THE EFFECT OF PREDATION BY MARSH HARRIERS *Circus aeruginosus* ON THE SURVIVAL OF DUCKLINGS AND GAME BIRD CHICKS

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ABSTRACT The level of predation by a pair of Marsh Harriers *Circus aeruginosus* on ducklings and gamebird chicks was calculated from observations of hunting ranges, feeding rates and diet, and estimates of the availability of prey during the breeding season. The harriers took 22% of the Pheasant chicks 4.2% of the Grey and Red-legged Partridge chicks and 25.3% of the Mallard ducklings, which hatched within their hunting territories. Many of the chicks taken by the harriers would otherwise have died before reaching maturity. It was estimated that an additional 10.2% of Pheasant chicks, 0.7% of Grey and 1.1% Red-legged Partridge chicks and 11.1% of Mallard chicks would have survived to fledging in the absence of harrier predation according to calculations on survival rates of those chicks not taken by harriers. However, mean fledged brood sizes of the four prey species were similar to those recorded elsewhere, where harriers did not breed. The conclusion is that predation by the harriers had little effect on final numbers of gamebirds and ducks.

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INTRODUCTION

Marsh Harriers *Circus aeruginosus* are large, open country raptors which hunt by slow quartering flight and catch prey on the ground by dropping onto it from above. A wide variety of prey is taken, ranging from 10 to 600 g in weight and including most species of bird and mammal found within the hunting range (Underhill-Day 1985). The diet can include young gamebirds and ducklings, and competition for these quarry species between game preservers and birds of prey in many European countries, has led to widespread persecution of raptors (Bijleveld 1974). This paper attempts to quantify the effects of predation by a pair of Harriers on the productivity of four quarry species, Mallard *Anas platyrhynchos*, Pheasant *Phasianus colchicus*, Grey Partridge *Perdix perdix* and Red-legged Partridge *Alectoris rufa*.

STUDY AREA AND METHODS

The study area consisted of some 50 km^2 of intensively farmed arable land in East Anglia, England, mostly cultivated for wheat, barley, oil seed rape, sugar beet and vegetable crops. Individual fields were separated by ditches, grass covered earth banks or farm roadways, and a small river, partly canalised, crossed the area. Gamebirds were not artificially reared, but well grown juvenile Pheasants were imported and released late in the season. A number of pairs of Marsh Harriers nested in the areas, mostly in small reedbeds in the bends of the river and ditch systems. The pair chosen for this study nested in a field of winter wheat in the centre of the arable complex, with no woodland within their foraging areas.

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The harriers

Hunting ranges Estimation of the hunting range of the pair of harriers was based on observations of attempts to catch prey (prey strikes), during the periods before laying (courtship), between laying and hatching (incubation), hatching and fledging (nestling) and post fledging (fledgling). Observations by a team of observers took place throughout the hunting ranges, using 2-way radios to follow the hunting birds. The location of each prey strike was mapped and minimum convex polygons drawn around the furthest strike points during each phase. This method was chosen, although the birds ranged more widely during display fighting and other activities, since only the occurrence of a strike showed that the birds were definitely hunting. Two hundred and twenty-four strikes were recorded for the male, and 136 for the female, which did not hunt until 13 days after hatching of the first chick. Observations began before courtship started, and finished at the end of August when practically all young gamebirds and ducks were fully grown.

Feeding rates These rates by the male to the female, and later both adults to the young, were based on 447 h of observation at the nest area. At no time was prey seen to be caught or delivered before 0500 or after 2100 h.

For each phase of the breeding season the number of hours observations for each hour during a 16 hour day, and the number of deliveries for each hour were extracted and expressed as deliveries h^{-1}. These were then summed over the 16 hour day to give the mean number of food items delivered per day.

Diet Information on diet was obtained from the analysis of pellets, identification of prey remains, and from observations of successful kills or the identification of prey carried back to the nest. Using these methods the sample sizes of prey caught by the pair of harriers described here was small, so the analysis was based on data from all harriers nesting in the study area in the same year, 1984. It was assumed that the proportions of different prey species in the prey captured by male and female harriers was the same. Since the use of food data was derived from several pairs of harriers, and the breeding cycles were asynchronous, data on diet were analysed by calendar months for all birds. To arrive at the proportion of any prey species in the diet, the total number of individuals of that species identified by the three methods in any month were summed and divided by the total number of food items identified by all methods during the same period.

Preliminary analysis showed that there were no significant differences between the proportions of Mallard ducklings, Pheasants and Partridges as a percentage of total items by the three sampling methods overall or within months (Kruskall-Wallis 1-way analyses of variance). It was not possible to separate the chicks of Grey and Red-legged Partridges by the methods used, and the two species have therefore been combined. It was assumed that predation of the chicks of the two species was proportional to their density in calculating final predation rates on each. Overall the data were derived from 651 identified prey items, approximately 19% of the total items caught by all birds.

The prey

Census of ducks Breeding Mallard were confined to the river and the ditch systems. Representative sample length of 3.65 km of river and 5.70 km of ditches were surveyed on 20 occasions during the season. All Mallard with young were recorded and mapped, and the ducklings classified by size as up to 1/4, 1/2 or 3/4 grown. Final fledged brood sizes were censused in late summer before the broods finally dispersed.

Census of gamebirds Two 1 km^2 sample plots were chosen in March as being representative of the area as a whole. There was no woodland in either plot. Each plot was sampled on six occasions in early morning and late afternoon; female Pheasants were counted, and partridge pairs of both species mapped. Female Pheasant numbers

were taken to be the maximum number recorded. All the Pheasants roosted in limited areas of hedgerow within the plots, so estimates based on maximum number seen were likely to be reliable, as the birds were counted coming and going to roost. The edges of all fields within the plots were walked, since Grey Partridges tended to stay close to the field boundaries. Confirmation of the location of partridges continued until growing crops prevented further observation in mid-May.

The location, brood size and chick size of all Pheasant and partridge broods were recorded throughout the season. Final fledged brood sizes were based on counts in stubble fields in August/September. Data on brood sizes were based on sightings of 57 Peasants, 23 Grey Partridge and 81 Red-legged Partridge broods within the whole study area. Care was taken using map references to avoid duplication of counts of the same brood in calculating the number of newly hatched broods per month.

RESULTS

Estimation of prey taken

Hunting ranges (km^2) of the male and female marsh harrier, together with the ditch and river lengths (m) contained within each range for different phases of the breeding season are shown in Table 1. It seemed possible that the size of hunting range was a function of the number of strike observations (since the two were closely correlated $r_4 = 0.893$, $P < 0.025$), rather than a reflection of true differences between phases.

This possibility was tested by using the data set of distances (m) between the nest and each strike point for each phase, and conducting randomisation tests between sets (Sokal & Rohlf 1981). The largest data set for the male was that obtained during the nestling phase (160 prey strikes), so this was compared with courtship (16 prey strikes), incubation (16 prey strikes) and fledging (32 prey strikes) by means of S^2_2/S^2_1 tests. For each comparison, a distribution of S^2_2/S^2_1 ratios based on 500 random partitions of the data was calculated, and the probability of the observed ratio occurring was assessed. A similar procedure was adopted to compare the females' 2 hunting ranges.

The alternative hypothesis was that the observed nest/strike distances for each phase came from different distributions. This was the case for the male, with the variance for courtship incubation and fledgling strike/nest distances differing significantly from those for the nestling phase (courtship x nestling, $F_{15,159} = 2.44$, $P = 0.036$; incubation x nestling, $F_{15,159} = 3.47$, $P = 0.004$; fledgling x nestling, $F_{31,159} = 4.02$, $P < 0.002$). The variances between the nest/strike distances of the female nestling phase and fledgling phase did not differ significantly. This was not surprising since they were based on a similar number of observations (53 and 83 prey strikes respectively) and the resulting hunting ranges were simi-

Table 1. The hunting ranges (km^2) and watercourse lengths (m) within the ranges of a male and female Marsh Harrier during four phases of the breeding season.

Breeding phase	Hunting range		Watercourse lengths			
	Male	Female	Male		Female	
			River	Ditch	River	Ditch
Courtship	2.17	-	1500	9550	-	-
Incubation	1.70	-	1000	8750	-	-
Nestling	11.12	7.86	5700	38500	4200	38500
Fledgling	3.10	8.69	2300	9200	4100	30600

Table 2. Mean number of food items delivered per 16 hour day by a male and female Marsh Harrier during four phases of the breeding season, together with number of days in each phase and seasonal totals.

Breeding phase	Prey items per day		Days	Total prey items	
	Male	Female		Male	Female
Courtship	3.75	-	20	75	-
Incubation	4.44	-	30	133	-
Nestling	10.76	5.60	39 (28)*	420	157
Fledgling	2.89	7.59	31	90	243
Totals	-	-	121	718	400

* Based on period from first observed prey delivery by female to fledging.

Table 3. Percentage of 651 prey items from pellets, prey remains and sightings consisting of young Pheasants, partridges and Mallard ducklings in the diet of Marsh Harriers during May-August 1984.

		May	June	July	Aug.
Pellets	Pheasant	0.0	17.9	20.9	36.8
	Partridge	0.0	0.0	0.9	0.0
	Mallard	0.0	8.5	9.1	4.5
Prey remains	Pheasant	0.0	8.9	22.3	36.4
	Partridge	0.0	0.0	2.1	4.5
	Mallard	0.0	5.1	10.6	0.0
Sightings	Pheasant	2.6	31.0	34.9	45.4
	Partridge	0.0	1.7	6.3	0.0
	Mallard	17.1	12.1	7.9	0.0
Total	Pheasant	2.3	18.1	24.7	38.5
	Partridge	0.0	0.4	3.4	1.9
	Mallard	14.0	8.2	9.4	1.9
n		89	243	267	52

lar in area. It was concluded that differences between phases in range size were not merely an artefact of the larger sample sizes in some phases.

The mean number of prey items per day brought to the female/nestling/fledglings, together with the number of days and the total number of items in each phase is shown in Table 2.

During the whole season (excluding the period after September 1st, when adults and young ranged more widely) the total number of prey items caught by the harriers was calculated to be 1118.

Table 3 shows the estimated percentage contribution to the diet of the Marsh Harriers made by young Mallard and gamebirds during May-

Table 4. Numbers of young Pheasants, partridges and Mallard taken by a pair of Marsh Harriers during the breeding season. Hunting range (km²): table 1; Total prey items taken: tabel 2; % in diet: table 3; Total prey items per km² = column 2/column 1; Ducklings taken in hunting range: column 2 x column 3; Number of poults taken per km²; column 3; Number of poults taken per km²: column 4/5 x column 2/column 1.

Phase	Month	Hunting range	Total prey items taken	% in diet			Total prey items per km²	Ducklings taken in hunting range	Number of poults taken per km²	
				duck-lings	phea-sant	part-ridge			phea-sant	part-ridge
Male										
Courtship	May	2.17	75	14	2.3	0	34.6	10.5	0.8	0
Incubation	May	1.70	40	14	2.3	0	23.5	5.6	0.5	0
	June	1.70	93	8.2	18.1	0.4	54.7	7.6	9.9	0.2
Nestling	June	11.12	97	8.2	18.1	0.4	8.7	7.9	1.6	0
	July	11.12	323	9.4	24.7	3.4	29.1	30.4	7.2	1.0
Fledgling	July	3.10	3	9.4	24.7	3.4	1.0	0.3	0.2	0
	August	3.10	87	1.9	38.5	1.9	28.1	1.7	10.8	0.5
Female										
Nestling	July	7.86	157	9.7	24.7	3.4	20.0	15.2	4.9	0.7
Fledgling	July	8.70	8	9.7	24.7	3.4	0.9	0.8	0.2	0
	August	8.70	235	1.9	38.5	1.9	27.0	4.5	10.4	0.5
Totals								84.5	46.5	2.9

August. No adult Mallard or Pheasants were seen to be taken. A small number of adult partridges was seen to be killed, but these represented only 0.6% of total prey items. Based on the data in Tables 1-3, the number of ducklings taken within each hunting range and the number of gamebird chicks taken per km² within each phase are shown in Table 4. Each phase was divided between months since percentage contribution to the diet of prey species was calculated on a monthly basis.

Estimation of prey available

The total number of available broods was estimated from the observed densities of Mallard broods on ditch and river sample lengths within each range. The total was then seasonally apportioned by taking the percentage of all broods seen in each phase (observations of $^1/_4$ grown ducklings), and multiplying by mean brood size of 10.4 at hatching (Ogilvie 1964) (Table 5), to give the number of ducklings hatched in each phase within each hunting range.

Based on the sample surveys, the number of female Pheasants per km² was 48. It was assumed that 85% of these bred and that 65% of the clutches laid survived to hatching (Hill pers. comm.). The density of Grey and Red-legged Partridges was 3 and 5.5 pairs per km², all of these were assumed to have bred with 75% and 60% of clutches surviving to hatch (Green pers. comm.). Mean hatched brood sizes were assumed to have been; Pheasant 9.83 (Hill 1985), Grey Partridge 13.80 and Red-legged Partridge 11.40 (Potts 1980). The number of hatched gamebird chicks, seasonally adjusted was then calculated for each phase (Table 6).

Table 5. Seasonal availability of Mallard ducklings (broods x 10.4 = means brood size at hatching) within the hunting of a pair of Marsh Harriers based on observed densities of 1/4 size broods on river (1 brood per 365 m) and ditch (1 brood per 712 m) systems together with the numbers taken overall (table 4) and as a percentage of those available from hatching by a pair of Marsh Harriers during four phases of the breeding season.

Breeding phase	Total broods during	% Hatched during	Ducklings available	Ducklings taken	% taken
Male					
Courtship	17.5	23.9	43	10.5	24.4
Incubation	15.0	26.1	41	13.2	32.2
Nestling	69.7	43.5	315	38.3	12.2
Fledgling	19.2	6.5	13	2.0	15.4
Female					
Nestling	54.6	30.4	173	15.2	8.8
Fledgling	54.2	6.5	37	5.3	14.3

Table 6. Seasonal availability of young Pheasants (= broods x total Pheasant chicks hatched per km² = 262) and number taken per km² as a percentage of those available from hatching by a pair of Marsh Harriers dring four phases of the breeding season 1984.

Breeding phase	% broods hatched during	Number available/km²	Pheasants taken by		% taken by	
			Male	Female	Male	Female
Courtship	27.8	72.3	0.8	-	1.1	-
Incubation	22.2	57.7	10.4	-	18.0	-
Nestling	44.4	115.5	8.8	4.9	7.6	4.2
Fledgling	5.5	14.3	11.0	10.6	76.9	74.1

Predation rates and productivities

Using the data from previous tables, the percentages of available ducklings and gamebird chicks taken by the male and female harrier during each phase of the breeding season were calculated (Tables 5-7). For the whole season, the harrier pair took at most 25.3% of hatched ducklings, 22.0% of hatched Pheasants and 4.2% of hatched partridges.

Mean fledged brood sizes (± SE) based on autumn counts were; Mallard 3.25 ± 0.51 (n = 16), Pheasant 3.40 ± 0.40 (n = 10), Grey Partridge 2.78 ± 0.22 (n = 9) and Red-legged Partridge 3.35 ± 0.25 (n = 20). However these figures reflected successful broods only, and took no account of broods which failed completely. Based on geometric mean fledged brood sizes and constant rates of loss, methods have been developed for calculating survival rates of chicks including those in broods depleted to nil. In the absence of empirical data for all species, the method in Green (1984), has been followed, and this gives percentage survival rates from hatching to fledging in the study area for Mallard 17.2%, Pheasant 24.8%, Grey Partridge 13.4% and for Red-legged Partridge 20.9%. The simpler method given by Hill (1985) for calculating chick survival rate for Pheasants, gives a higher rate of 32.5% for Pheasant chicks on the study area.

Table 7. Seasonal availibility of young partridges and the number taken per km² as a percentage of those available from hatching by a pair of Marsh Harriers during four phases of the breeding season, 1984. Total Grey Partridge chicks hatched per km = 31; Total Red-legged Partridge chicks hatched per km = 37.5

Breeding phase	% broods hatched during		Number available per km²		Total chicks available per km²	Number taken by		% taken by	
	Grey	Red-legged	Grey	Red-legged		Male	Female	Male	Female
Courtship	0	0	0	0	0	0	-	0	-
Incubation	20.0	22.0	6.2	8.3	14.5	0.2	-	1.4	-
Nestling	60.0	72.2	18.6	27.1	45.7	1.0	0.7	2.2	1.5
Fledgling	20.0	5.6	6.2	2.1	8.3	0.5	0.5	6.0	6.0

DISCUSSION

Any attempt to estimate the effect of raptor predation on the population or productivity of avian prey species is difficult, due to the considerable number of variables which have to be sampled (Tinbergen 1946, Craighead & Craighead 1956, Picozzi 1978). The best estimates have been obtained where the prey species' population has been artificially boosted, by rearing and release of a known number of gamebirds for example (Kenward 1977), or where a proportion of the prey is marked so that individuals subsequently killed by the raptor are identifiable (Perrins & Geer 1980).

Several extrinsic factors favoured the production of reliable data, notably the homogenous nature of the habitat, the absence of released gamebirds and ducks during the main part of the breeding season, and the absence of predator control other than the shooting of foxes on an adjoining estate which effectively precluded them from gaining access to the study area. The open nature of the habitat allowed lengthy and detailed observations of the activities of the harriers from a sufficient distance to minimise disturbance, and enabled reliable estimates of breeding gamebird populations to be made in the spring.

The assumption that the proportions of different prey species caught by male and female harriers was the same seemed reasonable, since: 1. The birds were hunting over arable farmland where cropping patterns and other habitat features (e.g. old seabanks, farm tracks) were repetitive. 2. Hunting ranges of the two exhibited considerable overlap. 3. The variety of main prey species was small, with 57-61% of the diet (based on an examination of pellets and prey respectively) consisting of only four species, young Pheasants, Mallard ducklings, Starlings and rabbits (Underhill-Day 1985). It is known that female Marsh Harriers take larger prey than males (Altenberg *et al.* 1982, Underhill-Day 1985), and it seemed possible that intra-specific differences between the sexes were more likely to be related to size of prey taken to prey species composition.

The weakest link in the chain of calculations was the estimate of percentage occurrence of prey species in the diet from the small sample which was derived from a number of birds, not just the pair of harriers that were the subject of this study. Any bias due to the greater likelihood of identifying larger prey items will tend to give higher estimates of the number of gamebirds and ducklings taken than actually occurred. The calculations ignore the prey taken by the adult birds and eaten away from the nest, but this is unlikely to have affected the findings since most prey is brought back to the nest. During courtship no gamebird chicks were available, although some ducklings may have been taken by the male and not brought back. The female was not seen to hunt from the start of courtship until 10 days af-

ter hatching. On only a few occasions was a hunting male seen to catch and eat a prey item without returning to the nest with all or part of it, and it was assumed that the male's diet largely consisted of a proportion of the prey items which were delivered to the female or young. All prey seen to be caught by the female was subsequently delivered in whole or in part to the young. The estimate of the percentage contribution to the diet of ducklings and gamebird chicks used was the best that could be obtained although the methods of calculation used made it impossible to calculate confidence limits. In calculating prey densities it was assumed that the movement of broods out of the area was balanced by inward movement of broods from surrounding areas; and that broods were evenly dispersed throughout the area generally due to the homogenous nature of the habitat, although clearly some patchiness in distribution of broods must have occurred from time to time.

The predation levels given were probably maxima, for a number of reasons.

1. The study pair of harriers had a brood of 5 chicks, all of which were reared.
2. Food delivery rates by males and females correlate closely with brood size in this species (own obs.); delivery rates by this pair (with five young) during the nestling period were the highest observed at 12 nests during 1983-4. Since mean fledged brood size of Marsh Harriers in Britain was 2.89 ± 0.66 (n = 339) for successful nests (Underhill-Day 1984), the delivery rate by an average pair of Marsh Harriers in situations where prey availability is not limiting will be approximately 60% of that recorded here, with a corresponding decrease in predation levels.
3. Range sizes were based on the location of observed strikes, rather than sightings of the birds as is more usual. If hunting and prey captures took place outside the mapped ranges this would reduce the calculated predation levels.
4. The predation levels recorded have been summed for male and female for the whole season, but this level of predation would only have occurred where the ranges all overlapped, which constituted only 5.8% of the total 14.3 km^2 area which the two harriers hunted.

The hunting ranges of the study pair overlapped with that (based on strikes) of the neighbouring bigamously mated male (but not with those of his females), only during the nestling phase. The overlap was 2.95 km^2 (26%), and 0.87 km^2 (11%), of the male and female hunting ranges respectively. Using the same methods of calculation, predation by the bigamous male within the overlapping area could be estimated. Overall predation rates for the whole season by all three birds was at most 28.9% of all hatched ducklings, 25,6% of hatched Pheasants and 5.7% of hatched partridges per km^2. From estimates of chick losses from other causes it was calculated that harrier predation on juveniles which would otherwise have fledged was Mallard 11.1%, Pheasant 10.2%, Grey Partridge 0.7% and Red-legged Partridge 1.1%. If predation by the bigamous male is also allowed for, these figures become 13.3%, 11.2%, 0.8% and 1.2% respectively.

It was only not known why predation of partridge chicks was so low when compared with that on Pheasants, but this may have been because partridge broods stayed closer to cover at field edges. On a number of occasions where the harriers caught gamebird chicks in cereal fields, when the capture site was examined the prey was invariably a Pheasant poult.

The high number of ducklings in the prey was partly due to a seasonal effect, since Mallard start breeding earlier than gamebirds, and young ducklings were available when other prey was scarce. High rates of predation on the small number of later hatched broods of both gamebirds and Mallard occurred at the end of the season. If this pattern of predation is characteristic of other avian predators, it may help to explain the lower survival rates of young hatched later in the season in many species of birds preyed upon by raptors (Klomp 1970).

The survival rate for Pheasants (using the same method of calculation), was similar to that given by Hill (1985) for a much larger sample during 1970-1984 of 33.4%. Pheasant chick survival rates in for his two study sites in Hampshire and one in Sussex where harriers were absent, were 34.6%, 46.2% and 26.8% (mean 35.9%), (Hill pers. comm.). Predation levels by the Marsh Harriers on the two partridge species (4.2%), were too low to have significantly affected their productivity.

Few studies were available of fledged brood sizes of Mallard. Mean fledged brood sizes (± S.E.) of 4.96 ± 0.50 in Somerset and 2.4 ± 0.40 in Buckinghamshire have been found (Boyd & King 1964, Hill *et al.* 1987) on a reservoir and gravel pit respectively, neither of which differed significantly from that of 3.25 ± 0.50 found here. Hill (1982) also reports a mean brood size of 4.3 on river systems in Hampshire.

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SAMENVATTING

In dit onderzoek worden gegevens gepresenteerd over predatie door een paartje Bruine Kiekendieven op kuikens van eenden, Fazanten en patrijzen (Patrijs en Rode Patrijs). De gegevens zijn gebaseerd op waarnemingen aan de grootte van het jaaggebied, het aantal prooien per tijdseenheid, de soort prooi en de prooibeschikbaarheid in de loop van het seizoen. De kiekendieven vingen 22% van alle geboren Fazantenkuikens, 4.2% van alle patrijzenkuikens en 25.3% van alle Wilde Eenden-kuikens. Veel van de door de kiekendieven gepredeerde kuikens zouden toch zijn doodgegaan, ook wanneer ze niet door deze roofvogels gepakt zouden zijn. Uit een berekening volgt, dat bij afwezigheid van predatie door de Kiekendieven de volgende percentages kuikens extra zouden zijn uitgevlogen: 10.2% Fazant, 1.8% Patrijs en 11.1% Wilde Eend. Opmerkelijk was, dat het gemiddelde aantal uitgevlogen jongen van de verschillende prooisoorten gelijk was aan dat in gebieden waar geen Bruine Kiekendieven voorkwamen. De auteurs trekken hieruit de conclusie dat de kiekendieven weinig invloed uitoefenden op de uiteindelijke aantallen van het aanwezige jachtwild.-J.V.