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Ornithologie

TROPHIC ECOLOGY OF DIPPERS, *CINCLUS CINCLUS*, IN THE BABOR MOUNTAINS, NORTH-EAST ALGERIA

par

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We studied the diet composition of Dippers (*Cinclus cinclus*) in the Babor Mountains (north-east Algeria). Diet composition was determined from analysis of faecal pellets (n = 90) during April-June of 2010 and 2011. Prey items were classified according to habitat origin (i.e. aquatic or terrestrial prey). The mean size of each prey taxon was determined separately for each faecal pellet for each month. The diet composition was expressed as mean richness and diversity per faecal pellet. The faecal pellets contained indigestible remains of 2049 prey items. Ephemeroptera (e.g. Baetidae: 26.5%) dominated the contents. Aquatic prey were 57.6% more abundant than terrestrial prey. Mean prey species richness, diversity index, and mean prey size calculated for each faecal pellet were not significantly different between months. The proportions of terrestrial prey (e.g. ants) found in the faecal pellets of Dippers in the Babor Mountains were larger than those observed for other populations studied in Europe.

Keywords: Algeria, Babor Mountains, diet, Dipper, faecal pellets.

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Écologie trophique du Cincle plongeur *Cinclus cinclus* dans la région des Babors, Nord-Est Algérien

Nous avons étudié la composition du régime alimentaire du Cincle plongeur *Cinclus cinclus* dans la région des Babors (Nord-Est algérien). Le régime alimentaire du Cincle plongeur est déterminé par l'analyse des fientes (n = 90) et durant la période de reproduction en 2010 et 2011. Les taxons-proies identifiés sont classés selon leurs habitats d'origine (i.e. proies aquatiques ou terrestres). La taille moyenne estimée des proies est définie pour chaque mois. La composition du régime alimentaire est exprimée en richesse et en diversité moyenne par fiente. L'ensemble des fientes analysées contenait 2049 items indigestes. Les Éphéméroptères (notamment les Baetidae = 26,5 %) dominent le contenu des fientes. Les proies d'origine aquatique sont plus abondantes (57,6 %) que les proies terrestres. La richesse moyenne, la diversité et la taille moyenne des proies calculées pour chaque fiente ne présentent pas de différences significatives entre les mois. Les proportions des proies d'origine terrestre (*e.g.* fourmis) trouvées dans les fientes du Cincle plongeur des monts Babor sont plus importantes par rapport aux données notées pour les autres populations étudiées en Europe.

Mots-clés : Algérie, Babors, régime alimentaire, Cincle plongeur, fientes.

Introduction

In North Africa, the Dipper, *Cinclus cinclus,* is known to nest along mountain rivers of Morocco and Algeria (HEIM DE BALSAC & MAYAUD, 1962; THÉVENOT *et al.,* 2003). In Algeria, the nesting area of the Dipper is limited to a few localities in the highest mountains of central-northern Algeria (LEDANT *et al.,* 1981; BOUGAHAM & MOULAÏ, 2014). As noted by TYLER and ORMEROD (1991), the pattern of distribution reflects the relative availability of permanent streams and their associated prey. The diet of this species has been well studied in Europe (ORMEROD & TYLER, 1986; ORMEROD *et al.,* 1987; SANTAMARINA, 1990; JENKINS & ORMEROD, 1996; TAYLOR & O'HALLORAN, 1997; TAYLOR & O'HALLORAN, 2001; HORVÁTH, 2002). Diet composition is known to vary geographically and locally, due to seasonal or weather-dependent changes in prey abundance or availability (ORMEROD & TYLER, 1986; SANTAMARINA, 1990; TYLER & ORMEROD, 1991; TAYLOR & O'HALLORAN, 1997; HORVÁTH, 2002). Other important factors are the biotope structure of the territory, habitat quality, and changes in the species structure of insect communities (ORMEROD, 1985; ORMEROD & TYLER, 1991; TAYLOR & O'HALLORAN, 2001). However, apart from a preliminary study (for the November-December period) on the diet of a Moroccan Dipper population (TYLER & ORMEROD, 1991), no detailed study has been conducted on this species in North Africa.

Studies of the diet of the Dipper have generally been based on the analysis of faecal samples (e.g. ORMEROD & TYLER, 1986; SMITH & ORMEROD, 1986; ORMEROD *et al.,* 1987; SANTAMARINA, 1990; ORMEROD & TYLER, 1991), although a few studies have also analysed regurgitated pellets (e.g. TAYLOR & O'HALLORAN, 1997; HORVÁTH, 2002). The latter studies found that the composition and prey size identified in faeces did not differ from that in regurgitated pellets. TAYLOR and O'HALLORAN (1997) suggested that the diet of the Dipper was best assessed using faecal samples, because they are easier to find than regurgitated pellets.

In this paper, we describe for the first time the composition of prey remains found in faecal pellets of the Dipper in the Babor Mountains (north-east Algeria). We examined and compared richness, diversity, proportion of aquatic and terrestrial prey, and prey size across months from faecal samples. In addition we review the available data for the diet of this species across its breeding distribution range, and explore whether the dietary differences between southern and northern Dipper populations are due to differences in prey preferences between populations or to local differences in prey availability.

Material and methods

Collection and samples analysis

The study was conducted in the Babor Mountains in north-east Algeria, south-east of the town of Bejaia (Figure 1). The climate is continental Mediterranean

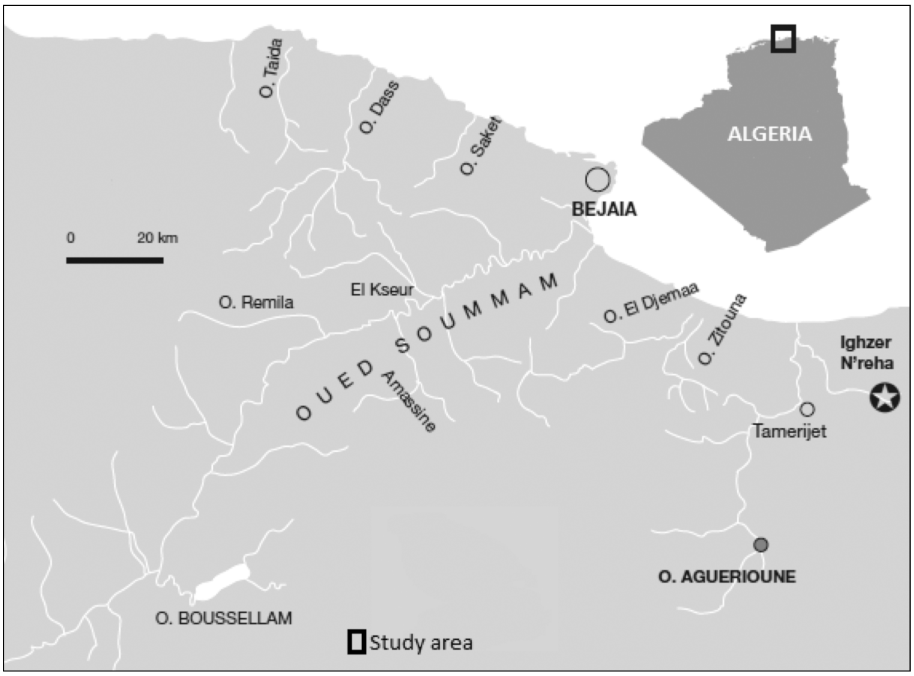

Figure 1
The geographical location of the study site.
Localisation géographique du site d'étude.

(SELTZER, 1946), with wet winters and dry summers. Mean annual rainfall was 940.5 mm during the period 1978-2014. The study site was a stream (Ighzer N'reha; 36°24'27.4'' N, 5°24'25.8'' E) that supported four breeding pairs of Dippers, as described in BOUGAHAM *et al*. (2011, 2014). The local breeding success to fledging during six years was 3.83 chicks fledged per pair (*n* = 6 nests (BOUGAHAM & MOULAÏ, 2016).

During April-June of 2010 and 2011, we collected 15 faecal pellets per month. Fresh faecal pellets were collected on emerged rocks in the immediate surroundings of Dipper nests. Pellets were more easily located during the breeding period, because adults showed restricted activity around the nest. The faecal samples were preserved in ethanol (70%) in labelled Eppendorf tubes. Faecal pellets analysis followed the methods used by BOUGAHAM *et al.,* 2014) in their study of the diet of the Grey Wagtail, *Motacilla cinerea*. The identification method of prey taxa fragments (e.g. mandibles, elytra, pronota, heads, etc.) has been described more fully elsewhere (AÏT HABIB & BOUDJEMAÂ, 2013) and was performed using a range of guides (ZAHRADNIK, 1988; TACHET *et al.,* 2000; BOUCHARD, 2004; GREENHALGH & OVENDEN, 2009). Prey taxa were counted and their total sizes (length of body) were determined using a graph paper scale and/or a range of identification guides (TACHET *et al.,* 2000; GREENHALGH & OVENDEN, 2009).

Diet composition

Data on Dipper diet were converted to numeric frequency (%N, percentage of items belonging to each prey-taxon relative to the total of prey) and frequency of occurrence (%O, the percentage of faecal pellets in which each prey-taxon occurred). For each month (two years combined), the diet composition was expressed in terms of mean richness and diversity (H', SHANNON-WEAVER, 1949) per faecal pellet. Prey was classified according to its habitat use: aquatic prey (A) and terrestrial prey (T). For example, larvae of Ephemeroptera, Trichoptera, Plecoptera and Anisoptera were deemed to originate from aquatic foraging habitat. In contrast, winged adults of Zygoptera, Carabidae, Staphylinidae and Chrysomelidae were classified as prey originating from the terrestrial foraging habitat (BOUGAHAM *et al.,* 2014). The mean (± s.d.) number of individuals of each prey-taxon category (A/T) per faecal pellet was calculated for each month (Table 2). The mean (± s.d.) size of each prey-taxon was determined separately for each faecal pellet and for each month (combined for the two years).

Analysis of data

Data were normalized where necessary using log-transformation (richness of faecal pellets, number of each prey-taxon category and their sizes). We tested the differences across months (two years combined) using one-way ANOVA (for richness, diversity and prey-taxon size) or two-way ANOVA (for mean number of each prey-taxon category of faecal pellet). The comparison between the proportion of aquatic and terrestrial prey-taxa (see Appendix 1) found in the faeces (2010 versus

Diet of the Dipper in Algeria

Appendix 1

Diet composition of the Dipper in Babor Mountains (Algeria) in 2010 and 2011.
Composition du régime alimentaire du Cincle plongeur dans les Babors (Algérie) en 2010 et 2011.
Abréviations : (**A**) Aquatic prey ; (**T**) Terrestrial prey.

Prey-data	**Faecal 2010**	**Faecal 2011**	**Prey-data**	**Faecal 2010**	**Faecal 2011**
Araneae sp.1	T	T	Colymbetinae sp.2	-	A
Araneae sp.2	T	T	Hydroporinae sp.	-	A
Araneae sp.3	T	T	*Hygrochus* sp.	A	A
Araneae sp.4	T	T	Hydrophilidae sp.1	A	A
Araneae sp.5	T	T	Hydrophilidae sp.2	A	A
Hydrachna sp.	-	A	Hydrophilidae sp.3	A	A
Acari sp.	-	A	Hydrophilidae sp.4	A	A
Amphipoda sp.	A	A	Hydrophilidae sp.5	A	-
Potamon sp.	A	A	*Hydrochus* sp.	A	A
Julidae sp.1	-	T	Staphylinidae sp.	T	-
Julidae sp.2	-	T	Omaliinae sp.1	T	T
Potamanthus sp.	A	-	Omaliinae sp.2	T	T
Baetidae sp.1	A	A	Omaliinae sp.3	T	T
Baetidae sp.2	A	A	Oxythelinae sp.1	T	T
Baetidae sp.3	A	A	Oxythelinae sp.2	T	-
Leptophlibiidae sp.	A	-	Oxythelinae sp.3	T	-
Heptageniidae sp.	-	A	*Onthophagus* sp.	T	-
Zygoptera sp.	A	-	Elmidae sp.1	-	T
Anisoptera sp.	A	A	Elmidae sp.2	-	T
Cordulegaster sp.	A	A	Chrysomelidae sp.1	T	-
Plecoptera sp.1	A	A	Chrysomelidae sp.2	T	T
Plecoptera sp.2	A	A	Curculionidaesp.	T	T
Plecoptera sp.3	A	-	*Anthonomus* sp.	T	-
Plecoptera sp.4	A	-	Haliplidae sp.	A	A
Perlodidae sp.	A	A	*Haliplus* sp.1	A	A
Perloïdea sp.	A	A	Hydraenidae sp.	-	A
Protonemura sp.	A	-	*Aphaenogaster testaceo-pilosa*	T	T
Nemouridae sp.	A	A	*Camponotus* sp.1	T	T
Orthoptera sp.	-	T	*Camponotus* sp.2	T	-
Plea sp.1	T	-	*Tapinoma nigerimum*	-	T
Plea sp.2	T	-	*Plagiolepis barbara*	-	T
Veliidae sp.1	A	A	*Crematogaster scutellaris*	-	T
Veliidae sp.2	-	A	*Tetramourium biskrensis*	T	T
Gerridae .sp	-	A	*Cataglyphis bicolor*	-	T
Corixidae sp.	-	A	Ichneumonidae sp.1	T	-
Carabidae sp.1	T	T	Chalcidae sp.	T	-
Carabidae sp.2	T	-	Trichoptera sp.	A	A
Carabidae sp.3	T	-	Leptoceridae sp.	-	A
Carabinae sp.	T	T	Odontoceridae sp.	A	A
Pterostichinae sp	-	T	Philopotamidae sp.1	A	A
Harpalinae sp.1	T	T	Philopotamidae sp.2	A	A
Dytiscidae sp.1	A	A	Philopotamidae sp.3	-	A
Dytiscidae sp.2	-	A	Brachycera sp.1	T	T
Dytiscidae sp.3	-	A	Brachycera sp.2	-	T
Agabus sp.	-	A	Brachycera sp.3	-	-
Dytiscinae sp.	A	A	Sciaridae sp.	A	-
Dytiscus sp.1	A	A	Stratiomyidae sp.	-	A
Dytiscus sp.2	A	-	Ceratopogonidae sp.	-	A
Colymbetes fuscus	-	A	Simuliidae sp.	A	-
Colymbetinae sp.1	-	A	-	-	-

Total Richness : 99 ; A/T faecal 2010 : 38/31 ; A/T faecal 2011 : 46/29.

Table 1

Dipper diet composition in the Babor Mountains.
n: sample size , **%N**: numeric frequency, **%O**: occurrence frequency.

Composition du régime alimentaire du Cincle plongeur dans les Babors.
***n** : taille de l'échantillon, **N%** : fréquence centésimale, **O%** : fréquence d'occurrence.*

			Faecal 2010 n = 45		**Faecal 2011** n = 45	
	Prey-taxa categories		**%N**	**%O**	**%N**	**%O**
Arachnida	Araneae	*	1.2	20	0	0
	Acarina	*	0	0	0.1	2.2
		Hydrachnidia	0	0	0.1	2.2
Crustacea	Amphipoda	*	0.2	4.4	0.1	2.2
	Decapoda	Potamidae	0.4	8.9	2.2	42.2
Diplopoda	Julida	Julidae	0	0	1.1	26.7
Insecta	Ephemeroptera	Potamanthidae	0.1	2.2	0	0
		Baetidae	37.4	91.1	17.2	86.7
		Heptageniidae	0	0	2.3	33.3
		Leptophlebiidae	5.2	53.3	0	0
	Odonata	*	0.3	6.7	0.1	2.2
		Cordulegasteridae	6.2	53.3	2.5	46.7
	Plecoptera	*	9.8	80	3.9	73.3
		Perlodidae	0.3	6.7	0.3	6.7
		Nemouridae	0.6	13.7	0.5	4.4
	Orthoptera	*	0	0	0.1	2.2
	Hemiptera	Pleidae	0.4	6.7	0	0
		Veliidae	0.1	2.2	0.4	8.9
		Gerridae	0	0	2.2	13.3
		Corixidae	0	0	0.2	4.4
	Coleoptera	Carabidae	0.7	20	0.7	22.2
		Dytiscidae	2.2	33.3	2.8	46.7
		Hydrophilidae	5.4	71.1	6.2	68.9
		Staphylinidae	1.2	20	8	26.7
		Elmidae	0	0	0.3	6.7
		Scarabidae	0.2	4.4	0	0
		Chrysomelidae	0.3	6.7	0.1	2.2
		Curculionidae	0.5	11.1	0.7	8.9
		Haliplidae	0.8	13.3	0.5	8.9
		Hydraenidae	0	0	0.1	2.2
	Hymenoptera	Formicidae	6.6	28.9	7.8	44.4
		Chalcididae	0.1	2.2	0	0
		Ichneumonidae	0.1	2.2	0	0
	Trichoptera	*	2.5	22.2	0.2	4.4
		Leptoceridae	0	0	0.1	2.2
		Odontoceridae	3	31.1	3	15.5
		Philopotamidae	11.1	80	27.4	88.9
	Diptera	*	0.1	2.2	1.3	13.3
		Sciaridae	0.1	2.2	0	0
		Stratiomyidae	0	0	0.4	8.9
		Ceratopogonidae	0	0	2.2	15.5
		Simuliidae	0.3	6.7	0	0

Number of class	4	Individuals number in 2010	941
Number of order	14	Individuals number in 2011	1108
Number of family	34	(*): identification effort only carried out to order level.	

2011) was made using a Chi-square test (χ^2). A non-parametric WILCOXON test (W) was used to test whether there were significant differences between abundances of prey-classes, prey-orders, and prey-families.

Results

A total of 99 prey-taxa were identified from 90 faecal pellets (Appendix 1). They were represented by 2,049 individual prey items; 941 in 45 faecal pellets for 2010 and 1,108 in 45 faecal pellets for 2011 (Table 1). Insects were most abundant in all (n=90) faecal pellets (1,992 individuals; χ^2=37.74, d.f.= 3, P=0.0005).

The prey-order abundance varied significantly between all faecal pellets analyzed (two years combined) (W=34, n=15, P=0.05). The diet of Dippers was largely dominated by Ephemeroptera and Trichoptera (Table 1). The families Baetidae and Philopotamidae were most represented (Table 1). The number of prey-taxa per faecal pellet varied between 4 and 18. The medium prey-taxa richness per faecal pellet varied between 9.7 and 10 prey-taxa per month (Table 2) and was not significantly different between months ($F_{2,87}$ =0.045, P> 0.05). The faecal pellet diversity index (H') showed no significant differences between months ($F_{2,87}$ = 0.005, P> 0.05).

The aquatic prey-taxa abundance in faecal pellets was higher than terrestrial prey (Table 2). The mean number of aquatic prey items per faecal pellet varied between 7.3 and 8.5 per month. The maximum mean value of terrestrial prey items was 2.7 and the minimum was 1.5 prey items per month. The number of each prey-taxon category varied significantly between months (two-way ANOVA, prey-taxa category: $F_{1, 174}$ =375.25, P= 0.001; month: $F_{2,174}$ =0.95, P>0.05). A significant correlation was observed between months and prey-taxon categories (month × prey-taxa category: $F_{2, 174}$ = 8.45, P=0.001).

The mean of total size of prey-taxa in faecal pellets varied between 14.2 mm (June) and 16.1 mm (April) and was not significantly different between months (one-way ANOVA, $F_{2, 87}$=2.8, P>0.05; Table 2).

Table 2

Details of the diet composition in Dipper faecal pellets. Values given as mean ± s.d.

Composition détaillée du régime alimentaire du Cincle plongeur.

Les valeurs sont données en moyenne ± s.d.

	Faecal pellets combined: 2010 and 2011		
	April *n* = 30	**May** *n* = 30	**June** *n* = 30
Richness	9.96 ± 3.25	9.73 ± 2.66	10 ± 3.42
Diversity (H')	0.27 ± 0.10	0.26 ± 0.10	0.28 ± 0.16
Number of aquatic prey	8.46 ± 2.30	8.20 ± 0.36	7.30 ± 3.28
Number of terrestrial prey	1.50 ± 1.45	1.50 ± 1.43	2.70 ± 1.78
Prey-taxa size (mm)	16.06 ± 3.31	15.31 ± 3.12	14.18 ± 3.56

Discussion

Ephemeroptera and Trichoptera were the most abundant prey-taxa in the diet of the Dipper in the Babor Mountains. Overall, these results agree with those obtained elsewhere across the distribution of the species in Europe (ORMEROD & TYLER, 1986; ORMEROD et al., 1987), where Dipper diet was dominated by Ephemeroptera. In contrast, SMITH & ORMEROD (1986) noted (in the catchment of the Welsh River Wye) the dominance of Diptera, Trichoptera and Ephemeroptera in the diet of Dippers. In the Babor Mountains, Baetidae were the prey most frequently consumed by Dippers, followed by Philopotamidae and Formicidae (Table 1). An abundance of Baetidae in the diet of the Dipper was also reported by ORMEROD *et al.* (1987) in Wales. Baetidae seem to be more abundant in torrential streams with high flow (ZOUGGAGHE, 2010), like the stream of Ighzer N'reha. Baetidae were probably more available and more easily captured by the Dipper. At the end of the breeding season (July), SMITH & ORMEROD (1986) found that the most abundant prey-families in faecal pellets of the Dipper in Wales were Simuliidae and Baetidae. In Morocco, the analysis of faecal pellets collected in winter (November-December) showed that Hydropsychidae and Baetidae were the most common prey of *Cinclus cinclus minor* (TYLER & ORMEROD, 1991). In Ireland, Ephemerellidae, Simuliidae and Hydropsychidae were the most consumed prey of the Dipper (TAYLOR & O'HALLORAN, 1997).

The faecal pellets obtained in the present study showed a higher richness of aquatic prey-taxa (principal prey) compared to terrestrial prey-taxa. Overall, the consumption of prey types was variable, being linked to their relative abundance or to habitat conditions (ORMEROD *et al.,* 1985b; ORMEROD & TYLER, 1991; TAYLOR & O'HALLORAN, 2001). In Europe, aquatic prey were the only food for most of the northern Dipper populations (ORMEROD & TYLER, 1986; ORMEROD *et al.,* 1987; JENKINS & ORMEROD, 1996; TAYLOR & O'HALLORAN, 1997), and the proportion of terrestrial prey (e.g. in Spain) increased as latitude decreased (ANTAMARINA, 1990), whereas for Dipper in the Babor Mountains, terrestrial prey was better represented in the diet (41.66%). The increased importance of terrestrial prey in the diet is probably related to the high abundance of these prey categories at the end of the breeding season and the reduced energy required to capture them. Some authors (ORMEROD & TYLER, 1986; ORMEROD *et al.,* 1987; JENKINS & ORMEROD, 1996; TAYLOR & O'HALLORAN, 1997) have probably under-estimated the importance of terrestrial prey in the diet. The lack of principal food resources (aquatic prey) later in the breeding season may force the Dipper to move away from the stream to search for alternate food, such as ants (CRAMP, 1988). During the Dipper's breeding period, ants become important in the diet of the Dipper in the Babor Mountains (6.6% in 2010, 7.8% in 2011). Northern latitudes in the range of the Dipper, with cooler temperatures and earlier snow during the breeding period, may lead to a reduction in the availability of terrestrial prey; however, when available, they are readily captured. Our results agree with those observed in Wales (ORMEROD & TYLER, 1986), where the diet of the Dipper was based on aquatic invertebrates and supplemented by alternative resources both in time and space (e.g. terrestrial prey), which can allow better survival rates with reduced energy expense, even in unfavourable and very low flow hydro-climatic conditions.

There was no significant variation in prey size between the three months sampled. Overall, Dippers in the Babor Mountains eject in faecal pellets the remains of prey that have a median size of 15 mm. This could be due to a large predominance of Baetidae and Philopotamidae. These prey items are generally aquatic insects with large size (e.g. Baetidae sp.1 = 20 mm and Philopotamidae sp.2 = 20 mm) and were well represented by individuals in faecal pellets. The number of Baetidae (Ephemeroptera) increase during early spring to become the most abundant prey in the stream. These prey do not have a high caloric value and lack key nutrients, such as calcium for egg laying, although their relative abundance is likely to allow rapid energy gain per unit foraging effort (MORRISSEY *et al.,* 2010). We supposed that consumption of Philopotamidae (Trichoptera) would be more profitable in terms of biomass acquired. Trichopteran larvae may be an essential food source for Dippers, especially for nestlings, and their importance increased up to day 15 after hatching (ORMEROD, 1985).

The dietary composition of the Dipper in the Babor Mountains was characterized by a lower proportion of terrestrial prey and by the higher proportions of aquatic prey. With respect to the data from northern populations of the Dipper in Europe, there are differences in the importance of particular prey-taxa in the diet. Some of these differences have a natural character (e.g. geographical location, habitat quality), whilst others may result simply as an adaptation (e.g. hunting strategies) to a more arid distribution. Further studies are needed to explore the foraging ecology of the Dipper across seasons and localities, as well as to understand the importance of these scarce habitats for Dippers.

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