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Biometric relationships between body size and bone lengths in fish prey of the Eurasian otter *Lutra lutra*: chub *Leuciscus cephalus* and perch *Perca fluviatilis*

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A b s t r a c t . We determined regression relationships between head bone lengths and body size (standard length and weight) in chub *Leuciscus cephalus* and Eurasian perch *Perca fluviatilis*, two species taken frequently by the otter in the River Lee catchment. All relationships yielded significant linear equations, whereas those for bone vs. body weight were logarithmic. Regression slopes for head bones do not differ greatly within species but do across species of the same family.

Introduction

Investigations of prey size selectivity are important to understand the interactions between predators and their prey (M a n n & B e a u m o n t 1980, H a n s e l et al. 1988, M e h n e r 1990). Essential to dietary studies of fish predators, such as the European otter *Lutra lutra* (L.) (E r l i n g e 1967, C h a n i n 1981, K o ž e n á et al. 1992, H a r n a 1993, J u r a j d a et al. 1996), are statistical relationships to estimate the size of the fish taken (W i s e 1980, P r e n d a & G r a n a d o - L o r e n c i o 1992, C a r s s & P a r k i n s o n 1996). Such studies provide a better understanding of both the composition and size of preferred fish prey, so as to assess how fish stocks can be managed to favour the maintenance and expansion of otter populations (e.g. K r u u k et al. 1993, L a n s z k i & K ö r m e n d i 1996). As part of investigations related to otter conservation in Hertfordshire, England (e.g. R o c h e et al. 1995), and in South Bohemia, Czech Republic (R o c h e 2001), the present study aimed to determine the biometric relationships between head bones and body size in two common species of fish prey. Cyprinid and percid fishes represent important elements of the otter diet throughout Europe, so we concentrated on the chub *Leuciscus cephalus* and the Eurasian perch *Perca fluviatilis,* two species of particular importance in the diet of otters in the River Lee catchment (G.H. C o p p & K. R o c h e , unpublished data) and for which relatively little biometric information exists.

Material and Methods

Specimens over a range of sizes, corresponding roughly to ages 1 to 5 — i.e. those taken by otters in the River Lee catchment (G.H. C o p p & K. R o c h e , unpublished data), were collected from the River Lee in October 1995 (chub) at Woolmers Park (Nat. Grid Ref. TL 288 100) and in October 1996 (perch) from a quarry lake adjacent to the River Lee at Amwell (Nat. Grid Ref. TL 375 132). The specimens were captured at both sites using a Millstream, generator-powered, DC electrofishing apparatus and additionally (at Amwell) a beach seine net. The specimens were killed using benzocaine and frozen. After defrosting, the fish were measured for standard (SL) length in mm and for weight in g. Chub were boiled until flesh was easily removed, but this was insufficient to loosen the flesh in perch, which were subsequently immersed in a solution comprised of one third 50% sodium hydroxide solution and two-thirds water; immersion was for 15 minutes, the solution heated from cold. In both species, the bones were left to air dry before measurement.

Measurements of chub head bones followed Prenda & Granado-Lorencio (1992) for cyprinids (dentaries, maxillae, premaxillae, pharyngeals), but also included the cleithra and opercula as per Hansel et al. (1988). For perch, we measured the four head bones suggested by Libois et al. (1987): premaxillae, dentaries, opercula and preopercula. The dentaries were measured from the mandibular symphysis to the posterior ventral tip, the maxillae from the anterior edge to the posterior processus, the premaxillae from the maxillary symphysis to the anterior limb of the ascendant processus, the pharyngeals from the dorsal tip to the ventral tip (Prenda & Granado-Lorencio 1992), the cleithra from the dorsal tip to the anterior tip and the opercula from the fulcrum tip to the primary ray tip (Hansel et al. 1988), the preopercula from the dorsal tip to the ventral tip (Libois et al. 1987).

Simple linear regressions were generated, as many relative growth characters in fish are related in this manner to their body length. Natural log (ln) transformation was used where necessary (e.g. body weight) to achieve a linear model. Other regression assumptions were examined to ensure the validity of the tests. The bone length data were regressed against SL, rather than the opposite, such as undertaken in some studies (e.g. Prenda & Granado-Lorencio 1992) as we view the length of bones to be more dependent on the overall size of a fish than is overall size dependent on the length of any given bone. However, to permit comparison with some published equations, we also regressed SL or total length (TL) against bone length.

Results and Discussion

In both chub and perch, similar slope and intercept values were obtained in the regressions of bones from the left and right sides with respect to standard length (Table 1). The only exception was the pair of intercepts for left and right premaxillae in chub vs. body length. Otherwise, there appears to be little need in these species to distinguish the side of fish when back-calculating fish size from bone length. Our slope values (SL regressed against bone length) for chub are similar to those reported by Prenda & Granado-Lorencio (1992) for the Iberian chub *L. cephalus pyraenaicus* (dentary b values common chub vs. Iberian chub, respectively = 11.76 vs. 12.57; maxilla b values = 12.36 vs. 12.18; premaxilla b values = 12.18 vs. 12.77; pharyngeal b values = 9.63 vs. 11.50). This suggests that the relationships between bone size and body length are relatively constant within species across geographical ranges. However, the slope and intercept values (TL regressed against bone length) within Cyprinidae (values from Libois & Hallet-Libois 1988) vary greatly, reflecting natural variability in ontogenies between the species compared. The onset of skeleton formation during early development of fish is species specific, and also strongly depends on environmental conditions, especially temperature and oxygen concentration (e.g. Balon 1981).

Libois et al. (1987) provided a bone length to body size relationship for only one of the four head bones they examined in perch: body length vs. preopercula length (pob) relationship of TL = 7.742 Lpob + 15.368 (r^2 = 0.93); their regression slope value

Table 1. Number of specimens, regression slope, intercept values, and coefficients of determination for linear and logarithmic relationships of bone sizes (in mm) regressed against standard length[1] (bone size = bSL ± a) and body weight (bone size = b[lnWt] ± a) for the left (L) and right (R) sides of chub (mean SL = 231.7 mm, SE = 8.434, n = 59, min./max. = 124/375 mm) from the River Lee and perch (mean SL = 97.1 mm, SE = 4.815, n = 39, min./max. = 55/208 mm) from Amwell lake, Hertfordshire. In perch, the equation for bone size vs. weight is: ln(bone size) = b(lnWt) ± a. All models were significant at $P \leq 0.001$.

			standard length (mm)			body weight (g)		
species	bone	n	b	a	r^2	b	a	r^2
chub	L-dentary	58	0.086	-0.206	0.98	6.099	-13.623	0.93
	R-dentary	58	0.086	-0.425	0.97	6.138	-13.941	0.93
	L-maxilla	50	0.080	+0.025	0.96	6.048	-14.459	0.92
	R-maxilla	44	0.082	-0.329	0.96	6.401	-16.412	0.96
	L-premaxilla	48	0.080	-1.639	0.97	6.081	-16.300	0.93
	R-premaxilla	46	0.079	-7.781	0.97	6.095	-16.601	0.94
	L-pharyngeal	59	0.103	-2.169	0.98	7.332	-18.343	0.92
	R-pharyngeal	59	0.103	-2.412	0.98	7.384	-18.695	0.92
	L-cleithrum	56	0.169	-1.996	0.96	12.334	-30.295	0.92
	R-cleithrum	56	0.170	-2.333	0.97	12.096	-28.885	0.92
	L-operculum	57	0.108	-0.446	0.97	7.762	-17.819	0.91
	R-operculum	59	0.109	-0.746	0.98	7.840	-18.138	0.94
perch	L-dentary	39	0.112	-1.659	0.93	0.347	+1.174	0.92
	R-dentary	39	0.109	-1.283	0.93	0.335	1.221	0.91
	L-premaxilla	39	0.087	-0.296	0.90	0.311	+1.162	0.88
	R-premaxilla	39	0.096	-1.097	0.90	0.320	1.139	0.85
	L-preoperculum	37	0.133	-0.336	0.95	0.299	-1.691	0.94
	R-preoperculum	38	0.138	-0.172	0.99	0.312	1.650	0.92
	L-operculum	37	0.119	-0.792	0.95	0.319	+1.426	0.94
	R-operculum	38	0.105	+0.496	0.95	0.295	1.494	0.91

[1] Conversion equations between standard (SL), fork (FL) and total (TL) lengths are (G.H. C o p p , unpublished data): chub, FL = 1.118SL + 0.249; TL = 1.209SL + 0.297, TL = 1.081FL + 0.038; perch, SL = 1.09FL + 4.478, SL = 1.135TL + 6.323, FL = 1.039TL + 1.831 (all with $r^2 \geq 0.993$).

corresponds well with our preopercula data (left side: 7.85; right side: 7.48) when plotted TL vs. bone length (Table 2). Head bones are particularly useful for identifying fish prey species in otter spraints, as they withstand digestion and are of good taxonomic value. But head bones

Table 2. Regression slope and intercept values for linear relationships ($TL = bL_{bone} \pm a$) between total length (TL in mm) and left-side head bone sizes (mm) for chub (see Table 1) and for bleak *Alburnus alburnus* (n = 31 and 27 for dentary and maxilla, respectively), carp *Cyprinus carpio* (n = 25, 25, 25), common bream *Abramis brama* (n = 15, 16, 16), gudgeon *Gobio gobio* (n = 15, 17), roach *Rutilus rutilus* (n = 88), rudd *Scardinius erythrophthalmus* (n = 17, 16), and tench *Tinca tinca* (n = 41, 41, 41) reported by L i b o i s et al. (1988). Coefficients of determination were all ≥0.95.

species	chub	bleak	carp	c. bream	gudgeon	roach	rudd	tench
dentary								
b	14.22	18.07	14.44	19.02	16.68		19.31	23.52
a	3.23	-9.32	-1.86	-1.89	6.26		-11.57	-10.93
maxilla								
b	14.94	19.29	15.20	19.52			18.82	18.49
a	-0.08	8.92	0.20	7.04			2.49	-4.95
pharyngeal								
b	11.64		8.79	17.75	19.60	14.87		13.81
a	23.54		-2.13	7.21	-3.69	-1.52		-5.00

can occur in a low proportions, depending upon the size distribution of the prey population, e.g. 25 (dentaries, maxillae) to 40 % (pharyngeals) of otter spraints (Prenda & Granado-Lorencio 1992). And when a larger fish prey is taken, the head is often discarded uneaten (Erlinge 1968), so other body bones such as vertebrae can be useful (Wise 1980), as do scales (K. Roche, personal communication). Vertebrae also withstand digestion, but they are of less taxonomic value and, as with scales (Kožená et al. 1992), it is difficult to know their exact origin along the vertebral column.

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LITERATURE

BALON E.K. 1981: Saltatory processes and altricial to precocial forms in the ontogeny of fishes. *Amer. Zool. 21: 573-596.*

CARSS D.N. & PARKINSON S.G. 1996: Errors associated with otter faecal analyses. Estimating prey size and distribution from bones. *J. Zool. 238: 219–332.*

CHANIN P. 1981: The diet of the otter and its relation with the feral mink in two areas of south-west England. *Acta Theriol. 26: 83–93.*

ERLINGE S. 1967: Food habits of the fish otter *Lutra lutra* L. in south Swedish habitats. *Viltrevy 4: 371–443.*

ERLINGE S. 1968: Food studies on captive otters *Lutra lutra*. *Oikos 19: 259–270.*

HANSEL H.C., DUKE S.D., LOFY P.T. & GRAY G.A. 1988: Use of diagnostic bones to identify and estimate original lengths of ingested prey fishes. *Trans. Amer. Fish. Soc. 117: 55–62.*

HARNA G. 1993: Diet composition of the otter *Lutra lutra* in the Bieszcady Mountains, south-east Poland. *Acta Theriol. 38: 167–174.*

JURAJDA P., PRÁŠEK V. & ROCHE K. 1996. The autumnal diet of otters (*Lutra lutra*) inhabiting four streams in the Czech Republic. *Folia Zool. 45: 9–16.*

KOŽENÁ I., URBAN P., ŠTOURAČOVÁ I. & MAZUR I. 1992: The diet of the otter (*Lutra lutra* Linn.) in the Poľana Protected Landscape Region. *Folia Zool. 41: 107–122.*

KRUUK H., CARSS D.N., CONROY J.W.H. & DURBIN L. 1993: Otter *Lutra lutra* numbers and fish productivity in rivers of North East Scotland. *Symp. Zool. Soc. London 65: 171–191.*

LANSZKI J. & KÖRMENDI S. 1996: Otter diet in relation to fish availability in a fish pond in Hungary. *Acta Theriol. 41: 127–136.*

LIBOIS R.M. HALLET-LIBOIS C. & ROSOUX R. 1987: Éléments pour l'indentification des restes craniens des poissons dulçaquicoles de Belgique et du nord de la France: 1 – Anguilliformes, Gastérostéiformes, Cyprinodontiformes et Perciformes. *Fiches d'ostéologie animale pour l'archéologie. Série A : Poissons, No. 3. Juan-les-Pins: APCDA.*

LIBOIS. R.M. & HALLET-LIBOIS C. 1988: Éléments pour l'indentification des restes craniens des poissons dulçaquicoles de Belgique et du nord de la France. 2 – Cypriniformes. *Fiches d'ostéologie animale pour l'archéologie. Série A, No. 4. Juan-les-Pins: APCDA.*

MANN R.H.K. & BEAUMONT W.R.C. 1980: The collection, identification, and reconstruction of lengths of fish prey from their remains in pike stomachs. *Fish. Manag. 11: 169–172.*

MEHNER T. 1999: Zur Bestimmung der Beutefischarten aus Fragmenten der Wirbelsäule bei der Nahrungsanalyse. *Zool. Anz. 225 (3/4): 210–222*.

PRENDA J. & GRANADO-LORENCIO C. 1992: Biometric analysis of some cyprinid bones of prey fishes to estimate the original lengths and weights. *Folia Zool. 41: 175–185.*

ROCHE K. 2001: Sprainting behaviour, diet, and foraging strategy of otters (*Lutra lutra*) in the Třebon Biosphere Reserve (Czech Republic). *PhD Thesis, Institute of Vertebrate Biology, Academy of Sciences of the Czech Republic, Brno, 135 pp.*

ROCHE K., HARRIS R., WARRINGTON S. & COPP G.H. 1995: Home range and diet of re-introduced European otters *Lutra lutra* (L.) in Hertfordshire rivers. *Aquat. Conserv. Mar. Freshwat. Ecosys. 5: 87–96.*

WISE M.H. 1980: The use of fish vertebrae in scats for estimating prey size of otters and mink. *J. Zool. (London)*