SCUTE DIFFERENTIATION BETWEEN ATLANTIC AND SHORTNOSE STURGEON: AN ARCHAEOLOGICAL INVESTIGATION

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*We have observed and describe herein a morphological difference in visible ornamented bone (body scutes, head and pectoral girdle dermal bones) surface morphology distinguishing between Atlantic Sturgeon (*Acipenser oxyrinchus*) and Shortnose Sturgeon (*A. brevirostrum*), applicable to accurate species identification in fragmentary archaeological sturgeon bone. The external surface of Atlantic Sturgeon body scutes is heavily ornamented with a typical "pitted" (honeycombed or alveolar) appearance, in contrast to the (more lightly ornamented) "stumped" (or tubercular) appearance of Shortnose Sturgeon body scutes. In addition, measurements and descriptions of series of scutes and dermal bones from several Atlantic Sturgeon specimens (see the Appendices) allow archaeologists to accurately identify more complete scutes and dermal bones from archaeological specimens to approximate body location and fish size, and to elucidate minimum number of individuals (MNI).*

INTRODUCTION

Sturgeon are members of a primitive fish family (Acipenseridae), relatively little changed since the Cretaceous period (Daniels 1996; Hilton and Grande 2006). Only two anadromous sturgeon species inhabit the northern Atlantic coastal drainages of North America. Although in the same genus, the species may not be that closely related (Choudhury and Dick 1998). Atlantic Sturgeon (*Acipenser oxyrinchus*) occupies the coastal zones along the Atlantic seaboard from the St. Lawrence estuary and Newfoundland-Labrador to Florida and the Gulf of Mexico (Hilton et al. 2016). The more estuarine/riverine Shortnose Sturgeon (*A. brevirostrum*) inhabits larger rivers along the coastal drainages from New Brunswick to Georgia.

Atlantic and Shortnose Sturgeon are anadromous and spawn in freshwater, above the influence of salt water on estuaries and rivers (Munro et al. 2007). Atlantic Sturgeon primarily lead a marine existence, while Shortnose Sturgeon, aside from seasonal migrations to estuarine waters, are thought to rarely occur in the marine environment (NMFS 1998) [but see below].

After juvenile Atlantic Sturgeon reach a certain age or size (2-6 years, 75-96 cm), they leave their natal estuary and forage along the coast and lower estuaries, often in shallow water (< 20 m) over sandy or muddy bottoms in spring, summer and fall (Hilton et al. 2016:37). Adult Atlantic Sturgeon may migrate substantial distances along the coast, generally foraging in shallow water (< 40 m) in spring, summer and fall (*ibid.*) Atlantic Sturgeon from rivers as far south as New Jersey participate in a spring and summer feeding aggregation of 10-30,000 individuals in the Bay of Fundy (Dadswell et al. 2016). For reviews of Atlantic Sturgeon biology and status, see Hilton et al. (2016); Kynard (1997); and Smith and Clugston (1997).

Once generally thought of as "estuarine" fishes, both of these sturgeon species apparently move between estuaries along the Maine coast and neighboring states and provinces. Recent tracking studies indicate a high percentage of movement of Shortnose Sturgeon individuals between river estuaries within the Gulf of Maine (Zydlewski et al. 2011), necessarily including movement along the marine coast.

The Gulf of Maine *Distinct Population Segment* (DPS) of Atlantic Sturgeon was listed as threatened by NOAA in 2012 (NOAA 2015; see also Hilton et al. 2016), while Shortnose Sturgeon were originally listed as an endangered species in the United States in 1967 and are a threatened species in the Canadian provinces. Large numbers of sturgeon scutes found in Native American shell middens of about 3,000 years of age or less

Figures 1a and b. Top: Juvenile Atlantic Sturgeon, caught and released 9/2/2009,with George Zink, Maine Department of Marine Resources. Bottom: Shortnose Sturgeon, live tagged and released, Kennebec River 2012. Prominent features to note are the dorsal (top) and lateral (side) rows of scutes, the opercular (gill area), the dorsal fin in front of the tail, and the tail with upswept (heterocercal) portion and bottom portion of the tail (folded under on the Shortnose Sturgeon). Photos courtesy of Jason Bartlett, Maine Department of Marine Resources.

on the Maine coast and islands (Spiess and Halliwell 2012; Spiess et al. 2013) provide pre-Contact archaeological confirmation of movement of sturgeon inshore in shallow waters along the Gulf of Maine coast outside of river estuaries. Hence, sturgeon is an important fisheries resource for archaeologists to accurately speciate at archaeological sites along the major rivers and estuaries in the Gulf of Maine and along the marine coast.

During the past decade, the authors have been collaborating on the accurate identification of fish species bony remains historically found at pre-contact archaeological sites in coastal Maine. The majority of the archaeological materials are remnants of bony fishes (Actinopterygii), comprised of a mixture of marine, estuarine and freshwater resident fish species (Spiess and Halliwell 2012). Distinguishing between smaller striped bass (*Morone saxatilis*) and larger white perch (*M. americanus*) archaeological specimens is one example. However, the bony remains of resident cartilaginous fishes – sturgeon body scutes and elasmobranch (primarily shark) vertebral centra, teeth, and spines (Handley 1996; Rick et al. 2002; Moyer et al. 2015) – are also represented to varying degrees in these archaeological sites. Over the past several years, we have focused our attention on trying to differentiate between Atlantic and Shortnose Sturgeon.

Sturgeon have largely cartilaginous endoskeletons, with some ossified head bones and bony dermal scutes (Helfman et al. 1997; Hilton et al. 2011). *Acipenser* species possess five rows of overlapping bony scutes running along their bodies from the opercular region just posterior to the head to the caudal peduncle at the base of their tail (Daniels 1996; Hilton et al. 2011), a single median dorsal row, and paired lateral and ventral rows (Figures 1a and b; Figure 2). Atlantic Sturgeon have a row of two to six bony plates between

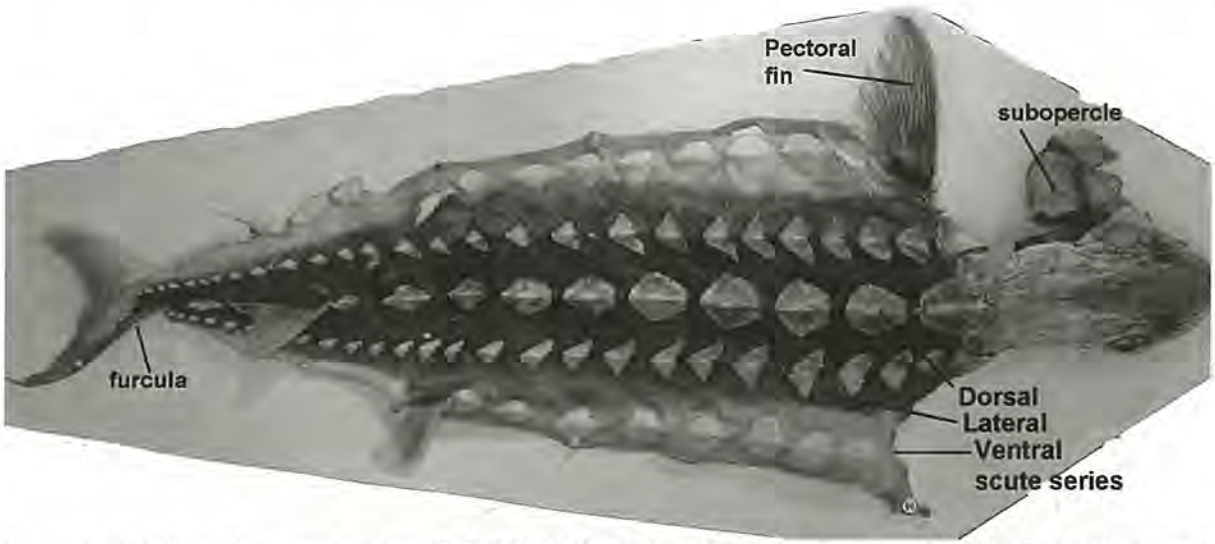


Figure 2. Skin from Shortnose Sturgeon (SNS-FOMB) found dead, Cathance River, Bowdoinham, Maine. Dorsal and lateral scute series in the darker portion of the skin. Ventral scute series visible along the edges of the skin. Note left pectoral fin sticking laterally (top of photo) behind the head. Right pectoral girdle missing (see description in the Shortnose Sturgeon portion of the paper below). Also note the skin flap with left gill cover area (subopercle bone) just above the head. Prepared by Ed Friedman, Friends of Merrymeeting Bay. Photo courtesy of Ed Friedman.

the base of the anal fin and lateral row of scutes, which are absent in Shortnose Sturgeon (Hartel et al. 2002). Importantly, the shape and size of these bony plates and scutes vary with position on the body and the age of the fish (ibid).

Sturgeon scutes are generally defined by a single near-planar surface (the exterior), with a characteristic pitted or rough morphology which is easy to identify even on smaller fragments. There are some elongated, ossified dermal bones called "basal fulcra" that form on the leading edges of fins. Also, some endochondral (internal head) bones ossify well enough to preserve in archaeological sites. These bones have some value for use in archaeological studies as diagnostic of sturgeon in general, but probably not for differentiating Shortnose and Atlantic Sturgeon. The external surface of all scutes, and the exposed portion of skull dermal bones (Figure 3), is characteristically "heavily ornamented...." (Hilton et al. 2011). We follow Hilton et al. (2011) in referring to the external, pitted surface as "ornamentation," but we further find that this ornamentation differs in visible and generally recognizable morphological character between the two resident species of sturgeon found to occur in Maine and adjacent New England states and Canadian provinces, the Atlantic and Shortnose Sturgeon.

The primary goal of this study is to distinguish Atlantic from Shortnose Sturgeon on the basis of observed differences in body scute ornamented surface morphology. As mentioned above and further described below, the ornamentation on the outer surface of sturgeon scutes differs between these two resident sturgeon species, and that difference can be recognized with simple visual inspection.

We also have mapped and identified (Appendices A and B) individual body scutes to body row (one of five) and relative location within each row, while determining relative size and age of the donor fish, primarily with Atlantic Sturgeon. Atlantic Sturgeon grows much larger than Shortnose Sturgeon, and adult Atlantic Sturgeon generally have more scutes in the dorsal and lateral rows than do smaller-sized Shortnose Sturgeon. The presence or absence of these individual bones/scutes, of course, would be unnoticeable in typically disarticulated, fragmentary pre-contact archaeological animal bone assemblages.

Following a review of pertinent European literature (Artyukhin and Vecsei 1999; Debus 1999; Desse-Berset 2011; Ludwig et al. 2008), we believe that northeastern U.S./Canadian sturgeon species (Atlantic and

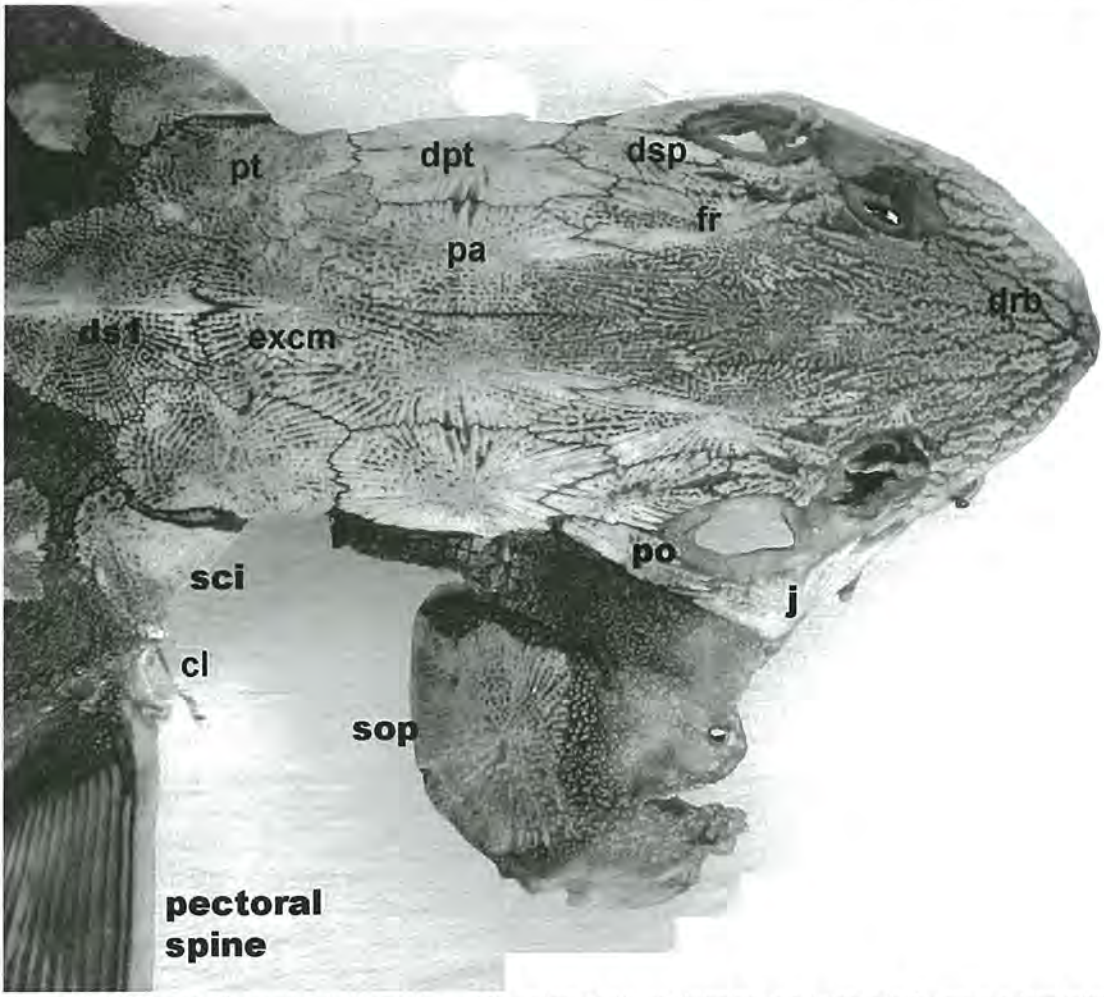


Figure 3. Shortnose Sturgeon skull specimen. Dorsal scute 1 (ds1) labeled as a landmark for comparison with dorsal scute series. Other bones of the head, gill and shoulder girdle are labled: excm = median extrascapular; pa = parietal; pt = posttemporal; dpt = dermopterotic; dsp = dermosphenotic; fr = frontal; sci = supracleithrum; sop = subopercle; po = postorbital; j = jugal; drp = dorsal rostral bones; cl = cleithrum.

Shortnose Sturgeon) can readily be identified by means of a single species-specific morphological feature (Debus 1999): the observed difference in the "radially striated/symmetric structure" (or "ornamentation") of the exterior side of the bony body plates and scutes. Similar morphological scute differences were first documented for European (North Sea, *A. sturio*) and Atlantic sturgeon in Russia (Tikhii 1929, referenced in Artyukhin and Vecsei 1999, and Debus 1999) and in France (Magnin and Beaulieu 1963). Correct terminology for scute surface ornamentation, possibly dating back to Tikhii (1929), is as follows. Atlantic Sturgeon (North American/European) races of *A. oxyrinchus* are characterized by having *alveolar*-radial (honeycombed/pitted, small holes) scute surface patterns. In contrast, European (North Sea, *A. sturio*), Shortnose *(A. brevirostrum*) and Lake Sturgeon (*A. fulvescens*) are all three characterized by having the *tubercular*-radial (forested/stumped, protuberances) pattern (e.g. Elvira et al. 2015). (See also the excellent drawings by Hans Winkler in Ludwig and Gessner 2007:290, Figure 4.) Interestingly, these latter two North American sturgeon species (*A.brevirostrum* and *A. fulvescens*), both with freshwater affinities (large coastal rivers and large inland lakes) also are closely related systematically (Choudhury and Dick 1998; Hilton et al.

2011). The North American/European Atlantic Sturgeon races (*A. oxyrinchus*) are, of course, also closely related.

We have also mapped and identified (see Appendix) individual body scutes to body row (one of five) and relative location within each row, while determining relative size and age of the donor fish, primarily based on available Atlantic Sturgeon material. Atlantic Sturgeon grow much larger than Shortnose Sturgeon. Shortnose Sturgeon grow to a maximum length of 1.4 m, compared with 4 m or larger attained by Atlantic Sturgeon (Hartel et al. 2002; Hilton et al. 2011, 2016). As previously mentioned, adult Atlantic Sturgeon may have more scutes in the dorsal and lateral rows than do Shortnose Sturgeon. The presence or absence of these individual bones and scutes, of course, would be unnoticable in typically disarticulated and fragmented archaeological animal bone assemblages.

To date, North American archaeologists have simply enumerated "sturgeon" scute abundance as counts or weights (e.g., Spiess and Lewis 2001). Aside from recent European contributions (see Desse-Berset 2011), there have been no published guides for archaeologists depicting the morphometric variation of body scutes *in situ* on sturgeon, nor any information available to determine sturgeon body size (and/or age) from archaeological scutes that are disarticulated from each other and are often fragmentary. In the absence of this type of detailed information, it is not possible to reconstruct the minimum number of individuals (MNI) or compare the amount of biomass represented by sturgeon with associated fish species in archaeological fish assemblages. In this work we hope to improve archaeologists' ability to identify accurately sturgeon bony remains and further analyze sturgeon bony remains from archaeological sites, especially along the Atlantic coast of the United States and Canada.

MATERIALS

Atlantic Sturgeon Comparative Specimens

Two Atlantic Sturgeon skeletal specimens were available for this comparative work.[1]

ATS-JUV (Atl-#9 from the NMFS permit) is a 990 mm (total length) *juvenile* Atlantic Sturgeon found in February 2008 on Silver Beach, New York, and collected under NMFS permit #1614, presumably by fisheries biologists. Portions of this specimen were stored frozen at the University of Maine, Orono, and these pieces were donated to MHPC under the same permit number in May 2013 (courtesy of Dr. Gale Zydlewski and Matt Altenritter). A head (cut off toward the posterior end) and two strips of body scutes embedded in skin were received (including the dorsal row of scutes to the base of the tail, as well as the lateral row of scutes). Body scutes were removed by boiling and defleshing. Hence, ATS-JUV is missing the ventral (lower lateral) scutes, caudal scutes and bones, and internally ossified head bones.

ATS-ADU (originally labeled "B+S 81-1") is a 1.42 m (4 feet 8 inch) *large sub-adult or young adult* Atlantic Sturgeon (29 pounds dressed weight, appx. 13 kg, with internal organs removed), possibly a male based on a pair of linear gonad-like sacks along the spine observed at the time of purchase (by the late Dr. Brian Robinson) from R&S Seafood, June 18, 1984. This specimen is currently in use in the comparative skeletal collection at the Department of Anthropology, University of Maine, Orono, and was on loan to MHPC for this study. ATS-ADU appears to be a complete specimen, and it has been very well processed by Robinson: each scute is labeled (Figure 4), and sketches of some of the skull and scute series accompany the specimen.

Shortnose Sturgeon Comparative Specimens

SNS-UMO. Close-up photographs of the ornamented external surfaces of two Shortnose Sturgeon dorsal scutes were originally provided by Dr. Gayle Zydlewski and Matt Altenritter (University of Maine, Orono). They allowed us to inspect several other Shortnose Sturgeon scutes and we compared them with photographs of archaeologically derived sturgeon scutes. Jason Bartlett, Maine Department of Marine Resources, lent us

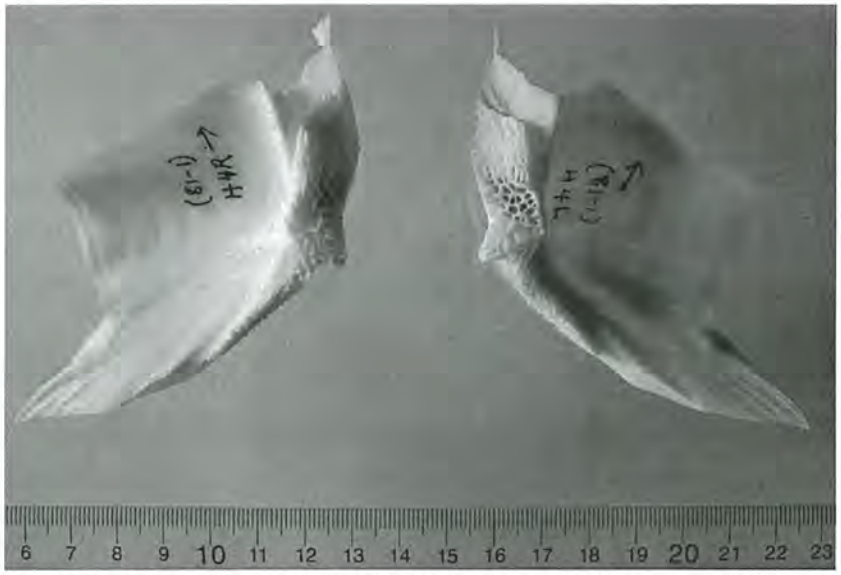


Figure 4. ATS-ADU bones are well labeled. This pair of bones are cleithrum(s) (cl, H4 in the specimen inventory), right and left bones labeled H4-R and H4-L respectively. Arrows point anterad. The narrow, ornamented exterior surface is shown on both specimens. The cleithrum is part of the shoulder (pectoral) girdle; only a small portion of this bone shows, articulating with the supracleithrum, in Figure 3.

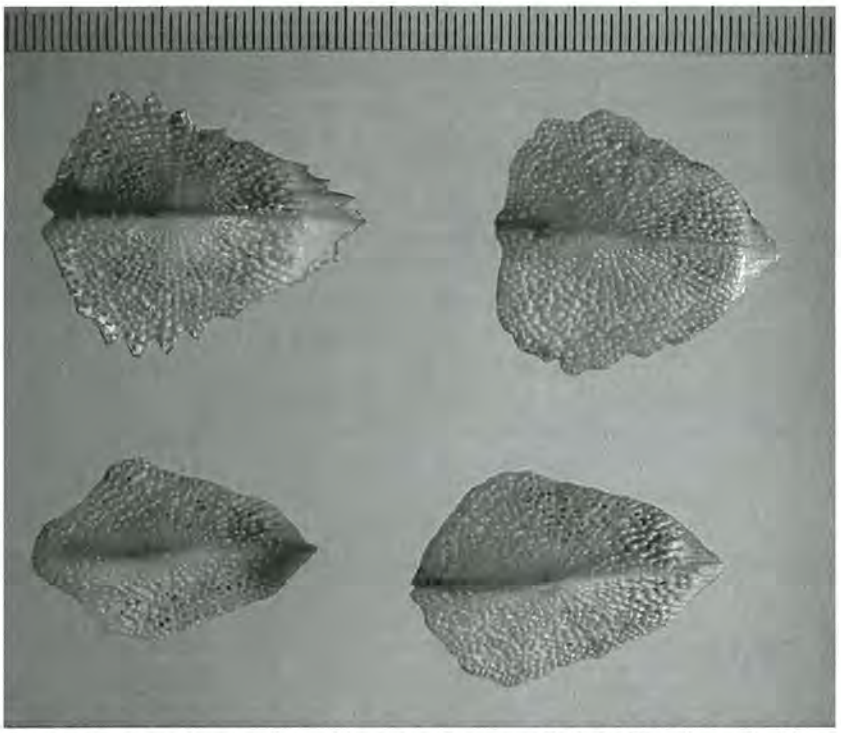


Figure 5. Dorsal scutes from Shortnose Sturgeon SNS-DMR. The scale (short bars) is millimeters. See the Appendix for discussion of placing each scute in the dorsal series.

a dozen disarticulated Shortnose Sturgeon scutes **(SNS-DMR)** from one or more specimens they had prepared by defleshing via burial and subsequent exhumation (Fig. 5).

SNS-FOMB. Ed Friedman, *Friends of Merrymeeting Bay*, recovered a dead, 37-inch (0.94 m) long Shortnose Sturgeon on the shore of the Cathance River, Bowdoinham, Maine, on August 12, 2014. This specimen is probably an adult male (Ed Friedman, personal communication) and is judged to be of a similar size as the immature 0.99 m ATS-JUV specimen. Mr. Friedman prepared the skin of the specimen for exhibit with scutes and head bones in place (see Figure 2). He invited us to closely examine it, and supplied excellent photographs. He also donated the right pectoral area (spine, cleithrum and portion of the clavicle) to this project and the MHPC collection (subsequently prepared by boiling and degreasing in dilute hypochlorite solution).

During the process of examining the available comparative sturgeon specimens, along with several archaeologically derived scutes, we noticed that the surface morphology ornamentation on the Shortnose Sturgeon and Atlantic Sturgeon appeared qualitatively different to the unaided eye and with low magnification (see Figure 6 below).

RESULTS

Ornamentation Differences in Sturgeon Body Scutes

There appears to be a useful difference in the morphology of the characteristic "roughness" on the ornamented bone and scute surfaces between the Atlantic and Shortnose Sturgeon species. The Atlantic Sturgeon scute external morphology appears to be "pitted" with a raised bony surface surrounding pits or "holes." In contrast, the external surface of the Shortnose Sturgeon scute appears to be "forested" with vertical, raised protrusions ("stumps") being primarily evident. Deeper enclosed pits are much less common. The ornamentation on the external surface of Shortnose Sturgeon dermal bones of the skull is created by "a dense array of pits and ridges that are formed by the fusion of denticle or tubercle-like elements to the underlying bone" (Hilton et al. 2011). "The external surface of all scutes is heavily ornamented...with an irregular honeycomb appearance...similar to the ornamentation of all other superficial dermal bones in the sturgeon" (ibid).

A larger magnification of the comparison photos between ATS-JUV and SNS-DMR serves to show this potential diagnostic contrast in enhanced detail (Figure 6). It appears that the primary difference is in the degree of "coalescence" of the raised bony elements – "fusion of the denticle or tubercle-like elements" (ibid). Greater development causes the denticle elements to fuse or coalesce into "walls" to surround pits in the Atlantic Sturgeon (Figure 7). There is variability in this effect across the surface of some individual ornamented bones of the immature ATS-JUV (generally pits), some specific bones on ATS-ADU, and of coalescence of the raised stumps in the Shortnose Sturgeon (SNS-DMR: generally more stumps than pits). In ATS-ADU the margins of the ventral scutes, for example, show more stumps than coalesced pits, although the central 2/3 of the scute shows coalescence around well-developed pits (Figure 8). As noted in the comparison of ATS-JUV with ATS-ADU, and other larger archaeologically-derived sturgeon bones, the pitted nature of the external surface of Atlantic Sturgeon scutes becomes more pronounced with larger size and older specimens. Since ATS-JUV is an immature individual, a consistent difference between the morphology of its scute (external or outer) surface, as compared with SNS-UMO, appears to be diagnostic. That consistent difference (mostly "stumpy" rather than deeply "pitted") is visible on all of the skull ornamented bones and scutes in SNS-FOMB. This ornamented surface difference between Atlantic and Shortnose Sturgeon is easily visible on these similarly-sized fish.

Pectoral Spine, Girdle Ornamented Bones, and Fulcra

We have the right pectoral spine and two pectoral girdle bones (cleithrum and ornamented portion of the clavicle) from SNS-FOMB for comparison. The SNS-FOMB pectoral spine is not obviously different morphologically from the Atlantic Sturgeon specimens (Figure 9). It is approximately the same size (9 cm in length) as the ATS-JUV specimen, which would be expected in similarly-sized fish. Similarly, the cleithrum is not different in overall shape between the two sturgeon species. However, the ornamented surfaces of the SNS-FOMB cleithrum and clavicle (Figure 10) can be characterized as "more stumps" and "less pits" than on the ATS-ADU specimen. In fact, the clavicle ornamented scute surface of SNS-FOMB is mostly a "forest of stumps." In contrast, the ornamented surface of the cleithrum of SNS-FOMB is a mixture of stumps and moderately developed pits. Again, as with scutes, there are visible differences in the ornamentation between Shortnose and Atlantic Sturgeon (compare with Figure 4, Atlantic Sturgeon cleithrum, with ornamented surface all "pits").

Fulcra are specialized, elongated and narrowed scutes located along the leading edge of the tail (Figure 11). The upper surface (away from the body) of some fulcra is partially ornamented (pits and/or stumps). The anterior end of each fulcrum bone is forked, and the distal end tapers to a point, so the bones "articulate." These bones strongly resemble small, plastic "cocktail forks," or antique wooden clothes pins, making them easily identifiable once one is aware of their shape. Moreover, they are rugose and resist breakage, showing up as identifiable elements in archaeological collections. We do not have a large enough comparative sample

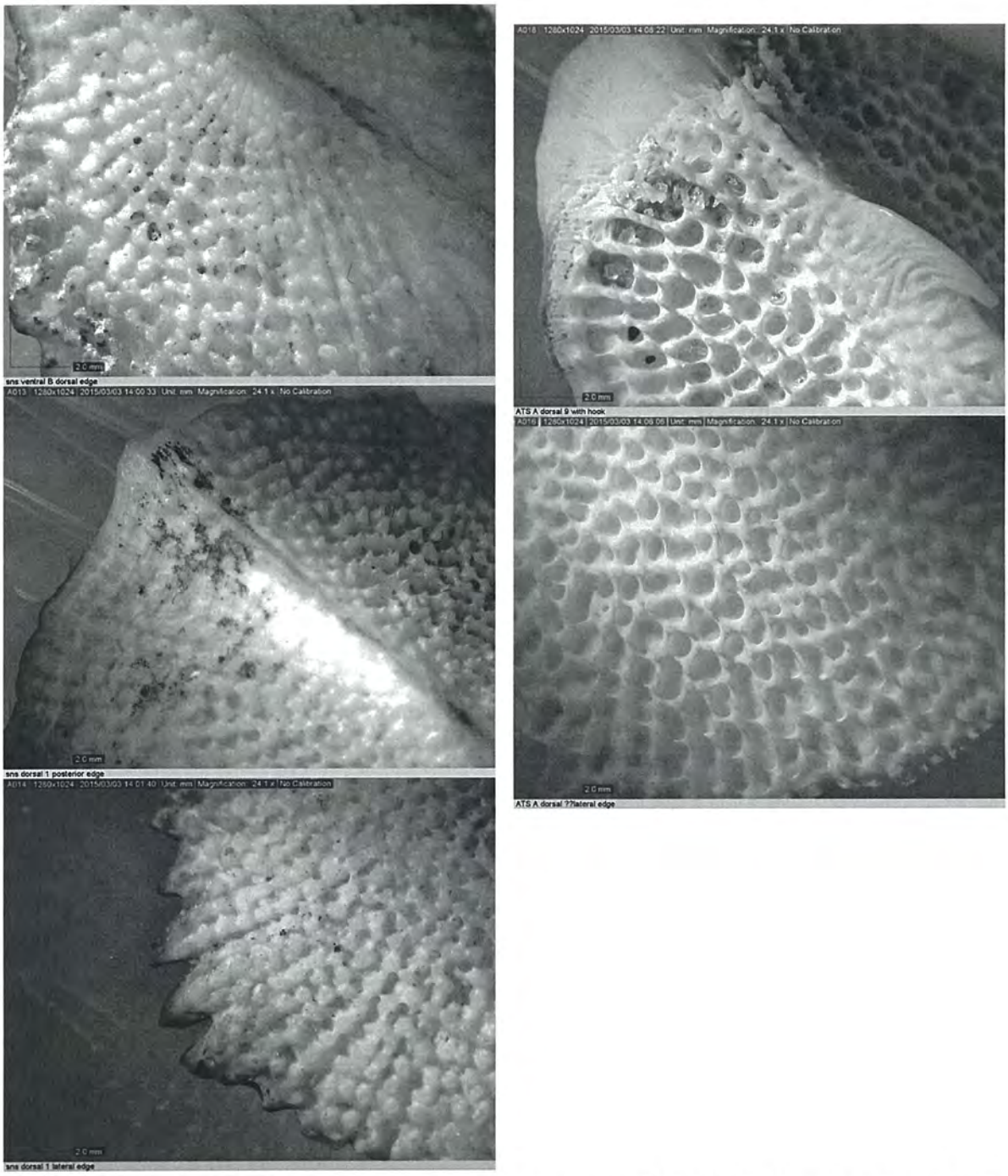


Figure 6. Photomicrograph comparison of portions of Atlantic Sturgeon (ATS-JUV) and shortnose sturgeon (SNS-DMR) dorsal scutes. Left column three images are SNS-DMR, top to bottom: ventral scute; dorsal scute 1 posterior edge; dorsal scute 1 lateral edge. Right column two images are ATS-JUV: top dorsal scute 9; bottom, edge of another dorsal scute. Note scale in lower left of each image, a right angle hairline (each limb is 2 mm).

Figure 7 (right). Comparison of dorsal scute 8 of Shortnose Sturgeon (top) with juvenile Atlantic Sturgeon (ATS-JUV) bottom. Note the consistent difference between "stumps" and "pits." Anterior to the left. Scale numbers are centimeters.

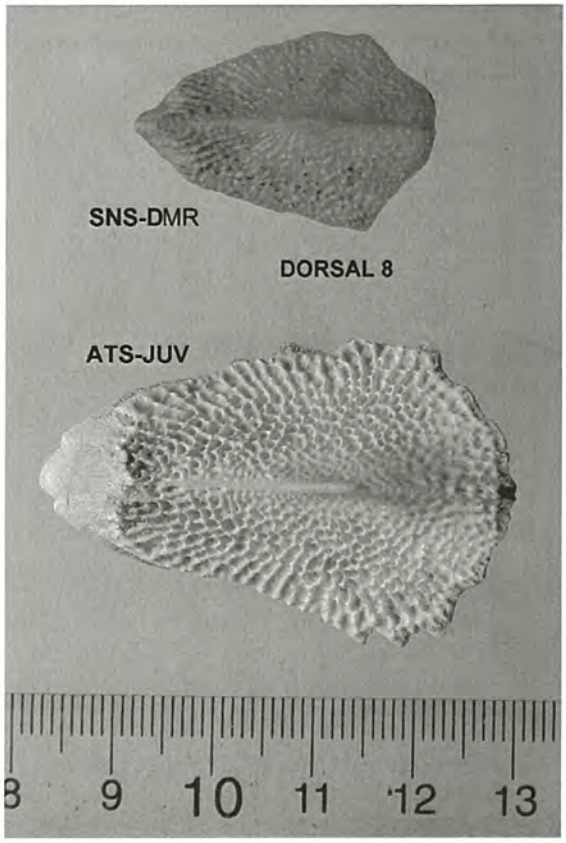
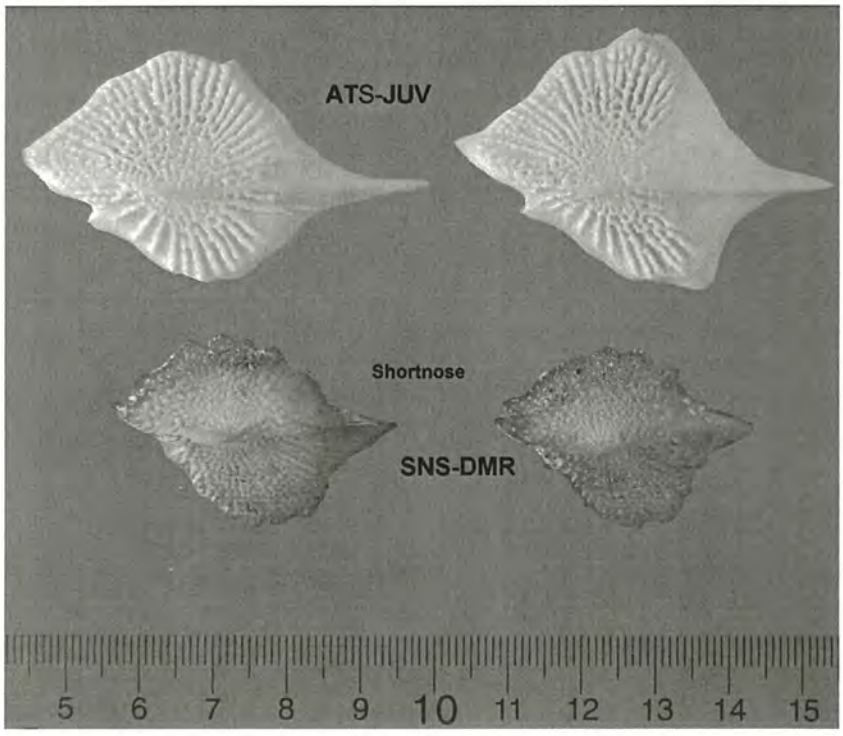


Figure 8 (below). Comparison of ventral scutes of juvenile Atlantic Sturgeon (ATS-JUV) top, with Shortnose Sturgeon (SNS-DMR) bottom. Note the stumpy appearance of the unfused ornamentation around the margins of the ATS-JUV Atlantic Sturgeon, with fused pits toward the middle of the scute. The Shortnose Sturgeon scutes exhibit only "stumps" for ornamentation. Anterior to the right.



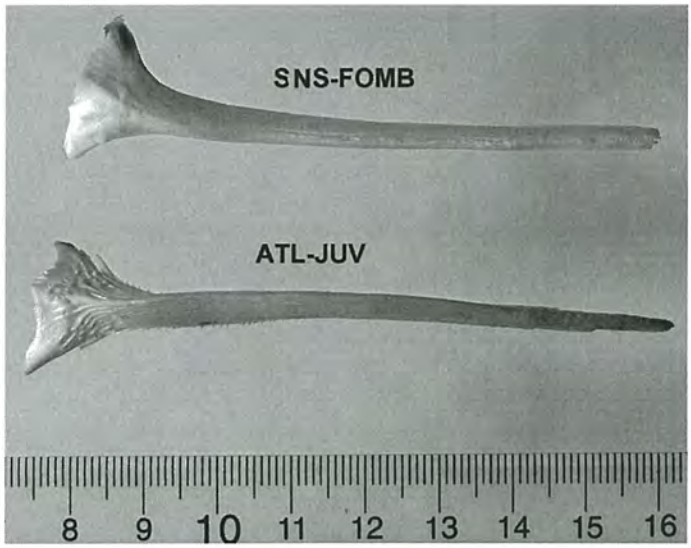


Figure 9 (top). Pectoral spines of Shortnose Sturgeon SNS-FOMB (top) and ATS-JUV (bottom). The fish are very similar in size, as are the pectoral spines. Pectoral spine overall morphology is similar as well.

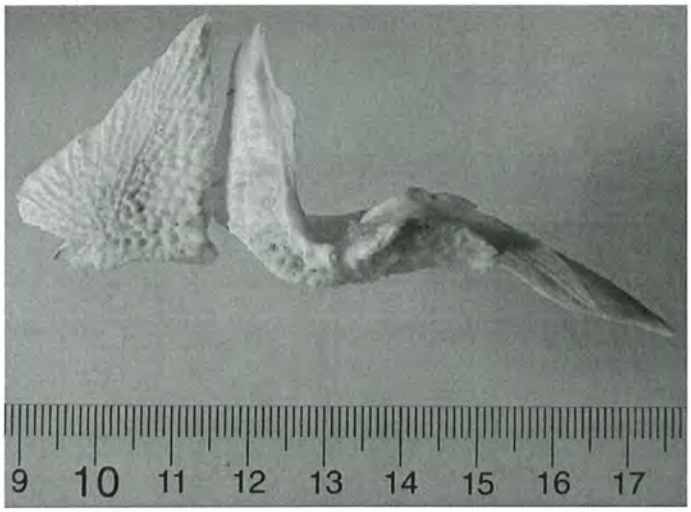
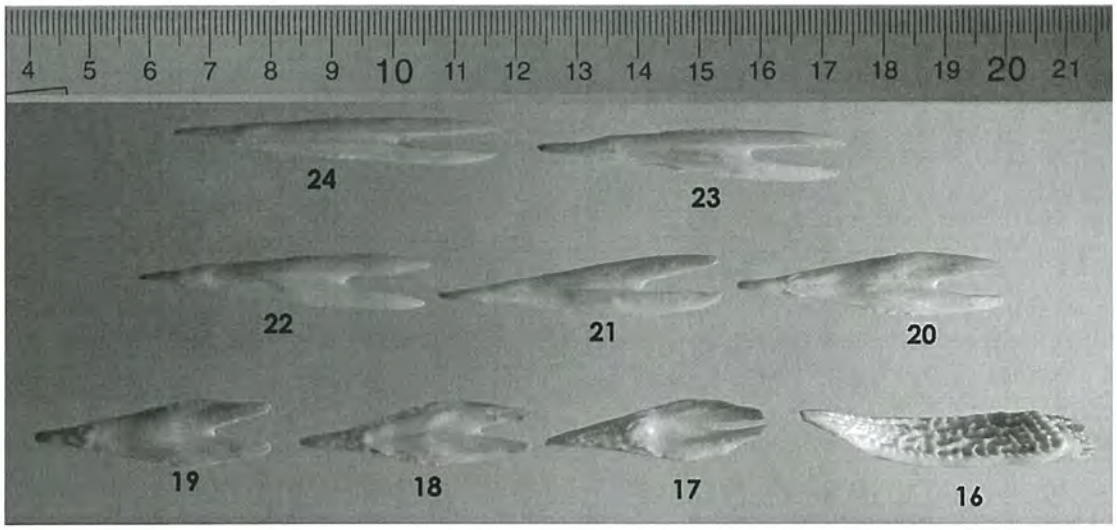


Figure 10 (middle). Shortnose Sturgeon SNS-FOMB cleithrum (right) and broken portion of clavicle (left), ornamented surfaces. Ornamented surfaces on Shortnose Sturgeon skull and shoulder girdle bones are recognizably different (more "stumps") than in Atlantic Sturgeon (compare Figure 4, Atlantic Sturgeon cleithrum). Note: cleithrum is viewed "edge on" in Figure 10, and obliquely in Figure 4.

Figure 11 (bottom). Dorsal caudal scute 16 (terminal scute in dorsal row), plus basal fulcra (#17-24), dorsal view, from ATS-JUV. Basal fulcra protect the anterior (leading) edge of the tail. Note that scute 16 is the same scute shown in Appendix Figure 4.



to state whether fulcra can be identified as Atlantic or Shortnose Sturgeon based on the small areas of ornamentation. However, what we presume are Shortnose Sturgeon archaeological examples seem to be less rugose (more sharply pointed, narrower) than our comparative Atlantic Sturgeon example (see archaeological example below).

Size of Sturgeon Body Scutes

Adults of these two sturgeon species also differ in relative size. The longest Shortnose Sturgeon on record is 1.43 m (4.7 feet) total length (Hilton et al. 2011), compared with the 4.3 m to 4.6 m (12-14 feet) total length attained by adult Atlantic Sturgeon (Hartel et al. 2002; Hilton et al. 2016:34). Growth rates, and thus size at specific ages and size and age at sexual maturity, vary between more northern and southern Atlantic Sturgeon populations and between males and females (Hilton et al. 2016:33-4). The 1.42 m length of ATS-ADU reported herein converts to approximately a 12-14 year old fish from the Hudson or Kennebec River populations (ibid. Figure 4, page 34). The ATS-ADU specimen therefore represents the minimal size of a sexually mature Atlantic Sturgeon (12-20 years, *ibid.*), or a very large subadult.

In any case, ATS-ADU is equal in size to the largest reported Shortnose Sturgeon. Thus, scutes or ornamented bones from Gulf of Maine archaeological sites equal to or greater than this size (e.g., the 1.4 m ATS-ADU Atlantic Sturgeon, Appendix Tables 1-6, see "pits/cm" column) are Atlantic Sturgeon. The measurements and photographs of ATS-ADU scutes and ornamented bones herein can be used as a "diagnostic" test for Atlantic Sturgeon. Fragmentary ornamented bones or scutes can be compared with ATS-ADU if the scute can be identified to approximate location on the body (scute series and approximate number), or the bone can be identified with measurable "landmarks."

There also appears to be a correlation between size of the pits on the ornamented scute and cranial bone surface and overall fish size in Atlantic Sturgeon. For fragments of scutes that are not further identifiable, a count of pits per centimeter estimated with a metric scale can be used as a proxy for size. A count of 8 pits (or pores) per cm characterizes the 1 m long fish in our sample. Although there are scute and ornamented bone portions on ATS-ADU with smaller pores/pits (more pits per centimeter), a count of five (5) or six (6) pores/pits per centimeter is "diagnostic" of most of the scutes on a 1.4 m sturgeon, and therefore likely an Atlantic Sturgeon. Larger pores/pits (smaller counts per centimeter, such as four [4]), are certainly from adult Atlantic Sturgeon (> 1.4 m length), even on smaller bony fragments. A regression of pits/cm on a range of several dozen individual sturgeon over a large size range would be useful, but is beyond our work at present.

Differential Sturgeon Body Scute Identification

For biologists with access to complete specimens, the skeletal morphology of the Atlantic Sturgeon is primarily distinguished from Shortnose Sturgeon by the presence or absence of some scutes, for example, a row of small scutes (bony plates) above the anal fin (Hartel et al. 2002). Shortnose Sturgeon lacks these small bony plates (scutes) between the base of the anal fin and the lowest row of primary scutes (ibid). Atlantic Sturgeon adults may have more scutes in the dorsal and lateral rows (11 dorsal, 29 lateral, 10 ventral in specimen ATS-ADU) than do Shortnose Sturgeon (9 to 12 dorsal, 24 to 29 lateral, 9 ventral (Hilton et al. 2011). However, in typically fragmentary and disarticulated archaeological samples of sturgeon bone, these criteria would not be useful.

Comparing individual scutes between Shortnose and Atlantic Sturgeon of similar size, slight differences in shape or margin curvature (e.g., Figure 7, Appendix figures) between SNS-FOMB and ATS-JUV are probably not diagnostic for distinguishing between the two sturgeon species. More sturgeon specimens need to be studied to make these determinations. Typical fragmentation and disassociation of scutes series in archaeological collections would make such studies/comparisons very difficult.

Table 1. Scute and ornamented bone weights for ATS-JUV and ATS-ADU specimens.
(ATS-JUV is incomplete, so total figures are extrapolated from scutes/bones present in both specimens. Note: 7 ornamented bones of the skull, opercular area and shoulder girdle are present in ATS-ADU and complete (yielding weights). For these 7 bones the relative weight of ATS-JUV versus ATS-ADU is 9.1 gr versus 33.0 gr, or 27.6%. (We have no weights for Shortnose Sturgeon scute series for comparison.)

	ATS-JUV (length 0.99 m)	**ATS-ADU** (length 1.4 m)	**ATS-ADU** (bone labels)
Dorsal scute series, single, not paired	20.4 gr (#2-11) [corrected for missing #1, 22.2 gr] 27.3% of ATS-ADU weight	81.3 gr	A1-11
Dorsal caudal series, paired	----	4.8 gr x 2 = 9.6 gr	A12-16
Lateral scute series, 1-29 right and left pairs	15.4 gr (#3-28), [corrected for #1-2 = 16.3 gr] x 2 = 32.6 gr; 29.2% of ATS-ADU weight	55.8 gr x 2 = 111.6 gr	B1-29
Ventral scute series, paired	----	21.0 gr x 2 = 42 gr	C1-10
Ventral scutes, caudal to anus, paired	----	10.0 gr x 2 = 20.0 gr	#E1-8
Ornamented dermal bones of the skull		2.7 + 25.2x2 = 53.1 gr	H1, 2, 7-10
Ornamented dermal bones, surrounding eye, paired	2.1 gr x 2 = 4.2 gr; 28% of ATSADU	7.1 gr x 2 = 14.2 gr	H11-13
Opercular and shoulder girdle ornamented bones		31.5 x 2 = 63.0	H3-6
Snout, dorsal rostral bones		3.4 x = 6.8	
Border rostral bones		4.1 gr x 2 = 8.2 gr	
Small ornamented dermal bones, platelets (squamation)		4.8 gr	
TOTAL WEIGHT	116 gr (estimated) (414.6 gr x 28%)	414.6 gr	

DISCUSSION

The descriptive information herein (including the metric data on individual scute size, plus the accompanying figures including Appendices tables and figures) should be sufficient to allow identification of mostly complete scutes or ornamented bones to the scute series or bone location on the sturgeon. Thus, archaeologists can now begin to use this guidance to sort out scutes and bones from individual sturgeon (minimum number of individuals determination) in archaeological collections that are not heavily fragmented.

As an additional aide in quantifying archaeological sturgeon bone, one 1.4 m Atlantic Sturgeon (13 kg dressed or gutted weight) will yield approximately 415 grams of (dry) ornamented scutes and bones (Table 1). An Atlantic Sturgeon approximately 1.0 m long (ATS-JUV) will yield approximately 116 grams of

ornamented scutes and bones (although this figure is an estimate arrived by extrapolation on several series of scutes). We assume a similar scute/ornamented bone weight for an adult Shortnose Sturgeon of the same length (116 grams, 1.0 m total length). Differentiating Atlantic Sturgeon overall body size in highly fragmented scute assemblages can be accomplished using "pits per linear centimeter" counts. Counts of 7 or 8 indicate a specimen approximately 1.0 m long. Counts of 4 or less per centimeter indicate a very large Atlantic Sturgeon (> 1.5 m length).

In addition, metric data can be used for species identification (to Atlantic Sturgeon), if the size of ATS-ADU is equaled or exceeded (Appendix B Tables 1-5).

We are also confident that the "pits" versus "stumps" observation will serve to differentiate scutes and ornamented bones of immature and mature Atlantic Sturgeon from mature Shortnose Sturgeon (in the 1.0 m body length range and larger). Slightly smaller scutes or bones with noticeably "stumpy" ornamentation are also present at coastal archaeological sites (e.g. Site 26.59 below) and appear to be representative of juvenile Shortnose Sturgeon. Thus, the morphological "pits" versus "stumps" characterization of the exterior scute surface appears to hold for immature individuals of the two sturgeon species.

We plan to present applied use of this sturgeon ornamented guidance to the existing range of archaeologically derived sturgeon scutes from Maine coastal archaeological sites in future papers, and we present an example in the next section.

ARCHAEOLOGICAL EXAMPLE: SITE 26.59

As a test of the utility of our methods to recover information about sturgeon from a fragmentary archaeological bone assemblage, we have sorted and identified 349 ornamented sturgeon scute and bone fragments from a shell midden site (Maine archaeological survey 26.59) in Edgecomb, Maine (Figure 12). Both Shortnose Sturgeon and Atlantic Sturgeon are present, and both species are represented by a range of sizes/ages. Recent acoustic tagging research (Zydlewski et al. 2011) has shown that the Damariscotta River estuary and other small rivers between the Penobscot and Kennebec drainages are used by Shortnose Sturgeon today, "part of an emerging pattern of SNS movements between large rivers and among small coastal rivers" (ibid.:42). (The Sheepscot estuary, immediately west of the Damariscotta and of similar size, was not set up with acoustic receivers for that study.) The upper Kennebec River estuary and restored habitat above former Edwards Dam at Augusta appears to be a focus of Shortnose Sturgeon spawning (Wipplehauser et al. 2015). See also Wipplehauser and Squires (2015) confirming Shortnose Sturgeon spawning in the Androscoggin River estuary. Possibly the Kennebec River is a focus of spawning of a Gulf of Maine metapopulation, drawing individuals who feed in many Gulf of Maine Rivers (Wipplehauser et al. 2015:748), or possibly the populations in various rivers are interconnected with "reproduction occurring in each" (ibid.). The sturgeon data we have developed for the upper Sheepscot estuary from roughly 1000 years ago (see below) may contribute to this discussion.

Site 26.59 is located on the east shore of a widened (1.5 km) "bay" in the upper Sheepscot River estuary, approximately 20 km upstream from the Gulf of Maine at Southport, and about 5 km below the head of tide (Figure 12). The shoreline of the widened Sheepscot estuary at Wiscasset and Edgecomb is the location of a score of pre-European archaeological sites, many containing sturgeon bone (MHPC survey records). Site 26.59 incorporates a thin (20 cm thick) shell midden (360 sq meters of deposits containing discarded clam shells [*Mya arenaria*]) along the shore into a larger site extending upslope away from the river. Assessment of the shell midden age is based on incorporated ceramic sherds with dentate stamped decoration (Mosher et al. 2008), dating between roughly 2200 and 1000 years ago. The food animal bone (faunal remains) preserved in the midden (by the shell buffering against soil acid) thus records roughly a millennium of subsistence practices by Native American inhabitants. Ceramic period Native Americans were canoe-based and seasonally mobile. There is no evidence of storage or long-distance transport of foodstuffs by Ceramic

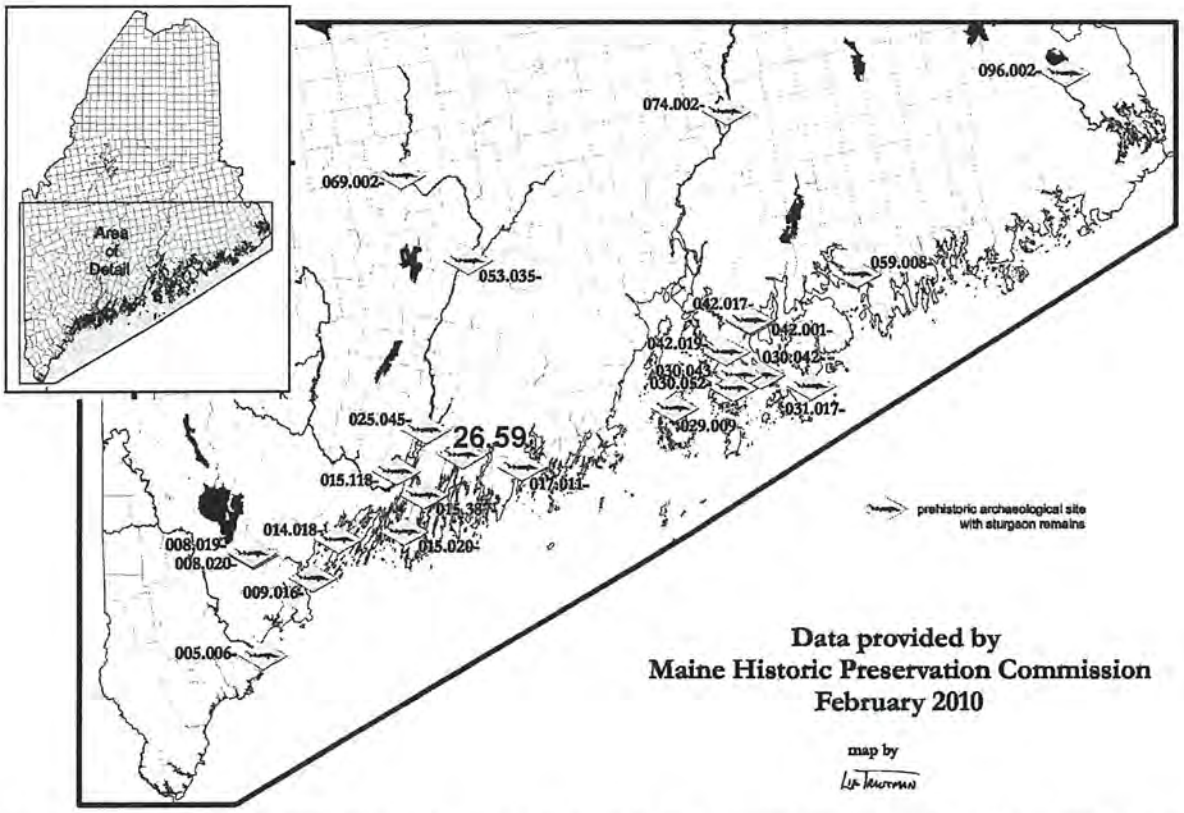


Figure 12. Map of Maine coast and lower rivers showing sites with sturgeon remains. Site 26.59 is located on the Sheepscot River, at the sturgeon symbol under the **26** in 26.59. For a table listing the sites on this map, see Spiess and Halliwell 2012:18-20; Table 5.

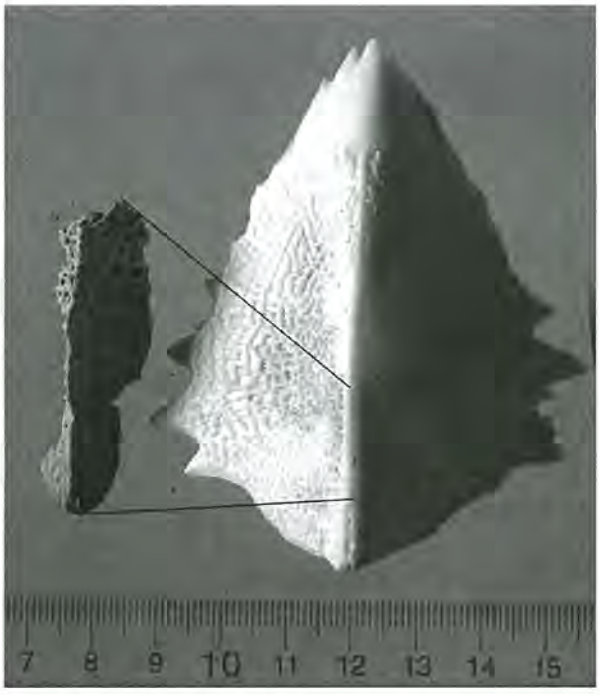


Figure 13 (right). Archaeological specimen (left), a very large adult dorsal scute ridge fragment, compared with fifth dorsal scute of ATS-ADU, a 1.4 m long Atlantic Sturgeon. Portion of dorsal scute represented by the archaeological specimen is indicated.

period Native Americans around the Gulf of Maine, so we consider the faunal remains in shell middens to be locally caught, and to reflect local (viz. 5 km radius) environmental availability of the animals represented.

Approximately four square meters of 26.59 shell midden were excavated, yielding 1074 fish bone fragments, 183 mammal, 29 bird, and 18 turtle (Mosher et al. 2008). Beaver, deer, and seal are most common in the identifiable mammals; loon, swan, ducks and geese are identifiable in the bird bone sample. The fish bone sample is 75% sturgeon (753 bones), with a few identified eel, striped bass,

sea sculpin, and gadid (cod family) bones (5 or less each). This study examined in detail a sample of 349 sturgeon scute and bone fragments (58.6 grams) from one square meter (N99E69). Of these, 137 fragments (13.7 gr) could not be identified as either Shortnose or Atlantic Sturgeon. Unfortunately, the season(s) of occupation of site 26.59 have not been determined.

The Atlantic Sturgeon sample is 62 bones (15.0 gr), including dorsal and lateral scutes (Figures 13 and 14), ornamented skull and orbital area bones Figure 15), and ornamented shoulder girdle (pectoral fin support) bones (Figures 16 and 17) (Table 2). Size range of the fish is reconstructed from the pores/cm proxy measure of size (range: 8 to 3.5), and from measurements taken from the archaeological specimens compared with the ATS-ADU (1.4 m) and ATS-JUV (1.0 m) specimens. Atlantic Sturgeon bones (Table 2) derive from three or more individuals, one or more being equivalent to the ATS-JUV (1.0 m) and one or more being equivalent to the 1.4 m ATS-ADU in size. In addition, there is a dorsal scute fragment from a truly large adult, estimated by comparative measurement to be 3 m or more in length (see Figure 13).

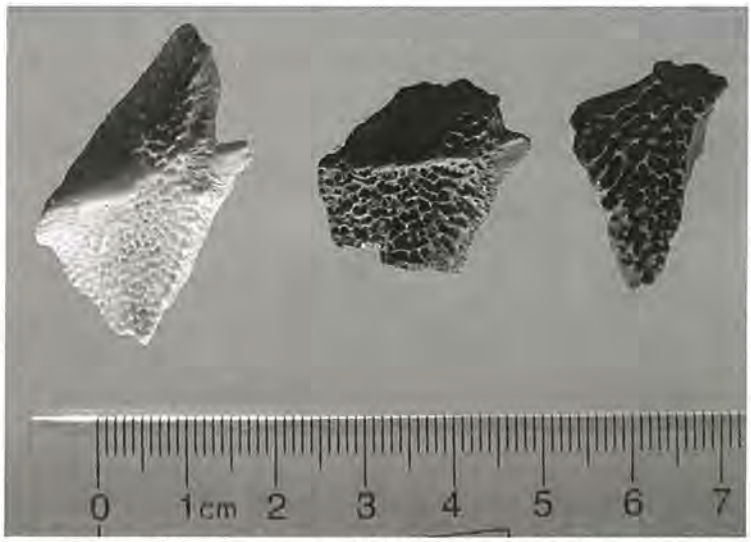


Figure 14. Lateral scutes. Left light color, ATS-JUV comparative specimen, anterior to the left. Center, Atlantic Sturgeon fragmentary archaeological specimen with mid-line ridge and posterior margin. Right, Atlantic Sturgeon fragmentary archaeological specimen, ventral portion (below the mid-line ridge).

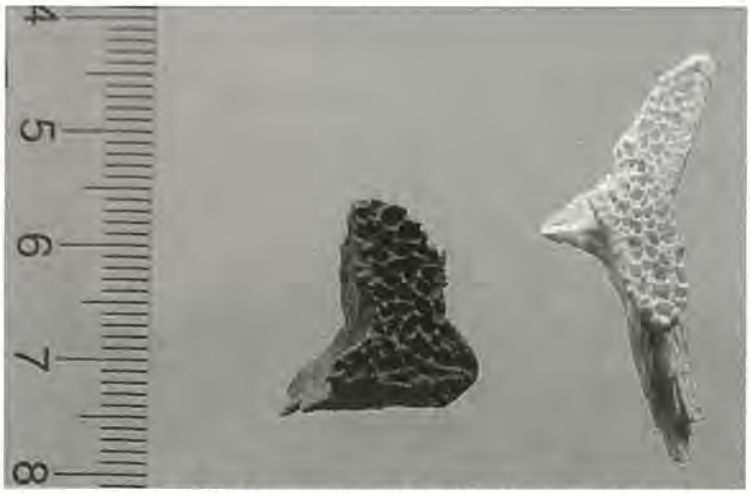


Figure 15. Postorbital bones. Central portion fragment of an Atlantic Sturgeon archaeological specimen (left) compared with ATS-JUV. Note archaeological specimen is approximately 30% larger (wider) than ATS-JUV.

The Shortnose Sturgeon sample is 150 bones (29.9 gr), twice the number and weight of the Atlantic Sturgeon. Dorsal, lateral, and ventral scutes (Figures 18, 19, and 20), fulcra (tail) (Figure 21), ornamented skull and orbital area bones (Figures 22 and 23), and ornamented shoulder girdle bones comprise the identified sample. Again, three or more individuals are represented (see Table 2), including individuals in the 0.5 m, 0.6-0.75 m, and 1.0 m length range. This size range includes both juvenile and adult Shortnose Sturgeon.

Because of the relative numbers of sturgeon bones in the overall faunal sample, we suspect that sturgeon netting and/or fishing was a seasonal focus of Native American activity from this site location. Moreover, the presence of adult and juvenile sturgeon of both species may indicate that this "bay" in the Sheepscot estuary was used by both species for seasonal residence and feeding by multiple age groups and/or for spawning by adults.

Table 2. Archaeological sturgeon bones from site 26.59, Edgecomb, Maine. Combined samples from shell midden levels in 1m square, N99E69, mostly 20 to 30 cm depth.

NOT IDENTIFIABLE TO SPECIES

Fragments, stumps versus pits pattern equivocal, N=137, 13.7 gr

SHORTNOSE STURGEON

Scute or bone fragments body part not identifiable, N = 104, 14.8 gr

Dorsal scutes, n = 12, 4.5 gr, fragmentary, identifiable by preservation of much of dorsal mid-line and symmetrical shape or remainder of fragment. *Longest scute*: 0.8 gr, 3.6 cm length, left lateral half and midline ridge preserved, width est. 4.4 cm, best match scute 4 or 5. *Second longest scute*: 0.5 gr. 3.4 cm length, 1.9 mm thickness; matches scute 5 best by acute internal angle. This scute is ¾ of the length of ATS-JUV. Other dorsal scute fragments 1.1 to 1.3 mm thick. Multiple (N = 2 or more) individuals represented by variability in size.

Lateral scutes, n = 12, 2.5 gr.. Only a few are complete enough to differentiate right (n=2) from left (n=1) by the dorsal-ventral asymmetry. At least 3 scutes represented by the ventral triangular portion of the scute. Two are measurable at 12 and 19 mm length from the mid-line ridge. By comparison, same measurement on ATS-JUV ranges from 15 to 18 mm. So, these lateral scutes represent Shortnose specimens that are about 1 m in length, or shorter (to 0.6 m).

Ventral scutes, n = 2. Two scutes are clearly identifiable by their shape and anterior spine as ventral scutes. One, a left side scute, is small (1.7 cm overall length, 0.1 gr). The second, a right side scute, is larger (3.5 cm length, including spine, 0.6 gr). This compares with 5 cm length for the equivalent scute from ATS-ADL (1.4 m length). Thus the larger ventral scute comes from a Shortnose sturgeon approximately 1 m in length, or likely an adult Shortnose. The smaller scute represents a 0.5 m juvenile.

Shoulder girdle bone fragments. N = 4. 1.8 gr. Could not match bone from photos. Too fragmentary. Decoration morphology definitely shortnose "stumps".

Cranial or skull dermal bones, fragments unidentified to specific element. N = 4, 1.9 gr. Again, decoration is definitely shortnose.

Frontal bone, anterior portion. Left. 1.0 gr.

Fulcra. There are four fulcra fragments (0.2 gr). They exhibit "stumps" for decoration, as small in size (about 50% of the size of ATS-ADL), and exhibit a more gracile shape than the Atlantic sturgeon. The most complete specimen is 18 cm in length and 7 mm in width.

Ventral rostral bone. 0.2 gr. Noticeably different decoration morphology from Atlantic sturgeon.

Supraorbital fragment. 0.4 gr

Postorbital fragment. Right side, 0.2 gr. Portion preserved is 2 cm long, comparative portion on ATS-JUV is 3.3 cm long, so this bone represents an individual that is 60% length of a 1 m fish (ATS-JUV), or 0.6 m. [Note, we have the comparative bone for ATS-JUV for this element. For some other bones we have had to use ATS-ADU for comparative size.]

Supracleithrum, 0.7 gr, portion of posterior margin, small decorated area and large, undecorated extension. Portion preserved is 3.5 cm long, comparable portion on ATS-ADL is 5.0 cm long, so this is a 1 m long fish.

Cleithrum. Two fragments, 0.9 gr.

Clavicle. Decorated surface fragment, 0.1 gr, Comparative measurement not accurate, but this is a small fish, about 0.5 m length.

ATLANTIC STURGEON

Scute or bone fragments, body part not identifiable. N = 50, 6.6 gr; pores per cm range from 8 to 5, with the modal value (most common) being 6

Dorsal scute, fragment of lateral edge 1.1 gr. Element identification based on radial growth pattern on bottom, and slight concavity upward on the pitted surface. 0.25 cm thick. 6 pores/cm.

Dorsal scute, fragment of central ridge. two pieces that fit and were glued with B-72. Best match is 5th dorsal, and the fragment is from the highest point to the posterior portion of the ridge where vertical striations appear on either side of the ridge. 2.6 gr, dorsal ridge height 1.3 cm, compare 0.45 cm on ATS-ADU <4 pores/cm on the side of the ridge. Length is 4.8 cm, while a roughly comparable length on 5th dorsal of ATS-ADU is 1.3 cm. This is a huge adult sturgeon, 3 m or more in length.

Lateral scute, ventral portion, 0.6 gr, 5 pores/cm

Lateral scute, with midline ridge, left. 0.7 gm. antero-posterior length 2.38 cm, 6 pores/cm. Same size as ATS-ADU (1.4 m).

Scute, lateral base of caudal fin. "E" series scute on ATS-ADU. 03 gr, 8 pores/cm

Dorsal rostrum, rhomboidal bone with decorated surface. 0.1 gr

Postorbital, fragment of central decorated portion. 0.5 gr, 6 pores/cm, about 30% larger than ATS-JUV based on photographic comparison. Appx 1.3 m fish.

Postorbital, decorated portion of middle of bone, 0.2 gr, 7 pores/cm.

Supraorbital, fragment decorated surface. 0.7 gr. Size close to ATS-ADU (1.4 m fish).

Supracleithrum, fragment, decorated portion of middle of bone, 0.7 gr, 0.5 cm thick, 7 pores/cm

Cleithrum, portion of decorated surface and undecorated extension. 0.5 gr. 8 pores/cm

Cleithrum, central ridge portion, right element, 0.4 gr By comparison with ATS-ADU (photo), the archaeological specimen comes from a fish perhaps 80% of the length of 1.4 m.

SUMMARY COUNTS AND WEIGHTS

Sturgeon not identifiable to species	n = 137 (39%)	13.7 gr (23%)
Shortnose Sturgeon	n = 150 (43%)	29.9 gr (51%)
Atlantic Sturgeon	n = 62 (18%)	15.0 gr (26%)
TOTAL	n = 349	58.6 gr

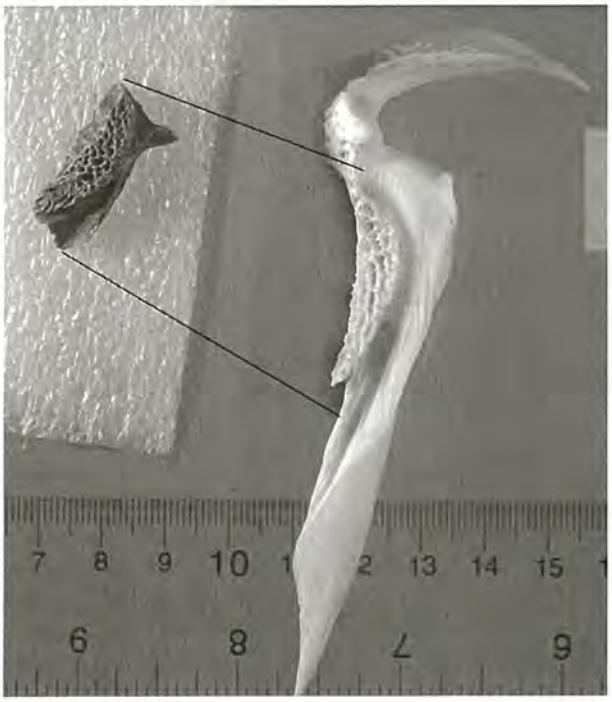


Figure 16 (above). Cleithrum, decorated portion, fragmentary Atlantic Sturgeon archaeological specimen (left) compared with cleithrum of ATS-ADU. Lines indicate approximate portion of bone represented in the archaeological specimen.

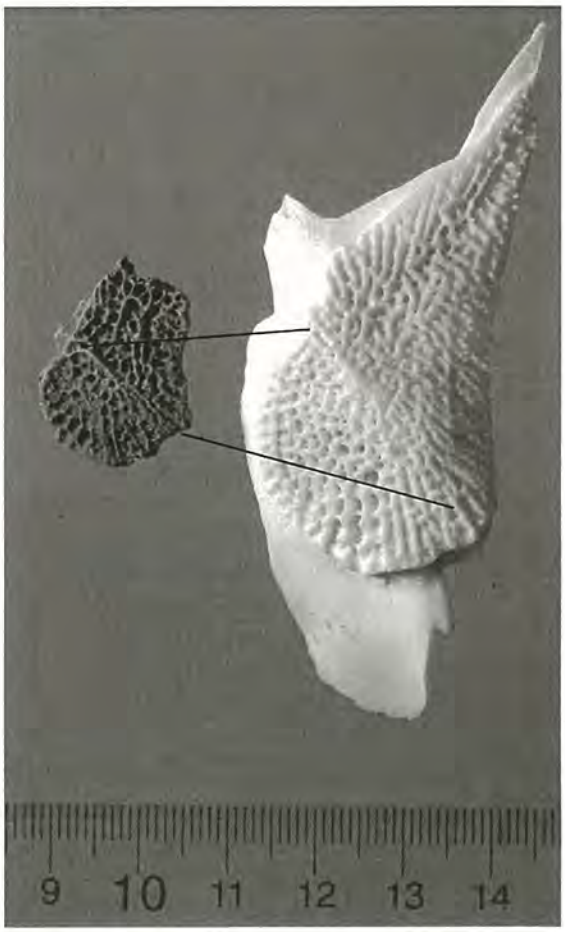


Figure 17 (right). Atlantic Sturgeon archaeological supracleithrum fragment compared with ATS-ADL supracleithrum. Lines indicate approximate portion of bone represented by the archaeological fragment.

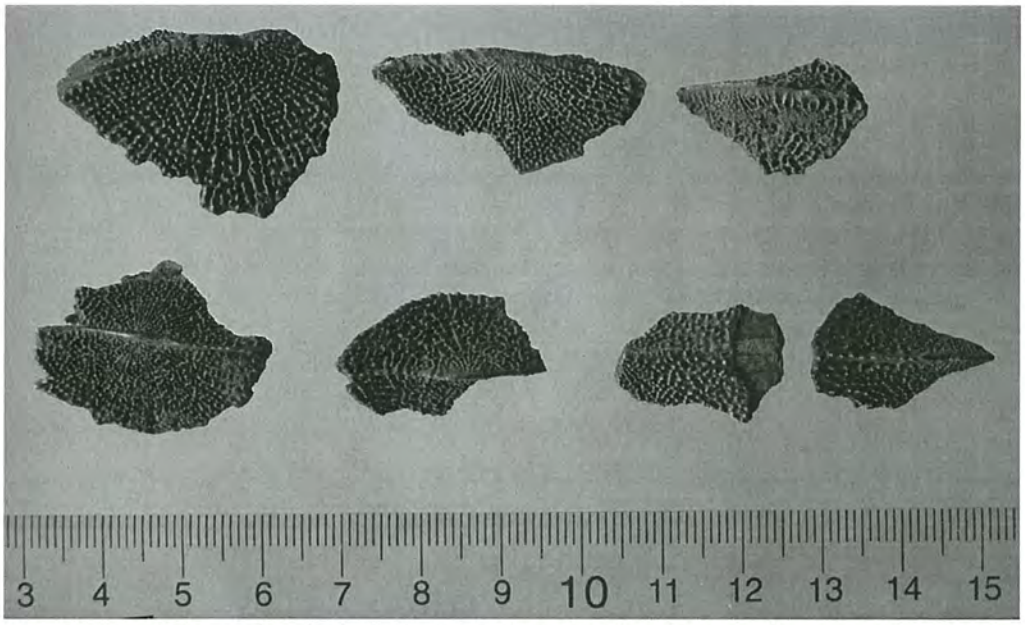


Figure 18. Seven archaeological Shortnose Sturgeon dorsal scutes fragments identified by ornamented surface morphology ("stumps"). Midline ridge is visible on all specimens.

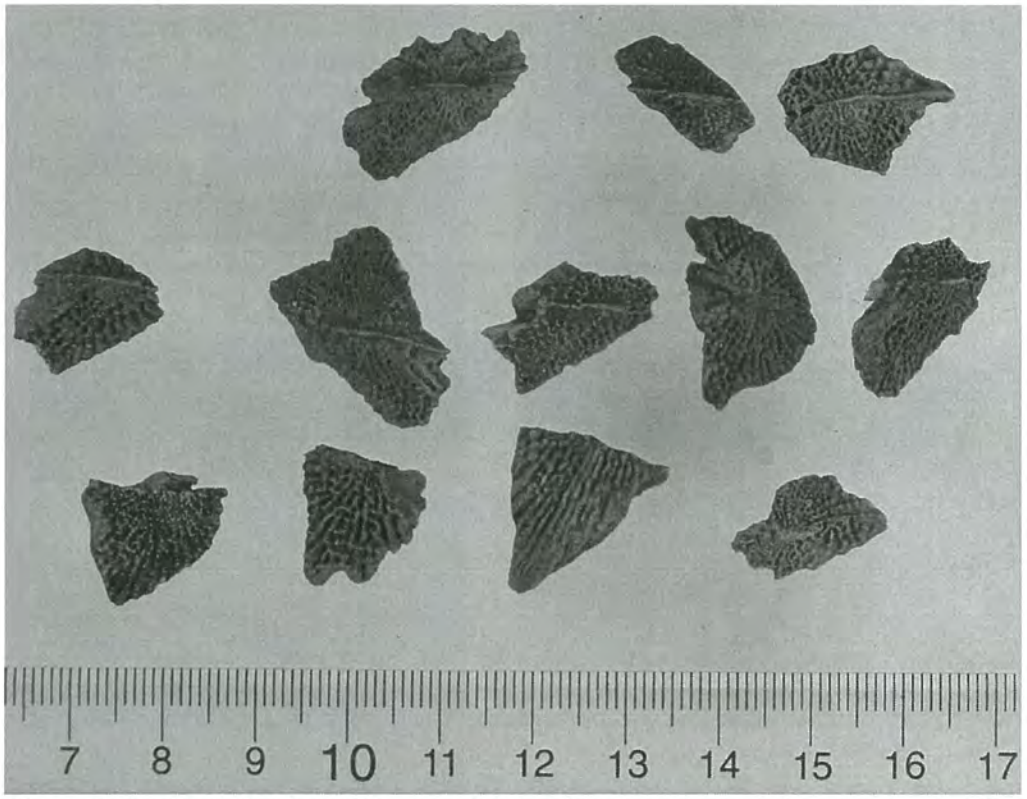


Figure 19. Twelve archaeological Shortnose Sturgeon lateral scutes, mostly fragmentary, identified by ornamented surface morphology. Most of the specimens retain the mid-line ridge. Three at lower left are ventral portions of lateral scutes.

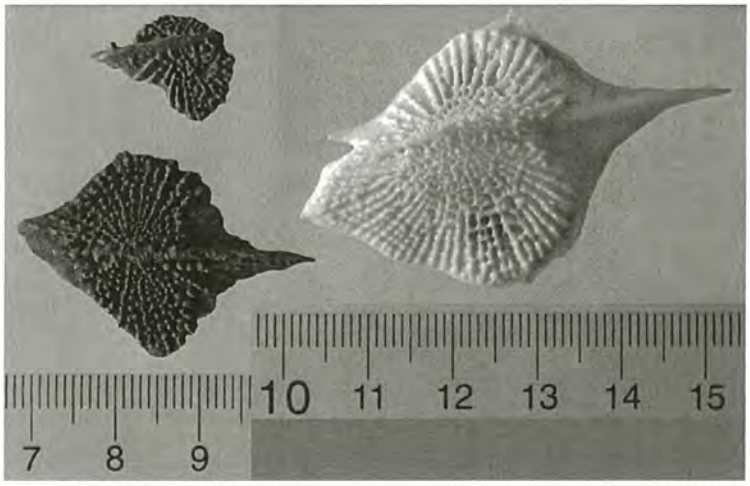


Figure 20. Two archaeological Shortnose Sturgeon ventral scutes (left, dark specimens), compared with ATS-ADU ventral scute (right). The two archaeological specimens are from different-sized fish. One is a left side scute (upper) and one is a right-side scute (lower). The smaller archaeological specimen is from a fish approximately 1/3 of the length of the 1.4 m long ATS-ADU.

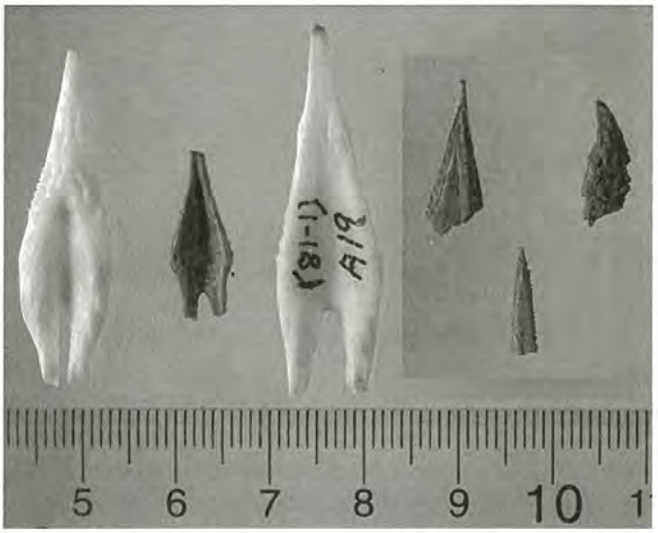


Figure 21. Fulcra (tail edge scutes). The four of darker color are archaeological specimens. Light color fulcra are from ATS-ADU. Because of the visible difference in morphology, we suspect that the four archaeological specimens are Shortnose Sturgeon.

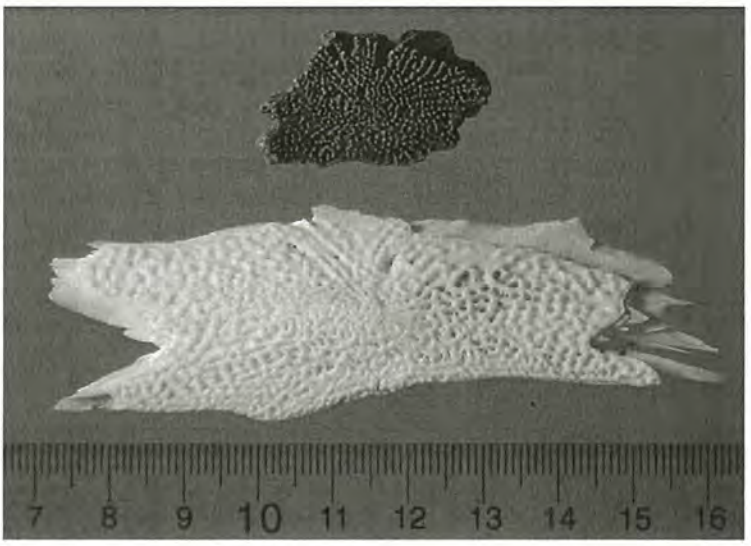


Figure 22. Archaeological specimen (top, darker color) frontal bone central section fragment. Its surface ornamentation indicates that it is a Shortnose Sturgeon (stumps). The archaeological specimen is roughly comparable in size with Atlantic Sturgeon ATS-JUV frontal bone (light color, below), a 1.0 m long fish.

Figure 23. Postorbital bones. Archaeological fragmentary specimen (darker, left), identifiable as Shortnose Sturgeon by its ornamentation ("stumps"). At right, complete postorbital from Atlantic Sturgeon ATS-JUV for comparison. Note the species difference in the decoration, but similarity in size. ATS-JUV is a 1.0 m long fish.

CONCLUSIONS

The morphological differences in the scutes (ornamented bones) that we have observed and documented here allow for routine *species* differentiation of Shortnose and Atlantic Sturgeon archaeological specimens from the Northeast Atlantic coast and estuaries, even with fragmented bones. The primary diagnostic differences are in larger size of adult Atlantic Sturgeon, and in the differential morphology of the exterior ornamentation on the scute and bony surfaces (i.e., primarily pitted in the Atlantic Sturgeon versus stumped in the Shortnose Sturgeon). The ornamentation on the outer surface of the scutes and skull dermal bones differ morphologically in a predictable way between the two sturgeon species, regardless of body location, and seemingly in immature specimens of both species. This difference can be detected with unaided visual inspection or slight magnification.

Our examination of an archaeological collection has documented a sturgeon breeding/nursery and/or feeding area for both species in the upper Sheepscot estuary dating between roughly 2200 and 1000 years ago. Prior work (Spiess and Halliwell 2012) documented the geographic distribution of sturgeon bone in Maine pre-European archaeological sites, with many specimens coming from sites along lower estuaries and the marine coast outside of estuaries. Maine Native Americans did preserve fish and other food by drying and smoking, but they did not trade or move food stuffs in large quantity. In fact, archaeologically identified fish bones are uniformly found adjacent to a logical place to harvest the fish (Spiess and Halliwell 2012), often harvested we think using a weir or nets set in the inter-tidal zone.

Combining the archaeological data of geographic location and (approximate) age of the site occupation with species identification (Atlantic versus Shortnose Sturgeon), and limited ability to reconstruct fish size (age), gives archaeologists a powerful tool to reconstruct the range and habitat used by these two species over long spans of time. Longer time baseline information may also show how resilient these two species are (were) to past climatic changes around the Gulf of Maine.

ENDNOTE

[1] The *Maine Historic Preservation Commission* (MHPC) archaeological laboratory in Augusta (Dr. Arthur Spiess) had been added to the National Marine Fisheries Service (NMFS) permit #1614-03 (as of 2013) for sturgeon research, along with the *Friends of Merrymeeting Bay* land trust (Ed Friedman).

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The authors wish to thank the late Dr. Brian Robinson, University of Maine, Orono, for the loan of his excellently prepared, well-labeled adult Atlantic Sturgeon skeletal specimen (ATS-ADU). We thank Dr. Gayle Zydlewski, University of Maine, Orono, for her interest in the possible use of sturgeon bone from archaeological sites for comparative use for documenting modern sturgeon distribution when we were initiating this study. We also thank her student, Matt Altenritter, for the donation of elements of an immature Atlantic Sturgeon (ATS-JUV). We thank Ed Friedman for allowing us to examine a Shortnose Sturgeon skin (SNS-FOMB) and excellent photographs, and we thank Maine DMR fisheries staff member Jason Bartlett for the loan of disarticulated Shortnose Sturgeon scutes.

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APPENDIX A: DESCRIPTION OF ATLANTIC STURGEON SCUTES AND ORNAMENTED BONES

Descriptions and metrics follow for various bones of the Atlantic Sturgeon with ornamented surfaces, based on the juvenile (smaller, ATS-JUV) and adult (larger, ATS-ADU) specimens. We include the dorsal, lateral and ventral linear arrays of scutes, dermal bones near the tail, skull bones, and opercular and pectoral region bones.

We begin the appendix with descriptions of "series" of body scutes of Atlantic Sturgeon. By convention, the scutes in the dorsal, lateral and ventral rows are labeled from cranial (head end), beginning with #1, and extending toward the tail. The anterior-most scute (#1) in the dorsal series is incorporated into the posterior skull roof, where it is in lateral contact with the post-temporal bones of the skull (see descriptions of skull bones below). Based on the close examination of both ATS-JUV and ATS-ADU, there is some variation in morphology (e.g., extent of sharp spines on scute margins) between the sub-adult and adult Atlantic Sturgeon. According to Daniels (1996), as sturgeon age "surface ornamentation diminishes" on the scutes. The ATS-ADU *adult* specimen scutes appear to be much more rugose in construction, as well.

Dorsal Scutes (Appendix Figures 1a-d; Appendix B Table 1)

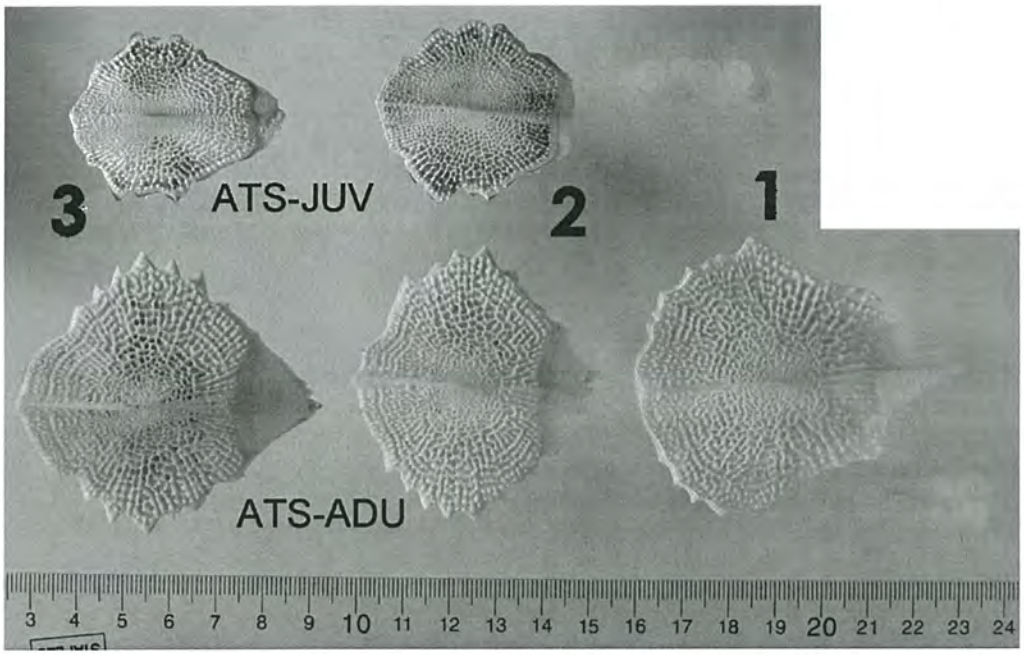
There are 11 scutes in the dorsal series of Atlantic Sturgeon. The series from ATS-JUV available to us begins with scute #2. (The posterior portion of the skull with scute #1 had been cut off.) Scutes overlap or are in close contact in juveniles, and are well spaced apart in adults (Hilton et al. 2011). At the caudal end of the dorsal series, dorsal scute #11 is tear-drop shaped, with further transition caudally to dorsal caudal scutes and the basal fulcra (see below).

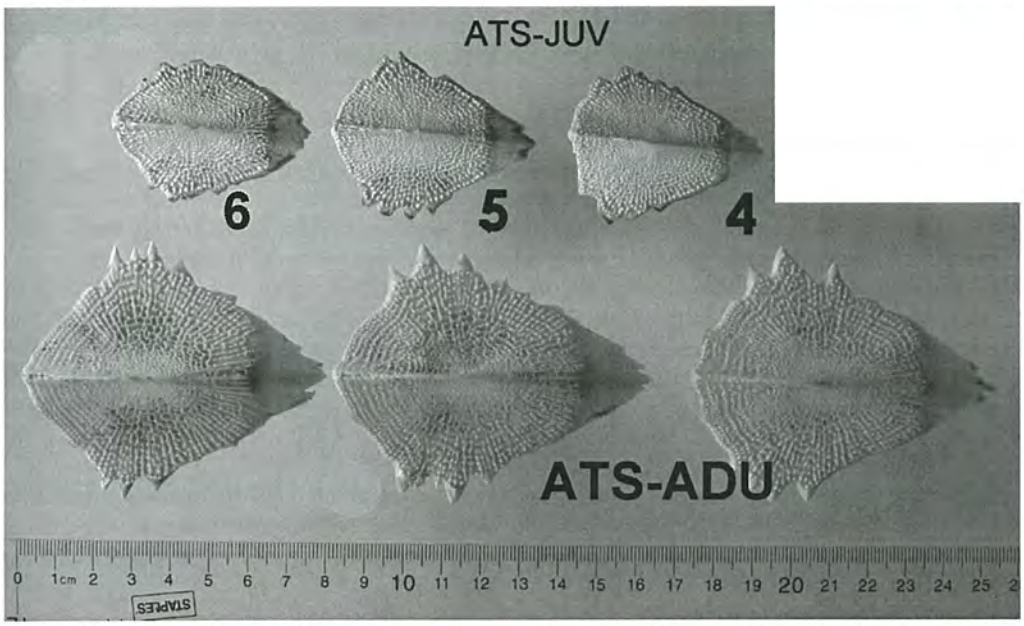
The dorsal scutes (and all others) exhibit "ornamented" exterior surfaces, and have nearly smooth interior surfaces (buried in the skin). The anterior exterior margin of each scute is not ornamented, and remains embedded in the skin in the living fish. Each scute in the dorsal series exhibits a ridge that runs antero-posteriorly along the mid-line. The scute is angled slightly convex downward (convex internally) along this ridge. The angle decreases from near 120 degrees (estimated) at scute #2 to approximately 90 degrees at scute #6; then proceeding caudally, the angle flattens out again to 120 degrees (estimated). The dorsal scutes are round in general outline anteriorly, and more elongated posteriorly.

Lateral margins exhibit spikes of various lengths. On ATS-JUV dorsal scutes #8 - #10 all have small spines in the dorsal ridge with #8 and #9 exhibiting the most pronounced spines. The spine on #9 is approximately 2 mm high above the dorsal ridge. These dorsal spines are less noticeable on the larger scutes of ATS-ADU, as the spines disappear as the fish grows and the scutes get thicker (Hilton et al. 2011).

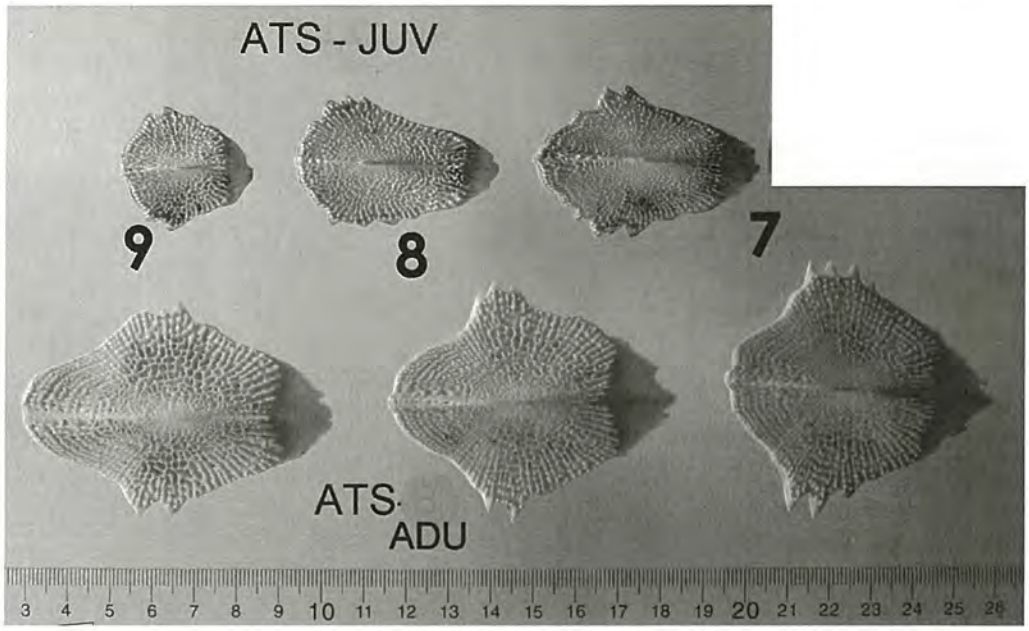
Lateral Scutes (Appendix Figures 2a-c; Appendix B Table 2)

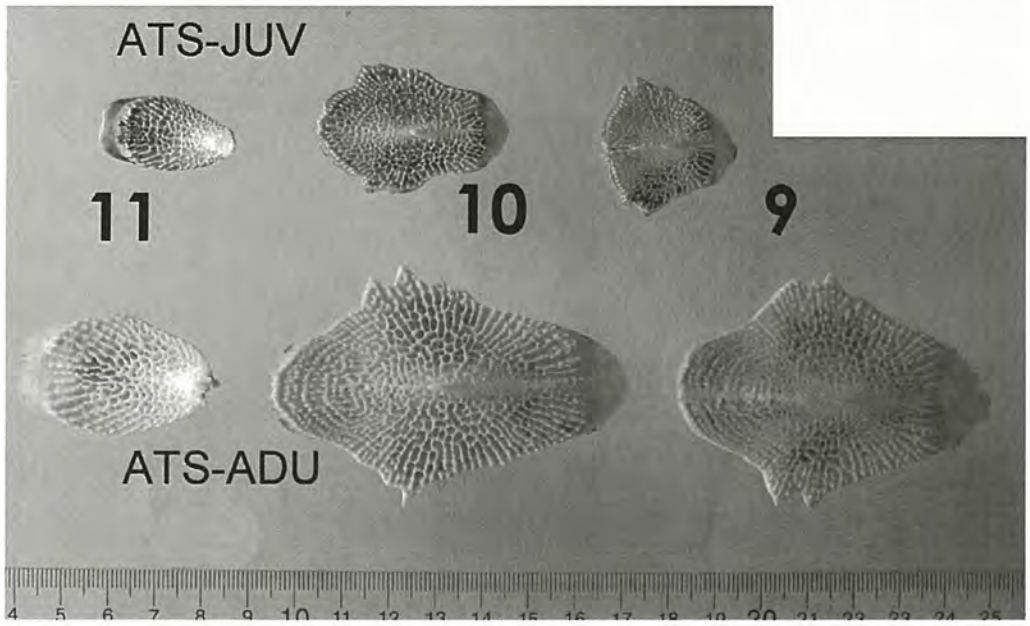
In ATS-JUV (the smaller specimen), the first two lateral scutes (1 and 2) are missing. For ATS-ADU, both right and left lateral rows are available for comparison, and the caudal-most scute is a small #29. Lateral scutes are generally diamond-shaped, and as with all scutes the exterior surface is ornamented. The anterior margin of the scutes that remain under the skin is unornamented or smooth, but the anterior margin develops rounded projections or spines that extend anterad (toward the anterior). (These projections are present in ATS-ADU, not in ATS-JUV). Also in ATS-ADU a spike or spine projects a short distance from the upper (dorsal) and lower (ventral) end of the lateral scutes. In ATS-ADU there is a short lateral crest or ridge that divides the ornamented portion of each lateral scute into a dorsal and ventral portion. The size of the scutes diminishes gradually but noticeably from 24 to number 28 or 29. The longest dimension of the lateral scutes is from apex of the dorsal to apex of the ventral portion of the ornamented surface. It is actually at about





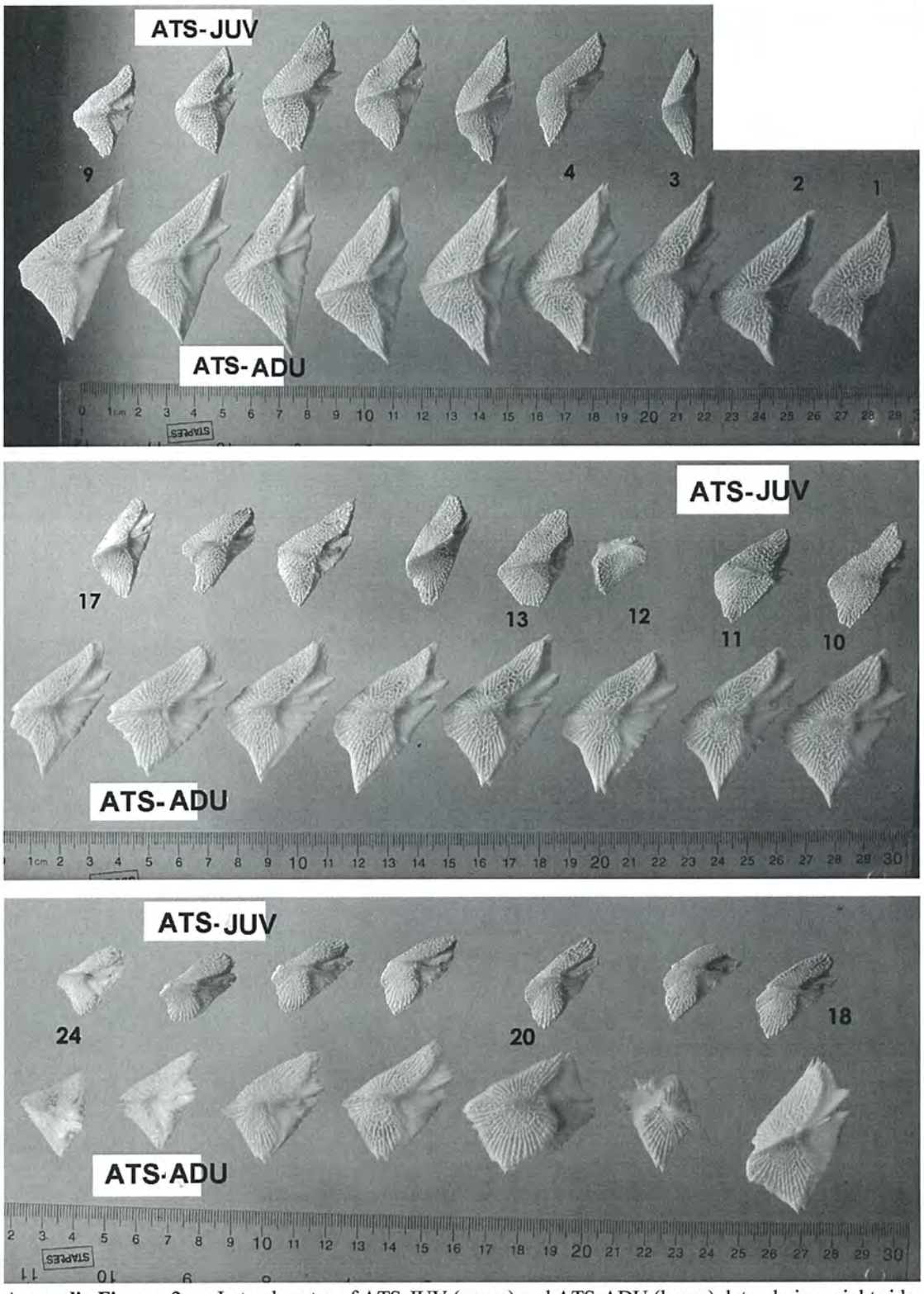
Appendix Figures 1 (1a,b above and 1c,d facing page). Each figure shows dorsal scutes of ATS-JUV (upper) and ATS-ADU (lower) in dorsal view. Scutes are numbered in sequence (1-11) from anterior to posterior. Anterior edge of each scute to the right. Anterior-most scute (1) of ATS-JUV missing. Note, scute #9 is shown twice (once each in 1c and 1d).



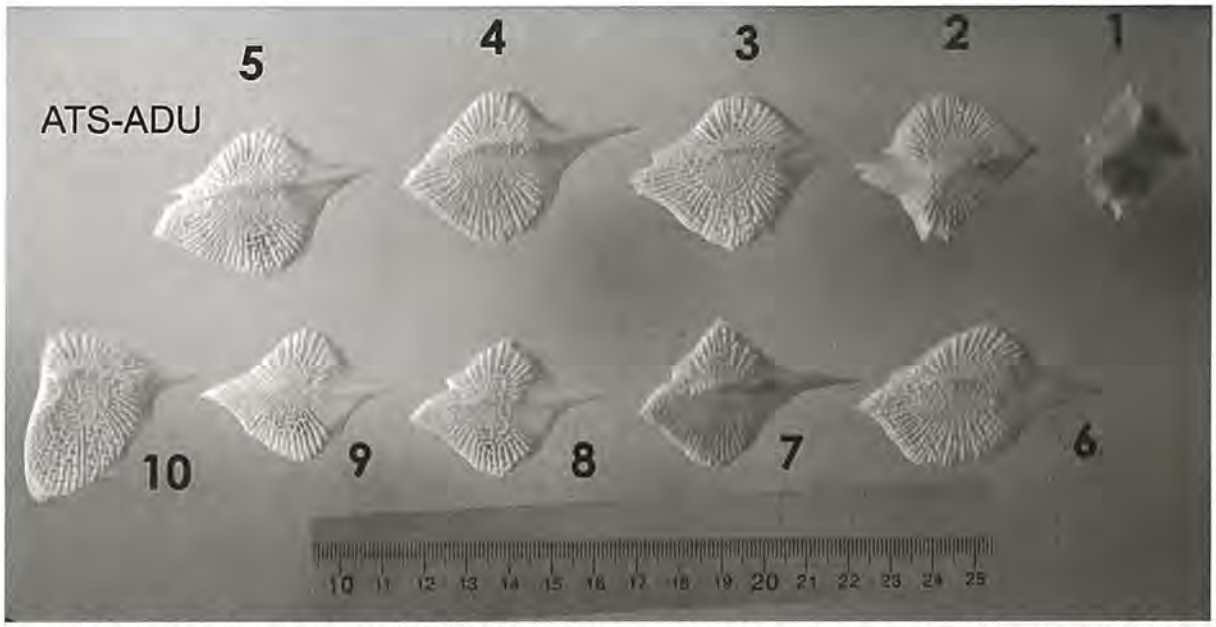


a 45° angle to the horizontal long axis of the fish. Scute thickness was measured 2 to 1 cm away from the longitudinal ridge.

The right and left series of lateral scutes in ATS-ADU are not symmetrical mirror-images. From scute 18 caudally to scute 29, there is some variation in size and shape between right and left series in this specimen. It appears that there is some local control over scute growth based on the growth in adjacent scutes. For example, R(right)18 is larger than L18. R19 is diminutive, about half the size of R18, with a poorly-developed ventral section. There is a similar growth issue or damage to R12 on ATS-JUV, with enlarged adjacent lateral scutes, but we do not have the left lateral row for comparison. It appears that adjacent scutes grow to make up for smaller size in an abutting scute.



Appendix Figures 2a-c. Lateral scutes of ATS-JUV (upper) and ATS-ADU (lower), lateral view, right side. Scutes are numbered in sequence (1-24) from anterior to posterior. Anterior edge of each scute to the right. Note incompletely formed scutes at #12 in ATS-JUV and #19 in ATS-ADU.



Appendix Figure 3. Ventral scutes of ATS-ADU, lateral view, right side. Scutes are numbered in sequence (1-10), from anterior to posterior. Anterior edge (spine) of each scute to the right.

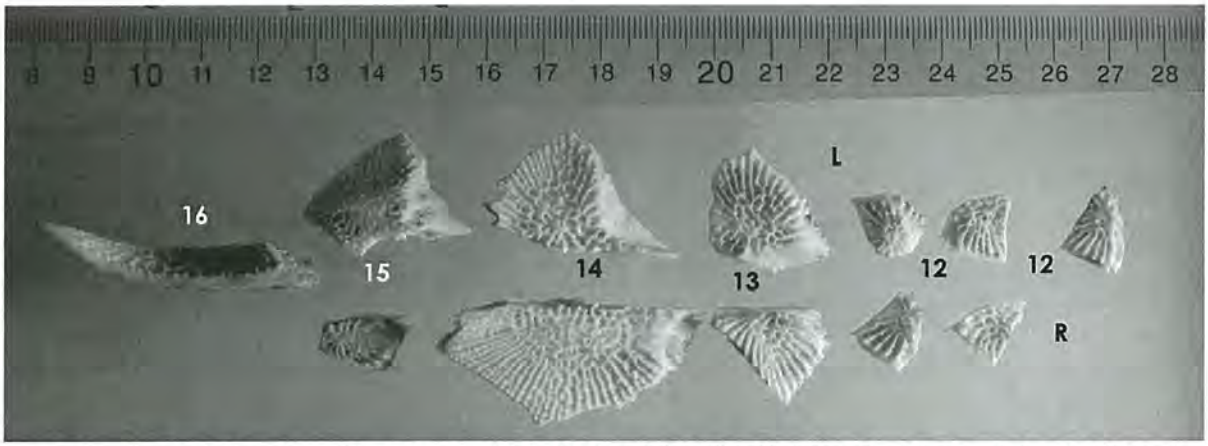
Ventral Scutes (Appendix Figure 3; Appendix B Table 3)

This description of ventral scutes is based on the larger ATS-ADU specimen, because this row of scutes was not included with the ATS-JUV specimen. These scutes come from the ventral margin of the lateral side of the sturgeon, located along the border between the lateral side and the underbelly of the fish. With the exception of the first two anterior scutes, these scutes are tear-drop shaped, with a sharp spine of 1 to 1.5 cm length pointing anterad. (The spine sticks out from the forward part of the scute.) The spine is strengthened by a dorsal ridge that continues posteriorly into a ridge along the scute. Generally the ventral portion of the scute (ventral to the ridge) is larger than the dorsal portion by 50 to 100% in area. The ventral portion of the scute seems to be symmetrical anterior-posteriorly, except for scute 10 where the ventral portion points caudally as well as ventrally.

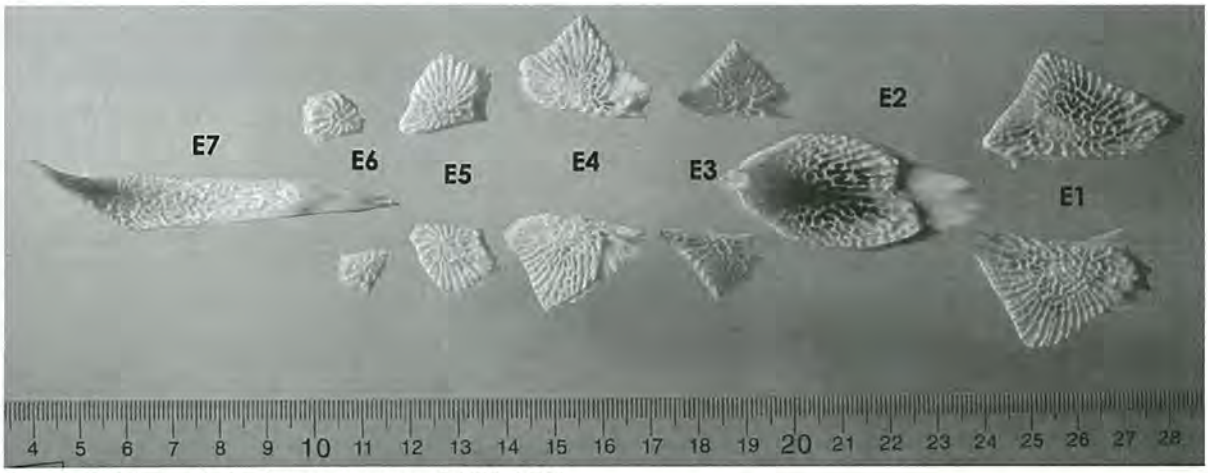
The first (#1, anterior) scute has a series of short spines sticking anteriorly and posteriorly, dorsally and ventrally. The second scute has a clear articular groove posteriorly for the anterior spine of the third scute on its dorsal surface, so the spines are laying on the dorsal side of the scute in front of them. They would seem to provide a sharp defensive series of spines to anything grabbing the fish from behind. The spines seem to be "tough" and likely to survive in archaeological specimens.

Dorsal Caudal Scutes and Basal Fulcra Bones (Appendix Figure 4, Figure 11 in main text for basal fulcra; Appendix B Table 4)

The anterior margin of the dorsal fin rises caudally of (just behind) the last dorsal midline scute (labeled A 11 on the ATS-ADU specimen). Beginning behind (caudally of) the base of the dorsal fin there are a cluster of small scutes (labeled A12 in that specimen, 12 in Appendix Figure 4) and three paired small scutes (A13-15, R and L) as the dorsal series of scutes transitions to the midline of the base of the tail. The scutes are "paired," but are not identical in size in the right and left series. The shapes of these caudal small scutes (labeled A13-15 on ATS-ADU, 13 to 15 in Appendix Figure 4) are generally rhomboidal, with side lengths and angles that vary from 3 to 5-sided. Found in archaeological context, these bones would be recognized as "scutes," with an ornamented exterior surface and a smooth interior surface. One midline bone (not paired) is transitional from the caudal dorsal line scutes to the bones that are further caudal. It has a flat outer surface and a rounded or oval, thick body underneath, tapering to an upturned point caudally (labeled 16 in Appendix Figure 4). The outer surface is roughened and pitted (ornamented), and would be recognizable by this pattern as sturgeon "scute" if found in fragmented condition. Behind this bone, a series of 8 *basal fulcra* (Hilton et al 2011) (labeled A16 through A21 on ATS-ADU) protect the leading dorsal edge of the tail as it rises. (Basal fulcra are described in the main text, because they are represented in the archaeological collection.).



Appendix Figure 4. Dorsal caudal scutes (caudal to the dorsal fin) of ATS-ADU. Dorsal view, left and right scutes. Scute 16 is located at the base of the rise to the tail (caudal) fin. Scute 16 is shown at a slight lateral angle.



Appendix Figure 5. Anal ventral scutes of ATS-ADU.

Anal Ventral Line Scutes (Appendix Figure 5; Appendix B Table 5)

There is a short series of scutes of variable morphology along the ventral midline, posterior to the anus in the Atlantic Sturgeon. The anus is anterior to the anal fin, so these scutes are located between the anus and the anal fin. (These scutes are labeled the AE series in specimen ATS-ADU.) The series includes mid-line (unpaired) scutes E2 and E7, and five pairs of scutes on either side of the mid-line (E1, E3-E6). The midline scutes E2 and E7 protect the anterior edge of the anal fin (E2) and the anterior base of the beginning of the downsweep of the tail (E7). At the anterior base of the anal fin, scute E2 is located on the midline (not paired), and exhibits a tear-drop shape with an upswept posterior point. The anterior edge is smooth (under the skin), while most of the exterior surface is ornamented. It seems that it would be difficult to differentiate this ventral series of scutes (E1 - E6) from the dorsal series A11 to A16 in archaeological assemblages. The paired scutes of both series are small (1 to 3 cm side) irregular polygons of variable shape with almost straight edges. Posterior to the paired scutes E6 is another unpaired, midline scute protecting the base of the downswept anterior margin of the tail (E7). This scute is long, thin and diamond shaped (four sided), with an upswept point posteriorly. The anterior edge is smooth along the exterior, and pits (or stumps ornamentation) appear about 2 cm behind the anterior edge. The interior (skin side) is smooth.

The dorsal and ventral scutes that are located at the anterior base of the dorsal fin (A11 on ATS-ADU, Appendix Figure 1d) and anterior base of the anal (ventral) fin (E2 on ATS-ADU, Appendix Figure 5) appear to be homologous scutes. We anticipate that recognizing them as dorsal or anal series scutes in disassociated and fragmentary archaeological collections would not be possible. On the other hand, these two scutes are easily recognizable by their

tear-drop shape. There are only two per individual. Moreover, they exhibit similar pit sizes (ornamentation) on their exterior surfaces. Thus, they may be useful in minimum-number counts of sturgeon in large archaeological collections, and in determining sturgeon body size.

Small Scutes Between Dorsal and Lateral Rows (Appendix Figure 6)

Hilton et al. (2011:92) describe three types of bony "squamation" in addition to the cranial ornamented bones and the lines of dorsal, lateral and ventral scutes: 1) [small] bony platelets in the skin between the rows of scutes, 2) rhomboidal caudal scales, and 3) round-based scales associated with the internal surface of the pectoral girdle. In ATS-ADU the small scutes from between the dorsal scutes and lateral line scutes, from the left side of the body, weigh 3.3 gr. Mostly they are diamond shaped, 1.1 x 0.7 cm modal size, and 0.2 cm thick (see Appendix Figure 7). We estimate that there are 100 of these small scutes. (They exhibit slight pitting or ornamentation on the exterior surface.) The three largest scutes are 1 cm diamond shapes, 0.4 gr total. The smallest (n=100 estimated) weigh 1.5 gr total, and are small diamonds in shape, 1 mm or 2 mm on a side.

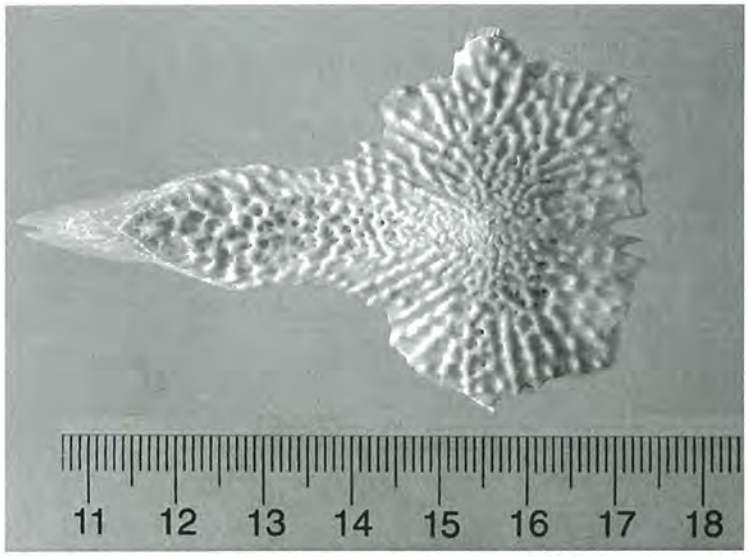
Appendix Figure 6. Small dermal scutes ("squamation" of Hilton et al. 2011) located near the tail between the posterior ends of the dorsal, lateral and ventral rows of larger scutes.

Dermal Bones of the Skull (Appendix B Table 6, figure numbers listed in App B Table 6)

Dermal bones invest (cover the exterior of) the head: the skull roof, circumorbital (eye) area, and much of the snout, and the the gill cover and pectoral area. The exterior surfaces of these bones are partially or mostly ornamented with a pitted surface visually similar to the pitted surfaces on the exterior of body scutes. The ornamented bones of the main portion of the skull are thin compared with their length and width. We doubt that they would survive in most archaeological collections except as fragments. On small fragments from an archaeological site, the ornamentation on a skull bone appears similar to the ornamentation on a body scute. Thus, archaeologically identified fragmentary sturgeon 'scutes,' identified based on the exterior ornamentation, could be either from the body or skull.

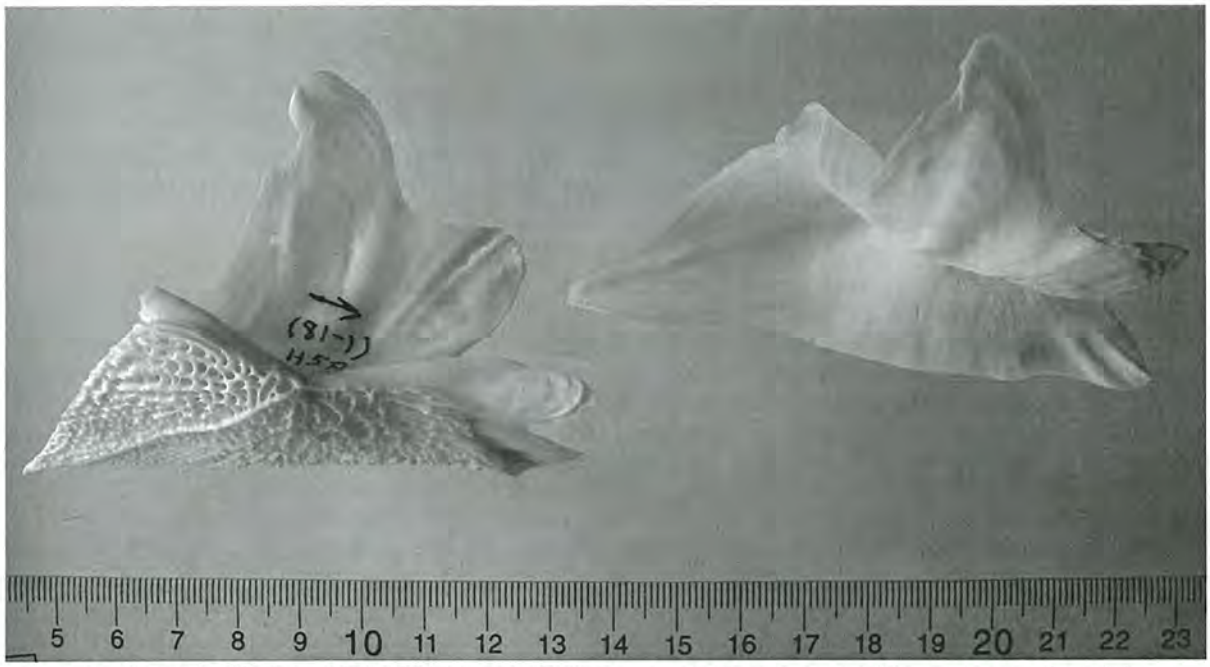
The ornamented, dermal bones of the head and pectoral area can be divided into various regions. The pattern of bone shape in many of the head regions "is marked by extreme variation" in outline shape and often lateral asymmetry (Hilton et al. 2011:19; see also Jollie 1980). Nine elements (7 paired, two midline) "form the stable elements of the functional dermal skull roof (i.e. those elements ... incorporated into the skull, that are readily comparable among specimens)" (Hilton et al. 2011:19). Laterally symmetrical bones that apparently vary relatively little among specimens also include the orbital area, and the subopercle of the gill area. The ATS-ADU specimen head and pectoral area ornamented bones have been carefully labeled by Brian Robinson H1 to H22. Those labels are referenced in Appendix Table 6, along with abbreviations following Hilton et al. (2011).

The functional dermal skull roof includes the first dorsal scute (A1 in ATS-ADU). The first dorsal scute is the posterior-most bone of the skull "roof", incorporated along the midline into other posterior interlocking bones of the skull. The reader is referred to Hilton et al. 2011 for drawings and photographs showing the positions and articulation of these bones. There are paired (left and right) suborbital area scutes as well that complete bony protection around the eye.



Appendix Figure 7. Median extrascapular, ATS-ADU. Anterior to the left. Located on the midline of the posterior skull, this bone articulates posteriorly with the first dorsal scute (see Figure 3).

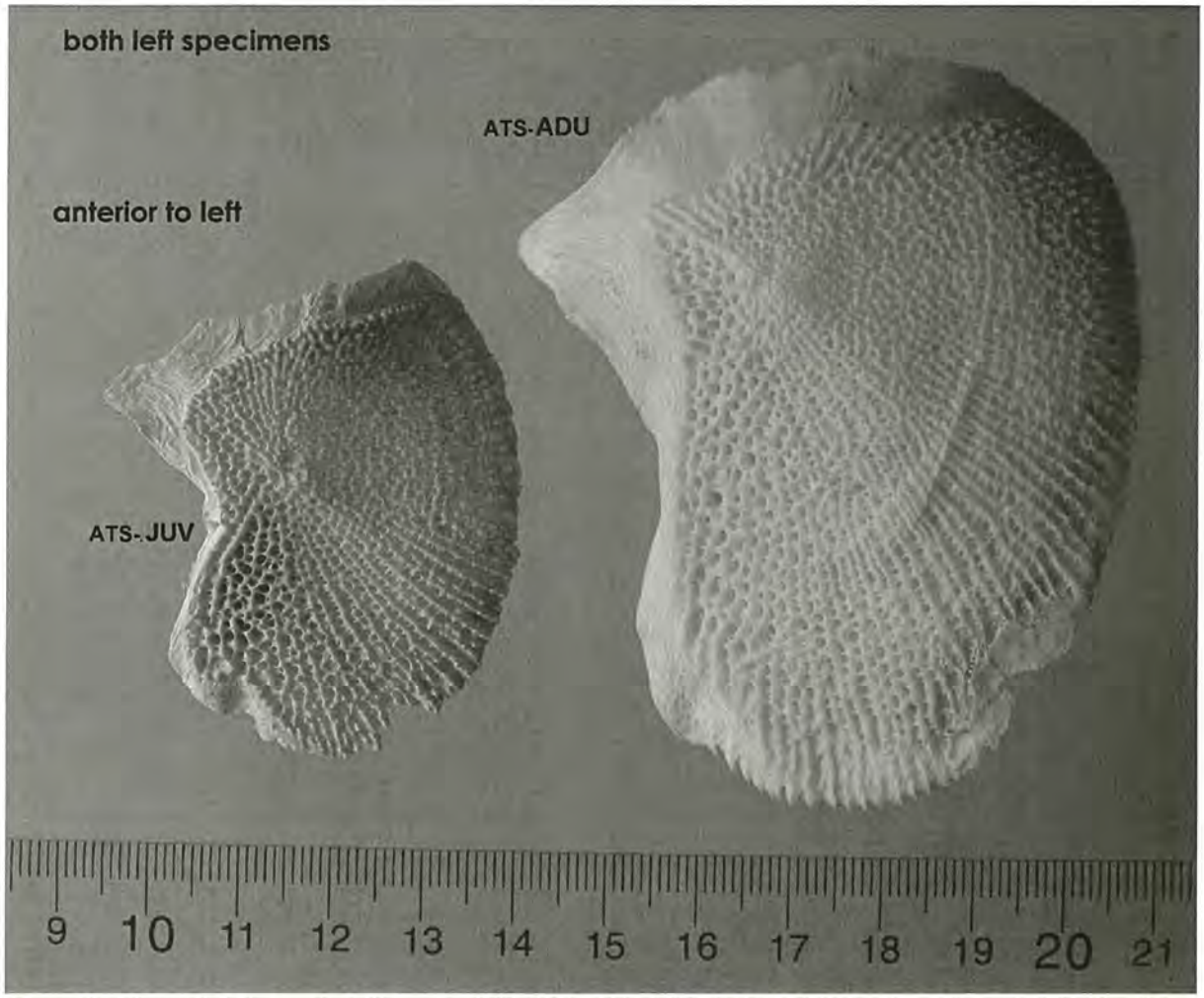
Smaller, variable interlocking bones with ornamented surfaces (scute-like) extend forward on the dorsal surface of the snout (dorsal rostral bones of Hilton et al. (2011:29-30); H15-H22 on ATS-ADU, Appendix Figure 17). These dorsal rostral bones are perhaps 8 to 10 in number per side, and are long (antero-posteriorly) and narrow. They are not symmetrical (not all paired). The dorsal rostral bones are fairly thick for their length and width. The interior surface is smooth, but the exterior surface is ornamented. The border rostral bones (n = 9 in ATS-B) are very irregularly shaped, with a smooth interior surface and ornamented exterior. All nine weigh 4.1 gr. They are 2 to 2.5 mm thick. We think that these rostral bones are structurally strong enough to survive in archaeological context, but it would be impossible to "match" them, except to state that they are rostral bones.



Appendix Figure 8. Clavicle, ATS-ADU. Note the limited ornamented surface and delicate construction of the bone. Arrow points anterad.

Opercular Area and Pectoral Girdle (Appendix B Table 6, figure numbers in App B Table 6)

Many of the bones in the opercular area and pectoral girdle have ornamented exterior surfaces, and thus in fragmentary condition could be mis-classified as "scutes." The opercular series of bones (gill area) is composed of a large, plate-like subopercle and (usually) two branciostegals on each side (Hilton et. al. 2011:52). The subopercle (H6, sob, Appendix Figure 9), is thin, with a dorsal surface that is mostly ornamented. The paired subopercles are

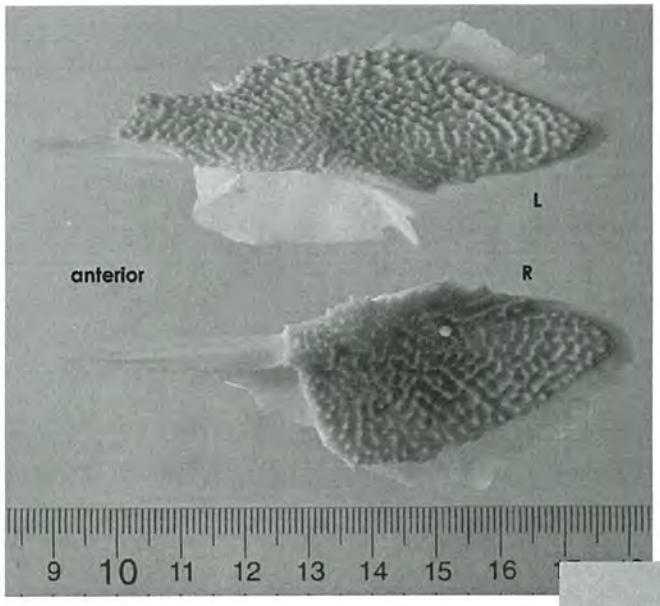


Appendix Figure 9. Subopercle (gill cover). ATS-JUV at left, ATS-ADU at right. Both are from the left side of the fish.

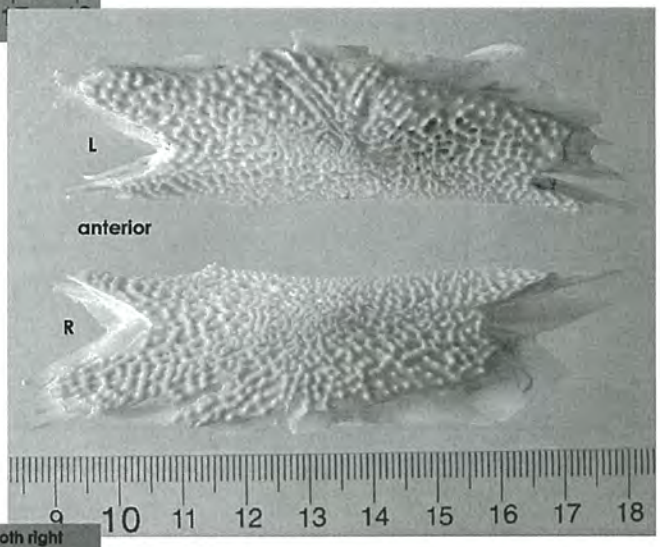
symmetrical (mirror images) in ATS-ADU. The bone exhibits an unornamented anterior extension, and the posterior margin exhibits a vague, radiating pattern to the ornamentation. The interior surface is typically smooth.

Three bones of the pectoral girdle (posterior to the gill area, support for the pectoral fin) ossify with some surface ornamentation (supracleithrum, cleithrum, clavicle). The supracleithrum (scl; H3 in ATS-ADU, Figure 17) is a well-ossified structure with a roughly triangular ornamented component, slightly concave anteriorly (Hilton et al. 2011:81, 83). The substantial ornamented portions of the supracleithrum, we suspect, would survive as identifiable in archaeological samples. The cleithrum (H4, cl, Figures 4, 10, 16, see Table 6) is a complex, curved thin bone with a thickened ornamented overlay on its exterior edge. The ornamented portion articulates ventrally with the larger ornamented portion of the clavicle. The ornamented surface exhibits a distinctive fold or protuberance separating a larger from smaller (long and thin) ornamented portion. Only the thickened, ornamented portion would survive archaeologically.

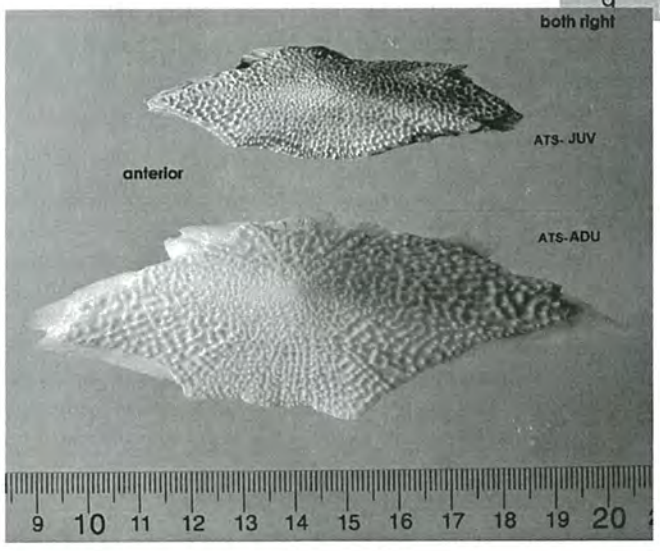
Finally, the clavicle (H5, clv, Appendix Figure 8) we describe generally as L-shaped in antero-posterior view, with the interior or upper portion of the L being thin and unornamented bone. Located ventrally to the supracleithrum, the ventral (exterior) face of the clavicle exhibits a large ornamented area (8x4 cm in ATS-ADU), exposed on the surface. The entire bone is very thin except for the ornamented area, with a complex three dimensional shape. This bone would not survive as recognizable in most archaeological contexts, except as broken "ornamented" pieces.



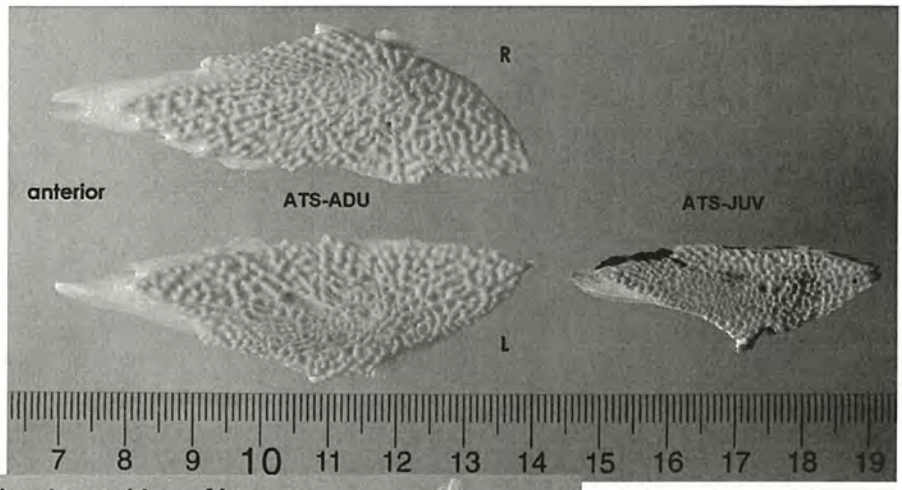
Appendix Figure 10 (left). Parietal bones, ATS-ADU. Anterior to the left. Note that the bones are not identical in symmetry.



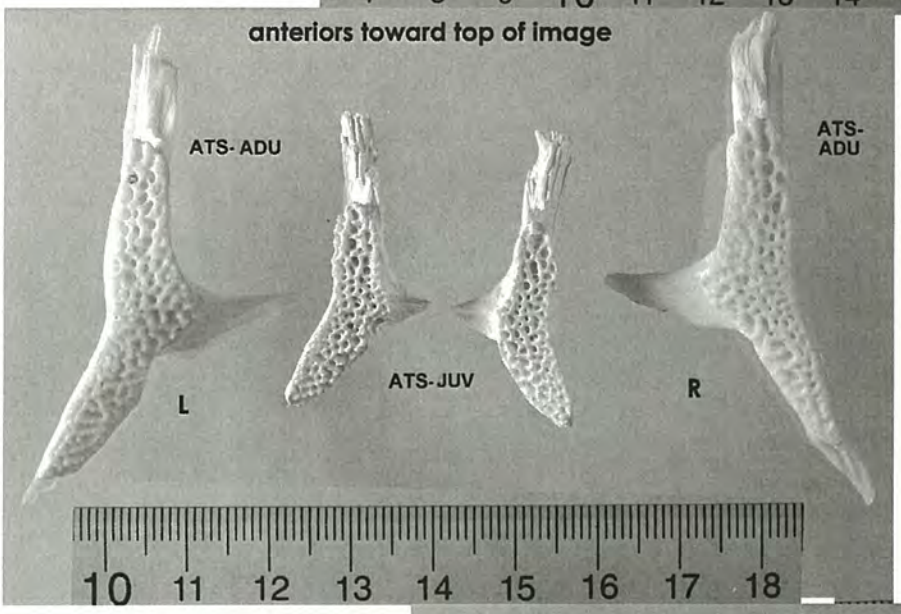
Appendix Figure 11 (right). Demopteroic bones, ATS-ADU. Note that the images are placed with the lateral edges together.



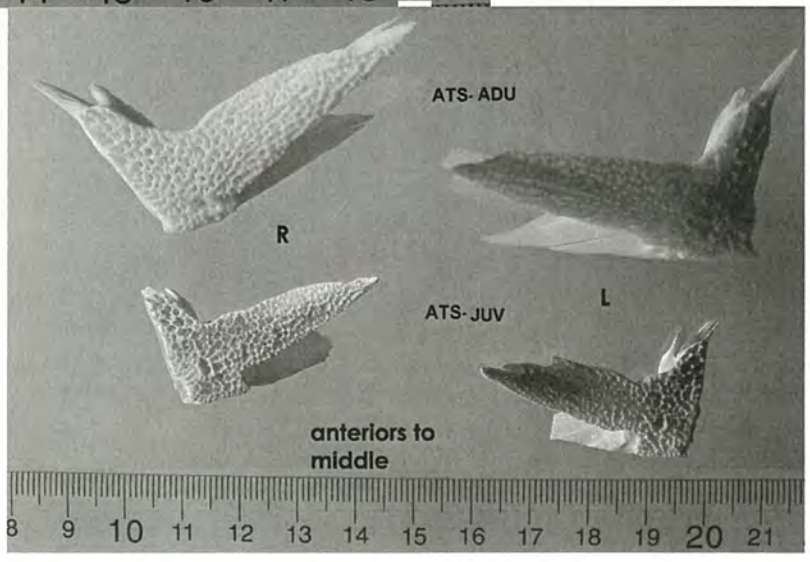
Appendix Figure 12 (left). Frontal bones. ATS-JUV above, ATS-ADU below. Both are from the right side of the skull. Anterior to the left.



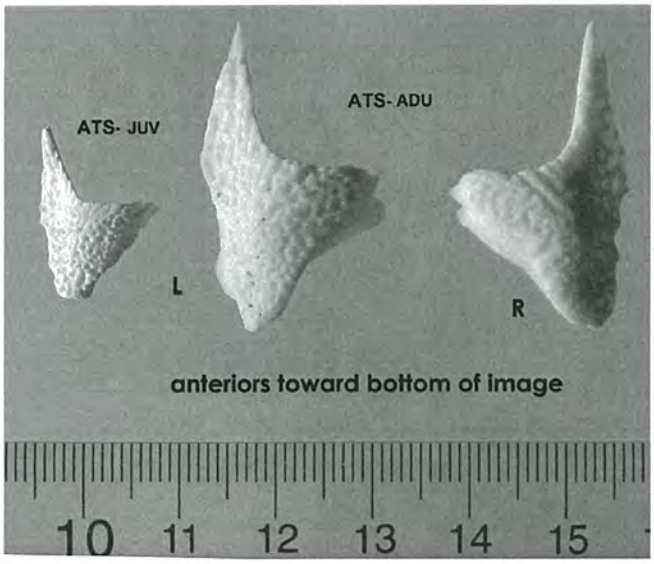
Appendix Figure 13 (rht). Dermosphenotic bones. ATS-ADU (left and right) to the left, ATS-JUV (left element only) to the right. Anterior to the left.



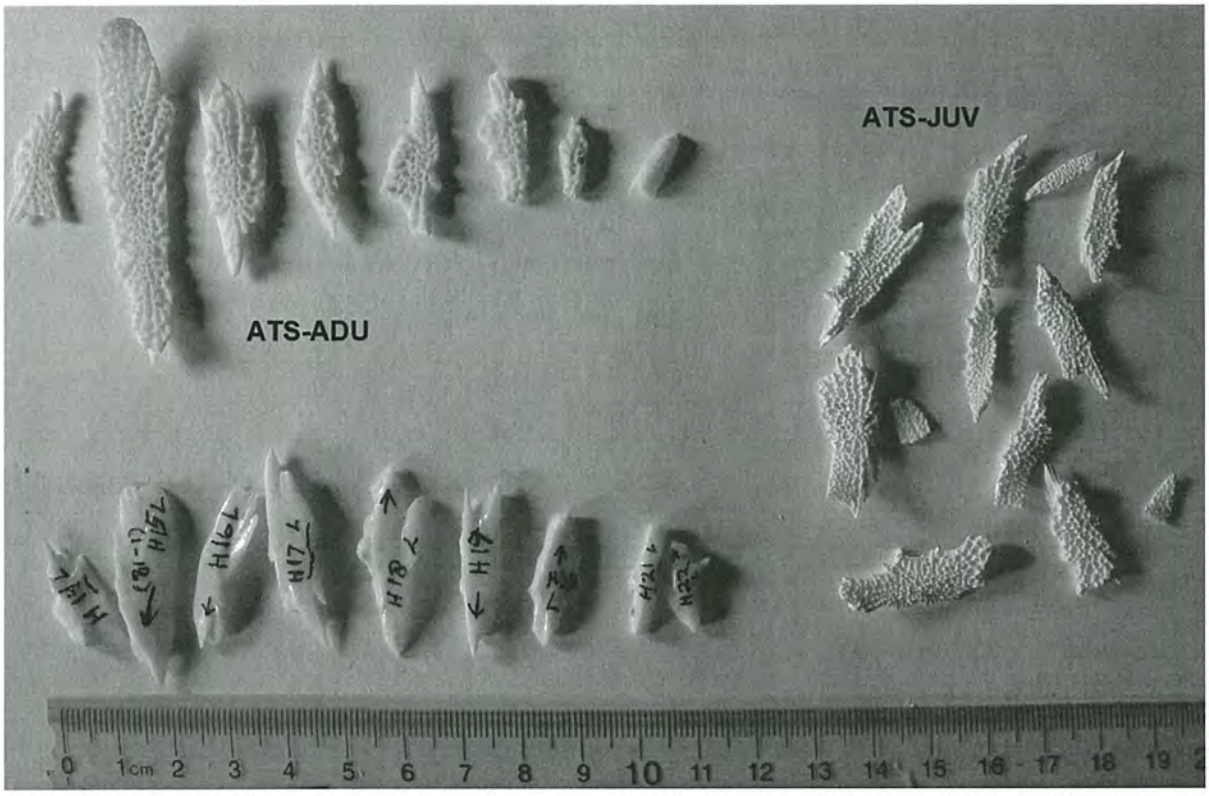
Appendix Figure 14 (left). Postorbital bones. ATS-ADU outside left and right, ATS-JUV middle two. Bone anterior is toward the top of the image.



Appendix Figure 15 (right). Jugal bones (circumorbital area). ATS-ADU right and left to the top, ATS-JUV to the bottom. Note, bones are oriented with the anterior toward the middle of the image.



Appendix Figure 16 (left). Subraorbital bones. Left bone, ATS-JUV at left. Paired left and right ATS-ADU center and right. Anterior of bone to the bottom of the image.



Appendix Figure 17. Nasal and dorsal rostral bones. (P) paired, in the sense that there are right and left, but not matched shapes. ATS-JUV view of ornamented (dorsal) surfaces at right. At left, ATS-ADU with upper portion of figure showing dorsal (ornamented) surface, and lower showing undecorated (ventral) bone surface. Note that different bones are shown with dorsal and ventral surfaces.

APPENDIX B: MEASUREMENTS OF ATLANTIC STURGEON SCUTES AND ORNAMENTED BONES

Appendix B consists of tables of measurements of various scutes and ornamented bones from two Atlantic Sturgeon specimens. Values without parentheses are for ATS-JUV. Values in parentheses are for ATS-ADU.

Appendix B Table 1. Dorsal Scute Measurements. Measurements in cm. and degrees. Measurement for ATS-JUV is followed by ATS-ADU (in parentheses). (Scutes are numbered A1-A11 on the ATS-ADU specimen.) Dash (–) is missing data. Measurement abbreviations: weight in grams; a-p length is total antero-posterior length; a-p length anterior not ornamented, antero-posterior length of the unornamented anterior projection; med-lat width is the medio-lateral width in dorsal view, or the straight cord width ventrally; largest pits/cm, number of pits per linear centimeter of the largest pits on the decorated surface; scute thick is the thickness of the scute about 1 cm from margin; dorsal angle degrees, is the apex angle of the scute at midline, measured transversly.

Scute #	weight gr	a-p length	a-p length anterior not ornamented	med-lat width	largest pits/cm	scute thick	dorsal angle degrees
1	-- (6.0)	– (7.4)	-- (2.2)	– (5.9)	--	--	--
2	2.0 (5.6)	4.29 (5.2)	0.39 (1.2)	3.98 (6.0)	7 (6)	0.17	120
3	2.2 (7.3)	4.56 (6.5)	0.73 (1.8)	3.95 (6.1)	6.5 - 7	0.20	97-100
4	2.5 (10.0)	5.07 (7.8)	1.16 (1.9)	4.06 (6.7)	8	0.15	95
5	2.7 (10.4)	5.20 (8.2)	1.41 (1.9)	4.28 (6.8)	7 (6)	0.16	111
6	2.7 (9.3)	4.92 (7.9)	0.83 (2.0)	3.70 (6.5)	7	0.18	90
7	2.7 (7.9)	5.59 (6.5)	1.00 (1.5)	3.58 (6.1)	8 (6)	0.18	95
8	2.1 (7.2)	4.83 (6.9)	0.94 (1.65)	3.32 (5.8)	7	0.19	109
9	1.1 (6.8)	3.21 (7.4)	0.65 (1.4)	3.06 (5.2)	7	0.18	115
10	1.5 (7.1)	4.21 (7.2)	0.64 (1.0)	2.93 (5.2)	6 (6)	0.18	120
11	0.9 (3.7)	3.07 (4.2)	0.31 (0.6)	1.6 (2.6)	7 (6)	0.29	N/A

Total scute weight, ATS-JUV, scutes # 2-11 (n=10), 20.6 gr (weighed as a group)
Total scute weight, ATS-ADU, scutes # 2-11 (n=10), 75.3 gr, for comparison with ATS-JUV
Total scute weight, ATS-ADU, scutes # 1-11, 81.3 gr

Appendix B Table 2. Lateral Scute Measurements. Measurements in cm. ATS-JUV (followed by ATS-ADU). (Labeled 1 through 29 on ATS-ADU specimen.) – indicates missing data. Measurement abbreviations: lgth apex to apex is the maximum "length" of the scute from dorsal-most to ventral-most point; scute thick is the maximum thickness of the scute; largest pits/cm, number of pits per linear centimeter of the largest pits on the decorated surface. Scutes #12 on ATS-JUV and 18/19 on ATS-ADU are not symmetrical left to right.

Scute #	weight gr	lgth apex to apex	scute thick	largest pits/ cm
1	missing (est 2.1)	-- (5.2)	-- (0.3)	-- (7)
2	missing (est 2.5)	-- (5.8)	-- (0.3)	-- (7)
3	0.5 (2.9)	3.9 (6.6)	0.15 (0.30)	9 (6)
4	0.8 (3.2)	4.3 (6.1)	0.2 (0.30)	9 (6)
5	0.9 (3.2)	4.5 (6.6)	0.2 (0.30)	9 (6)
6	1.0 (3.0)	4.4 (6.2)	0.2 (0.30)	8 (5-6)
7	1.2 (3.0)	4.7 (6.7)	0.2 (0.30)	8 (6)
8	0.9 (2.9)	3.9 (6.3)	0.2 (0.30)	8 (6)
9	0.6 (2.9)	3.35 (6.3)	0.2 (0.30)	8 (6)
10	0.8 (2.9)	3.9 (5.7)	0.2 (0.30)	8 (6)
11	0.8 (2.5)	3.6 (5.6)	0.2 (0.30)	7 (6)
12	0.2 (2.4)	[2.2] (5.2)	0.2 (0.30)	- (7)
13	0.7 (2.5)	3.4 (5.6)	0.2 (0.30)	
14	0.7 (2.4)	3.7 (5.7)	0.2 (0.30)	8 (6)
15	0.8 (2.3)	4.1 (5.4)	0.2 (0.30)	
16	0.6 (2.3)	3.4 (5.1)	0.2 (0.30)	8 (6)
17	0.6 (2.0)	3.4 (5.1)	0.2 (0.30)	
18	0.6 (2.4) [1.8 left]	3.25 (3.98)	0.17 (0.2)[1.8 L]	9 (7)
19	0.5 (1.0)[1.8 left]	3.2 (3.90)	0.14 (0.21) [1.8 L]	
20	0.5 (1.9)	3.2 (3.6)	0.2 (0.25) [1.9 L]	10 (7)
21	0.5 (1.9)	3.1 (4.1)	0.18 (0.27)	
22	0.4 (1.5)	2.9 (3.9)	0.19 (0.22)	9 (7)
23	0.4 (1.3)	2.7 (3.4)	0.18 (0.31)	
24	0.3 (1.1)	2.4 (2.9)	0.12 (0.18)	9 (7)
25	0.4 (1.3)	2.2 (2.4)	0.18 (0.23)	10 (7)
26	0.4 (1.1)	2.1 (2.3)	0.20 (0.21)	
27	0.2 (0.9)	2.1 (2.3)	0.15 (0.22)	10 (8)
28	0.1 (0.6)	1.8 (2.5)	0.18 (0.23)	
29	--- (0.3)	-- (1.57)	---	

Total scute weight lateral row, right scutes 1-29, for ATS-ADU = 26.0 + 19.4 + 16.3 = 61.7 gr
Total scute weight lateral row, right scutes 3-28 for ATS-JUV = 15.4 gr, corrected for missing #1-2 by addition of 0.9 grams = 16.3 grams.

Appendix B Table 3. Ventral Row Scutes (all ATS-ADU). Measurements in cm. Total antero-posterior length includes the spine. Note: ATS-JUV specimen is missing this series of scutes. Labeled CR or CL (for right and left), numbers 1- 10 on ATS-ADU. Right side scutes of ATS-ADU were weighed and measured. Measurement abbreviations: weight in grams; a-p length is total antero-posterior length; a-p length anterior not ornamented, antero-posterior length of the unornamented anterior projection; max dorso-ventral width is straight cord width; largest pits/cm, number of pits per linear centimeter of the largest pits on the decorated surface; scute thick is the thickness of the scute about 1 cm from margin; dorsal angle degrees, is the apex angle of the scute at midline, measured transversly.

Scute #	weight gr	a-p length	a-p length anterior not ornamented	max dorso-ventral width	largest pits/cm	scute thick-ness	dorsal angle degrees
1 (C)	(1.4)	(3.5)	(0.3)	(3.25)	(7)	(0.32)	(120)
2	(1.8)	(4.4)	(0.5)	(3.4)	(7)	(0.22)	(130)
3	(2.4)	(5.6)	(1.0)	(3.85)	(8)	(0.25)	(125)
4	(2.4)	(5.8)	(1.8)	(3.7)	(8)	(0.22)	(120)
5	(2.4)	(5.85)	(2.0)	(3.7)	(7)	(0.21)	(120)
6	(2.6)	(6.05)	(2.4)	(3.55)	(7)	(0.19)	(120)
7	(1.9)	(5.3)	(2.3)	(3.5)	(7)	(0.18)	(120)
8	(1.8)	(5.0)	(1.7)	(3.4)	(7)	(0.20)	(115)
9	(1.8)	(5.0)	(1.9)	(3.2)	(7)	(0.21)	(115)
10	(2.4)	(3.8)	(1.05)	(4.2)	(7)	(0.25)	(110)

Appendix B Table 4a. Dorsal caudal scutes (A12-16).
Length and width are measured on longest and next-longest sides of polygonal shape. Left and right specimens of A13, A14, A15 measured to provide range of variation. All measurements from ATS-ADU. (These scutes are missing from ATS-JUV specimen).

	wt (gr)	length (cm)	width	thickness	pits/cm max
A12 (1)	(0.1) (L)	(1.3)	(1.1)	(0.2)	(8?)
A12 (2)	(0.1)	(1.45)	(1.3)	(0.2)	(8?)
A13 L/R	(0.5/0.3)	(2.5/2.2)	(1.8/1.75)	(0.35/0.35)	(6/6)
A14 L/R	(1.0/1.9)	(3.5/4.7)	(2.15/2.2)	(0.5/0.55)	(6/6)
A15 L/R	(0.9/0.7)	(2.8/1.7)	(2.2/1.1_	(0.5/0.2)	(7/8)
A 16	(2.2)	(4.9)	(0.95)	(0.7)	(6 or 7)

Appendix B Table 4b. Dorsal caudal basal fulcra (A17-24).

basal fulcra (unornamented)	wt (gr)	length	width max	thickness	depth of "fork" indentation
A17	(0.8)	(3.6)	(1.0)	(0.4)	(0.75)
A18	(0.8)	(3.8)	(1.05)	(0.35)	(0.9)
A19	(0.9)	(4.0)	(1.1)	(0.35)	(0.95)
A20	(0.9)	(4.4)	(1.05)	(0.4)	(1.2)
A21	(0.8)	(4.6)	(0.95)	(0.3)	(1.3)
A22	0.8)	(4.75)	(0.9)	(0.3)	(1.35)
A23	(0.8)	(5.0)	(0.85)	(0.35)	(1.55)
A24	(0.7)	(5.3)	(0.75)	(0.3)	(1.65)

Appendix B Table 5. Anal ventral scutes. All measurements from ATS-ADU, in cm. Where two measurements are given, they are from the left and right scutes of ATS-ADU, which are not symmetrical. For E2 and E7, the length of the portion of the bone with ornamented surface is estimated. E2: 4.1 cm, portion with ornamented surface. E7: 5.3 cm, portion with ornamented surface.

	wt (gr)	length	width	thickness	pits/cm max
E1 (L/R)	(2.0/1.7)	(4.4)	(2.4)	(4.6)	(6)
E2	(3.7)	(5.5)	(2.4)	(4.7)	(6)
E3 L/R	(0.4/0.3)	(2.4)	(1.2)	(0.3)	(7-8)
E4 L/R	(0.9/0.9)	(2.9)	(2.1)	(0.4)	(6)
E5 L/R	(0.3/0.4)	(2.25)	(1.65)	(0.25)	(7)
E6 L/R	(0.1/0.1)	(1.3)	(1.2)	(0.15)	(7-8)
E7	(2.6)	(7.5)	(1.35)	(0.550	(7)
E8 L/R	(0.1)	(3.9)	(0.5)	(0.15)	
E9 (1) L/R	(0.1)	(3.4)	(0.35)	(0.15)	
E9 (2) L/R	(0.10	(3.2)	(0.3)	(0.1)	

Appendix B Table 6. Sturgeon "head" and pectoral girdle ornamented bones. For bones present in the ATS-JUV specimen, the smaller ATS-JUV specimen values are given first. ATS-ADU data are given in parentheses.

`1(1) Measurement for H15 (drb) is given for the right side bone which is larger than the left side bone. (P) = paired, weight given for one of the pair. Figure number refers to images of these bones either in the main text (Fig #) or appendix (AppFig #). H# is from ATS-ADU specimen. Abbreviation and bone name from Hilton et al. (2011).

Bone	Figure number	Wt (gr)	ornament surface	width	thickness	pits/ cm
H1; excm, median extrascapular	AppFig 7	– (2.7)	– (7.1)	– (4.4)	– (0.2)	– (5)
H2; pt, posttemporal (P)	none	– (4.2)	– (6.9)	– (2.85)	– (0.3)	– (5)
H3; scl, supracleithrum (P)	Fig 17	– (4.4)	– (5.8)*	– (0.3)	– (0.4)	– (5)
H4; cl, cleithrum (P)	Figs 4, 10, 16	– (8.3)	– (5.8) **	– (1.6)***	– (0.7)	– (6)
H5; clv, clavicle (P)	AppFig 8	– (8.1)	– (9.0)	– (2.9)	– (0.4)	– (5)
H6; sob, subopercle (P)	AppFig 9	2.7 (10.7)	5.5 (8.2)	4.4 (6.5)	0.4 (0.7)	7 (5)
H7; pa, parietale (P)	AppFig 10	1.7 (6.5)	6.8 (10.5)	1.9 (2.8)	0.2 (0.4)	7 (5)
H8; dpt, dermopterotic (P)	AppFig 11	– (5.8)	– (8.1)	– (2.7)	– (0.4)	– (6)
H9; fr, frontal (P)	AppFig 12	1.8 (6.0)	7.2 (11.8)	2.2 (4.0)	0.2 (0.3)	8 (5)
H10; dsp, dermosphenotic (P)	AppFig 13	0.8 (2.7)	4.2 (6.2)	1.6 (2.2)	0.3 (0.35)	8 (6)
H11; po, postorbital (P)	AppFig 14; Figs 15, 23	0.7 (2.1)	2.6 (4.3)	0.9 (1.3)	0.7 (0.9)	8 (6)
H12; j, jugal (P)	AppFig 15	1.2 (4.0)	4.2 (6.0)	2.2 (3.0)	0.6 (0.7)	8 (6)
H13; so, supraorbital (P)	AppFig 16	0.2 (1.0)	1.8 (3.2)	1.2 (1.8)	0.2 (0.4)	9 (6)
H14; n, nasal (P)	AppFig 17	– (0.2)				
H15(1) - dorsal rostral bone, largest	AppFig 17	– (1.3)	– (5.9)	– (1.2)	– (0.2)	– (6)
H16 - H22, drb, dorsal rostral bones(s)	AppFig 17	– (2.1)			– (0.2)	– (6)
H25 (border rostral bones) n=9		– (4.1)			-- (0.2)	

* H3 overall length with extensions lacking "scute" surface is 8.0 cm
**H4 overall length with extensions lacking "scute" surface is 10.4 cm
*** H4 overall width with extensions lacking "scute" surface is 4.9 cm

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