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A PRISTID SAWFISH FROM THE LOWER PLIOCENE OF LUCCIOLABELLA (RADICOFANI BASIN, TUSCANY, CENTRAL ITALY)

Abstract - A. Collareta, S. Casati, A. Di Cencio, *A pristid sawfish from the lower Pliocene of Lucciolabella (Radicofani basin, Tuscany, central Italy).*

In this paper we report on a partially preserved rostral spine attributed to *Anoxypristis*? sp. from lower Pliocene (Zanclean) marine deposits exposed at Lucciolabella (Province of Siena, Tuscany, central Italy). This finding represents the first unambiguous record of pristids in lower Pliocene deposits of Italy, corroborating the persistence of sawfish in the Mediterranean basin after the so-called Messinian Salinity Crisis. Our finding supports the hypothesis of the persistence of climatic and ecological conditions propitious to warm-water marine vertebrates along the early Pliocene coasts of Tuscany and suggests that, after centuries of scientific study, the Pliocene elasmobranch palaeocommunities of Tuscany can still bring surprises.

Key words - Elasmobranchii, Mediterranean, Messinian salinity crisis, Zanclean, palaeobiogeography, palaeoecology, vertebrate palaeontology

Riassunto - A. Collareta, S. Casati, A. Di Cencio, *Un pesce sega della famiglia Pristidae dal Pliocene inferiore di Lucciolabella (Bacino di Radicofani, Toscana, Italia centrale).*

Nel presente lavoro è descritta una spina rostrale parziale di un pesce sega (identificato come *Anoxypristis*? sp.) da depositi marini del Pliocene inferiore (Zancleano) affioranti presso Lucciolabella (Provincia di Siena, Toscana, Italia centrale). Si tratta del primo rinvenimento di un pristide in depositi italiani di età zancleana. Esso conferma la persistenza della famiglia Pristidae nel bacino Mediterraneo a seguito della nota "crisi di salinità del Messiniano". Questo ritrovamento permette di inferire condizioni climatiche ed ecologiche favorevoli alla presenza di vertebrati marini di acque calde lungo le coste della Toscana durante il Pliocene inferiore e suggerisce che, dopo secoli di studi paleontologici, le paleocomunità ad elasmobranchi del Pliocene toscano possano ancora riservare delle sorprese.

Parole chiave - Elasmobranchii, Mediterraneo, crisi di salinità del Messiniano, Zancleano, paleobiogeografia, paleoecologia, paleontologia dei vertebrati

Introduction

Among extant rays, members of family Pristidae are characterised by an elongated, saw-like rostrum bearing lateral lancet-like dermal elements (e.g., Welten *et al*., 2015); hence their vernacular name "sawfishes". Pristids are currently represented by two genera (*Pristis* Linck, 1790, accounting for five living species, and the monotypic *Anoxypristis* White & Moy-Thomas, 1941) of large-sized shark-shaped organisms which live in warm waters and occupy proximal marine and brackish/freshwater environments worldwide (e.g., Dulvy *et al*., 2014). At present, pristid sawfishes are absent from the Mediterranean basin (Dulvy *et al*., 2014; Ferretti *et al*., 2016), although some old museum materials, as well as pre-Twentieth century literature and archive data, could support the presence of a population of *Pristis* sp. along the coasts of southern Italy till historical times (Psomadakis *et al*., 2009; Ferretti *et al*., 2016, and references therein).

Except for the late Cretaceous genus *Peyeria* Weiler, 1935, whose identification as a sawfish is still debated, Pristidae are known as fossils from deposits as old as the Palaeocene (e.g., Wueringer *et al*., 2009, and references therein). In the Mediterranean region pristids have a long fossil record dating back to the early Eocene (Cappetta, 2012, and references therein). The Italian fossil record of Pristidae is scattered but worth of attention. De Zigno (1881) erected the new species *Pristis bassanii* De Zigno, 1881 ("*Pristis Bassani*" in the original publication) based on a few rostral spines from the "nummulitic limestone" of Monte Duello (once called Zuello; Province of Verona, Veneto, north-eastern Italy), whose fossil assemblage has been referred to the upper portion of the middle Eocene (Altichieri, 1980). Later, Vigliarolo (1891) reinterpreted three fragments of a fossil rostrum from the Miocene "Pietra Leccese" (Province of Lecce, Apulia, southern Italy), previously identified by Costa (1853) as belonging to a dolphin, as the fossilized remains of a new pristid species (*Pristis lyceensis* Vigliarolo, 1891) (Capasso, 2016). De Stefano (1910) reported on "some unpublished fragmentary jaws bearing small and obtuse teeth, having an obtuse crown, resembling those identified by Lawley as remains of *Pristis*" from the Pliocene site of

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Orciano Pisano (Province of Pisa, Tuscany, central Italy). This latter record, likely a determination mistake, cannot be either confirmed or denied as the specimens cited by De Stefano (1910) could have been lost (Marsili, 2006). Finally, Collareta *et al.* (2017) reported on two fossil rostral spines discovered in Pliocene (3.61 to 3.19 Ma) marine mudstones at Tegoliccio (Province of Florence, Tuscany, central Italy) and identified as belonging to the extant, currently Indo-Pacific genus *Anoxypristis*. The pristid remains described by Collareta *et al.* (2017) represent the first record of *Anoxypristis* in Italy, as well as the geologically youngest occurrence of this genus in the Mediterranean basin.
In this paper we report on a fossil pristid rostral spine from an early Pliocene locality of southern Tuscany and briefly outline its palaeobiological meaning.

Geographical And Geological Setting

The fossil specimen described herein was discovered by one of the authors (S.C.) at Lucciolabella (Province of Siena, Tuscany, central Italy). The Lucciolabella site (Fig. 1) is located in the Radicofani basin, a NW-SE oriented normal-fault bounded basin, which takes place in the hinterland of the Northern Apennines (Bianucci *et al.*, 2009). This basin mostly developed between the late Miocene and the Early Pliocene under a substantially extensional regime (Pascucci *et al.*, 2006). The sedimentary filling of the Radicofani basin mostly consists of lower Pliocene deposits depicting deltaic to offshore depositional settings (Pascucci *et al.*, 2006).

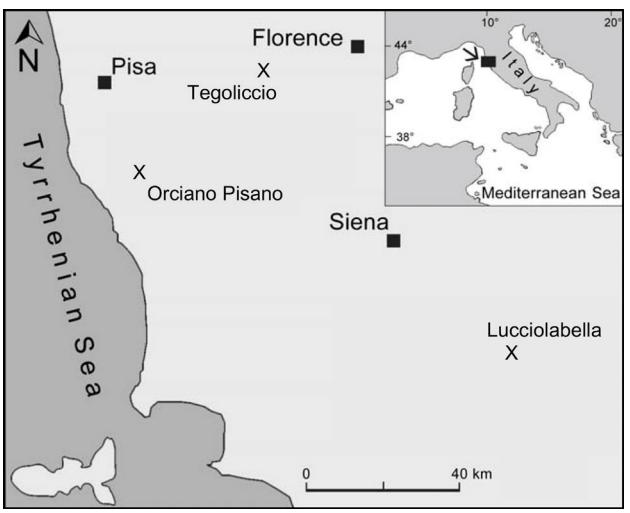

Fig. 1 - Simplified regional map showing the sites of occurrence of fossil pristids in Pliocene marine deposits of Tuscany: Orciano Pisano (*Pristis*? sp.: De Stefano, 1910), Tegoliccio (*Anoxypristis* sp. cf. *A. cuspidata*: Collareta *et al.*, 2017), and Lucciolabella (*Anoxypristis*? sp.: this work). Modified after Bianucci *et al.* (2009).

In particular, the sedimentary succession exposed in the area is entirely lower Pliocene in age; it consists of a 25-m-thick section of massive and pervasively bioturbated silty clays, occasionally interrupted by layers of normally graded sands (Bianucci *et al.*, 2009).
Analyses of the foraminiferal assemblages of the Lucciolabella section allowed to recognize the early Pliocene MPL 3 zone and MPL 4 a subzone of Cita (1975), as well as to infer an outer shelf/upper slope depositional environment characterized by relatively low oxygen availability and high concentrations of organic matter at the seafloor (Bianucci *et al.*, 2009). The pristid specimen described in the present paper was found a few meters below a partial cetacean skeleton, attributed by Bianucci *et al.* (2009) to the extinct delphinid species *Etruridelphis giulii* (Lawley, 1876), which in turn was collected from the stratal package referred to the MPL 3 zone. The bounding bioevents of the MPL 3 zone have been recently calibrated at 4.52 Ma and 3.98 Ma (Violanti, 2012).

Nomenclatural Remarks

Many terms have been proposed and are currently utilized to indicate the highly derived placoid scales which take place along the lateral margins of the rostrum of pristids, including "rostral teeth" (e.g., Cappetta & Case, 2016; Bradney *et al.*, 2017; Jabado *et al.*, 2017; Landini *et al.*, 2017a; Leeney, 2017; Seitz & Hoover, 2017; Nevatte *et al.*, in press), "saw-teeth" (e.g., Smith *et al.*, 2015; Welten *et al.*, 2015), and "rostral spines" (e.g., Carrillo-Briceño *et al.*, 2015; Collareta *et al.*, 2017; Di Celma *et al.*, 2017; Landini *et al.*, 2017b). Since Welten *et al.* (2015) provided wide evidence that these tooth-like elements are not homologous to oral teeth, representing instead an independent derivation from dermal denticles, we argue that terms such as "rostral teeth" and "saw-teeth" could sound somewhat ambiguous. In turn, the term "rostral spines" is unambiguous and widely accepted (see also Carrillo-Briceño *et al.*, 2015). Moreover, its usage in ichthyological literature dates back to the late Eighteenth century (Cigala Fulgosi *et al.*, 2009). Based on these considerations, in this paper we use exclusively the term "rostral spines".

Systematic Palaeontology

Class Chondrichthyes Huxley, 1880
Subclass Elasmobranchii Bonaparte, 1838
Infraclass Neoselachii Compagno, 1977
Superorder Batomorphii Cappetta, 1980
Order Rhinopristiformes Naylor *et al.*, 2012
Family Pristidae Bonaparte, 1838
Genus *Anoxypristis* White & Moy-Thomas, 1941

Anoxypristis? sp. (Fig. 2)

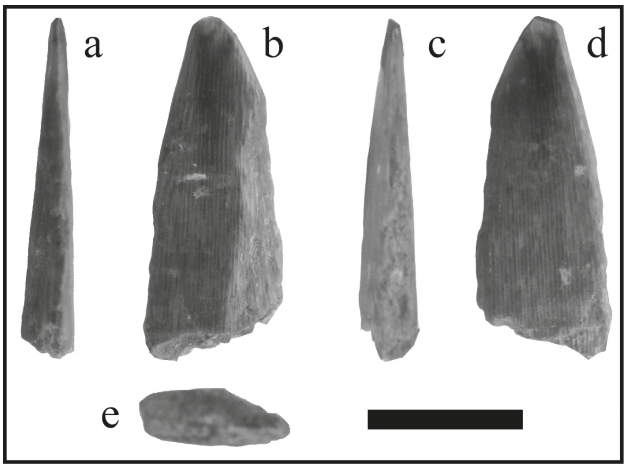

Fig. 2 - GAMPS-00885c, ?left rostral spine of *Anoxypristis?* sp. from the Lower Pliocene of Lucciolabella, Province of Siena, Tuscany. a: posterior view, b: ?dorsal view, c: anterior view; d: ?ventral view, e: proximal (i.e., basal) view. Scale bar = 10 mm. Panels 2a and 2e allow to verify the absence of any crescent-shaped incision on the posterior edge of GAMPS-00885c. A crescent-shaped incision, which reflects the presence of a groove along the posterior edge of the rostral spine, can be observed in transverse sections of adult rostral spines of *Pristis* spp. but not in those of *Anoxypristis* spp. (see e.g. Bourdon, 1999; Compagno & Last, 1998; Cappetta, 2012; Wueringer *et al.*, 2009; Faria *et al.*, 2013; Whitty *et al.*, 2014).

Material – One ?left rostral spine currently stored at Badia a Settimo (Scandicci, Italy) in the permanent exhibition of "Gruppo AVIS Mineralogia e Paleontologia Scandicci" under accession number GAMPS-00885c.
Horizon – Early Pliocene (i.e., Zanclean) silty clays exposed at Lucciolabella (Radicofani basin, Tuscany, central Italy).
Description, comparisons, and remarks – The rostral spine is incomplete, lacking the apex (i.e., the lateral termination) as well as the base (i.e., the medial termination) and part of the anterior and posterior cutting edges. Nevertheless, GAMPS-00885c is distinctly blade-shaped, remarkably dorsoventrally flattened, and apically tapered. The preserved distal portions of both cutting edges are sharp; the anterior one is gently convex, the posterior one is sub-straight and not excavated. Finely spaced longitudinal striae are present throughout the specimen. Similarly to what observed in GAMPS-00885a and GAMPS-00885b, a shallow but distinct transversely-oriented incision is preserved on the ?dorsal face of GAMPS-00885c. Following Collareta *et al.* (2017), this feature is here interpreted as resulting from the flow of water laden with sediment at the sides of the rostrum; extant sawfishes are indeed known as nectobenthic organisms which exploit their long snouts to uncover infaunal prey from the seafloor (Wueringer *et al.*, 2009, and references therein).
On the whole, the morphology and size of GAMPS-00885c are consistent with rostral spines of the extant knifetooth sawfish *Anoxypristis cuspidata* (Latham, 1794) (e.g., Bourdon, 1999; Compagno & Last, 1998; Cappetta, 2012; Wueringer *et al.*, 2009) (Fig. 3). Moreover, GAMPS-00885c is strongly reminiscent of GAMPS-00885a and GAMPS-00885b, two Pliocene rostral spines from the Pliocene of Tegoliccio, identified by Collareta *et al.* (2017) as belonging to *Anoxypristis* sp. cf. *A. cuspidata*. A slight difference in dorsoventral thickness (2.8 mm vs 2.2 mm) exists between GAMPS-00885c and the specimens from Tegoliccio; however, intraspecific variability is notoriously high in extant *Anoxypristis*, as well as in other fossil and living sawfishes, with respect to the morphology and proportions of rostral spines (Wueringer *et al.*, 2009; Cappetta & Case, 2016; Collareta *et al.*, 2017).
Moreover, the association of GAMPS-00885c with open marine mudstones makes the setting of our finding somewhat similar to that of Tegoliccio, suggesting open-sea habits for the Pliocene pristids of Tuscany; interestingly, although extant sawfish species are typically depicted as shallow-marine organisms, *Anoxypristis cuspidata* has been recorded in offshore waters exceeding 120 m in depth (Peverell, 2009, and references therein). However, given that the proximal portion of the posterior edge of GAMPS-00885c is not preserved, and considering that some extant species of *Pristis* (i.e., *Pristis clavata* Garman, 1906 and *Pristis zijsron* Bleeker, 1851) can exhibit rostral spines with only partially developed longitudinal grooves (e.g., Faria *et al.*, 2013; Whitty *et al.*, 2014), here we prudentially refer to GAMPS-00885c as belonging to *Anoxypristis?* sp.
Purdy *et al.* (2001) described three pristid rostral

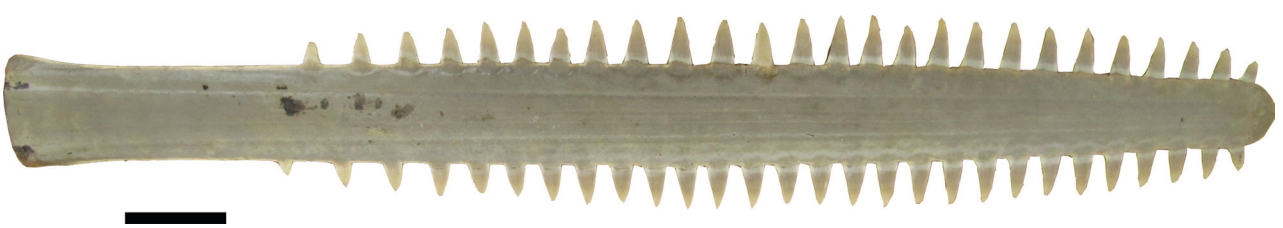

Fig. 3 - Dried rostrum of an adult specimen of the extant knifetooth sawfish *Anoxypristis cuspidata*. Uncatalogued specimen kept at Badia a Settimo (Scandicci, Italy) in the permanent exhibition of GAMPS. Scale bar = 50 mm.

spines from the early Pliocene Yorktown Formation of North Carolina (USA) as follows: "These teeth [*sic*] may be those of juveniles because they lack a groove along their posterior edges: this condition also is found in an extant species with rostral teeth of similar form (*Pristis* sp., USNM 232696). All three specimens are slightly abraded, and their surfaces exhibit bite marks. Teeth from Lee Creek Mine are relatively short (23.5-25.5 mm in length) and thin (2.6-2.9 mm in thickness; ratio of width to thickness 2.1-2.7). They show no trace of a subbasal barb". These fossil rostral spines, kept in the collections of the National Museum of Natural History (USNM) under accession numbers USNM 281389, USNM 281390, and USNM 412220, were attributed by Purdy *et al.* (2001) to *Pristis* sp. However, their morphology (as depicted by Purdy, 2001: Figs. 8a, b) could better match that of the rostral spines of adult and sub-mature specimens of extant *Anoxypristis cuspidata*, as well as that of the Pliocene Italian specimens, in being strongly dorsoventrally flattened and blade-shaped, with no groove running along their posterior edges. We also argue that the putative bite marks observed by Purdy *et al.* (2001) on the pristid specimens from the Yorktown Formation could be more parsimoniously interpreted as wearing features caused by the engraving action of sediment particles, as observed in both extant and fossil rostral spines of *Anoxypristis* (Collareta *et al.*, 2017; Nevatte *et al.*, in press; this work).

Discussion and Concluding Remarks

As highlighted above, pristid sawfish are currently absent from the Mediterranean, and their post-Miocene record in this basin is rather lacunous, being indeed limited to a couple of Pliocene fossil occurrences from Libya, Spain, and Italy (Pawellek *et al.* (2012); Collareta *et al.*, (2017), plus the very dubious report by De Stefano (1910)) and neontological data from archives, historical collections, and XIX century publications (Psomadakis *et al.*, 2009; Ferretti *et al.*, 2016, and references therein). Therefore, even an isolated fossil rostral spine is noteworthy. In fact, our finding represents the first unambiguous evidence of the presence of pristid sawfishes in Italy during the early Pliocene and, along with the reports by Pawellek *et al.* (2012) and Collareta *et al.* (2017), it corroborates the presence of Pristidae in the Mediterranean basin after the so-called "Messinian Salinity Crisis" (hereinafter: MSC). The latter has traditionally been interpreted as a devastating event, involving: *i*) the complete (or almost complete) desiccation of the Mediterranean basin; *ii*) the collapse of the Mediterranean marine biota, with the exception of some taxa able of surviving in brackish or hypersaline environments; *iii*) the re-flooding of the Mediterranean basin by North Atlantic waters at the start of the Pliocene, and the consequent re-colonization of this sea by frankly marine North Atlantic taxa (e.g., Cita, 1976; Domingues *et al.*, 2005). However, investigations on several late Messinian fossil fish assemblages have recently questioned the reliability of this reconstruction (e.g., Carnevale *et al.*, 2006, 2008, 2018; Carnevale, 2016) and put in evidence that a remarkable number of marine fish taxa (both steno- and euryhaline) were present in the Mediterranean basin through the MSC, thus suggesting the local continuity of frankly marine environments and biotopes. A similar hypothesis was anticipated by Cappetta & Nolf (1991) and Pawellek *et al.* (2012), who evoked the possibility that frankly marine fish communities could have persisted in residual basins, characterized by normal values of salinity, which would have been continuously present in the Mediterranean during the late Messinian. As already reported, sawfishes (including *Anoxypristis* spp.) have a long fossil history in the Western Tethyan/Mediterranean realm before the Pliocene (see e.g. Cappetta, 2012; Collareta *et al.*, 2017, and references therein); moreover, extant pristids are generally known as euryhaline species (e.g., Compagno & Last, 1998), and estuarine waters are regarded as much suitable habitats for juveniles and pupping females of *Anoxypristis* (Peverell, 2005; D'Anastasi *et al.*, 2013). Therefore, we argue that, during the MSC, pristids (including representatives of the genus *Anoxypristis*) continuously inhabited within the Mediterranean basin, in more or less broad areas characterized by environmental conditions inside the ranges currently utilized by sawfishes. However, it should be noted that knifetooth sawfishes were present along the coasts of southwestern Portugal (i.e., few hundreds of kilometres afar from Gibraltar) in latest Miocene times (Antunes *et al.*, 1999), and as such, they could have easily re-colonized the Mediterranean basin following the "Zanclean flood", if the MSC really saw a sterilization of this marine realm.

Moreover, as pristids are currently known as strictly tropical/subtropical fishes, the rostral spine described in this work suggests palaeoclimatic and palaeoecological conditions propitious to warm-water marine vertebrates along the early Pliocene coastline of Tuscany (Collareta *et al.*, 2017, and references therein). At this regard, however, the above reported possibility that some species of sawfishes inhabited the Mediterranean basin till historical times deserves some further comments, as it has found support in recent studies. Ferretti *et al.* 2016 suggested that two extant species of Pristidae (*Pristis pectinata* Latham, 1794 and *Pristis pristis* (Linnaeus, 1758)) could have utilized some coastal and estuarine areas of the Mediterranean as parturition grounds till the 1960s-1970s. This scenario challenges current knowledge on sawfish ecology

(Dulvy *et al.*, 2014) and, to date, does not find support in the Mediterranean fossil record. To our knowledge, in this broad region, the last fossil appearance of sawfishes occurred indeed in Pliocene times; moreover, Mediterranean remains of pristids have been invariantly found in more or less direct association with warm-water faunal assemblages. Interestingly, however, recent research suggests that other large-sized marine (vertebrates such as some migratory baleen whales which currently breed and calve in low-latitude areas outside the Mediterranean Sea) could have also exploited this enclosed marine region for parturition purposes in late Holocene times (Rodrigues *et al.*, 2016; but see also Speller *et al.*, 2016; Bosselaers *et al.*, 2017) as they likely used to do during part of the Pliocene and Pleistocene epochs (e.g., Bianucci *et al.*, 2006a, b; Collareta, 2016; Collareta *et al.*, 2016). In this hypothesis, in very recent times, the Mediterranean basin would have been the scenario of a far-from-banal history of behavioural complexity, ecospace preferences, and philopatry of large marine vertebrates which still has to be disclosed.

In conclusion, our finding indicates that, 350 years after Steno's seminal essay on the organic origin of fossil shark teeth (Steno, 1667; for a synthesis of Steno's outstanding contribution to the beginnings of palaeontology see e.g. Morello, 1979; Azzaroli, 1988, 2002-2003; Abbona, 2002; Cutler, 2003; Kermit, 2003; Pantaloni *et al.*, 2017; Romano & Palombo, 2017), the late Neogene central Mediterranean elasmobranch palaeocommunities still have to be exhaustively understood, and the study of the Pliocene fossil record of Tuscany can still bring significant additions to current palaeofaunistical lists (e.g., Spadini & Manganelli, 2015). In this respect, continuous collaboration between amateur and professional palaeontologists, in compliance with both the laws in force and modern scientific and museological standards, has the potential to highlight new crucial findings.

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