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Biometric data and bone identification of topmouth gudgeon, *Pseudorasbora parva* and sunbleak, *Leucaspius delineatus*

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A b s t r a c t . Biometric relationships between bone dimensions and body size are presented for topmouth gudgeon *Pseudorasbora parva* and sunbleak *Leucaspius delineatus*, two invasive fish species in the UK. This study also provides a tool for identification of these species using key bones. Such information facilitates the assessment of the potential role of these invaders in the diet of piscivorous fauna.

Key words: bones, alien species, cyprinids, native predators, non-native

Introduction

Identification and analysis of the size and composition of prey taken by piscivorous predators assists in the further understanding of ecology of piscivorous fauna (M a n n & B e a u m o n t 1980, H a n s e l et al. 1988, C o p p & R o c h e 2003). Comprehensive evaluation of the digested prey is central to the assessment of predation impacts and is equally important for sustainable fisheries management.

Two non-native fish species in England that may be potential prey for native species are sunbleak *Leucaspius delineatus* (Heckel) and topmouth gudgeon *Pseudorasbora parva* (Temminck et Schlegel). These species were introduced to English waters in the mid 1980's (F a r r - C o x 1996, G o z l a n et al. 2002) where they have since developed extensive populations (G o z l a n et al. 2003, H i c k l e y & C h a r e 2004). Recent studies associate sunbleak and topmouth gudgeon with novel non-native parasites (B e y e r et al. 2005, G o z l a n et al. 2005). Results such as these have emphasized the need to be able to identify these two species as part of the native predators' diet.

The aim of the study was to provide a tool for species identification and to elaborate the biometric relationships between bone dimensions and body size of sunbleak and topmouth gudgeon. Head bones of fish are particularly useful for identifying the size and composition of prey species from the food remains of predators, as they withstand digestion and are taxonomically valuable (C o p p & K o v á č 2003).

Material and Methods

Specimens of sunbleak were collected from Stoneham Lakes (Hampshire, England: 50°57'14'' N; 1°22'48'' W) and of topmouth gudgeon from an aquaculture facility near

Romsey (Hampshire, England: 51°00' N; 1°26'48'' W). Forty specimens of each species were killed with an overdose of 2-phenoxyethanol. In the laboratory, each specimen was measured for standard length (SL in mm) and weight (Wt, to nearest 0.01 g). Fish were boiled in water until flesh was easily detached, after which the bones were left to air dry. Some bones were lost due to breakage during this process, which resulted in a variable number of bones (n) used for analysis (Table 1).

Table 1. Number of specimens of topmouth gudgeon *Pseudorasbora parva* and sunbleak *Leucaspius delineatus*, regression slope, intercept values, and coefficients of determination for linear and logarithmic relationships of bone sizes (Bl, in mm) regressed against standard length (BL = *b*SL ± *a*) and body weight (BL = *a*Wt^{b}) for the left (L) and right (R) sides of sunbleak (mean SL = 47.7 mm, SE = 1.03, n = 40, min. = 36, max. = 56 mm) from the Stoneham Lakes and topmouth gudgeon (mean SL = 55.5 mm, SE = 1.37, n = 40, min. = 35.7, max. = 70.5 mm) from an aquaculture facility in Hampshire. All models were significant at $P \leq 0.001$.

			Standard length (mm)			Body weight (g)		
Species		n	r^2	*a*	*b*	r^2	*a*	*b*
topmouth gudgeon	R-dentary	31	0.912	-5.672	22.617	0.939	0.054	3.763
	L-dentary	34	0.898	-5.733	22.925	0.909	0.066	3.625
	R-maxilla	34	0.913	-1.435	22.838	0.885	0.110	3.322
	L-maxilla	30	0.911	-4.770	24.074	0.906	0.089	3.557
	R-premaxilla	23	0.917	-7.272	28.814	0.911	0.154	3.260
	L-premaxilla	24	0.917	-0.508	24.434	0.918	0.123	3.755
	R-pharyngeal	31	0.931	-6.423	22.984	0.900	0.061	3.685
	L-pharyngeal	32	0.902	-4.025	21.913	0.855	0.070	3.524
	R-cleithrum	30	0.904	-0.577	7.557	0.885	0.002	3.469
	L-cleithrum	33	0.929	-4.233	8.047	0.928	0.002	3.652
	R-operculum	33	0.900	+4.396	12.395	0.904	0.034	3.005
	L-operculum	33	0.904	+2.903	12.750	0.882	0.030	3.085
sunbleak	R-dentary	39	0.951	+5.790	11.335	0.886	0.013	2.826
	L-dentary	39	0.952	+5.561	11.381	0.886	0.013	2.837
	R-maxilla	38	0.943	+6.801	14.286	0.879	0.029	2.773
	L-maxilla	37	0.930	+7.426	14.180	0.864	0.032	2.709
	R-premaxilla	37	0.874	+7.922	15.469	0.801	0.043	2.676
	L-premaxilla	35	0.924	+4.652	16.720	0.849	0.035	2,897
	R-pharyngeal	38	0.944	+4.548	14.055	0.890	0.020	2.936
	L-pharyngeal	39	0.959	+6.158	13.437	0.899	0.023	2.810
	R-cleithrum	37	0.963	+4.909	6.326	0.902	0.002	2.898
	L-cleithrum	40	0.954	+5.347	6.289	0.893	0.002	2.869
	R-operculum	40	0.942	+9.480	9.460	0.858	0.015	2.566
	L-operculum	38	0.951	+9.568	9.442	0.863	0.015	2.564

In both species, measurements of bone dimensions followed Prenda & Granado-Lorencio (1992) for dentaries, maxillae, pre-maxillae, pharyngeals and Hansel et al. (1988) for cleithra and operculi. The dentaries (length) were measured from the mandibular symphysis to the posterior ventral tip, the maxillae (length) from the anterior edge to the posterior processus, the pre-maxillae (length) from the maxillary symphysis to the anterior limb of the ascendant processus, the pharyngeals (articulation axis height) from the dorsal tip to the ventral tip (Prenda & Granado-Lorencio 1992), the cleithra (chord length) from the dorsal tip to the anterior tip, and the opercula (articular axis height) from

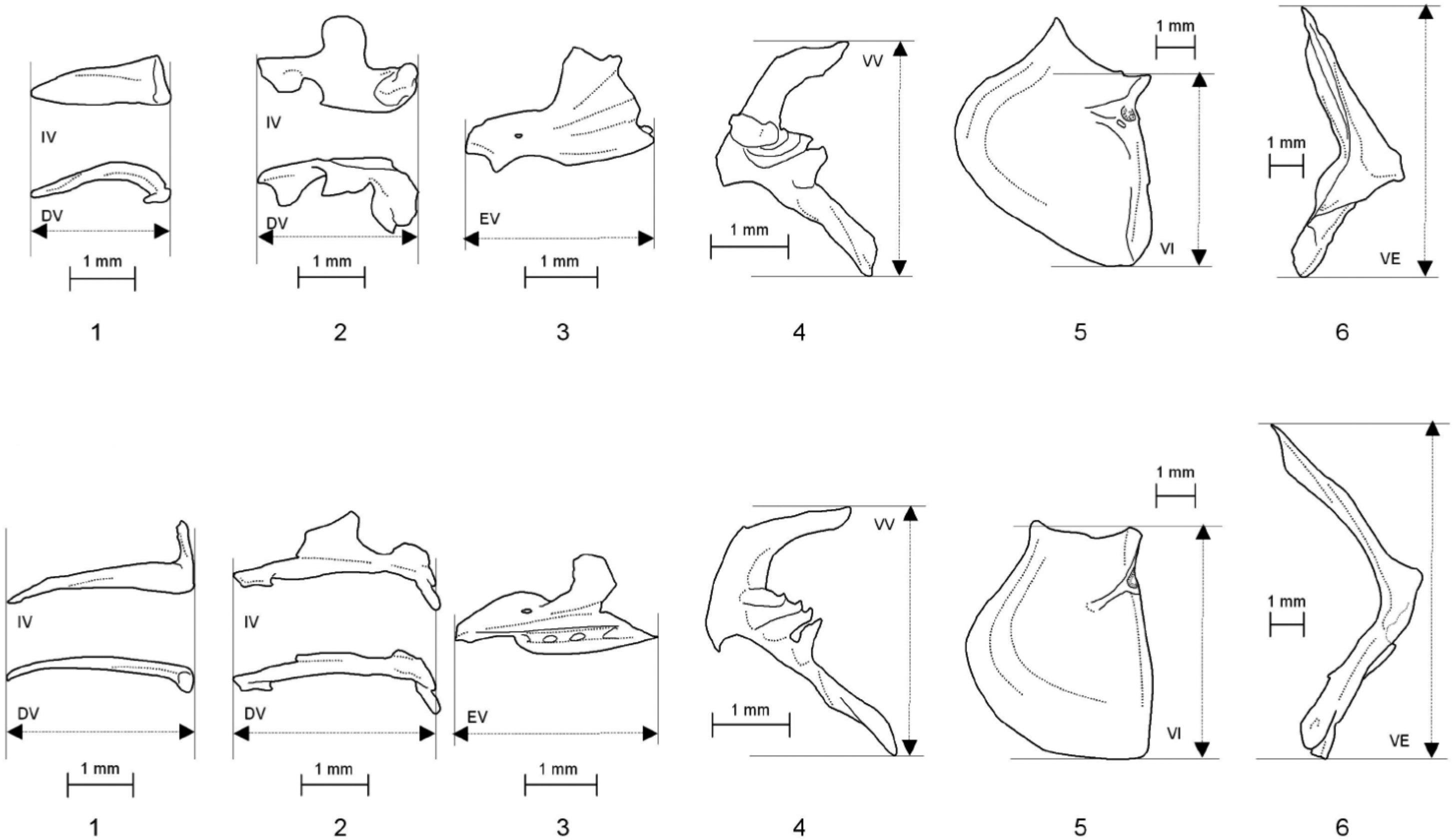

Fig. 1. Measurements of pre-maxillae (1), maxillae (2), dentaries (3), pharyngeals (4), operculi (5) and cleithra (6) and the top row represents bones taken from topmouth gudgeon *Pseudorasbora parva* and the bottom row from sunbleak *Leucaspius delineatus*. All bones shown are from the left body side (EV = external view, IV = internal view, DV = dorsal view, VV = ventral view).

the fulcrum tip to the primary ray tip (H a n s e l et al. 1988) (Fig 1). The bones were photographed using a binocular magnifying glass (Leyca MZ6), with an integrated digital camera (Canon PowerShot S45). Pictures were measured to the nearest 0.01 mm using a measure acquisition program (WinDIG version 2.5). The nomenclature to describe the bones follows that recommended by the World Ichtyo-archeaological Community (H o w e s 1978, R o s e l l ó 1989, M i r a n d a & E s c a l a 2005).

Measured bone dimensions (BL, in mm) were regressed against SL and Wt as per (C o p p & K o v á č 2003). Linear regressions were generated in the SL relationships (BL = bSL ± a), and multiplicative (BL = $a\mathrm{Wt}^b$) in the weight relationships, where a is the intercept of the regression curve and b the regression coefficient. Simple linear regressions were generated for body length (K o v á č et al. 1999), and multiplicative regressions for body weight. For comparative purposes, the paired bone structures were regressed against the SL and Wt separately. To compare measurements within and between paired bone structures Student's t-test was performed. Levene's statistical test was used to determine equality of variances for all variables. Normality was tested using Kolmogorov-Smirnov test. All statistical tests were performed with Minitab 14 (Minitab, Inc, PA, USA).

Results

The bones were generally sturdy in topmouth gudgeon and more delicate in sunbleak (Fig. 1). Measurements of head bones from the left and right body side did not differ for the same specimen in sunbleak (paired Student's t-test, $P > 0.66$) but did in topmouth gudgeon for dentaries ($P = 0.028$) and pre-maxillae ($P < 0.001$) only. In both species, the biometric relationships between bones with standard length and weight were highly significant ($P < 0.001$), with all coefficients of determination > 0.874 in sunbleak and > 0.898 in topmouth gudgeon (Table 1).

Premaxillae in sunbleak are slender rods (Fig. 1), gently curved with a thin anterior ascending process, whereas in topmouth gudgeon they are rough bones, with a little ascending process that does not protrude from the bone. Maxillae of sunbleak are elongated (Fig. 1), with a trapezoidal ascending process; the anterior angle is acute and more elevated than the posterior area; the posterior process is hook-shaped. In topmouth gudgeon, they are short and solid, with a curved and relatively high ascending process; the posterior process is triangular.

Dentaries in topmouth gudgeon are gently curved (Fig. 1); the coronoid process is triangular in shape with a lobed posterior edge; the mandibular lateral line canal has no pores; the symphysis is broad and concave. Whereas in sunbleak, dentaries have a narrow coronoid process with a curved border; the mandibular lateral line canal bears three pores ventrally. Pharyngeals in sunbleak are slender (Fig. 1); they have a long ventral limb and a hook-shaped dorsal limb; the arc-angle is acute and well delimited; the external angle is strong, hook-shaped and inclined towards the ventral limb; teeth are slim, acute and end in a little hook; they occur in one row of four or five teeth. In topmouth gudgeon, pharyngeal bones are strong and have a short ventral limb, which forms a 90° angle with the dorsal limb; the arc-angle and external angle are well delimited, and the latter is directed to the external area; five teeth arranged in a row, are denticulated and end in a hook.

Operculi of sunbleak have a thin surface (Fig. 1); the articular process and opercular arm are narrow and elongated; the posterior angle is rounded and the auricular process is well developed. In the topmouth gudgeon, the articular process and opercular arm are strong; the posterior angle is in an elevated position and the auricular process is protruding and has an acute angle. Cleithra of sunbleak are elongated (Fig. 1), with a slender dorsal limb ending in an acute tip; the posterior angle is prominent and rounded; margins of the ventral limb are of similar dimension and the articulation crest is widened and gently curved towards the ventral area. Cleithra of topmouth gudgeon are more robust, with the dorsal limb being straight and ending in an acute tip; the posterior angle is pronounced and with the end inclined downwards; the internal margin of the ventral limb is longer than the external one.

Discussion

Head bones of fish have species-specific adaptive characteristics and are of high taxonomic value (Prenda & Granado–Lorencio 1992). Therefore, they are very useful in prey fish identification and in size estimates (Libois et al. 1987, Hansel et al. 1988). However, in the diet of large piscivorous predators, the head bones of fish can occur in relatively low proportions (Prenda & Granado–Lorencio 1992), and the heads of larger fish prey are often discarded uneaten (Erlinge 1968). However, small-bodied species such as sunbleak and topmouth gudgeon are more likely to be taken whole by large predators (Erlinge 1968, Jensen et al. 2004), and therefore the head bones can be a very useful diagnostic tool for assessing the extent to which predators exert predation pressure on these species.

Problems might occur when using bones to estimate the length and weight of fish taken as prey. The influence of the digestive process and the drying of the bones in preparation for examination may inflict bias in terms of bone disfiguration (Britton & Shepherd 2005). Relationships between body and bone size may vary between geographical locations, but in some species, e.g. chub *Leuciscus cephalus*, the variability appears to be low (Copp & Kováč 2003). These factors may play a role when considering the accuracy of estimates, which should probably be used as suggestive (rather than absolute measures) of prey size.

The use of biometric relationships and identification tools to facilitate diet reconstruction are vital in ecology and vertebrate biology. The outputs of this study provide a tool for species identification and biometric relationships that enable estimation of length and weight using head bones. This information should facilitate the assessment of the diet of piscivorous fauna in the UK, but potentially wherever these sunbleak and topmouth gudgeon occur.

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