



THE UNIVERSITY *of* EDINBURGH

Edinburgh Research Explorer

Sturgeon fishing in the Middle and Lower Danube region

Citation for published version:

Bartosiewicz, L, Bonsall, C & iu, V 2008, 'Sturgeon fishing in the Middle and Lower Danube region'. in C Bonsall, V Boronean & I Radovanovi (eds), *The Iron Gates in Prehistory: new perspectives*. BAR International Series, vol. 1893, Archaeopress, Oxford, pp. 39-54.

Link:

[Link to publication record in Edinburgh Research Explorer](#)

Document Version:

Publisher final version (usually the publisher pdf)

Published In:

The Iron Gates in Prehistory

General rights

Copyright for the publications made accessible via the Edinburgh Research Explorer is retained by the author(s) and / or other copyright owners and it is a condition of accessing these publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

The University of Edinburgh has made every reasonable effort to ensure that Edinburgh Research Explorer content complies with UK legislation. If you believe that the public display of this file breaches copyright please contact openaccess@ed.ac.uk providing details, and we will remove access to the work immediately and investigate your claim.



Sturgeon fishing in the middle and lower Danube region

László Bartosiewicz, Clive Bonsall & Vasile Şişu

Abstract: Migrating sturgeons were the largest fish in the middle and lower Danube region. Most of these species, however, have been brought to the brink of extinction by habitat loss and overfishing. This review is a synthesis of sporadic archaeological evidence, zoological and environmental data as well as ethnohistorical information in two regions: the Iron Gates at the southeast edge of the Carpathian Basin and the Hungarian section of the Danube within the basin. In addition to ichthyological and taphonomic questions, fishing techniques as well as the varying perceptions of these large fish are summarized in an attempt to draft a multidisciplinary interpretive framework for the archaeological evaluation of future finds.

Key words: sturgeon, Acipenseridae, fishing, weirs, Danube, Iron Gates, seasonality

Introduction

Sturgeon has become one of the most elusive animals in modern day fishing. Its osseous remains, decimated by taphonomic loss in archaeological deposits, yield relatively scarce evidence of their dietary role in past times. Their dwindling stocks, brought to the brink of extinction in the 20th century, are only a pale shadow of their economic importance until the recent past.

Over-exploitation, habitat loss and pollution have severely hit all 27 species in the Acipenserid family worldwide. Sturgeons, the largest fish in the Danube, were relatively common until dams were built in the Iron Gates section where the river forms the border between Romania and Serbia. The first dam (Iron Gates I) which became operational in 1971, was built where the Danube leaves the Iron Gates gorge, and effectively marks the divide between the middle and lower Danube. The dam was designed in part to improve navigation through the 130 km long gorge section, where the Danube (prior to impounding) was characterized by strong currents, rapids and exposed rocks that were hazardous to shipping. The second dam (Iron Gates II), operational in 1984, is located 80 km downriver, 875 km from the river's mouth. The dams effectively cut off the migration route of endangered beluga sturgeon and other anadromous fish in all major sections of the Danube, as reviewed at the 1994 International Conference on Sturgeon Biodiversity and Conservation in New York (Bacalbaşa-Dobrovici 1997; Hensel & Holčík 1997).

Against this background, reconstruction of ancient sturgeon fishing becomes a truly multidisciplinary task:

1. Ichthyoarchaeological finds offer evidence of which species were targeted.
2. The palaeohydrological reconstruction of riverine habitats helps in identifying locations where sturgeon fishing may have taken place.
3. Familiarity with fish behaviour points to seasons when migrating sturgeons were most easily caught.
4. Historical accounts describe techniques by which sturgeons were caught.
5. Ethnohistorical records reveal attitudes toward these great fish as food as well as symbols.

Although the disciplinary boundaries between these areas of research often overlap, this list is intended to provide an interpretive framework for archaeologists interested in any period, touching upon the complex interactions between nature and society as reflected in sturgeon fishing.

Our research hypothesis is that it should be possible to outline geographical locations as well as seasons when the probability of catching various species of sturgeon was increased. These parameters should correspond to and complement the scanty archaeological evidence for these important fish.

This overview of zooarchaeological, documentary and ethnohistorical evidence of sturgeon fishing in the middle Danube region represented by two contrasting sections of the river, in Hungary and the Iron Gates (Fig. 1), is also aimed at interpreting ichthyoarchaeological data within a broader, culture-historical context.

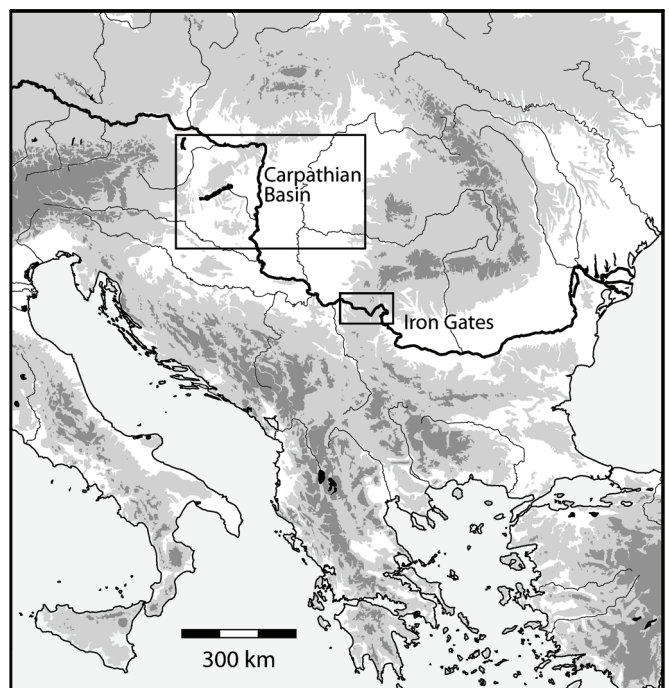


Figure 1. The Danube Valley in Europe and areas discussed in this study (see also Figures 7–8).

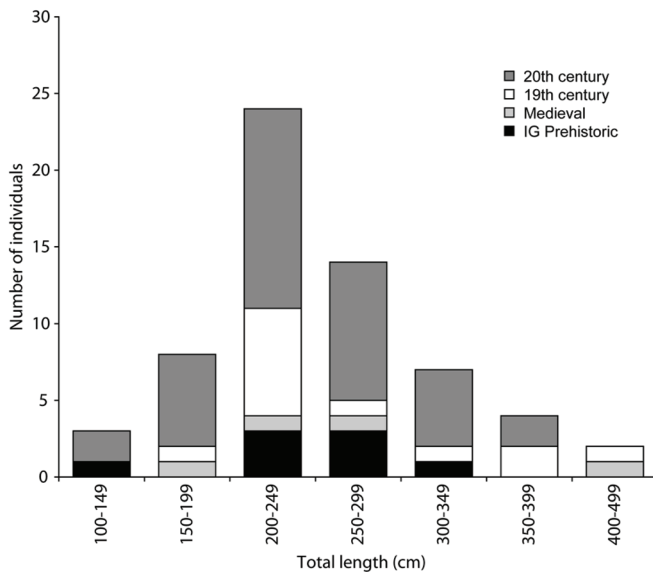


Figure 2. Lengths of Danubian sturgeon in the historical record (Hungary) and by prehistoric estimates (Iron Gates).

Ichthyoarchaeological data

This study is built around the osteological evidence for sturgeon from the Danube. Sturgeon remains recovered from archaeological sites are discussed in terms of taxonomic identifiability and taphonomic bias, as well as possibilities of size reconstruction.

The Romanian–British excavations (1992–1996) at the Late Mesolithic and Early Neolithic settlement of Schela Cladovei (Romania) 7 km downriver from the Iron Gates I dam brought to light 139 sturgeon bones, mostly identifiable only to family level (Table 1). These remains have been recovered by water sieving from several features, located on one of the river’s terraces, near the present day riverbank. Although these numbers of sturgeon bones may seem modest, given the sample size of hand-collected bones at this site (Bartosiewicz *et al.* 2001: 16, table 1) and others in the region they may be considered relatively high. Of the skeletal re-

mains represented in the Schela Cladovei assemblage, dorsal and lateral scutes as well as pectoral fin rays could, to some extent, be identified to species. Osseous elements from small but mature individuals could be assigned to sterlet on the basis of size.

The first (i.e. most cranially located) pectoral fin ray is well developed and has been used in osteometric analyses of common sturgeon by Desse-Berset (1994: 84). The mediolateral width of this bone in beluga sturgeon (Bartosiewicz & Takács 1997: 12, fig. 8/1) has also been used in size estimations in the present paper. Greatest lengths of the Schela Cladovei sturgeons were estimated as shown in Table 2.

When plotted together with modern, historical data (Khin 1957), the distribution of these estimated lengths largely corresponds to that of the largest specimens from historical periods (Fig. 2). The latter display a slight positive skew, and the distribution of the prehistoric specimens is within the same range, suggesting that randomly caught prehistoric sturgeons were as large at Schela Cladovei as the largest modern specimens in Hungary. While, owing to the small number of cases no significant difference can be observed between the two groups, the Schela Cladovei sturgeons were indubitably large. Sporadic records of the amount of meat some record animals represented (Table 3) indicate that approximately two-thirds of the live weight estimated for large prehistoric sturgeons represented edible protein, and other lines of evidence show that fish were the major source of animal protein in the diet of the Mesolithic inhabitants of Schela Cladovei (Bonsall *et al.* 1997, 2000).

Ichthyorachaeological research has shown early signs of overfishing common sturgeon (*Acipenser sturio* Linné 1758) in the southern Baltic region (Benecke 1986: 16, fig. 1) at archaeological sites in Gdańsk, Poland (10th to 13th century AD) and Ralswiek, Germany (8th to 12th century AD). Osteometric data show that these sturgeons were at least larger than the 1.4 m long modern reference specimen available to that author (Benecke 1986: 17, fig. 2).

Recent sturgeon sizes in the Danube are also worth considering. Aside from a random element (fishermens’ luck), the frequency and actual size of the largest individuals landed

Table 1. Sturgeon bones from Schela Cladovei.

	Mesolithic			Early Neolithic	
	Acipenserid	Russian Sturgeon	Sterlet	Acipenserid	Sterlet
frontale				3	
parashenoideum	5				
praemamillo-maxillare	1				
dentale	1				
praeoperculare	1		1		
operculare	1				
cleithrum	10		1	2	1
dorsal scute			1		1
lateral scute	5	2	3		3
pectoral fin ray	7		2	2	
dorsal/anal fin ray	2			1	
flat bone	75		2	6	
Total number	108	2	10	14	5
Find weight (g)	287.5	2.4	8.2	63.6	2.2

Table 2. Length and weight estimates for prehistoric sturgeons from Schela Cladovei.

Period	GW fin ray (mm)	Estimated length (m)	Estimated live weight (kg)
Mesolithic	24.4	1.44	28.2
Mesolithic	36.4	2.15	72.8
Mesolithic	43.3	2.56	110.1
Mesolithic	50.0	2.95	154.0
Neolithic	37.5	2.21	77.7
Neolithic	42.0	2.48	102.1
Neolithic	44.1	2.60	114.2

Table 3. The meat output of some record sturgeons from Hungary.

Year	Location	Live weight (kg)	Carcass weight (kg)	Live weight (kg)
1922	Gemenc	90	70	70.0
1957	Paks	138	100	72.0
1987	Paks	181	100*	55.2*

* Pure meat with spine but without skin

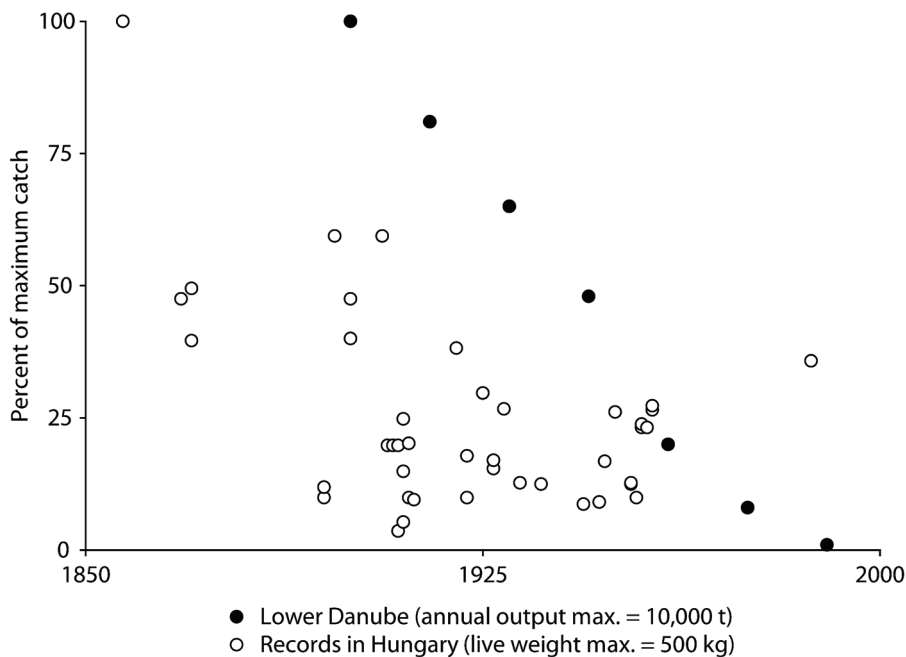


Figure 3. Diachronic temporal decline in gross sturgeon catch in Romania and in the size of record sturgeon in Hungary.

depends on the reproductive capacity and growth characteristics of fish stocks (Miranda *et al.* 1987: 219). Since 1800, an estimated 1.84 kg average annual decrease in record sturgeon body weights was found to be statistically significant (Bartosiewicz & Takács 1997: 9). This decrease is paralleled by a decline of the overall weight of sturgeons landed in Romania (Fig. 3).

The unusually large, 181 kg specimen caught at Paks (Hungary) in 1987 (Fig. 4), nearly two decades after the closure of the Iron Gates 1 dam (Pintér 1989: 24), may have attained this respectable size after having been trapped upstream, behind the dam.

Sturgeon taxonomy

In spite of the difficulties of identification at a species level in this family of fish, the body dimensions as well as skeletal variability among, and habitat preferences of, Acipenserids are worth considering. Appraising these parameters is of help in defining ranges within which archaeological finds can be better understood.

Sturgeons (Acipenseriformes) are large (80–600 cm), late maturing (almost 25 years for some females) fish of concomitant longevity. They inhabit coastal sea waters, rivers and lakes, mostly within a latitudinal range from 30–70° N

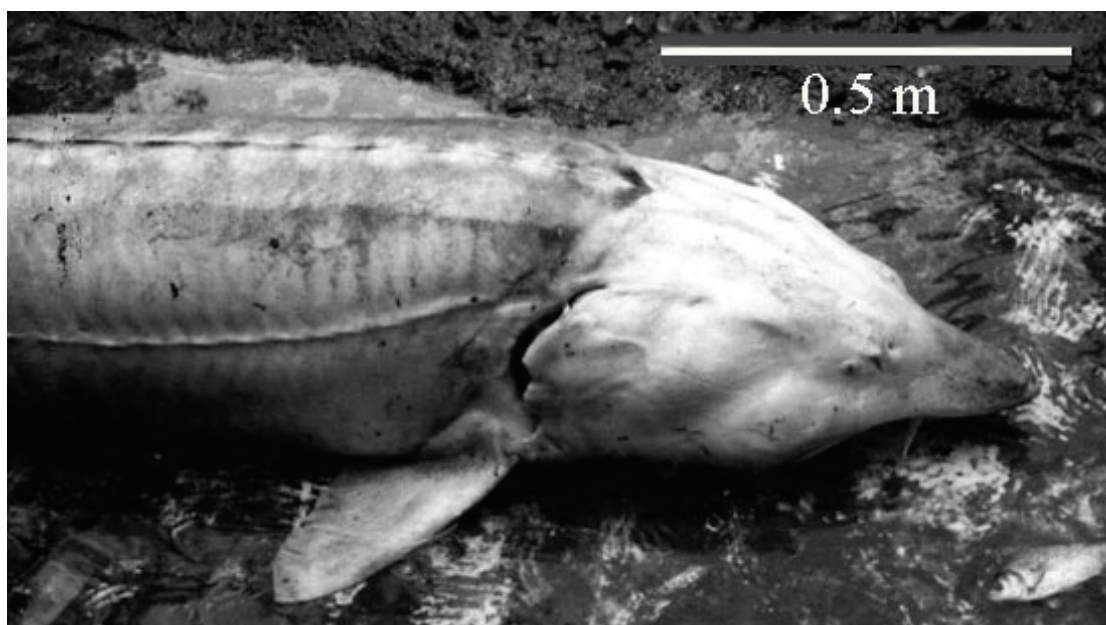


Figure 4. Sturgeon, weighing 181 kg, caught at Paks (Hungary) in 1987. Photo: István Takács.

Table 4. Characteristic dimensions of Danubian sturgeons.

Species		Total length (m)	Live weight (kg)
Beluga sturgeon	<i>Huso huso</i> Linné 1758	2–3 (max. 10)	80–100 (max. 1000)
Common sturgeon	<i>Acipenser sturio</i> Linné 1758	1.5–2.5 (max. 3.5)	70–100 (max. 320)
Russian sturgeon	<i>Acipenser gueldenstaedti</i> Brandt 1833	2–2.5	80–100
Ship sturgeon	<i>Acipenser nudiventris</i> Lovetzky 1828	2	40–50
Stellate sturgeon	<i>Acipenser stellatus</i> Pallas 1771	1.5–2	30–50
Sterlet	<i>Acipenser ruthenus</i> Linné 1758	1–1.2	15–16 (max.)

(Hankó 1931: 9). They feed on small animals, including molluscs, crustaceans and small fishes (anchovies, sprats, gobies) as well as plants, and are anadromous, i.e. migrate up-river to breed and spawn. Because of this migratory behaviour, Luigi Ferdinando Marsigli, an 18th century military engineer surveying the lower Danube valley, classified beluga sturgeons as *fluviatiles marini*, marine fish that live in rivers (Marsigli 1726). Systematic work on the complex taxonomy of sturgeons began relatively recently (Berg 1904).

As with the archaeological record, most historic references to sturgeon are vague as to species identification. This is related to the fact that some sources not only predate Linnæan nomenclature, but the living fish species are also often difficult to tell apart. This is, to some extent, a consequence of natural hybridization. The main dimensions of species relevant to this study are summarized in Table 4. The large species central to this study include beluga sturgeon, Russian sturgeon, ship sturgeon and stellate sturgeon (Fig. 5).

Occurrences of common sturgeon have been reported from the Danube only relatively recently. According to Antipa (1905) these fish spawn on the sandy sea bottom before the Danube estuary. Some distribution maps (Muus & Dahlström 1965: 63, fig. 26; Terofal 1971; Vuković & Ivanović 1971: 111; Wheeler 1978: 56; Müller 1983: 123, fig. 28) suggest that it does live in the Danube. Other sources,

however, assert that common sturgeon is a fish of the Atlantic/Baltic region (Maitland & Linsell 1978: 78; Curry-Lindahl 1985: 230). This species certainly has not been recorded in the Hungarian section of the Danube (Berinkey 1966: 17; Pintér 1989: 24), and a reference to its occurrence in Transylvania has also been questioned by Hankó (1931: 9). Although common sturgeon was mentioned in the discussion of ‘Neolithic’ Padina (Clason 1980: 167), that faunal list only contains the item ‘*Acipenser* sp./*Huso huso*’ (Clason 1980: 149).

Sterlet is the smallest Acipenserid in the region. It is not anadromous, having adapted to freshwater conditions. Owing to its smaller size and behaviour it falls beyond the focus of this paper.

Osteology and taphonomy

The selective survival of different animal remains has a direct bearing on archaeological interpretations. Studying the *post mortem* history of excavated bone is indispensable for the critical understanding of archaeozoological assemblages. Taphonomic analyses must be based on familiarity with the original, complete skeleton. Interspecific comparisons between morphologically similar Acipenserid species are made difficult by at least two skeletal characteristics of these fish:

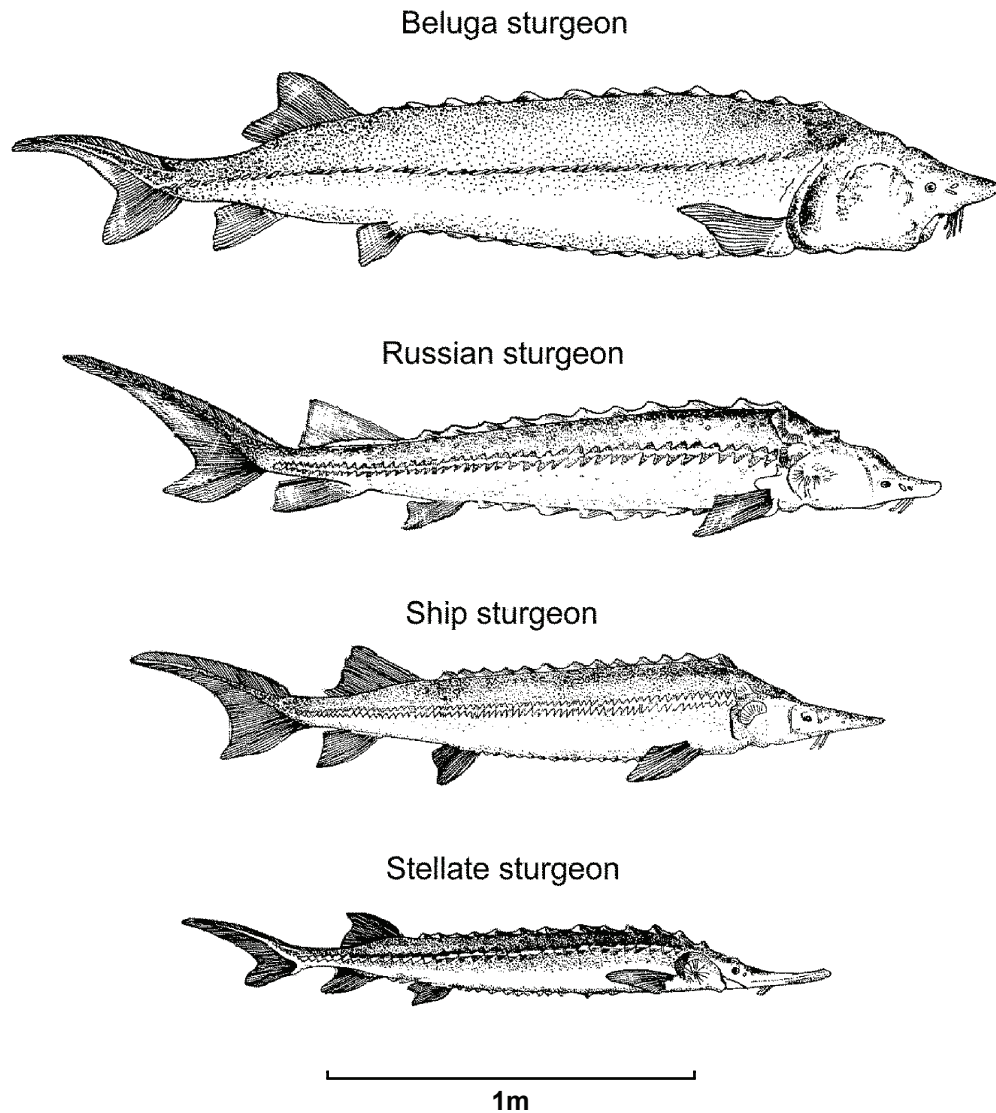


Figure 5. Sturgeon species of major importance in the Danube, drawn to scale on the basis of mean lengths in Table 4 (compiled and redrawn to scale after Berinkey 1967 and Pintér 1989).

1. The sheets of dermal bone covering the head of Acipenserids tend to be numerous and irregular in shape to such an extent that they may even be strongly asymmetric within the same individual.
2. While bones from large fish would more likely be recovered, their survival is poorest in old Acipenserids (especially beluga sturgeon), whose skeleton reabsorbs minerals with the advancement of age. Thus, the largest bones tend to be most easily destroyed or eroded beyond recognition in archaeological deposits.

Brinkhuizen (1986) reviewed differences between the usually resistant and morphologically most characteristic dermal scutes of beluga and Russian sturgeons from the Iron Gates. The dorsal scutes of beluga sturgeon are oval in shape with an elongated, horn-like process. In mature individuals, these scutes are covered by skin. The lateral scutes of beluga sturgeon are toothed. In old individuals, they are partially reabsorbed and develop a spongy, eroded look.

The dorsal scutes of common and stellate sturgeon display a more marked morphological difference. These bones are almond-shaped with roof-like cross-sections. The medial

edge of the 'roof' is largely symmetric in common sturgeon, while it is slightly skewed in a cranial direction in stellate sturgeon giving it a rose-thorn profile line. A strong radial pattern is also characteristic of stellate sturgeon. In other Danubian Acipenserids, even this character looks transitional between the two morphological extremes.

It is chiefly large and compact dermal scutes with characteristic surface patterning that show up even in hand-collected assemblages, which otherwise contain few fish remains. These scutes are arranged in dorsal, lateral and ventral rows along the body of sturgeons and differ both in size and shape by anatomical location (Casteel 1976: 38, fig. 19).

According to Berinkey (1966: 18–22), Vuković & Ivanović (1971: 106–112), Pintér (1989: 24–31) and a review of nine authors by Brinkhuizen (1989: 41), the number of dermal scutes and fin rays varies between the discussed species as shown in Table 5 and Figure 6. As is shown by these data, dermal scutes not only form continuously changing rows on individuals of varying sizes, but also their numbers differ by species which makes their quantitative analysis a nightmarish enterprise.

Table 5. The number of some skeletal elements in Danubian Acipenserids.

Species		Fin rays		Scutes			Branchio-spinae
		dorsal	anal	dorsal	lateral	ventral	
Beluga sturgeon	<i>Huso huso</i> Linné 1758	62–73	28–41	9–17	37–53	9–12	17–31
Common sturgeon	<i>Acipenser sturio</i> Linné 1758	31–43	22–27	9–16	24–39	9–14	18–25
Russian sturgeon	<i>Acipenser gueldenstaedti</i> Brandt 1833	33–51	21–33	5–19	24–50	14–16	15–31
Ship sturgeon	<i>Acipenser nudiventris</i> Lovetzky 1828	45–57	23–37	11–17	50–74	11–17	24–36
Stellate sturgeon	<i>Acipenser stellatus</i> Pallas 1771	40–46	24–29	9–16	26–43	9–14	24–26
Sterlet	<i>Acipenser ruthenus</i> Linné 1758	37–54	19–31	12–17	57–71	10–19	16–21

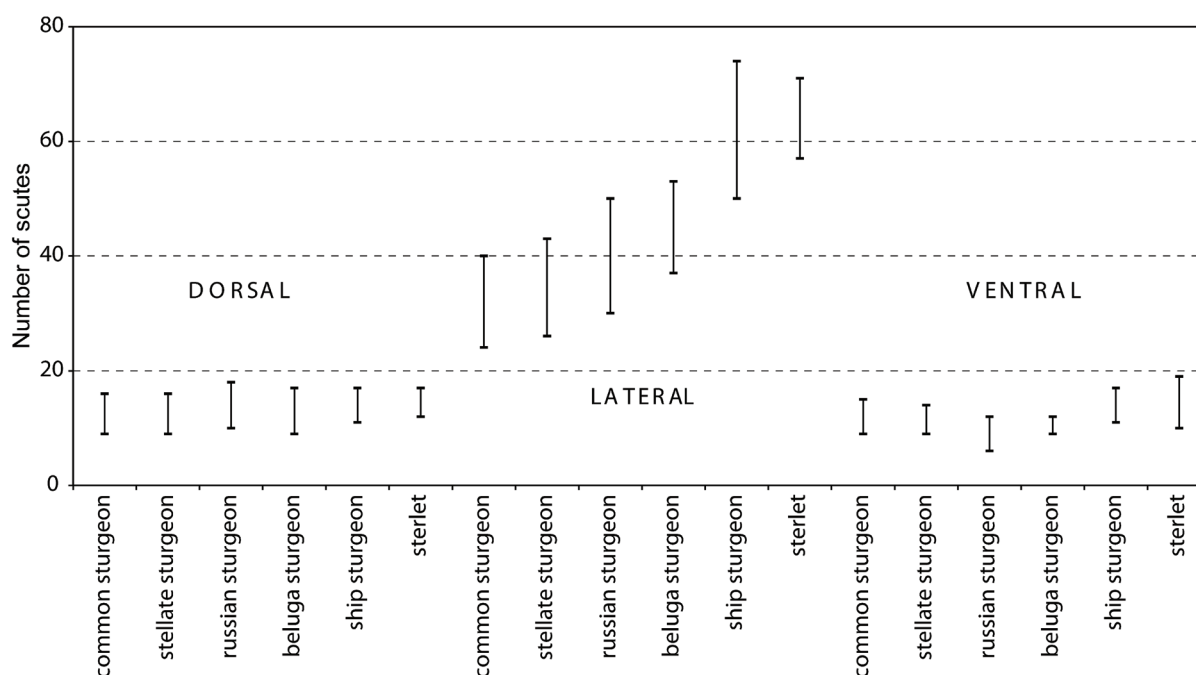


Figure 6. Variability in the number of dermal scutes in Danubian acipenserid species.

Habitat reconstruction

The presence/absence of sturgeon bones at archaeological sites is not only a matter of preservation. It may be presumed that, at least in prehistoric times, primary butchery of large sturgeon took place near where the fish was landed. The Schela Cladovei finds on a low-lying terrace of the Danube are indicative of this tendency. In later periods, carcass dismemberment may have taken place away from where the fish was pulled ashore, at markets or high status sites of consumption.

Prehistoric findspots (Fig. 7) as well as historically recorded catch sites (Fig. 8) suggest that understanding habitat preferences of sturgeon may point to locations where they could be caught most efficiently — information whose intimate knowledge was essential to fisherfolk throughout the millennia.

Water properties

Anadromous Acipenserids migrate into rivers for spawning: for this purpose they need deep, well aerated waters with a hard, preferably sandy or rocky substrate. Geographical latitude/climate, distance upstream from the river’s mouth,

and variation in discharge rate affect the abundance and distribution of anadromous fish populations (Schalk 1977).

The quantity of oxygen dissolved in water (y mg/l) is a function of current speed (x_1 m/s) and water temperature

$$\begin{array}{lll}
 x_1 = \text{speed of current:} & y = 1.953x + 1.984 & r = 0.943 \\
 x_2 = \text{temperature:} & y = -0.221x + 13.669 & r = -0.979
 \end{array}$$

(x_2 °C). On the basis of empirical data published by Pénczes and Tölg (1977: 327, table 4) as well as Harka (1993) this relationship was expressed using the following regression equations by Bartosiewicz & Bonsall (2004: 263):

The regression coefficients express the idea that every additional 1 m/s in water velocity increases dissolved oxygen content by almost 2 mg/l in rivers, while a 1 °C rise in temperature would result in a 0.2 mg/l loss. This is why oxygen-loving sturgeons seek rapid rivers during the spring for

sterlet (<i>Acipenser ruthenus</i> Linné 1758)	3.0–3.5 mg/l
pikeperch (<i>Stizostedion lucioperca</i> Linné 1758)	2.0–3.0 mg/l
tench (<i>Tinca tinca</i> Linné 1758)	0.7 mg/l

spawning, and why water temperature is of decisive importance in the timing of their migration. The minimum requirements of dissolved oxygen by three characteristic freshwater

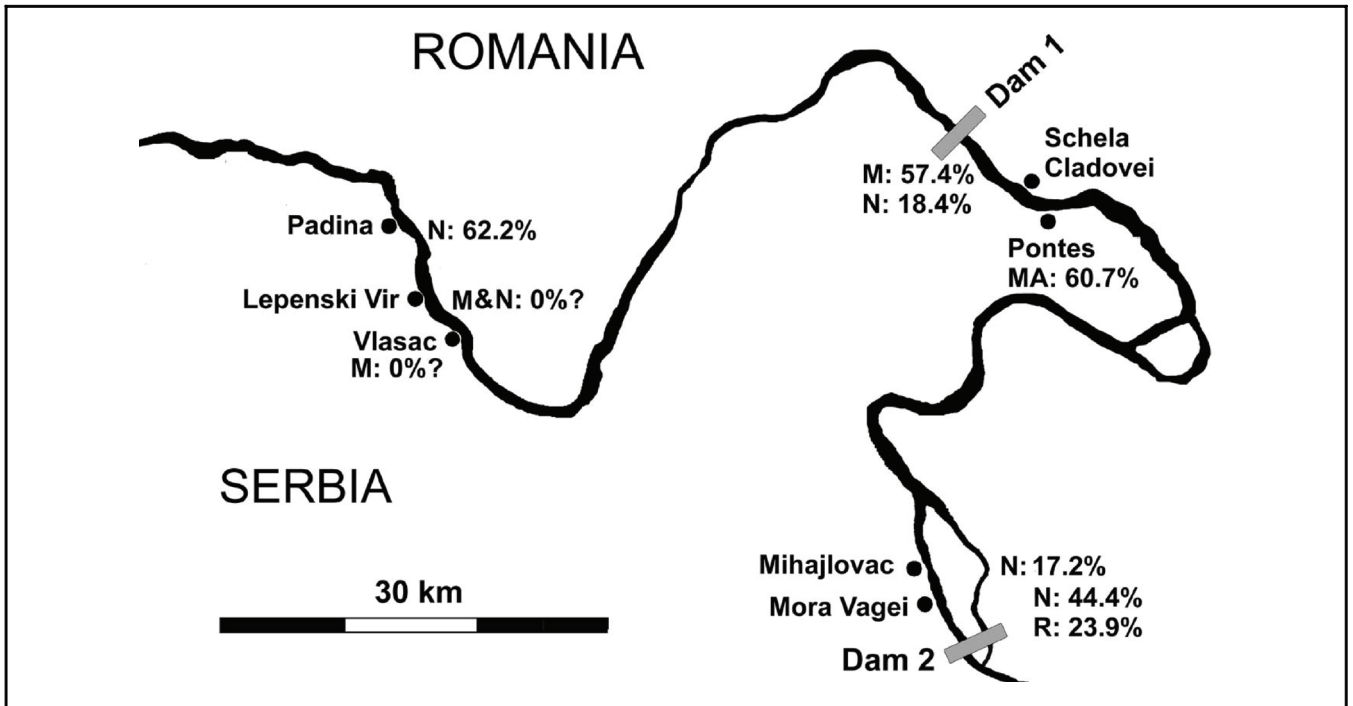


Figure 7. Archaeological sites and sturgeon bone finds in the Iron Gates gorge section of the Danube.

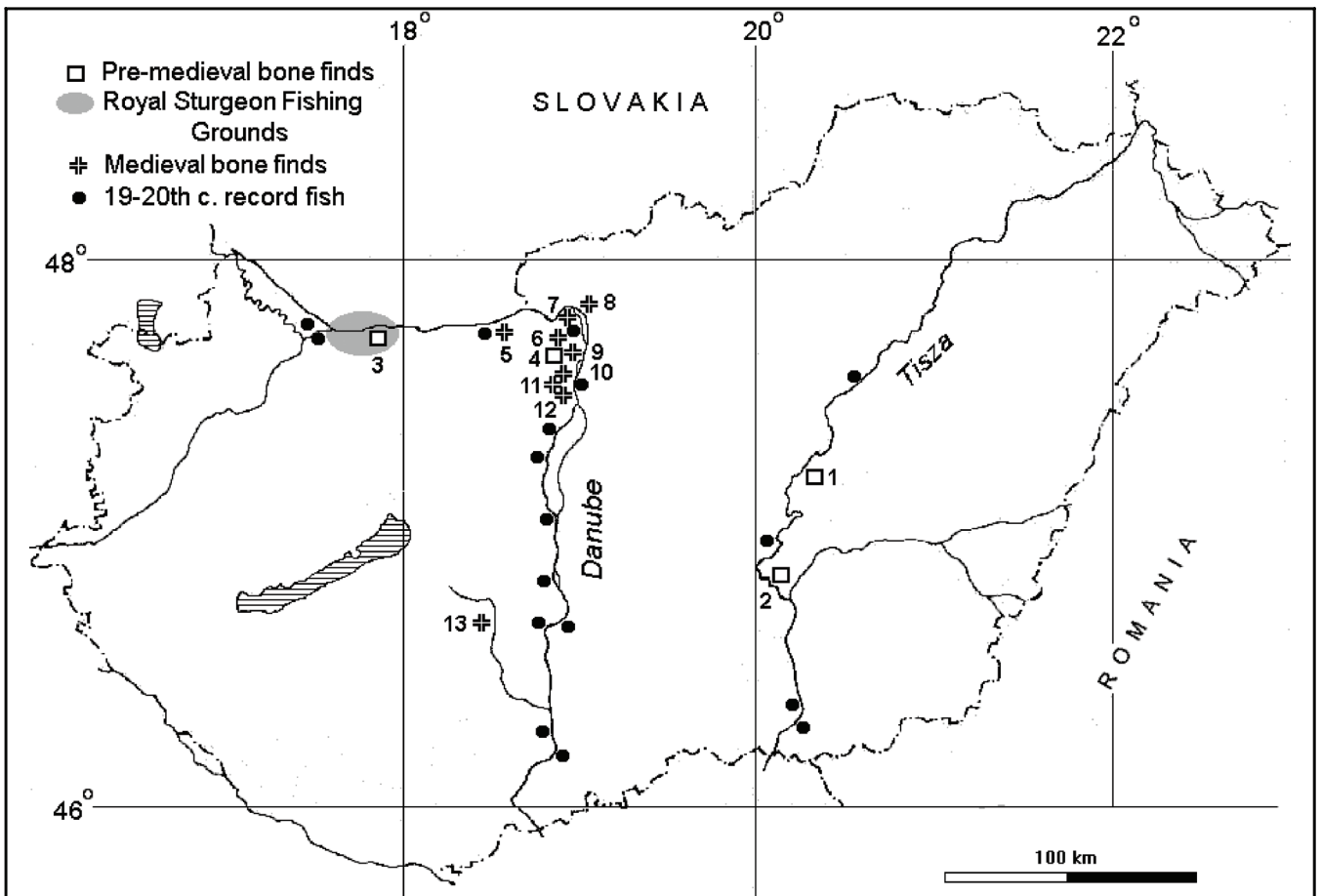


Figure 8. Archaeological sturgeon finds and the occurrence of 19–20th century record specimens (full circles) in present-day Hungary. Archaeological site codes: 1=Tiszaöldvár (prehistoric), 2=Tiszaug (prehistoric), 3=Ács (Roman period), 4=Szentendre, 5=Esztergom, 6=Pilisszentkereszt, 7=Visegrád, 8=Vác, 9=Szentendre, 10–12=Buda Castle, 13=Sárszentlőrinc.

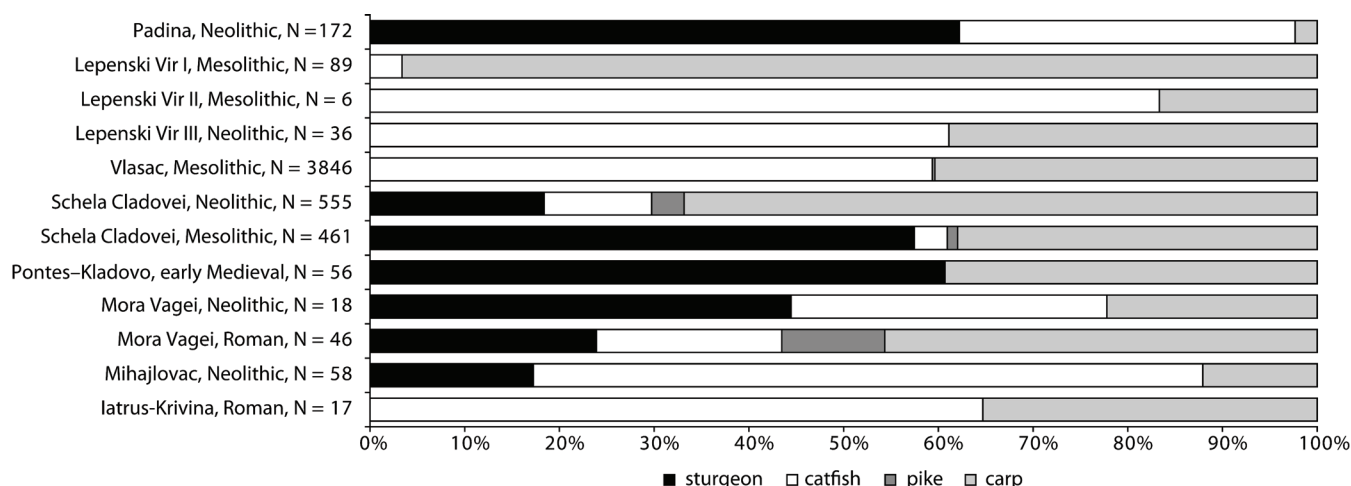


Figure 9. The relative frequency of sturgeon bones in hand-collected fish assemblages along the Iron Gates section of the Danube (after Bartosiewicz & Bonsall 2004: 266).

fish species are as follows (Pénzes & Tölg 1977: 327):

Although sterlet is not an anadromous species, it clearly illustrates the highest requirement of dissolved oxygen of Acipenserids in this comparison. As the speed of the river is greater towards its source (and its temperature tends to decrease with increasing altitude), the further upstream sturgeons move, the better the circumstances for spawning. Aeration parameters were summarized by Harka (1993). From the tabulated summary of his data it is evident that foothill and lower foothill river sections with 3.0 to 4.0 mg/l of dissolved oxygen would provide ideal spawning grounds for sturgeons (Bartosiewicz & Bonsall 2004: 263, table 4).

Even during the 20th century, beluga sturgeons as heavy as 900 kg used to be caught by the Donji Milanovac fishermen inside the Iron Gates gorges. Naturally, the distribution of such spots varies with the discharge along a river as determined by climate and topography.

The *c.* 2300 m³/s average discharge of the Danube at Budapest more than doubles to over 5600 m³/s in the Iron Gates gorge. Before the construction of the Iron Gates 1 dam, this *c.* 130 km long section of the Danube was characterized by extreme changes in water levels. Minimum discharge was 1400 m³/s, while 16,000 m³/s values were also measured (Băncilă *et al.* 1972: 9). Moreover, prior to dam closure, the riverine environment of the Iron Gates gorges was characterized by strong currents, hard substrates, and was rich in nutrients, aquatic plants, insects and invertebrates (e.g. Gammaridae and Corophiidae sp.) that sustained rich and varied fish resources. Thus, this section of the Danube provided an ideal habitat for large sturgeons as well as sterlet.

Topography and changes in riverbed gradient

The river was confined to a width of only 170 m in the Khazan gorge. As is shown by the pre-regulation measurements of the river from 1872 (Bartosiewicz & Bonsall 2004: 265, fig. 6), depths varied tremendously, between 0.5 and 50 m before the river exited to the plain. In the lower part of the Iron Gates gorge, upstream from Schela Cladovei (near Turnu-Severin) in Romania, the riverbed has a very steep gradient, falling 8 m in only 20 km. By contrast, over the 935 km between Schela Cladovei and the Black Sea, the riverbed declines overall by only 34 m (Giurescu 1964: 101).

Thus the net gradient is three orders of magnitude different (40% vs 0.037%) not to mention the considerable differences in topography and relief between these two sections of the Danube valley.

Lake sturgeon in Canada spawn in rivers at depths of *c.* 0.5–5 m, in areas of swift water or rapids at the foot of low falls that slow down further migration (Needs-Howarth 1996: 149). Given the mass movement during the spawn run, such places must have been packed with sturgeons of all sorts in the Iron Gates gorge as well, making them increasingly vulnerable to human predation at these natural traps.

This possibility seems to be supported by the differential proportion of sturgeon bones to those of other large fish in hand-collected archaeozoological assemblages from sites at different locations within the Iron Gates (Fig. 9; Bartosiewicz 1996, 1997). The Late Mesolithic/Early Neolithic site of Schela Cladovei, located downstream from the rapids, prior to dam construction marked the exit from the Iron Gates gorge, and must have been one of the ideal fishing spots where great numbers of migrating fish could be targeted.

The reported absence of sturgeon bones at the prehistoric sites of Lepenski Vir and Vlasac raises the question of author-related bias: the bones were identified by Sándor Bökönyi, a leading expert in mammalian osteology. Did some of the large 'catfish' bones identified by Bökönyi (1969, 1978) originate from sturgeon? However, if nothing else, the ornate head bones and unmistakable dermal scutes of sturgeons would surely have attracted his attention since they can be most easily recognized in excavated assemblages (Desse & Desse-Berset 1992); Bökönyi himself identified sturgeon remains at the Neolithic site of Mihajlovac-Knjepiste (Bökönyi 1992: 79). More recent work suggests that Acipenserid bones did occur on sites upstream from Schela Cladovei, including sites within the Iron Gates gorges. Borić & Dimitrijević (2005) have reported sturgeon (beluga) bones from the floors of some of the trapezoidal buildings at Lepenski Vir. In addition to sterlet, commonly represented at prehistoric sites along the Danube in Romania, remains of great sturgeon (beluga) were also reported from the Epipalaeolithic sites of Ostrovul Banului and Icoana. Bones of Epipalaeolithic Russian sturgeon were also identified at Cuina Turcului (Păunescu 2000: 342). In the time of the

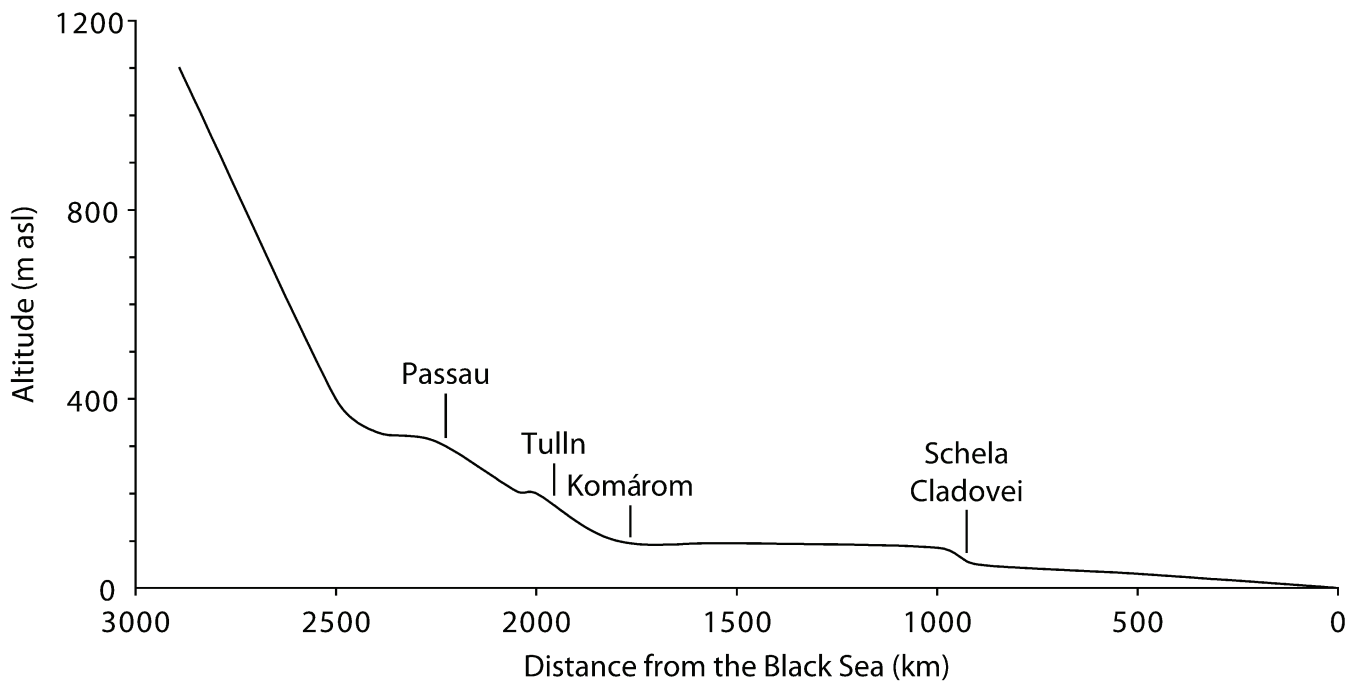


Figure 10. *Schela Cladovei and major sturgeon catch sites along the Danube.*

Boian and Gumelnița cultures, anadromous sturgeons were also caught at sites along the lower Danube, notably Borduşani, Hârsova and Isaccea (Radu 1997, 2003).

When some historically renowned sturgeon fishing grounds are plotted along the entire section of the Danube (Fig. 10), many of them pinpoint locations downstream from reaches with a steep gradient in the riverbed (large sturgeon were regularly caught at Tulln, upstream from Vienna, and a 1692 record is known from Bavaria).

In addition to the river's gradient, changes along its course also created opportunities for sturgeon fishing. Until the mid-19th century, the Danube meandered through floodplains and wetlands, shifting its course with each spring flood. Fish turned such marshes, e.g. around Szentendre, north of Budapest, into rich hatcheries.

In the plains, the variable course of the river resulted in underwater shoals, fords, smaller and larger islands that all influenced currents and created spots where sturgeons could be caught more easily. In 1690, "50–100 sturgeons were caught and butchered daily" at the island of Ada-Kaleh, downstream from Orşova in the Iron Gates (Marsigli 1726). Plotting the catch sites of 19th–20th century record specimens on the map of present-day Hungary (cf. Fig. 8), the horizontal patterning appears more homogeneous, although confluences with tributaries and major river bends seem to be indicative of good sturgeon fishing grounds.

Sturgeon were regularly caught in many of the Danube's tributaries, including the Váh, Maros and Tisza rivers (Hankó 1931: 9). In the latter, sporadic prehistoric bone finds as well as modern records (Bartosiewicz 1999) confirm Hankó's statement (cf. Fig. 8). In 1518, following a long medieval tradition, the city of Komárom in northern Hungary was given the rank of Royal Sturgeon Fishing Grounds (Herman 1980: 267). This strategically important point is located at the confluence of two branches of the Danube, downstream from

Europe's largest inland river delta where sturgeon were already caught in Roman times (Bartosiewicz 1989: 611). The monopoly of Komárom fisherfolk can still be detected in the 18th century, when they let sturgeon fishing rights from as far as the Tisza river between Tiszacsege and Tiszafüred (Bencsik 1970: 98).

The mouth of a small left bank tributary of the Danube, across from the northern tip of Margaret Island in Budapest, is called 'Sturgeon Catcher', another indication that such natural topographic features were exploited in sturgeon fishing.

Sturgeon shoals thinned out as the river was regulated and walled off from the floodplain (Woodard 2000). Large-scale commercial navigation along the Danube also had a negative impact as it became necessary to keep the riverbed clean of sand and gravel deposits. By the mid-20th century, beluga sturgeon seldom swam upstream beyond the Iron Gates.

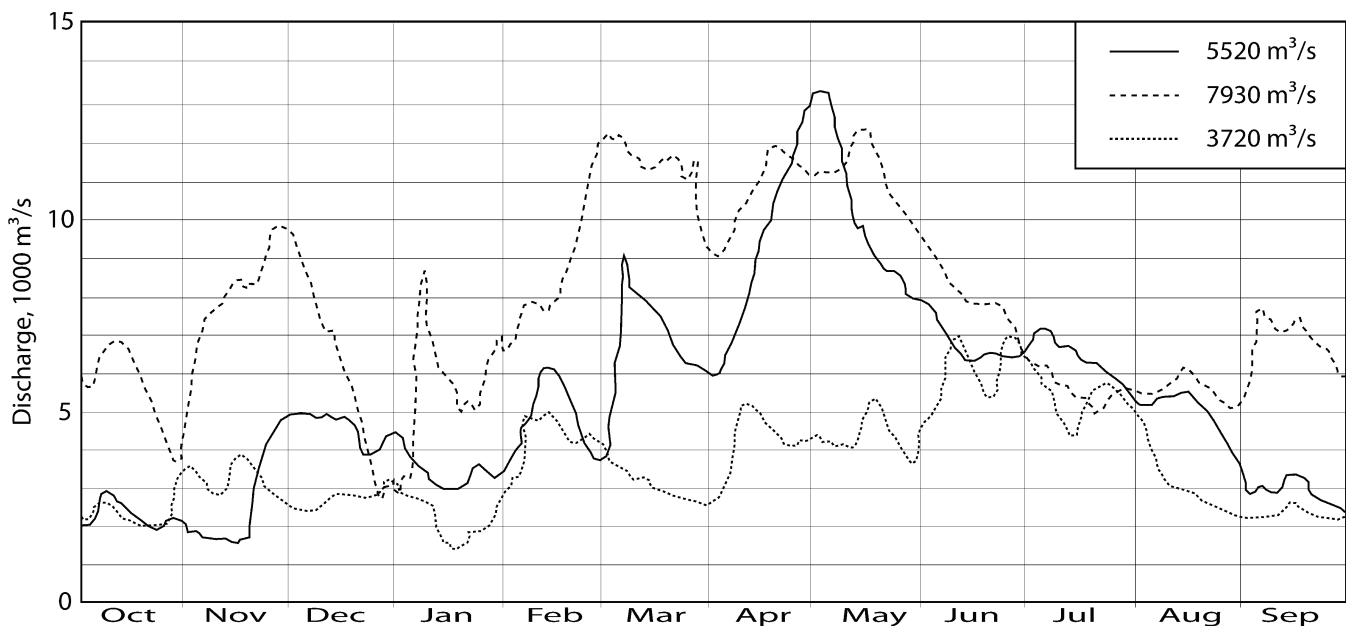
Sturgeon behaviour

Sturgeons may live for up to a 100 years. Male beluga sturgeons become sexually mature by the age of 12 years. Females usually start spawning at 18 years (Deckert 1967: 66). Prior to sexual maturity, Acipenserids approach the coastal areas of the Black Sea. Following a short period of adaptation, they start moving upstream into the rivers. From that point onwards, patterns of migration and seasonality directly influenced the success of sturgeon fishing inland.

Some stocks already begin to move into the Danube delta in September–October. Others begin the spawning run in the sea in March–April. By late summer, young sturgeons move into the lower Danube. They reach sexual maturity by next spring (Table 6). The arrival of these immature individuals, as well as their prolonged presence in rivers seems to indicate

Table 6. Spawning parameters of various sturgeon species in the Danube (Berinkey 1966).

Species		Spawning time	Water temperature
Beluga sturgeon	<i>Huso huso</i> Linné 1758	March–May	9 °C
Common sturgeon	<i>Acipenser sturio</i> Linné 1758	April–May	8–18 °C
Russian sturgeon	<i>Acipenser gueldenstaedti</i> Brandt 1833	April–May	10–17 °C
Ship sturgeon	<i>Acipenser nudiiventris</i> Lovetzky 1828	April–June	—
Stellate sturgeon	<i>Acipenser stellatus</i> Pallas 1771	April–June	10–17 °C
Sterlet	<i>Acipenser ruthenus</i> Linné 1758	April–June	12–17 °C

**Figure 11.** Seasonal variations in river discharge in the Iron Gates in 'characteristic years' prior to dam construction. Inset: mean annual values. (after Băncilă et al. 1972).

that they are keen on adapting to fresh water. Groups of migrating sturgeon, therefore, tend to include individuals of different ages and sizes, as was observed in North America (Roussow 1957).

Beluga sturgeon is the first to move into fresh water, as soon as icy floods are over (Hankó 1931: 9). They are followed by Russian and stellate sturgeon swimming up to the Iron Gates. All three species are actively targeted by fishermen between January to June as well as October to December. These two periods largely correspond to the spring and autumn migrations in the Iron Gates gorge. Most notably, they also coincide with seasons of high discharge in this region (Fig. 11; Băncilă et al. 1972: 19), when low water temperatures and high water velocity favour spawning. Sturgeon fishing between June and September only took place opportunistically in the Iron Gates when water temperatures were high and discharge low. Mátyás Bél (1764: 39), an 18th century Hungarian naturalist, documented the same two seasons in Hungary: spring fishing began in March and continued uninterrupted until June (cf. Table 7). The autumn season lasted from August until December, unless winter began early. These data contradict somewhat 19th century records that in Hungary only 7–15% of the yearly sturgeon catch were landed between February and April, while

41–57% were caught between September to November. The rest were caught opportunistically throughout the year (Khin 1957). Identifying the season of death may be attempted by thin-sectioning pectoral fin rays from archaeological sites. The low precision of this method, however, makes the identification of fish caught during the spawn run contradictory (Desse-Berset 1994; Needs-Howarth 1996). Seasonal differences in fish size are also difficult to establish. Some 19th–20th century record specimens of known date are listed by season in Table 7.

Owing to the random nature of the catch, no significant seasonal weight or length difference could be detected between record sturgeons. These data reconfirm, however, that equally large sturgeons could be caught both during the spring and in the late autumn/winter.

Interspecific differences in spawning temperatures, as well as the presence of off-season stragglers meant that sturgeons were available year round. The use of their bones as seasonal indicators in archaeological assemblages, therefore, is limited to probabilistic interpretations. It would seem logical that sturgeons could be most successfully targeted when they were rushing upstream along the Danube in great numbers. However, this is contradicted by the 41–57% September to November catch statistics given previously.

Table 7. Measurements of sturgeon caught at known seasonal dates in the Hungarian section of the Danube.

Year	Date	Location	Weight (kg)	Length (cm)
1957	March 2	Paks	138	273
1922	March 3	Gemenc	90	220
1950	March 8	Százhalombatta	132	300
1936	March 18	Dunapataj	63	215
1927	'Good Friday'	Dunapentele	86	235
1987	May 16	Paks	181	300
1957	May	Baja	134	280
1954	May 27	Paks	50	203
Mean value, spring			109.3	253.3
Standard deviation			44.2	39.5
Winter				
1911	early September	Orsova (Iron Gates)	102	252
1956	October 6	Ercsi	117	263
1870	'winter catch'	Ásvány-Győr	250	365
1894	'winter catch'	Pozsony	100	200
1955	January 31	Ercsi	117	263
1953	February 1	Ercsi	63	213
Mean value, spring			109.3	253.3
Standard deviation			44.2	39.5
P-value of Student's <i>t</i> -test			0.600	0.819

Historical accounts of sturgeon in the Danube

While large Acipenserid bones commonly occur in some Mesolithic and Neolithic archaeological assemblages, they seem to become rare by the late Middle Ages. In part, this may be explained by a shift in the focus of archaeological research: catch sites were more likely to coincide with the sites of consumption during prehistory. By the Middle Ages, however, sturgeon remains are best known from high status settlements in the Danube Bend gorge in Hungary (Fig. 8). This valuable fish is known to have been traded over both short and long distances. From an archaeological point of view, however, most relevant historical information relates to methods of catching these animals. Given the large size of beluga sturgeon especially, landing it posed a special challenge to fisherfolk in all periods. According to Masen (1681: 898), "the beluga is similar to sturgeon and as strong as a tuna, frequent in the Danube". While there is no direct evidence of prehistoric sturgeon fishing techniques along the Danube, elaborate systems for sturgeon fishing have been documented since the Middle Ages.

Sturgeon weirs

In accordance with the large size and strength of these animals, traps or enclosures placed in rivers to catch sturgeon, often included massive timber structures, sometimes in combination with large-holed netting. The placement of weirs was of strategic importance. Familiarity with sturgeon habitats, i.e. features of riverbed and adjacent topography, as well as the knowledge of sturgeon behaviour were, thus, instrumental in minimizing labour expenditure required for the construction of weirs.

The German naturalist Johann Georg Gmelin became a professor of chemistry and natural sciences in St. Petersburg, Russia in 1731. He documented a sturgeon weir shaped like

a maze and made from timber fencing which stretched across the Volga river. Sturgeons swimming upstream were trapped in the four, curvaceous 'pockets' of this complex structure (Khin 1957: 12, fig. 7).

Nineteenth century sturgeon traps in the Iron Gates gorge were described by Jókai (1872: 7) as follows: "Between the islets, the narrow branches of the Danube are disrupted [by] double post structures made from robust timber, arranged in a V-shape, opening downstream... Once the sturgeons enter, it is not their habit to turn downstream. As they proceed in the ever-narrowing funnel, they wind up in the 'death chamber' at the end...".

Mixed-media weirs included the use of strong nets as well. Khin (1957: 14–15) refers to a 16th century description by Miklós Oláh. Wooden posts were staked across the Danube in November, before the waters grew icy. Fishermen in boats stretched nets between the evenly placed posts, then cannons were fired to scare sturgeons into the traps.

Medieval documents suggest that full closure of rivers would have been considered an unfriendly or even illegal move. A 1528 court case in Hungary between the city of Vác and the royal capital, Buda (located downstream), clearly shows the competing interests of their sturgeon fishing communities (Szilágyi 1995: 114). Weirs, therefore, were often placed between the bank and smaller islets, thus, exploiting only one of the river's branches.

One of the most instructive documents on sturgeon fishing in the Iron Gates gorge is found in Volume IV of Marsigli's 1726 work. The frontispiece (Fig. 12) portrays numerous technical details. It shows a tunnel of three A-shaped gates built between a small island and the right bank of the Danube (an arrow clearly indicates the downstream direction). In the lower half of the picture the narrow gorge is flanked by steep, misty cliffs. Dense ripples indicate a more rapid current here. Sturgeon are being caught at the downstream end of this sec-

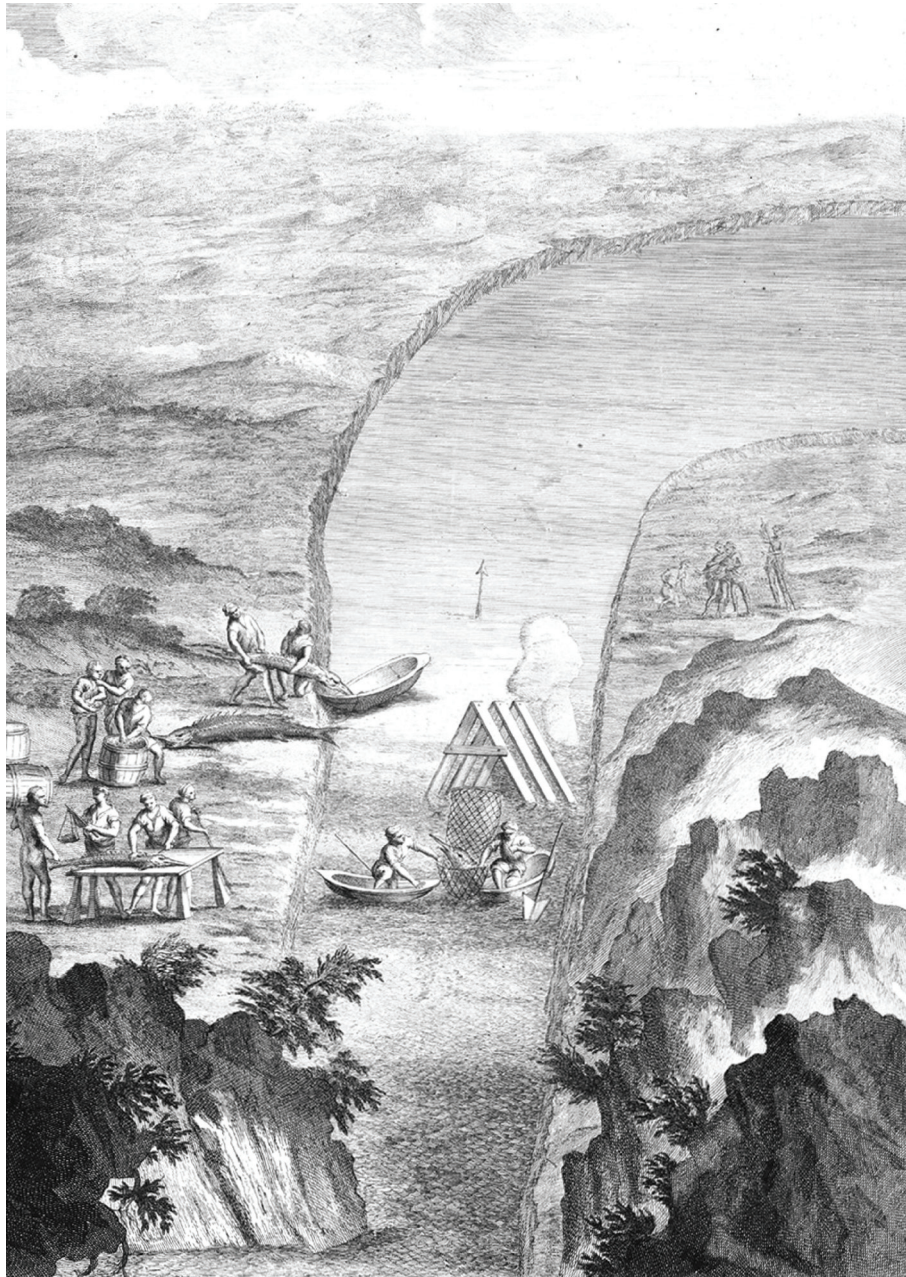


Figure 12. Sturgeon fishing at the exit from the Iron Gates gorge (from Marsigli's 1726 book).

tion, where the hills and the plain meet. Fishermen in small boats haul sturgeons onto the bank, where primary butchering takes place on a makeshift table.

According to a 1702 description by Bél (1764: 39), willow with fencing was combined with strong hemp nets at a slight elevation in the riverbed at Földvár (Tolna county, Hungary). The soft substrate mentioned in his text (onto which sturgeons were driven and caught) may be a reference to a submerged sandbank.

The construction of weirs, even at the best loci, required tremendous investments of labour. In the 16th century along the Tisza river entire villages of serfs were enlisted to build weirs using oak logs, under the direction of the *magister clausurae*. Aside from having an allowance of fish during construction work, these serfs had the right to half of the catch in the new weir — *with the exception of sturgeons*

(Maksay 1959: 703).

Building and maintaining sturgeon weirs not only required labour. In agricultural areas, shipments of appropriate oak logs from distant forests also had to be organized. According to a 1493–1495 price list, for example, 220 such 'weir' logs were bought by the Eger episcopate in Hungary (Kandra 1887: 378). Although the sporadic nature of the written data do not permit us to estimate the costs of sturgeon weirs, their construction must have represented a major investment, affordable only by well-organized estates in medieval Hungary.

The lack of archaeological evidence for weirs does not exclude the possibility that such complex structures could have been erected in ancient times. The possibility of such cooperative efforts is clearly illustrated by the construction in AD 103–105 of Trajan's bridge across the Danube at Drobeta (modern-day Turnu-Severin) a few kilometers downriver

from the prehistoric site of Schela Cladovei.

Other equipment

By the 19th–20th century hardly any references to sturgeon weirs occur in Hungary (Szilágyi 1995: 108). Large and strong, so-called pipola nets, were made especially for sturgeon fishing out of hemp. However, by the second half of the 19th century large sturgeons became scarce (cf. Fig. 3), so that these special nets were used but rarely (Herman 1887: 281). Sturgeons could also be caught with gill nets, suspended vertically in the water to trap fish by their gills, as the strong pectoral fins of sturgeons easily became hooked in its meshes (von Brandt 1964: 170).

Sturgeons were also caught using sharp hooks strung on a strong rope and stretched across rivers. In contrast to similar methods of catfish (*Silurus glanis* Linné 1758) fishing, such hooks did not have to be baited, since curious sturgeons often ‘played’ with these glossy pieces of metal and were caught by chance (Khin 1957: 16). By the late 19th century, such hooks became the primary means of sturgeon fishing (Herman 1887: 368).

Lake sturgeons in North America could be speared even from the shore in shallow waters (Needs-Howarth 1996: 149). Fish, injured and dazed, were then dragged near the bank. According to Marsigli (1726), fishermen enveloped such fish in a large net in the Danube and provoked it further onto the bank by ‘titillating’ it until it became stranded. Captured sturgeons were sometimes kept tethered to trees or strong poles, before being towed upstream by boat to the nearest market. The capitals of Buda and Vienna were supplied with live sturgeon in this way (Bél 1764: 41).

Aside from hefty hooks and harpoons, grapnels must have been important tools in landing these large fish at all times. By the 18th century, the great sturgeons were even ‘hunted’ with firearms (Marsigli 1726, in Deák 2004: 74).

Cognitive aspects of sturgeon fishing

Sturgeons were the largest fish in the Danube. Their sheer size and powerful movement must have impressed people throughout history. The renowned abundance of sturgeons during the spawning run must have further enhanced their awesome perception. Thus, it is likely that these great beasts had dualistic symbolic meanings related to both life and death in the spiritual life of peoples in the region.

Positive perceptions

Isotopic studies of human remains by Bonsall *et al.* (1997, 2000, 2004) have confirmed the results of previous faunal analyses (e.g. Bökönyi 1978, Bartosiewicz *et al.* 1995), indicating that Mesolithic populations in the Iron Gates consumed considerable amounts of fish (aquatic resources were still exploited during the Early Neolithic, but the dietary role of terrestrial resources increased). Even if sturgeon was available on a seasonal basis, owing to the quantities of meat even single individuals yielded, its contribution to the diet cannot be underestimated, and probably determined the prehistoric perception of these animals.

Highly valued sturgeon meat won the name ‘Royal Fish’

for beluga sturgeon in Medieval Hungary. Aside from the impressive quantity of food provided by a single specimen, the quality of sturgeon flesh was also appreciated, regardless of size. Of the species that resembled great sturgeon, Marsigli (1726) devoted most attention to the small sterlet whose meat was said to be simply ‘the best’. A quarter of a millennium later, this view was confirmed during ethnographic interviews conducted by Vasile Şişu among the fishermen of Dubova district (Iron Gates gorge, Romania).

According to the Torah, only fish with scales and fins are kosher. Accordingly, the bones of sturgeon and similarly scaleless catfish occurred only in the Christian layers above deposits associated with the 13th century Jewish community in a well excavated in the Buda Royal Castle in Hungary. The latter contained only remains of kosher carp-like fish (Cyprinidae) and high status pike (*Esox lucius* L.; Bartosiewicz 2003). The ganoid type (Lagler *et al.* 1977: 108, fig. 4.2) scutes of sturgeon are not considered scales in this religious context, since the skin is often torn during descaling that renders the fish tref. Sturgeon meat and caviar therefore were avoided by Ashkenazi Jews who settled in Medieval Eastern Europe. ‘Legalizing’ sturgeon meat with reference to its ganoid scales, however, became an important halachic issue in the early 19th century Jewish religious reform in Hungary (Frojimovics *et al.* 1995: 293).

Needs-Howarth (1996: 153) concluded that concentrations of lake sturgeon bones at certain archaeological sites in Canada indicate that these animals had mythical or religious meaning for Iroquoian people. In their artistic renditions of Lake Superior native American mythology, Longfellow (1855) and Kohl (1859 II: 143) indeed equate the ‘King of Fishes’ with sturgeon.

It is not difficult to imagine that the much-awaited spring arrival of masses of sturgeon amounted to some sort of a feast during the Mesolithic and Early Neolithic of the Iron Gates. According to a structuralist interpretation by Radovanović (1997: 88–89), the upstream movement of beluga sturgeon may have symbolized life to the prehistoric inhabitants of the gorge, possibly counterweighted by the downstream orientation of the deceased in Mesolithic burials along the riverbank.¹

Negative perceptions

The perception of animals tends to be dualistic, ranging between extremes (Bartosiewicz 1998: 69). At the prehistoric site of Lepenski Vir in the Iron Gates gorge, the stone statue dubbed *Danubius* by the excavator (Srejović 1972: fig. 52) has been tentatively identified with sturgeon, having even a crest of ‘dermal scutes’ carved along its back (Radovanović (1997: 93, figs. 1–2). Although the exaggerated, even frightening, facial features (such as the large, bulging eyes) are not at all reminiscent of the modern perception of sturgeons — sturgeon have very small eyes (cf. Fig. 4), this hypothesis is not implausible if, as suggested by Srejović (1972: 111), the sculpture was conceived as an apotropaic representation with the power to avert evil or catastrophe. Bonsall *et al.* (2002) suggested that the Lepenski Vir sculptures were intended to protect against unpredictable and catastrophic floods. If so, the ability of sturgeon to swim against the flow even at times of high discharge, overcoming the power of the river, may

explain their use in imagery.

Other, more negative associations must also be reckoned with. Although ancient fisherfolk were perfectly able to distinguish between species based on their intimate first-hand knowledge, the image of powerful sturgeons may have been distorted by beliefs in water monsters. For example, in an Ojibway myth from North America, a giant fish threatens to swallow a young boy (Williams 1956: 168). However, in Lake Superior, the only fish that large is lake sturgeon, a harmless bottom feeder.

A comparably large Danubian species is European catfish (also known as sheathfish or wels). Large specimens of this fish species reach the average size of sturgeons (c. 2.5 m, 120 kg; Pintér 1989: 135) and may grow up to 5 m (330 kg) in the Dniepr (Curry-Lindahl 1985: 259). In contrast to sturgeon, however, catfish are indeed ferocious carnivores with fearful reputations. One of their vernacular synonyms, *parasztfaló*, bluntly means ‘peasant gobbler’ in Hungarian (Gozmány 1979: 957). The English synonym, sheathfish, seems to relate this species with sturgeon, whose Indo-European names were associated with ‘greave’ (a piece of armor worn to protect the shin) by von Sadvoszky (1995: 17–19). Moreover, the Hungarian name for Acipenserids, *tokhal*, could be best translated as ‘case fish’ or, actually, ‘sheathfish’. Although the linguistic evaluation of apparent similarities is beyond the scope of this paper, it may indicate how the perceptions of these two large fish merged in popular mythology.

Both in the Csallóköz region (the aforementioned inland delta, located upstream from Komárom), and in the Iron Gates, sturgeons following boats were considered a bad omen. As a 19th century fisherman put it: “See, how that infernal monster swims ceaselessly alongside our boat. It’s an old sturgeon, almost half a ton. It always means trouble, when evil beasts are racing with the boat like that” (Jókai 1872: 94).

Danubian sturgeons of all species have four barbels in front of the mouth equipped with taste buds (Lagler *et al.* 1977: 350, fig. 11.9). According to Kriesch (1876: 68), rare specimens without such ‘whiskers’ were called ‘calamity fish’ in Hungary, an omen of disaster, threatening the region or even the entire country. They must have occurred among the young of stellate sturgeon especially. This means that the negative perception of sturgeon was not necessarily linked with large size and the concomitant challenge posed by sturgeon fishing.

Overcoming sturgeons

In spite of all these benign and fearsome connotations, it was only the landing of sturgeons that was indubitably trying and dangerous. Overcoming such a formidable adversary required fishing skills, strength and probably involved a major element of *machismo* at all times. According to 18th century Hungarian fishermen, the tail of a landed great sturgeon should not be approached because “even the most able-bodied lad can be killed by a single slap from it” (Bél 1764: 40). The hard work of sturgeon fishing probably also served as an outlet for social aggression.

Taphonomic loss and problems of seasonal dating make it impossible to tell whether prehistoric sturgeon landings

reached the frenzy of the much-publicized, traditional *Grindadrap* on the Faeroe Islands, during which pilot whales (mostly the so-called Atlantic blackfish, *Globicephala melaena* Traill 1809), are driven ashore and massacred, mostly by men. A remarkable similarity between these small cetaceans and sturgeons in size and, to some extent, shape could be a functional basis of such hypotheses. The late 1st century BC Greek author, Strabo (*Geographica Lib. VII.3.18*, cited by Bél 1764: 35) actually compared sturgeons to dolphins in terms of size.

While it is possible that some prehistoric sturgeon remains from the Iron Gates were the result of opportunistic fishing, historical data on the scale and intensity of sturgeon exploitation make the *Grindadrap* parallel sound reasonable. The vivid late Baroque description of sturgeon fishing by Bél (1764: 40–41) is as reminiscent of a gracious rite as of archetypal human predation.

Conclusions

While it cannot be demonstrated that sturgeons always played a key role in the lives of all peoples living along the Danube, their significance should not be neglected at sites where their bones have been found. This multidisciplinary review of sturgeon fishing should provide archaeologists with insights into the possible ways to interpret sturgeon bones encountered in ichthyoarchaeological assemblages.

1. Owing to their poor resistance to taphonomic loss sturgeon bones tend to be underrepresented at most sites. On the other hand, their large size guarantees the recovery of the surviving remains even in hand-collected assemblages. Although species-level identification is limited to special elements, large Acipenserids must have played comparable roles in most cultures
2. Animals with such a large body mass must have been a desirable prey for subsistence fishers. Their capture, however, required special skills that included a thorough knowledge of both habitats and fish behaviour, which determined the probability of taking the best catch.
3. Aside from some degree of specialization, sturgeon fishing could only succeed as a fundamentally cooperative enterprise throughout history. It took planning and coordinated action by fishing communities, which only increased in significance as fishing techniques became ever more complex. As a group activity, carried out by men in historical times, sturgeon hunting may have had strong associations with male identity.
4. Developing infrastructure for large-scale sturgeon fishing required investments, which in turn increased the commercial value of these animals. Medieval trade in sturgeons shows the consumer’s end of this chain; some sturgeon remains were found at sites, spatially separated from catch sites, which were probably the places of primary butchering.
5. Sporadic archaeological data cannot be used in studying the depletion of stocks. Decline by the 19th century, however, is reflected both in fish sizes and in the ethno-historical records. Over a century ago Kriesch (1876: 12–17) recognized that deforestation, river regulation

works, damming, water pollution, steamboats and timber floating were directly responsible for habitat degradation. Owing to their low reproductive rate and high visibility, sturgeons were particularly hard hit by what he termed 'human greed', i.e. overfishing.

6. While the often-anecdotal ethnohistorical and literary examples cannot be used directly in the interpretation of archaeological sturgeon finds, they show the complexity of attitudes (mostly related to the immense size and particular appearance of sturgeons) that are unlikely to have developed only in recent centuries.

Note

1. Some Final Mesolithic burials at Lepenski Vir (cf. Bonsall *et al.* 2004, this volume) are oriented parallel to the Danube with their heads pointing downstream, but this is not a consistent feature of Mesolithic burials from the Iron Gates.

Acknowledgements

A preliminary version of this paper was presented in September 2001 at the 12th Meeting of the Fish Remains Working Group (International Council for Archaeozoology) in Paihia Bay, New Zealand, organized by Drs Foss Leach and Janet Davidson. Figure 12, from Marsigli's original work, was kindly provided by Andrea Kreutzer, Librarian in the Museum of Military History in Budapest. Dr Antal András Deák kindly gave permission to quote from his manuscript on Marsigli prior to publication. Thanks are due to Dr Alice M. Choyke for useful comments on the text as well as Dr Erika Gál and László Daróczi-Szabó, zooarchaeologists, who translated texts from Romanian.

References

- Antipa, G. 1905: *Die Störe und ihre Wanderungen in den europäischen Gewässern mit besonderer Berücksichtigung der Störe der Donau und des Schwarzen Meeres*. Wien: Sitzungsberichte der internationale Fischerei Kongress.
- Bacalbaşa-Dobrovici, N. 1997: Endangered migratory sturgeons of the lower Danube River and its delta. *Environmental Biology of Fishes* 48: 201–207.
- Băncilă, I., Diakon, A., Djordjević, V., Hvoj, J., Jakovlević, P., Neimarević, K., Nouresku, A., Sandul, G., Vasiliju, A. & Verčon, M. (eds) 1972: *Système hydro-énergétique et navigable Đerdap (Les Portes de Fer)*. Belgrade: Export-Press.
- Bartosiewicz, L. 1989: Animal remains from the fort. In Gabler, D. (ed.) *The Roman Fort of Ács-Vaspuzta (Hungary) on the Danubian Limes*. Part ii. BAR International Series 531. Oxford: British Archaeological Reports, 600–623.
- 1996: Early Medieval faunal remains from Pontes (Iron Gates gorge, eastern Serbia). *Acta Archaeologica Academiae Scientiarum Hungaricae* 48: 281–315.
- 1997: Őskori vizahalászat a Duna vaskapui szakaszán (Prehistoric sturgeon fishing in the Danube). *Halászatfejlesztés* 20: 92–103.
- 1998: Attitudes to pets in the ethnolinguistic record. In Anreiter, P., Bartosiewicz, L., Jerem, E. & Meid, W. (eds) *Man and the Animal World. Studies in Memoriam Sándor Bökönyi*. Budapest: Archaeolingua Kiadó, 65–78.
- 1999: 'Bronze Age fish remains in the Tisza River region, Hungary'. Paper delivered at the 10th meeting of the ICAZ Fish Remains Working Group, New York City.
- 2003: 'Eat not this fish — a matter of scaling'. Paper delivered at the 12th meeting of the ICAZ Fish Remains Working Group, Guadalajara, Jalisco State, México.
- Bartosiewicz, L., Bonsall, C., Boroneanţ, V. & Stallibrass, S. 1995: Schela Cladovei: a preliminary review of the prehistoric fauna. *Mesolithic Miscellany* 16(2): 2–19.
- Bartosiewicz, L., Boroneanţ, V., Bonsall, C. & Stallibrass, S. 2001: New data on the prehistoric fauna of the Iron Gates: a case study from Schela Cladovei, Romania. In Kertész, R. & Makkay, J. (eds) *From the Mesolithic to the Neolithic*. Budapest: Archaeolingua, 15–22.
- Bartosiewicz, L. & Bonsall, C. 2004. Prehistoric Fishing along the Danube. *Antaeus* 27: 253–272.
- Bartosiewicz, L. & Takács, I. 1997: Osteomorphological studies on the great sturgeon (*Huso huso* Brandt). *Archaeofauna* 6: 9–16.
- Bél, M. 1764 [1984]: *Tractatus de Rustica Hungarorum: A magyarországi halakról és azok halászatáról* (Hungarian Country Life: The Fish of Hungary and their Fishing). Hungarian translation of the 1764 copy: Antal András Deák, 1984. Budapest: Vízügyi Történeti Füzetek.
- Bencsik, J. 1970: Egy jobbágyközség gazdasági, társadalmi élete az úrbérendezéstől a jobbágyfelszabadításig (The economic and social life of a serfs' community between the urbanium bill and emancipation). *Acta Universitatis de Ludovico Kossuth Nominatae Series Historica* 10: 49–91.
- Benecke, N. 1986: Some remarks on sturgeon fishing in the southern Baltic region in Medieval times. In Brinkhuizen, D.C. & Clason, A.T. (eds) *Fish and Archaeology. Studies in Osteometry, Taphonomy, Seasonality and Fishing Methods*. BAR International Series 294. Oxford: British Archaeological Reports, 9–17.
- Berg, L.S. 1904: Zur Systematik der Acipenseriden. *Zoologischer Anzeiger* 27: 665–667.
- Berinke, L. 1966: *Halak – Pisces*. Budapest: Akadémiai Kiadó.
- Bonsall, C., Lennon, R., McSweeney, K., Stewart, C., Harkness, D., Boroneanţ, V., Bartosiewicz, L., Payton, R. & Chapman, J. 1997: Mesolithic and Early Neolithic in the Iron Gates: a palaeodietary perspective. *Journal of European Archaeology* 5: 50–92.
- Bonsall, C., Cook, G., Lennon, R., Harkness, D., Scott, M., Bartosiewicz, L. & McSweeney, K. 2000: Stable isotopes, radiocarbon and the Mesolithic–Neolithic transition in the Iron Gates. *Documenta Praehistorica* 27: 119–132.
- Bonsall, C., Macklin, M., Payton, R. & Boroneanţ, A. 2002: Climate, floods and river gods: environmental change and the Meso–Neolithic transition in southeast Europe. *Before Farming: the archaeology of Old World hunter-gatherers* 3_4(2): 1–15.
- Bonsall, C., Cook, G., Hedges, R., Higham, T., Pickard, C. & Radovanović, I. 2004. Radiocarbon and stable isotope evidence of dietary change from the Mesolithic to the Middle Ages in the Iron Gates: new results from Lepenski Vir. *Radiocarbon* 46: 293–300.
- Borić, D. & Dimitrijević, V. 2005: Continuity of foraging strategies in Mesolithic–Neolithic transformations: dating faunal patterns at Lepenski Vir (Serbia). *Atti della Società per la Preistoria e Protostoria della Regione Friuli-Venezia Giulia* 15 (2004–05): 33–80.
- Bökönyi, S. 1969: Kičmenjaci (prethodni izveštaj). In Srejić, D., *Lepenski Vir: Nova praistorijska kultura u Podunavlju*. Belgrade: Srpska književna zadruga, 224–228.
- 1978: The vertebrate fauna of Vlasac. In Srejić, D. & Letica, Z. (eds) *Vlasac: Mezolitsko naselje u Đerdapu*, vol. 2. Belgrade: Serbian Academy of Science and Arts, 35–65.
- 1992: Animal remains of Mihajlovac–Knjepište, an early Neolithic settlement of the Iron Gate gorge. (Hommage à Nikola Tasić à l'occasion de ses soixante ans). *Balkanica* 23: 77–87.
- Brandt, A. von 1964: *Fish Catching Methods of the World*. Farnham: Fishing News Books.
- Brinkhuizen, D.C. 1986: Features observed on the skeletons of

- some recent European Acipenseridae: their importance for the study of excavated remains of sturgeon. In Brinkhuizen, D.C. & Clason, A.T. (eds) *Fish and Archaeology. Studies in Osteometry, Taphonomy, Seasonality and Fishing Methods*. BAR International Series 294. Oxford: British Archaeological Reports, 18–33.
- 1989: *Ichthyo-archeologisch onderzoek: methoden en toepassing aan de hand van romeins vismateriaal uit Velsen (Nederland)*. Unpublished PhD thesis. Rijksuniversiteit Groningen, Groningen.
- Casteel, R.W. 1976: *Fish Remains in Archaeology and Palaeoenvironmental Studies*. London: Academic Press.
- Clason, A.T. 1980. Padina and Starčevo: game, fish and cattle. *Palaeohistoria* 22: 141–173.
- Curry-Lindahl, K. 1985. *Våra fiskar. Havs- och sötvattenfiskar i Norden och övriga Europa*. Stockholm: Norstedt & Söners.
- Deák, A. A. 2004: *A Duna fölfedezése* (The Discovery of the Danube). Budapest: Vízügyi Múzeum, Levéltár és Könyvgyűjtemény.
- Deckert, K. 1967: *Urania-Tierreich: Band 4: Fische, Lurche, Kriechtiere*. Leipzig: Urania Verlag.
- Desse, J. & Desse-Berset, N. 1992: Pêches locales, côtières ou lointaines: le poisson au menu des Parisiens du Grand Louvre, du 14^e au 18^e siècle. *Anthropozoologica* 16: 119–126.
- Desse-Berset, N. 1994: Sturgeons of the Rhône in Arles (6th–2nd century BC). In Van Neer, W. (ed.) *Fish Exploitation in the Past*. Tervuren: Koninklijk Museum voor Midden-Afrika, 81–90.
- Frojmimovics, K., Komoróczy, G., Pusztai, V. & Strbik, A. 1995: *A zsidó Budapest. Emlékek, szertartások, történelem I–II*. (Jewish Budapest. Monuments, Rituals, History I–II). *Hungaria Judaica* 7. Budapest: MTA Judaisztikai Kutatócsoport.
- Giurescu, C.C. 1964: *Istoria pescuitului și a pisciculturii în România* (The History of Fishing and Pisciculture in Romania). București: Editoriul Academiei.
- Gozmány, L. 1979: *Vocabularium nominum animalium Europae septem linguis redactum*. Budapest: Akadémiai Kiadó.
- Hankó, B. 1931: Magyarország halainak eredete és elterjedése (The origins and distribution of fishes in Hungary). *A Debreceni Tisza István Tudományegyetem Állattani Intézetéből* 10: 3–34.
- Harka, Á. 1993: A folyóvizek halrégiói (The fish regions of rivers). *A természet* 44(5): 85–87.
- Hensel, K. & Holčík, J. 1997: Past and current status of sturgeons in the upper and middle Danube river. *Environmental Biology of Fishes* 48: 185–200.
- Herman, O. 1887: *A magyar halászat könyve I–II* (The Book of Hungarian Fishing). Budapest: Kir. Magyar Természet-tudományi Társulat.
- 1980: *Halászat és pásztorélet* (Fishing and Pastoralism). Budapest: Gondolat Kiadó.
- Jókai, M. 1872 [2001]: *Aranyember I* (The Golden Man I). Budapest: Talantum Kiadó.
- Kandra, K. 1887: Bakócs-codex vagy Bakócs Tamás egri püspök udvartartási számadókönyve 1493–6. évekből (The Bakócs Codex, the court accounting books of Bishop Tamás Bakócs of Eger, 1493–6). *Adatok az Egri Egyházmegye történelméhez* 2: 333–452.
- Khin, A. 1957: *A magyar vizák története* (The History of Hungarian Sturgeons). Budapest: Mezőgazdasági Múzeum Füzetei 2.
- Kohl, J.G. 1859: *Kitschi-Gami oder Erzählungen vom Oberen See I–II*. Bremen: C. Schünemann.
- Kriesch, J. 1876: *Hasznos és kártékony állatainkról. Kézikönyv II. rész. Halak* (Handbook of Useful Animals and Pests. Vol. II. Fish). Budapest: Szent István Társulat.
- Lagler, K.F., Bardach, J.E., Miller, R.R. & May Passino, D.R. 1977: *Ichthyology*. New York: Wiley.
- Longfellow, H.W. 1855 [1964]: *The Song of Hiawatha*. New York: Bounty Books.
- Maitland, P.S. & Linsell, K. 1978: *Europas sötvattenfiskar*. Stockholm: Albert Bonniers.
- Maksay, F. (ed.) 1959: *Urbáriumok XVI–XVII. század* (16th–17th Century Urbaria). Budapest: Akadémiai Kiadó.
- Marsigli, L.F. 1726: *Danubius Pannonico-Mysicus, observationibus geographicis, astronomicis, hydrographicis, historicis, physicis perlustratus*. Vol. VI. Amsterdam–The Hague.
- Masen, J.S.J. 1681: *Speculum Imaginum Veritatis Occultae*. Ed. tertia prioribus correctior. Köln: J.A. Kinckius.
- Miranda, L.E., Wingo, M.W.M., Muncy, R.J. & Bates, T.D. 1987: Bias in growth estimates derived from fish collected by anglers. In Summerfelt, R.C. & Hall, G.E. (eds) *Age and Growth of Fish*. Ames, IA: Iowa State University Press, 211–219.
- Müller, H. 1983: *Fische Europas*. Leipzig: Neumann.
- Muus, B. & Preben, D. 1965: *Meeresfische der Ostsee, der Nordsee, des Atlantiks: Biologie, Fang, wirtschaftliche Bedeutung*. München: BLV-Verlagsgesellschaft.
- Needs-Howarth, S. 1996: Lake sturgeon fishing at prehistoric Iroquoian sites near Lake Simcoe, Ontario. *Archaeofauna* 5: 147–154.
- Păunescu, A. 2000: *Paleoliticul și Mezoliticul din spațial cuprins între Carpați și Dunăre*. București: Agir.
- Pénzes, B. & Tölg, I. 1977: *Halbiológia horgászoknak* (Fish Biology for Anglers). Budapest: Natura–MOHOSZ.
- Pintér, K. 1989: *Magyarország halai* (The Fish of Hungary). Budapest: Akadémiai Kiadó.
- Radovanović, I. 1997: The culture of Lepenski Vir: a contribution to the interpretation of its ideological aspects. In Lazić, M. (ed.) *Antidoron Dragoslavo Srejić completis LXV annis ad amicis, collegis, discipulis oblatum*. Belgrade: Centre for Archaeological Research, University of Belgrade, 87–93.
- Radu, V. 1997: Archaeological researches at Bordoșani-Popină (Ialomița County). Preliminary report 1993–1994. *Pisces. Cercetări arheologice*, 10: 96–105.
- 2003: *Exploitation des ressources aquatiques dans les cultures néolithiques et chalcolithiques de la Roumanie méridionale*. Thèse de doctorat de l'Université Aix–Marseille I, Préhistoire, Archéologie, Histoire et Civilisation de l'Antiquité et du Moyen-Age, Aix-en-Provence, France.
- Roussow, G. 1957: Some considerations concerning sturgeon spawning periodicity. *Journal of the Fisheries Research Board of Canada* 14: 553–572.
- Sadovszky, O. von 1995: *Fish, Symbol and Myth*. Budapest: Akadémiai Kiadó.
- Schalk, R.F. 1977: The structure of an anadromous fish resource. In Binford, L.R. (ed.) *For Theory Building in Archaeology: Essays on Faunal Remains, Aquatic Resources, Spatial Analysis, and Systemic Modelling*. New York: Academic Press, 207–249.
- Srejić, D. 1972: *Europe's First Monumental Sculpture: New Discoveries at Lepenski Vir*. London: Thames & Hudson.
- Szilágyi, M. 1995: *A Tiszai halászat. Az eszközök és fogási módok történeti változásai* (Fishing in the Tisza. Historical Changes in Equipment and Methods). Budapest: Akadémiai Kiadó.
- Terofal, F. 1971: Kwastsnoeken, steuren en verwanten. In Grzimek, B. (ed.) *Het leven der dieren IV, Vissen I*. Nijmegen: Thieme & Cie, 148–146.
- Vuković, T. & Ivanović, B. 1971: *Slatkovodne ribe Jugoslavije* (Freshwater Fish of Yugoslavia). Sarajevo: Zemaljski Muzej Sarajevo.
- Wheeler, A. 1978: *Key to the Fishes of Northern Europe*. London: Frederick Warne.
- Williams, M.L. (ed.) 1956: *Schoolcraft's Indian Legends*. East Lansing: Michigan State University Press.
- Woodard, C. 2000: Singing the Danube blues. *Christian Science Monitor*, May 11, 2000.