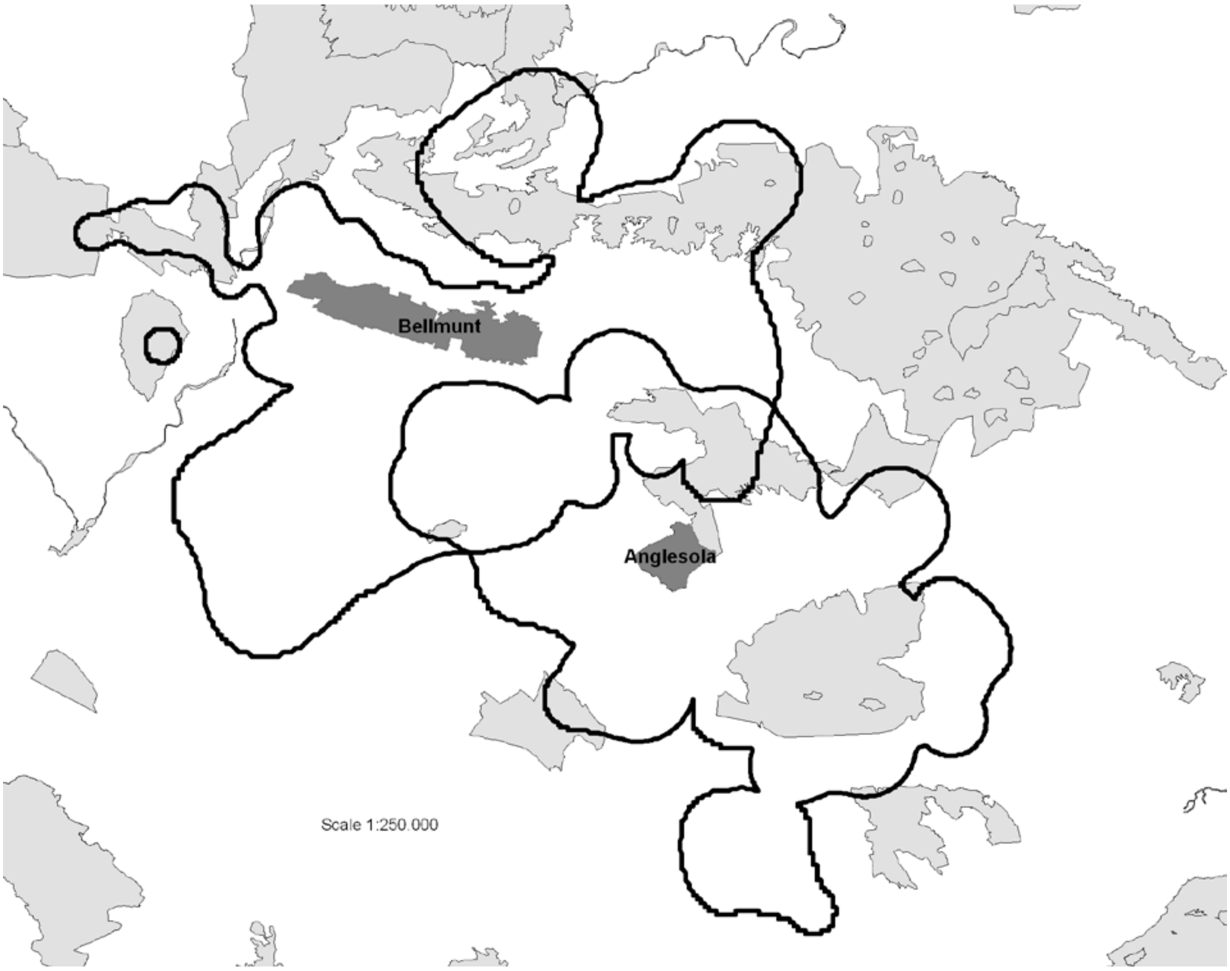
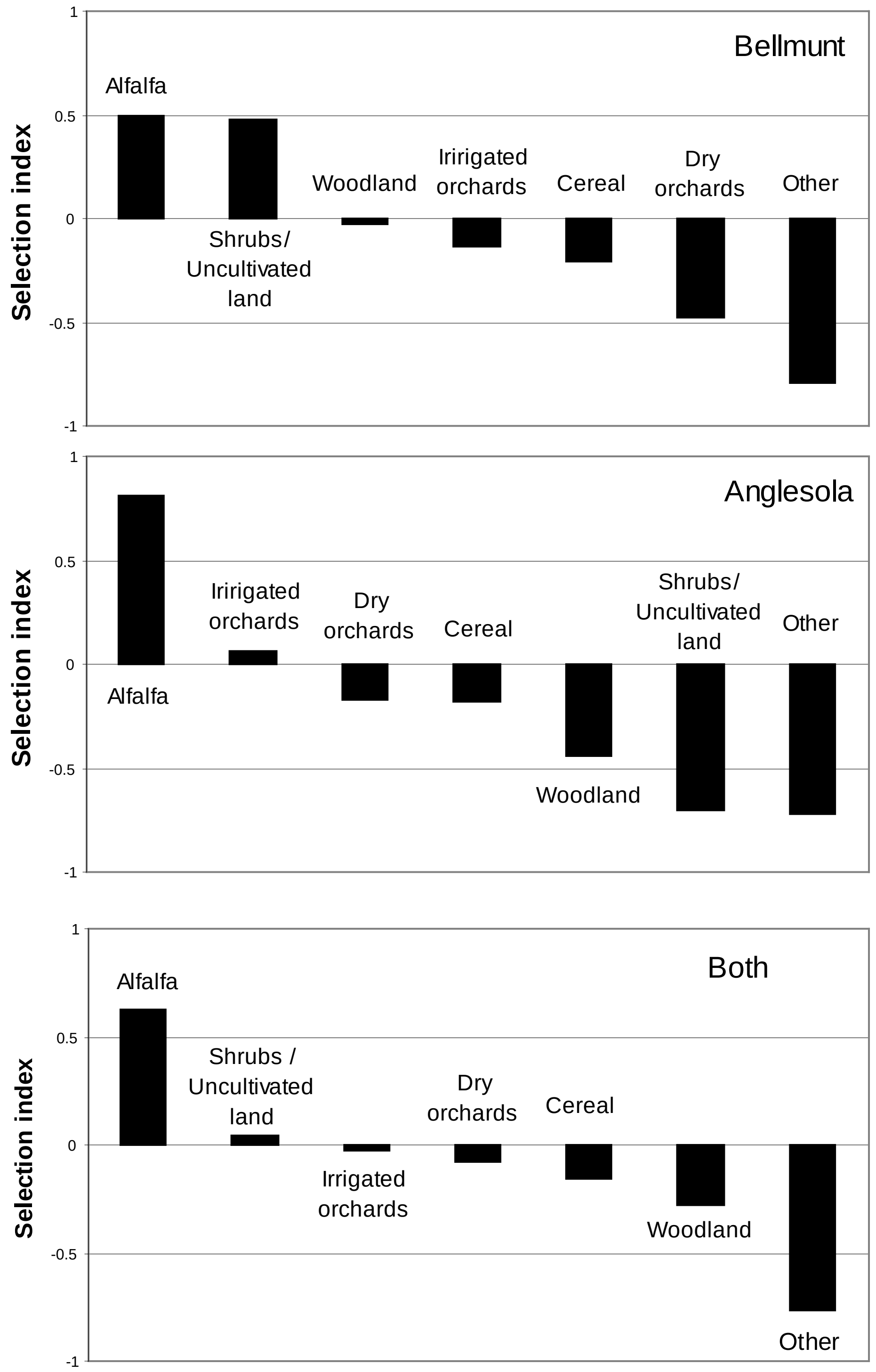
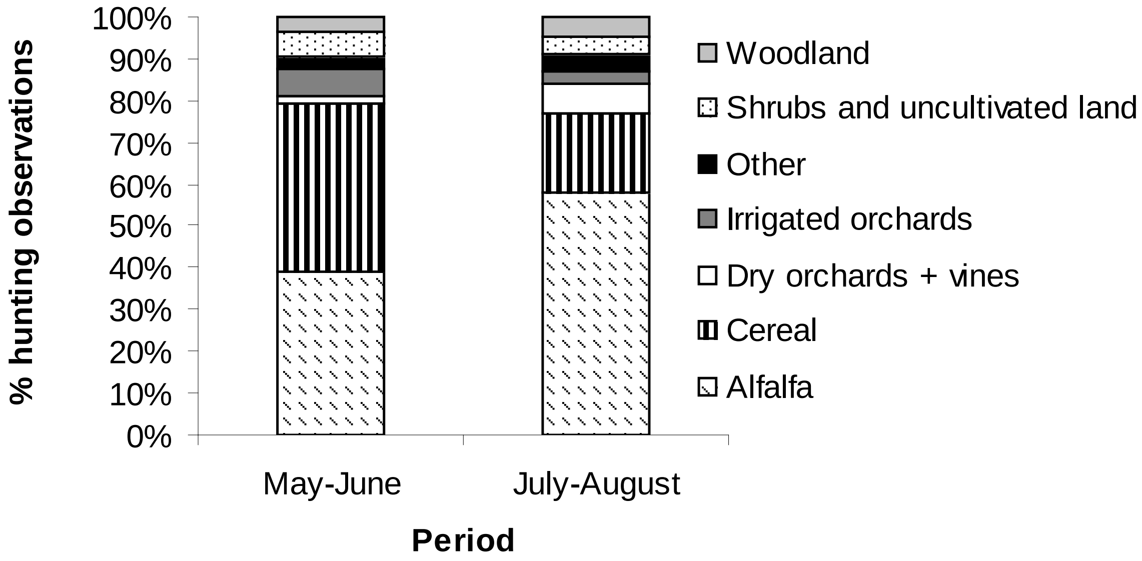


FIG. 2


Bellmunt
Selection index
1
0.5
0
-0.5
-1
Alfalfa
Shrubs/
Uncultivated
land
Woodland
Iririgated
orchards
Cereal
Dry
orchards
Other
Anglesola
Selection index
1
0.5
0
-0.5
-1
Alfalfa
Iririgated
orchards
Dry
orchards
Cereal
Woodland
Shrubs/
Uncultivated
land
Other
Both
Selection index
1
0.5
0
-0.5
-1
Alfalfa
Shrubs /
Uncultivated
land
Irrigated
orchards
Dry
orchards
Cereal
Woodland
Other


100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% hunting observations
May-June
July-August
Period
Woodland
Shrubs and uncultivated land
Other
Irrigated orchards
Dry orchards + vines
Cereal
Alfalfa

1