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Langhian rays (Chondrichthyes, Batomorphii) from Brielas, Lower Tagus Basin, Portugal

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ABSTRACT

The Langhian Vc unit of Brielas section (Caparica road, Almada), in the marine Miocene of the Lower Tagus Basin (West Portugal), is rich in batoid species. In this study, batoids are represented by 149 isolated fossil teeth and a single fossil dental plate collected from a bulk sample of washed and sorted sediment. A total of 12 species belonging to the orders Rhinopristiformes, Rajiformes, Torpediniformes and Myliobatiformes were identified. All genera and some species are known to have extant representatives. *Aetobatus cappettai* ANTUNES AND BALBINO, 2006, is described now from Langhian material which suggests it is older than previously supposed. The biogeographic ranges, environmental constraints and behaviour of the species described in this study point out to an infralittoral environment characterized by the dominance of warm water conditions, where episodic upwelling contributed to the occurrence of different types of batoids coexisting in the same habitat.

KEYWORDS **Langhian. Chondrichthyes. Batomorphii. Brielas. Portugal.**

INTRODUCTION

The specimens described in this study were collected from the Middle Miocene marine beds of the Lower Tagus Basin that crop near the Costa de Caparica road, Almada city (Setúbal Peninsula, West Portugal), with geographical coordinates: 38º39'13.6''N, 009º13'30.9''W. This outcrop,called Brielas, is very rich in fossil species of sharks and rays. The first reference to the Brielas outcrop was made by Antunes and Jonet (1970) in a study of sharks from Serravallian-Tortonian beds. More recently, Legoinha (2001) worked on the micropaleontology of this outcrop. The aim of the present study is to increase the knowledge of the Miocene Chondrichthyes present at Brielas.

According to Legoinha (2001) the fossiliferous beds exposed in this outcrop correspond to the Lisbon lithostratigraphic units Vc and Via (Fig. 1):

- Vc unit (base of Brielas section, about four meters thick) - yellowish sandy-silty beds, interbedded with fossil-rich biocalcarenites.

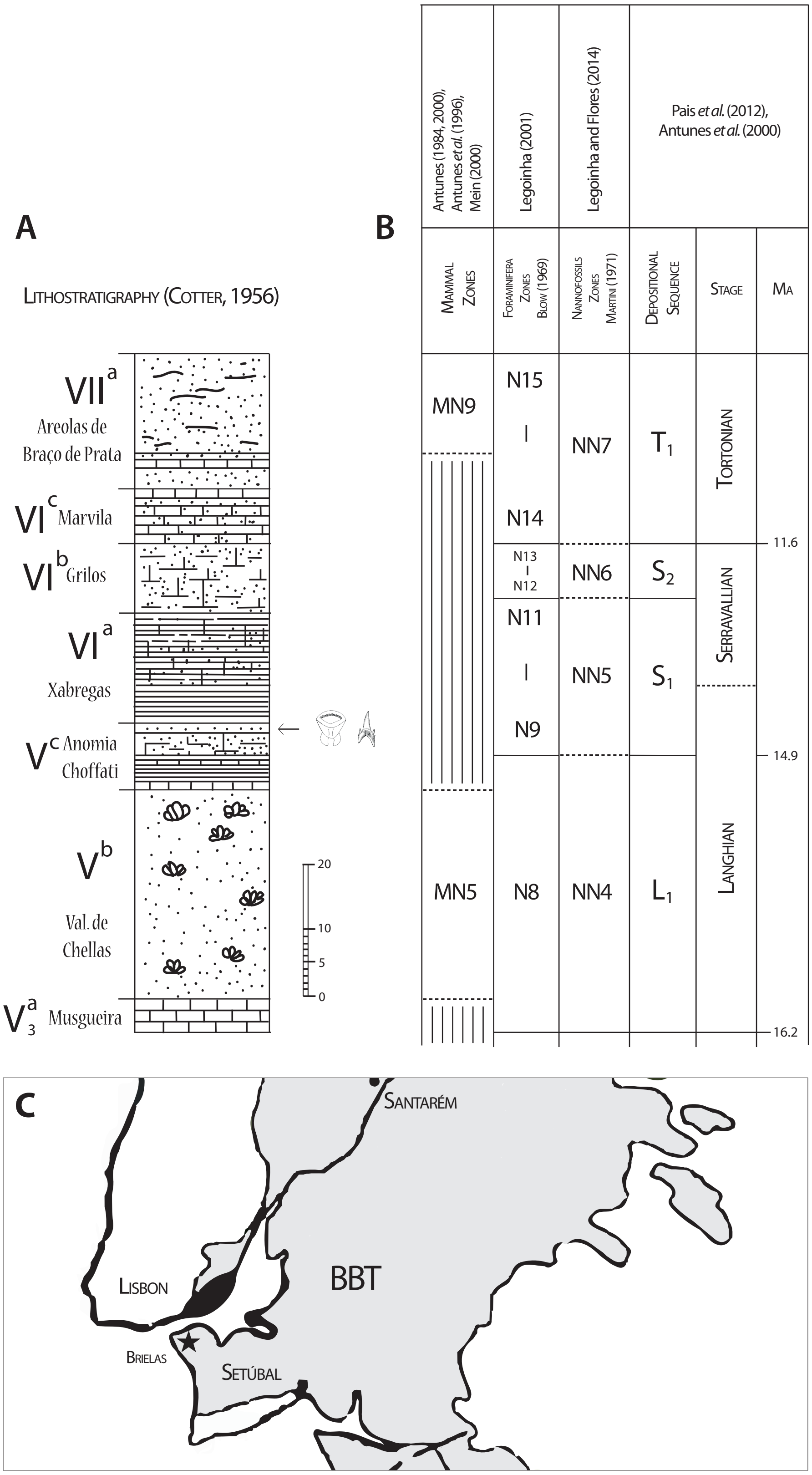

FIGURE 1. A) Stratigraphic position of the geological unit from which the sediments were collected (arrow) in a stratigraphic log located in Peninsula of Setúbal, Lower Tagus Basin, site of Brielas. Geological units: VIIa, VIc, VIb, VIa, Vc, Vb, Va3. Scale in meters. B) Chronostratigraphic framework for the Middle to Upper Miocene of the Lower Tagus Basin. MN: Mammal Neogene zonation; N: Foraminifera zone; NN: Nannofossil zone; T: Tortonian; S: Serravalian; L: Langhian; Ma: megaannum. Scale in meters. C) Geographic position of the fossil site Brielas (geographical coordinates: 38º39'13.6"N, 009º13'30.9"W). BBT: Lower Tagus Basin.

- VIa unit (top of Brielas section, about 11 meters thick) - blue, fossil-poor clays interbedded with more carbonated banks rich in shell debris.

The sampling made in the basal part of the Vc unit (Fig. 1) by Legoinha (2001) yielded abundant planktonic foraminifera: *Globigerina bulloides, G. praebulloides, Globigerinella aequilateralis, Globigerinoides immaturus, G. trilobus, Globorotalia peripheroronda, Orbulina suturalis, Praeorbulina glomerosa, P. transitora, Globoquadrina dehiscens, Dentoglobigerina altispira*. This association is characteristic of the Langhian biozone N9 (15.1 to 13.82Ma) (Legoinha, 2001). The ^{87}Sr/^{86}Sr dating of a scallop shell pointed to 14±0.4Ma age (Antunes *et al.,* 1999b). These beds also record the depositional sequence S1 proposed by Antunes *et al.* (2000).

The Brielas outcrop is now inaccessible due to the construction works in the Costa da Caparica road. It is covered by dense vegetation and fully fenced.

MATERIAL AND METHODS

The sediment for this study was sampled in the Vc unit in the Brielas outcrop by Ausenda Balbino, in 1995, at M. Telles Antunes suggestion. A total of 93.5kg were collected in the upper 50cm of this unit. Sediment was disaggregated with hydrogen peroxide and washed with running water through sieves of decreasing mesh (2.5mm, 1.0mm, 0.5mm). The concentrate was then sorted and fossil items were described and identified.

The sample yielded 1,046 Teleostei fossils (not studied) and 2,168 Chondrichthyes fossils: 149 identified and 307 in analysis batoid teeth; 376 identified and 1,336 in analysis shark teeth. The studied specimens are housed in the Palaeontological Collections of the University of Évora, Portugal. Each taxon is stored in an individual numbered eppendorf unit or crystal box, depending on the size and amount of fossils. The labelling process follows the reference: UEBR (taxon number) (specimen number).

The photographic record of the fossils was made through three different processes depending on their size. Small teeth like those of *Rhinobatos antunesi* JONET, 1968 (Fig. 2H-K) were coated with gold prior to SEM photographic register. This record was performed with a VP-SEM-EDS HITACHI 3700N at the HERCULES Lab in Évora (Portugal) using an acceleration voltage of 10kV to 20kV. Medium teeth like the ones of *Aetobatus arcuatus* AGASSIZ, 1843 (Fig.3E-F) were recorded by using a Leica EZ4W Stereo Zoom Microscope Integrated Camera. The larger ones such as the rostral tooth of *Anoxypristis* sp. (Fig. 2A-C) were recorded with a photographic camera mounted on a tripod.

The classification proposed by Compagno (1973) and modified by Cappetta (1987, 2012) was adopted here, using, whenever necessary, updated taxonomic data available from Last *et al.* (2016a, b), Naylor *et al.* (2012) and Weigmann (2016, 2017), and the open nomenclature procedures of Bengtson (1988). Synonymy was gathered by analysing the information found at www.shark-references.com (Pollerspöck and Straube, 2018).

SYSTEMATIC PALEONTOLOGY

Class: Chondrichthyes HUXLEY, 1880
Subclass: Elasmobranchii BONAPARTE, 1838
Subcohort: Neoselachii COMPAGNO, 1977
Superorder: Batomorphii CAPPETTA, 1980
Order: Rhinopristiformes NAYLOR, CAIRA, JENSEN, ROSANA, STRAUBEAND LAKNER, 2012
Family: Pristidae BONAPARTE, 1838
GENUS ***Anoxypristis*** WHITE AND MOY-THOMAS, 1941
Anoxypristis sp.
Fig. 2A-C

Material. One rostral tooth (UEBR_1.1).

Description. The tooth is broken near the base. It is approximately 3cm long and flattened dorso-ventrally, with sharp anterior and posterior edges (Fig. 2A, B). The tip of the tooth is slightly inclined. The morphology of the tooth suggests that its basal face had an elliptic shape (Fig. 2C) and the remaining area presents several foramina.

Discussion. The tooth was initially compared with the isolated rostral teeth of *Anoxypristis mucrodens* WHITE, 1926 and *Pristis* sp. figured by Cappetta (2012, pp. 394-395, figs. 384 I-M and 385 I-N) for the genus assessment. Although the tooth apex morphology resembles the one of the genus *Pristis* LINCK, 1790, it lacks the distinctly concave posterior edge characteristic of this selachians. For this reason, it was attributed to the genus *Anoxypristis* WHITE AND MOY-THOMAS, 1941. Only two of the three fossil species of this genus, *Anoxypristis fajumensis* STROMER, 1905, and *Anoxypristis mucrodens* WHITE, 1926, have been found in the Miocene (Pollerspöck and Straube, 2018). The studied tooth is more compressed dorso-ventrally than the rostral teeth of *A. mucrodens* (Cappetta, 2012, pp. 394-395, fig. 384 I-M) and of *A. fajumensis* figured by Stromer as *Pristis fajumensis* (1905, tafel VI, II, figs. 1-3). It is morphologically very similar to the rostral tooth of *Anoxypristis* sp. described by Zalmout *et al.* (2012, p. 79, fig. 5N). In the absence of more material, it is not possible to attribute this tooth to any species, hence it is left in open nomenclature.

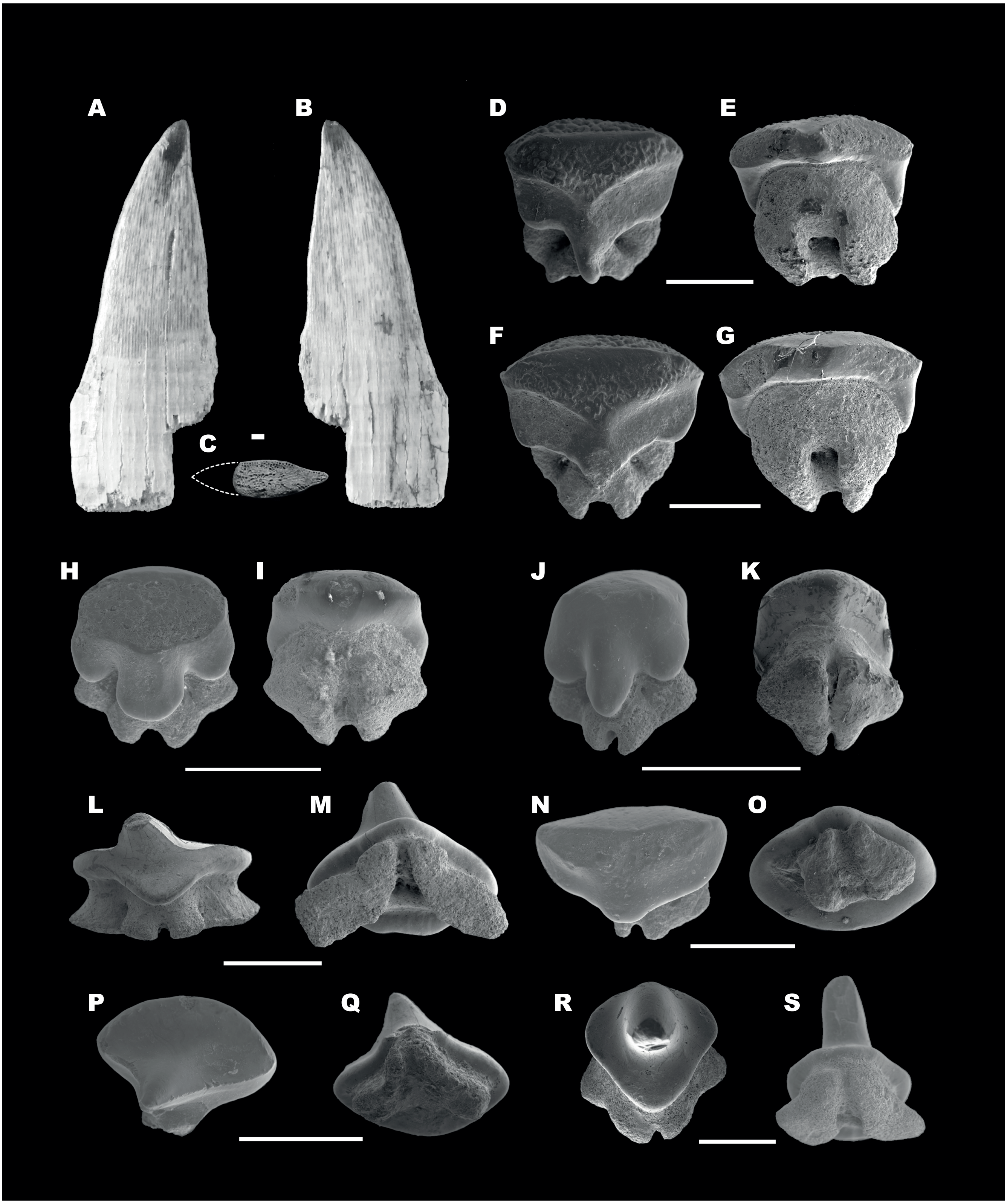

FIGURE 2. A-C) *Anoxypristis* sp. rostral tooth (UEBR_1.1): A) upper view, B) lower view and C) basal view. D, E) *Rhynchobatus pristinus* lateral tooth (UEBR_2.1): D) occlusal view and E) basal view. F, G) *Rhynchobatus pristinus* lateral tooth (UEBR_2.2): F) occlusal view and G) basal view. H, I) *Rhinobatos antunesi* tooth (UEBR_3.1): H) occlusal view and I) basal view. J, K) *Rhinobatos antunesi* tooth (UEBR_3.2): J) occlusal view and K) basal view. L, M) *Raja olisiponensis* tooth (UEBR_4.1): L) lingual view and M) basal view. N, O) *Raja olisiponensis* tooth (UEBR_4.2): N) occlusal view and O) basal view. P, Q) *Raja olisiponensis* tooth (UEBR_4.3): P) occlusal view and Q) basal view. R, S) *Raja olisiponensis* tooth (UEBR_4.4): R) occlusal view and S) basal view. Scale bars: 1mm.

Family: Rhinidae Müller and Henle, 1841
GENUS ***Rhynchobatus*** Müller and Henle, 1837
Rhynchobatus pristinus (Probst, 1877)
Fig. 2D-G
1877. *Pristis pristinus* n. sp. - Probst, p.81, pl. 1, figs. 17-18.

Material. 28 teeth (UEBR_2.1 to UEBR_2.28).

Description. These are small and massive teeth, with approximately 2.5mm of height in average. In occlusal view, they show a globular, rhomboid-shaped crown with rounded edges (Fig. 2D, F). In the oral face of the crown can be recognized three distinct areas, labial, central and lingual. The labial area is convex and the central area, which is separated from the labial area by a marked straight crest, is triangular. These two regions have a very distinct granular ornamentation that may be abraded. In occlusal view, the third area, the lingual face of the crown, is smooth and has a well-developed middle enameloid extension forming a long uvula. This central uvula may or may not protrude beyond the root groove (Fig. 2D, F). The root is massive and divided into two lobes by a deep, wide groove. The lingual face of the root presents a well-marked depression in each side of the uvula, with distinct lingual marginal foramina. In basal view, there are two or three main central foramina in the root groove, between the two lobes (Fig. 2E, G). The lobes are parallel and have flat basal faces.

Discussion. According to the shark-references database (Pollerspöck and Straube, 2018), there are currently three fossil species of *Rhynchobatus* described in the Miocene: *Rhynchobatus pristinus* Probst, 1877; *Rhynchobatus rudolffischeri* Laurito Mora, 1999; *Rhynchobatus vincenti* Jaekel, 1894. The described teeth were compared with the individual teeth of *R. rudolffischeri* (Laurito Mora, 1999, pl. 28, figs.1-7). They differ from these specimens, in having more developed crowns, a longer central uvula and shorter roots. We also compared the studied material with isolated teeth of *R. vincenti*. The specimens figured by Bor (1985, p. 107, pl. 6, figs. 1-3) show some similarities with the studied specimens in the crown shape, length of the central uvula and root morphology. However, the latter do not have the distinct protuberance on the crown labial visor, seen in basal view, in *R. vincenti*. Between the anterior and lateral teeth of *R. vincenti* figured by Herman and Van Den Eeckhaut (2010, pl. 51) and the studied material are fewer similarities, the former have a less developed crown, a tenuous horizontal crest separating the labial area from the triangular central area, and a very short central uvula. We found that the fossil specimens of this study were very similar to several isolated antero-lateral, lateral and posterior teeth of *R. pristinus* figured by Cappetta (1970, pl. 23, figs. 17-27; 2012, p. 336, fig. 326 A-H) and to the lateral teeth of this species illustrated in Adnet and Cappetta (2011, p. 251, figs. 4, 2), Antunes and Balbino (2007, pl. 1, figs. 1, 2), Cicimurri and Knight (2009, p. 636, fig. 6A), Laurito Mora (1999, pl. 29, figs. 1-7) and Vialle *et al.* (2011, Fig. 4, 2). In occlusal view, we can observe the same rhomboid shape of the crown, granular ornamentation, long central uvula and depressions on the root lobes. Abrasion or total absence of ornamentation in smaller specimens may be due to the ontogenetic heterodonty of *R. pristinus* as stated by Cicimurri and Knight (2009). Because the overall similar dental morphology of these specimens to *R. pristinus*, we attributed them to it.

Remarks. *Rhynchobatus pristinus* is an extinct species, thought to have been a nektobenthic carnivore, present in marine, coastal and even fluvial-deltaic habitats, according to the fossilworks database (Alroy, 2017).

Stratigraphic range. Oligocene to Miocene (Cicimurri and Knight, 2009).

Family: Rhinobatidae Müller and Henle, 1838
GENUS ***Rhinobatos*** Linck, 1790
Rhinobatos antunesi (Jonet, 1968)
Fig. 2H-K
1968. *Rhinobatus antunesi* nov. sp. - Jonet, pl. I, figs. 6-a, 6-b, 6-c.

Material. Five teeth (UEBR_3.1 to UEBR_3.5).

Description. These are small teeth, with an average height of 1.3mm and 1.2mm wide. In occlusal view, the crown is globe-shaped, and may be flat because of functional wear or erosion (Fig. 2H). The crown is wider than it is long, elongated in the middle, forming a uvula that does not reach the root notch. The middle uvula is flanked by two shorter expansions and is distinctly separated from them by a groove more or less wide. These three uvulas are rounded. In occlusal view, there are two root depressions, adjacent to the crown notches between the uvulas, and a margino-lingual foramen occurs on each depression (Fig. 2H, J). In basal view, the crown is slender and overhangs the root with a rounded enameloid bead (Fig. 2I, K). The root is thick and rather long. It is separated into two lobes by a subtle groove at the upper half, deepening into a small rounded indentation in the lower edge. The basal surface of the two lobes is sub-triangular in shape with rounded corners.

Discussion. Only two species of *Rhinobatos* have been found in the Miocene: *Rhinobatos antunesi* Jonet, 1968 and *Rhinobatos sahnii* Sahni and Mehrotra, 1981 (Pollerspöck and Straube, 2018). By comparing the studied specimens with the lateral teeth of *Rhinobatos* sp. described in Antunes and Balbino (2007, p. 111, pl. 1, figs. 3-8) we found that the specimen in Figure 5A is extremely similar to the specimen of UEBR_3.1 (Fig. 2H, J) found at Brielas. However, the rest of the teeth depicted as *Rhinobatos* sp. have crowns less globulous and, in some of them, the middle uvula is longer and less round than the one observed in the studied specimens. The study material was also compared with the anterior and lateral teeth of *R. antunesi* figured by Jonet (1968, pl. I, fig. 6a-c) and Cappetta (1970, pl. 23, figs. 7-10), which are characterized by presenting globulous crowns with three round uvulas, the middle one being longer than the lateral ones, and two root lobes presenting a sub-triangular basal face. Since the studied specimens have the same morphology as these fossil teeth, we ascribe them to *R. antunesi*.

Remarks. Thought to have been a Miocene nektobenthic carnivore (Alroy, 2017).

Stratigraphic range. Miocene (Alroy, 2017).

Order: Rajiformes BERG, 1937
Suborder: Rajoidei GARMAN, 1913
Family: Rajidae BLAINVILLE, 1816
GENUS ***Raja*** LINNAEUS, 1758
Raja olisiponensis (JONET, 1968)
Fig. 2L-S
1968. *Narcine olisiponensis* nov. sp. - Jonet, pl. 1, fig. 7a, 7b, 7c, 9, 10, 11.
2008. *Dipturus olisiponensis* Jonet, 1968 - BRISSWALTER, pl. 9, fig. 1-2.
2015. *Rostroraja olisiponensis* Jonet, 1968 - ANDRIANAVALONA *et al.,* p. 13, fig. 5A.

Material. 34 teeth (UEBR_4.1 to UEBR_4.34).

Description. Small teeth with an average width of approximately 2mm. The enameloid crown is smooth. In occlusal view, the base of the crown is circular to oval, depending on the position of the tooth. It overhangs the root peripherally, more marked at the lingual visor, leaning and forming a subtle bead or uvula (Fig. 2L, N, O, R). The crown has a curved cusp in its center, bent lingually and, in some cases, even beyond the lingual visor of the crown (Fig. 2R, S). In occlusal view, the lingual face of the crown is less developed than the labial face. They are separated by a marked transverse crest. The lingual face of the crown is strongly concave in profile, while the labial face is convex especially in the middle. The crown cusp is more or less elongated depending on the specimen. In basal view, the root is well developed but lower than the crown. It is divided into two lobes by a deep groove with several foramina (Fig. 2M, O, Q, S). The diverging root lobes outgrow the outline of the crown in most cases and are slightly concave. Each of them is vertically divided into two zones, different in size and shape, by a small notch in the outline (Fig. 2M).

Discussion. According to the shark-references database (Pollerspöck and Straube, 2018), only three species of *Raja* have been found in the Miocene: *Raja gentili* JOLEAUD, 1912; *Raja holsatica* REINECKE, VON DER HOCHT AND GÜRS, 2008; *Raja olisiponensis* (JONET, 1968). By comparing the studied specimens with the teeth of *R. Gentili* figured by Brisswalter (2008, pl. 9, fig. 3) and Cappetta (1970, pl. 20, figs. 28-31), we could see that the morphology was very different. The crown does not have a prominent cusp and the root lobes are not divided into two regions. The same was observed when the specimens were compared with the anterior and anterior-lateral teeth of *R. holsatica* figured by Reinecke *et al.* (2011, pl. 88, fig. 4, 5, pl. 89, fig. 2), where the overall morphology of the specimens is too different as well. The studied fossil teeth were also compared with the anterior and antero-lateral teeth from male and female specimens of *Dipturus olisiponensis* figured by Brisswalter (2008, pl. 9, figs. 1, 2) and Cappetta (2012, p. 359, fig. 348), lateral teeth of *R. olisiponensis* (Antunes and Balbino, 2007, pl. 2, figs. 1-4; García *et al.,* 2014, p. 264, figs. 3, 5-8), and teeth of *Narcine olisiponensis* (Jonet, 1968, pl. 1, figs. 7a-c, 9-11). They are markedly similar, presenting a crown with a median bead, a marked cusp in male teeth and wider crowns in female teeth with a less developed transverse crest. Because the high similarity between the studied teeth and the specimens of *R. olisiponensis* (and synonymies), we can ascribe these fossils to this species.

Remarks. *Raja olisiponensis* is an extinct batoid species thought to have been a nektobenthic carnivore of marine habitats (Alroy, 2017).

Stratigraphic range. Neogene (Alroy, 2017).

Order: Torpediniformes DE BUEN, 1926
Superfamily: Torpedinoidea COMPAGNO, 1973
Family: Torpedinidae BONAPARTE, 1838
GENUS ***Torpedo*** HOUTTUYN, 1764
Torpedo sp.
Fig. 3A-B

Material. One tooth (UEBR_5.1).

Description. Only a single tooth was found, with a height of 0.9mm per 1.4mm of width. In occlusal view, the enameloid crown shows several many foramina, probably due to bioerosion (Fig. 3A). The crown is wide, with an almost rectangular shape, and a transverse crest developed into a long, sharp, slightly tilted cusp. In occlusal view, it is very symmetrical. Marginal angles are present. The lower edge of the labial visor of the crown is concave. The lingual visor of the crown, in occlusal view, is marked by a notch and exposes the limits of the root lobes (Fig. 3A). In basal view, the root is divided by a deep, wide groove into two small lobes, with a circular basal surface (Fig. 3B).

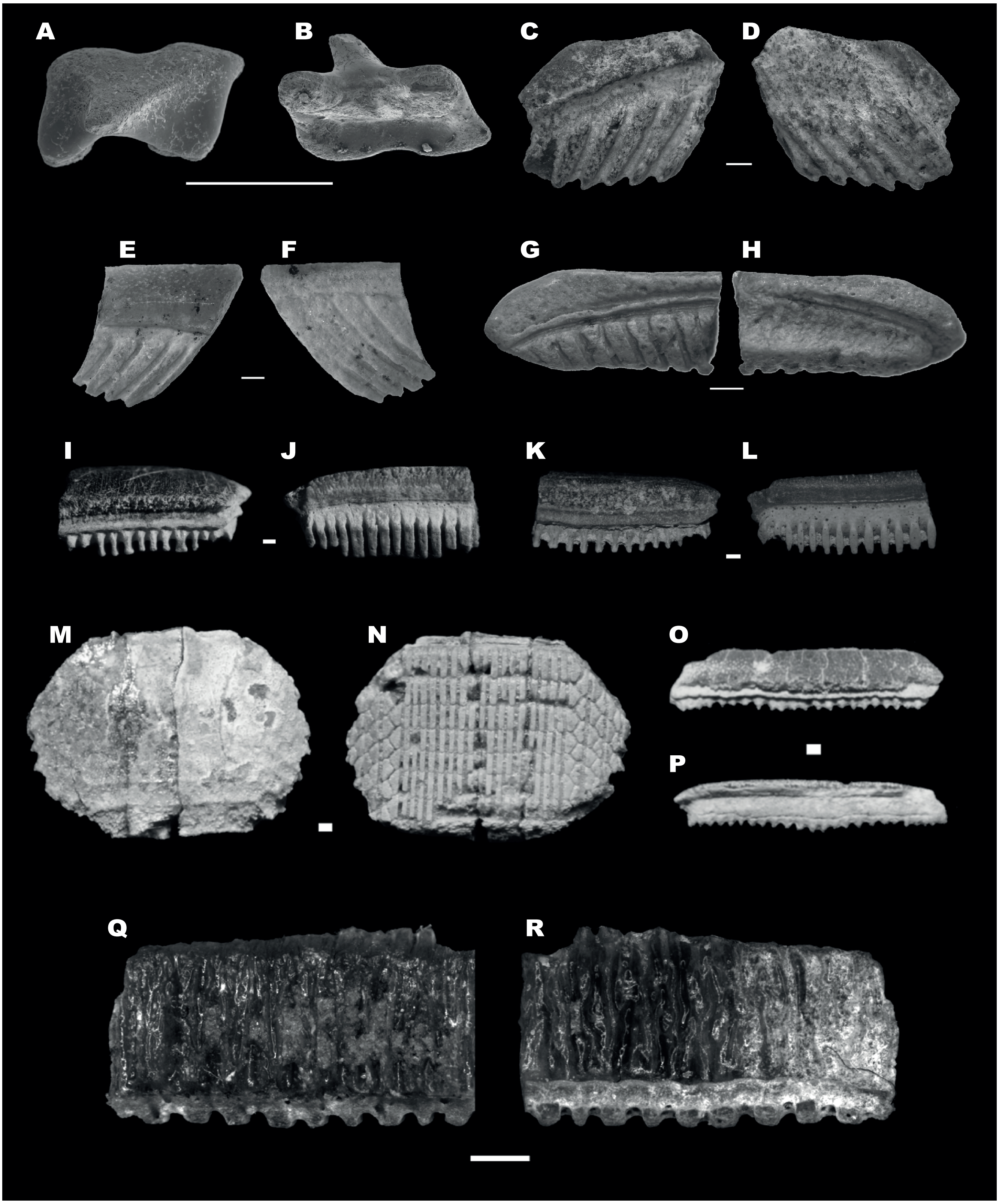

FIGURE 3. A, B) *Torpedo* sp. tooth (UEBR_5.1): A) occlusal view and B) basal view. C, D) *Aetobatus arcuatus* mandibular tooth (UEBR_6.1): C) lingual view and D) labial views. E, F) *Aetobatus arcuatus* mandibular tooth (UEBR_6.2): E) lingual view and F) labial view. G, H) *Aetobatus cappettai* upper tooth (UEBR_7.1): G) lingual view and H) labial view. I, J) *Aetomylaeus* sp. median tooth (UEBR_8.1): I) lingual view and J) labial view. K, L) *Aetomylaeus* sp. median tooth (UEBR_8.2): K) lingual view and L) labial view. M, N) *Myliobatis* sp. dental plate (UEBR_9.1): M) occlusal view and N) basal view. O, P) *Myliobatis* sp. median tooth (UEBR_9.2): O) lingual view and P) labial view. Q, R) *Mobula fragilis* tooth (UEBR_10.1): Q) lingual view and R) labial view. Scale bars: 1mm.

Discussion. According to the shark-references database (Pollerspöck and Straube, 2018) there are four fossil species of *Torpedo*. Only specimens left in open nomenclature have been described in the Miocene fossil record. This fossil tooth was compared with a lower antero-lateral male tooth of *Torpedo torpedo* (LINNAEUS, 1758) (Cappetta, 2012, p. 411, fig. 401, E-H) and the teeth of *Torpedo* sp. described by Antunes *et al.* (1999a). Although the crown and root of this specimen is very similar to the tooth of *T. torpedo*, nomenclature was left open because the lack of more material.

Order: Myliobatiformes COMPAGNO, 1973
Superfamily: Myliobatoidea COMPAGNO, 1973
Family: Myliobatidae BONAPARTE, 1838
GENUS ***Aetobatus*** BLAINVILLE, 1816
Aetobatus arcuatus (AGASSIZ, 1843)
Fig. 3C-F
1843. ***Aetobatis arcuatus*** Agassiz - fide Cappetta, pl. 24, figs. 6-9.
1858. ***Aetobatis tardiveli*** - Rouault, p. 101.
1867. ***Aetobatis profundus*** - Cope, p. 139.
1871. ***Aetobates omaliusi latidens*** - Delfortrie, pl. XI, fig. 42, A, a.
1871. ***Aetobates omaliusi curtidens*** - Delfortrie, pl. XI, figs. 43, A, a; 44, B, b; 45 C, c.
1904. ***Aetobatis biochei*** - Priem, p. 287, fig. 2.

Material. Two teeth (UEBR_6.1 and UEBR_6.2).

Description. These are fragments of mandibular teeth, with an average height of 7.7mm and width of 6.7mm. They have a curvature that may imply an arched complete tooth. In lingual view, the crown is low and abraded. The surface of the crown is flat with straight edges. In one of the specimens it is possible to observe the alveolar ornamentation on the crown (Fig. 3E). In labial view, the crown is displaced labially in relation to the root, which is long and markedly distally inclined, comprising multiple grooves (Fig. 3D, F). The root blades and grooves are more distinct in lingual view (Fig. 3C, E).

Discussion. There are currently three species of *Aetobatus* described for the Miocene: *Aetobatus arcuatus* AGASSIZ, 1843; *Aetobatus cappettai* ANTUNES AND BALBINO, 2006; *Aetobatus irregularis* AGASSIZ, 1843. The two fossil teeth fragments were compared with the specimens of *A. irregularis* figured by Agassiz (1843, pl. 47, figs. 3-5), but while the Brielas teeth have crowns displaced labially in relation to the root, in *A. irregularis* the root is not markedly displaced, being even higher. When compared with the lower and superior teeth of *A. cappettai* (Antunes and Balbino, 2006, figs. 1-8) the curvature is similar in the lower teeth, but not as much as in the studied fossils. We also compared the material with the lower and superior median teeth of *A. arcuatus* figured by Cappetta (1970, pl. 24, figs. 6-9), Laurito Mora (2004, p.73, fig. 5b-c), Laurito and Valerio (2008, pl. 2, figs. 8, 9) and Szabóand Kocsis (2016, fig. 9A-C). The comparative analysis showed that the morphology of the studied teeth is very similar to that of the lower teeth of *A. arcuatus* and synonymies. Consequently, although they are only fragments of median lower teeth, they were attributed to *A. arcuatus.*

Remarks. Fossil nektobenthic carnivore ray found in marine and fluvial habitats (Alroy, 2017).

Stratigraphic range. Oligocene to Miocene (Alroy, 2017).

Aetobatus cappettai ANTUNES AND BALBINO, 2006
Fig. 3G-H

Material. One tooth (UEBR_7.1).

Description. Fragment of an upper tooth, 7.6mm long, narrow, slightly convex, and with a height of approximately 3.6mm. In lingual view, the crown is low with a prominent lateral extremity. There is a narrow edge separating the lingual face of the crown from the root (Fig. 3G). The root is flat and higher than the crown, with decreasing thickness towards the extremity. It has a polyaulacorhize root with shallow, narrow grooves separating the root blades. In labial view, the equally spaced root grooves are very shallow, almost imperceptibles, while in lingual view they are distinct until the extremity (Fig. 3G, H).

Discussion. The tooth was compared with the upper teeth of the three species of *Aetobatus* described for Miocene: *Aetobatus arcuatus* (Cappetta, 1970, pl. 24, figs. 6-9; Laurito, 2004, p.73, fig. 5b-c; Laurito and Valerio, 2008; Szabóand Kocsis, 2016); *Aetobatus cappettai* (Antunes and Balbino, 2006, figs. 1-8); *Aetobatus irregularis* (Agassiz, 1843, tab. 47, figs. 3-5). Despite being only one fragment of an upper tooth, the similarity with the teeth described by Antunes and Balbino (2006) is noticeable; it appears to correspond to an extremity of an upper tooth of *A. cappettai*, hence it was ascribed to this species.

Remarks. This fossil species is only known from the Miocene of Portugal (Alroy, 2017). This is the second time it has been described.

Stratigraphic range. Miocene (Cappetta, 2012).

GENUS ***Aetomylaeus*** GARMAN, 1908
Aetomylaeus sp.
Fig. 3I-L

Material. Seven teeth (UEBR_8.1 to UEBR_8.7).

Description. These teeth show signs of abrasion, with a total height of 4.4mm in average. In lingual view, the crown presents an alveolar ornamentation (Fig. 3I, K). In labial view, the root is higher than the crown, probably due to the abrasion of the latter (Fig. 3J, L). The lateral teeth are complete while the median teeth are broken. In occlusal view, the crown of the lateral teeth has an irregular hexagonal outline, and presents a marked visor protruding over the root. In basal view, the root has four blades. In labial view, it is possible to observe the arch present in the median teeth, the labial visor of the crown hanging over the labial face of the root, and the root displaced from the crown (Fig. 3J, L). In both views, it is possible to observe the polyaulacorhize root with its multiple blades separated by deep, wide grooves.

Discussion. According to the shark-references database (Pollerspöck and Straube, 2018), there are only two fossil species of the genus *Aetomylaeus*: *Aetomylaeus cojimarensis* ITURRALDE-VINENT, MORA, ROJAS AND GUTIERREZ, 1998, and *Aetomylaeus cubensis* IITURRALDE-VINENT, MORA, ROJAS AND GUTIERREZ, 1998. The studied fossil teeth were compared with the lower and upper teeth of *Aetomylaeus* sp. (Cappetta, 2012, p. 446, fig. 439, C-D); *A. cojimarensis* and *A. cubensis* (Iturralde-Vinent *et al.,* 1998), but we found the crown morphology to be dissimilar in all cases for both median and lateral teeth. In face to our current knowledge, we decided to leave this teeth in open nomenclature.

GENUS ***Myliobatis*** CUVIER, 1816
Myliobatis sp.
Fig. 3M-P

Material. 20 isolated teeth and one dental plate (UEBR_9.1 to UEBR_9.21).

Description. The dental plate is flat, with a variable height of approximately 5mm in the middle decreasing to 2mm towards the lateral teeth. It is well preserved, despite the abrasion of the crowns. In occlusal view, it is possible to distinguish seven rows of median and lateral teeth (Fig. 3M). In basal view, the median teeth show polyaulacorhize roots and the lateral teeth holoaulacorhize roots (Fig. 3N). The individual median teeth, in occlusal view, are long and show an irregular hexagonal outline (Fig. 3M) and, in lingual view, it is possible to observe a tenuous ornamentation (Fig. 3O). In labial view, these teeth are slightly arched (Fig. 3P). The crown is higher than the root, which is displaced from the crown, and the labial visor of the crown protrudes over the labial face of the root. The lateral teeth are smaller and present a hexagonal outline in occlusal view. In basal view, the root is exposed and divided into two lobes, displaced from the crown.

Discussion. The studied dental plate was compared with fossil upper and lower plates of *Myliobatis aquila* CUVIER, 1816 of male and female adult specimens (Herman *et al.,* 2000, p. 19, text plate 8) and of a juvenile (Cappetta, 2012, p. 451, fig. 446, A-B); *Myliobatis* sp. (Sharmaand Patnaik, 2013, p. 165-166, figs. 2, 3); and some individual median and lateral teeth of *Myliobatis toliapicus* AGASSIZ, 1843 and *Myliobatis* sp. (Bor, 1985, pl. 8, figs. 1, 2 and 3-6). Since there are no distinctive features in the studied teeth that could be correlated with the material compared with, probably due to the poor preservation of the studied specimens, we decided to leave the nomenclature open.

Superfamily: Mobuloidea WHITLEY, 1936
Family: Mobulidae BONAPARTE, 1838
GENUS ***Mobula*** RAFINESQUE, 1810
Mobula fragilis (CAPPETTA, 1970)
Fig. 3Q-R
1970. *Manta fragilis* - Cappetta, pl. 26, figs. 10-11.
2009. *Paramobula fragilis* Cappetta, 1970 - Cicimurri and Knight, fig. 6, D.

Material. One tooth (UEBR_10.1).

Description. This is a very narrow tooth, with an extremely high and thin crown, with approximately 3.9mm height per 6.7mm width. It is compressed labio-lingually in profile view. In lingual view, the oral surface of the crown is broad but short (Fig. 3Q). In labial view, the anterior face of the crown is very high and vertical. It is marked by irregular vertical edges separated by narrow grooves. The anterior visor of the crown overlaps the root in labial view, creating a smooth depression between the crown and the root (Fig. 3R). In lingual view, the posterior face of the crown is marked by vertical ridges and it has a concave profile. The posterior visor of the crown is not very developed. The low root is polyaulacorhize. It has nine distinct blades separated by wide but shallow grooves, with different widths and depths.

Discussion. There are six fossil species of the genus *Mobula* (Pollerspöck and Straube, 2018), and all of them have been found in Miocene beds: *Mobula cappettae* JONET, 1976; *Mobula fragilis* CAPPETTA, 1970; *Mobula lorenzolizanoi* LAURITO MORA, 1999; *Mobula loupianensis* CAPPETTA, 1970; *Mobula melanyae* CASE, 1980; *Mobula pectinata* CAPPETTA, 1970. The specimen recovered was compared with *M. lorenzolizanoi* (Laurito Mora, 1999, pl. 39, figs. 2b, 3a-c, 4, 5a-b and pl. 40, fig. 3a-c), *Manta melanyae* (Case, 1980, pl. 10, figs. 1a-d, 2a-e), *M. loupianensis* (Brisswalter, 2008, pl. 9, figs. 5, 6 and pl. 10, fig. 10; Cappetta, 1970, pl. 26, figs. 1-6; Carrillo-Briceño *et al.,* 2016, p.16, fig.12, 2-18) and *M. pectinata* (Cappetta, 1970, pl. 26, figs. 7-9) and we found no morphological similarities. However, when we compared the studied tooth

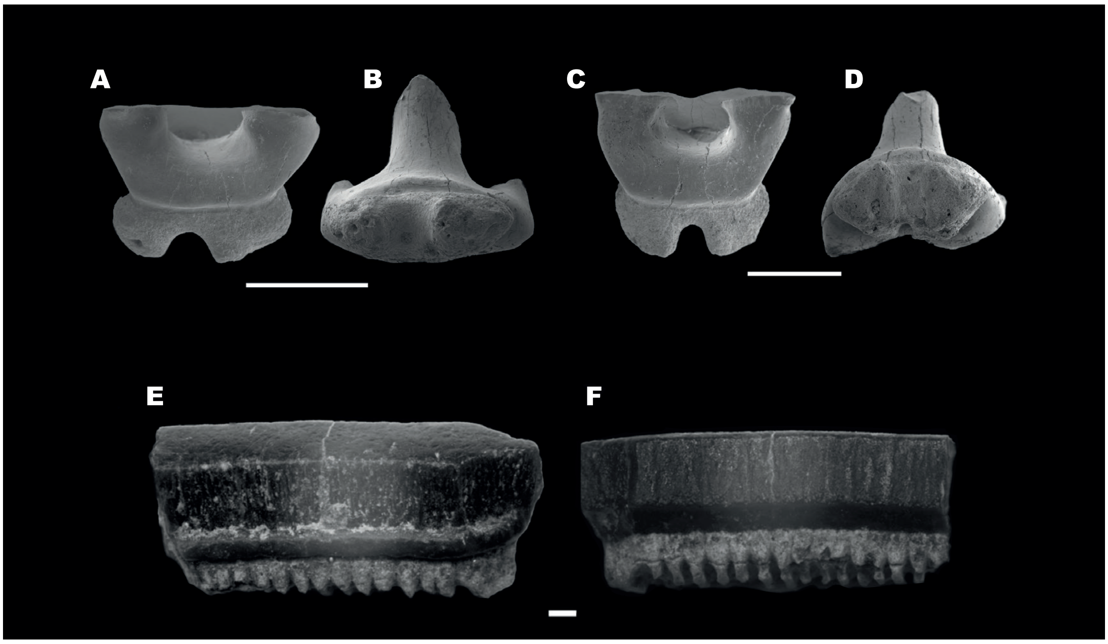

FIGURE 4. A, B) *Mobula loupianensis* anterior tooth (UEBR_11.1): A) occlusal and B) basal views. C, D) *Mobula loupianensis* lateral tooth (UEBR_11.2): C) occlusal view and D) basal view. E, F) *Rhinoptera* sp. median tooth (UEBR_12.1): E) lingual view and F) labial view. Scale bars: 1mm.

with the teeth of *M. fragilis* figured by Bor, Reinecke and Verscheren (2012, pl. 52, figs. 5-8) and Carrillo-Briceño *et al.* (2016, p.16, fig. 12, 1-11), *Manta fragilis* mentioned by Cappetta (1970, pl. 26, figs. 10, 11) and *Paramobula fragilis* cited by Cicimurri and Knight (2009, fig. 6D), we found that the morphology of the Brielas tooth was nearly identical to the morphology of these specimens. This justifies the attribution of this tooth to the species *M. fragilis.*

Remarks. The teeth of this fossil species are extremely fragile, so it is rare to find specimens that came through the fossilization process unscathed.

Stratigraphic range. Late Oligocene to Middle Miocene (Adnet *et al.,* 2012).

Mobula loupianensis CAPPETTA, 1970
Fig. 4A-D

Material. Nine teeth (UEBR_11.1 to UEBR_11.9).

Description. These are small teeth, with an average height of 1.7mm per 2.2mm of width. In occlusal view, the anterior teeth have a broad crown marked by a transverse crest elongated in a posterior tip or cusp, broken in some specimens (Fig. 4A). The latero-posterior regions of the crown are slightly depressed and almost vertical. The posterior face of the crown has a concave profile and its visor slightly overhangs the root. In basal view, the root is high, subvertical and bilobed (Fig. 4B). The two lobes have a small basal surface. The lateral teeth are more transversely elongated, in occlusal view. The anterior section of the oral face of the crown may have small folds (Fig. 4C, D). The posterior tip or cusp is also present on the lateral teeth, despite being shorter and wider at the base. The latero-posterior regions of the crown are marked by depressions. Visible in both occlusal and basal views, the root presents two more developed lobes separated by a deep, wide groove.

Discussion. As indicated above all the six known fossil species of the genus *Mobula* have been found in the Miocene (Pollerspöck and Straube, 2018). The studied material was compared with specimens of *Mobula lorenzolizanoi* (Laurito, 1999, pl. 39, figs. 2b, 3a-c, 4, 5a-b and pl. 40, fig. 3a-c), *Manta melanyae* (Case, 1980, pl. 10, figs. 1a-d, 2a-e), *Mobula loupianensis* (Brisswalter, 2008, pl. 9, figs. 5, 6 and pl. 10, fig. 10; Cappetta, 1970, pl. 26, figs. 1-6; Carrillo-Briceño *et al.,* 2016, p.16, fig.12, 12-18), *Mobula pectinata* (Cappetta, 1970, pl. 26, figs. 7-9), *Mobula fragilis* (Bor *et al.,* 2012, pl. 52, figs. 5-8; Carrillo-Briceño *et al.,* 2016, p.16, fig. 12, 1-11), *Manta fragilis* (Cappetta, 1970, pl. 26, figs. 10, 11) and *Paramobula fragilis* (Cicimurri and Knight, 2009, fig. 6D). The studied teeth are morphological more similar to the specimens of *M. loupianensis* than those of the other species, hence the attribution to this species.

Remarks. *Mobula loupianensis* was a nektobenthic carnivore that lived in coastal and reef habitats (Alroy, 2017).

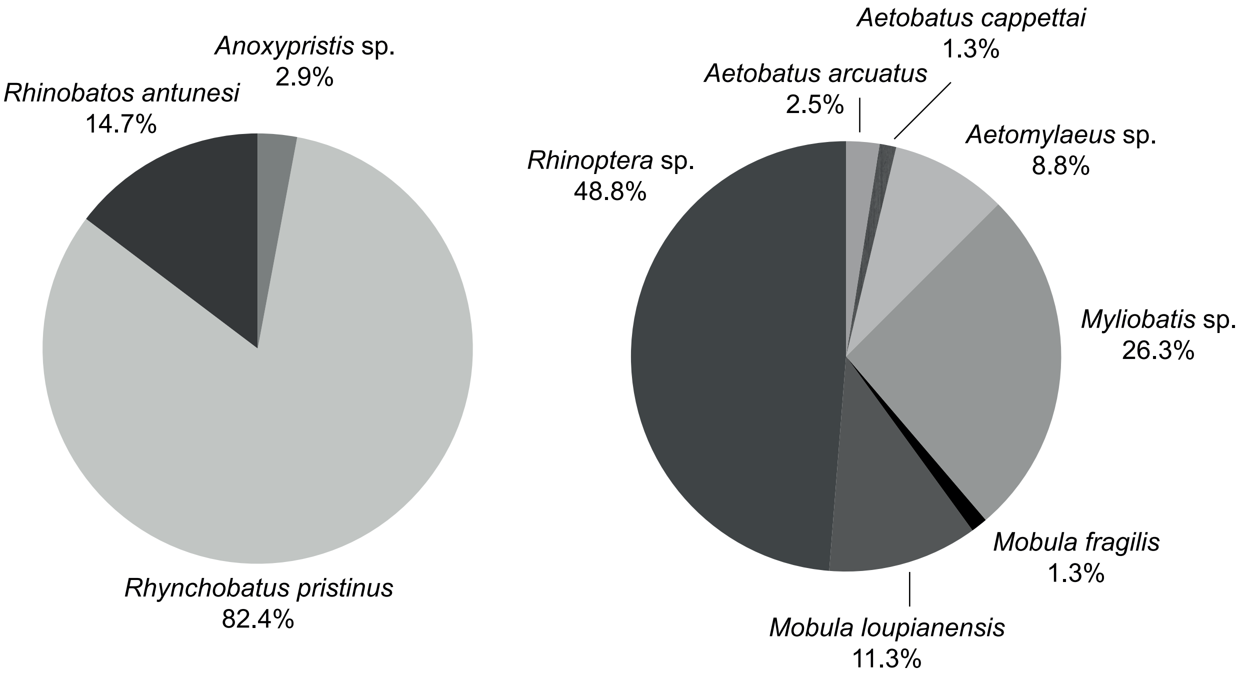

FIGURE 5. Graphic representation of the distribution of the studied material of Rhinopristiformes (on the left) and Myliobatiformes (on the right).

This is the second time that *M. loupianensis* has been described in the Neogene stratigraphic record of Portugal.

Stratigraphic range. Middle Miocene (Adnet *et al.*, 2012).

Family: Rhinopteridae JORDAN AND EVERMANN, 1896
GENUS ***Rhinoptera*** CUVIER, 1829
Rhinoptera sp.
Fig. 4E-F

Material. 39 teeth (UEBR_12.1 to UEBR_12.39).

Description. Complete and fragmented median teeth, 1.5cm long in average. In lingual view, the worn- out crown, has a hexagonal outline and alveolar ornamentation (Fig. 4E). The root is low and aligned with the crown in profile. In labial view, these teeth are slightly arched in the middle (Fig. 4F). In both views, it is possible to observe the root multiple blades separated by grooves. The three complete lateral teeth, in profile, have a very low, worn-out crown. In occlusal view, the crown has a hexagonal outline. In basal view, the root is polyaulacorhnize, with multiple blades and deep grooves.

Discussion. There are eight fossil species of *Rhinoptera* (Pollerspöck and Straube, 2018), but only *Rhinoptera raeburni* WHITE, 1934, *Rhinoptera schultzi* HIDEN, 1995, *Rhinoptera smithii* JORDAN AND BEAL, 1913 and *Rhinoptera studeri* AGASSIZ, 1843, have been found in Miocene units. The studied teeth were compared with median individual teeth of *R.* cf. *studeri* Arambourg, 1952 and *R. raeburni* described by Sharmaand Patnaik (2013, p. 169, fig. 4H-J) and *Rhinoptera* sp. described by Brisswalter (2008). Due to their poor state of preservation, it was decided to leave them in open nomenclature.

RESULTS

The Middle Miocene batoid fauna from Brielas (Costa da Caparica, Portugal) is composed of 8 families, 10 genera and 12 species. The distribution of the studied material over the different species is shown in Table 1. The most diverse order is Myliobatiformes with 7 species, accounting for more than a half of the total fossil material (53.7%), followed by Rhinopristiformes with three species (22.8%), Rajiformes with one species (22.8%) and Torpediniformes with one species and a single fossil tooth (0.7%) (Fig. 5).

DISCUSSION

The Brielas outcrop with its 12 species of batoids described from a bulk sample of 149 teeth can be considered a very rich paleontological site. Legoinha (2001) characterized the local sedimentary succession as typical of an infralittoral environment of moderately warm waters, with increasing depth upwards, transitioning to a circalittoral environment. The predominance of demersal batoids (benthic and benthopelagic forms) like *Rhynchobatus, Myliobatis* and *Rhinoptera,*

Order	Family	Species	Fossils	Frequency
Rhinopristiformes	Pristidae	*Anoxypristis* sp.	1	0.7%
	Rhinidae	*Rhynchobatus pristinus*	28	18.8%
	Rhinobatidae	*Rhinobatos antunesi*	5	3.4%
Rajiformes	Rajidae	*Raja olisiponensis*	34	22.8%
Torpediniformes	Torpedinidae	*Torpedo* sp.	1	0.7%
Myliobatiformes	Myliobatidae	*Aetobatus arcuatus*	2	1.3%
		Aetobatus cappettai	1	0.7%
		Aetomylaeus sp.	7	4.7%
		Myliobatis sp.	21	14.1%
	Mobulidae	*Mobula fragilis*	1	0.7%
		Mobula loupianensis	9	6.0%
	Rhinopteridae	*Rhinoptera* sp.	39	26.2%
			149	100%

TABLE 1. Absolute and relative frequencies of the batoid species sampled in the Langhian outcrop at Brielas, Costa da Caparica, West Portugal.

characteristics of tropical to temperate littoral and neritic zones, coexisting with genera of colder environments such as *Raja* and pelagic forms such as *Mobula* (Last *et al.,* 2016b), further reinforces this interpretation. In addition, both batoid rich infralittoral and circalittoral environments could be related to a possible upwelling activity. This process allows the mixing and overlapping of water bodies with different mean values of salinity and temperature, including cold, deep bodies of water, rich in nutrients, that rise to replace shallow warmer bodies poor in nutrients (Kosro *et al.,* 1991). This phenomenon increases the biological productivity of surface waters (Cushing, 1969), attracting demersal and pelagic species, and may explain the presence of such association of batoids in these waters.

CONCLUSIONS

The Vc unit of Brielas section is rich in selachians forms, with the fossil material associated with batoid organisms (456) accounting for 21.0% of the total material found in the studied sample. The four orders of Batomorphii selachians, Rhinopristiformes, Rajiformes, Torpediniformes, and Myliobatiformes, are present with a total of 10 genera and 12 species: *Anoxypristis* sp.; *Rhynchobatus pristinus*; *Rhinobatos antunesi*; *Raja olisiponensis*; *Torpedo* sp.; *Aetobatus arcuatus*; *Aetobatus cappettai*; *Aetomylaeus* sp.; *Mtliobatis* sp.; *Mobula fragilis*; *Mobula loupianensis* and *Rhinoptera* sp. Myliobatiformes is the predominant order with 7 species accounting for 53.7% of the identified batoid material, and *Rhinoptera* the commonest occurring genus (Fig. 5).

Interestingly, a fossil tooth of *Mobula fragilis* was found in the studied sediments; due to its unique morphology, it is not usual to find fossil teeth of this genus in a good state of preservation.

The studied sample is also characterized by the presence of batoid forms from typically distinct climatic and bathymetric zones. The depositional environment has been described by Legoinha (2001) as in transition from infralittoral to circalittoral. This occurrence may be explained by upwelling activity which attracts a great faunal diversity.

Further research on the Vc unit in other outcrops would provide a better understanding of the biodiversity and distribution of the Langhian Elasmobranchii species in Portugal.

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