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Diet of the nominate Southern Grey Shrike *Lanius meridionalis meridionalis* in the north of its range (Mediterranean France)

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Capsule In this region the diet is mainly cold-blooded prey, mostly insects such as beetles.
Aims To describe the diet of this newly separated, poorly documented and endangered species.
Method Diet was inferred from pellet analysis, collected during a single breeding and winter period in the steppe of the Crau.
Results A total of 5409 prey were identified from 257 pellets. Vertebrates were seldom taken, except by adults (small passerines) during the fledgling period. High seasonal differences were found. Hymenoptera were largely consumed in autumn, Arachnida in autumn and winter, Orthoptera in summer and autumn and Lepidoptera larvae in winter and spring and by fledglings. Nevertheless, Coleoptera were ingested in large proportions all year round. Carabidae were the main prey in winter and Melolonthidae were especially important for adults during the nestling period, as were Cetoniidae for the fledglings.
Conclusion Small mammals and small birds were less exploited in France and Spain (*L. m. meridionalis*) than in Israel (*L. m. elegans* or *L. m. aucheri*), whereas the opposite might be expected, following a north–south climatic gradient. Thus, the nominate subspecies *L. m. meridionalis* differed in diet from *L. m. elegans* or *L. m. aucheri*.

The Southern Grey Shrike *Lanius meridionalis* has been recently recognized as a distinct species from the Great Grey Shrike *Lanius excubitor* (Snow & Perrins 1998). Unlike the Great Grey Shrike, little is known about its ecology and the published information comes from only two main study areas, one in Spain (*Lanius meridionalis meridionalis*) and the other in the Negev' desert in Israel (*Lanius meridionalis elegans* or *Lanius meridionalis aucheri*; see Lefranc & Worfolk 1997 for notes on taxonomy). The main studies were reproductive biology (Yosef 1992, Hernández 1993a) and diet and feeding ecology (Yosef *et al.* 1991, Hernández 1993b, Hernández *et al.* 1993, Budden & Wright 2000). The largest population of the nominate *L. m. meridionalis*, in the Iberian Peninsula, is considered to be decreasing (Tucker & Heath 1994). Generally, the decline of shrikes in the Holarctic is associated with intensive agricultural practices (Lefranc & Worfolk 1997, Yosef *et al.* 2000): use of pesticides, loss of prey, habitat loss or loss of extensive grazing.

We describe the diet of the nominate *Lanius meridionalis meridionalis*, a protected and endangered species, in the north of its range, and assess the proportions of cold-blooded and warm-blooded prey. The hypotheses tested were (i) that the diet of *L. m. meridionalis* in the Crau consists mainly of cold-blooded prey, as in other Southern Grey Shrike populations, and (ii) that the proportion of warm-blooded prey in the diet (expected to be small) is comparable to that in the diet of the nominate subspecies in Spain and the other subspecies (*L. m. elegans/aucheri*) in Israel.

MATERIAL AND METHODS

Study area

The study area (1200 ha), located near the Camargue (southern France: 43°29′–43°33′N, 4°48′–4°52′W), is on

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the western edge of the Crau, an area of steppe with scattered bushes (11 500 ha), described by Cheylan (1975), Devaux *et al.* (1983) and Lepley *et al.* (2000). During the study period (September 1994 to August 1995), data were collected from 12 pairs, of which only the males appeared to be residents (Newton & Lepley unpubl. data).

Pellets and caches

Diet was quantified by examining regurgitated pellets. Caches of impaled prey were sought during all pellet searches and bird observations throughout the study area. Adult pellets were usually found under territorial posts (bushes), but in January and February the shrikes were so mobile that each territory had to be scanned for regurgitating birds, using a 30 × 60 telescope. Pellets from three fledged broods were also collected beneath the perches used by the chicks.

A total of 257 pellets was collected. Prey items were identified using reference collections of chitinous organs (invertebrates) and bones (vertebrates). Prey numbers were transformed into wet, rather than dry biomass, because water is important in this hot and dry habitat. Wet biomass of invertebrates was estimated in the field with a precise balance, and vertebrate biomass was estimated from the literature (Saint Girons 1973, Géroudet 1980, 1984).

Statistical analysis

To assess the quality of the pellet sampling, we used the EstimateS software (Colwell 1997) and considered the Michaelis–Menten richness estimator (Raaijmakers 1987).[a] We performed 50 and 100 randomizations and checked several initial 'seeds' for the random number generator.

The main taxa eaten by the shrikes were examined using Canonical Correspondence Analysis (Lebreton *et al.* 1990). A second analysis was undertaken for the most important families of predominant Coleoptera. Data were expressed from estimated wet biomass per taxon per pellet. Interpretations were made according to Prodon & Lebreton (1994) with the use of descriptive variables, i.e. date (months) and age (adults or fledglings). The annual cycle of the shrikes was subdivided in four 'seasons' defined following the two first axes of the first canonical correspondence analysis (Fig. 1). Summer was defined as the period from June to August (i.e. fledgling period), autumn from September to November, winter from December to April and the month of May as spring (i.e. nestling period).

χ^2 tests were used to test for differences in diet between seasons and between ages (Scherrer 1984), considering the main group of prey. To interpret the significant difference between ages we performed backward eliminations, i.e. each group of prey was successively removed from the analysis to identify which had caused the difference.

RESULTS

Caches

In the steppe of the Crau, the nominate subspecies

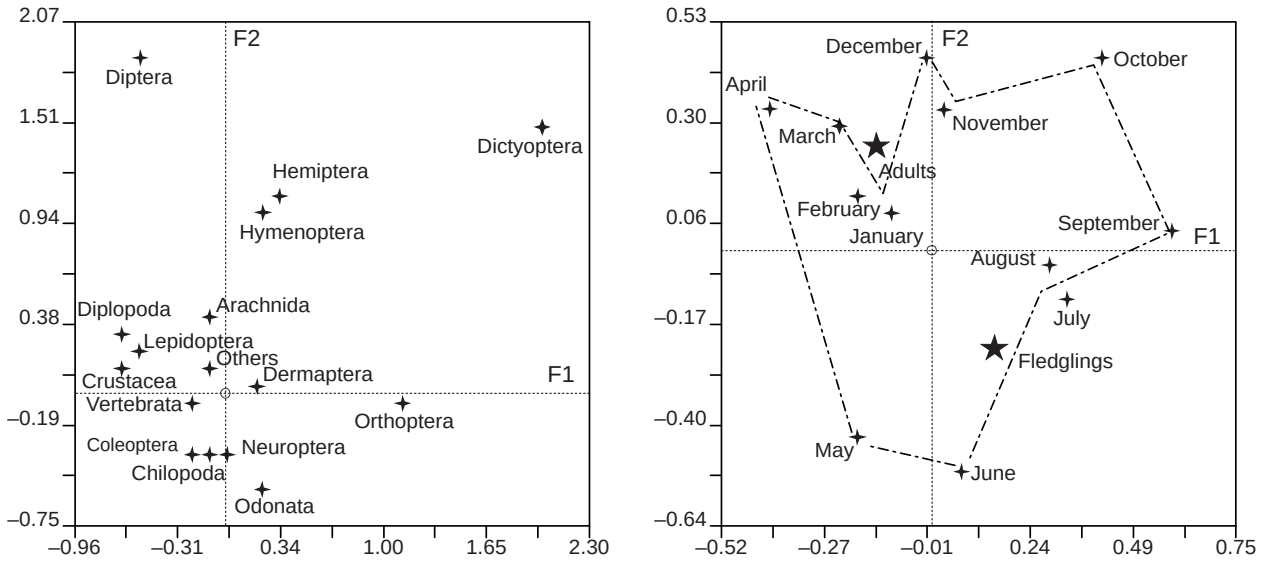

Figure 1. Canonical Correspondence Analysis (CCA) of the Southern Grey Shrike diet in the Crau.

meridionalis rarely impaled its prey. Despite systematic searching, only six caches were found, containing a total of 29 impaled prey: one Arachnida, one Scolopendra, three Orthoptera and 24 Hymenoptera.

Pellets

A total of 70 pellets were collected in spring, 69 in summer, 51 in autumn and 67 in winter; 5409 prey were identified (1433 g wet biomass); 71 species (mainly beetles, locusts and grasshoppers, see Appendix) were counted among a total of 108 identified taxa. According to the Michaelis–Menten method, sampling could be assumed to be complete as the total estimated richness (106) was lower than the currently observed richness (108).

Diet: seasonal and age variations

The main prey of the Southern Grey Shrike in the steppe of the Crau is insects, with Coleoptera, Lepidoptera larvae, Orthoptera, Arachnida and Hymenoptera in decreasing importance (Table 1). Vertebrates, such as small lizards or small mammals were rarely found, but a few small passerines were eaten in June. The biomass ingested differed significantly between adults and fledglings (χ^2 = 29.063, df = 6, $P < 0.001$), because of the consumption of vertebrates by adults. Diet also differed markedly between seasons (χ^2 = 411.114, df = 18, $P < 0.001$). The results of the Canonical Correspondence Analyses, considering F1/F2 axis, show that seasons and age explained 64% of the variance in the composition of the overall diet, and 77% considering only Coleoptera. Hymenoptera were mostly consumed in autumn, Arachnida in autumn and winter, Orthoptera in summer and autumn and Lepidoptera larvae in winter, spring and by fledglings (Fig. 1). A large proportion of Coleoptera was taken all year round, especially Carabidae in the cold period. Figure 2 shows that Melolonthidae were distinctively associated with the adults' diet during the nestling period (May), and that Cetoniidae were particularly important for fledglings (June).

Table 1. Overview of the diet of *Lanius meridionalis meridionalis* in the Crau, southern France, 1994–95, determined from pellet analysis.

			Summer							
	Spring		Adult		Fledgling		Autumn		Winter	
Prey	np (%)	wb (%)	np (%)	wb (%)	np (%)	wb (%)	np (%)	wb (%)	np (%)	wb (%)
Arachnida	10.2	8.4	10.2	7.3	11.1	6.1	5.6	13.4	16.4	15.2
Crustacea	1.5	1.3	–	–	–	–	–	–	2.7	1.8
Chilopoda	–	3.7	1.1	4.8	2.0	8.1	–	–	–	2.7
Odonata	1.6	4.3	1.4	1.9	2.0	2.3	1.5	1.6	–	–
Orthoptera	–	4.6	19.0	16.4	22.2	21.6	26.3	36.1	1.1	1.3
Dermaptera	–	–	3.1	–	4.2	1.0	1.6	–	1.7	–
Dictyoptera	–	–	–	–	–	–	2.0	3.1	–	–
Hemiptera	–	–	–	–	–	–	1.0	–	–	–
Coleoptera	74.7	48.9	43.8	24.1	47.5	32.9	26.2	13.2	51.8	20.8
Neuroptera	–	–	–	–	1.5	–	–	–	–	–
Hymenoptera	4.3	1.4	6.8	1.3	2.7	2.4	24.6	13.1	15.2	6.8
Lepidoptera	5.2	14.6	4.2	8.4	5.7	11.8	1.4	4.8	8.7	30.8
Mammalia	–	10.3	–	6.8	–	–	–	11.9	–	4.5
Aves	–	–	–	24.7	–	11.2	–	–	–	11.8
Reptilia	–	–	–	–	–	1.9	–	1.3	–	1.1
Amphibia	–	2.1	–	2.4	–	–	–	–	–	1.1
Others	2.5	0.4	10.4	1.9	1.1	0.7	9.8	1.5	2.4	2.1
Number of pellets	46		69		24		51		67	
Total number of prey	1087		1345		406		990		1581	
Total wet biomass (g)	244.05		417.63		133.82		196.51		440.91	

np (%), proportion from number of prey; wb (%),proportion from estimated wet biomass; –, values less than 1%, which were accumulated with 'others'.

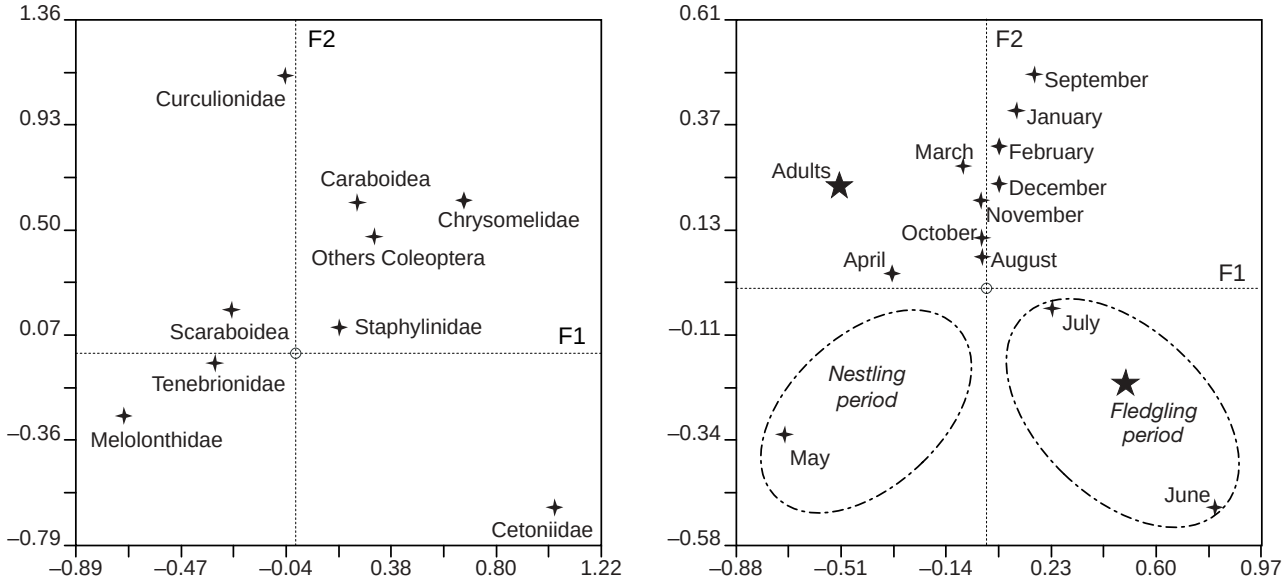

Figure 2. Canonical Correspondence Analysis (CCA) of beetles found in the diet of the Southern Grey Shrike in the Crau.

DISCUSSION

Seasonal and age differences in the diet

In the steppe of the Crau, Southern Grey Shrike mainly relied on invertebrates, especially Coleoptera for food. Two periods of the breeding season, the nestling period (May) and the fledgling period (June), were clearly dissociated from each other and from the non-breeding periods of the year on the basis of Coleoptera use, with a very high consumption of Melolonthidae and Cetoniidae, respectively. The Melolonthidae *Amphimallon ruficorne* accounted for 29% (wet biomass) of the adults' diet during the nestling period. Similarly, breeding Lesser Grey Shrike *Lanius minor* often use large numbers of a closely related Melolonthidae (*Melolontha melolontha*; see Kristín & Zilinec 1998). This last species has a high protein content (27%; Juillard 1984) compared with other small animals, such as rodents and small birds (average 19%; Juillard 1984), which may explain its importance.

In order to assess whether protein content was the basis of prey choice by the Southern Grey Shrike in the Crau, three potential prey species (*Amphimallon ruficorne*, *Netocia oblonga/morio* and *Omophlus lepturoides*) were collected and their protein content estimated (through the measurement of total nitrogen rate using a LECO FP248 instrument) at the CIRAD-AMIS laboratory in Montpellier. The most abundantly consumed *Amphimallon ruficorne* had the lowest protein level of the three insects (19.9%, 28.1% and 24.9% respectively), suggesting that protein content was not the basis for prey choice in this case.

A further indication that protein content is not necessarily a primary criterion in prey choice, comes from the absence of *O. lepturoides* in the diet. It is very unlikely that the lack of this very common insect in the diet of Southern Grey Shrike is due to a chemical repulsive effect (see Yosef *et al.* 1996), since this insect is known to be used by Lesser Grey Shrike in the Languedoc (Lepley *et al.* unpubl. data). This question remains unresolved. During the fledgling period, however, *Netocia oblonga* and *N. morio* (Cetoniidae) were caught in high proportion. Considering their high protein level, it suggests that they are probably important for the growth of the young (see Carey 1996).

Diet differences between species and subspecies

Feeding ecology, including diet, has been used as a criterion for species differentiation among 'Grey Shrikes' (Schön 1998). The Southern Grey Shrike (*Lanius meridionalis*) relies on cold-blooded prey in hot weather, whereas the Great Grey Shrike (*Lanius excubitor*) mainly relies on warm-blooded prey in cold weather. The diet of the 'Grey Shrike' of the Crau is typical of that of the Southern Grey Shrike, since cold-blooded prey (especially Coleoptera) form the greater part of its diet.

Results from the Crau differ from those from Spain (Hernández 1993b, Hernández *et al.* 1993) and Israel

(Yosef *et al.* 1991, Budden & Wright 2000). Although in all three cases *L. meridionalis* fed mainly on Coleoptera, Lepidoptera, Orthoptera, Arachnida or Hymenoptera, with local and seasonal variations depending on prey availability, differences in the use of warm-blooded prey were observed. During the young period, they were seldom eaten in the Crau (0.97% of prey numbers in adults and 0.50% in young), whereas they were more frequent in Spain (3.32% and 5.87%, see also Hernández 1995a) and even more so in Israel (10.40% and 16.05%). Further, the vertebrate prey were predominantly consumed by adults in the Crau (mainly small passerines) (see Lorek & Tryjanowski 2000), while they were mostly used by young in other studies. Cold-blooded vertebrates, such as small lizards (see Hernández 1995b), were also consumed in higher proportions in other studies. In addition to these differences in diet, difference in feeding behaviour was also apparent, as caches were rarely seen in our study area, while they were more frequently observed in Spain and Israel. It is true that differences in the diet of the nominate subspecies *L. m. meridionalis* (steppe of the Crau; mountains of Cantabria, Spain) could simply be the consequence of different prey availabilities, related perhaps to altitude and temperature. Thus, considering that cold-blooded prey are normally used in increasing proportions along a north–south climatic gradient, and considering diet, on this basis, as a criterion for species differentiation in 'Grey Shrikes' *sensu lato*, then the nominate *meridionalis* could be a different species from the current *elegans* or *aucheri* subspecies. This hypothesis can be also supported by high differences in coloration (Jany 1948) but require genetic investigations for further elucidations.

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ENDNOTE

a. The Michaelis–Menton estimator expresses the relationships between the cumulative number of samples (n) and the cumulative number of species (S). It derives from the Michaelis–Menton equation for enzyme kinetics and was found to perform better than the other estimators (Toti *et al.* 2000).

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APPENDIX

Detailed list of prey of the Southern Grey Shrike from pellets collected in the steppe of the Crau, southern France (1994–95).

Taxa		Mass
Group	Determined	(g)
Arthropoda	Arthropoda undetermined	0.07
Arachnida	*Lycosa narbonensis* Walckenaer	62.27
	Lycosa sp.	71.9
	Araneae undetermined	11.72
	Opiliones undetermined	6.7
Crustacea	*Armadillidium vulgare* Latreille	12.68
Chilopoda	*Scolopendra cingulata* Latreille	51.65
	Chilopoda undetermined	0.17
Hexapoda	Hexapoda undetermined	0.94
Odonata	Anisoptera undetermined	24.65
Ensifera	*Tettigonia viridissima* L.	1.33
	Decticus albifrons (Fabricius)	2.78
	Platycleis sp.	10.04
	Tettigoniidae undetermined	10.8
	Gryllus campestris L.	3.07
	Gryllotalpa gryllotalpa Latreille	16.38
Caelifera	*Calliptamus* sp.	31.38
	Locusta migratoria L.	2.04
	Oedaleus decorus (Germar)	15.38
	Oedipoda caer.(L.)/*charpent.*Fieber	6.14
	Dociostaurus maroccanus (Thunberg)	14.96
	Chorthippus sp	6.26
	Euchorthippus sp.	10.12
	Caelifera undetermined	54.57
Dermaptera	*Euborellia moesta* (Géné)	0.2
	Forficula auricularia L.	7.9
Dictyoptera	*Ameles decolor* (Charpentier)	0.08
	Mantis religiosa (L.)	2.96
	Empusa pennata (Thunberg)	0.74
	Mantidae undetermined	1.9
	Mantodea undetermined	0.66
Hemiptera	*Cicada* sp. larvae	0.24
	Heteroptera undetermined	1.44
Caraboidea	*Cicindela camp.*L./*maroc.*Fabricius	3.43
	Calosoma sycophanta (L.)	7.92
	Carabus coriaceus L.	5.94
	Calathus fuscipes (Goeze)	5.3
	Poecilus koyi (Germar)	12.96
	Zabrus ignavus Csiki	0.78
	Amara aenea (De Geer)	0.02
	Amara eurynota (Panzer)	14.21
	Acinopus picipes (Olivier)	15.12
	Harpalus affinis (Schrank)	0.73
	Harpalus distinguendus (Duftschmid)	0.36
	Harpalus dimidiatus (Rossi)	11.52
	Harpalus sulphuripes Germar	0.12
	Licinus silphoides (Rossi)	2.4
	Lamprias cyanocephala (L.)	0.16
	Cymindis axillaris (Fabricius)	0.06
	Caraboidea undetermined	13.91
Staphylinidae	*Ocypus olens* (Müller)	21.48
	Ocypus ophtalmicus (Scopoli)	3.82
	Ocypus obscuroaeneus (Fairmaire)	2.88
	Staphylinidae undetermined	1.04
Trogidae	*Trox perlatus* (Geoffroy)	0.22
Geotrupidae	Geotrupidae undetermined	0.83
Scarabaeidae	*Onthophagus vacca* (L.)	0.3
	Onthophagus emarginatus Mulsant	1.47
	Scarabaeidae undetermined	2.72
Melolonthidae	*Rhizotrogus marginipes* Mulsant	14.49
	Amphimallon ruficorne (Fabricius)	88.05
	Rhizotrogus/Amphimallon sp. larvae	20
Cetoniidae	*Cetonia aurata* (L.)	6.27
	Netocia oblonga (Gory & P.)/*morio* (Fab.)	59.61
Scarabaeoidea	Scarabaeoidea undetermined	4.41
Melyridae	*Henicopus pilosus* (Scopoli)	0.08
Tenebrionidae	*Asida sericea* (Olivier)	34.8
	Scaurus atratus Fabricius	3.6
	Bioplanes meridionalis Mulsant & Rey	0.07
	Phylan abbreviatus (Olivier)	0.6
	Opatrum cf. *sabulosum* (L.)	0.06
	Tenebrionidae undetermined	0.25
Chrysomelidae	*Chrysolina* cf. *haemoptera* (L.)	0.07
	Chrysolina quadrigemina (Suffrian)	0.03
	Chrysomelidae undetermined	1.11
Brachyceridae	*Brachycerus muricatus* (Fabricius)	1.35
Curculionidae	*Stephanocleonus nigrosuturatus* (Goeze)	0.72
	Pseudocleonus cinereus (Schrank)	0.45
	Hypera zoilus (Scopoli)	0.06
	Curculionidae undetermined	7.89
	Coleoptera undetermined	8.1
Neuroptera	*Palpares libelluloides* (L.) larvae	1
	Neuroptera undetermined larvae	0.58
Hymenoptera	*Prionyx* cf. *subfuscatus* Fabricius	0.22
	Polistes cf. *dominulus* L.	0.15
	Vespa crabro L.	1.56
	Vespula germanica Fabricius	2.86
	Anthophora cf. *plumipes* Pallas	1.3
	Xylocopa violacea L.	4
	Bombus terrestris L.	18.6
	Apis mellifica L.	0.24
	Formicidae undetermined	4.12
	Hymenoptera undetermined	34.54
Lepidoptera	Lepidoptera undetermined	0.89
	Lepidoptera undetermined larvae	230.93
Diptera	Diptera undetermined	2.45
Diplopoda	*Schizophyllum sabulosum* (L.)	3.48
Mammalia	*Crocidura russula*	33.4
	Apodemus sylvaticus	23.4
	Muridae undetermined	40
Aves	*Saxicola torquata*	42
	Passeriformes undetermined	128
Reptilia	*Pod. muralis/Psam. hispanicus*	10
Amphibia	*Rana esculenta*	10
	Hyla meridionalis	5
	Anura undetermined	5
Others	Snails undetermined	2.87
	Seeds undetermined	0.44