Orn. Anz. 41: 119-134

Conservation of Montagu's Harrier *Circus pygargus* in agricultural areas

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Zusammenfassung

Schutz der Wiesenweihe in landwirtschaftlichen Gebieten

Die Wiesenweihe *Circus pygargus* ist vermutlich der charakteristischste Greifvogel landwirtschaftlicher Lebensräume, da sie heutzutage in Westeuropa hauptsächlich in Getreidefeldern brütet. Dieser Biotopwechsel von den ursprünglichen Grasländern bewirkt, dass sie gegenüber Veränderungen in dieser vom Menschen gestalteten Umgebung anfällig wird. Die Fortpflanzung der Wiesenweihe hängt vor allem vom Nahrungsangebot in naturbelassenen Biotopen ab. So vermag die Verringerung der Biodiversität in landwirtschaftlichen Nutzungsräumen die Bestände der Wiesenweihe langfristig zu beeinflussen. Zusätzlich können Erntefahrzeuge die noch nicht flüggen Nestlinge zur Erntezeit töten. In Westeuropa (welches den Hauptanteil – Russland ausgenommen – der Brutpopulation beherbergt) könnten auf diese Weise 60 % der Nestlinge ohne Schutzmaßnahmen nicht überleben. Daher ergibt sich die Notwendigkeit zur Entwicklung eines nachhaltigen und effizienten Schutzplanes. Wir stellen gegenwärtige Schutztechniken in Frankreich und Spanien vor und untersuchen mit Modellrechnungen Wege zur Optimierung von Schutzanstrengungen. Auf großem Maßstab sollten landwirtschaftliche und ökologische Maßnahmen zur Sicherung der Beutenahrung eingebracht werden. Durch ein Netzwerk relativ kleiner Schutzflächen dagegen sollten die Weihennestlinge von den Erntearbeiten geschützt werden. Kurzfristig sollten folgende Schutzmaßnahmen Priorität haben: Förderung des Schutzes natürlicher Vegetationsgebiete, Identifizierung und Schutz der produktivsten und stabilen Brutkolonien in Landwirtschaftsgebieten und Testversuche zu Faktoren, die Wiesenweihen in geschützten Gebieten anziehen und erhalten.

Introduction

Montagu's Harrier *Circus pygargus* is one of the most typical birds of agricultural habitats. This ground nesting raptor uses crops as its habitat in various ways, building nests and hunting mainly within winter cereal fields, ray-grass, alfalfa or rapeseed fields (CRAMP & SIMMONS 1980). Use of crops for breeding by Montagu's Harrier is relatively recent (just a few decades, except in the Iberian Peninsula and France), but has spread rapidly after first observation. As a result, Montagu's Harriers seem to have substituted their original habitat by crops in most part of their breeding range and actually, the proportion of Montagu's Harriers breeding in crops exceeded 15-20 % in northeastern Europe (FLINT et al. 1984, KROGULEC 1993, IVANOVSKI 1993) and 50 % in central Europe (MARTELLI & PARODI 1992, HOLKER 1997). Furthermore, it reached at least 70 % in France (SALAMOLARD et al. 1999) and 90 % in Spain and Portugal (FERRERO 1995). The latter three countries hold about 80 % of the European population excluding Russia (TUCKER & HEATH 1994).

Fig. 1: Location of the study areas in France and Spain. DS=Deux Sèvres; R=Marais de Rochefort; BA=Baie de l'Aiguillon; M=Madrid. – *Abb. 1: Lage der Untersuchungsgebiete in Frankreich und Spanien.*

The dependence on such a man-made environment makes this species particularly vulnerable to all potential changes occurring in this habitat. At a European level Montagu's Harrier is included in conservation category SPEC 4 (species with a favourable conservation status but concentrated in Europe, TUCKER & HEATH 1994). However, the conservation status for the species in France and the Iberian Peninsula, the stronghold of western Europe, is "vulnerable" (SNPRCN 1990, BLANCO & GONZÁLEZ 1992, SALAMOLARD et al. 1999).

Throughout this paper, we wanted to know what the are the implications of this change in land use for the species in the future. We present some thoughts about this issue based in our long-term work in four study areas (Fig. 1) in western France and central Spain.

Study Areas

Most of the results presented here come from medium to long-term studies (6 to 12 years) carried out in four study areas. Three of them are located in western France: (i) Marais de Rochefort (45°57'N, 0°55'W), monitored since 1988; (ii) south of Deux Sèvres (46°11'N, 0°28'W), with data available from 1994, and (iii) Baie de l'Aiguillon (46°24'N, 1°24'W), with data collected from 1995. The fourth study area is located north-east of Madrid, central Spain (40°38'N, 3°30'W), and has been monitored since 1991. These four study sites each cover between 200 and 340 km².

Additionally, we have used data collected in other areas of Spain and France when necessary, particularly for estimates of the percentage of nestlings potentially affected due to harvesting activities.

Methods

Harrier monitoring

All nests were located each year in each study area, and were visited regularly to collect data on breeding parameters (success, timing, etc.). Additionally, a wing-tagging programme of nestlings and adults has been carried out in these areas for several years, which allowed to get data on juvenile and adult dispersal, and to develop adult and juvenile survival rate estimates.

Food and land use monitoring

Quantitative data on vole abundance based on line trapping (BUTET & LEROUX 1993) were obtained each year of the study in the three study areas in western France, and are expressed as captures/100 night-traps (for more details see ARROYO et al. in press). The land use in Deux Sevres was monitored in the field each year and incorporated in a Geographical Information System (ArcView 3.0), which allowed to calculate the surface covered by each crop type in the whole study area. Additionally, long-term data on the land use in Rochefort and Deux Sevres study areas was available through the Recensement Général Agricole (1970-1989).

Demographic simulations

Demographic parameters (breeding rates, age of first breeding, adult and juvenile survival) were used to model population dynamics using Vortex 7.0, a stochastic simulation programme (LACY et al. 1995). Age of first breeding was set at 2 years for females, and 3 years for males, which is the average observed for the species (LEROUX & BRETAGNOLLE, in prep.). Adult survival was estimated at 80 ± 7 % (LEROUX & BRETAGNOLLE, in prep.). Observation rates of wing-tagged juveniles in years after

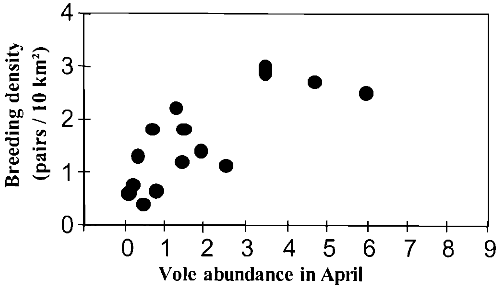

Fig. 2: Number of breeding pairs in western France and vole numbers in April. – *Abb. 2: Zahl der Brutpaare der Wiesenweihe in Westfrankreich gegen Wühlmaushäufigkeit im April.*

fledging allowed estimating juvenile survival between 35-65 %. We used 50 % ± 20 for the simulations.

Simulations were run for 100 years, and we performed 100 iterations per simulation. For the simulations, we used the following premises: no inbreeding depression, environmental variation in reproduction not correlated with environmental variation in survival, reproduction not density dependent, monogamy, sex ratio at hatching 0.5, only juveniles migrate between populations. Except when otherwise stated, simulations were performed starting from an initial population size of 50 pairs, as this is the average population size for a 200 km² area in our study sites.

Results and discussion

The importance of food for Montagu's Harrier populations

As in many other raptors, food is one of the main factors limiting reproduction in Montagu's Harrier. Fig. 2 shows how the number of breeding pairs in western France increased with vole numbers. In that area, vole abundance influenced all breeding parameters: breeding density increased with increasing vole abundance, as did clutch size and fledging success (SALAMOLARD et al. 2000). The same patterns were visible in central Spain with variations in hare availability (the main prey in that area).

In conclusion, despite a high level of plasticity in relation to diet (from lagomorphs to insects through small mammals and birds), Montagu's Harrier reproduction is strongly influenced by food abundance.

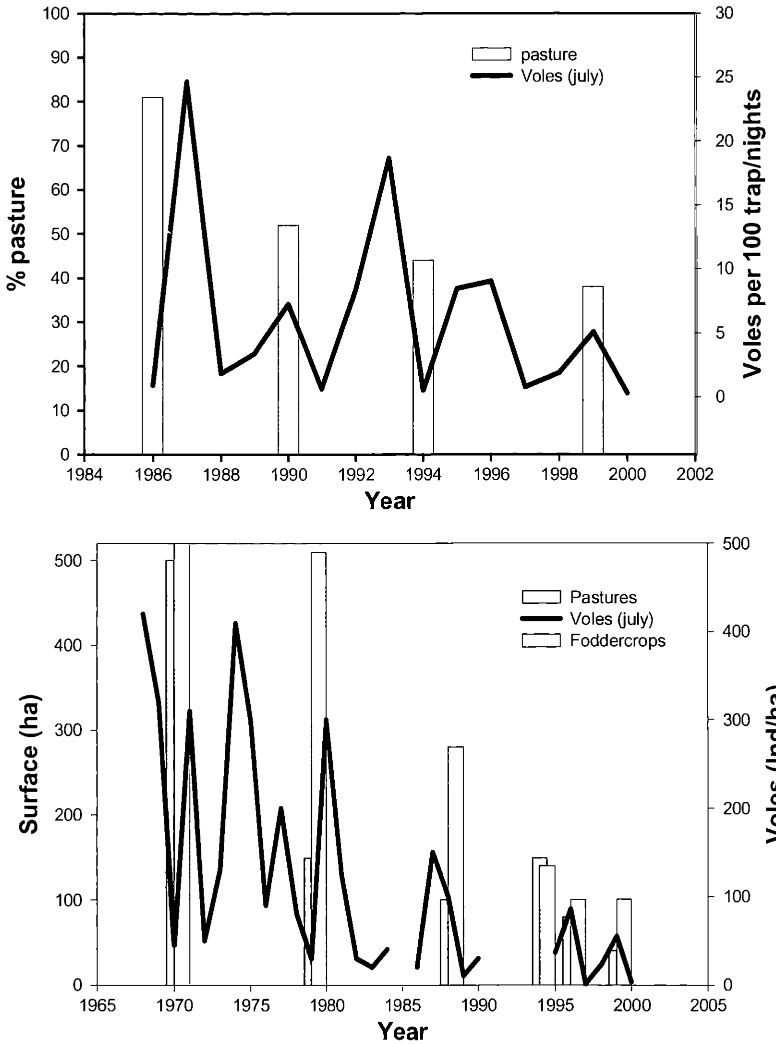

Fig. 3: Trends in land use and vole abundance in Marais de Rochefort (above) and Deux Sevres (below). Data for Marais de Rochefort from SALAMOLARD et al. (2000) and CNRS. Land use data for Deux Sevres from CNRS and RGA (corresponding to Saint-Blandine parish); vole data for Deux Sevres from QUERE et al. (1991) and CNRS (corresponding to Beauvoir parish). – *Abb. 3: Trends in Landnutzung und Wühlmaushäufigkeit in Marais de Rochefort (oben) und Deux Sevres (unten). Quellen wie oben.*

Food supplies in agricultural environments

However, agricultural habitats are currently impoverished in terms of food. A long term decline in vole abundance is apparent in two of the French areas: Marais de Rochefort, with the amplitudes of the vole cycles being progressively smaller, and in Deux-Sèvres (Fig. 3). These declines are associated to a strong reduction in the area covered with grassland and/or pasture

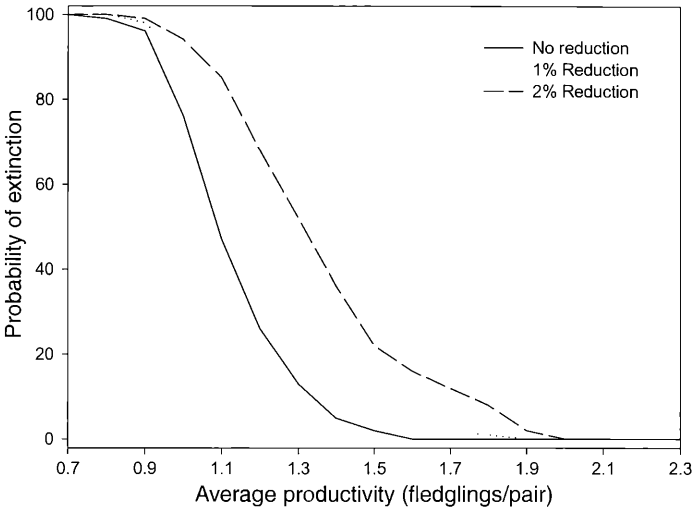

Fig. 4: Probability of extinction within 100 years of a population of Montagu's Harrier (initial population size: 50 pairs) according to variations in average harrier productivity, and according to reductions in carrying capacity of the environment. – *Abb. 4: Wahrscheinlichkeit der Auslöschung innerhalb von 100 Jahren einer Population der Wiesenweihe (anfängliche Populationsgröße 50 Paare) gemäß unterschiedlicher Reproduktionsrate und verschiedener Annahmen der Reduktion der Tragfähigkeit der Umwelt.*

land (see also DELATTRE et al. 1992). Land use changes in agricultural habitats may thus have an impact on food supply. The same pattern is visible for many other prey types: the number of insects and passerines in farmland has highly decreased throughout Europe due to changes in land use and agricultural practices (POTTS 1991, TUCKER & HEATH 1994, PAIN & PIENKOWSKI 1997, NEWTON 1998).

Therefore, agricultural habitats are associated to impoverished food supplies, and this trend might continue, particularly in countries like Spain or Portugal (or those of eastern Europe), which have entered more recently in the productive markets.

Implications for harrier sustainability

As food supply is the main factor regulating breeding performance in Montagu's Harrier, and food supply may be impoverished in agricultural habitats, what does this imply for the future of harrier populations?

Fig. 4 shows the results of the simulations evaluating the effect of variations in harrier productivity on harrier sustainability. This graph shows that if harrier productivity declines below 1.5 fledglings per pair, the probability of extinction of the populations increases strongly, and the effect is more marked if the carrying capacity (maximum number of breeding pairs in the population) declines as little as 1 or 2 %. So poor food supply in farmland may be an important limitation for harriers in the future.

The impact of harvesting activity

If harvesting (or mowing) occurs before the nestlings are able to fly, the combine harvesters may kill those nestlings. This problem has been highlighted by harrier

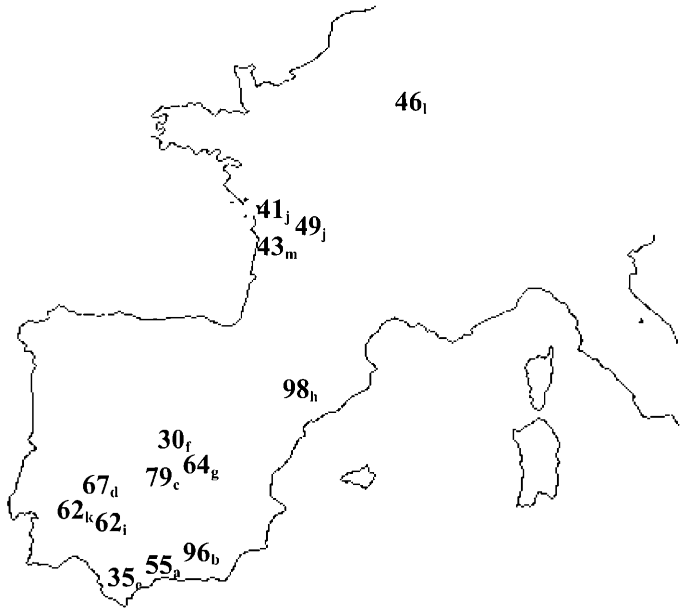

Fig. 5: Geographical variation of the percentage of nestlings at risk (i.e., nesting in agricultural habitats and unfledged at the moment of harvesting). Data sources: a) F. CABELLO DE ALBA, unpubl. data. (1999-2000); b) J. RIVAS FERNÁNDEZ, unpubl. data (1998-2000); c) CASTAÑO 1995 (1988-1994) and ESPARVEL, unpubl. data (1999-2000); d) AMUS, & J. M. TRAVERSO, unpubl. data (1999-2000); e) COCN (Colectivo Ornitológico Cigüeña Negra), unpubl. data (1999-2000); f) ARROYO & BRETAGNOLLE 2000 (1991-1998), and J. T. GARCIA, unpubl. data (1999-2000); g) GREFA, unpubl. data (1999-2000); h) POMAROL et al. 1995 (1988-1994); i) CORBACHO et al. 1997 (1987-1991); j) ARROYO & BRETAGNOLLE 2000 (1994-1998); k) CLARO 2000 (1997-1998); l) MILLON et al. in press (1993-2000); m) ARROYO, BRETAGNOLLE & LEROUX, unpubl. data (1992-1998). – *Abb. 5: Geographische Unterschiede im Prozentsatz bedrohter Nestlinge (d.h. Nisten in landwirtschaftlich genutzten Lebensräumen und nicht flügge zur Erntezeit). Quellen wie oben.*

conservationists for almost 20 years (e.g BERTHEMY et al. 1983, PALMA 1985), and nestling mortality due to this factor has been quoted to be very high, at least in some areas (e.g. PÉREZ CHISCANO & FERNÁNDEZ CRUZ 1971, MARTELLI 1987, PANDOLFI & PINO D'ASTORE 1990). This problem has been accentuated in recent years due to the increased mechanisation of agriculture. Additionally, intensification of agriculture (use of nitrates and other genetic varieties) has also favoured earlier and faster growing crops, allowing earlier harvesting.

The impact of harvesting activities in France and the Iberian Peninsula is very high (around 60 % of nestlings would die to harvesting if unprotected). Fig. 5 shows the values of the percentage of nestlings in agricultural areas that might be potentially at risk from harvesting activities (i.e., those unfledged at harvest time). In other words, average productivity could be reduced up to 60 %, assuming that all unfledged nestlings would die by combine harvesters if unprotected. The latter is not strictly true, as some (5-25 %) nestlings may survive by chance even in the absence of conservation measures, at least in some areas (ARROYO 1996, CASTAÑO 1995). Nev-

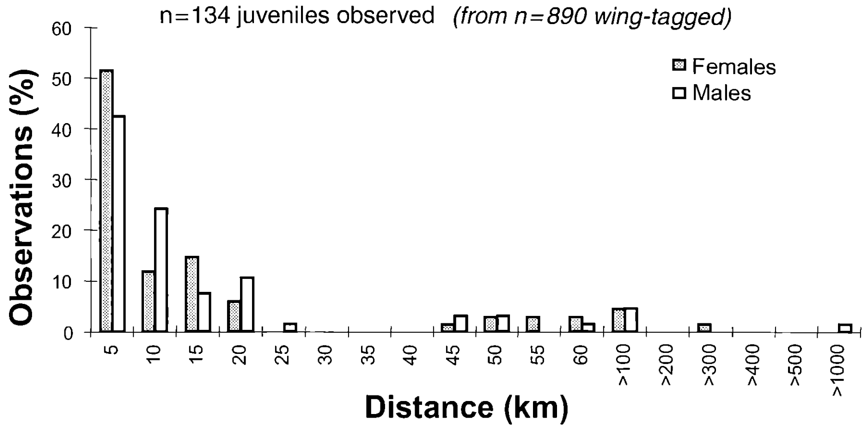

Fig. 6: Observations of birds wing-tagged as nestlings in subsequent years and distance from natal areas. – *Abb. 6: Wiederfunde (Folgejahre) von Wiesenweihen, die als Nestlinge flügelmarkiert wurden, in Abhängigkeit von der Distanz vom Geburtsort.*

ertheless, even a 40 % reduction in productivity makes harrier populations unsustainable in the absence of conservation measures (ARROYO & BRETAGNOLLE 2000). Therefore, harvesting activities represent a threat for harrier sustainability even in the short term.

Optimising our conservation effort

Our question was, if conservation measures are so necessary, how can we optimise our efforts and make them sustainable in the long term? Several aspects of Montagu's Harrier biology are important to give answers to that.

First, harrier populations are not isolated. Wing-tags have allowed us to see that, even if some birds come to their natal area to breed, many others disperse to breed in different areas (ARROYO & BRETAGNOLLE 2000). In Fig. 6, we show that at least 15 % of the observations of birds wing-tagged as nestlings occurred more than 50 km away from the natal areas.

This connectivity between areas through natal dispersal has a strong influence on population sustainability: for example, Fig. 7 shows that the probability of extinction of a population where 50 % of the nestlings would die due to harvesting activity (Deux Sevres, in black) would drop to almost cero even in the absence of conservation measures, if 5 % of the nestlings produced in a protected area dispersed to the first area to breed.

These results imply that conservation measures applied to a given area also affect all other areas connected to it through juvenile dispersal. Therefore, if resources are limited and they do not allow full protection of all breeding areas, the choice exists as to how to distribute those resources in the most efficient way. This raises the question: is it better to concentrate these resources in a particular area, or to share them among as many areas as possible? We explored that option with simulation analyses (Fig. 8). We evaluated the probability of extinction of four hypothetical populations of Montagu's Harriers connected bilaterally through juvenile dispersal (1 % of fledglings produced in each area would settle in each of the other 3 areas each year). Each population held in-

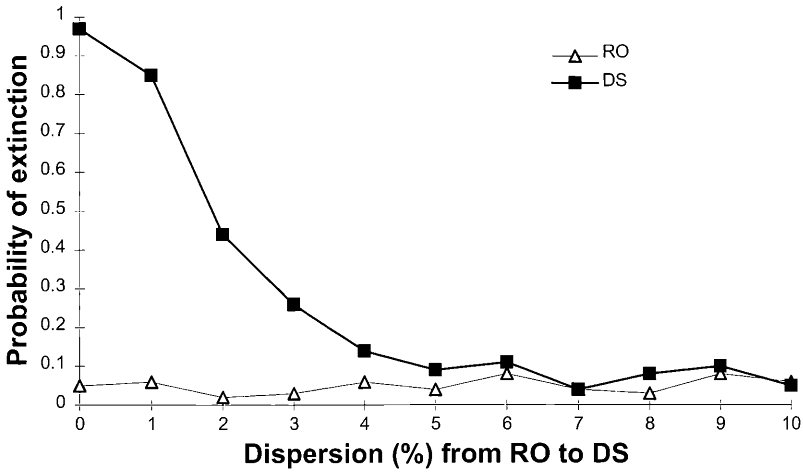

Fig. 7: Effect of connectivity through natal dispersal on population sustainability of a fully productive population (RO = Rochefort, in white) and another one loosing 50 % of its nestlings due to harvesting activities(DS = Deux Sevres, in black) in the absence of conservation measures. – *Abb. 7: Effekt des Zusammenhalts durch postnatale Dispersion auf die Beständigkeit der Population von einer voll produktiven Population (RO = Rochefort, weiß) und einer, die 50 % ihrer Nestlinge durch Erntevorgänge verliert (DS = Deux Sevres, schwarz), ohne Schutzmaßnahmen.*

itially 80 breeding pairs, had a potential productivity of 2 fledglings per pair, and suffered 50 % nestling mortality through harvesting activities in the absence of conservation measures. The simulation presents four potential scenarios, assuming that we only have resources to save 40 nests per year. The first scenario contemplates that those resources would be used equally among all areas, thus saving 25 % of affected nests in each area. In the second and third scenario, the resources would be distributed among only two of the populations (saving either 50 % of affected nests in each population, or 75 % of affected nests in one, and 25 % in the other). In the last scenario, all resources would be concentrated in only one of the four populations, saving 100 % of the affected nests there, but leaving unprotected all other three areas. Fig. 8 represents the probability of extinction of each of the populations and the whole metapopulation in each of those scenarios. As observed in that figure, the most effective situation (in terms of maximising persistence) would be the one in which one of the populations is fully protected.

These results highlight the importance of maintaining fully productive populations. The first way to attain this in a sustainable and economic way would be to protect populations that are naturally productive and unaffected by harvesting problems, such as those breeding in natural vegetation. This conclusion is particularly important when considering that most conservation measures for the species have been based in protection of nests in agricultural areas, and that most natural vegetation populations in Spain and France are unprotected. Secondly, these results also suggest that, if resources are limited and do not allow full protection of all breeding areas, it is more efficient to concentrate conservation efforts in a given area, making sure that most nests are saved there, rather than working less intensively in lar-

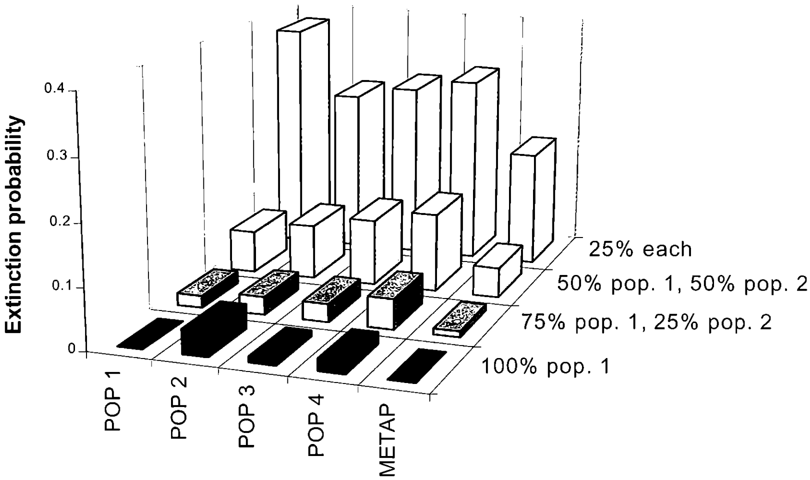

Fig. 8: Probability of extinction of four hypothetical populations (initial population size: 80 pairs) and the whole metapopulation of Montagu's Harriers connected bilaterally through juvenile dispersal, and each suffering 50 % nestling mortality due to harvesting activities, according to the percentage of nests saved in each population (all scenarios represent the same amount of resources used). – *Abb. 8: Wahrscheinlichkeit der Auslöschung 4 hypothetischer Populationen (anfängliche Populationsgröße 80 Paare) und der gesamten Metapopulation von Wiesenweihen, die gegenseitig durch Dispersion im Jugendalter verbunden sind, jede mit 50 % Nestlingssterblichkeit durch Erntearbeiten angenommen, in Abhängigkeit vom Prozentsatz geretteter Nester in jeder Population (alle Szenarien mit gleichem angenommenen Anteil an Ressourcen).*

ger areas. An efficient and economic way of attaining this would be to concentrate conservation efforts in areas that are easy to protect. For example, in areas where the impact of harvesting activities is relatively low, fewer nests would have to be protected. Another way of optimising the effort would be to concentrate resources in areas where farmers are particularly sensitive to agro-environmental measures (for example, in areas where they are already subject to such measures for other species). Finally, efforts could be also concentrated in areas where other special protection measures are already implemented, such as in Special Protected Areas (SPAs).

In any case, the most efficient and sustainable way of protecting Montagu's Harrier nestlings from harvesting activity would probably involve habitat management, rather than nest management. As opposed to many other raptors, which build nests that are durable from one year to the next, nests of Montagu's Harriers are not solid physical structures, and are built each year. Human resources used to locate the nests are therefore considerable, and have to be renewed each year. Habitat management, for example through agro-environmental measures (e.g. delaying harvesting until most nestlings have fledged), would allow to protect the nestlings without the need of locating the nests. An analysis over two years in several areas in Spain of the relationship between timing of harvesting and timing of fledging showed that overlap in most areas would be avoided by delaying harvesting by only 7-10 days (Iberian Working Group of Harriers, unpublished data).

However, this brings out another problem. It is not always easy to apply habitat

Fig. 9: Location of Montagu's Harrier nests in Deux Sevres area (data from 1992 to 1999). – *Abb. 9: Fundorte von Wiesenweihennestern im Gebiet Deux Sevres (Daten von 1992 bis 1999).*

measures (e.g. agro-environmental measures) over big surfaces. Which would be the minimum surface on which we should act upon? In other words, how to minimise (thus optimise) our efforts in terms of surface? Another aspect of Montagu's Harrier biology gives insight about how to answer that question.

Harriers as semi-colonial species

Montagu's Harriers, as opposed to many raptors that are territorial, breed semi-colonially. This means that, even if some nests appear isolated, the majority of nests are distributed in a highly clumped fashion (Fig. 9).

We may consider harrier populations as a compound of subpopulations (the colonies) connected through dispersion in a meta-population. Dispersal data from wing-tagged juveniles showed that, even for the ca. 5 % of juveniles that came back to breed in the natal area, the majority of them did not breed in their colony of origin (Fig. 6).

In theory, we could organise conservation measures in a network of small protected areas. Fig. 10 shows the results of simulation analyses for a meta-population model in which a varying number of those colonies would be protected. The results show that, in such circumstances, the whole metapopulation would persist (and to a level at least 70 % of initial population size) with as few as 5 (40 %) colonies protected. Obviously, these results should not be taken literally, because the premises used for simulation analyses are somewhat simplistic. Nevertheless, the simulation shows that, at least theoretically, a scenario of a network of a relatively reduced number of small protected areas could be efficient.

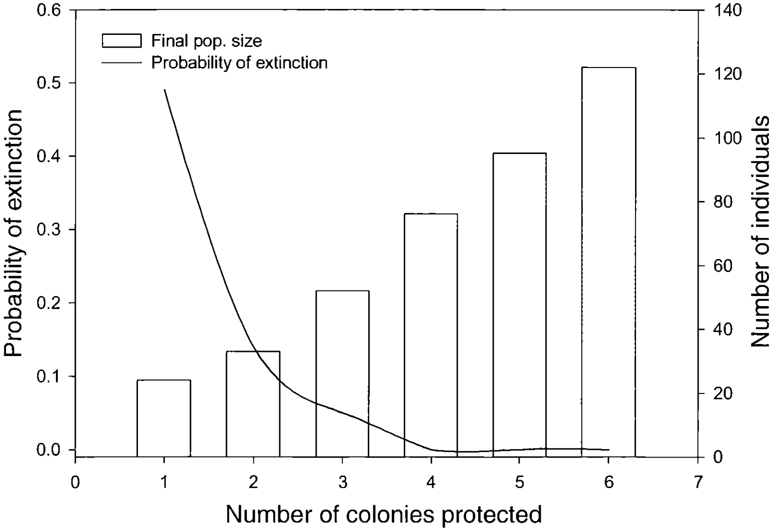

Fig. 10: Probability of extinction and final population size of a hypothetical population of Montagu's Harriers, distributed in 12 colonies each 7-15 pairs, and suffering 50% nestling mortality due to harvesting activities in the absence of conservation measures, according to the number of those colonies protected. – *Abb. 10: Wahrscheinlichkeit der Auslöschung und endgültige Populationsgröße einer hypothetischen Population der Wiesenweihe, verteilt auf 12 Kolonien á 7-15 Paare, mit angenommenen 50 % Nestlingssterblichkeit durch Erntevorgänge in Abwesenheit von Schutzmaßnahmen, in Abhängigkeit von der Zahl geschützter Kolonien.*

Such a possibility would indeed be interesting, given that it would be easier to manage, both logistically and economically.

It brings, however, another problem. As stated above, colony location is not fixed, and Montagu's Harriers may move considerable distances between one reproductive event and the following one. Even if such a network of protected areas were in place, how could we make sure that the harriers would use them instead of settling nearby? In other words, how could we attract and maintain harriers in protected areas? Knowledge about factors influencing nest area choice in this species may help to answer this question.

Parameters affecting choice of nest site

Some studies have shown that vegetation height is important in nest area selection by Montagu's Harrier (see, for example data provided by Joao Claro in this workshop). Additionally, as in many other raptors, food abundance is also important in determining nest location. Harriers used preferentially areas with high vole abundance, but the relationship was not very strong (Fig. 11 and Table 1). In many colonial species, conspecific attraction is also important to determine nest area choice, and also conspecific breeding success. When we included the total number of fledglings produced in a given 1 km² in the previous breeding seasons the model improved strongly (Table 1). In other words, harriers are attracted to areas where young

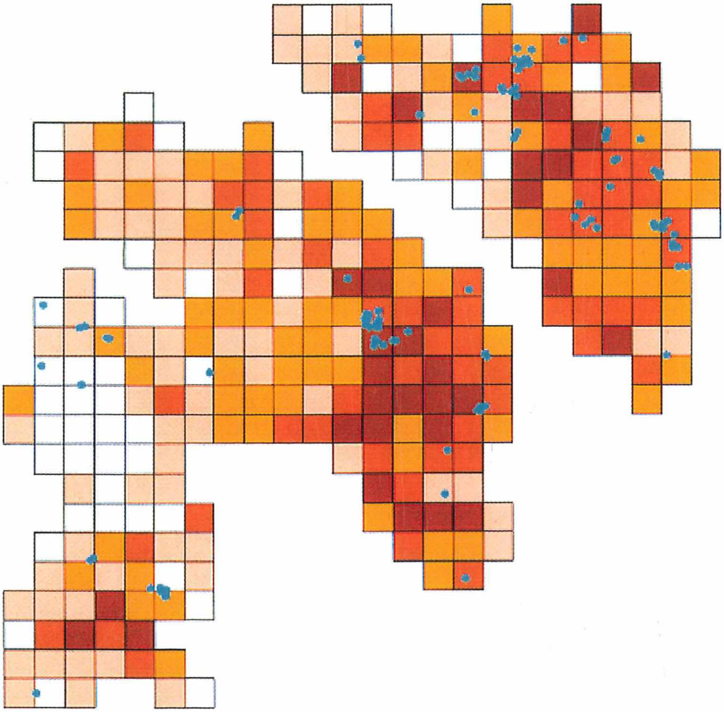

Fig. 11: Montagu's Harrier nest location (blue dots) in Deux Sevres study area and vole abundance estimated by vole traps in each 1 km². Increased darkness in the colour of squares show increased density of voles. – *Abb. 11: Neststandorte der Wiesenweihe (blaue Punkte) im Untersuchungsgebiet Deux Sevres und Wühlmausabundanz geschätzt nach Fallenergebnissen pro km². Zunehmende Schattierung der Quadrate zeigt zunehmende Wühlmausdichte an.*

Table 1: Results of both, voles and voles + previous breeding success, in explaining presence of nests in each square (see also Fig. 11). – *Statistische Ergebnisse von a) Wühlmäusen und b) Wühlmäusen und vorherigem Bruterfolg (Wiesenweihe) zur Erklärung der Präsenz von Nestern pro Quadratkilometer (siehe dazu Abb. 11).*

Influence of vole abundance on the number of nests found in each square			
Regression	**Voles**	$F_{1,309}=11.81$	P=0.001, r^2=3.4 %
Influence of vole abundance and conspecific previous breeding success on the number of nests found in each square.			
Logistic Regression	**Voles**	–2LogLR=5.21	P=0.025
	Breeding success	–2LogLR=11.76	**P=0.0006**

harriers are produced each year, and which contain good food supplies.

All those variables (vegetation height, food abundance, fledging success) could be thus potentially used to attract and maintain harriers to protected areas. Experimental evaluations could be developed to determine the most attractive vegetation heights, or land use that maximises food abundance in each area. Additionally, traditionally productive colonies could be protected in priority, given that they are more likely to be used in subsequent years. Finally, in some circumstances, breeding success could even be artificially manipulated (e.g. boosted) in protected areas.

Conclusions

The Montagu's Harrier is clearly dependent on conservation measures for its sustainability in the long term. This paper does not attempt to give all the answers, but rather to highlight the fact that there is a need to think of sustainable and efficient conservation measures.

1. Habitat management is probably more efficient than nest management on the long term, so
2. Agro-environmental measures should be applied where possible (to improve food supply in the environment, or to delay harvesting in large areas, etc.). Otherwise, conservation could be implemented at small scale (at the colony level), and
3. Experiments could be performed to see which measures (vegetation height, food abundance, productivity) can be used best to attract and maintain harriers to protected areas.

Acknowledgements

Many people helped with fieldwork in our study areas throughout the years, but particular thanks are due to Marc Salamolard, Marie-Helene Froger and Luis Palomares. Alain Leroux started the wing-tagging programme, and helped both in the field and with advise throughout the project. Carole Attié helped in many stages of the work (and thanks are also due for last minute assistance). We also thank all participants of the Iberian Working Group on Harriers and to the participants in the Spanish National Campaign for study and Conservation of Harriers, for discussion and for allowing the use of unpublished data.

Summary

Montagu's Harrier *Circus pygargus* is probably the most characteristic raptor of agricultural habitats, as it breeds nowadays mainly in cereal crops in western Europe. This habitat shift from the original grasslands implies that changes in this man-made environment are most likely to affect it. Montagu's Harrier reproduction is mainly dependant on food supply in natural conditions, so biodiversity decline in agricultural areas might affect harrier sustainability in the long term. Additionally, combine harvesters may kill harrier nestlings if unfledged at harvest time. In western Europe (which holds the stronghold of the breeding population, excluding Russia), an average of 60 % of nestlings in agricultural areas could perish like that in the absence of conservation measures. There is therefore a need for developing sustainable and efficient conservation plans. Such measures should include some directed to maintaining food supplies, as well as some directed to minimise impact of harvesting activities on harrier productivity. We review current conservation techniques and resources used in France and Spain, and explore with simulation techniques ways of optimising conservation effort. Large scale agro-environmental measures should be implemented for maintaining food supplies.

Protection of harrier nestlings from harvesting activity, in contrast, should be optimally implemented through a network of relatively small protected areas. Promoting protection of natural vegetation areas, identifying and protecting the most productive and stable colonies in agricultural areas, and testing experimentally factors that are likely to attract and maintain harriers in protected areas should be prioritary in the short term.

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