Christiane Trierweiler

Considerations on Demography and Conservation of Montagu’s Harrier *Circus pygargus* in east Groningen, Netherlands

Master of Science Thesis

Supervision: Ben Koks, Cor Dijkstra, Jan Komdeur

Animal Ecology Group and
Animal Behaviour Group
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Natuurbeleid staat of valt met een visie. In de visie van de meeste beleidsmakers staan biotopen als bos, hei, veen en moeras vaak centraal en vormt het cultuurland een ondergeschoven kindje.

- Ben Koks & Kees Van Scharenburg 1997 -

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Abstract

We studied correlations between reproductive parameters and environmental factors in Montagu's Harrier, breeding in agricultural habitat in east Groningen, Netherlands. Knowledge on such factors is of importance for conservation of the marginal population there. Common Voles (*Microtus arvalis)* made up between one third (considering estimated biomass) and half (considering prey number) of the diet. Diet was diverse, indicating generalist behaviour in 2003. During the study period (1992-2003), 1992 was the only good vole year. Voles were most numerous on fallow land and in high vegetation. Montagu's Harrier in east Groningen exhibited no numerical response to vole abundance during the study period. There was a trend of earlier laying in relatively good vole years, but other breeding parameters did not correlate with vole abundance. This and the generalist behaviour indicate that Montagu's Harrier was not single prey dependent in poor vole years. Breeding variables did not correlate with weather parameters. Vole abundance on the other hand correlated with maximal temperature and sunshine duration (average April-August). In protected nests, clutch sizes were larger and egg-fledgling survival better, but not significantly. We conclude that nest protection is still crucial but not effective on the long run. Habitat management aiming at better food supply, e.g. more extensive agriculture, set-aside edges with high vegetation and mowing management, is more likely to increase breeding pair numbers. Identifying and protecting most productive areas in the population supposedly covering the Netherlands, Germany and Denmark, could favour a sustainable sub-population in east Groningen.

Introduction

> *The factors that affect bird-of-prey populations are complex and various, and no species can be properly managed without some knowledge of its needs, and its limiting factors.*
>
> - Ian Newton 1979 -

During the 20th century, Montagu's Harriers (*Circus pygargus*) in the Netherlands switched from natural to farmland habitat (Koks & Visser 2002). Much of their natural heath, moor, dune and hayland habitat disappeared or deteriorated under human influence (Koks & Visser 2002). The development of the Dutch breeding population showed a decline from about 500-1000 pairs at the beginning of the last century to near extinction until the 1980's (Zijlstra & Hustings 1992, Koks & Visser 2002). Only since the 1990's, when settlement in farmland habitat started, a small population re-established (Koks & Van Scharenburg 1997).

East Groningen must still be regarded as a sink area, probably for German and Danish birds (Koks *et al.* 2001). Reproductive success is too low to maintain a population on the long run and reproduction depends largely on nest-protection (Koks *et al.* 2001).

The critical situation could possibly not only be caused by habitat loss in the breeding areas, but also by mortality during migration or in the winter quarters (West Africa). As causes for mortality outside the breeding season, Clarke (1996) names e.g. recent drought in the Sahel and pesticide use in West Africa. Shooting during migration occurs in Mediterranean countries.

It is thus not known to which extent these factors influence population size, and it remains unclear whether the situation on the breeding sites has contributed crucially to the population breakdown in the Netherlands. However, it is reasonable to assume that habitat loss has if not caused so at least aggravated the decline in the Netherlands.

To prevent extinction of a raptor species, different strategies can be thought of. As Newton (1979) pointed out, one can manage the birds' habitat, their food sources or the birds themselves. The goal of conservation measures in the Netherlands is to maintain or increase reproduction of Montagu's Harrier in order to form a stable and persistent population.

In the Netherlands, after fragmentation and degradation of natural habitat of Montagu's Harrier, the remaining patches play a minor role (Koks & Visser 2002). First, there was no substitution for natural habitat, as agricultural land with mostly cereal crops, like in east Groningen, was not attractive. Ploughing does not favour high prey densities (Newton 1979).

Changing habitat is usually the most difficult management possibility (Newton 1979). In east Groningen, the exceptional situation of a drastic change in land use occurred in the early 1990's: In 1989, by European Policy, large areas of cereal crop fields became fallow land (McSharry set-aside). As Common Voles (*Microtus arvalis*) are typically numerous in fallow land (Butet & Leroux 1988), this resulted in peaking Common Vole densities (Koks & Van Scharenburg 1997). The immense amelioration in food supply made the former intensively used arable land a suitable habitat for raptors, including Montagu's Harrier (Koks & Van Scharenburg 1997).

Montagu's Harrier in continental western Europe relies mostly on Common Voles as prey (e.g. Butet & Leroux 2001, Koks & Van Scharenburg 1997, Krogulec & Leroux 1994). Settlement of breeding pairs and fledging success have been shown to correlate with Common Vole density in spring respectively summer in a French Montagu's Harrier population, where voles make up the largest part of the diet (Butet & Leroux 1993). Also in other studies, correlations of food availability and reproductive parameters have been shown (Arroyo 1998, Salamolard *et al.* 2000). In east Groningen, smaller clutch sizes and fewer fledged young are observed in poor vole years (Koks *et al.* 2001).

After the colonisation of east Groningen in the early 1990s, the most urgent conservation measure appeared to be one of managing the birds themselves: by nest protection. Breeding in arable land has been shown to be less successful than in natural habitats, because nests in arable land can be destroyed by agricultural practices without protection (Corbacho *et al*. 1997). Set-aside patches have no suitable vegetation for nesting (Koks & Van Scharenburg 1997). Losses due to farming activities can possibly endanger whole populations (Arroyo *et al.* 2002). Modelling by Koks *et al.* (2001) predicted that the marginal east Groningen population of around 30 breeding pairs would not be sustainable without nest protection.

After the early 1990s, the McSharry set-aside regulation was replaced by more small scale, short lasting set-aside measures. The area of vole-rich fallow land decreased. Consequently, since around 1993, food supply deteriorated (Koks & Van Scharenburg 1997). It is now again a goal to maintain or improve the quality of the agricultural habitat in east Groningen in terms of food supply. Present set-aside measures are already used as a conservation tool, though implementation has to be improved.

In this study, we analyse correlates of demography and reproduction of Montagu's Harrier in east Groningen. Correlations with vole abundance, nest protection and weather are investigated. Results can be of importance when considering conservation strategies.

First, we estimate importance of voles for Montagu's Harrier from their proportion in the diet. We assess diet with three different methods: Pellets, prey remains and video observations of prey delivery at one nest. In our study, we consider the three methods separately (Underhill-Day 1993), then we compare proportions from the different methods and combine pellets and prey remains as well (Simmons *et al.* 1991). Furthermore, we compare species composition of small mammals from sightings to proportions from the vole trapping in order to verify whether our trapping method samples prey which is also selected by harriers.

Secondly, vole population dynamics in east Groningen since 1992 are analysed based on a data-set of a long-term project on Montagu's Harrier by Koks (1990-2003, Koks pers. comm.). For 2003, the relationship between vegetation structure and vole abundance is investigated. Lower vegetation height means better visibility to the hunting harrier and thus higher prey availability (Simmons *et al.* 2000). Prey is expected to be most abundant where it is least available to predators (Simmons *et al.* 2000). Also, one expects voles to shelter from predators in tall vegetation (Jacob & Hempel 2003).

Finally we investigate correlations of number of breeding pairs and reproductive parameters (laying date, clutch size at laying, brood size at fledging, egg-fledling survival) with vole abundance and we try to assess influences of nest protection and weather circumstances. Weather can probably directly influence reproductive success (Clarke 1996). We evaluate our findings in the context of conservation aspects and come to suggestions on how to improve conservation management.

Methods

> *’t Was een groot genot, daar uren achtereen te zitten en de roofvogelhuishouding gade te slaan. […] Nu glijdt een schaduw over ‘t nest, nog eens en nog weer en ‘t volgend ogenblik staat daar de kiekendief, het wijfje, op hoge poten.*
>
> \- Jac. P. Thijsse 1903 -

Study site

This study was conducted as a part of a long-term project (starting in 1990) on Montagu´s Harrier in the Netherlands. Data were collected from 20 April to 20 August 2003. The study site (surface area: 650 km^2) was located in the North of the Netherlands in the eastern part of the Province of Groningen (N 53°11", E 7°4", see Figure 1).

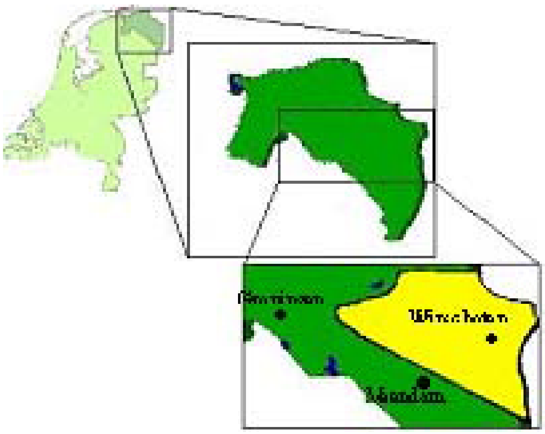

Figure 1
Map of study site (yellow, lowest figure; surface area: 650 km^2) in eastern part of Groningen (middle figure), Netherlands (upper figure).

Diet

For most nests, a pole was placed in the parcel edge of the breeding parcel early in the season, creating a perch post where pellets and prey remains would be concentrated. Perch posts, parcel edges and paths along ditches were checked for pellets and prey remains weekly. Pellets were analysed for their content in indigestible remains. The maximum number of individuals per pellet was counted (Arroyo 1997). From earlier studies, one expects remains to over-estimate bird prey and an under-estimate small mammals (Clarke 1996, Simmons *et al.* 1991). Pellets are expected to over-estimate small prey and under-estimate birds (Simmons *et al.* 1991). A combination of pellets and remains is believed to be less biased (Simmons *et al.* 1991, Arroyo 1997). As searching effort for pellets and remains was equal in our study, a combination was possible as well. Biomass was calculated by multiplying prey numbers with estimated average eaten prey biomass from Arroyo (1997): birds 52 g, eggs 18 g, small mammals 20 g, insects 1 g, large mammals 100 g. Biomass estimates were not used for statistical testing because of their inherent bias (Arroyo 1997). Prey remain and pellet data were available from 1992 onwards.

In 2003, prey delivery during the breeding season was observed at one nest. The nest was located in lucerne and protected. A hide was placed outside the nest protection fence at six metres from the nest. Observations were conducted by one observer during the nestling phase (10 July to 2 August). 13 observations were made (117 h). Average observation duration was 8.5 h. Observations were conducted during the daylight period between 7:30 h and 21:00 h. Prey delivered by the parents was filmed with a video camera by the observer and analysed afterwards. Simmons *et al.* (1991) describe direct observations as the most precise method, concerning proportions of small mammals and birds. He recommends to calibrate prey remain and pellet proportions with sightings. Other authors are critical about biases and reliability of sightings at the nest (Arroyo 1997, Clarke 1996, Maurel & Poustomis 2001, Underhill-Day 1993).

Prey type is more difficult to determine from sightings than from prey remains and pellets (Maurel & Poustomis 2001). Only 66 % of all prey which has been filmed could at least be categorised as vole or bird prey. Reasons for that were that prey was only shortly visible, in case the female was to feed the young with her back to the camera, or that the young already left the nest and prey was delivered at a greater distance from the camera, or behind the vegetation. For future video observations, it can be recommended to cease observations after the young are able to walk out of the nest. Successful prey observations became very scarce after that.

Diversity of the diet is calculated with the Shannon-Weaver diversity index H’ (Arroyo 1997), according to the following formula:

$$H' = - S \; P_i \; \log P_i$$

where

$P_i = X_i/X$

X_i = number of prey items from class *i* and

X = total number of prey items.

Vole population dynamics

During the long-term project, vole abundance in different agricultural habitats has been measured from 1992 onwards in the beginning of August each year. According to a standard method (e.g. Dijkstra *et al.* 1995), we used transects of traps with ten stations every 10 m, one station comprising five traps arranged in a circle of diameter four metres, if possible near vole runways or burrows. Transects were located in different habitats belonging to 10 categories, three of which were set-aside types (grassy set-aside, wood set-aside, fauna edge) and seven being regular habitat types (grass seed, nature reserve, lucerne, wood, dyke, grassy path, grain). After the traps were placed on day one, dead voles were removed and fresh carrots placed once a day during two days. Traps were removed on the fourth day.

Vegetation height at vole trapping plots was measured with a polystyrene disc diameter 45 cm and height 1.5 cm, sliding horizontally along a ruler through its middle, landing on top of the vegetation (Kuiper pers. comm.). Vegetation cover was estimated for a 20 x 20 cm square, being the percentage of the area which was no bare ground. Vegetation height and cover were measured ten times for each plot.

To analyse vole abundance data, we used a three-level generalised linear model working with MLwiN version 2.0 software. This kind of model accounts for the nested structure of the data and no problems arise from incomplete data-sets (Maas & Snijders 2003). Data are averages over 50 traps (one plot on one day), levels in the model are 1: day, 2: year, 3: plot. It was a random intercepts model with logit link function, assuming extrabinomial distribution and using 2nd order Penalised Quasi Likelihood (PQL) estimation. For analyses of vole and vegetation data of 2003 only, a generalised linear model similar to the above, but with two levels (level 1: day, level 2: plot) was used.

Reproduction and its correlates

Breeding pairs were located by observations of birds showing mating or nesting behaviour. Parcel owners were informed and asked permission to enter their land. When a pair was located, observations of a female landing with nest material were indicating the exact location of the nest. In case the nest was located in a field to be harvested in the egg or nestling phase, the nest was marked with sticks. All land owners spared a square of 11 x 11 m crop around nests without financial compensation. An electrical cattle fence against ground predators was placed around the square of crop (Koks *et al.* 2001). Reproduction parameters were noted during nest visits. Laying date was back-calculated from clutch size (assuming eggs have been laid every second day) or wing length according to a growth curve (Koks pers. comm.). Clutch size at laying and brood size at fledging were observed directly. Survival from egg to fledgling was calculated for nests with known clutch and brood size. Reproduction and protection data were available from 1992 onwards. Daily averages of weather parameters for 1992 to 2003 are taken from a database of the Royal Dutch Meteorological Society (KNMI).

Results

> *[…] The species‘ feeding habits (generalist* v *specialist) influence their population dynamics, the numbers of specialist hunters being more likely to fluctuate annually when dependent on a fluctuating food source.*
>
> - Beatriz Arroyo 1997 -

Diet

Proportions of prey numbers for all nests in 2003 are represented in Figure 2. Proportions from pellets and remains did not differ significantly (Wilcoxon signed rank test, $Z = -0.14$, $n = 5$, $P = 0.9$). Small mammals made up the largest part of the diet assessed from pellets (54%) and bird prey that from prey remains (73%). Large mammals were more often found in prey remains than in pellets. Eggs and insects were found more often in pellets than in prey remains. A combination of both methods is shown as well. Here, small mammals made up half of the diet and birds almost one third.

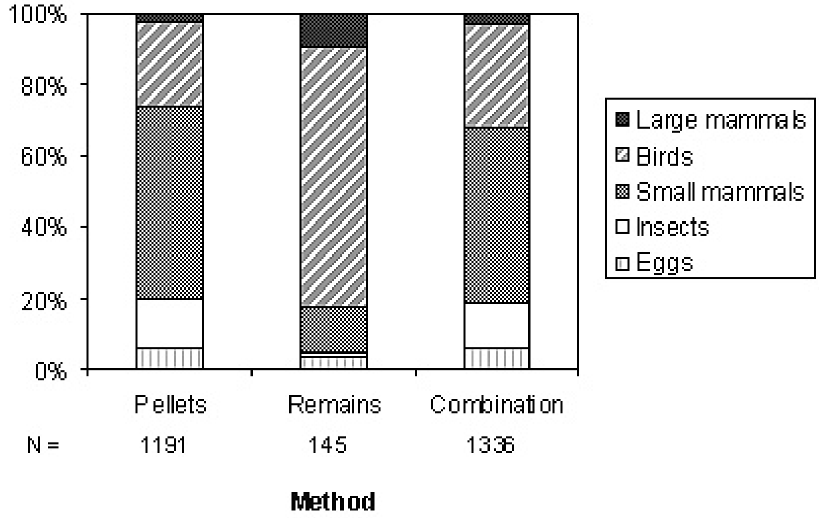

Figure 2
Percentage of total prey number of five prey categories from pellets and prey remains. Differences were not significant (Wilcoxon signed rank test, $Z = -0.14$, $n = 5$, $p = 0.9$). A combination of both methods is shown as well. Data are for all nests in east Groningen in 2003

To make a valid comparison between pellets and sightings, only pellets collected during the video observation period near the observed nest were used. Prey remains composition could not be compared to the other two methods, because only one item was found during the video observation period. From sightings and pellets could be concluded that the largest part of the diet consisted of small mammals (see Figure 3). Simmons *et al.* (1991) suggest to calibrate proportions of small mammals and birds in pellets by comparing them to sightings (the least biased method). Small mammals were under-estimated in pellets 0.7-fold and birds were over-estimated 2.4-fold respective to sightings. Differences between both methods were not significant (Wilcoxon signed rank test, Z = 0.0, n = 5, p = 1.0).

In Figure 4, the percentage of estimated biomass in pellets and remains for different prey categories is shown. Again, pellets and prey remains showed differences. Compared to prey number proportions, birds and large mammals increased in importance whereas small mammals, eggs and insects decreased. Now, birds made up 45 % of the diet and small mammals 40 %, according to pellets.

The Shannon-Weaver diversity index H' calculated from pellets in 2003 was 0.52 (n =1186), from prey remains it was 0.37 (n =144). For video observations, diversity was 0.22 (n =78).

Vole population dynamics

We compared species composition of small mammals from video observations to proportions from the vole census in order to verify whether trapping sampled prey which was also selected by harriers (see Table 1). The proportions of prey species from the vole census in 2003 were not significantly different from those recorded on video (Wilcoxon Signed Rank Test, Z = -0.14, n = 8, p = 0.9).

To investigate vole demography, year was entered as categorical variable into a three-level generalised linear model for vole abundance. Years differed significantly in the average number of voles trapped (Wald test: X^2 = 42.4, df = 10, p < 0.0001, see Table 2). 1992 was a significantly better vole year than all other years (p - values < 0.05). In 2003, significantly less voles were trapped than in 1992 (Wald test: X^2= 3.9, df = 1, p = 0.048). 2003 did not differ significantly from 1999 (Wald test: X^2= 1.8, df = 1, p = 0.2) and 1998 (Wald test: X^2= 3.0, df = 1, p = 0.08). In 2003, significantly more voles were trapped than in the remaining years, differences were significant at the 5%-level.

Habitat was entered as categorical variable in the generalised linear model already containing year. Habitats differed significantly in the average number of voles per trap per day, correcting for year differences (Wald test: X^2 = 26.4, df = 9, p = 0.002). Alternatively, type (the difference between regular and set-aside fields) was entered into the model containing year. More voles were trapped in set-aside types (including grassy set-aside, wood set-aside, fauna edge) than in regular types (grass seed, nature reserve, lucerne, wood, dyke, grassy path, grain; Wald test: X^2 =

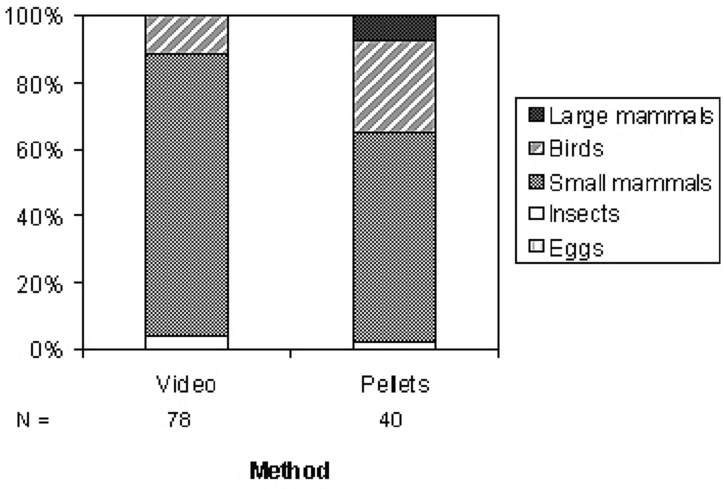

Figure 3
Percentage of total prey number of five prey categories, observed during sightings (video) and in pellets. Pellets were collected in the period of video observations near the observed nest. Differences between both methods were not significant (Wilcoxon signed rank test, *Z* = 0.0, *n* = 5, *p* = 1.0).

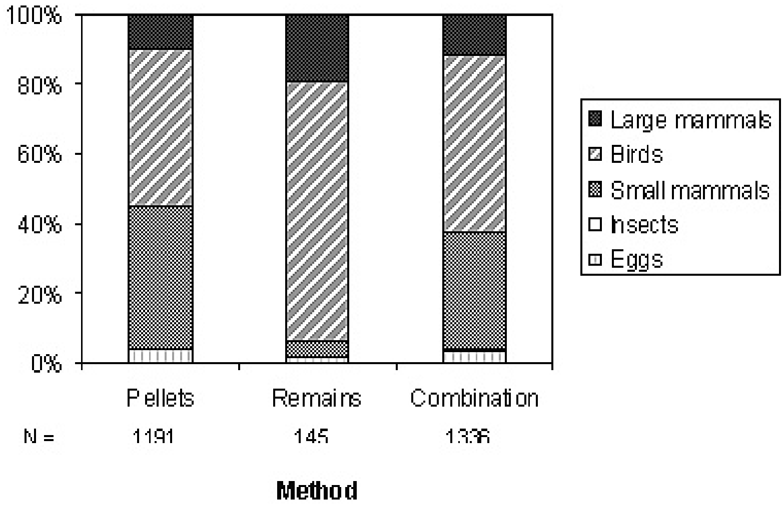

Figure 4
Percentage of prey biomass of five prey categories, found in pellets and prey remains. A combination of both methods is shown as well. Data are for all nests in east Groningen in 2003.

Table 1

Small mammal species observed in vole census and on video

Species	Percentage Census (all years)	 Census (2003)	 Video[1)]
Apodemus sylvaticus	7.0	2.5	4.2
Clethrionomys glareolus	0.0	0.4	0.0
Micromys minutus	0.8	0.8	4.2
Microtus agrestis	0.2	0.0	0.0
Microtus arvalis	87.5	93.8	91.7
Mus musculus	0.6	0.0	0.0
Sorex araneus	3.6	0.0	0.0
Sorex spec.	0.3	2.1	0.0
n	1322	240	24

1) The proportions of prey species recorded on video were not significantly different from those from the vole census, both over all years and in 2003 (2003: Wilcoxon Signed Rank Test, Z = -0.14, *n* = 8, *p* = 0.9).

Table 2

Generalised linear model1) for vole abundance and numbers of voles trapped

	Coefficient	(s.e.)	Wald test: X^2	*df*	*p*	Voles/trap/day2)	*n*3)
Fixed part							
Constant	-1.977	(0.441)					
Year			42.4	10	<0.001**		
1992	0	(0)				0.24	10
2003	-1.233	(0.492)				0.08	19
1999	-1.316	(0.525)				0.08	13
1998	-1.519	(0.531)				0.07	13
2000	-1.868	(0.583)				0.05	10
1996	-2.055	(0.567)				0.03	11
1995	-2.314	(0.564)				0.04	14
1993	-2.322	(0.538)				0.05	12
1994	-2.326	(0.566)				0.04	12
1997	-2.561	(0.596)				0.01	13
2001	-2.634	(0.578)				0.03	11
Type			6.1	1	<0.05*		
set-aside	0.702	(0.284)				0.09	71
regular	0	(0)				0.05	67
Random part							
o^2u (year level)	0.179	(0.166)					
o^2u (plot level)	1.039	(0.234)					

1) Random intercepts model with three levels: level 1: day, level 2: year, level 3: plot. Data are averages over 50 traps (one plot on one day). We used the logit link function, assumed extrabinomial distribution and used 2nd order PQL estimation. Main model: Vole abundance = Constant + Year + Type.

2) Average number of voles per trap per day represents averages uncorrected for type respectively year differences.

3) For ‘Year’, *n* is expressed as number of plots. For ‘Type’, *n* is expressed as number of plot years.

* significant at the 5%-level

** significant at the 1 %-level

6.1, *df* = 1, $p = 0.013$, see Table 2). A model including year and type instead of year and habitat had a slightly better fit (Year and type: AIC = -1412, Year and habitat: AIC = -1409).

When entering weather parameters instead of year as explanatory variables into the model containing type, the following variables were significant at the 1% or 5%-level: maximal temperature, sunshine duration and percentage sunshine of total possible duration (year averages April-August, Wald tests). The relationships with maximal temperature and sunshine duration are positive, whereas the relationship with percentage sunshine of total possible duration is negative. Rainfall parameters were not significant. The model has a worse fit than the above mentioned model including type and year (Type and year: AIC = -1412, type and weather parameters: AIC = -1400).

Vegetation parameters were entered into a two-level model for vole abundance in 2003. More voles were trapped in higher vegetation (Wald test, $X^2 = 7.9$, *df* = 1, $p < 0.05$, see Figure 5). There was no quadratic or third power relationship between vole abundance and vegetation height (Wald test, quadratic: $X^2 = 2.2$, *df* = 1, $p = 0.14$. Third power: $X^2 = 0.82$, *df* = 1, $p = 0.4$). For the 2003 data-set, differences between habitats and the difference between regular and set-aside fields were not significant (Wald tests. Habitat: $X^2 = 6.0$, *df* = 7, $p = 0.5$; type: $X^2 = 0.13$, *df* = 1, $p = 0.7$). There was no significant difference between fields with different vegetation use (categories: grazed, walked upon, mown, not mown, ploughed; Wald test: $X^2 = 4.1$, *df* = 4, $p = 0.4$). Neither was there a significant relationship with vegetation cover (Wald test: $X^2 = 1.6$, *df* = 1, $p = 0.2$).

Reproduction and its correlates

The number of breeding pairs in east Groningen between 1992 and 2003 does not differ significantly between years (see Figure 6, and Table 3 for statistical tests). Clutch size at laying is not significantly different between years (Table 3). Brood size at fledging differs significantly between years (see Figure 7 and Table 3). It was highest in the early 1990's, dropped to a low in 1994 and recovered in the following years. There are no year differences in survival from egg to fledgling (Table 3). Clutch size at laying and egg-fledgling survival did not relate to any of the weather parameters tested (Table 3). Brood size showed a trend towards a negative correlation with sunshine duration ($r_s = -0.17$, $n = 99$, $p = 0.09$, Table 3). Other weather parameters tested were not significant ($p > 0.2$).

Average laying date in east Groningen between 1990 and 2003 was 25 May ($n = 189$). The differences between years were significant (see Figure 8 and Table 3). In 1992 and 1993, laying dates were early, between 1994 and 1996 laying dates were latest, levelling off towards the turn of the century. The earlier laying date, the larger was clutch size at laying (Spearman correlation,

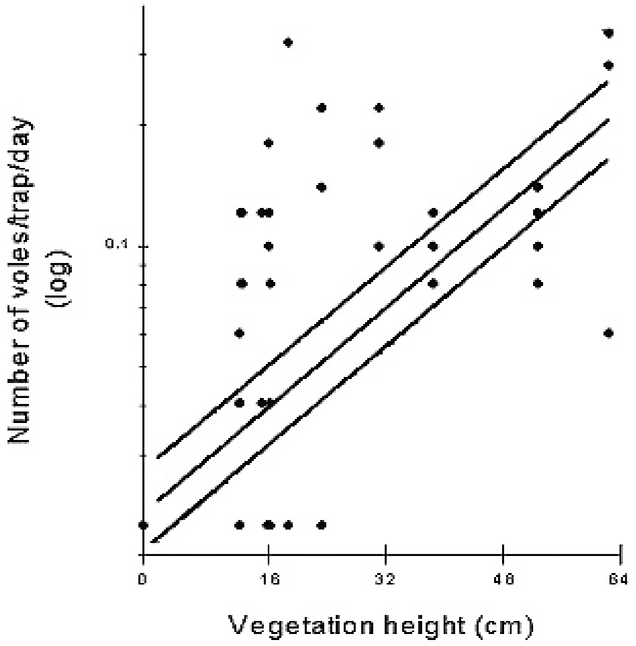

Figure 5
Number of voles increased with increasing vegetation height (Wald test, $X^2 = 7.9$, $df = 1$, $p < 0.05$). Number of voles was averaged over traps and is shown on logaritmic scale. Lines represent predictions from a two-level generalised linear model (level 1: day, level 2: plot) including day number and vegetation height as explanatory variables, for the three trap days (lowest line: day 1, middle line: day 3, upper line: day 2).

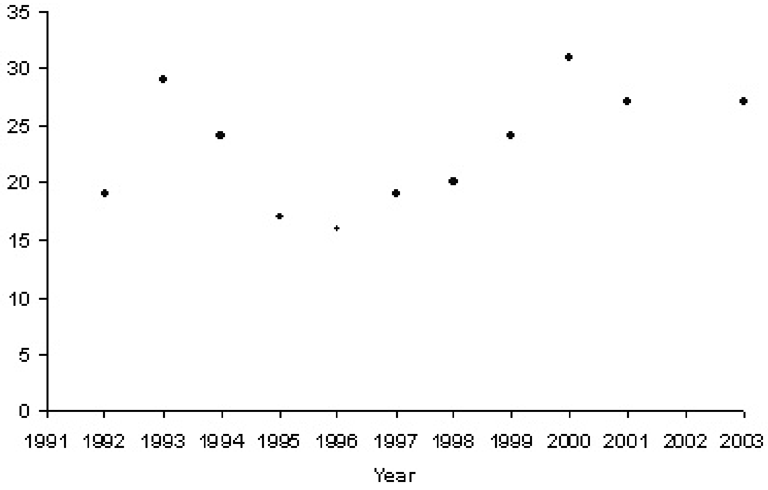

Figure 6
Number of breeding pairs in east Groningen from 1992 to 2003. Year differences were not significant (Pearson correlation, $r = 0.42$, $n = 11$, $p = 0.20$).

Table 3

Relationship of breeding variables with environmental factors (statistical tests)

	Number of breeding pairs	Clutch size at laying	Brood size at fledging	Egg-fledgling survival	Laying date
Year	Correlation	K-W - test	K-W - test	Wald test	K-W - test
Test statistic	$r = 0.4$	$X^2 = 10.6$	$X^2 = 20.8$	$X^2 = 6.0$	$X^2 = 33.3$
p	0.2	0.4	0.02*	0.9	<0.0001**
n / df	11	99	196	11	11
Weather parameters		Correlations	Correlations	Wald tests	Correlations
Test statistic		r_s	r_s	$?^2$	r_s
p		> 0.5	> 0.09	> 0.1	> 0.1
Vole abundence	Correlation	Correlation	Correlation	Wald test	Correlation
Test statistic	$r_s = 0.3$	$r_s = 0.1$	$r_s = 0.1$	$X^2 = 0.1$	$r_s = -0.15$
p	0.3	0.4	0.3	0.7	0.053
n / df	11	99	196	1	161
Nest protection			Correlation	Wald test	
Test statistic			$r_s = 0.1$	$X^2 = 2.1$	
p			0.11	0.15	
n / df			165	1	

* significant at the 5%-level

** significant at the 1%-level

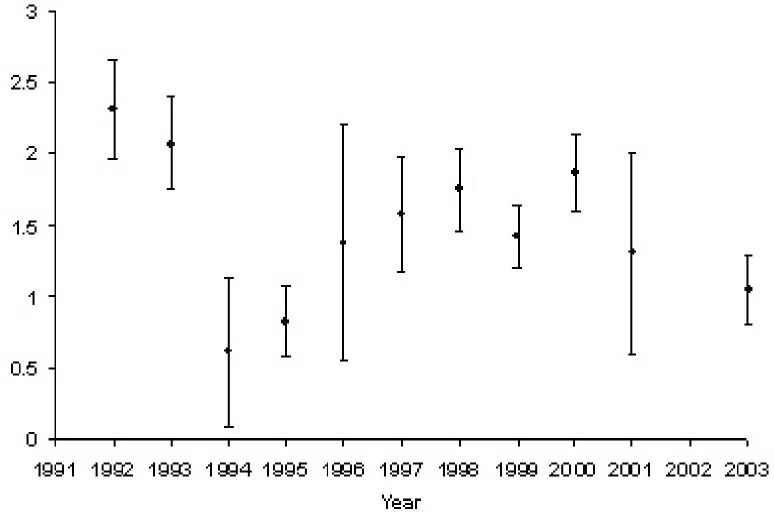

Figure 7
Average brood size at fledging in east Groningen between 1992 and 2003. Year differences were significant (Kruskal-Wallis test, X^2 = 20.8, *df* = 10, *n* = 196, *p* = 0.02). Error bars represent ± 1 s.e.

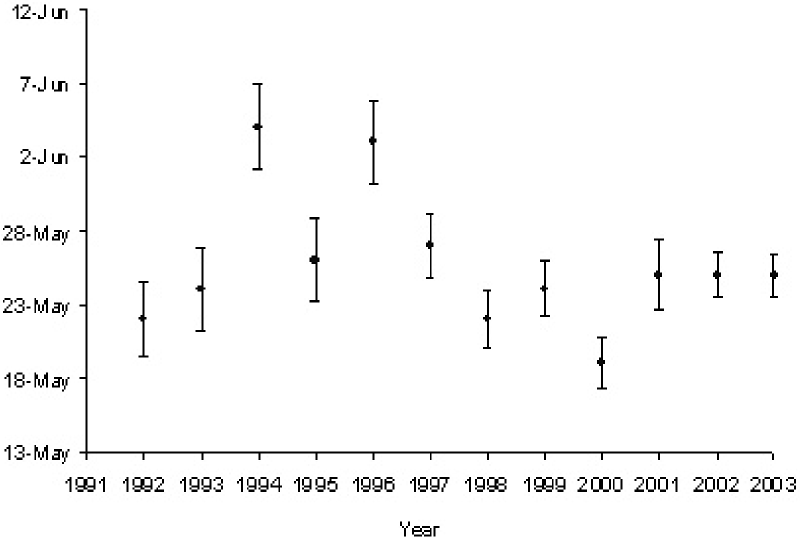

Figure 8
Average laying date for east Groningen breeding pairs between 1992 and 2003. Year differences were significant (Kruskal-Wallis Test, X^2=33.3, *df* =11, *n* =188, *p* <0.0001). Error bars represent ± 1 s.e.

r_s = -0.30, n = 119, p = 0.001) and brood size at fledging (Spearman correlation, r_s = -0.23, n = 159, p = 0.004, see Figure 9). Relative laying date with respect to annual mean was significantly correlated with clutch size at laying (Spearman correlation, r_s = -0.26, n =118, p = 0.005), but not with brood size at fledging (Spearman correlation, r_s = -0.1, n = 158, p = 0.2, see Figure 10). Laying date was not correlated with average weather parameters (year averages April-August: sunshine and precipitation parameters, see Table 3). There was a trend towards a negative relationship of laying date with average vole abundance per year (see Figure 11 and Table 3).

Vole abundance did neither significantly affect total number of breeding pairs, clutch size at laying nor brood size at fledging (Table 3). Vole abundance had no significant influence on egg-fledgling survival (Table 3).

There was a trend towards a positive correlation of nest protection and brood size at fledging (see Figure 12 and Table 3). We also found a trend of a positive correlation between protection and egg-fledgling survival (Table 3).

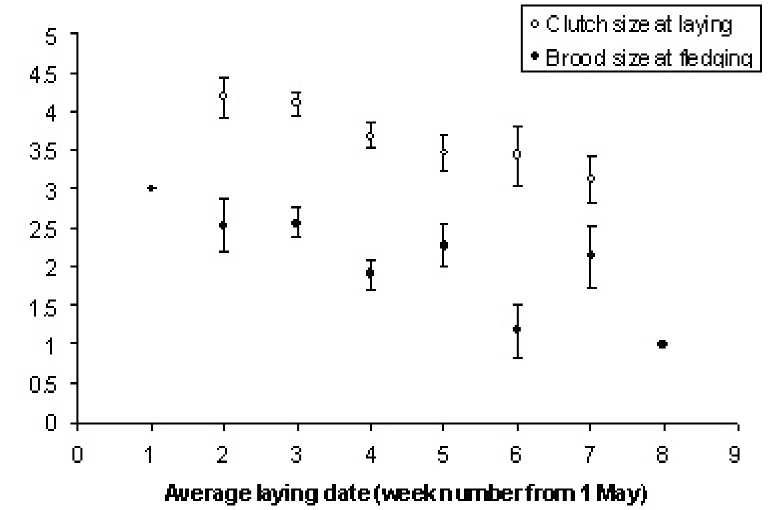

Figure 9

The earlier laying date, the larger clutch size at laying (Spearman correlation, $r_s = -0.30$, $n = 119$, $p = 0.001$) and brood size at fledging (Spearman correlation, $r_s = -0.23$, $n = 159$, $p = 0.004$). Laying date is represented here as weekly average over all years (week count starting from 1 May). Error bars represent ± 1 s.e.

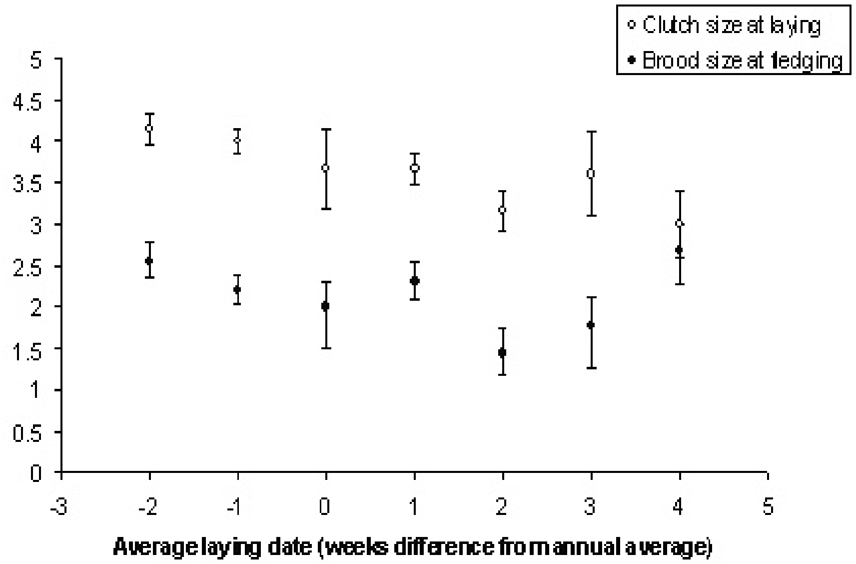

Figure 10

Relative laying date with respect to annual mean was significantly correlated with clutch size at laying (Spearman correlation, $r_s = -0.26$, $n = 118$, $p = 0.005$), not with brood size at fledging (Spearman correlation, $r_s = -0.1$, $n = 158$, $p = 0.2$). Laying date is represented here as difference in weeks from the annual average laying date. Error bars represent ± 1 s.e.

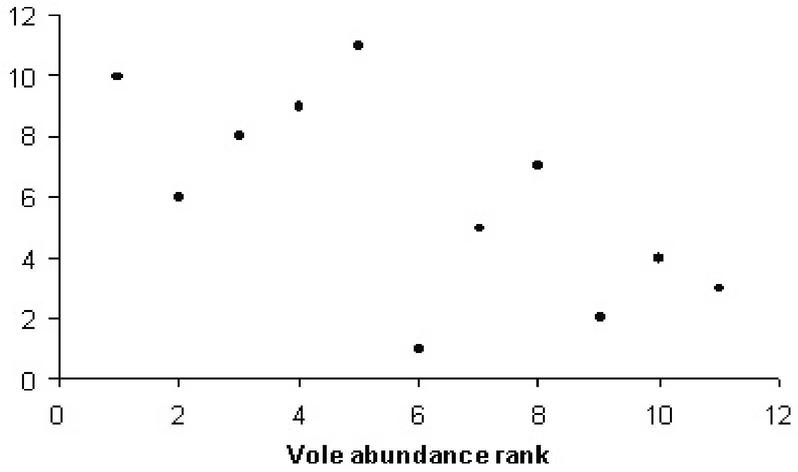

Figure 11
Trend towards a negative relationship of laying date with average vole abundance per year (Spearman correlation, r_s = -0.15, *n* =161, *p* = 0.053). Both laying date and number of voles per trap per day are represented here as rank for each year average.

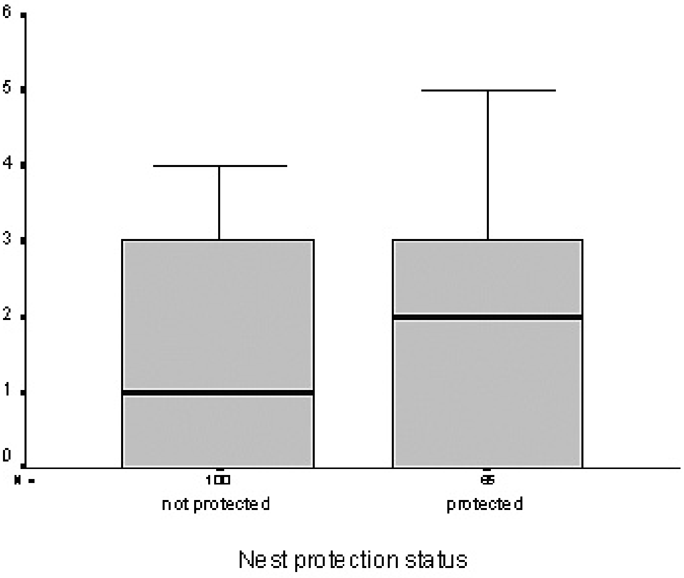

Figure 12
Trend towards a positive correlation of nest protection and brood size at fledging in east Groningen (1992-2003; Spearman correlation, r_s = 0.12, *n* = 165, *p* = 0.11).

Discussion

> […] *There is a need for global thought on the conservation plan for the species. This is particularly necessary as […] conservation efforts in one area influence viability in others.*
>
> - Beatriz Arroyo *et al.* 2002-

Diet

As expected, pellets contain more small mammals and prey remains contain more birds in terms of numbers, however, differences are not significant. Pellets and sightings do not differ significantly either, both contain mainly small mammals. Pellets under-estimate small mammals and over-estimate birds according to sightings. Simmons *et al.* (1991) on the contrary find pellets to be biased in the opposite direction. In the present study however, sample size is much smaller. Furthermore, results may be confounded because sightings can also be liable to some bias: Clarke (1996) supposes only large prey items would be transported to the nest. Arroyo (1997) on the other hand suggests smaller items might be better for the nestlings. We have reason to believe that more testing is needed before one can accept a combination of pellets and remains as the most accurate estimate of diet. As the number of pellets found in one season is much larger than of remains, the combination of pellets and remains for 2003 still indicates that small mammals are most important in the diet in terms of numbers (50% of total prey number).

The picture for biomass reveals a more important role for birds, now accounting for almost half of the diet according to pellets, slightly more than small mammals. As biomass is based on average mass, we cannot attach too much importance to this conclusion.

During the 1960's and 1970's, Schipper (1973) finds Montagu's Harriers in natural vegetation in the Netherlands having a diet of low diversity (Arroyo 1997) containing birds, lizards and small mammals. However, the conclusions on diversity (0.11, 0.39 respectively 0.39 for three locations) are drawn on sample sizes of 28, 36 respectively 82 pellets. The diversity of 0.52 calculated in the present study is based on a sample of 1191 pellets. This difference could have some influence on the result. Still, seen other studies of comparable latitude (see for overview Arroyo 1997), the diversity is unexpectedly high. The Netherlands are cited as one of the countries with least diverse diet (Arroyo 1997). This conclusion does at least not hold for the east Groningen population in 2003. The high diversity indicates that Montagu's Harrier in east Groningen behaved as a generalist in that year. The east Groningen polders obviously hold a more diverse prey spectrum than one would expect seen the intensive agriculture. Though, we cannot jump to the conclusion that Montagu's Harrier here is never specialised in Common Voles as it is in other European populations in agricultural habitat (Krogulec & Leroux 1994, Butet & Leroux 1988). An explanation could be that high diversity of diet is due to a poor vole year and Montagu's Harrier switching to alternative prey. Remarkable changes in the proportion of Common Voles in the diet over the years have been noted both in France and in the Netherlands (Krogulec & Leroux 1994, Koks & Visser 2002). If alternative prey is efficient enough to pay in terms of reproduction is doubtful (Butet & Leroux 2001).

Vole population dynamics

In the period between 1992 and 2003, there is only one good vole year, which is 1992. Between 1992 and all other years, there is a large gap in terms of vole abundance. 2003 is, although slightly better than some other years, still much worse than 1992. This confirms our expectations from the diverse diet. Harriers supposedly have to find alternative prey because of low vole abundance.

We find significantly higher vole abundance in fallow land, which has earlier been shown to hold true in France as well (Butet & Leroux 1988). Voles are more numerous in higher vegetation, as expected from theory (Simmons *et al.* 2000, Jacob & Hempel 2003). No difference in vole abundance is found for different vegetation cover. Jacob & Hempel (2003) find that vegetation height, but not cover, positively correlated with home-range size in Common Voles. This could mean that trapping probability is higher in taller vegetation. Assuming that we are dealing with real abundance differences, we could use the knowledge that it is in the first place vegetation height which is attractive to Common Voles in conservation measures aiming at better food supply for Montagu's Harrier. However, a further step would have to be taken, as high vole densities in tall vegetation do not mean high food availability. Availability could be increased on the short term e.g. by mowing. Mowing does not seriously affect survival of Common Voles (Jacob 2003). It has been shown that Common Voles do not emigrate from mown areas but behaviourally adapt to the higher predation risk (Jacob & Hempel 2003). Though, extensive mowing can decrease rodent abundance (Jacob 2003). Considered can be mowing only parts of parcels in order to spare some shelter and to spread high food availability over the harrier's breeding season. An experimental approach would be needed here.

Reproduction and its correlates

The total number of breeding pairs in the study area (corresponding to breeding pair density as study area was of constant size) does not vary significantly between years and does not correlate with average vole abundance. However, year differences and a relationship between nest density and vole abundance are observed e.g. in France (Butet & Leroux 1993, Butet & Leroux 2001). There, nest density correlates with spring vole density. The lack of correlation in the present study could be explained by us using summer vole density. However, Butet & Leroux (2001) detect a highly significant correlation of spring vole density and summer vole density. Whether such a correlation holds for east Groningen as well still needs to be tested. Arroyo *et al.* (2002) suggest that breeding density would only be affected by strong food abundance fluctuations. Millon *et al.* (2002) deal with the same question when investigating a population in east France which was supposed to rely on Common Voles as prey to a high degree. They mention three hypotheses to explain why they unexpectedly find only weak harrier density variations between years: Vole density variations might not be fluctuating, the study period could be too short to detect variation in vole density, or vole density could be too low for Montagu's Harrier to specialise and be dependent on Common Voles entirely. In east Groningen, vole abundance indeed shows no strong cyclical variation but only a steep decline after 1992. Variation in vole abundance in the remaining years could thus have been too small to be reflected in a numerical response. The finding that Montagu's Harrier in east Groningen behaved as a generalist in 2003 indicates as well that there is no strong dependency on Common Voles, at least not in this poor vole year. A correlation between vole abundance and breeding pair density would be expected only when harriers always behaved as specialists and were single prey dependent.

Clutch size at laying and egg-fledgling survival do not differ significantly between years. The absence of significant variation could be caused by a relatively small sample size with large standard deviations each year, like has been supposed in a study of García & Arroyo (2001) for Hen Harriers. Brood size at fledging however shows significant variation between years. There is no relationship of average vole abundance with the breeding parameters. In other studies, such relationships between certain breeding parameters and vole abundance are found (Arroyo 1998, Butet & Leroux 1993, Butet & Leroux 2001, Krogulec & Leroux 1994, Salamolard *et al.* 2002). Butet & Leroux (1993) consider the relationship between voles and reproduction to reflect single prey dependency. Again, our results indicate low dependency on Common Voles in poor vole years (1992 being the only good vole year during the study period). Alternatively, other effects might be stronger and confounding such a correlation.

There are significant differences in laying date between years, which show a reversed pattern compared to average brood size, as brood size (and clutch size) are larger when laying date is earlier. Laying date has earlier been shown to be a fitness component in Montagu's Harrier: Millon *et al.* (2002) found a negative relationship of laying date and productivity in an east France population. In the present study, laying date is the only fitness component which shows a trend towards a relationship with average vole abundance, laying being earlier when voles are abundant. This is in line with the prediction that laying date is advanced by high food supply (e.g. Arroyo 1998). The observed relationship indicates some importance of Common Voles as food source.

Laying date does not correlate with weather parameters averaged over April-August. One would expect laying date being earlier in warmer springs (Corbacho *et al.* 1997). It could be confounding that we average weather parameters over the whole season and do not correlate laying date to April conditions. Though, Corbacho *et al.* (1997) do not find a correlation of laying date with weather parameters only in April as well. They find smaller clutch sizes in years with cold April. We do not find a correlation between clutch size or egg-fledgling survival and weather parameters. We consider the trend towards smaller brood size with longer sunshine duration of minor importance. Seen the unexpected direction of the correlation, it could well be an artefact rather than a relationship.

In a model for vole abundance, maximal temperature and sunshine parameters are significant. The model including weather parameters exhibits no large difference in model fit with the one containing year as explanatory variable. Both models correct for differences in habitat type. This can be interpreted as year differences in vole abundance being for a large part explained by differences in temperature and sunshine duration. The remaining part of unexplained variance in vole abundance might be due to other environmental or intrinsic factors (e.g. density dependent factors, food supply). It is inherent to the generalised linear model that no absolute measure for model fit can be calculated. For that reason, we cannot evaluate to which extent variance is left unexplained.

Brood size at fledging and egg-flegling survival are higher in protected nests, though not significantly. In Spain, reproductive parameters have earlier been shown to correlate with nest protection in agricultural habitat (Corbacho *et al.* 1997).

Conservation

For east Groningen, a population decline is predicted in the absence of nest protection (Koks & Visser 2002). As Newton stated (1979), nest protection is only effective if one can expect an increase in the number of breeding pairs, not if the population is limited by other factors. No increase in breeding pair numbers has been observed in east Groningen in the presence of nest protection. That means there must be other factors limiting population size besides safe nest sites. Nest protection alone will probably not lead to a population which is independent of human intervention.

Arroyo *et al.* (2002) consider habitat management as a more efficient and sustainable way of protection. One could e.g. aim at an increase in food supply. A continuation of nest protection would still be necessary, at least in the beginning. But after a substantial increase in food supply, one can expect an increase in breeding pair numbers on the long run. An increase in food supply means here higher Common Vole abundance. Although we have shown that diet was diverse in a poor vole year and dependency of reproductive parameters on vole abundance almost absent, we expect Montagu's Harrier in east Groningen to be opportunistic, behave as a specialist in good vole years and to exhibit higher dependency then, like has been shown in similar habitats in Europe (Arroyo 1998, Butet & Leroux 1993, Butet & Leroux 2001, Krogulec & Leroux 1994, Salamolard *et al.* 2002). A transition from intensive agriculture to extensive, e.g. organic, low-impact farming is supposed to improve Common Vole habitat to such an extent that population outbreaks are predicted (Jacob 2003). It is doubtful whether such enormous ameliorations in food supply, providing chances for population growth for Montagu's Harrier, would still be desirable or acceptable for farmers. Extensivation on a smaller scale, e.g. governmentally subsidised set-aside parcel edges, have higher chances of being supported by farmers and are realised already to some extent. In order to favour higher vole abundance, it is probably suitable to have higher vegetation or to leave cut grass and stubble, creating refuges for voles with food and overwintering sites (Jacob 2003, Jacob & Hempel 2003). Advantages could arise from different duration of leaving land fallow. Supposedly, vole densities peak only for a few years and diminish after a longer fallow period (Koks pers. comm.). Partial mowing and changing mowing regimes could make voles temporarily available for Montagu's Harrier. An experimental approach would be needed to test the hypotheses.

Arroyo *et al.* (2002) showed that conservation effort is most efficient when concentrated in the most productive breeding areas of a population. Besides nest protection and habitat management, identifying and protecting most productive areas in the population supposedly covering the Netherlands, Germany and Denmark, could favour a sustainable sub-population in east Groningen.

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Jeroen Minderman
Christiane Trierweiler

> *It provides the enlivening element in its melancholy surroundings, it has brought life to places that were waste and desolate before.*
>
> \- Henning Weis 1923 -