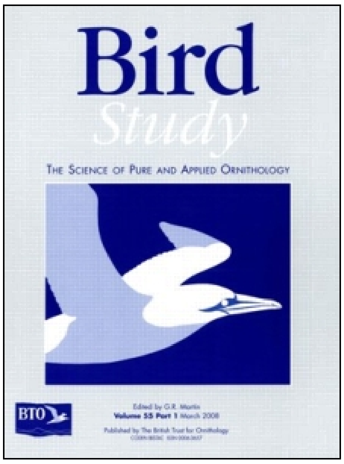

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The diet of Dippers Cinclus cinclus wintering in the catchment of the River Wye, Wales

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The diet of Dippers *Cinclus cinclus* wintering in the catchment of the River Wye, Wales

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We studied the diet of Dippers in the River Wye catchment by faecal analysis during the winters of 1983/84 and 1984/85. Diptera, Trichoptera, Ephemeroptera and Plecoptera comprised respectively 34, 23, 18 and 11% of 4650 items recorded from over 350 faecal samples. The Simuliidae (Diptera) and Baetidae (Ephemeroptera) were the commonest macroinvertebrate families recorded despite their small size. Fish and trichopteran larvae comprised respectively an estimated 63 and 19% of the diet by weight. By contrast with Dippers foraging for nestlings, the proportions and reconstructed weights of items appearing in faeces strongly reflected those in stream samples. Birds probably fed opportunistically. Consequently, Dippers feeding on hard water streams ingested more calcium-rich prey than those on soft-water streams. The results are discussed in relation to the influence of stream acidity on aspects of Dipper ecology.

In view of recent concern over the influence of stream acidification on the prey available to Dippers *Cinclus cinclus* in parts of Wales (Ormerod *et al.* 1985a; Ormerod *et al.* 1986) and Scotland (Fry & Cooke 1984), a full knowledge of the species' diet would be useful. However, most published information on the diet of Dippers relates to the breeding season (e.g. Jost 1975a; Ormerod 1985a,b; Ormerod & Perry 1986). For other times of the year, data are available only from small samples collected on mainland Europe (Vollnhofer 1906; Jost 1975a). This paper describes the diet, assessed largely by faecal analysis, of Dippers in the catchment of the Welsh River Wye during the winter periods of 1983/84 and 1984/85. It forms part of a continuing autecological investigation (Ormerod *et al.* 1985a, 1986; Ormerod *et al.* 1985b; Ormerod 1985a,b; Tyler & Ormerod 1985) and the study area has been described elsewhere (Edwards & Brooker 1982; Ormerod *et al.* 1985b).

METHODS

Faecal collection and analysis

Unpredictable patterns of weather, river-flow and local bird movements prevented any systematic collection of faeces. Nevertheless, samples representing over 50 birds were taken throughout the catchment at 38 sites incorporating a wide range of chemical and physical conditions; most faeces were collected in January and February (Table 1). In order to assess errors due to differences between prey in digestibility and gut throughput, remains in faecal and regurgitated pellets were compared at 7 sites.

Samples were analysed using the methods of Ormerod (1985a,b): most macroinvertebrates were identified to family and quantified by counting mouthparts at ×40 and ×100 magnification. Molluscs were identified from shell fragments and quantified by counting shell spires. Fishes were identified from scales

Table 1. The numbers of Dipper faecal pellets collected in each month of the study (pooled for 1983/84 and 1984/85)

Month	*Number of faecal pellets*
September	5
October	6
November	28
December	61
January	109
February	147
March	12
Total	368

or vertebrae (Maitland 1972; Webb 1974) and quantified by counting the latter (28 vertebrae = one fish, shown by dissection). Worm chaetae were not found in any faecal sample.

The composition of the diet by weight was estimated by multiplying the number of faecal occurrences of each prey type by its geometric mean dry weight in stream samples. For fish, a geometric mean dry weight for Bullheads *Cottus gobio* (the commonest fish recorded in faeces) was given by UWIST (1978).

In order to examine prey-size selection within taxa, dry weights of individual prey-items from the most commonly occurring families were reconstructed from faeces using regressions of weight on mandibular dimensions (Table 3). The latter were highly significant ($P < 0.001$ for each, Table 3). Mean weights were compared with those of the same taxa in stream samples using t-tests (Sokal & Rohlf 1981).

Intensive faecal collections (more than 20 pellets per site) were made at nine sites at which prey availability was also assessed (Table 2). Comparisons between the proportionate composition of available and ingested prey were made for major taxa using Wilcoxon signed rank tests (w-s test) (Siegel 1956). Prey preferences were also assessed using Jacobs' (1974) index (see Appendix) which gives values ranging from -1.0, indicating avoidance or inaccessibility of prey items, to $+1.0$, indicating active selection. This index has several advantages over other proposed preference measures (Jacobs 1974; Cock 1978).

Macroinvertebrate collection

An earlier study of the diet of Dippers in relation to available macroinvertebrates involved quantitative sampling in riffles alone (Ormerod 1985a). However, this method failed to represent some taxa which were associated with

Table 2. The location and characteristics of sites used to study prey selection and between-site differences in the winter diet of Dippers

Site	*National Grid Reference*	*Altitude m O.D.*	*pH*	*Total hardness ($mg\ CaCO_3 l^{-1}$)*	*Date kick-sampled*
Upper Irfon	SN 835 556	420	5.41 (0.62;28)	7.71 (1.52;27)	4.2.85
Upper Cammarch	SN 916 520	214	6.48 (0.27;6)	16.43 (1.72;6)	12.2.84
Irfon, Llangammarch	SN 934 470	170	6.74 (0.31;7)	18.81 (2.57;9)	—
Cammarch, Blackbridge	SN 934 473	175	7.05 (0.53;21)	25.54 (7.22;18)	26.1.85
Marteg	SN 952 715	266	7.27 (0.42;7)	26.37 (8.04;6)	—
Lower Chwefru	SN 997 530	160	7.16 (0.42;20)	39.96(16.49;18)	—
Upper Duhonw	SO 044 487	160	7.27 (0.37;19)	59.66 (16.76;17)	—
Lower Duhonw	SO 062 508	122			
Upper Ithon	SO 085 793	310	7.51 (0.37;22)	69.35 (20.91;20)	19.2.84
Bach Howey	SO 104 428	110	7.54 (0.33;16)	85.28 (17.47;14)	31.1.85
Edw, Cregrina	SO 123 518	180	7.80 (0.37;18)	89.02(22.0;17)	31.1.85
Monnow, Craswall	SO 277 361	291	8.10 (0.31;28)	150.51 (39.5;26)	2.2.85
Monnow, Forge	SO 503 137	21			
Angidy	SO 506 002	85	8.17 (0.29;25)	168.71 (16.24;24)	29.1.84; 2.2.85

Figures for pH and total hardness are arithmetic means from winter determinations (October–March inclusive) provided by Welsh water.
Figures in parentheses are standard deviations and sample sizes.

Table 3. Regressions of dry weight on mandibular dimensions for macroinvertebrate taxa preyed upon by Dippers

Taxon	*Equation*	x *variable*	n	r^2
Baetidae	$y = -2.41+0.068x$	Width of right mandible	52	0.88
Leuctridae/Nemouridae	$y = -1.73+0.065x$	Width of right mandible	19	0.94
Hydropsychidae	$y = -0.96+0.022x$	Length of right mandible	36	0.63
Simuliidae	$y = -1.74+0.038x$	Length of mandible	26	0.89

$y = \log_{10}$ dry weight (mg); x variables is $\mu m \times 10^{-1}$

other riverine habitats and which were important prey. Consequently, food availability was assessed in this study using a standardized kick-sampling technique (one 3 min sample per site; net mesh aperture 400 μm) across the range of microhabitats in which Dippers feed. Although kick-sampling does not permit estimates of absolute density, it probably represents faithfully the proportionate composition of macroinvertebrate faunas in fast-flowing streams (Armitage *et al.* 1974; Weatherley *et al.* 1985). Ormerod (1985a) has described the laboratory methods used. Subsamples of 3 to 86 individuals of important prey were dried at 80°C and weighed individually to 0.01 mg using an autobalance. Mandibular dimensions of Simuliidae (Diptera) and Leuctridae/Nemouridae (Plecoptera) were measured using a calibrated eyepiece and regressed against individual dry weight; similar regressions for the Baetidae (Ephemeroptera) and Hydropsychidae (Trichoptera) have been given previously (Ormerod 1985a).

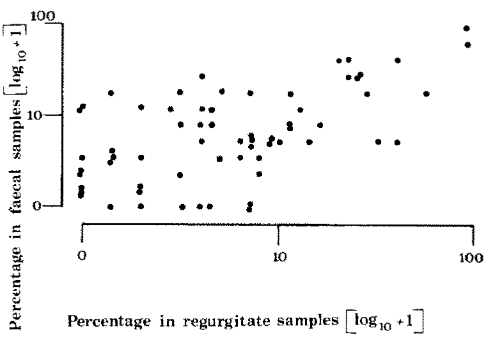

Figure 1. The percentage composition of Dipper faecal and regurgitated pellets at seven sites in the Wye catchment during winter. Each point represents the proportionate contribution by a macroinvertebrate family at a particular site (note log scale).

RESULTS

Faecal and regurgitated pellets

At the 7 sites where both regurgitated and faecal pellets were analysed, there was a strong correlation between their compositions (Fig. 1) and errors resulting from a dietary study based largely on faeces are probably small. Only molluscs were slightly under-represented in faeces by comparison with regurgitated pellets.

Dietary composition

In total, 368 faecal pellets and 7 regurgitated pellets were collected, containing the remains of 4850 prey from over 26 macro-invetebrate families (Table 4). Larval simuliids (Diptera), baetids (Ephemeroptera), leuctrids/nemourids (Plecoptera) and hydropsychids (Trichoptera) were the commonest families recorded despite their small size (under 1.5 mg geometric mean dry weight) (Table 4). Limnephilids (Trichoptera) also occurred widely in small numbers.

Similar rank orders of importance were apparent for prey taxa in their percentage frequency of occurrence and their percentage contributions to faeces (Spearman's rho = 0.895, $n = 27$, $t = 10.03$, $P < 0.001$; Table 4). At least for Dippers, therefore, percentage frequency of occurrence, which is easily assessed, probably provides an accurate indication of dietary importance.

Contributions by weight

Fish, notably Bullheads, comprised over 60% of the diet by weight and were the most important component. Trichopteran larvae,

Table 4. The diets of Dippers wintering in the catchment of the Welsh River Wye (based on the analysis of 368 faecal pellets and seven regurgitated pellets)

Taxon	*Geometric mean dry weight (mg)*	*Number*[1] *(%)*		*Frequency*[2] *(%)*	*Weight (%)*	
Mollusca			**5.2**			**6.1**
Ancylus	4.24 (2.03;3)	4.6		20.7	3.5	
Lymnaea	21.71 (1.22;4)	0.6		4.7	2.6	
Crustacea			**5.4**			**3.2**
Gammarus	3.25 (1.41;21)	5.4		25.3	3.2	
Ephemeroptera			**18.0**			**3.2**
Ephemeridae	7.4 (1.71;7)	0.1		1.5	0.1	
Baetidae	0.86 (1.17;86)	14.7		62.1	2.3	
Leptophlebiidae	0.95 (2.66;4)	0.4		5.7	0.1	
Ecdyonuridae	1.51 (1.34;15)	2.7		33.1	0.7	
Ephemerellidae	1.21 (3.25;5)	0.1		0.5	< 0.1	
Plecoptera			**11.3**			**1.3**
Leuctridae/Nemouridae	0.53 (1.40;35)	10.5		40.4	1.0	
Perlidae/Perlodidae	2.46 (2.63;14)	0.6		16.0	0.3	
Chloroperlidae	0.39 (1.12;12)	0.2		2.1	< 0.1	
Hemiptera			**0.3**			**(<0.1)**
Corixidae	1.61 (1.24;7)	0.3		4.1	< 0.1	
Trichoptera			**(23.3)**			**(19.4)**
Rhyacophilidae	3.67 (1.38;15)	2.1		33.2	1.4	
Glossosomatidae	1.74 (1.30;27)	2.5		34.7	0.8	
Hydropsychidae	1.42 (1.22;66)	9.3		68.3	2.4	
Polycentropopodidae	1.14 (1.72;4)	0.1		0.3	< 0.1	
Limnephilidae	11.28 (1.98;18)	3.6		63.2	7.3	
Odontoceridae	5.41 (1.17;7)	0.1		1.3	0.1	
Sericostomatidae	8.12 (1.31;12)	4.8		18.6	7.0	
Goeridae	2.92 (1.41;12)	0.4		8.2	0.2	
Leptoceridae	1.92 (1.21;12)	0.4		0.5	0.1	
Coleoptera			**(0.1)**			**(< 0.1)**
Elminthidae	0.22 (1.20;15)	0.1		1.0	< 0.1	
Diptera			**(33.4)**			**(3.1)**
Simuliidae	0.51 (1.17;53)	33.6		65.8	3.0	
Chironomidae	0.27 (1.7;32)	0.7		8.9	< 0.1	
Others	2.48 (2.37;12)	0.1		0.8	< 0.1	
Fishes[3]	213.0 (N.A.;1011)	1.7		38.3	63.7	
Totals		4850 items			27 069.3 mg	

Notes:[1]Total number of items recorded.
[2]Percentage of pellets with at least one of that prey.
[3]13.5% were salmonids, the rest Bullheads.
Values in parentheses are standard deviations and sample sizes (note geometric mean).

Table 5. Preference indices (Jacobs 1974) for Dippers feeding during winter at sites in the Wye catchment (Qualification-occurence in prey and kick–samples at > 3 sites)

Taxon	*Mean*	*1 sd*	*Range*	n *of sites*
Mollusca				
Ancylidae	0.15	0.78	−0.00; 1.00	6
Crustacea				
Gammaridae	−0.41	0.72	−0.97; 1.00	6
Ephemeroptera				
Baetidae	0.26	0.54	−0.23; 1.00	8
Ecdyonuridae	−0.54	0.71	−1.00; 1.00	7
Plecoptera				
Leuctridae/Nemouridae	−0.18	0.78	−1.00; 1.00	8
Perlidae/Perlodidae	−0.54	0.87	−1.00; 1.00	5
Trichoptera				
Rhyacophilidae	0.28	0.44	−0.38; 1.00	6
Glossosomatidae	0.43	0.62	−0.62; 1.00	6
Hydropsychidae	−0.26	0.75	−1.00; 1.00	8
Limnephilidae	0.60	0.45	−0.29; 1.00	9
Sericostomatidae	0.00	0.78	−1.00; 0.86	7
Diptera				
Simuliidae	0.06	0.73	−1.00; 0.99	9
Others (excl. Chironomidae)	−0.73	0.44	−1.00; 0.17	7

notably the case-bearing families Limnephilidae and Sericostomatidae, were second (Table 4).

Differences in diet between sites

Systematic differences in diet were examined only between those 14 sites from which more than 5 faecal pellets had been collected (pooled for all sampling occasions) and from which a range of environmental data was available (Table 2). Plecopteran nymphs were scarcer in diet, whilst *Gammarus*, molluscs and dipteran larvae (mostly Simuliidae) were more frequent at sites with harder waters. No such trends were apparent for other taxa or other environmental factors (Fig. 2).

Selection in relation to available prey

Chironomid larvae and Elminthidae, which consisted mostly of small individuals (< 0.3 mg dry weight, Table 4), were scarce or absent in faeces despite forming a large proportion of the animals collected at some sites. These taxa were excluded prior to the following calculations of prey selection.

Most macroinvertebrate taxa appeared in similar proportions in both faecal and kick-samples and most groups showed no consistent deviation from the lines of no selection (Fig. 3). However, plecopteran families and other Diptera were proportionately scarcer in faecal samples than in kick-samples, whilst trichopteran families were slightly more abundant in faeces (Fig. 3). Mean values of Jacobs' index were positve for 3 trichopteran families. However, values were highly variable between sites and only in a few cases were there significant differences from zero preference (Table 5).

Prey-size selection within taxa

The sizes of simuliids and baetids taken by Dippers were similar to those available. By contrast, ingested individuals in the Hydropsychidae and Leuctridae/Nemouridae were larger than those available but the difference was statistically significant only for the former (Table 6).

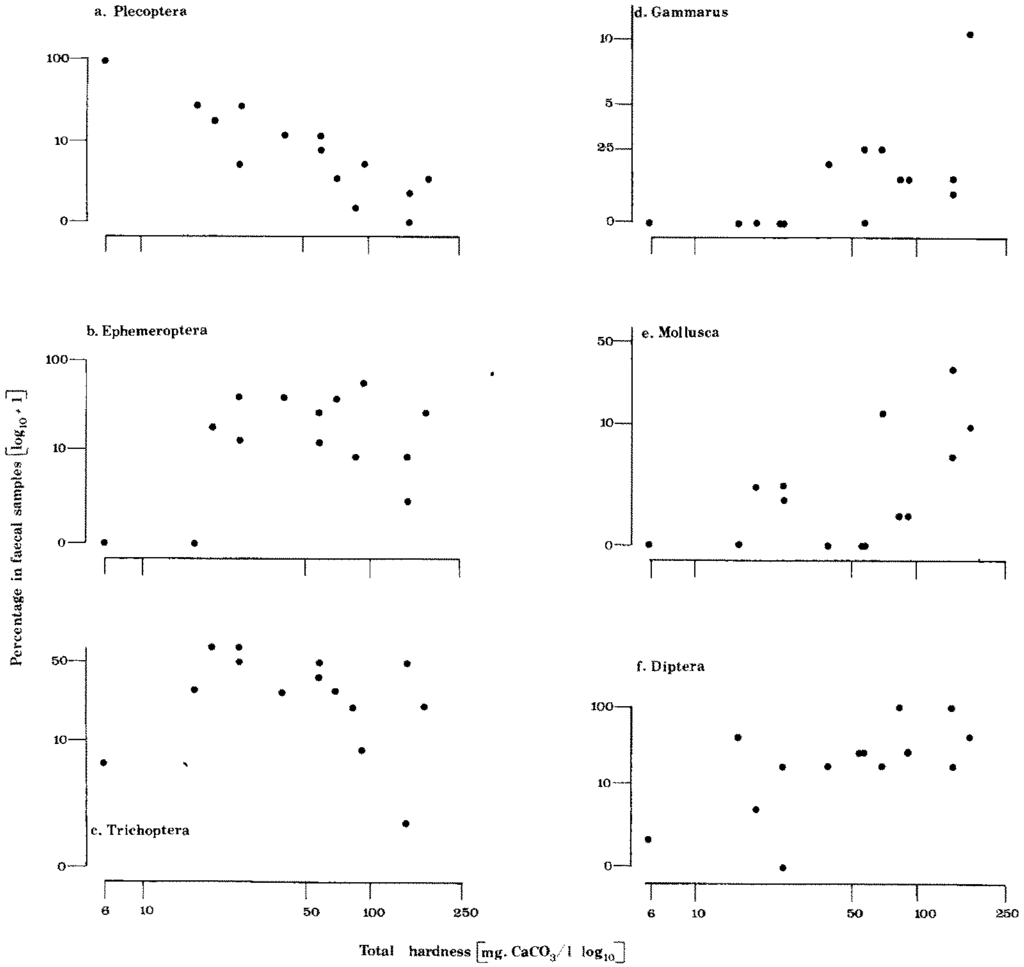

Figure 2. The percentage contributions by various prey to Dipper faecal samples at 14 sites in the Wye catchment in relation to total hardness during winter. Contributions by Plecoptera (Spearman's rho = −0.857, $P < 0.01$), *Gammarus* (rho = 0.673, $P < 0.01$), molluscs (rho = 0.562, $P < 0.05$) and dipteran larvae (rho = 0.566, $P < 0.05$) all correlated significantly with total hardness.

DISCUSSION

Only two studies have previously provided data on the diet of European Dippers in winter. Jost (1975a,b) analysed 330 regurgitated pellets collected from the upper Fulda (central Germany) between September and March (1965–69); 90% consisted mostly of *Gammarus* remains whilst the rest contained mostly trichopteran larvae. Despite a rich and diverse macroinvertebrate fauna in the streams concerned, only a small range of prey was identified (*Gammarus*, trichopterans, coleopterans, gastropods and fish) and Jost (1975a) noted difficulties in identifying items which were fragmented. In Hungary, Vollnhofer (1906) examined the guts of 145 Dippers collected between September and February; 264 items were recorded of which 50% were trichopteran larvae, 25% were *Gammarus* and 11% were plecopteran nymphs. However, such a small number of items from so many guts (cf. Thut 1970 on *C. mexicanus*) indicates that only large and whole prey were identified. Published information on the diet of other *Cinclus* spp. is also scarce (e.g. Thut 1970).

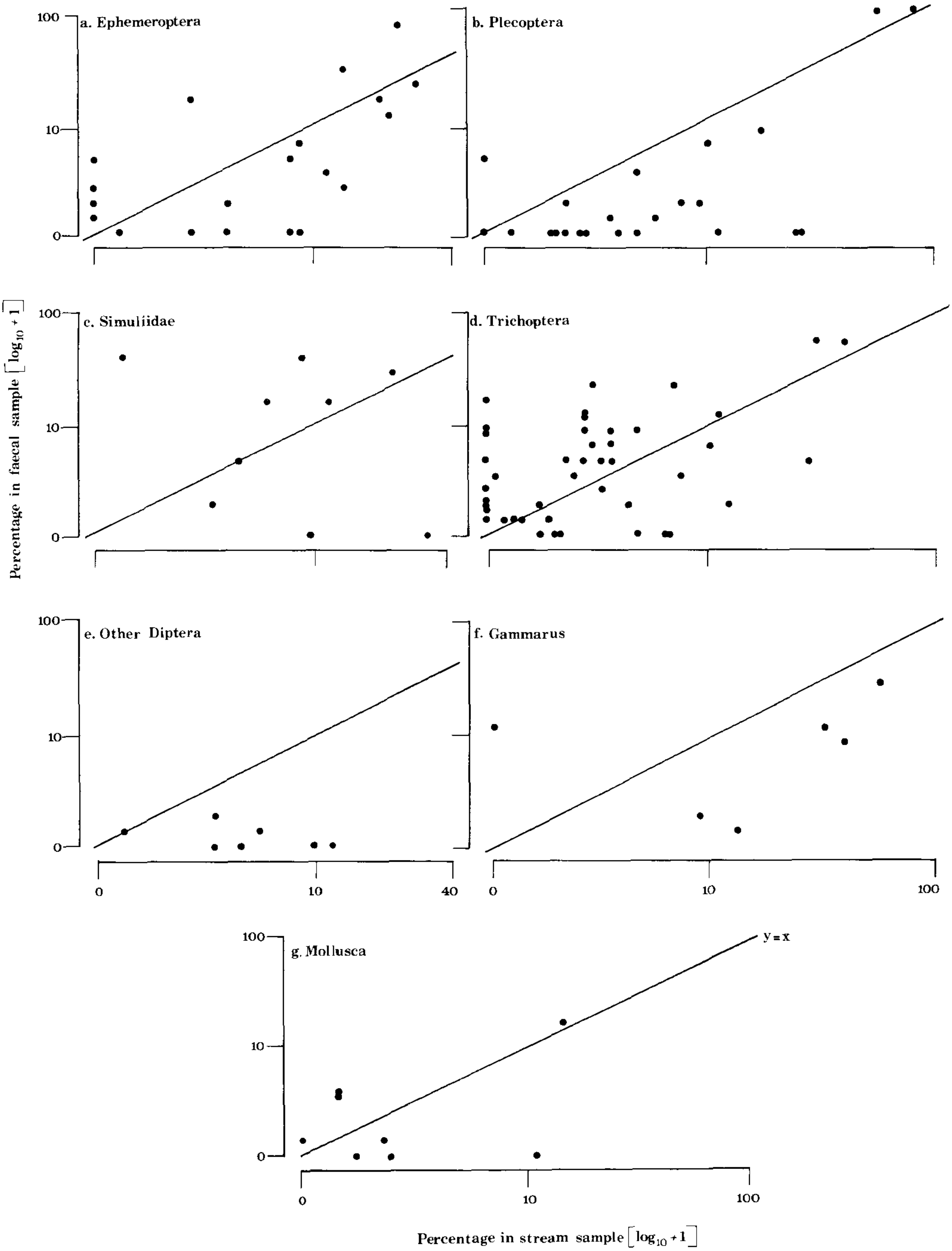

Figure 3. The percentage contributions by various taxa to faecal and stream samples at nine sites in the Wye catchment during winter. Each point represents a particular family at a particular site. The diagonal indicates $y = x$ and represents a line of no selection. Contributions by Plecoptera (w-s test, $T = 54$, $n = 23$, $P < 0.01$), other Diptera (w-s test, $T = 1$, $n = 7$, $P < 0.05$) and Trichoptera (w-s test, $T = 304.5$, $n = 44$, $2 = -2.275$, $P < 0.01$) all deviated significantly from the diagonal.

Table 6. The dry weights of prey in stream samples and in the diet of Dippers wintering in the Wye catchment

	Dry weight (mg)			
Family	*In stream sample*	*In faeces*	t	P
Leuctridae/Nemouridae	0.54 (0.38–0.76; 35)	0.82 (0.59–1.15; 21)	1.40	0.08
Baetidae	0.86 (0.74–1.01; 86)	0.81 (0.68–0.96; 103)	−0.46	0.64
Hydropsychidae	1.42 (1.16–1.73; 66)	2.43 (1.76–3.35; 27)	2.85	0.006
Simuliidae	0.51 (0.44–0.60; 53)	0.46 (0.42–0.51; 94)	−1.01	0.32

Weights of items in the faeces were estimated from mandibular dimensions (see text and Table 3). Values shown are geometric means, with 95% confidence limits and sample sizes in parentheses. (The limits are asymmetric because the means are geometric). *t* is Student's *t* for the difference between two means, calculated on log-transformed data. *P* is the corresponding probability.

Fish provided the dominant component of the diet by weight and, as in the upper Fulda (Jost 1975b), those most frequently taken in the Wye were Bullheads. They are present in tributaries of the Wye at densities of 0.25–2.3 per square metre (Edwards & Brooker 1982), are more benthic and less mobile than salmonids (Mills & Mann 1983) and are probably more easily caught by Dippers.

Although simuliid larva were present in the upper Wye during spring and summer at densities over 10,000 per square metre (Scullion *et al.* 1982), they provided less than 2.5% of the items eaten by breeding adult and nestling Dippers (Ormerod 1985a,b; Ormerod & Perry 1986). By contrast, simuliid larvae were numerically dominant in the winter faecal samples (33%, Table 4). Simuliid larvae have a markedly patchy distribution and form dense mats on the upper surfaces of some stones within riffles (Armitage 1976; Scullion *et al.* 1982). It is possible that Dippers can profitably use such patches during winter, when spates and accompanying turbidity prevent foraging on other benthic macroinvertebrates. However, the winter diet generally reflected the range of prey available and there was little or no evidence of significant prey selection (Fig. 3, Table 5). This contrasts markedly with Dippers foraging for nestlings when active prey selection is apparent and correlates strongly with prey weight (Ormerod 1985a,b). Apparent variation in selection between sites (Fig. 3, Table 5), particularly pronounced for simuliids (Fig. 3), may merely reflect random or opportunistic use of prey patches. Such opportunism may have considerable advantages to a species feeding in a changeable and heterogeneous environment where events such as spates can influence feeding behaviour (Da Prato 1981).

The apparent size-selection of larval Hydropsychidae was probably also determined by microdistribution and availability rather than active choice. Hydropsychids in Welsh rivers exhibit a marked bimodality between species in weight and instar development during winter: the smallest individuals (*Hydropsyche instabilis, H. siltalai*) occur in smaller interstices and in faster currents than larger ones (*H. pellucidula*) (Hildrew & Edington 1979).

Differences in diet in relation to water hardness (see Fig. 2) also reflect differences in the range of prey available: numerically, plecopterans dominate the insect fauna in soft-water acidic streams in the Wye catchment and elswhere, whilst the abundance of *Gammarus* and most molluscs increases with increasing total hardness (Sutcliffe & Carrick 1973; SJO, pers. obs.). Since Dippers occurred along some acidic streams during this study, stream acidity appears less likely to influence their distribution than during the energetically demanding period of breeding (Ormerod *et al.* 1985a, 1986). However, unproductive soft and acidic water may still provide inferior habitat to wintering Dippers. High calcium demands have been noted in other species prior to breeding (Maclean 1974; Jones 1976; Turner 1982) and Dippers feeding on *Gammarus* (which contain 107–124 mg Ca g^{-1} dry weight) and molluscs are less likely to encounter a shortfall in this mineral than when feeding predominantly on plecopterans (1.7–11.3 mg Ca g^{-1} dry weight; Sadler & Lynam 1985). The consequences of calcium scarcity for Dipper productivity are unknown, although birds breeding along calcareous tributaries in the southern Wye catchment are known to lay particularly large clutches (Tyler & Ormerod 1985). Further investigations of breeding performance in relation to stream acidity and calcium concentration are now in progress.

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REFERENCES

Armitage, P.D. (1976) A quantitative study of the invertebrate fauna of the River Tees below Cow Green Reservoir. *Freshwat. Biol.* **6,** 229–240.

Armitage, P.D., Machale, A.M. & Crisp, D. (1974) A survey of stream invertebrates in the Cow Green basin (Upper Teesdale) before inundation. *Freshwat. Biol.* **4,** 369–398.

Cock, M.J.W. (1978) The assessment of preference. *J. Anim. Ecol.* **47,** 805–816.

Edwards, R.W. & Brooker, M.P. (1982) *The Ecology of the Wye.* Junk, The Hague.

Fry, G.L.A. & Cooke, A.S. (1984) Acid deposition and its implications for nature conservation in Britain. *Focus on Nature Conservation, no. 7.* Nature Conservancy Council, Shrewsbury.

Hildrew, A.G. & Edington, J.M. (1979) Factors facilitating the co-existence of hydropsychid caddis larvae in the same river system. *J. Anim. Ecol.* **48,** 557–576.

Jacobs, J. (1974) Quantitative measurement of food selection. A modification of the forage ratio and Ivlev's electivity index. *Oecologia (Berl).* **14,** 413–417.

Jones, P.J. (1976) The utilisation of calcareous grit by laying *Q. quelea. Ibis,* **118,** 575–576.

Jost, O. (1975a) *Zur ökologie der Wassramsel (Cinclus cinclus) mit besonderer berücksictigung ihrer ernährung. Bonner zool. monogr. 6.* Zoologisches Forschungisinstitut und Museum Alexander Koenig, Bonn.

Jost, O. (1975b) Fisch-otolithen in Speiballen der Wasseramsel. *Natur Mus.* **105,** 283–286.

Maclean, S.F. (1974) Lemming bones as source of calcium for Arctic Sandpipers (*Calidris* spp). *Ibis,* **116,** 552–557.

Maitland, P.S. (1972) *A Key to British Freshwater Fishes. F.B.A. Sci. Publ. 27.* Freshwater Biological Association, Ambleside.

Mills, C.A. & Mann, R.H.K. (1983) The Bullhead *Cottus gobio,* a versatile and successful fish. *Ann. Rep. Freshwat. Biol. Ass.* **51,** 76–88.

Ormerod, S.J. (1985a) The diets of breeding Dippers *Cinclus cinclus* and their nestlings in the catchment of the River Wye, mid-Wales; a preliminary study by faecal analysis. *Ibis,* **127,** 316–331.

Ormerod, S.J. (1985b) Optimal foraging by breeding Dippers on a Lancashire hill-stream. *Naturalist,* **110,** 99–103.

Ormerod, S.J., Allinson, N., Hudson, D. & Tyler, S.J. (1986) The distribution of breeding Dippers (*Cinclus cinclus:* Aves) in relation to stream acidity in upland Wales. *Freshwat. Biol.* in press.

Ormerod, S.J. & Perry, K.W. (1986) A note on the diet of breeding Dippers *Cinclus cinclus hibernicus* and their nestlings in north-west Ireland. *Ir. Birds,* in press.

Ormerod, S.J., Tyler, S.J. & Lewis, J.M.S. (1985a) Is the breeding distribution of Dippers influenced by stream acidity? *Bird Study,* **32,** 32–39.

Ormerod, S.J., Boilstone, M.A. & Tyler, S.J. (1985b) Factors influencing the abundance of breeding Dippers *Cinclus cinclus* in the catchment of the River Wye, mid-Wales. *Ibis,* **127,** 332–340.

Prato, S.Da (1981) The effect of spates on the feeding behaviour of Dippers. *Bird Study,* **28,** 60–62.

Sadler, K. & Lynam, S. (1985) The mineral content of some freshwater invertebrates in relation to stream pH and calcium concentration. *TPRD/L/2781/N84.* CERL, Leatherhead.

Scullion, J., Parish, C.A., Morgan, N. & Edwards, R.W. (1982) Comparison of benthic macroinvertebrate fauna and substratum composition in riffles and pools in the impounded River Elan and the unregulated River Wye, mid-Wales. *Freshwat. Biol.* **12,** 579–595.

Siegel, S. (1956) *Nonparametric Statistics for the Behavioural Sciences.* McGraw Hill, New York.

Sokal, R.R. & Rohlf, F.J. (1981) *Biometry,* 2nd ed. Freeman, San Francisco.

Sutcliffe, D.W. & Carrick, T.R. (1973) Studies on mountain streams in the English Lake District. 1. pH, calcium and the distribution of invertebrates in the River Duddon. *Freshwat. Biol.* **3,** 437–462.

Thut, R.N. (1970) Feeding habits of the Dipper in south western Washington. *Condor,* **72,** 234–235.

Turner, A.K. (1982) Timing of laying by swallows (*Hirundo rustica*) and sand martins (*Riparia riparia*). *J. Anim. Ecol.* **51,** 29–46.

Tyler, S.J. & Ormerod, S.J. (1985) Aspects of the breeding biology of Dippers *Cinclus cinclus* in the southern catchment of the River Wye, Wales. *Bird Study,* **32,** 164–169.

UWIST (1978) Non-salmonid fish species in the upper River Wye and its tributaries. *U.W.I.S.T. Craig Goch Rep. No. 24.*

Vollnhofer, P. (1906) Über die fischwirtschaftliche Bedeutung der Wasseramsel (*Cinclus cinclus L.*) *Erdész. Kisérl.* **8,** 1–81.
Weatherley, N.S., Ormerod, S.J. & Boole, P. (1985) A comparison of two sampling methods for macroinvertebrates in small streams. *U.W.I.S.T. Acid Waters Rep. No. 1.*
Webb, J.B. (1974) Otter spraint analysis. *Occ. Pub. Mamm. Soc.* Mammal Society, Reading.

APPENDIX

Jacobs' (1974) index of feeding preference

Called D by Jacobs (1974), this index is given as:

$$D = \frac{Ne/Ne' - N/N'}{Ne/Ne' + N/N'}.$$

The notation follows Cock (1978), in which: Ne is the number of items of prey type 1 eaten, Ne' is the number of items of all other prey types eaten, N is the number of items of prey type 1 available, N' is the number of items of all other prey available.
Values range from -1, indicating avoidance or inaccessibility of prey type 1, to $+1$, indicating active selection of that type.

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ERRATUM

Tyler, S.J. & Ormerod, S.J. (1985) Aspects of the breeding biology of Dippers *Cinclus cinclus* in the southern catchment of the River Wye, Wales. *Bird Study*, **32,** 164–169
The legend to Fig. 4 (page 167) is incorrect. It should read as follows:

Figure 4. Seasonal (a) and annual (b) patterns in clutch (closed symbols) and brood sizes (open symbols) from this study (triangles) and from Shaw (1978; squares). The points joined are means, with vertical lines showing 95% confidence intervals, headed by sample sizes.