63. Size estimations of sturgeons (Acipenseridae) from the Mesolithic-Neolithic Danube Gorges

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The significant role of sturgeon fishing in the Mesolithic-Neolithic Danube Gorges has long been recognized, but the reconstruction of the sizes of individuals caught has been hindered by the lack of recent specimens from the Danube drainage in reference collections. This paper presents a method to reconstruct the total length from skeletal remains of several sturgeon species (*Huso huso*, *Acipenser gueldenstaedtii*, *A. nudiventris*, *A. stellatus*, and *A. ruthenus*) using linear and power regression equations, obtained from the database of biometric data of recent sturgeons from the Volga-Caspian Basin. The application of these regression equations to specimens from the Danube Gorge sites of Lepenski Vir, Padina, and Vlasac suggests that sturgeon fishing was oriented towards large adult individuals, with the largest specimens (in the case of beluga) surpassing 550 cm in total length. In addition to providing means for predicting body size of sturgeon specimens from archaeological contexts in areas where modern sturgeon stocks are diminished or completely extirpated, this study has important implications for investigating nutritional values, fishing techniques, and human-animal interrelationships in the Mesolithic-Neolithic Danube Gorges.

Keywords: sturgeons, Acipenseridae, size estimation, Mesolithic-Neolithic, Danube Gorges

Introduction

The significance of sturgeon (Acipenseridae) fishing in the Danube Gorges (north-central Balkans) in the Epipalaeolithic, Mesolithic, and Early Neolithic (*c.* 13,000–5500 cal BC, *cf.* Bonsall 2008; Borić 2011) is manifested by considerable amount of sturgeon remains (*cf.* Bartosiewicz *et al.* 2008; Bökönyi 1992; Borić 2003; Borić and Dimitrijević 2005; Brinkhuizen 1986; Clason 1980; Nalbant 1970; Păunescu 2000; Živaljević 2017) despite preservation biases affecting their largely cartilaginous skeleton (Bartosiewicz *et al.* 2008; Brinkhuizen 1986). The data obtained from stable isotope analysis of human bone collagen are in agreement with the consumption of protein derived from both freshwater and anadromous fish (Bonsall *et al.* 1997; Borić *et al.* 2004), and the significance of sturgeons is further attested by some of the sculpted boulders from Lepenski Vir depicting elements of sturgeon anatomy (Borić 2005; Radovanović 1997). Moreover, it has been suggested that the Upper Gorge sites of Padina, Lepenski Vir, and Vlasac (Fig. 63.1), occupied more or less continuously between *c.* 9500–5500 cal BC (corresponding to the Mesolithic, Mesolithic-Neolithic Transformation phase, and the Neolithic, *cf.* Borić 2011; Borić and Dimitrijević 2009), had been settled as optimal spots for specialized whirlpool fishing. Their location, as well as the location of the downstream sites of Cuina Turcului, Icoana, and Schela Cladovei (Fig. 63.1) greatly overlap with the most favourable localities for sturgeon fishing in more recent times (Borić 2003, 153; *cf.* Petrović 1998).

Prior to the completion of the dams in 1971 and 1984, several sturgeon species were undertaking their bi-annual (spring and autumn) spawning migrations to the Danube from the Black Sea. These included the beluga (*Huso huso*, Linnaeus 1758), Russian sturgeon (*Acipenser gueldenstaedtii*, Brandt and Ratzeburg 1833), ship sturgeon (*Acipenser nudiventris*, Lovetsky 1828), and stellate sturgeon (*Acipenser stellatus*, Pallas 1771). Remains of these species as well as those of freshwater sterlet (*Acipenser ruthenus*, Linnaeus 1758) have been identified in the faunal assemblages from Lepenski Vir, Padina, and Vlasac (Borić 2003; Brinkhuizen 1986; Clason 1980; Dimitrijević *et al.* submitted; Živaljević 2017). Sturgeon remains had also been found at the sites of Cuina Turcului (Nalbant 1970), Icoana, Ostrovul Banului (Păunescu 2000), Schela Cladovei (Bartosiewicz *et al.* 2008), and Knjepište (Bökönyi 1992) (Fig. 63.1).

Sturgeons can reach an impressive size, which indicates that their economic role in prehistory of the Danube Gorges must have been significant. Most species of the genus

Fig. 63.1. Map of the Danube Gorges with relevant sites discussed in the text. Image from Google Earth.

Table 63.1. Regression statistics for linear (y = ax + b) and power ($y = ax^b$) functions relating measurements (mm) of skeletal elements (*pinna pectoralis I, parasphenoideum, parietale, dentale, suboperculare, supracleithrale, claviculare, maxillare, palatopterygoideum, hyomandibulare, cleithrum*) to total length (TL) for Acipenseridae of the Volga – Caspian Basin. Coefficient of determination (r^2) and number of data pairs in regression (n). The regression equations were obtained from the database of osteological collection of sturgeon bones from recent (19th –21st century) specimens, Biomonitoring Laboratory, Institute of Problems in Ecology and Mineral Wealth, Tatarstan Academy of Sciences, Kazan, Russia. The measurements of elements for genus *Acipenser* (elements of *Acipenser gueldenstaedtii* used as an example) shown in Fig. 63.2, for *Huso huso* shown in Fig. 63.3.

Species	Length range (TL, cm)	Element	Measurement	Type of Regression	a	b	r^2	n
Acipenser gueldensta edtii	75.0–188.8	*pinna pectoralis I*	M1	Non-linear	5.1565	0.9062	0.9848	23
			M2	Non-linear	20.911	0.6771	0.9744	23
Acipenser ruthenus	24.3–58.8	*pinna pectoralis I*	M2	Non-linear	7.3087	1.1293	0.93	18
Acipenser stellatus	78.1–149.1	*pinna pectoralis I*	M1	Linear	4.5404	6.8927	0.9832	11
			M2	Linear	15.418	-9.998	0.9649	11
Acipenser gueldensta edtii	90.1–188.8	*parasphenoideum*	M1	Non-linear	4.9524	0.9889	0.9898	10
			M2	Linear	3.5413	20.435	0.9821	10
Huso huso	83.7–301.0	*parasphenoideum*	M1	Non-linear	8.9923	0.9319	0.9848	4
Acipenser gueldenstaedtii	90.1–188.8	*parietale*	M1	Linear	6.0064	-3.3276	0.9779	10
Acipenser gueldenstaedtii	90.1–188.8	*dentale*	M1	Non-linear	3.4726	0.9363	0.9793	10
			M2	Linear	15.399	7.3188	0.9903	10
Acipenser nudiventris	91.3–128.2	*dentale*	M2	Non-linear	23.894	0.6689	0.9676	3
Huso huso	83.7–301.0	*dentale*	M1	Non-linear	2.0972	0.9476	0.9858	4
			M2	Non-linear	12.536	0.9398	0.9927	4
			M3	Non-linear	21.603	1.008	0.9884	4
Acipenser gueldenstaedtii	90.1–188.8	*suboperculare*	M1	Linear	2.2758	16.456	0.9545	10
			M2	Linear	2.4807	10.932	0.9728	10
Acipenser gueldenstaedtii	90.1–188.8	*supracleithrale*	M1	Non-linear	1.0393	1.0899	0.9739	10
Acipenser gueldenstaedtii	90.1–188.8	*claviculare*	M1	Linear	3.2204	-3.8201	0.9757	10
Huso huso	83.7–301.0	*maxillare*	M1	Linear	19.663	0.5654	0.9734	4
Huso huso	83.7–301.0	*palatopte rygoideum*	M1	Non-linear	11.159	1.2535	0.9834	4
			M2	Non-linear	9.9349	0.8973	0.9829	4
Huso huso	83.7–301.0	*hyomandibulare*	M1	Non-linear	14.95	0.9366	0.9897	4
Huso huso	83.7–301.0	*cleithrum*	M1	Linear	44.624	-31.822	0.9891	4

Acipenser usually attain a size up to 2 m, while beluga sturgeons tend to grow even larger, up to 4–6 m (and even larger specimens have been documented) (Bănărescu 1964; Holčík 1989; Kottelat and Freyhof 2007; Svetovidov 1964). However, size reconstructions from their remains from the Danube Gorge sites have been hindered by a lack of reference material due to the sturgeons' disappearance from the Danube and other rivers of the Black Sea basin. Sturgeons had become rare in the Danube even before the dams effectively cut off their migratory routes, mainly due to overfishing and water pollution (Bartosiewicz *et al.* 2008; Lenhardt *et al.* 2014). Albeit most anadromous sturgeons are globally threatened due to the loss of spawning grounds, some Caspian Sea populations still migrate to the lower stretches of large rivers, most notably the Volga and Ural (Kottelat and Freyhof 2007). In this study, to determine the total length (hereafter TL) of the sturgeon specimens from Lepenski Vir, Padina, and Vlasac, we have applied the regression equations established from an osteological collection of recent sturgeons from the Volga-Caspian Basin.

Materials and methods

The material used in this study comprised sturgeon remains collected during the 1968–1970 excavations at Padina, from the partially preserved faunal assemblage from Lepenski Vir (1968–1970 campaigns), and from the revisory excavations (2006–2009) at Vlasac. Sturgeons constitute 19.2 percent (208 identified specimens, hereafter NISP) and 6.0 percent (155 NISP) of the identified fish remains in the fish faunal assemblages from Lepenski Vir and Padina, respectively (Živaljević 2017), collected by hand from settlement contexts (*cf.* Borić 2003, Appendix 3; Dimitrijević 2008). Their remains were fewer (161 NISP, or 1.2 percent) in the hand collected, water sieved and floated faunal sample from the new excavations of Vlasac (Dimitrijević *et al.* submitted; Živaljević 2017), which encompassed the peripheral part of the settlement (Borić *et al.* 2014). Previously, only sporadic comments on the size estimates of sturgeons from Padina were offered, based on the proportional method (Brinkhuizen 1986). Concerning the downstream sites, the size of sturgeons from Schela Cladovei has been estimated on the basis of the proportion of the greatest width of the articulation end of the first pectoral spine (*pinna pectoralis I*) and body length (Bartosiewicz *et al.* 2008).

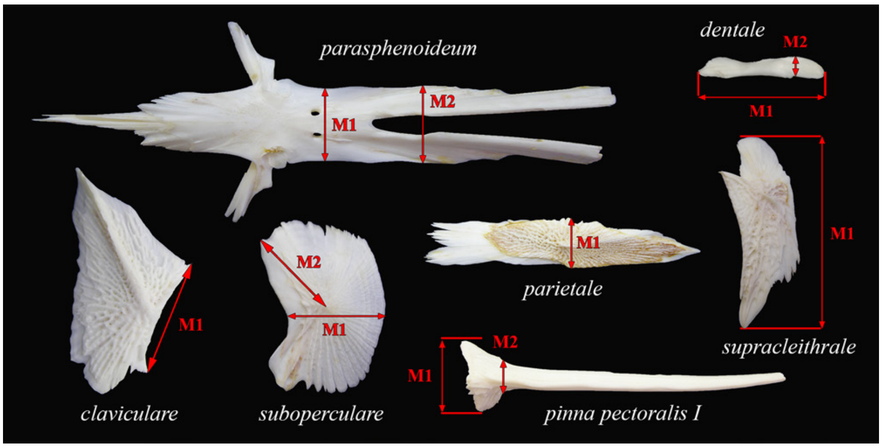

Fig. 63.2. Mesurements of selected *Acipenser gueldenstaedtii* elements. Images from the Biomonitoring Laboratory of the Institute of Problems in Ecology and Mineral Wealth, Kazan.

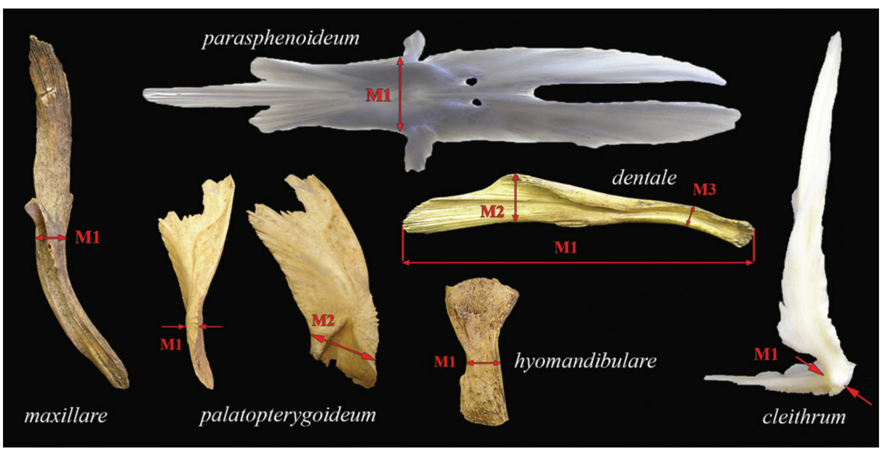

Fig. 63.3. Measurements of selected *Huso huso* elements. Images from the Biomonitoring Laboratory of the Institute of Problems in Ecology and Mineral Wealth, Kazan.

The analysis and size reconstructions of subfossil sturgeon remains from the Ponto-Caspian Basin have a much longer tradition. The first study was published by Nikolsky (1935), who estimated the size of specimens from archaeological sites in the Vetluga and Vyatka River drainages. This study was based on the ratio of dimensions (length and width of the articulation end) of the first pectoral spine and body lengths of recent Russian sturgeon and sterlet specimens. Later studies by Soviet ichthyologists (Lebedev 1960; Tsepkin and Sokolov 1970) were based on the assumption that there was a linear correlation between bone size and fish size. These authors utilized biometric data of modern specimens of known size, plotting them graphically with values of archaeological specimens and thus calculating their total lengths. Consequently, the proportional method has widely been used in size reconstructions of sturgeons from archaeological faunal assemblages (Casteel 1976 and references therein), including those from the Danube River Basin (Bartosiewicz *et al.* 2008; Bartosiewicz and Takács 1997; Brinkhuizen 1986; Radu 2003). Askeyev *et al.* (2013) first introduced the linear regression equation on the relationship between the width of the articulation end of the first pectoral spine and TL of Russian sturgeon specimens from the Volga Basin.

In this study, we have employed linear and power regression equations relating the measurements of selected ossified elements of beluga, Russian sturgeon, ship sturgeon, stellate sturgeon, and sterlet to their total lengths (Table 63.1). The equations were derived from the Biomonitoring Laboratory (Institute of Problems in Ecology and Mineral Wealth, Kazan) database of biometric data of individual elements and total lengths of recent sturgeon (19th–21st century) specimens from the Volga-Caspian Basin. Sturgeon remains from Lepenski Vir, Padina, and Vlasac have been measured with 0.1 mm precision, following schemes for species of the genus *Acipenser* shown in Fig. 63.2, and for beluga shown in Fig. 63.3.

Results and discussion

The results of size estimations of specimens from Lepenski Vir, Padina, and Vlasac are presented in Table 63.2. They suggest that predominantly large adult individuals were targeted. Most numerous were the remains of beluga, followed by those of Russian sturgeon, therefore the majority of measurable elements originated from these two species.

Estimated lengths of beluga specimens exhibited the most variability, ranging between 100.6–566.1, 96.7–498.3, and 148.9–376.0 cm at Lepenski Vir, Padina, and Vlasac, respectively (Table 63.2). The most frequent size class was between 200 and 350 cm, but exceptionally large belugas, surpassing 400 cm in TL were also caught (Fig. 63.4). The length of the largest specimen (estimated from a *cleithrum* found in the rear area of the Lepenski Vir settlement) measured *c.* 566 cm.

Estimated lengths of Russian sturgeon specimens from Lepenski Vir, Padina, and Vlasac ranged between 77.4–193.7 (Table 63.2), with the most frequent size class being between 100 and 150 cm. Few measurable elements of ship sturgeon, stellate sturgeon, and sterlet do not allow a precise assessment of the size classes targeted, but nonetheless originate from large adult individuals.

Cross-referenced with modern historical data, the estimated average lengths of Russian sturgeons from the Danube Gorges sites corresponded to those of individuals caught in the Danube in more recent times (*cf.* Bănărescu 1964; Holčik 1989). The length of a ship sturgeon specimen (215 cm), established on the basis of *dentale* measurements, almost reached the maximum length (221 cm) recorded in recent populations (*cf.* Sokolov and Vasil'ev 1989). Beluga sturgeons caught in the Mesolithic-Neolithic were as large as the largest modern specimens from the Black Sea basin, and their estimated average lengths were statistically greater than those recorded by twentieth century catches in the Danube (*cf.* Bănărescu, 1964; Bartosiewicz and Takács 1997; Holčik 1989). On the basis of the contextual

Table 63.2. Size estimations of sturgeon species from Lepenski Vir (LV), Padina (PA), and Vlasac (VL). NISP = number of identified specimens; n = number of measured specimens used in size reconstruction.

Site	Species	NISP	N	TL Range (cm)	Mean TL (cm)
LV	*Acipenser gueldenstaedtii*	54	21	77.4–193.7	135.2
	Acipenser nudiventris	4	1	215.0	215.0
	Acipenser ruthenus	9	2	73.3–76.2	74.8
	Huso huso	83	42	100.6–566.1	290.9
PA	*Acipenser gueldenstaedtii*	13	7	92.0–174.4	128.0
	Huso huso	72	31	96.7–498.3	293.8
VL	*Acipenser gueldenstaedtii*	10	1	171.2	171.2
	Acipenser stellatus	5	1	151.4	151.4
	Huso huso	27	5	148.9–376.0	271.4

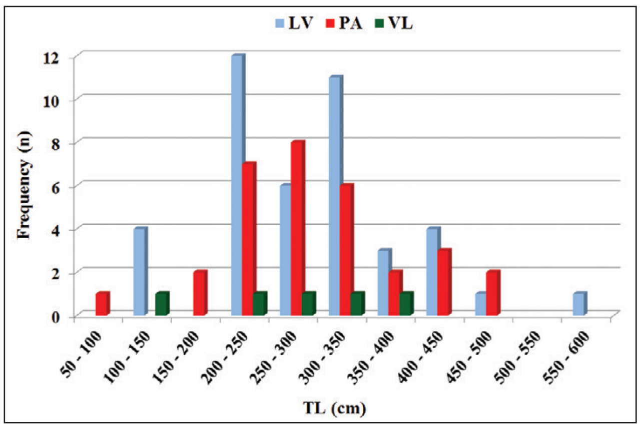

Fig. 63.4. Size classes of *Huso huso* specimens from Lepenski Vir (LV), Padina (PA), and Vlasac (VL).

provenance of sturgeon remains, which were related to Early Mesolithic (*c.* 9500–7400 cal BC), Late Mesolithic (*c.* 7400–6300/6200 cal BC), Mesolithic-Neolithic Transformation phase (*c.* 6300/6200–5900 cal BC), and Neolithic (c. 5900–5500 cal BC) occupations of the sites (*cf.* Borić 2011), it can be concluded that large sturgeon fishing represented a long-term local tradition.

Conclusion

The method for calculating the length of subfossil sturgeon specimens, established on the basis of biometric data of recent sturgeons from the Volga-Caspian Basin, provides a basis for reconstructing the size of specimens from faunal assemblages from other regions, where the species are no longer present and reference collections are inadequate or completely lacking. Consequently, this study represents the first application of linear and power regression equations in determining the total length of several sturgeon species that were encountered in the Danube drainage (*Huso huso*, *Acipenser gueldenstaedtii*, *A. nudiventris*, *A. stellatus* and *A. ruthenus*) from their skeletal remains. Size estimations of specimens from the Mesolithic-Neolithic faunal assemblages of the Danube Gorges are indicative of complex fishing strategies that were oriented towards large individuals, involving a great deal of planning, skill, cooperation, and a thorough knowledge of the landscape, fish habitats, and behaviour. Even if available during restricted times of the year, corresponding to their spring and autumn migrations, the impressive size of anadromous sturgeons, beluga in particular, probably made them an attractive prey and a significant dietary resource, and shaped perceptions of these large aquatic creatures.

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