

## Breeding season diet of the Goshawk *Accipiter gentilis* in Wales

E. P. TOYNE\*

Department of Biology, Imperial College of Science, Technology and Medicine, Prince Consort Road,  
London SW7 2BB, UK

Information on the diet of the Goshawk *Accipiter gentilis* during the breeding season was collected in Wales during 1991–1993. Diet consisted mainly of birds (87%) and mammals (13%). Forty-five prey species were collected, ten of which were important in numerical or biomass terms: Feral Pigeon *Columba livia*, Woodpigeon *Columba palumbus*, Crow/Rook *Corvus corone/Corvus frugilegus*, Magpie *Pica pica*, Jay *Garrulus glandarius*, Mistle Thrush *Turdus viscivorus*, Song Thrush *Turdus philomelos*, Blackbird *Turdus merula*, Grey Squirrel *Sciurus carolinensis* and Rabbit *Oryctolagus cuniculus*. Pigeon biomass was important throughout the breeding season and was more important in the diet of nesting Goshawks on higher ground (>250 m). On lower ground, corvids, mammals and pigeons were the main contributors to the Goshawk diet. Rabbits were more frequently taken at lower nesting territories, and thrushes occurred at all altitudes. Mammals, particularly Grey Squirrel, were found in higher numbers in the diet of Goshawks nesting in small woods (<1000 ha) compared with the diet of Goshawks nesting in two large forests (c. 3500 ha and c. 6100 ha). Goshawks preyed upon juvenile Woodpigeons, corvids and thrushes, and switched from young thrushes to young corvids as the latter became available. Predation peaks on young birds corresponded with the presence of nestling Goshawks in late May to early July. Predation of juvenile prey led to a decrease in mean prey item mass (April–May, 437 g; July, 376 g). No evidence was found to suggest that sexual size dimorphism in Goshawks resulted in partitioning of prey captured during the breeding season. Differences found were probably due to local abundance and vulnerability of prey species rather than specific selection by the two sexes.

Detailed studies on the Goshawk *Accipiter gentilis* diet in Europe were summarized by Cramp and Simmons (1980). Since then, additional data for Goshawks outside of Britain have been provided in Wikman and Tarsa (1980), Kenward *et al.* (1981), Thissen *et al.* (1981), Lindén and Wikman (1983), Goszcynski and Pilatowski (1986), Widén (1987), Widén *et al.* (1987), Myrberget (1989) and Mañosa (1994). Since the Goshawk's recolonization of Britain, information on the diet of Goshawks has been published by Marquiss and Newton (1982a), Hornbuckle and Herringshaw (1985), Cooper and Petty (1988) and Petty (1996).

Marquiss and Newton (1982a) summarized prey from 30 nesting localities for 1974–1980. Some 848 items were recorded between March and August. The data were analysed by altitude. On ground below 250 m, the principal prey items were Red Squirrel *Sciurus vulgaris*, Rabbit *Oryctolagus cuniculus* and Woodpigeon *Columba palumbus*. Above 250 m, where moorland occurred, Red Grouse *Lagopus lagopus* was a major food. These data were from the Sheffield area, where Hornbuckle and Herringshaw (1985) showed that the Gos-

hawk's breeding season diet comprised about 33% gamebirds, 28–30% pigeons and the remainder mammals, corvids, thrushes, waders and gulls. Petty (1996) found that birds were the main prey of Goshawks inhabiting upland forests in northern England and southern Scotland, whilst mammalian prey were taken less often.

Published information on the diet of Goshawks in the lowlands of Britain outside the breeding season is not extensive and involved free-flying falconry birds (Kenward 1979, 1982). These studies may not be comparable with other habitats in Britain or with the behaviour of wild Goshawks in Britain; consequently, extrapolating data from such studies could be misleading because prey selection by Goshawks differs from one area to another depending on the relative abundance and vulnerability of prey species (Kenward & Widén 1989). This paper presents information on the diet of Goshawks in Wales.

### STUDY AREA

Goshawk diet was investigated in Wales during the breeding seasons of 1991–1993. The study area was approximately

\* Present address: WWF-UK, Panda House, Weyside Park, Catteshall Lane, Godalming, Surrey GU7 1XR, UK.

65 km × 50 km (325,000 ha), of which *c.* 50% was forested. The rest of the area comprised farmland, moorland and watercourses. The altitude of the study area ranged from 80 m to 500 m, and the average altitude at which Goshawk nested was 255 m.

Two large forests, A and B, and most of the surrounding smaller woods were searched for Goshawk nests. Forest A was 3463 ha, of which half was considered potential Goshawk nesting habitat. The habitat adjacent to forest A was mainly improved grassland used for sheep farming with some open grass moorland. Forest B (6104 ha) was larger than forest A and contained 20% more potential nesting habitat. Surrounding habitat was improved grassland used for sheep farming and arable land. Smaller woods, varying in size from *c.* 50 ha to 1000 ha, that surrounded forests A and B were also searched for breeding Goshawks.

## METHODS

Goshawk prey remains were mostly collected within 200 m of the nest during March–September. When the nesting territory was on sloping ground, the area uphill of the nest was searched as Goshawks favour feeding perches overlooking the nest. During the Goshawks' incubation period, *c.* 30 min were spent searching in each nesting territory. As Goshawks were more tolerant of disturbance after their chicks had hatched, later searches were lengthened to 45 min (Toyne 1997). Each nesting territory was visited at least every fortnight during the breeding season until the young had left the nesting territory in late July and early August (Toyne 1997). Additional diet information was collected when the nestlings (20+ days old) were ringed in June, from hide observations and from pellets gathered around the nesting territory. To avoid duplicate sampling, data from pellets were discounted if remains of the same prey species were found as feathers or bones within the nesting territory.

Sterna were collected and used to identify and count medium-sized prey; plucked feathers were used to identify smaller bird prey. Unknown sterna and feathers were identified from a Forestry Commission reference set. The age of avian prey was recorded whenever possible as nestling, fledgling or adult according to the growth stage of the primary and secondary feathers (Newton & Marquiss 1982). For identification of mammalian prey, the skull and fur were collected and compared with a reference set. All prey remains found were removed from the site to prevent duplicate sampling.

No matter how carefully the forest floor was scanned, prey remains were undoubtedly missed, leading to their underrecording in the results. Four other biases were likely (Opdam *et al.* 1977, Kenward 1979, Newton & Marquiss 1982): (1) Remains from larger prey were more easily detected. Dark coloured, small-sized prey such as Blackbird *Turdus merula* were harder to detect than the paler feathers of pigeons. Counting just sterna reduced this bias, but during March–May, most kills found were feathers only, prob-

ably due to Foxes *Vulpes vulpes* eating skeletal remains. (2) Goshawks may not have taken to the nest a representative cross-section of what they killed. Prey brought to nests by the male were for the nestlings and the hen. It was assumed that males ate some prey away from the nest, as in the Sparrowhawk *Accipiter nisus* (Newton & Marquiss 1982). (3) Skeletal remains found near the nest in the post-fledging period were from mainly larger prey such as squirrels or crows. In previous studies on the Sparrowhawk, smaller prey were eaten completely, and therefore large prey were overrepresented (Tinbergen 1946, Newton & Marquiss 1982). This problem was highlighted in studies where small rodents were swallowed whole (Sládek 1963, Brüll 1964a, Höglund 1964, Opdam *et al.* 1977), but Goshawks are known to pluck small mammals such as voles (Lindley & Jenkins 1991). However, as Goshawks eat mainly larger mammals, these biases should not be as large as with other raptors, such as harriers, that concentrate on small mammals (Simmons *et al.* 1991). (4) Not all prey are fully eaten because parts are lost or not devoured (van Beusekom 1972). A small bird might be swallowed whole, whereas some bones and feathers or fur of larger birds and mammals are left. In most cases, it was impossible to tell how much of an animal was eaten. Therefore, the data refer to the gross mass, and the average mass eaten will be somewhat lower, especially for the larger prey species.

## DATA ANALYSIS

Prey items were converted into biomass using the mass given by Ratcliffe (1993) with the following exceptions. Adult Rabbit (1600 g) was taken as the middle of their mass range (1200–2000 g; Corbett & Harris 1991), and 300 g was used for juvenile Rabbit and juvenile Brown Hare *Lepus capensis* (Ratcliffe 1993). Grey Squirrels *Sciurus carolinensis* were not sexed or aged, so the average mean mass for males (532 g) and females (560 g) was used (Corbett & Harris 1991). As it was difficult to distinguish between the prey remains of Rook *Corvus frugilegus* and Carrion Crow *Corvus corone*, the average of their mass, 527 g (572 g and 482 g; Ratcliffe 1993), was used. The sterna of Stock Dove *Columba oenas* are inseparable from Feral Pigeon *Columba livia* and have been recorded with Feral Pigeon. Mass of other nestling and fledgling prey species were calculated as being two-thirds of the adult weight (Opdam 1975, Newton & Marquiss 1982) with the exception of the Goshawk, where I could be more accurate. Apart from one nestling female Goshawk, all other nestling and fledgling Goshawks that were eaten were males. Mass values used were the average for male weights at ringing (650 g) and after fledging (750 g; E.P. Toyne, 1994, unpublished PhD thesis, Imperial College, London).

### Diet variation in prey group, prey species and by altitude

Variations in the Goshawk diet were summarized by changes in the percentage frequency and percentage biomass of prey

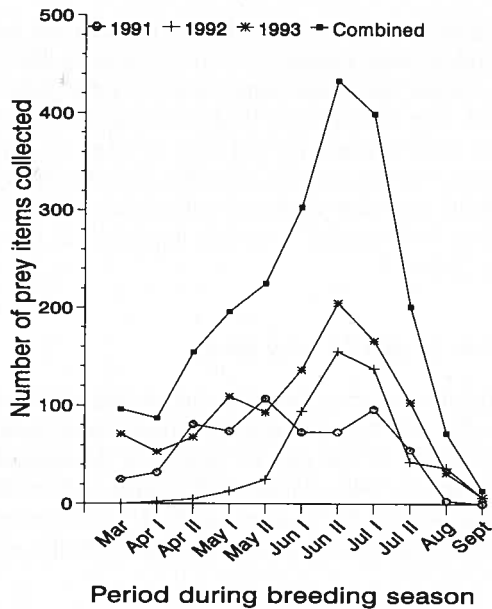


Figure 1. Numbers of Goshawk prey items collected March–September 1991–1993.

groups. Diet from 30 nesting territories, representing 51 nesting territory-years and where 21 or more prey items were collected, were analysed to assess differences in prey group composition with altitude of the nesting territory. Such data were then compared with the brood size at ringing and at dispersal to assess the influence of prey groups on breeding success. The same analysis was then carried out with most abundant groups/species: pigeons, Carrion Crow/Rook, Jackdaw *Corvus monedula*, Magpie *Pica pica*, Jay *Garrulus glandarius*, Grey Squirrel and Rabbit.

### Diet changes during the breeding season

Prey were assigned to half-month periods (apart from March and August, when small samples of Goshawk prey were collected) as most nesting territories were checked every 2 weeks, allowing for an analysis of seasonal change in diet.

Data were then grouped into the following categories: birds of prey (raptors and owls), pigeons (Feral Pigeon and Woodpigeon), corvids, thrushes, other birds (birds not in the previous groups) and mammals or by size class or prey species. Size classes chosen were a modification of van Beusekom's (1972) Goshawk prey classes: I = 10–20 g, II = 21–40, III = 41–80 g, IV = 81–160 g, V = 161–320 g, VI = 321–2000 g.

### Prey selection by sexes

Difference in prey size taken by males and females may be due to their difference in size (Höglund 1964, Synder & Wiley 1976, Cramp & Simmons 1980, Kenward *et al.* 1981). To investigate this, prey from April and May (when the male

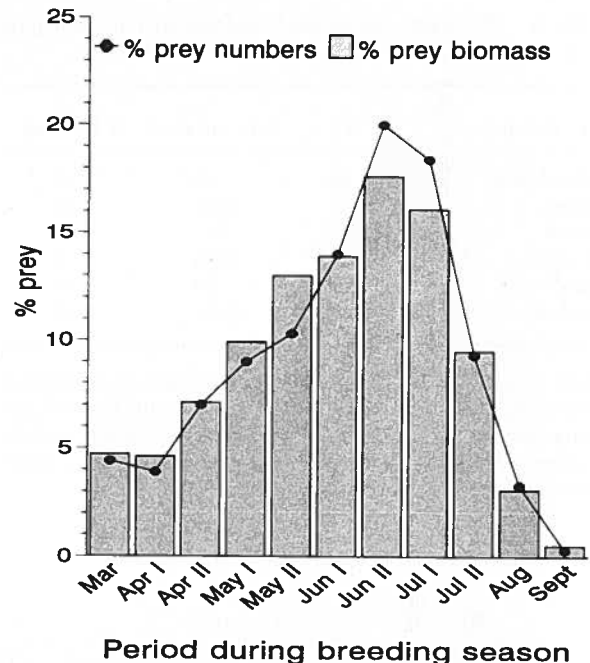


Figure 2. Goshawk prey items as a proportion of total prey collected March–September 1991–1993.

hunts) was compared to the July diet (when both sexes hunt). June data were not included as the hen may then do some hunting herself (Schnell 1958). July data include some prey caught by juvenile Goshawks, as some were capable of hunting by that time.

### Prey selection in different sized woods

To assess if there was a difference in diet selection between Goshawks nesting in different sized woods, the data collected over 3 years were grouped into woods >1000 ha and woods <1000 ha. The number of prey items and prey species collected varied between years and territories and was influenced by altitude, so prey data from nesting territories were selected if 21 or more prey items per breeding season had been collected and if such territories covered most years and all altitudes.

## RESULTS

The number of prey items collected varied each year: 1991,  $n = 654$  (29%); 1992,  $n = 518$  (23%), 1993,  $n = 1058$  (47%), a total of 2230 items. Sampling effort differed during the 3 years (Fig. 1), and few prey items were collected during March–May 1992. The number of prey remains found within nesting territories peaked around the end of June (Figs 1 and 2), coinciding with the peak demand of the nestlings.

Prey consisted of birds (87%) and mammals (13%). In

**Table 1.** Proportion (by numbers and biomass) of each prey group in the Goshawk breeding season diet in Wales

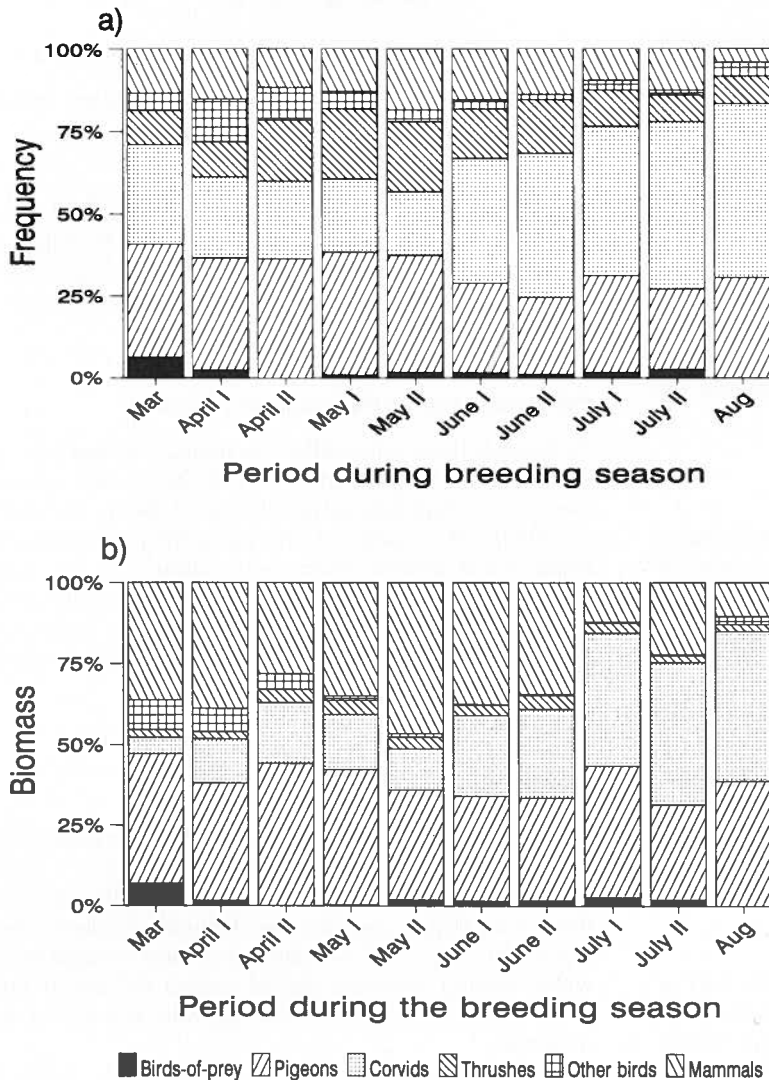
Prey group <sup>a</sup>	n	% by number	% biomass
Birds of prey	36	1.6	1.8
Pigeons	677	30.6	36.3
Corvids	802	36.2	26.2
Thrushes	322	14.6	3.3
Other birds	86	3.9	2.3
Mammals	290	13.1	30.8

<sup>a</sup> Birds of prey includes raptors and owls. Corvids includes Carrion Crow/Rook, Jackdaw, Magpie and Jay. Percentage numbers and percentage biomass for corvids and thrushes exclude birds from these categories that were identified only to prey group. "Other birds" includes all birds not listed in any other category.

all, 45 prey species were recorded (Appendix). Ten species (Woodpigeon, Feral Pigeon, Crow/Rook, Magpie, Jay, Mistle Thrush *Turdus viscivorus*, Song Thrush *Turdus philomelos*, Blackbird, Grey Squirrel and Rabbit) accounted for 90% of Goshawk prey numerically and 94% in terms of biomass (Appendix). Pigeons, corvids, thrushes and mammals were numerically the most important contributors to the Goshawk diet, but thrushes were less important in terms of biomass (Table 1).

### Variation in diet by prey group

Variations occurred in Goshawk diet during the breeding season (Fig. 3). Pigeons, corvids, thrushes and mammals were abundant in the diet of Goshawks throughout the breeding season, with pigeons and corvids numerically as important as the other groups combined. Birds of prey and other birds made only small contributions to the diet of Gos-

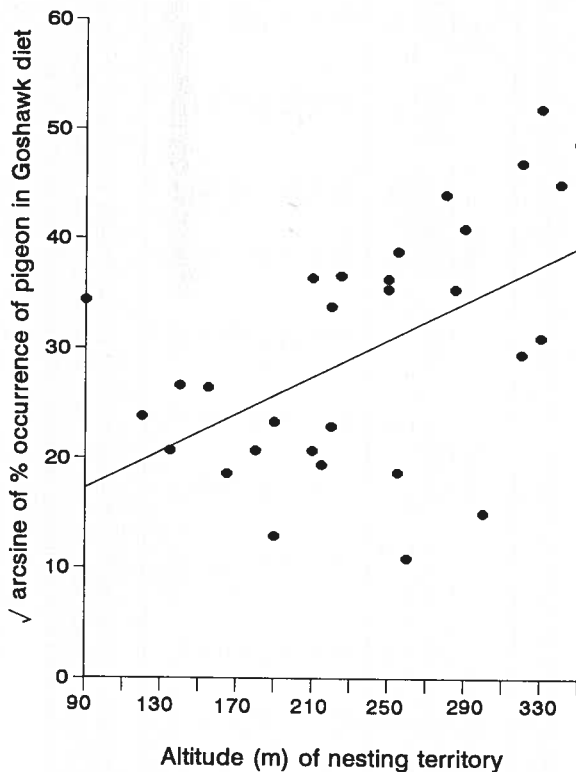


**Figure 3.** Goshawks' main prey groups March–August 1991–1993. (a) Percentage frequency; (b) Percentage biomass. Regression analysis of percentage prey group occurrence (after  $\sqrt{\text{arcsine}}$  data transformation) over the breeding season, March–August, revealed that numerically pigeons ( $r = -0.675$ ,  $P < 0.05$ ) and other birds ( $r = -0.699$ ,  $P < 0.05$ ) decreased whilst corvids increased ( $r = 0.832$ ,  $P < 0.01$ ). The biomass contribution of corvids in the Goshawk diet also increased ( $r = 0.944$ ,  $P < 0.001$ ) whilst mammals declined ( $r = -0.693$ ,  $P < 0.05$ ) as did other birds ( $r = -0.737$ ,  $P < 0.05$ ). These results suggested that Goshawks switched during the breeding season from pigeons and mammals to corvids. This switch was related to an increase of corvid abundance which coincided with the occurrence of corvid fledglings (Table 4) rather than to a decline in pigeon, other birds or mammal numbers.

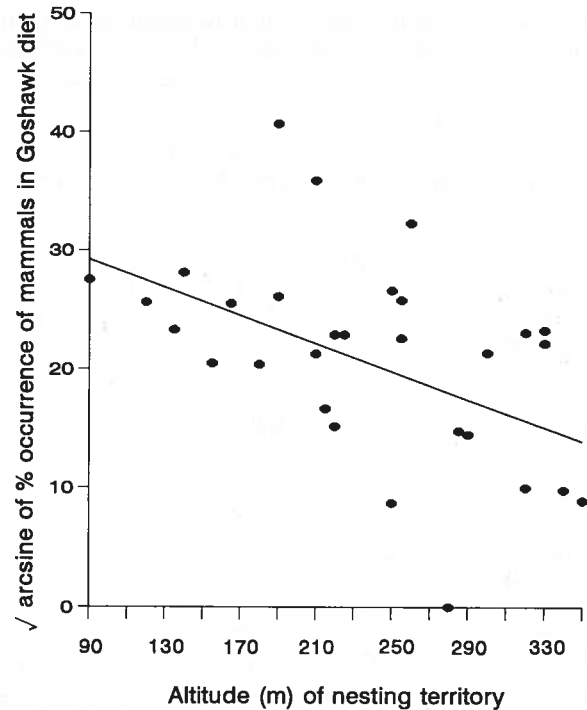
**Table 2.** Annual variation in percentage of numbers of Goshawk prey during the breeding season in Wales

Prey group	1991		1992		1993		Total	
	n	%	n	%	n	%	n	%
Pigeons	270	42	170	33	242	23	682	31
Corvids	196	30	220	43	381	37	797	36
Thrushes	3	13	68	13	170	16	321	15
Mammals	66	10	43	8	181	17	290	13
Other birds	33	5	16	3	70	7	119	5
Total	648		517		1044		2209	

Note: Data exclude unidentified prey items. Analysis of 1846 identified prey items collected at 30 nesting territories represents 51 nesting territory-years (1991, 14; 1992, 13; 1993, 24). At each territory, more than 20 prey items were collected each year (mean = 36.1, s.d.  $\pm 12.3$ ).



**Figure 4.** Percentage occurrence of pigeons in the Goshawk diet with altitude based on 30 Goshawk nesting territories during the breeding season (March–September 1991–1993). Regression equation for pigeons:  $y = 0.081x + 11.07$ ,  $r = 0.512$ ,  $P < 0.005$ , where  $y = \sqrt{\text{arcsine of \% pigeon numbers}}$  and  $x = \text{altitude of Goshawk nesting territory in metres}$ .



**Figure 5.** Percentage occurrence of mammals in the Goshawk diet with altitude based on 30 Goshawk nesting territories during the breeding season (March–September 1991–1993). Regression equation for mammals:  $y = -0.057x + 34.74$ ,  $r = -0.475$ ,  $P < 0.01$ , where  $y = \sqrt{\text{arcsine of \% mammal numbers}}$  and  $x = \text{altitude of Goshawk nesting territory in metres}$ .

hawks. There was some variation in prey composition between years ( $\chi^2_8 = 96.9$ ,  $P < 0.01$ ; Table 2). This variation was expected because as the study proceeded more nesting territories were found and surveyed for prey remains. Hence corvids, thrushes, other birds and mammals were found in higher numbers in the Goshawk diet in 1993 than previously. More pigeons were taken than expected in 1991 and less in 1992 ( $\chi^2_2 = 23.4$ ,  $P < 0.01$ ).

In terms of biomass, pigeons, corvids and mammals were the most important prey of the Goshawk (Fig. 3, Table 1). Mammalian biomass was far greater than numerical occurrence due to the high biomass of the Grey Squirrel and, particularly, the Rabbit. Conversely, the biomass of thrushes in the diet of Goshawk declined due to their low individual mass. Birds of prey and other birds comprised only a small amount of the Goshawk diet by biomass.

Analysis of diet at 30 nesting territories in relation to altitude (mean altitude = 236 m, s.d.  $\pm 70$  m) revealed relationships between pigeons and mammals with the altitude of each Goshawk's nesting territory (Figs 4 and 5). Pigeons increased in the Goshawk's diet with altitude (Fig. 4), while the opposite relationship occurred with mammals (Fig. 5). Within mammal prey, both Grey Squirrel and Rabbit showed a similar trend, but the trend was significant only for the Rabbit ( $r_{29} = -0.45$ ,  $P < 0.01$ ). Rabbits were more frequent

**Table 3.** Goshawk diet expressed by numbers and biomass of prey groups collected during April–May and July (1991–1993) in Wales

Prey group	n	% total individuals	Total biomass (kg)	% biomass
<b>April–May</b>				
Birds of prey	10	1.5	3.86	1
Pigeons	248	36.4	115.3	39
Corvids	144	21	45.1	15
Thrushes	128	19	10.7	4
Other birds	46	7	7.5	3
Mammals	104	15	114.7	38
Total	680	100	297.2	100
<b>July*</b>				
Birds of prey	12	2	5.1	2
Pigeons	165	27.7	76.7	34
Corvids	280	47	88.6	39
Thrushes	59	9.9	5.5	3
Other birds	15	2.5	0.7	+ <sup>b</sup>
Mammals	65	10.9	47.8	21
Total	596	100	224.5	100

\* One Common Lizard *Lacerta vivipara*, of negligible weight, was omitted from the July data.

<sup>b</sup>+ = negligible percent biomass.

in the diet of Goshawks in lowland nesting territories, whilst squirrels were found in the diet of Goshawks at all altitudes. There was no significant relationship between altitude and the occurrence in the Goshawk's diet of corvids or thrushes, although all seven species showed a slightly negative relationship, suggesting they may occur in a slightly greater frequency in the diet of Goshawks nesting at lower altitudes.

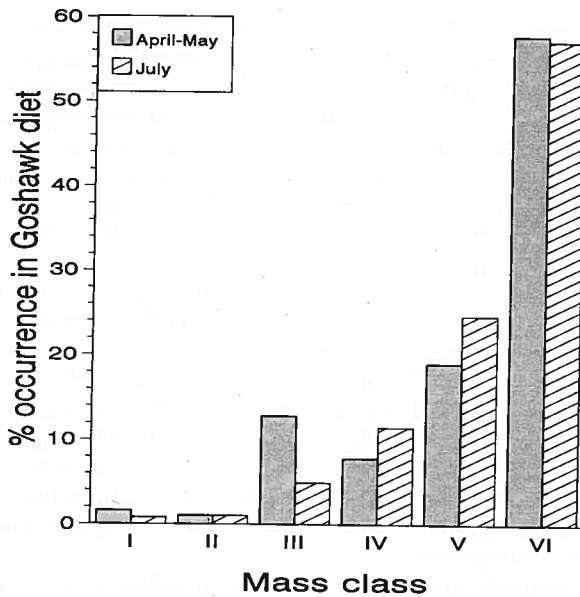
**Prey selection differences between sexes**

During April and May, when most prey are considered to have been captured by the male, 680 prey items from 34 prey species were collected in Goshawk nesting territories. This sample was compared with the Goshawk's diet in July, when both sexes hunted. During July, 597 prey items from 23 prey species were collected. The main difference in diet between these two periods was that lower proportions of pigeons ( $\chi^2_1 = 11.2, P < 0.01$ ), thrushes ( $\chi^2_1 = 29.6, P < 0.01$ ) and other birds ( $\chi^2_1 = 12.6, P < 0.01$ ) were taken in July, whilst more corvids were taken in July ( $\chi^2_1 = 95.4, P < 0.01$ ; Table 3). Most differences may reflect changes in local abundance of prey species rather than hunting differences between male and female Goshawks. This was particularly true for corvids (Table 4) and thrushes, when frequency in the diet increased as nestlings and fledglings became available. Their availability was probably the reason why fewer prey species were taken in July than in April–

**Table 4.** Goshawk predation on young Woodpigeon, corvids and thrushes during March–August in Wales

Month	Woodpigeon			Crow/Rook			Magpie			Jay			Mistle Thrush			Song Thrush			Blackbird			
	Fledglings		%	Fledglings		%	Fledglings		%	Fledglings		%	Fledglings		%	Fledglings		%	Fledglings		%	
	n	n		n	n		n	n		n	n		n	n		n	n		n	n		
March	29	0	0	16	0	0	2	0	0	6	0	0	2	0	0	3	0	0	5	0	0	0
April	72	3	4	13	1	7	16	0	0	20	0	0	7	6	46	9	4	31	10	3	2	2
May	132	9	6	29	3	9	21	2	9	15	1	6	21	12	36	21	10	32	7	18	72	72
June	125	19	13	43	10	19	53	29	35	69	82	54	24	9	27	27	15	36	25	14	36	36
July	125	3	2	105	3	3	45	7	13	72	27	27	21	6	22	13	0	0	13	6	32	32
August	15	2	12	17	0	0	6	0	0	9	0	0	2	0	0	3	0	0	1	0	0	0
Total	498	6	7	223	17	7	146	38	21	191	110	37	77	33	30	76	29	28	61	41	40	40

Note: Percentage fledglings is the proportion of fledglings in the overall monthly total (adults + fledglings). In 1991 during the April–May period, fewer nesting territories were more regularly surveyed for prey remains than in 1992 or 1993, when more nesting territories were less frequently surveyed. Sampling effort for the June–August period was similar for all years; sample sizes increased as more nesting territories were discovered and surveyed for prey remains.



**Figure 6.** Distribution of prey mass size classes when male Goshawks hunted (April–May) compared with when both sexes hunted (July). There was a statistically significant association between prey mass size classes and the two time periods ( $\chi^2_5 = 32.6$ ,  $P < 0.01$ ). In particular, more prey in the mass size class III were taken in the April–May period than expected and less than expected were taken in July. This difference was explained by Goshawk predation of thrushes, which was greater in April–May than July (Fig. 3). Such increased predation was also related to the abundance of fledgling thrushes, which were vulnerable to predation during these months (Table 4). Sample sizes are given in the text.

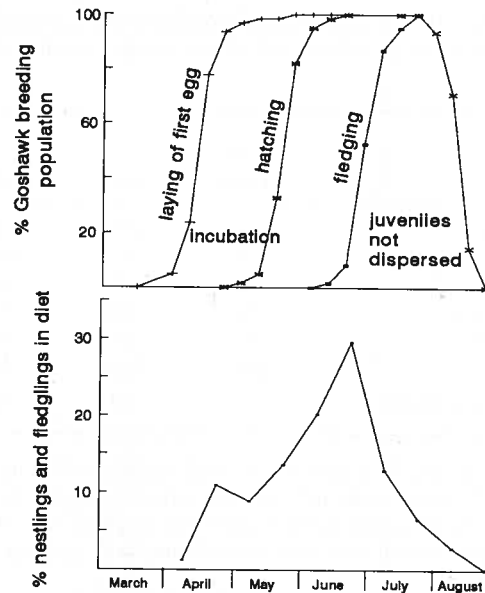
May. This result suggested that in July both male and female Goshawks hunted the same prey.

To investigate differences between prey items taken by male Goshawks and prey brought to the nest by both adults, prey were analysed by size class. During April–May (male kills), 77% of prey were greater than 161 g (size classes V and VI), and this increased slightly to 82% when both sexes hunted in July. Such data and the distribution of prey class sizes (Fig. 6) suggested that there were no significant changes in prey size classes and that male and female Goshawks were capable of taking a similar proportion of larger sized prey found within the study area.

The average mass of prey brought to nests during April–May was 437 g, which was significantly greater than the July average of 376 g ( $Z$ -test = 5.89,  $P < 0.01$ ) and could be explained by an increase in July in the proportions of nestling or fledgling prey, which have lower mass (Table 4).

#### Goshawk predation on fledglings and their importance in the timing of Goshawk breeding

The timing of breeding by Goshawk in relation to the appearance of nestling and fledgling birds in their diet was investigated (Table 4, Fig. 7). Nestlings contributed little to the total prey biomass or numbers compared with fledglings so were grouped with fledglings. Fledgling prey first oc-



**Figure 7.** Breeding of Goshawks in relation to the supply of nestling and fledgling prey species in Wales. (Upper) Proportion of Goshawks that laid eggs and reared young during 1991–1993; (Lower) Proportion of nestling and fledgling birds in the Goshawk diet during the breeding seasons 1991–1993. Proportion of fledglings is the percentage of identified fledglings in the total of identified prey items for each 2-week period.

curred in the Goshawk diet in April, increased through May and June and then declined in July, coinciding with their abundance in the environment (Table 4). Predation on fledgling birds coincided with peak food demands of Goshawk nestlings (Fig. 7).

Goshawks took 325 thrushes, of which 46% were fledglings (Appendix). Fledglings of Mistle Thrush, Song Thrush and Blackbird were first recorded in the Goshawk diet in the last 2 weeks of April and peaked in May (Mistle Thrush, Blackbird) or June (Song Thrush; Table 4). This sequential predation on fledgling thrushes partially reflected their breeding times. Mistle Thrush nested first, followed by Song Thrush, then Blackbird.

Magpies comprised 8.3% of the Goshawk diet (Appendix). Predation on Magpies peaked in June, corresponding with the main Magpie fledgling period; 21% (38 of 184) of all Magpie kills were fledglings. On several occasions, several Magpie nestlings were found at a Goshawk nest site on the same visit, suggesting that the Goshawks were returning to the Magpie nest to remove young until there were none left. Similar predation of Jay broods occurred. Jays comprised 13.5% of all Goshawk prey collected, of which 36.5% (110 of 301) were fledglings. Fledgling Jays were first detected in the Goshawk diet at the end of May and peaked in June, in common with Magpie, Carrion Crow/Rook and Woodpigeon (Table 4). Fledgling Woodpigeons comprised 6.5% (36 of 559) of all Woodpigeon prey. Seven percent (17 of 243) of all recorded Carrion Crow/Rook kills and 2.9% (2 of 69) of

**Table 5.** Number of prey found in Goshawk nesting territories in Wales according to woodland size during March–September 1991–1993

	Small forests	Forest A	Forest B
Pigeons	94	125	123
Corvids	154	137	149
Thrushes	63	69	55
Other birds	23	20	27
Mammals	82	34	44
Total	416	385	398
No. of prey species	21	23	24

Note: Prey data from territories in small woods ( $n = 5$ ) and forest A ( $n = 7$ ) corresponded to 11 nesting territory-years, and for forest B ( $n = 8$ ), 13 nesting territory-years. For simplicity, birds of prey were grouped with other birds in the "other birds" category.

Jackdaw kills were also fledglings. However, predation on fledglings of these species was small compared with proportions of young Magpies, Jays and thrushes taken (Table 4, Appendix).

### Influence of forest size on Goshawk prey

Variation in Goshawk diet with forest size was investigated during 1991–1993 between small nesting woods (<1000 ha), forest A (c. 3500 ha) and forest B (c. 6100 ha; Table 5). Differences in diet were explained partly by yearly variations of prey species abundance and by the altitudes of nesting territories (Table 5, Figs 4 and 5). To avoid these effects, prey data were selected from the three categories that covered all years and all altitudes. There were no differences in the altitudes of the different forest types, nor were there yearly prey differences between forest types. There was a statistically significant association between certain prey groups and forest size ( $\chi^2_6 = 30.5$ ,  $P < 0.01$ ). In particular, in small forests, mammals were more frequent in Goshawk diet than expected. The ANOVA revealed that this was because Grey Squirrels were commoner in the diet of Goshawks nesting in small forests compared with those nesting in forests A and B ( $F_{2,32} = 4.37$ ,  $P < 0.05$ ). There was no difference in the number of prey species taken with forest size ( $\chi^2_2 = 0.20$ , n.s.; Table 5).

### DISCUSSION

In Britain, there is controversy over the increasing numbers of Goshawk and their likely impact on scarce bird species or on species of economic value. As my study was in an area free from managed game birds or other artificially high prey densities, such as racing pigeons, it has been possible to quantify the normal range of Goshawk prey. The results

showed a high dependence on a few species: Feral Pigeon, Woodpigeon, Carrion Crow/Rook, Jay, Magpie, Grey Squirrel and Rabbit. Other studies of Goshawk diet during the breeding season in Scandinavia and central Europe have also shown their reliance on relatively few prey species, often those species between 250 g and 1200 g that were commonest in the environment (Brüll 1964b, Höglund 1964, Sulkava 1964, Opdam *et al.* 1977, Huhtala & Sulkava 1981, Lindén & Wikman 1983, Goszczynski & Pilatowski 1986). In Britain and central Europe, the commonest prey group was pigeons (Brüll 1964b, Opdam *et al.* 1977, Thissen *et al.* 1981, Goszczynski & Pilatowski 1986, Cooper & Petty 1988; Table 6). This study found that the proportion of pigeons in the Goshawk diet decreased as the breeding season progressed (Fig. 3), in contrast to studies in upland Britain and boreal Sweden, where the proportions of pigeons increased (Widén 1987, Cooper & Petty 1988). These results highlight differences in habitat and hence prey species availability in the different areas.

Mammals were important prey for Goshawks in Wales, as they were in temperate Sweden and Spain (Table 6). In those areas, Goshawks had a more varied prey base and were less reliant on pigeons for food (Table 6). In addition to the five mammal species recorded in the Goshawk diet in this study, other mammalian prey of Goshawks recorded in Britain include Brown Rat *Rattus norvegicus*, Domestic Cat *Felis domesticus*, Mountain Hare *Lepus timidus*, Red Squirrel, Stoat *Mustela erminea*, Water Vole *Arvicola amphibius* and Weasel *Mustela nivalis* (Marquiss & Newton 1982a, Lindley & Jenkins 1991; Appendix). Grey Squirrels and Rabbits are considered as pests due to the damage they cause to forest trees (Gill 1992). Control of these pests by trapping or shooting is often difficult and time consuming, and poisoning (illegal for some species) is ineffective due to their high reproductive rates. Grey Squirrel populations have expanded in areas of forestry, and damage to conifers has increased (Rowe & Gill 1985). In Wales, more Grey Squirrel carcasses were found at Goshawk nesting territories within small woods than in larger woods; such territories contained or were adjacent to stands of oaks (*Quercus* spp.) and Beech *Fagus sylvatica* where squirrels foraged. Here, predation risks to squirrels were probably high as there was little ground cover and shrub understorey. Goshawks preyed upon Rabbits and Brown Hare (Appendix), both of which occur in forests, where they damage trees by browsing and stripping bark (Gill 1992). Rabbits were found in greater proportions in the diet of Goshawks nesting at lower altitudes, and predation on Grey Squirrels was highest in small woods. Reasons for these differences were unclear, and prey densities in different habitats and at different altitudes were not investigated. The sheepwalk at all altitudes adjacent to forests A and B supported Rabbits. Grey Squirrels appeared to be commoner in the lowlands, where deciduous and mixed woodlands occurred in contrast to the conifer-dominated plantations above 250 m.

In common with previous studies (Brüll 1964b, Opdam *et al.* 1977, Goszczynski & Pilatowski 1986, Mañosa 1994),



**Table 6.** Percentage prey composition during the breeding season from five European studies of Goshawks

Prey group	Wales <sup>a</sup>	England/Scotland <sup>b</sup>	Sweden <sup>c</sup>	Holland <sup>d</sup>	Spain <sup>e</sup>
<b>Birds</b>					
Game birds	0.0%	8.4%	22.2%	5.2%	19.5%
Waders	1.2%	0.9%	1.0%	0.5%	0.0%
Pigeons	30.6%	48.5%	15.6%	63.1%	14.1%
Corvids	36.3%	19.6%	27.2%	10.5%	12.1%
Thrushes and starlings	15.6%	5.9%	12.5%	11.9%	14.1%
Other birds	3.2%	8.1%	7.1%	5.0%	17.0%
Total birds	86.9%	91.4%	85.6%	96.2%	76.8%
<b>Mammals</b>					
Lagomorphs	5.3%	5.2%	0.7%	3.5%	17.0%
Squirrels	7.7%	1.8%	13.7%	0.2%	4.4%
Other mammals	0.1%	1.6%	0.0%	0.1%	1.8%
Total mammals	13.1%	8.6%	14.4%	3.8%	23.2%
No. of prey items	2213	3980	904	4821	1964

<sup>a</sup> This study.

<sup>b</sup> S.J. Petty (unpubl. data).

<sup>c</sup> Widén (1987).

<sup>d</sup> Opdam *et al.* (1977).

<sup>e</sup> Mañosa (1994).

this study revealed the importance of young birds in the Goshawk's diet. In Wales, Goshawk predation on young birds increased as the breeding season progressed, peaking when nestlings were close to fledging. During this time, Goshawks partially switched from young thrushes to young corvids. Switching to juvenile prey by Goshawks has been recorded elsewhere. In Germany, the commonest juvenile birds in the Goshawk's diet were Blackbirds and Starlings *Sturnus vulgaris* during May–June and Jay and Woodpigeons during June–July (Opdam *et al.* 1977), whilst in Spain, the commonest juvenile prey were pigeons, corvids and thrushes during May–June and Red-legged Partridges *Alectoris rufa* in July (Mañosa 1994). The choice of prey species varies, depending on habitat and availability, but the Goshawk's ability to target vulnerable prey and switch between them as they become available appears to be universal.

This study found no strong evidence of prey partitioning between sexes in the nesting season in agreement with other studies on the Goshawk (Widén 1984, Goszcynski & Pilatowski 1986). Sex-related differences have been shown to exist in the diets of bird of prey species where the size dimorphism is greater than in the Goshawk (Höglund 1964, Storer 1966, Schipper 1973, Opdam 1975, Synder & Wiley 1976, Newton 1978). The great sexual size dimorphism in the Sparrowhawk allowed different hunting habitats to be utilized, so offering a greater range of prey species (Marquiss & Newton 1982b, Newton 1986). This presumably occurred in the Goshawk; the smaller, more agile males were probably responsible for most small songbird kills such as Chaffinch *Fringilla coelebs*, whilst the larger, more powerful females

were probably responsible for killing hares, as found by Kenward *et al.* (1981). Opdam (1975) found male Goshawks in March took prey weighing an average of 277 g (Woodcock *Scolopax rusticola* size), whereas for females, the average was 505 g (large Woodpigeon). If the prey collected in April and May was due to males alone, then the average prey mass of 437 g found in this study probably reflects the local abundance and vulnerability of large birds and mammals. The decline in mean prey mass to 376 g by July was due to the appearance of fledglings in the diet (Table 4, Fig. 7) rather than to any prey selection based on sexual differences.

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## APPENDIX

Prey items of the Goshawk diet in Wales March–September 1991–1993. Small discrepancies in column totals are a result of rounding numbers. Total numbers of each prey species are listed, together with their percentage contribution to Goshawk diet. The numbers of nestling and fledgling items for each species are also listed together with their percentage contribution to the overall diet. Total biomass contribution for each species was calculated using the mass listed, and allowances were made for nestlings and fledglings (see Methods). Prey species percentage contribution to the Goshawk diet in terms of biomass is listed

Prey species <sup>a</sup>	Total		Nestlings/fledglings		Mass (g) of individual	Total biomass (kg)	% biomass
	n	%	n	%			
Mallard <i>Anas platyrhynchos</i>	3	0.1	0	0	1010	3.0	0.4
Buzzard <i>Buteo buteo</i>	3	0.1	0	0	982	2.9	0.3
Goshawk <i>Accipiter gentilis</i>	6	0.3	6	0.3	650	3.9	0.5
Sparrowhawk <i>Accipiter nisus</i>	3	0.1	0	0	193	0.6	0.1
Merlin <i>Falco columbarius</i>	1	0.0	0	0	130	0.1	0
Kestrel <i>Falco tinnunculus</i>	10	0.5	0	0	208	2.1	0.2
Red Grouse <i>Lagopus lagopus</i>	1	0.0	0	0	637	0.6	0.1
Woodcock <i>Scolopax rusticola</i>	23	1.0	0	0	267	6.1	0.7
Curlew <i>Numenius arquata</i>	1	0.0	0	0	704	0.7	0.1
Redshank <i>Tringa totanus</i>	1	0.0	0	0	150	0.1	0
Black-headed Gull <i>Larus ridibundus</i>	2	0.1	0	0	266	0.5	0.1
Feral Pigeon <i>Columba livia</i>	118	5.3	0	0	425	50.1	5.8
Woodpigeon <i>Columba palumbus</i>	559	25.1	36	1.6	480	262.4	30.5
Cuckoo <i>Cuculus canorus</i>	2	0.1	1	0	110	0.2	0
Tawny Owl <i>Strix aluco</i>	13	0.6	0	0	427	5.6	0.6
Swift <i>Apus apus</i>	1	0.0	0	0	40	0	0
Green Woodpecker <i>Picus viridis</i>	1	0.0	0	0	186	0.2	0
Great-spotted Woodpecker <i>Dendrocopos major</i>	5	0.2	0	0	78	0.4	0
Meadow Pipit <i>Anthus pratensis</i>	1	0.0	0	0	20	0	0
Starling <i>Sturnus vulgaris</i>	10	0.4	2	0.1	77	0.7	0.1
Raven <i>Corvus corax</i>	1	0.0	1	0	825	0.8	0.1
Crow/Rook <i>Corvus corone/Corvus frugilegus</i>	243	10.9	17	0.8	527	125.0	14.5
Jackdaw <i>Corvus monedula</i>	69	3.1	2	0.1	245	16.8	1.9
Magpie <i>Pica pica</i>	184	8.3	38	1.7	245	39.5	4.6
Jay <i>Garrulus glandarius</i>	301	13.5	110	4.9	167	44.0	5.1
Unidentified corvids	5	0.2	0	0	215	1.1	0.1
Wren <i>Troglodytes troglodytes</i>	1	0.0	0	0	12	0	0
Warbler <i>Phylloscopus</i> sp.	1	0.0	0	0	9	0	0
Redstart <i>Phoenicurus phoenicurus</i>	2	0.1	0	0	15	0	0
Robin <i>Erithacus rubecula</i>	12	0.5	3	0.1	19	0.2	0
Mistle Thrush <i>Turdus viscivorus</i>	112	5.0	33	1.5	118	11.9	1.4
Fieldfare <i>Turdus pilaris</i>	2	0.1	0	0	112	0.2	0
Song Thrush <i>Turdus philomelos</i>	105	4.7	29	1.3	80	7.6	0.9
Blackbird <i>Turdus merula</i>	102	4.6	41	1.8	92	8.1	0.9
Unidentified thrushes	4	0.2	1	0	80	0.3	0
Treecreeper <i>Certhia familiaris</i>	1	0.0	0	0	9	0	0
House Sparrow <i>Passer domesticus</i>	1	0.0	0	0	29	0	0
Greenfinch <i>Carduelis chloris</i>	1	0.0	0	0	16	0	0
Siskin <i>Carduelis spinus</i>	3	0.1	0	0	15	0	0
Crossbill <i>Loxia curvirostra</i>	1	0.0	0	0	30	0	0
Chaffinch <i>Fringilla coelebs</i>	12	0.5	1	0	22	0.3	0
Grey Squirrel <i>Sciurus carolinensis</i>	170	7.6	3	0.1	550	92.9	10.8
Rabbit <i>Oryctolagus cuniculus</i>	110	4.9	7	0.3	1600	166.9	19.4
Brown Hare <i>Lepus europaeus</i>	7	0.3	6	0.3	3330	5.1	0.6
Bank Vole <i>Clethrionomys glareolus</i>	2	0.1	0	0	24	48	0
Common Shrew <i>Sorex araneus</i>	1	0.0	0	0	10	10	0
Common Lizard <i>Lacerta vivipara</i>	1	0.0	0	0	4	4	0
Unidentified items	12	0.5	0	0	—	—	0
Total	2230		337	15.1	—	861.5	99.8

In addition to these prey items, 49 prey items were collected in 1990: one Coot *Fulica atra*, four Feral Pigeon, 11 Woodpigeon, One Tawny Owl, one Skylark *Alauda arvensis*, 11 Crow/Rook, seven Magpie, four Jay, one Mistle Thrush, one Fieldfare, one Song Thrush, three Blackbird, one Grey Squirrel, one Rabbit. Of these, Coot and Skylark were new prey species in the study. Of the more unusual prey species, Buzzard and Kestrel had been recorded prior to 1990.