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Do Eurasian otters *Lutra lutra* (L.) in the Somerset Levels prey preferentially on non-native fish species?

Rafael Miranda[1], Gordon H. Copp[2, 6, *], James Williams[3], Kathleen Beyer[2,4,5], and **Rodolphe E. Gozlan[4,6]**

With 2 figures and 2 tables

Abstract: Eurasian otters *Lutra lutra* (L.) are known to be opportunistic, exploiting the most abundant prey available, however, there have been few studies of otter diet in lowland areas of Britain. The Somerset Levels and Moors, a coastal flood plain and marsh area of 64 000 ha in SW England, is an otter stronghold where a number of introduced, non-native fishes (common carp *Cyprinus carpio*, pumpkinseed *Lepomis gibbosus*, sunbleak *Leucaspius delineatus*) have been introduced, with the latter species occurring locally in high abundances. The present study aimed to determine whether otters of the Somerset Levels are preying on, and thus represent 'biological resistance' to, these non-native fishes. In 2004–2005, otter spraints (feces) were collected seasonally in areas of the Levels also subjected to fisheries surveys, and the data were used to determine diet composition and preferences. Otter diet was dominated by European eel *Anguilla anguilla* and threespine stickleback *Gasterosteus aculeatus*, and non-native species occurred relatively rarely (carp, sunbleak) or not at all (pumpkinseed) in the otter spraints. Seasonal variations in otter diet were observed, with birds notable for summer and sticklebacks for winter. Despite their relative prominence in the Somerset Levels, non-native fish species represented minor components of the otter's diet, a pattern also observed in Spain. In particular, the popular angling species (carp) was taken infrequently, but the species of high conservation interest (eel) was a preferred and common item in otter diet.

Key words: food preferences; dietary electivities; cyprinids; alien species; dispersal; conservation; angling amenity, biological resistance.

Introduction

With the rising incidence of non-native species introductions, the conservation of native species is invariably linked to an understanding of the environmental biology of both non-native and native species, and in particular keystone species (Power et al. 1996). As a top predator, the Eurasian otter *Lutra lutra*, which is classed as vulnerable by the IUCN (2003), is "important in maintaining the equilibrium of a freshwater ecosystem" (Chanin 2003, p. 68). As such, the otter is an apex predator species in both riverine and wetland systems as well as a 'signal species' (UK DETR 2001) for aquatic biodiversity issues, especially as regards

[1] **Authors' addresses:** Department of Zoology and Ecology, University of Navarra, E-31080 Pamplona, Spain.
[2] Salmon & Freshwater Fisheries Team, Cefas, Lowestoft, UK.
[3] Stoford Manor, West Buckland, Wellington, TA21 9LS, UK.
[4] CEH, Winfrith Technology Centre, Dorchester, Dorset, UK.
[5] HIFI, University of Hull, Cottingham Road, Hull, HU6 7RXD, UK.
[6] Current address: School of Conservation Sciences, Bournemouth University, Dorset BH12 5BB, UK.
* Corresponding author; E-mail: gordon.copp@cefas.co.uk

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the conservation and rehabilitation of ecosystem biotic integrity (Prenda et al. 2006). Consequently, efforts to maintain and enhance the otter's status in Europe have included habitat rehabilitation and re-introductions as well as studies of range development and diet in numerous European countries (e.g. Jefferies et al. 1986, Bekker & Nolet 1990, Kožená et al. 1991, Prenda & Granado-Lorencio 1996, Copp & Roche 2003). Given that fish are the otter's major prey type, it is important to understand the trophic interactions between fish and otters. Indeed, a recent review of otter status in Europe (Chanin 2003) identified a lack of dietary studies on otters inhabiting lowland areas of Britain. Although Chanin's (2003) review overlooked at least one relevant study on lowland rivers (Roche et al. 1995), there are still relatively few studies on the diet of otters re-colonizing lowland areas of Britain (e.g. Copp & Roche 2003).

In the UK, following a decline in numbers during the 1960s to 1990s, the otter has increased in numbers and distribution both in its stronghold areas (southwest England, Welsh borders) and in areas where it had disappeared (Chanin 2003). One area of southwest England where otters have resisted human impacts is the Somerset Levels and Moors, which is a coastal floodplain grazing marsh of ≈64 000 ha and is dissected by a largely man-made drainage system. The Somerset Levels system is the largest intact wetland in South West Britain, attracting international status as one of the most important sites of this type in the world. To help prevent the accelerating loss of wetland quality, the UK Government has designated just under half of the Levels and Moors as an Environmentally Sensitive Area (ESA), with the otter receiving special consideration.

Maintenance of the Somerset Levels' conservation status under the EC Water Framework Directive could be undermined by the presence of non-native fish species (UK TAG 2004, Prenda et al. 2006). The main non-native fishes present in the Somerset Levels are common carp *Cyprinus carpio*, ide *Leuciscus idus*, pumpkinseed *Lepomis gibbosus* and sunbleak *Leucaspius delineatus*. The most recent invader of the Somerset Levels, the sunbleak is a small-bodied freshwater cyprinid native to parts of Continental Europe. Although sunbleak is thought to be in decline in some parts of its native range (Arnold & Längert 1995), the species has spread throughout the Somerset Levels. It can occur in high densities and potentially threatens the ecological balance of this complex network of canals and lakes (Farr-Cox et al. 1996, Gozlan et al. 2003, Pinder & Gozlan 2003). Because the otter is an opportunistic predator, which feeds on the most abundant prey (Erlinge 1969, Taastrom & Jacobsen 1999), small-bodied fishes of size similar to sunbleak (i.e. 5–6 cm fork length) have been found to be taken in considerable numbers if they occur in high density (Roche 2001). Although sunbleak has not been found in otter stomachs from carcasses collected over a wide area of southwest England (Britton et al. 2006), only a small proportion of these carcasses were from the Somerset Levels. Similarly, the only previous study of otter diet in the Somerset Levels (Webb 1975) predates the introduction of sunbleak (Gozlan et al. 2003), and this fish species could now represent an important otter prey component in those parts of the Somerset Levels where it is very abundant.

At the same time, otters are known to take fish species of angling interest, such as the common carp and European eel *Anguilla anguilla*. The UK Environment Agency is promoting both otter conservation and that of eels (MAFF 2000), which are in decline across most of Europe. Eels are well known to be the preferred prey of otters (Chanin 1981, Copp & Roche 2003), and carp are also known to be taken by otters in the southwest of England (Britton et al. 2005), so there is a potential conflict in the Somerset Levels between the angling amenity interests in carp and the conservation initiatives to favour otters and eels.

In light of the otter's known opportunistic foraging habits and the apparent high abundance of non-native species (especially of sunbleak) in the Somerset Levels in fisheries surveys, the aim of the present study was to determine whether non-native fish species represent an important component of the otter's diet, and as such represent a so-called 'biological resistance' to invading species (Moyle & Light 1996). As such, the study also addresses the paucity of information on otter diet in lowland areas of England (Chanin 2003, Copp & Roche 2003), specifically in the Somerset Levels, as well as the dietary contribution of species of conservation interest (eel) and angling amenity (large cyprinids, carp). Based on the analysis of otter spraints, the specific objectives of the present study were to determine the relative proportions that sunbleak, carp, eel and large native cyprinids represent in the diet of otters in the Somerset Levels, and to determine seasonal variations in the otter's dietary preferences.

Table 1. Catch per unit of effort (CPUE, number of specimens / hour) of fishes at sampling locations in the Somerset Levels. Fishes were obtained either by seine netting (by the authors) or by electrofishing (Environment Agency Staff).

Water body	Bridgewater-Taunton Canal						Sowy	Dunwear	Kings-Sedgemoor Drain		R Huntspill
Site	B-TC Buck	Maiden Brook	Hyde Lane	B-TC Creech	B-TC Charlton	B-TC Outwood	River Sowy	Dunwear Pond	K-SD Parchey	K-SD Bawdrip	K-SD Woolav
Latitude	51° 02′ 56″ N 2° 59′ 39″ W	51° 01′ 22″ N 3° 03′ 32″ W	51° 01′ 19″ N 3° 03′ 03″ W	51° 01′ 29″ N 3° 02′ 15″ W	51° 02′ 46″ N 2° 59′ 37″ W	51° 03′ 49″ N 2° 59′ 18″ W	51° 06′ 04″ N 2° 52′ 11″ W	51° 07′ 06″ N 2° 58′ 48″ W	51° 08′ 06″ N 2° 55′ 39″ W	51° 09′ 03″ N 2° 56′ 47″ W	51° 11′ 19″ N 2° 56′ 19″ W
Anguilla anguilla		307.5	120.0	109.0	56.3	63.8					
Gasterosteus aculeatus							20.0				48.0
Rutilus rutilus	391.6	855.0	540.0	1138.5	412.5	581.3	176.0	12.9	90.0	3.5	128.0
Perca fluviatilis	3.2	3.8					12.0		15.0		
Gobio gobio	15.8		3.8	3.8	3.8	11.3	4.0				
Esox lucius	6.3	41.3	30.0	41.3	67.5	86.3	8.0				
Leucaspius delineatus	375.8	3.8	7.5	492.0	3.8	33.8	980.0	295.7	1413.8	105.9	20.0
Cyprinus carpio				3.8							
Barbatula barbatula	100.0										4.0
Scardinius erythrophthalmus	3.2	3.8			3.8	37.5					
Abramis brama	101.1		7.5	7.5	11.3	45.0	124.0		41.3	3.5	8.0
Gymnocephalus cernuus				4.0							8.0
Tinca tinca	6.3	3.8	3.8	4.0	3.8	3.8					
Pungitius pungitius										36.0	

Study area, material and methods

Field collection of otter spraints in the Somerset Levels took place seasonally, with collections undertaken at least once in each season of the year (2004–2005). Field sampling was carried out by the authors and members of the Somerset Otter Group, in collaboration with local wildlife stakeholders. Spraints were placed in individual, labeled plastic bags in the field, and stored in cardboard boxes for later analysis. Nine spraint sampling points were monitored, and data from fish surveys at 11 locations were obtained either by seine netting (by the authors), as per Coles et al. (1985), or by electrofishing undertaken by Environment Agency staff (Table 1).

Laboratory processing of the spraints and identification of the remains was carried out at the CEH laboratories in Dorset and the University of Navarra using standard methods (e.g. Conroy et al. 1993, Copp & Roche 2003). After the spraints had been washed through filters (0.5 mm sieve) and dried, the remains of prey items were separated, sorted by category (fish scales, vertebrae, bones, teeth, fur), and then identified using a variety of keys (e.g. Conroy et al. 1993, Miranda & Escala 2002, Prenda et al. 2002). The approximate total length (L_T) and weight (W) of the fish prey were determined from regressions of bone length vs. fish body size as described in the literature (Conroy et al. 1993, Copp & Kováč 2003, Beyer et al. 2006, Miranda & Escala 2007). Weight of some fish species was determined from published regressions of body length vs. total weight (Oscoz et al. 2005, Leunda et al. 2006). The number of prey items was estimated by species and size class from the bone parts and scale size distributions using the methods described by Roche (2001) to determine the relative frequency of prey items in spraints (number of spraints in which prey type occurs / total number of spraints × 100) and the proportion of prey in spraints (number of spraints in which prey type occurs / the sum of counts for all prey types × 100).

Percentage principal components analysis (%PCA) was carried out to examine diet composition data, using the proportion of a prey in each spraint (de Crespin de Billy et al. 2000). Supplementary quantitative variables were added to determine whether differences existed between seasons. These variables were included in a biplot but they were not used in the original analysis. Some variables may be excluded because they represent an entirely different kind of information (Graffelman & Aluja-Banet 2003).

To examine the biomass contribution of each prey in the otter diet, a PCA of prey weight ($\log_{10}$ Wt+1 transformed) was performed. Besides fish, moorhens *Gallinula chloropus*, water vole *Arvicola terrestris* and frogs *Rana temporaria* are the most abundant alternative prey types taken by otters in the area (Webb 1975). Literature values were used for the mean weights of moorhen (Cramp & Simmons 1987), water vole (Garde & Escala 1996) and frogs (Esteban et al. 1995). Dietary preferences were calculated using Jacobs' (1974) modified version of Ivlev's electivity index ($D = r–p /[r+p] – 2rp$) in which r is the proportion of the resources used by each species (interval) and p is the proportion of fish available in the environment. Index values approaching or equal to +1 indicate that a prey type was taken proportionately more often than expected (preference), and those approaching or equal to -1 indicate that a prey type was taken proportionately less often than expected (avoidance), whereas values near to 0 show that the prey type was taken in proportion to their estimated availability (indifference). Statistical analyses were performed with SPSS 11.0 and XLSTAT 2006.

Results

Otter diet in the Somerset levels was dominated by eels and threespine stickleback *Gasterosteus aculeatus*, which overall were a preferred prey type (Table 2). Eurasian perch *Perca fluviatilis* and gudgeon *Gobio gobio* were also highly preferred, whereas roach *Rutilus rutilus* and sunbleak were taken less than expected (avoided), despite the high abundance of sunbleak in the seine samples (Table 1). Otters in the Somerset Levels took northern pike *Esox lucius* and rudd *Scardinius erythrophthalmus* in proportion to their estimated availability.

Regarding seasonal dietary analysis, threespine sticklebacks were a predominant prey in winter,

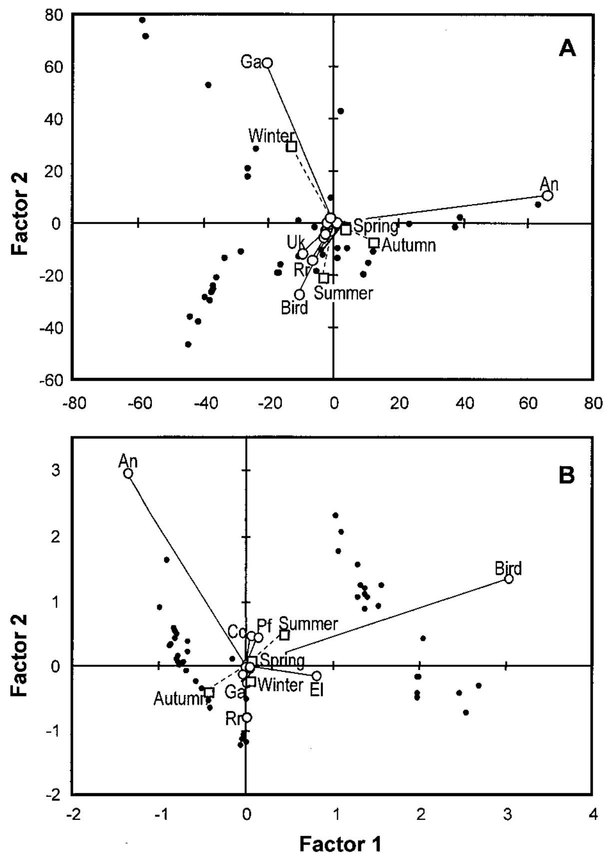

Fig. 1. Principal Component Analysis of the numerical proportion **(A)** and the biomass **(B)**, in log W+1 transformed, of each prey in each spraint analysed (black circles). In both A and B, PC1 and PC2 explain 52 % of the cumulative variability (in A: PC1 = 37 %, PC2 = 16 %; in B, PC1 = 31 %, PC2 = 21 %). Prey variables eigenvalues loadings (white circle) and seasonal supplementary variables (white square) are represented (Ga = *Gasterosteus aculeatus*, An = *Anguilla anguilla*, Uk = Unknown prey, Rr = *Rutilus rutilus*, Cc = *Cyprinus Carpio*, Pf = *Perca fluviatilis*, El = *Esox lucius*).

Table 2. From 358 otter spraints collected in the Somerset Levels (southwest England) during 2004–2005, the number of total prey identified (N) by season (WI: winter, SP: spring, SU: Summer and AU: Autumn), percentage of total biomass estimated (W) and distinguishing seasons, the relative proportion of occurrence (PFO: number of spraints in which prey type occurs / the sum of counts for all prey types × 100), the relative frequency of occurrence (RFO: number of spraints in which prey type occurs / total number of spraints × 100) and the overall Ivlev electivity index (*D*) for each prey type. Ivlev's D was not been calculated where fish data were not representative, indicated by '–'.

Prey species or type	N	N_{WI}	N_{SP}	N_{SU}	N_{AU}	W	W_{WI}	W_{SP}	W_{SU}	W_{AU}	PFO	RFO	D
European eel *Anguilla anguilla*	472	32	22	268	150	27.84	30.40	15.06	21.54	55.73	36.36	68.16	0.67
3-spine stickleback *Gasterosteus aculeatus*	250	122	6	97	25	0.37	1.18	0.03	0.33	0.26	19.26	24.58	0.91
roach *Rutilus rutilus*	142	12	6	88	36	6.52	2.56	14.87	5.42	7.58	10.94	30.73	–0.71
Eurasian perch *Perca fluviatilis*	81	6	2	47	26	2.37	0.87	0.51	3.06	1.92	6.24	17.88	0.88
gudgeon *Gobio gobio*	48	2		36	10	0.55	0.20		0.64	0.71	3.70	11.17	0.81
northern pike *Esox lucius*	30	2	4	20	4	19.69	21.02	39.96	20.69	3.44	2.31	8.38	–0.03
sunbleak *Leucaspius delineatus*	35	2	2	22	8	0.04	0.03	0.03	0.04	0.06	2.70	8.38	–0.87
European bullhead *Cottus gobio*	48			20	29	0.07			0.04	0.24	3.70	6.98	–
common carp *Cyprinus carpio*	19		3	12	4	3.35		0.25	4.33	3.71	1.46	4.75	–
stone loach *Barbatula barbatula*	10			10		0.01			0.02		0.77	2.79	–
rudd *Scardinius erythrophthalmus*	5	2		1	2	0.39	0.84		0.08	1.41	0.39	1.40	–0.01
Undetermined Cyprinidae	24	2	4	12	6	0.35	0.27	0.82	0.19	0.64	1.85	6.70	–
Unknown	47	10		17	20						3.62	13.13	–
Mammal	6			2	4	1.97			1.07	7.37	0.46	1.68	–
Bird	74	8	6	54	6	36.26	40.35	28.47	42.54	16.93	5.70	20.67	–
Amphibian	7		7			0.23	2.29				0.54	1.96	–
Total number of prey	1298	200	62	706	330								

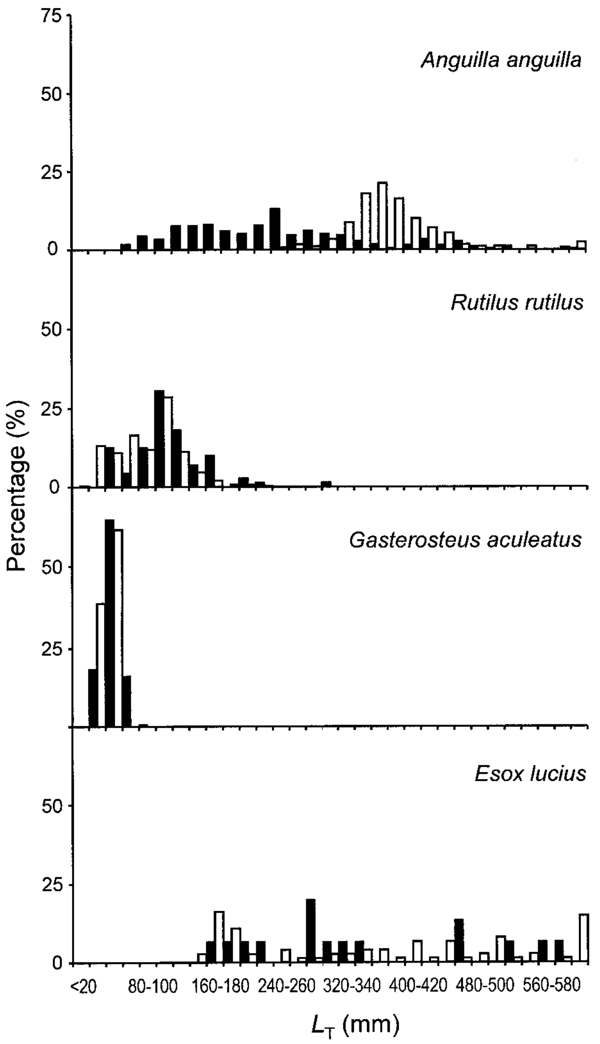

Fig. 2. Length distributions (in mm L_T) of major prey types found in otter spraints (grey bars) and caught by electrofishing or seine netting (white bars).

and in summer important prey items were roach and birds (Fig. 1). In summer, roach were taken in greater number than in winter, but the roach taken in winter were larger, and therefore constituted an important prey type in both seasons (Fig. 1). Other fish species that appeared in low abundance but high biomass were common carp, Eurasian perch and northern pike.

Four species (eel, roach, stickleback, northern pike) were sufficiently well represented in the samples to permit size class selectivity analysis (Fig. 2). These data reveal that otters did not take fish >600 mm L_T, they selected small eels, and they did not appear to demonstrate size selectivity for roach or stickleback.

Discussion

Prey preference

Carp and sunbleak remain common fish species in still waters of the Somerset Levels, as reported by Farr-Cox et al. (1996), but these species were taken relatively infrequently by the otters (Table 2). Although pumpkinseed occurs in at least one pond near two spraint sampling sites (pers. observ.), the species is in relatively low abundance (Villeneuve et al. 2005) and was absent in the spraints examined. Otters can travel considerable distances between feeding bouts (Erlinge 1969, Taastrom & Jacobsen 1999, Roche 2001) and are well known to prey on the most abundant prey types available, with the possible exception of eels, which otters are known to take preferentially (Roche et al. 1995).

Otter diet in the Somerset Levels does not appear to have changed much since the early 1970s (Webb 1975). In both studies, otters fed preferentially on native species, with introduced fish species being either infrequently taken (common carp, sunbleak) or absent (pumpkinseed) in the sprints examined. This disproportionately low use of an introduced potential prey resembles that reported for otters in Spain (Prenda et al. 2006).

As is common in otters (e.g. Roche et al. 1995, Taastrom & Jacobsen 1999), diet varied seasonally and was related to prey availability (Fig. 1, Table 2). Birds are more likely to be taken as prey in summer due to breeding activities (Taastrom & Jacobsen 1999). Presence of roach in the otter diet is higher in summer than in winter, but roach taken in summer were larger i.e. greater biomass, when eels were less abundant.

Electivity indices could not be calculated for common carp, stone loach *Barbatula barbatula* and bullhead *Cottus gobio* because of sampling bias. Despite being present at the survey sites, only seven carp, one stone loach and no bullhead were captured in the fish survey (Table 1); this is likely to be due to the reduced efficiency of the sampling methods for capturing benthic fishes (i.e. stone loach and bullhead) and large carp (i.e. larger than ≈15 cm fork length), which are known to be difficult to capture unless a series of block nets is used (G. H. Copp, pers. observ., K. J. Wesley, pers. comm.). Carp are particularly abundant in still waters, most of which in the Somerset Levels are situated adjacent to the rivers and canals. Although riverine fish species may be predominant in the diet of otters in the southwest of England (Britton et al. 2005, 2006) in general, otters in the Somerset Levels demonstrated a preference for ubiquitous fish species (Table

2), which could have been taken from either still or flowing waters (i.e. eel, threespine stickleback, roach, perch, gudgeon).

With regard to size class selectivity, foraging on fish prey of sizes that are more easily captured, and thus of greater energetic benefit (Lundvall et al. 1999, Miranda et al. 2006), could explain the observed foraging patterns (Fig. 2).

Conservation perspectives

The results of the present study have implications for the conservation of both the otter and the eel. Despite the Somerset Levels and Moors' renown as a prime otter habitat, the actual number of animals present is comparatively low (Scott 1985, Crawford 2003). Therefore, the distribution of the spraints and the diet they reflect may be attributable to some extent to the individual mannerisms or habits of the otters involved, which can vary with age. Some spraints were collected during summer, a period when at least two, possibly three, litters of well-grown cubs were present in the study area. In summer, adult birds are actively breeding and thus are more available as prey, but they are less easy for young otters to capture than the young and inexperienced water birds, potentially an attractive and relatively easy target. This assumption is supported by the present results, and lends some support to the concerns of bird conservationists that otters are contributing to the recruitment problems of water birds, though the frequency of occurrence in otter diet across Europe is < 10 % (Chanin 2003).

The European eel is known to be in severe decline throughout Europe (ICES-WGEEL 2006), but the present study demonstrates that otters continue to select eels preferentially and to ignore some abundant alternatives. This could be a concern for eel conservation but less so for otters, which are known to take a wide range of other food types when eels are absent (e.g. Lanszki & Széles 2006) or in low abundance (e.g. Copp & Roche 2003, Brzeziński et al. 2006). Less easy to negotiate is the potential conflict between otter conservation and the sport angling for carp, which has undergone a massive growth in popularity in Britain in recent decades, and in the county of Somerset it represents a major, economically important, leisure activity. The perception of the angling press is that otters are a considerable and expensive nuisance, and that their conservation, unfairly, takes place at the expense of the fishermen. And this is believed to have led to instances of illegal killings of otters. The results of the present study indicate that, overall, carp is not a major prey type for otters both in numbers and weight (Fig. 1). Otter predation on large fish such as carp is known to be under-estimated from spraints, as otters preferentially feed on the soft tissue, and they are less likely to ingest the bones from which diet is estimated (Carss & Nelson 1998). However, an analysis of otter stomach contents (from road-kill carcasses) also revealed that carp are rarely taken, and that some specimens were taken just prior to their natural death (Britton et al. 2005). Nonetheless, in the Somerset Levels and Moors, where carp are known to be taken mainly in periods of cold weather (Somerset Otter Group, unpublished records), the killing of even a small number of carp (especially large fish) attracts a disproportionately high level of attention.

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