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Seasonal and habitat-related variation of otter *Lutra lutra* diet in a Mediterranean river catchment (Italy)

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A b s t r a c t . To investigate time- and spatial related variations in the composition of otter *Lutra lutra* diet, a total of 838 faecal samples was collected in the upper catchment of the Agri River (Basilicata region, southern Italy), and analysed. Data were split up according to the four seasons and between the main river and three of its tributaries. Fish and amphibians formed the bulk of otter diet, their consumption being inversely correlated. Trophic niche breadth was positively correlated with the frequency of occurrence of fish, whilst it was negatively correlated to that of amphibians and the altitude of the sampling stations. The frequency of consumption of fish did not vary through the year, whilst amphibians were mainly eaten during their hibernation and breeding period. Otter diet along the four main rivers differed significantly, the species being mainly piscivorous on the main river, whilst relying on alternative food resources on its tributaries, where habitat features or human interference reduced fish abundance. Fish availability seems to represent the main factor determining the composition and diversity of otter diet.

Key words*:* alternative preys, amphibians, main river, tributaries, altitude

Introduction

The otter (*Lutra lutra*) is a semi-aquatic carnivore and, being at the top of the trophic chain, it is particularly sensitive to the environmental variations which affect freshwater ecosystems, particularly in Mediterranean climates (G a s i t h & R e s h 1999, M a g a l h ä e s et al. 2002).

The diet and feeding habits of otters have been widely investigated throughout Europe, from Fennoscandia (S u l k a v a 1996) to Mediterranean regions (reviews in R u i z - O l m o & P a l a z ó n 1997 and P r i g i o n i 1997). Although fish are the staple food of otters everywhere (M a s o n & M a c d o n a l d 1986, C a r s s 1995), a marked decrease of their consumption is reported along the latitudinal gradient from north to south, as a consequence of the lower availability and stability of water in Mediterranean freshwater habitats (C l a v e r o et al. 2003). Accordingly, in the southern regions of Europe otters rely on a wider range of preys, including amphibians, crayfish and reptiles.

Also habitat features, particularly aquatic productivity and water richness, can influence the composition of otter diet, alternative preys being eaten more frequently along streams and oligotrophic rivers, where otter compensate for the lower richness and abundance of fish, in comparison to lakes and large rivers, by using alternative prey (J e d r z e j e w s k a et al. 2001). Accordingly, R e m o n t i et al. (2008) found a positive correlation between fish consumption by otters and both fish biomass and mean summer discharge.

Prey availability is considered to play a main role in otter ecology, influencing its distribution, density, breeding period, reproduction success and mortality (review in K r u u k

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2006). As a consequence, conservation programmes require as deep as possible knowledge of those aspects of otter ecology related to prey availability and the effects of its spatial and temporal variation.

In Italy, otter populations sharply declined in the last decades of the 20th century (P r i g i o n i et al. 2007) and currently 88% of the species range is included in a few southern regions, namely Campania, Basilicata, Apulia and Calabria, where the otter seems to be recovering in numbers (P r i g i o n i et al. 2007).

The Agri River (Basilicata region) hosts one of the main Italian otter populations and the pattern of sprainting activity suggests the presence of a stable population on a wide part of the river catchment (P r i g i o n i et al. 2006b). Moreover, the upper river basin may represent an important way of connection between the otter populations of the Campania region in the north and those of the Pollino massif in the south (Basilicata and Calabria regions).

In this paper, we report on an extensive investigation carried out in the upper catchment of the Agri River in 2006–2007, with the aims of assessing 1) the overall and seasonal composition of otter diet and 2) its variation in relation to altitude-related differences in the same watercourse (upstream *vs*. downstream reaches) and different stream orders inside the same catchment (main river *vs*. tributaries), both parameters being considered to affect water stability and river mean flow.

In particular, examining the habitat-related pattern of variation of otter diet at the local scale in the Mediterranean area, we addressed the hypothesis that the European latitudinal trend highlighted by C l a v e r o et al. (2003) and the water richness gradient reported by J e d r z e j e w s k a et al. (2001) may be not mutually exclusive.

Study Area

The study was carried out in the upper catchment of the Agri River (total length: 136 km), which rises on the slopes of Mounts Maruggio and Volturino (southern Apennines) and flows into the Ionian Sea. The monitored reach of the Agri River ran between the dam of Marsico Nuovo (780 m a.s.l.) and the confluence of the Racanello River (350 m a.s.l.) and included the tributaries Cavolo, Alli, Casale, Sciaura, Maglia and Racanello. About 10 km upstream of the confluence of the Racanello River, the main river is dammed, forming a 4.5 km^2 wide artificial lake (Lake Pertusillo). Among the investigated watercourses were also included the Cogliandrino River, which flows southwards in parallel to the Maglia River and could represent a way of connection with the otter population of the Pollino National Park, and the streams Melandro and Presco, flowing, respectively, north-west and north-east of the upper course of the Agri River (Fig. 1).

Most watercourses are characterised by a torrential flow, with rapid, shallow waters, except for the downstream reaches of the rivers flowing into the lake, where waters are forced to reduce their speed, the lower reach of the main river and the streams Melandro and Presco. During the study period, the flow of the rivers varied markedly, the tributaries suffering water stress from the last part of spring to autumn, particularly in mid-summer.

Riverside woods consist of poplars (*Populus alba*, *P. nigra*), alders (*Alnus glutinosa*, *A. cordata*) and willows (*Salix alba*, *S. purpurea*, *S. triandra*). The river bed of the "fiumare", typical watercourses of the Mediterranean region which are almost completely dry for most of the year (S a b a t o & T r o p e a n o 2004), hosts above all shrubs of tamarisks (*Tamarix*

gallica, *T. africana*) and oleanders (*Nerium oleander*). Dry soils are mainly covered by oaks (*Quercus cerris*, *Q. frainetto*), which can be associated to maples (*Acer obtusatum*, *A. campestre*), hornbeams (*Ostrya carpinifolia*, *Carpinus betulus* and *C. orientalis*) and wild-cherries (*Prunus cocomilia*, *P. mahaleb*). Land use is predominantly pasture and extensive agriculture.

Material and Methods

A total of 22 sampling stations (Fig. 1), corresponding to 600 m long reaches of watercourses, was identified. From March 2006 to February 2007, otter spraints were searched monthly, walking into the water on both riversides and around small islands and exploring typical otter marking sites (e.g. large stones, bridges, pool banks, confluences; Macdonald & Mason 1983).

In the laboratory, each spraint was soaked for 12 hours in a solution of hydrogen peroxide; subsequently, each spraint was placed into two identical sieves, with 0.5 mm wide meshes, overlapped so as to match the respective upper margins, and washed by a strong water jet, obtained by affixing a short rubber tube to the tap. This procedure allowed an effective and relatively quick cleaning of the faeces without the loss or wear of the undigested remains.

By a binocular microscope, fish remains were identified from their vertebrae, jawbones and scales, using personal reference collections and the keys of different authors (Webb 1976, Wise 1980, Camby et al. 1984, Prigioni 1997). Reptiles and amphibians were identified by the keys of Di Palma & Massa (1981), birds feathers were identified with reference to Day (1966), whilst mammal hairs were compared at 20× and 40× magnifications with the keys of Debrot et al. (1982). The undigested remains of insects (wings, legs and cuticle parts) were identified using personal reference collections.

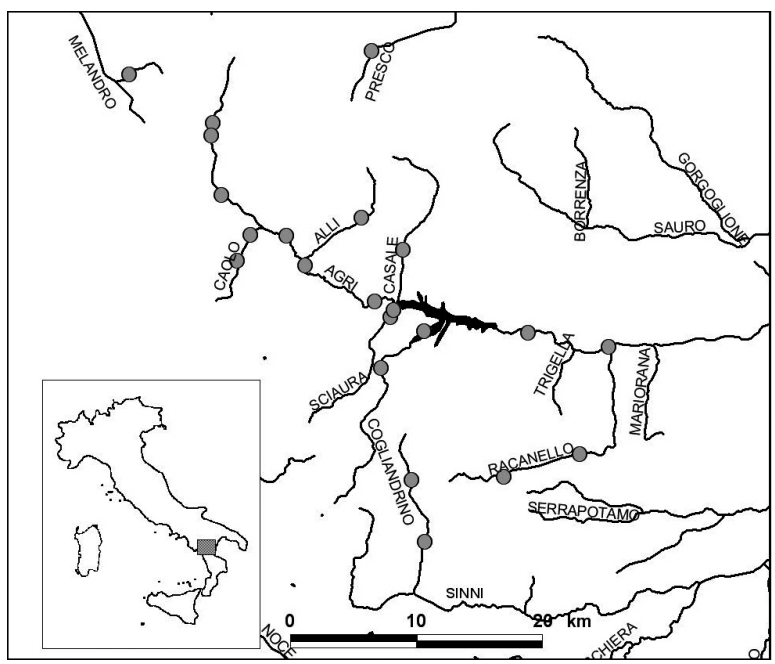

Fig. 1. Study area with the 22 sampling stations (grey dots).

Results were expressed as percent frequency of occurrence (F% = number of spraints containing a specific food items/total number of examined spraints × 100), percent relative frequency of occurrence (FR% = number of occurrences of an item / total number of items × 100), estimated percent volume (V% = total estimated volume of each food item as ingested / number of spraints containing that item) and percent mean volume (Vm% = total estimated volume of each food item as ingested / total number of examined spraints).

The relative percent volume of each prey item was estimated according to Kruuk & Parish (1981). For each sample the minimum number of individuals of each kind of prey was estimated by the number and position (left-right) of diagnostic hard parts (as mouth bones for fish, illions for amphibians). When no diagnostic part was found the remains of a prey were considered to belong to a single individual. Then the bulk of each prey in the food of otters corresponding with each spraint sample was assessed, by eye, through multiplication of the number of remains by the estimated weight of each prey "as ingested" by otters. For fish, the weight was assessed by comparing the size of the jawbones found in otter spraints to a personal reference collection of jawbones collected from fish of known size. A constant weight was assigned to the other prey items: insects 1 g, amphibians 30 g, reptiles and crustaceans 50 g, birds 100 g.

Trophic niche breadth (B) was estimated by Levins' index (Feinsinger et al. 1981): $B = 1/(R \sum p_i^2)$, using FR (p_i) and grouping data in 14 main food categories (R): insects, crustaceans, centrarchids, salmonids, barbels, roach, chub, bleak, carp, other fish, amphibians, reptiles, birds and "other items" (grouping items other than fish with FR < 1).

The raw frequency data (F%) for different seasons (winter: I-III, spring: IV-VI, summer: VII-IX, autumn: X-XII) or main watercourses (rivers Agri, Maglia, Cogliandrino and Cavolo) were compared using the chi-square test (χ^2). Because of the great number of repeated tests on related data, the level of significance was calculated by Bonferroni's sequential technique (Rice 1989). Kruskall Wallis test was applied for evaluating the variation of otter main food categories expressed as per cent volume (V%). Spearman's rank correlation test (r_s) was used to check for any relationship between the F% and V% of the otters' main food categories, the index B and the average altitude of 11 regularly monitored sampling stations.

Results

A total of 838 spraints were collected and analysed. Fish (mainly trout *Salmo trutta* and cyprinids) and amphibians (*Rana* sp.) formed the bulk of otter diet, together totalling, in terms of Vm%, about 90% of the overall diet (Fig. 2, Table 1). Their consumption by otters was inversely correlated ($r_s = -0.7$; $P = 0.016$; n = 11). Alien species (*Rutilus aula*, *Carassius carassius*, *Chondrostoma genei*, *Lepomis gibbosus*, *Micropterus salmoides* and *Cyprinus carpio*) represented 11.9% of the total estimated number of fish preyed upon by otters. The frequency of consumption of amphibians increased with the altitude of sampling stations ($r_s = 0.73$; $P = 0.011$; n = 11). Reptiles (snakes) and crustaceans (mainly the river crab *Potamon fluviatilis fluviatile*) were much less important food resources (Vm% = 3.4 and 2.6, respectively), whilst other items were eaten only occasionally.

Trophic niche breadth was positively correlated with the percent frequency of fish in otter diet ($r_s = 0.81$; $P = 0.003$; n = 11), particularly that of Cyprinids ($r_s = 0.95$; $P < 0.0001$; n = 11), whilst it was negatively correlated with the percent frequency of amphibians ($r_s = -0.79$; $P = 0.004$; n = 11) and the altitude of sampling stations ($r_s = -0.72$; $P = 0.013$; n = 11; Fig. 3).

The frequency of consumption of fish did not vary during the year, except for centrarchids (Table 2); nonetheless, as a consequence of variation in percent volume (Table

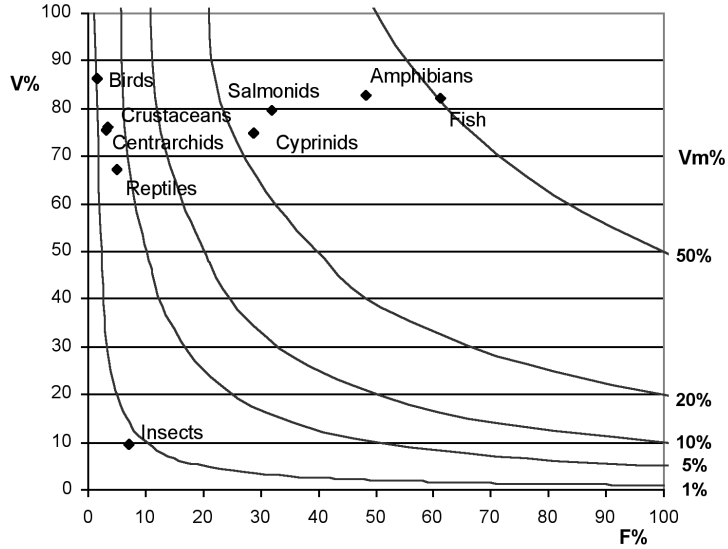

Fig. 2. Overall diet of the otter in the study area: estimated volume (V% = y) of otter food categories, whenever eaten, vs their per cent frequency (F% = x). Isopleths connect points of equal per cent mean volume (Vm%) in the overall diet.

3), the overall importance of fish in otter diet was higher in autumn (Vm% = 61.4) and winter (Vm% = 50.9), cyprinids predominating in the first season and salmonids in the latter. Amphibians were mainly preyed upon in winter (Vm% = 45.8) and spring (Vm% = 41.0), whilst crabs predominated in autumn (Vm% = 6.0) and reptiles in spring (Vm% = 7.0) and summer (Vm% = 8.1). Trophic niche breadth increased from winter to autumn ($B_w = 0.27$; $B_{sp} = 0.38$; $B_{su} = 0.38$; $B_a = 0.50$).

Grouping diet data for the main watercourses, the composition of otter diet differed significantly (Tables 4 and 5). On the main river, otters relied mostly on fish (Vm% = 60.1), particularly cyprinids, whilst salmonids prevailed in otter spraints from the Cavolo River, where otter diet was formed by fish and amphibians in equal parts (Vm% = 49.3 and 40.5,

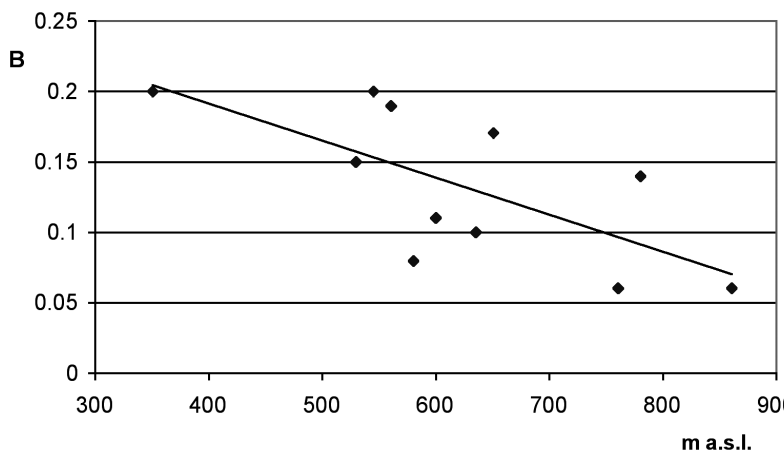

Fig. 3. Otter trophic niche breadth in relation to the altitude of 11 sampling stations ($r_s = -0.72$; $P = 0.013$).

Table 1. Overall diet of the otter in the study area (spraints: 838; items: 1162).

Food items	F%	FR%	V%	Vm%
Fruit	0.36	0.26	100.00	0.36
Insects	7.04	5.08	9.68	0.68
Odonata	0.24	0.17	5.00	0.01
Plecoptera	0.72	0.52	6.33	0.05
Orthoptera	0.24	0.17	17.50	0.04
Hymenoptera	0.24	0.17	7.50	0.02
Trichoptera	1.91	1.38	9.69	0.18
Coleoptera	4.06	2.93	9.03	0.37
Gasteropods	0.24	0.17	5.50	0.01
Crustaceans	3.46	2.50	76.21	2.64
Potamon fluviatilis fluviatile	2.98	2.15	80.40	2.40
Austropotamobius pallipes	0.24	0.25	100.00	0.24
Fish	61.34	44.23	82.29	50.47
Centrarchidae	3.22	2.32	75.56	2.43
Micropterus salmoides	2.15	1.55	70.56	1.52
Lepomis gibbosus	2.15	1.55	76.67	1.65
Undetermined centrarchids	0.12	0.09	100.00	0.12
Esocidae	0.12	0.09	100.00	0.12
Esox lucius	0.12	0.09	100.00	0.12
Salmonidae	31.86	22.98	79.69	25.39
Salmo trutta	31.86	22.98	79.69	25.39
Cyprinidae	28.64	20.65	75.00	21.48
Barbus spp.	5.13	3.70	66.42	3.41
Rutilus rubilio	5.49	3.96	66.78	3.67
Rutilus aula	0.95	0.69	54.38	0.52
Leuciscus cephalus	9.19	6.63	70.36	6.47
Tinca tinca	1.19	0.86	52.50	0.63
Alburnus sp.	5.61	4.04	24.91	1.40
Carassius carassius	0.12	0.09	10.00	0.01
Chondrostoma genei	0.48	0.34	50.50	0.24
Cyprinus carpio	1.43	1.03	99.17	1.42
Undetermined cyprinids	0.24	0.17	42.50	0.10
Undetermined fish	5.61	4.04	78.09	4.38
Amphibians	48.33	34.85	82.70	39.97
Rana sp.	47.85	34.51	82.35	39.41
Bufo sp.	0.60	0.43	94.00	0.56
Reptiles	5.01	3.61	67.14	3.37
Lacertidae	0.24	0.17	73.50	0.18
Ophidia	4.89	3.53	64.22	3.14
Birds	1.55	1.12	86.15	1.34
Rallidae	1.31	0.95	88.18	1.16
Passeriformes	0.12	0.09	100.00	0.12
Undetermined birds	0.12	0.09	70.00	0.08
Mammals	0.36	0.26	66.67	0.24

Table 2. Seasonal variation of the percent frequency of otter main food items (**P<0.01, ***P<0.001, df = 3).

Food items	F% spring	F% summer	F% autumn	F% winter	χ^2
Insects	14.8	3.4	7.3	5.0	18.7**
Crustaceans	-	4.0	7.7	2.5	18.0**
Fish	63.5	70.5	67.3	58.4	5.8
Centrarchids	1.1	0.7	3.2	7.4	15.8**
Salmonids	32.3	42.3	28.6	35.4	8.1
Cyprinids	31.7	30.9	35.9	21.7	9.3
Amphibians	52.9	46.3	33.1	51.5	21.9***
Reptiles	9.5	12.7	1.6	0.6	34.8***
Birds	1.6	3.4	1.6	-	5.5
	n = 189	n = 149	n = 248	n = 161	

Table 3. Seasonal variation of the percent volume of otter main food items (**P<0.01, ***P<0.001, df = 3).

Food items	V% spring	V% summer	V% autumn	V% winter	χ^2
Insects	10.9	8.4	6.1	14.1	3.76
Crustaceans	-	83.3	77.9	57.5	0.2
Fish	75.5	71.6	91.2	87.2	37.9***
Centrarchids	100	20.0	86.2	66.7	7.84
Salmonids	73.7	72.3	83.9	87.9	17.4**
Cyprinids	66.4	65.4	88.0	68.9	21.2***
Amphibians	77.4	70.8	82.3	88.8	19.1***
Reptiles	73.7	62.8	60.0	60.0	1.6
Birds	73.3	90.0	87.5	-	1.5
	n = 189	n = 149	n = 248	n = 161	

Table 4. Variation of the percent frequency of otter main food items along four watercourses (**P<0.01, ***P<0.001, df = 3).

Food items	F% Agri	F% Cavolo	F% Maglia	F% Cogliandrino	χ^2
Insects	4.5	8.0	8.2	9.3	4.5
Crustaceans	1.7	1.6	3.1	15.1	38.1***
Fish	71.4	64.0	55.7	12.8	101.0***
Centrarchids	5.0	0.8	3.1	1.2	6.7
Salmonids	31.6	47.2	28.9	11.6	30.3***
Cyprinids	38.6	18.4	21.6	3.5	53.6***
Amphibians	40.9	52.8	56.7	77.9	40.7***
Reptiles	5.3	9.6	3.1	3.5	5.7
Birds	1.7	-	6.2	-	14.4**
	n = 357	n = 125	n = 97	n = 86	

respectively). These last ones formed the bulk of otters diet on the Maglia River (Vm% = 48.4) and, particularly, on the Cogliandrino River (Vm% = 72.2) where crustaceans were also more frequently eaten by otters. Among secondary food items, reptiles prevailed on

Table 5. Variation of the percent volume of otter main food items along four watercourses (*P<0.05, ***P<0.001, df = 3).

Food items	V% Agri	V% Cavolo	V% Maglia	V% Cogliandrino	χ^2
Insects	2.7	23.9	18.5	8.2	0.8
Crustaceans	70.0	50.0	66.7	93.8	6.2
Fish	84.1	77.0	71.3	70.8	13.5*
Centrarchids	97.8	30.0	100	100	5.2
Salmonids	82.8	76.8	64.3	84.7	11.3*
Cyprinids	73.8	66.6	82.7	10.7	11.5*
Amphibians	78.3	76.7	85.4	92.7	15.5***
Reptiles	64.9	61.7	41.0	75.0	4.4
Birds	81.7	-	88.3	-	0.9
	n = 357	n = 125	n = 97	n = 86	

the Cavolo River, whilst birds were eaten more frequently on the Maglia River (Fig. 4). The F% and V% of the main food categories for different seasons or rivers were not correlated, except for the Cavolo River (r_s = 0.90; P = 0.002; n = 9).

Trophic niche breadth was the highest on the Agri River (B= 0.44) and the lowest on the Cogliandrino River (B= 0.17), showing almost equivalent values on the Maglia (B= 0.31) and Cavolo rivers (B= 0.28).

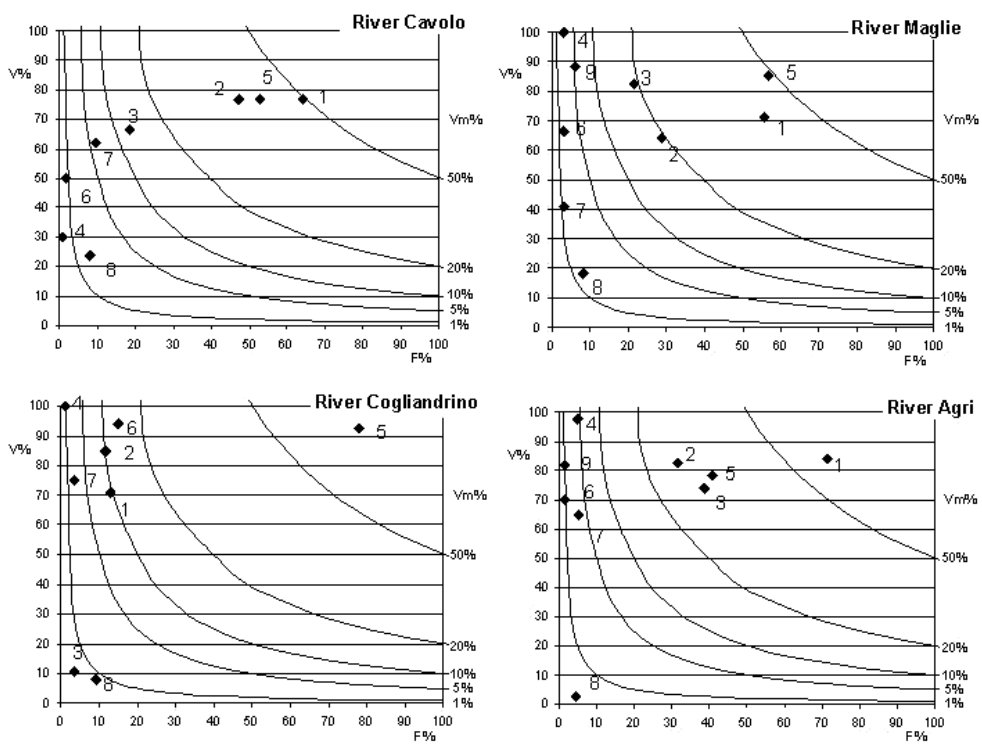

Fig. 4. Diet of the otter along four main watercourses (1: Fish, 2: Salmonids, 3: Cyprinids, 4: Centrarchids, 5: Amphibians, 6: Crustaceans, 7: Reptiles, 8: Insects, 9: Birds; see Fig. 2 for more details).

Discussion

Fish diversity in otter diet corresponded to the likely composition of the fish assemblage in the different rivers and agreed with the results of a preliminary fish census reported by Prigioni et al. (2006a), trout being mainly eaten in the epirithron sections (Cavolo River and upstream sampling station of the Cogliandrino River) and cyprinids prevailing along the lower course of the main river and next to the lake.

The almost constant frequency of fish in the diet of otters contrasts with the results of Prigioni et al. (2006a) in a previous study carried out in the lower part of our study area, when the winter decrease of the consumption of fish had been imputed to a sharp increase of river flooding caused by heavy rainfall, reducing suitable micro-habitats for cyprinids. These contrasting results could have been due to the exceptional scarcity of precipitation in winter 2006. Seasonal variation in the use of centrarchids reflected their relative availability in the reaches upstream the rivers' confluence into the Lake of Pertusillo (Prigioni et al. 2006a).

Amphibians were an important, alternative resource to fish, as reported for the neighbouring catchment of the Sinni River (Remonti et al. 2008) and for other areas of southern Italy (review in Prigioni 1997) and the Mediterranean region (Clavero et al. 2003). According to Jedrzejewska et al. (2001), they played a main role in the upper reaches of the monitored rivers and, in particular, in some tributaries (Maglia and Cogliandrino rivers) of the main river, which are characterised by swift, shallow waters hosting mainly trout and, secondarily, roach and eels (Prigioni et al. 2006a).

Fish diversity and biomass decrease with altitude (Ruiz-Olmo 1998), trout being the only or dominant species in oligotrophic streams (Prigioni et al. 2003). Contrary to Ruiz-Olmo (1998), the proportion of fish in otter diet did not increase with altitude, while fish were replaced by amphibians, particularly during their hibernation and breeding periods (see also Sulkava 2006), as reported for other mustelids, such as the badger *Meles meles* (Balestrieri et al. 2004).

Fish biomass can be further reduced by illegal fishing, such as in the Maglia and Cogliandrino rivers, where bleach or other detergents have been used as poison or where electro-fishing using self-made apparatuses has been conducted (Sgrosso, pers. comm.).

Secondary food items were used by otters according to their likely seasonal availability – reptiles being taken during summer and crustaceans in summer and autumn, when crabs are mostly active at night (Gherardi et al. 1988), suggesting that otters adopted an opportunistic feeding strategy, using these secondary preys aside from the availability of their main trophic resource (Clavero et al. 2003, Prigioni et al. 2006a). The seasonal variation of trophic niche breadth complied with the pattern recorded in the Pollino National Park (southern Italy), where the index was correlated with fish biomass (Remonti et al. 2008).

The estimate of the contribution of each prey type to the total bulk of each spraint allowed a more detailed picture than the use of the F% alone (see also Ciucci et al. 1996), the otter largely relying on non-fish preys with different flesh to indigestible parts ratios (Jacobsen & Hansen 1996, Remonti et al. 2008).

According to previous studies (Sulkava 1996, Ruiz-Olmo et al. 2001, Remonti et al. 2008), fish availability seems to represent the main factor determining the composition of otter diet. Where fish, namely cyprinids, are abundant, as in the Agri River and the lower course of its tributaries, otters are mainly piscivorous, though they always

completed their diet with other aquatic prey. Where the combined effects of the lower stability of river flow, altitude and human interference reduce fish availability, otters are able to rely on alternative food resources, accordingly to the seasonal variation of their abundance.

In these terms, habitat-related variation in the richness and temporal stability of water seems to affect the composition of otter diet also at a local scale (at least in the Mediterranean area), suggesting that the geographical pattern highlighted by C l a v e r o et al. (2003) is a superimposed effect caused by the global latitudinal trend of variation of environmental parameters from temperate to Mediterranean ecosystems.

Long-term studies on otter distribution and abundance, through the analysis of time-related variation in otter marking activity, are needed to verify if these habitats are able to sustain the stable presence of the species. Nonetheless, this ability of the otter to adapt to river habitats offering different food resources may play an important role in the species ongoing recovery in several European countries.

A c k n o w l e d g e m e n t s

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