

Systematic palaeontology (Vertebrate palaeontology)

First archaeozoological identification of Atlantic sturgeon (*Acipenser oxyrinchus* Mitchill 1815) in France

Nathalie Desse-Berset

UMR 6130, CEPAM/CNRS, université de Nice Sophia-Antipolis, 250, avenue Albert-Einstein, 06560 Valbonne, France

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Abstract

To this day, the only sturgeon to be listed on the French vertebrate inventory is the European sturgeon (*Acipenser sturio* Linnaeus, 1758). The recent study of sturgeon remains on various French archaeological sites shows the presence of another species: the Atlantic sturgeon (*A. oxyrinchus* Mitchill 1815). This species already existed in the French Atlantic region at the end of the Neolithic Age 5000 years ago and was still to be found 3000 years later. Thus the *A. oxyrinchus* determined in several Baltic medieval sites are neither the only nor the first sturgeons to have inhabited European waters. Sturgeon restoration projects in European rivers necessitate a precise determination of the native species. In the case of relict or extinct species, the bone remains found on archaeological sites represent the most reliable source of information. This discovery will also be the starting point of palaeogenetical research (mitochondrial and cellular aDNA) and will give information about the genetic diversity of these threatened or recently extinct populations. **To cite this article:** N. Desse-Berset, C. R. Palevol 8 (2009).

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Résumé

Première identification en France de l'esturgeon atlantique (*Acipenser oxyrinchus* Mitchill 1815) par l'archéozoologie. À ce jour, le seul esturgeon retenu sur la liste des Vertébrés de France est l'esturgeon européen (*Acipenser sturio* Linnaeus, 1758). L'étude récente de restes d'esturgeons de plusieurs sites archéologiques français révèle la présence d'une autre espèce, l'esturgeon atlantique (*A. oxyrinchus* Mitchill 1815). Cette espèce se trouvait déjà dans la zone atlantique française à la fin du Néolithique, il y a 5000 ans, et y était encore 3000 ans plus tard. Ainsi, les *A. oxyrinchus* déterminés dans plusieurs sites médiévaux baltes ne sont ni les seuls, ni les premiers, à avoir vécu dans les eaux européennes. Les programmes de réintroduction des esturgeons dans les fleuves européens nécessitent une détermination précise de l'espèce d'origine. Dans le cas d'espèces relictives ou disparues, les restes osseux des sites archéologiques représentent la source d'information la plus fiable. Cette découverte sera également le point de départ de recherches paléogénétiques (ADNa mitochondrial et cellulaire), qui apporteront des informations sur la diversité génétique de ces populations menacées ou récemment éteintes. **Pour citer cet article :** N. Desse-Berset, C. R. Palevol 8 (2009).

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Mots clés : Esturgeons ; *Acipenser oxyrinchus* (esturgeon atlantique) ; *A. sturio* (esturgeon Européen) ; Première identification d'*A. oxyrinchus* en France ; Archéozoologie ; Réintroduction

E-mail address: berset@cepam.cnrs.fr.

1. Introduction

The remains dug up through archaeological excavations represent an essential source of information for the history of biodiversity. They are the most reliable evidence to confront present with past populations. In the case of extinct species, they represent the only proof of a former existence. In France, the sole sturgeon species described as native during the Holocene in fauna inventories listed on the national territory is, to this day, the European sturgeon [5,21].¹ This species is also attested to in faunal studies of archaeological sites, like for instance the site of “*Jardin d’Hiver*” in Arles (in the Mediterranean region), which has revealed a large number of sturgeon remains [7]. Recent archaeozoological and palaeogenetical studies have confirmed the sole presence of *A. sturio* in the main French river basin in which the presence of *A. naccarii* was hypothesized, namely the Rhône River [4,10,20]. The recent analysis of sturgeon remains found on several archaeological sites from the French Atlantic region allows us to announce today that another species was present and has been present for many a millennium.

In the context of sturgeon restoration projects implemented to preserve these worldwide threatened and endangered species,² the determination of the native species is fundamental [24]. Information can be found in inventories or local fauna guides [5,21], as well as in historical sources (texts). Animal collections in museums whether they are naturalized or immersed in alcohol or formol represent another possible source of information. Their origin is often subject to caution especially

for animals collected as early as the 18th century: labeling errors may have occurred at a time when trade and importations were frequent. Moreover these specimens are not always well preserved and may have suffered harsh treatment (painting, varnish...).

The remains dug up during archaeological excavations performed in stratigraphy and according to meticulous recording methods turn out to be extremely important: they represent the most reliable factual data. They allow us today to announce the presence in France of a second species, usually thriving along the North-American Atlantic coast: the Atlantic sturgeon (or black sturgeon).

2. Material and methods

2.1. Presentation of the archaeological sites

The results shown here come from archaeozoological analyses carried out on three sites (Fig. 1):

- Le Langon (Vendée) once located next to the “*Marais poitevin*”, which has become dry today, was an important Gallo-Roman town on the course of a Roman road and a harbour on the Vendée River estuary. The rescue excavations directed by Bernard and Pascal [2] has revealed fish bones among which we have determined 22 sturgeon scutes remains coming from several specimens. The majority of these bones have been dated by relative chronology to the Augustean period (first half of the first century AC). Only one fragment belongs

¹ See the National Inventory of the natural Heritage (*Inventaire national du Patrimoine naturel* [INPN] de la France. Web site: <http://inpn.mnhn.fr>); (*Muséum national d’histoire naturelle* [MNHN], Paris) and the Taxonomic Register of Flora and Fauna for metropolitan France and French overseas Departments (*Référentiel taxonomique des taxons de faune et de flore pour la France métropolitaine et les départements d’outremer* [TAXREF]).

² The sturgeons are protected by several international conventions: The Washington Convention (CITES), 1973; The Bern Convention, 1979; The Bonn Convention, 1979; OSPAR Convention, 1992; The Barcelona Convention, 1995; The Convention on biological diversity, 1992. Since 1982, it is forbidden to catch sturgeon in France. The sturgeon is a species appearing in the II and IV appendix of the “Directive Habitats” and is categorized as critically endangered worldwide by the IUCN. On the national level it used to inhabit most of the large rivers but has little by little disappeared from the Seine, the Rhine, the Rhone and the Loire basins. Today, at European level, it profits from a research and a protection project and from three «*Arrêtés préfectoraux de Protection de Biotope*» (APB) in Aquitaine by the Garonne basin, one of them having as its essential mission, to preserve a spawning ground (5 [p. 32], 24 [p. 251]).

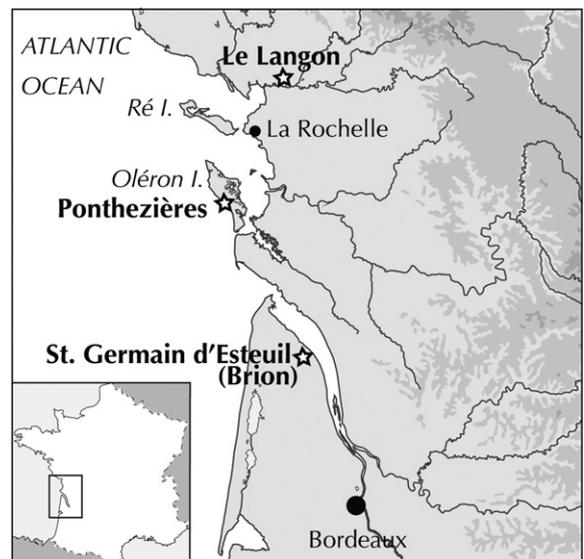


Fig. 1. Location of mentioned archaeological sites.
Fig. 1. Carte des sites archéologiques cités.

to the most ancient phase of occupation (around the era change);

- the site of Brion, in Saint-Germain d'Esteuil, on the Gironde River estuary, has brought up the discovery of 65 sturgeon remains that spread out over five centuries (from the 3rd century BC to the 2nd century AD) according to the excavations Director P. Garmy [11]. They mainly consist of dermal plate fragments and pectoral fin rays elements;
- the third site on which we will focus is connected to the Neolithic and dates back to late 4th – early 3rd millennium BC, according to L. Laporte, Director of the excavations [13]. Ponthezières, on the Oléron Island, is the name of this site. Thirty-six fragments of bones mainly coming from the exoskeleton have attested to the existence of sturgeons on this very site [8,9].

2.2. Morphological criteria of discrimination between *A. sturio* and *A. oxyrinchus* on archaeological bone remains

These sister species have for a long time been considered as the same species. Morphological [17,18] and morphometrical [19] comparison studies were first published in the sixties. Their aim was to describe the differences between the two species. Magnin studied hundreds of *A. sturio* specimens from the Gironde River estuary and *A. oxyrinchus* from Canada (90 *A. sturio* and 1814 *A. oxyrinchus*). He had established a list of differences between the two species [17–19]. Back then, sturgeons were still abundant and biologists could work on populations quantitatively important: whether they talk about *A. sturio* (in France in the Gironde basin) or *A. oxyrinchus* (in North America), their observations were based on hundreds of specimens which still lived in natural conditions and which provided meristic, morphometric and morphological data. Since then the situation has changed: even if the *A. oxyrinchus* is still thriving thanks to regulation measures, the *A. sturio* is threatened and only one relict spawning population of European sturgeon still exists in the Gironde River (they are both on the Red Liste: *A. oxyrinchus*: Status: Near Threatened Population. Trend: increasing. *A. sturio*: Status: Critically Endangered A2d.).

For the archaeozoologist, only a few morphological elements from the bony parts can be considered because the majority of archaeological remains come from the exoskeleton, especially fragments from the dermal scutes (it should be noted that each specimen has a hundred of them spread out in five rows). Naturalized specimens found in museums can provide information

about the morphology of the external bone elements. The examination of several sturgeons from both species kept at the MNHN (Paris) represented the starting point of observations on the surface of dermal scutes, which led us to the conclusion that *A. oxyrinchus* were present around the Oléron Island. This study has proven our quest for *A. oxyrinchus* reference-skeletons necessary. Thanks to the CEMAGREF, we have been able to obtain, during the past 20 years, several *A. sturio* specimens on which osteometrical and morphological studies have been made [7–9]. Thanks to the generosity of Canadian colleagues (M. Courtemanche, P. Corbeil, P. Dumont, H. Massé), we were given a complete *A. oxyrinchus* skeleton along with a few isolated bones and some photographs. The comparative study of these different skeletons has allowed us to establish specific discriminations between the scutes of both species, which can also be observed on the archaeological material. These specific discriminations will be the base of our following study.

3. Results

Among the list of differences established by Magnin between the two species [17–19], only one criterion can be applied to fragmented archaeological material: the superficial structure of the scutes. According to Magnin, “the *A. oxyrhynchus* has larger shields and their external surface is made of small and deep alveoli limited by thin sharp septa. On the contrary, the external surface of the *A. sturio* has small and round tubercles that are rough to the touch” (18 [p. 9–10 and fig. 5 p. 13]). These descriptions have since been endorsed and repeated by every author who has searched morphological differences between both species [1,3,6,14–16]. Our observations made on modern sturgeon skeletons (Fig. 2) as well as on various MNHN specimens confirm these discriminant characteristics.

In the three sites mentioned above, parts of the elements from the exoskeleton present on their surface deep and circular alveoli, separated by thin septa, typical of Atlantic sturgeons (*A. oxyrinchus*) and very different from the tubercular surface of European sturgeons (*A. sturio*). In Langon, the bony material is very well preserved and all the sturgeon bones come from large sized specimens. All 22 determined fragments show deep circular alveoli on their surface separated by thin septa characteristic of *A. oxyrinchus* (Fig. 3). In Saint-Germain d'Esteuil, among the 32 identified elements of dermal plates, 27 belong to the *A. sturio*; the dermal plate fragments carry the tubercular patterns specific to the *A. sturio*, observed through the study of several hundred bone remains coming from the Rhone River and dug

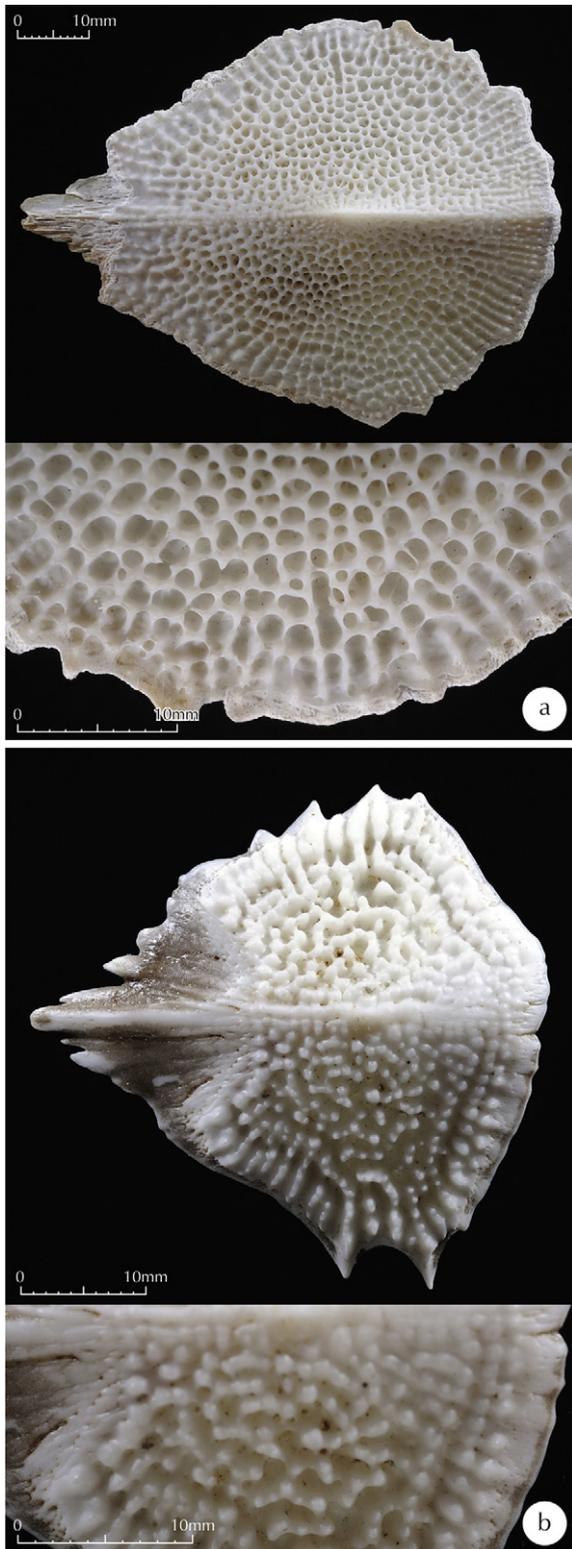


Fig. 2. Modern dorsal scutes of *Acipenser oxyrinchus* (a) and *Acipenser sturio* (b) showing the differences between them. (Reference Collection of the Laboratory of Archaeozoology, Valbonne)

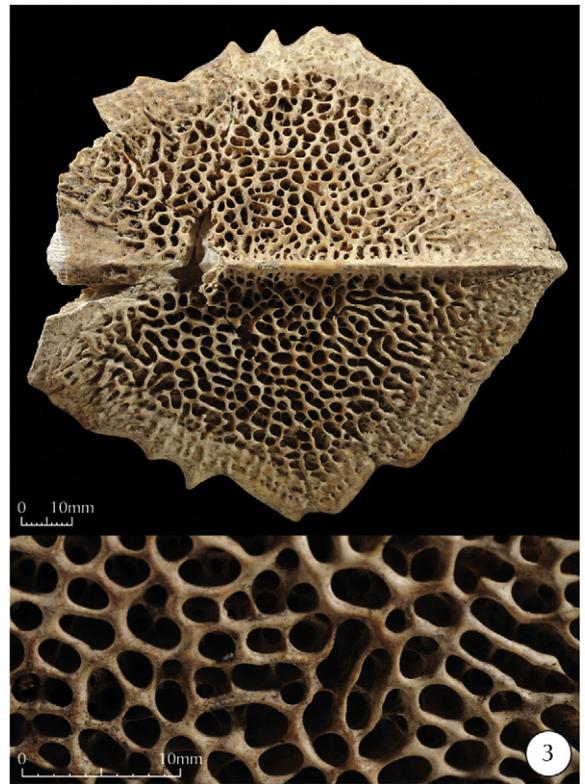


Fig. 3. Le Langon: dorsal scute of *Acipenser oxyrinchus*.
Fig. 3. Le Langon : écusson dorsal d'*Acipenser oxyrinchus*.

up in Arles-Jardin d'Hiver [4,7,10] (Fig. 4) and in Montmajour (material still under study). But in Saint-Germain d'Esteuil, five scutes present characteristic *A. oxyrinchus* alveoli and therefore prove the existence of this species alongside with the *A. sturio* (Fig. 5). At last, the Pontzezières site on the Oléron Island has provided a majority of dermal scutes, showing at their surface characteristic *A. oxyrinchus* alveoli together with a minority of *A. sturio* remains (Fig. 6).

In a recent study about the fish remains from Neolithic sites on the Oléron island, handed to the editor before obtaining a complete *A. oxyrinchus* skeleton, the attribution of these sturgeons remains to another species different than the *A. sturio*, namely, the *A. oxyrinchus* has been evoked several times [9]. This hypothesis was based on observations made on a large MNHN specimen, as well as on criteria previously described as discriminating by Magnin between both species. Magnin's photographic reproductions were not used because of poor quality

Fig. 2. Écussons dorsaux modernes montrant les différences entre *Acipenser oxyrinchus* (a) et *Acipenser sturio* (b) (Collection de référence du Laboratoire d'archéozoologie, Valbonne).

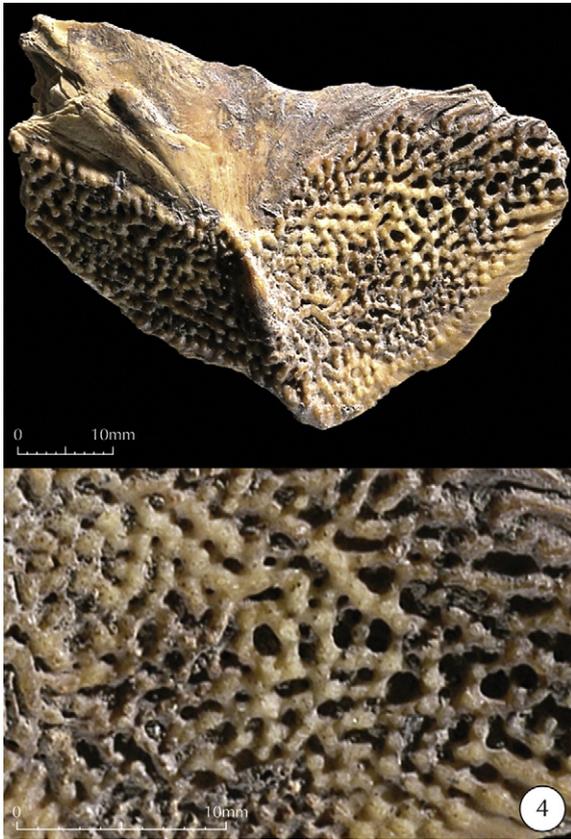


Fig. 4. Arles, Jardin d’Hiver: lateral scute showing the characteristic pattern of *Acipenser sturio*.

Fig. 4. Arles, Jardin d’Hiver : écusson latéral présentant la surface caractéristique d’*Acipenser sturio*.

but his descriptions corresponded with the observations made on the archaeological collections of the sites named above.

Today we can say that our hypotheses are confirmed and that the two species are present on the Oléron island, the majority of the specimens being *A. oxyrinchus*. Thus the analyses performed on these three sites allow us to state:

- the *A. oxyrinchus* already lived along the shores and in French rivers 5000 years ago and was still to be found between the 3rd century BC and the 2nd century AD;
- the *A. oxyrinchus* and *A. sturio* co-existed in the same geographical region during this period.

4. Discussion

Sturgeon restoration projects in Germany, in rivers flowing into the Baltic Sea are at the root of several

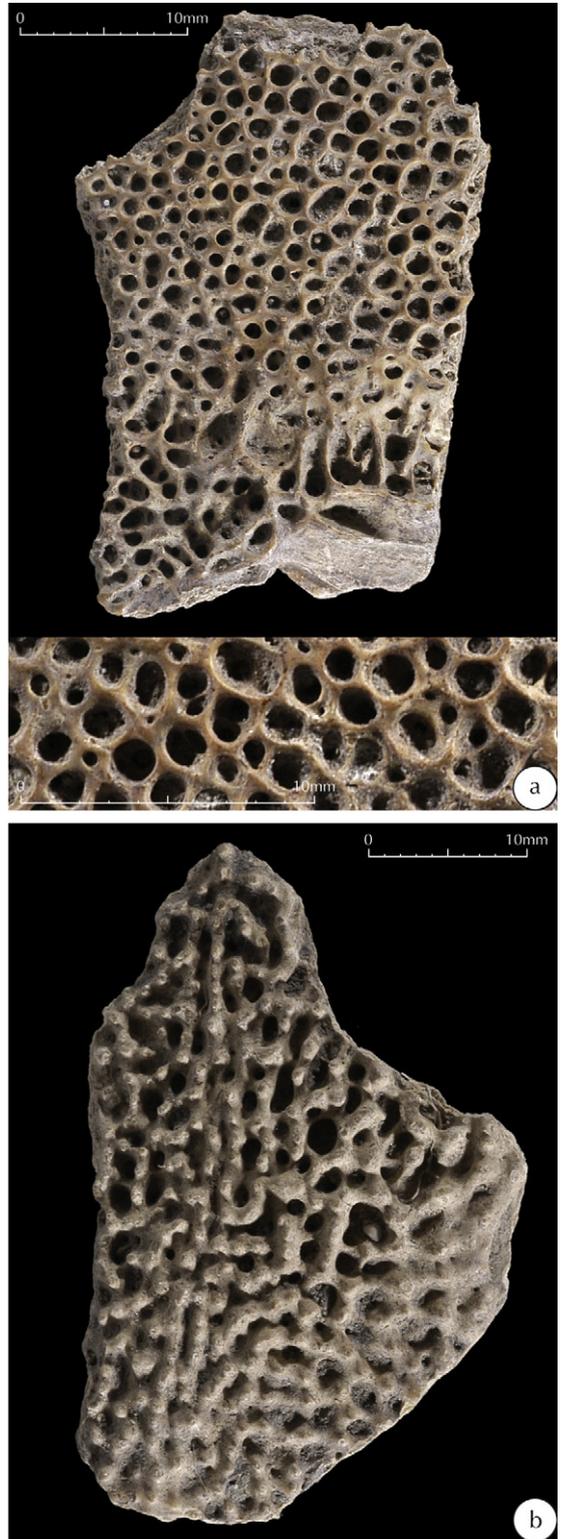


Fig. 5. Brion, Saint-Germain d’Esteuil: fragmentary dermal plates of *Acipenser oxyrinchus* (a) and *Acipenser sturio* (b).

Fig. 5. Brion, Saint-Germain d’Esteuil: fragments de plaques dermiques d’*Acipenser oxyrinchus* (a) et d’*Acipenser sturio* (b).

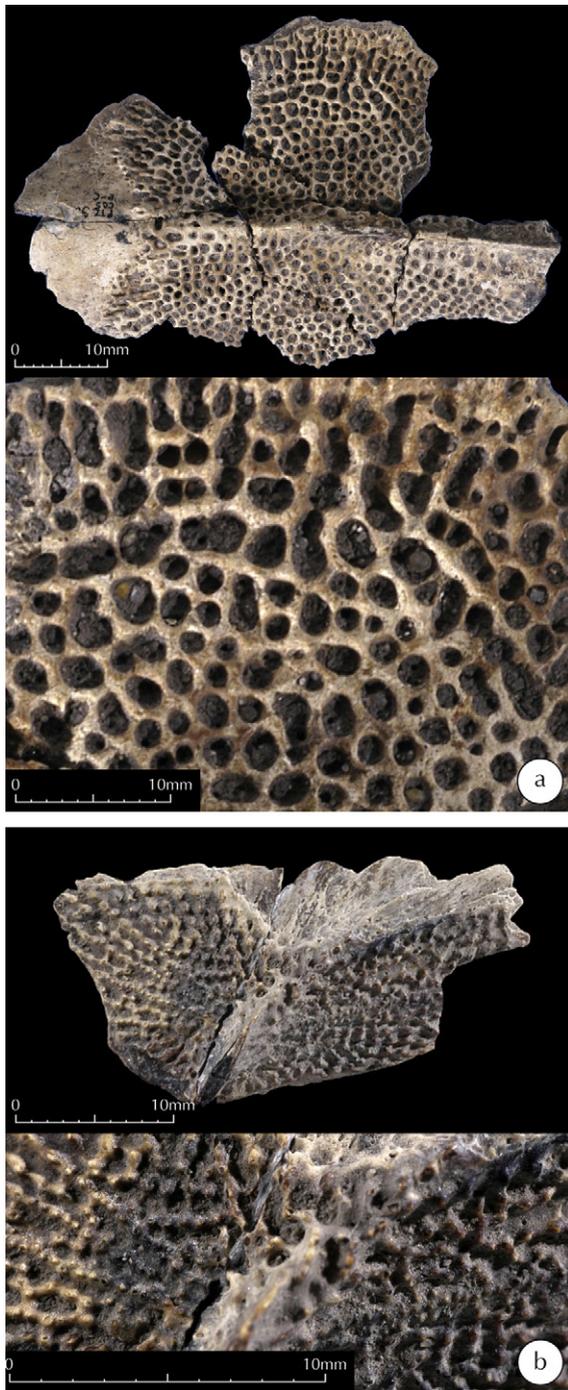


Fig. 6. Ponthezières, Oléron island: fragmentary scutes of *Acipenser oxyrinchus* (a) and *Acipenser sturio* (b).

Fig. 6. Ponthezières, île d'Oléron : fragments d'écussons d'*Acipenser oxyrinchus* (a) et d'*Acipenser sturio* (b).

original publications and have modified the ideas previously admitted (that is to say: *A. sturio* is the only present species).

A. oxyrinchus has been identified for the first time in northern Europe by a multidisciplinary group of researchers [15], among sturgeon remains dug up in the Medieval archaeological sites of Ralswiek and Wilhemshof (between the 8th and the 13th century) along the German Baltic coast [3]. The authors of this important discovery have attributed the arrival of *A. oxyrinchus* to cooler climatic conditions (Medieval Little Ice Age) and according to them more favourable to the reproduction of this species than to the *A. sturio*. They have also evoked the replacement of *A. sturio*, which already lived there, by *A. oxyrinchus*.

The hypothesis of a hybridation between both species has been proposed and confirmed [12,22]. Recently the assumption that a small number of specimens (about ten *A. oxyrinchus*, male and female) coming from North America, at that time, were at the root of the expansion of this species in the Baltic Sea, has been developed [14].

The authors have all used the morphology of scutes described by Magnin for their discrimination of the archaeological material, alongside palaeogenetical analyses. They all come to the conclusion that this is the first establishment of this American species in Europe and the oldest evidence of this colonisation.

Our results modify these assertions. *A. oxyrinchus* lived in the French Atlantic region many a millennium before its arrival in the Baltic Sea. Thus many questions are raised: back to when does this establishment date? Were they already present after the end of the last glaciation, at the beginning of the Holocene? Did they cross the Atlantic at a period that still needs to be defined? Is the *A. oxyrinchus* a native French species for the same reasons as the *A. sturio*? We do not have the data to answer all these questions, namely: new archaeological material.

The search for other archaeological sturgeon remains will allow us to increase our knowledge in terms of spatiotemporal spreading of both species. The re-examination of bones systematically determined as *A. sturio* in various archaeological sites in France is necessary. Beside the morphological determinations and the studies made according to archaeozoological methods, biomolecular analyses are foreseen. They could reveal information about the diversity of the sturgeon populations, about past and present populations, about a sympatry between both species or about possible hybridations between them [12,14,22,23].

5. Conclusions

The presence in France of *A. oxyrinchus* on several archaeological sites and during different periods is already in itself an important source of information and allows us to make the following statements:

- the Atlantic sturgeon inhabited rivers and lived along the French Atlantic coasts long before the sturgeon population identified in the Baltic Sea. There, this very cold period (the Little Ice Age) may have been a favourable climate for the establishment of the species in the Baltic Sea during the Middle Age. But our discoveries show that the species was already present in the French Atlantic region 5000 years ago (at the end of the 4th millennium BC), and was still present until approximately 200 AD;
- moreover *A. oxyrinchus* probably lived in sympatry with *A. sturio*.

Following these results, new studies (morphological, biomolecular) will be decisive in order to select the relevant species to be reintroduced within the scope of sturgeon restoration projects under way in several European rivers.

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References

- [1] E. Artyukhin, P. Vecsei, On the status of Atlantic sturgeon: conspecificity of European *Acipenser sturio* and North American *Acipenser oxyrinchus*, J. Appl. Ichthyol. 15 (1999) 35–37.
- [2] E. Bernard, J. Pascal, Le Langon, une agglomération portuaire sur l'estuaire de la Vendée (site 85.121.014.AH), in: M. Monteil, Notice rédigée en 2007 dans le cadre du Projet collectif de recherche « Agglomérations secondaires dans l'Ouest de la Gaule ». (à paraître).
- [3] N. Benecke, Some remarks on sturgeon fishing in the southern Baltic region in Medieval Time in: D.C. Brinkhuizen, A.T. Clason (Eds.), Fish and archaeology, 294, British Archaeological Reports International Series, 1986, pp. 11–17.
- [4] Brosse L, Berrebi P, Desse-Berset N, Lepage M. Sturgeon Recovery Plan in the Rhône River (France). Preliminary Results on Species Determination and Habitat Suitability, In: Carmona, et al., (Eds), Biology, Conservation and Sustainable Development of Sturgeons, Springer Science + Business Media B.V, 2009, Chapter 25, pp. 403–421.
- [5] J. Comolet-Tirman, G. Grech, J.-P. Sibley, J. Trouvilliez, Le patrimoine naturel protégé grâce aux Arrêtés préfectoraux de Protection de Biotope (APB): milieux naturels, faune et flore, in: Un bilan après trente années d'existence d'un outil de protection souvent méconnu et sous-estimé, Rapport SPN 2008/2, MNHN-DEGB-SPN, 2008, 80 p.
- [6] L. Debus, Meristic and morphological features of the Baltic sturgeon (*Acipenser sturio* L.), J. Appl. Ichthyol. 15 (1999) 38–45.
- [7] N. Desse-Berset, Sturgeons of the Rhône during Protohistory in Arles (6th–2nd century BC), in: Fish Exploitation in the Past, Proceedings of the 7th Meeting of the ICAZ Fish Remains Working Group (Louvain, sept. 1993), Annales du Musée Royal de l'Afrique centrale, N° 274, Tervueren (1994) 81–90.
- [8] N. Desse-Berset, La pêche est au bout du jardin... Deux îles, hier et aujourd'hui, IV^e Colloque International de l'Homme et l'Animal, Société de recherche interdisciplinaire. Genève, novembre 1994, Anthropozoologica 21 (1995) 7–20.
- [9] N. Desse-Berset, La pêche dans l'économie de subsistance des sites de Ponthezières et de la Perroche (Île d'Oléron, Néolithique final), in: L. Laporte (Ed.), Des premiers paysans aux premiers métallurgistes sur la façade atlantique de la France (3500–2000 av. J.C.), Édition Association des publications Chauvinoises, Mémoire XXXIII Chauvigny, 2009, pp. 584–609.
- [10] N. Desse-Berset, M. Pagès, L. Brosse, C. Tougard, O. Chassaing, C. Hänni, et al., Specific identification of the extinct population of sturgeon from the Rhône River by mtDNA analysis from bone remains (Jardin d'Hiver, Arles, France, 6th to 2nd century BC), in: P. Béarez, S. Grouard, B. Clavel (Eds.), Archéologie du poisson. Trente ans d'archéo-ichtyologie au CNRS, Hommage aux travaux de Jean Desse et Nathalie Desse-Berset. XVIII^e rencontres internationales d'archéologie et d'histoire, Éditions APDCA, Antibes, 2008, pp. 195–200.
- [11] P. Garmy, Introduction, présentation générale, 17, Saint-Germain d'Estueil, Aquitania, 2000, pp. 153–166.
- [12] F. Kirschbaum, S. Wuerz, P. Williot, R. Tiedemann, G.M. Arndt, E. Anders, et al., Prerequisites for the Restoration of the European Atlantic Sturgeon, *Acipenser sturio* and the Baltic Sturgeon (*A. oxyrinchus* × *A. sturio*) in Germany, in: R. Carmona, et al. (Eds.), Biology, Conservation and Sustainable Development of

- Sturgeons, Springer Science + Business Media B.V, 2009, pp. 385–401, Chapter 24.
- [13] L. Laporte, Des premiers paysans aux premiers métallurgistes sur la façade atlantique de la France (3500–2000 av. J.C.), Édition Association des publications Chauvinoises, Mémoire XXXIII Chauvigny, 2009, 816 p.
- [14] A. Ludwig, J. Gessner, What Makes the Difference? Sea Sturgeon on Both Sides of the Atlantic Ocean, American Fisheries Society Symposium 56 (2007) 285–300.
- [15] A. Ludwig, L. Debus, D. Lieckfeldt, I. Wirgin, N. Benecke, I. Jenneckens, et al., When the American sea sturgeon swam east, Nature 419 (2002) 447–448.
- [16] A. Ludwig, U. Arndt, S. Lippold, N. Benecke, L. Debus, T.L. King, et al., Tracing the first steps of American sturgeon pioneers in Europe, BMC Evolutionary Biology 8 (2008) 214–221, doi:10.1186/1471-2148-8-221.
- [17] E. Magnin, Recherches sur la systématique et la biologie des Acipenséridés, Annales de la station centrale d'hydrobiologie appliquée (Paris) 9 (1962) 288.
- [18] E. Magnin, Validité d'une distinction spécifique entre les deux Acipenséridés: *Acipenser sturio* L. d'Europe et *Acipenser oxyrinchus* d'Amérique Du Nord, Le Naturaliste Canadien 41 (1964) 5–20.
- [19] E. Magnin, G. Beaulieu, Étude morphométrique comparée de *Acipenser oxyrinchus* Mitchell du Saint-Laurent et *Acipenser sturio* Linné de la Gironde, Le Naturaliste Canadien 40 (1) (1963) 5–38.
- [20] M. Pagès, N. Desse-Berset, C. Tougard, L. Brosse, C. Hänni, P. Berrebi, Historical presence of the sturgeon *Acipenser sturio* in the Rhône basin determined by the analysis of ancient DNA cytochrome *b* sequences, Conserv Genet 10 (2009) 217–224, doi:10.1007/s10592-008-9549-6.
- [21] M. Pascal, O. Lorvelec, J.-D. Vigne, Invasions biologiques et extinctions. 11 000 ans d'histoire des vertébrés en France, Éditions Belin, Paris, 2006, 350 p.
- [22] R. Tiedemann, R., K. Moll, B. Paulusk, M. Scheer, P. Williot, R. Bartel et al., Atlantic sturgeons (*Acipenser sturio*, *Acipenser oxyrinchus*): American females successful in Europe, Revue Naturwissenschaften, 94 (3) (2007) 213–217, Éditeur Springer Berlin/Heidelberg, Category Short Communication, doi: 10.1007/s00114-006-0175-1.
- [23] P. Williot, E. Rochard, G. Castelnaud, T. Rouault, R. Brun, M. Lepage, et al., Biological characteristics of European Atlantic sturgeon, *Acipenser sturio*, as the basis for a restoration program in France, Environmental Biology of Fishes 48 (1997) 359–370.
- [24] P. Williot, E. Rochard, T. Rouault, F. Kirschbaum, *Acipenser sturio* Recovery Research Actions in France, In: R. Carmona, et al. (Eds), Biology, Conservation and Sustainable Development of Sturgeons, Springer Science + Business Media B.V, Chapter 15, 2009, pp. 247–263.