

Otoliths in situ from Sarmatian (Middle Miocene) fishes of the Paratethys. Part IV: Scorpaenidae, Labridae, and Gobiesocidae

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Received: 23 November 2016 / Accepted: 6 January 2017 / Published online: 13 February 2017
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Abstract Percomorph fishes are relatively uncommon in the Sarmatian deposits of Dolje and Belgrade where they are primarily of small size, often representing juvenile specimens. Here, we describe otoliths in situ from “*Scorpaena*” *minima* Kramberger 1882 (Scorpaenidae), *Symphodus woodwardi* (Kramberger 1891) (Labridae), and from an indeterminate clingfish tentatively placed in *Apletodon* (Gobiesocidae). “*Scorpaena*” *minima* is based on juvenile specimens and does not exhibit a complete set of features for a robust diagnosis, although it certainly represents a nominally valid species. *Symphodus woodwardi* is redefined herein based on the holotype and an additional small and well-preserved specimen, and a comparative analysis including Neogene congeners from the Mediterranean and Paratethys is discussed. *Apletodon?* sp. represents the first documented fossil clingfish in the record, even if the preservation of the three specimens identified does not allow a detailed taxonomic definition to the species level. None of the species with otolith in situ described herein can be related to any of the known coeval isolated otolith-based species, although in the case of the

scorpaenid, such correlation is hampered by the juvenile nature of the available specimens.

Keywords *Symphodus* · *Apletodon* · Croatia · Serbia

Introduction

In our studies dealing with the otoliths in situ from Sarmatian fishes of the Paratethys, we focus here on certain acanthomorph fishes of the families Scorpaenidae, Labridae, and Gobiesocidae. Their skeletal remains are less common than those pertaining to other groups in the two main studied localities, i.e., Dolje near Zagreb, Croatia, and Belgrade, Serbia. In addition, there is no coeval record of isolated otoliths that would relate to any of the species described here with otoliths in situ, except possibly for a rare scorpaenid identified from the Sarmatian and Konkian of the Eastern Paratethys—*Pontinus? obrotchishtensis* (Starshimirov 1981). Among the specimens documented herein, there is the first fossil record of the family Gobiesocidae. Despite the recognition of three individual articulated skeletons with otoliths in situ clearly belonging to this family, their overall preservation is inadequate to allow a detailed taxonomic assignment.

Editorial handling: Daniel Marty.

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Materials and methods

Eight articulated or partially articulated skeletons are described from the collection of the Croatian Natural History Museum, Zagreb (CNHM), of which four had otoliths in situ, and one articulated skeleton with an otolith in situ from the collection of the collection of the Chair of Historical Geology, Department of Regional Geology,

Faculty of Mining and Geology, University of Belgrade (RGF), and indicated with the collection acronym AJ (referring to the collection of Jelena Anđelković). All the specimens with otoliths in situ housed at the CNHM are from the Sarmatian s. s. (Vohlynian) deposits cropping out near Dolje, north of Zagreb. The RGF specimen with an otolith in situ was collected from temporary excavations in 1961–62 during the renovation of the Rajko Mitić football stadium (formerly ‘Red Star’) in Belgrade. For a detailed description of the localities, see Schwarzzhans et al. (2016).

The morphological terminology of otoliths was established by Koken (1891) modified by Weiler (1942) and Schwarzzhans (1978). Abbreviations: general: vs = versus, HT = holotype; skeletons: SL = standard length, TL = total length, HL = head length, D = dorsal-fin rays, A = anal-fin rays, P = pectoral-fin rays, V = pelvic-fin rays, C = principal caudal-fin rays, cor = coracoid, ep = epural, hy = hypural, op = opercle, ph = parhypural, rad = radials, sc = scapula, sop = subopercle, un = uroneural; Roman numbers indicate fin spines, Arabic numbers indicate branched soft rays; otoliths: OL = otolith length, OH = otolith height, OT = otolith thickness, SuL = sulcus length, OsL = ostium length, CaL = cauda length.

The term “otolith” refers to the saccular otolith. Lagellar and utricular otoliths are described as asteriscus and lapillus, respectively.

Systematic paleontology

Order Scorpaeniformes sensu Imamura and Yabe 2002

Family Scorpaenidae Risso 1827

Genus *Scorpaena* Linnaeus 1758

“*Scorpaena*” *minima* Kramberger 1882

(Figs. 1a–f, 2a–b; Table 1)

1882 *Scorpaena minima* Kramberger—Kramberger: pl. 22, Fig. 2

1969 *Scorpaena minima* Kramberger 1882—Anđelković 1969: pl. 3, Fig. 2

1989 *Scorpaena minima* Kramberger 1882—Anđelković 1989: pl. 19, Fig. 5 (refigured from Kramberger, 1882)

Material Three partially complete articulated skeletons, two of which are from Dolje, Croatia, Sarmatian s.s. (Vohlynian), CNHM 142, holotype, 17 mm SL (Fig. 1a, b), CNHM 257, 18 mm SL (Fig. 2a, b); another specimen, which contains an otolith in situ, RGFAJ 28, 14 mm SL, was collected in 1961–62 from Sarmatian s.s. (Vohlynian) deposits in Belgrade, Serbia (Fig. 1c–f).

Description The body is short and compact, with a large head. Counts and measurements are summarized in Table 1.

Neurocranium, jaws, and suspensorium. The head bones are extremely damaged in all the examined specimens, so that their morphology cannot be recognized. There is no evidence of jaw teeth in any of the available skeletons.

Opercular series The preopercle is well preserved in CNHM 142 (Fig. 1a), and partially preserved in RGFAJ 28 (Fig. 1d, e); it shows a very long, upward oriented first preopercular spine followed by two shorter and narrower and downward oriented second and third preopercular spines (Fig. 1a, d, e). The lower part of the preopercle is preserved exclusively in the specimen CNHM 142 (Fig. 1a) and shows a blunt, much shorter fourth spine. There is a faint indication of a small opercle just above the preopercle in CNHM 142.

Axial skeleton. The vertebral column (Figs. 1b, c, 2a) contains 24 (10 + 14) vertebrae. The anterior three abdominal vertebrae are usually hidden under crushed head bones and difficult to recognize. The vertebral centra are subrectangular and higher than long, with lateral ridges and fossae along their flanks. The neural spines of the abdominal vertebrae are short, becoming longer backwards, but are often poorly recognizable. Short parapophyses are visible in CNHM 142 at least on the posterior four abdominal vertebrae. The caudal vertebrae show long neural and haemal spines that are increasingly more inclined backwards.

Caudal skeleton. The caudal skeleton is well preserved in the specimen CNHM 257 (Fig. 2b, c). The hypurals 1 + 2 and 3 + 4 are fused into two broad triangular plates. The fifth hypural is thin and elongate. The first uroneural is clearly recognizable. There are three long and narrow epurals, of which the first is the longest. The autogenous parhypural is long and pointed. The haemal spine of the penultimate vertebra is strongly widened and long, and that of the pre-penultimate pleural center moderately widened. The neural arch of the penultimate vertebra is reduced to a short crest. 15 principal caudal-fin rays appear to be present; there are two dorsal and two ventral procurent rays.

Median fins (Figs. 1a, c, 2a). The dorsal fin is very long; it inserts just behind the nape extending posteriorly up to the level of the seventh or eighth caudal vertebrae; it consists of 12 spines and 7 soft rays. The length of the first spine is about 2/3 to 3/4 of the length of the second spine; the third spine is the longest (16–22% SL). The anal fin consists of three spines plus four or five soft rays; the anal fin originates just below the third or fourth caudal vertebra. The first two anal-fin spines are in supernumerary association with the very large first anal-fin pterygiophore.

Paired fins and girdles. The pectoral fin and girdle are always incompletely preserved. At least ten pectoral-fin

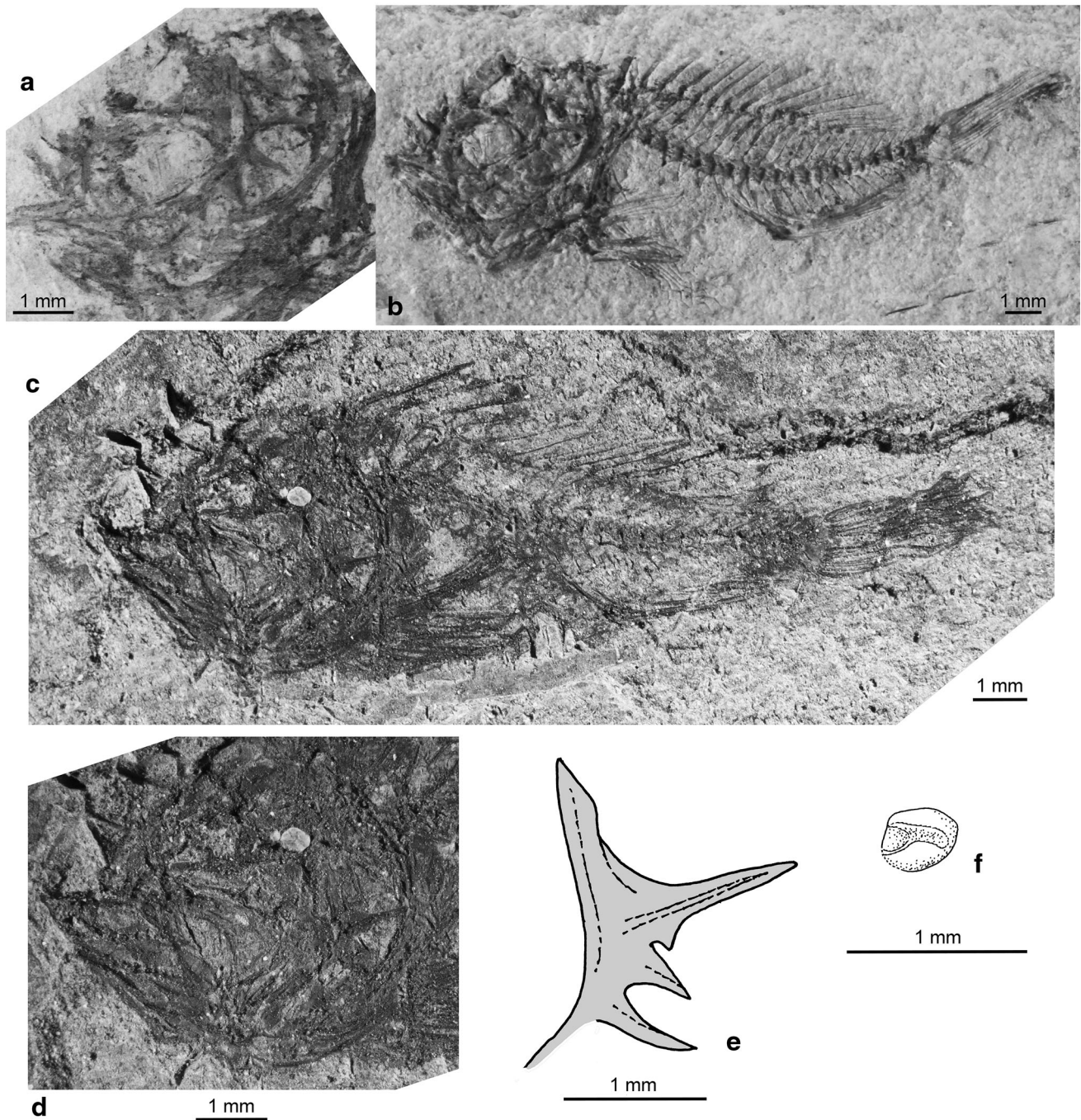


Fig. 1 “*Scorpaena*” *minima* Kramberger 1882. **a, b** CNHM 142, holotype; **a** close-up of the head; **b** articulated skeleton; **c–f** RGFAJ 28 (reversed); **c** articulated skeleton; **d** close-up of the head; **e** reconstruction of the preopercle; **f** drawing of the otolith

rays can be observed on the specimen CNHM 257, while not less than eight rays are preserved in the other two specimens. The pectoral and pelvic fins are about as long as the longest dorsal fin spine. The pelvic fin contains a single massive spine plus five delicate rays.

Otolith (Fig. 1f). One otolith in situ is preserved in RGFAJ 28. It is extremely small, about 0.4 mm long, regularly oval

in outline, and slightly damaged along the anterior and ventral rims. The sulcus shows a ventrally widened ostium and a cauda, which is only slightly bent and slightly widened at its tip. It is a very generalized juvenile morphology without much diagnostic value.

Discussion All the investigated specimens are of very small size, being 18 mm or less in SL. Considering their size and

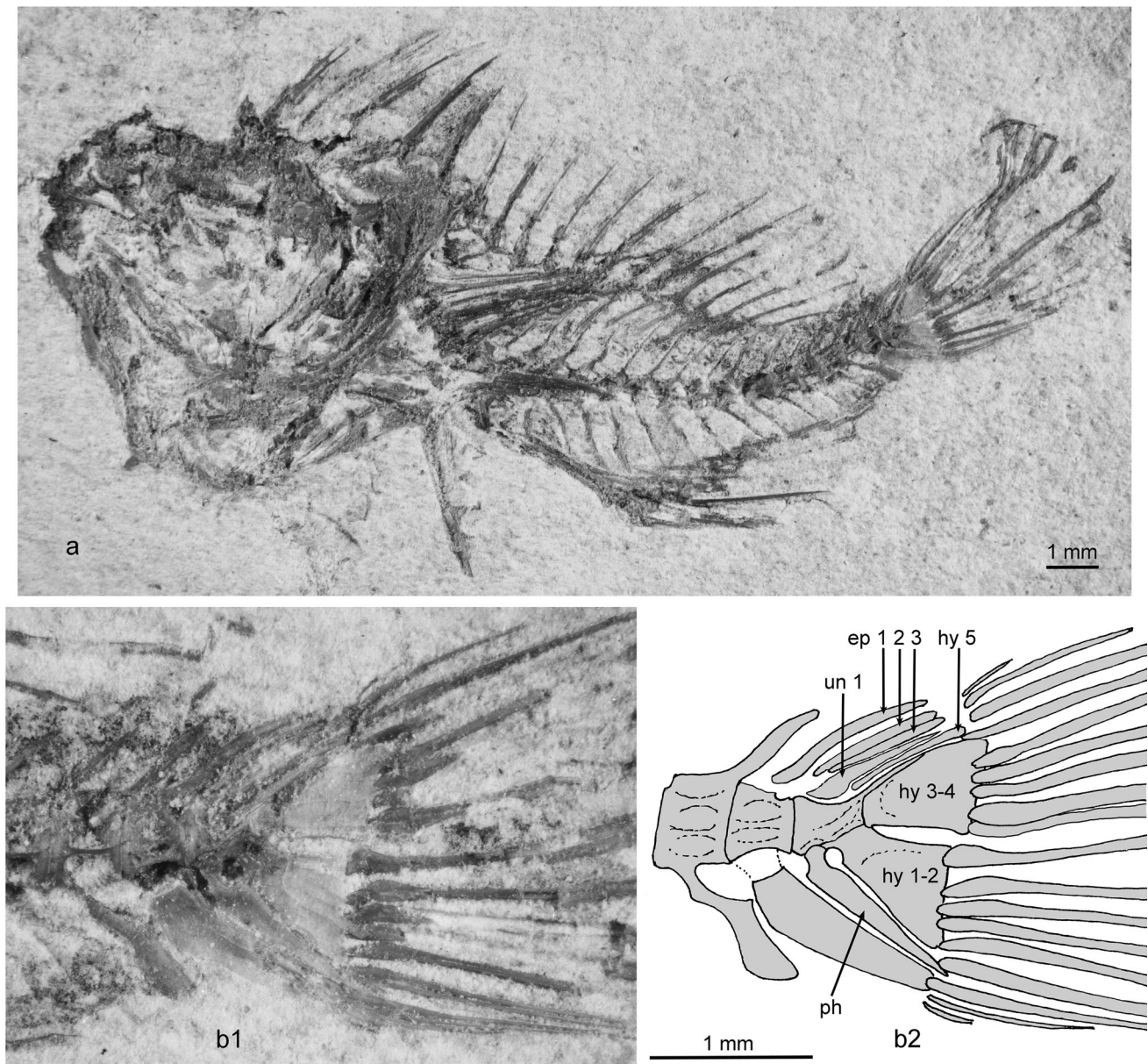


Fig. 2 “*Scorpaena*” *minima* Kramberger 1882, CNHM 257.1 (reversed). **a** Articulated skeleton; **b** 1–2 photograph and reconstruction of the caudal skeleton

their completely developed dorsal fin, it is reasonable to conclude that these scorpaenid fishes are juvenile individuals, and that their heads and preopercular spines were comparatively enlarged with respect to their overall body size (e.g., Moser et al. 1977; Fahay 2007). As discussed above, the otolith morphology is also consistent with such conclusion. This hampers comparison with the Badenian *Scorpaena prior* Heckel 1861. In the redefinition of *S. prior*, Schultz (1993) made extensive use of the shape of the preopercle and associated spines. We recognize that the configuration of the spines in *Scorpaena minima* is similar to that of *S. prior*; however, the configuration described for

“*Scorpaena*” *minima* likely would have been modified ontogenetically, as always occur in the extant members of the family Scorpaenidae (Moser et al. 1977; Fahay 2007); therefore, the taxonomic relevance of this feature cannot be fully assessed. In our assessment, “*Scorpaena*” *minima* certainly represents a valid species, even if any conclusion about its taxonomic status is not possible until more complete and larger specimens would be available, allowing a better comparison with *Scorpaena prior* and Recent Scorpaenidae.

Schultz (1993) has extensively discussed the relationships of *Scorpaena prior* based on a detailed comparative

Table 1 Counts and measurements of “*Scorpaena*” *minima* and *S. prior* from the Badenian of Austria for comparison

	“ <i>Scorpaena</i> ” <i>minima</i>			<i>Scorpaena prior</i>
	RGF AJ 28	CNHM 257	HT CNHM 142	After Schultz (1993)
SL (mm)	14	18	17	209*
HL (mm)	5.5	7.5	7.0	96*
HL in % of SL	39.3	41.7	43.5	45.9*
Otolith	Yes	–	–	–
Vertebrae	10 + 14	10 + 14	10 + 14	11 + 13
D	XII + 6+	XIII + 5+	XII + 7	XII + 8–9
A	III + 4	III + 5	III + 5	III + 5–6
P	8+	10+	8+	16
V	I + 5 or 6	nm	I + 5	I + 5
C	15	15	15?	14 or 15
Preopercular spines	3 Spines preserved, 1st longest	No spines visible	4 Spines, 1st longest, 2nd–4th decreasing in length	3 Spines, middle spine shortest

* From photo of NHM 1988/140/49

analysis with a large set of Recent scorpaenid fishes and concluded that the fossil species can be confidently included within the range of the genus *Scorpaena* (see also Eschmeyer 1969). Based on the arguments discussed by Schultz (1993), “*Scorpaena*” *minima* seems to pertain to the same genus, but the otoliths are unusually compressed even when considering their juvenile nature and the consequences of allometric ontogeny. Moreover, otoliths of extant *Scorpaena* species show a steeply curved caudal tip, while in Sebastinae, for instance, it is more gently bent like in “*Scorpaena*” *minima*. Schultz (1993) reported 14 principal caudal-fin rays in *Scorpaena prior* (14 or 15 based on his photographs), while Kramberger (1882) reported 10–12 caudal-fin rays in *Scorpaena minima* (15 principal caudal-fin rays observed by us). Although consistent with each other, this low number is in conflict with extant species of *Scorpaena*, which have 17 principal caudal rays (e.g., Eschmeyer 1969). Because of the discrepancies in the number of caudal-fin rays and otolith morphology, we consider the generic position of “*Scorpaena*” *minima* as unresolved and leave it in this genus only provisionally.

Kramberger (1882) described a second scorpaenid species from the Sarmatian of Croatia, *Scorpaena pilari* from Radoboj. Although *Scorpaena pilari* has not been studied herein, Kramberger’s figure depicts a somewhat larger specimen with completely disintegrated head. We, therefore, consider *Scorpaena pilari* as a doubtful species.

Isolated scorpaenid otoliths are generally rare in the fossil record and they can be easily confused with otoliths of the members of the closely related family Serranidae (Imamura and Yabe 2002). In the Paratethys, a single scorpaenid otolith-based species has been recorded—*Pontinus? obrotchishtensis* (Strashimirov 1981)—from the

Konkian of Bulgaria and Kazakhstan (Bratishko et al. 2015). These are also fairly small otoliths of mostly less than 2 mm length, i.e., probably not deriving from fully adult specimens. With the currently limited data at hand, it would be premature to postulate any degree of relationship between these two species.

Order Labriformes *sensu* Kaufman and Liem 1982

Family Labridae Cuvier 1816

Genus *Symphodus* Rafinesque 1810

Symphodus woodwardi (Kramberger 1891)

(Figs. 3a–c, 4a–f; Tables 2, 3)

1891 *Labrus (Crenilabrus) woodwardi* Kramberger—Kramberger: pl. 2, Fig. 4

1969 *Bodianus woodwardi* Kramberger 1891—Anđelković 1969: pl. 6, Fig. 3

1989 *Bodianus woodwardi* Kramberger 1891—Anđelković 1989: pl. 18, Fig. 3

Material Two nearly complete articulated skeletons from Dolje, Croatia, Sarmatian s.s. (Volhynian). CNHM 127, holotype, 29.5 mm SL (Figs. 3a, 4d), and its counterpart, CNHM 128 (Figs. 3b, 4e); CNHM 277, 20 mm SL (Figs. 3c, 4a–c, f), containing a well-preserved otolith with the inner face exposed (Fig. 3c).

Diagnosis: A *Symphodus* species with head length larger than body depth; upper jaw with six to seven recurved, anteriorly conical, and subsequently labio-lingually compressed teeth; dentary with three to five large conical teeth followed by three or four smaller labio-lingually compressed teeth; 29–30 vertebrae, of which 11 abdominal; dorsal fin with 13 or 14 spines and nine or ten rays; anal fin with three spines and 11 or 12 rays; preopercle with about

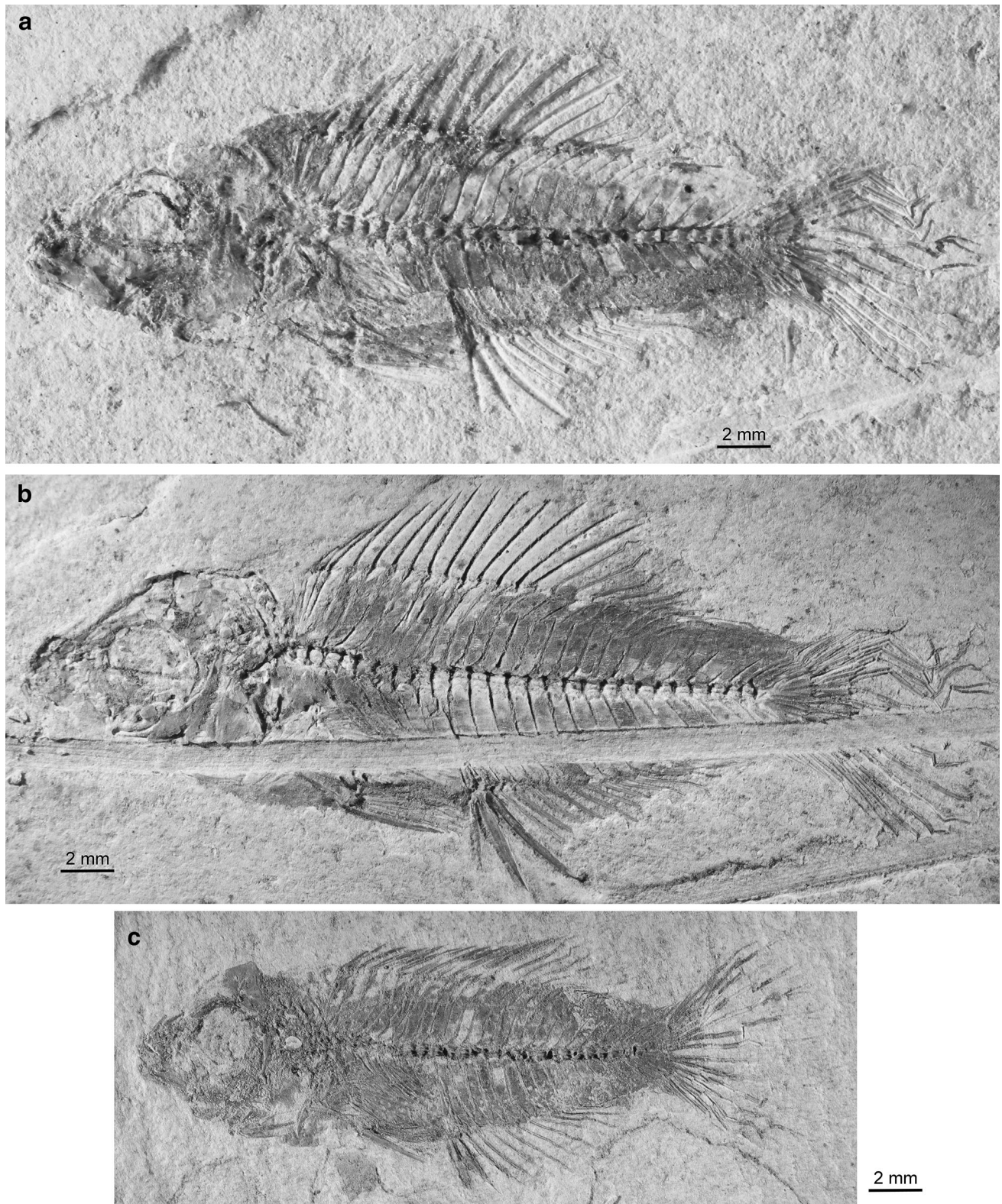


Fig. 3 *Symphodus woodwardi* Kramberger 1891, photographs of the articulated skeletons. **a** CNHM 127, holotype; **b** CNHM 128 (reversed), counterpart of holotype; **c** CNHM 277

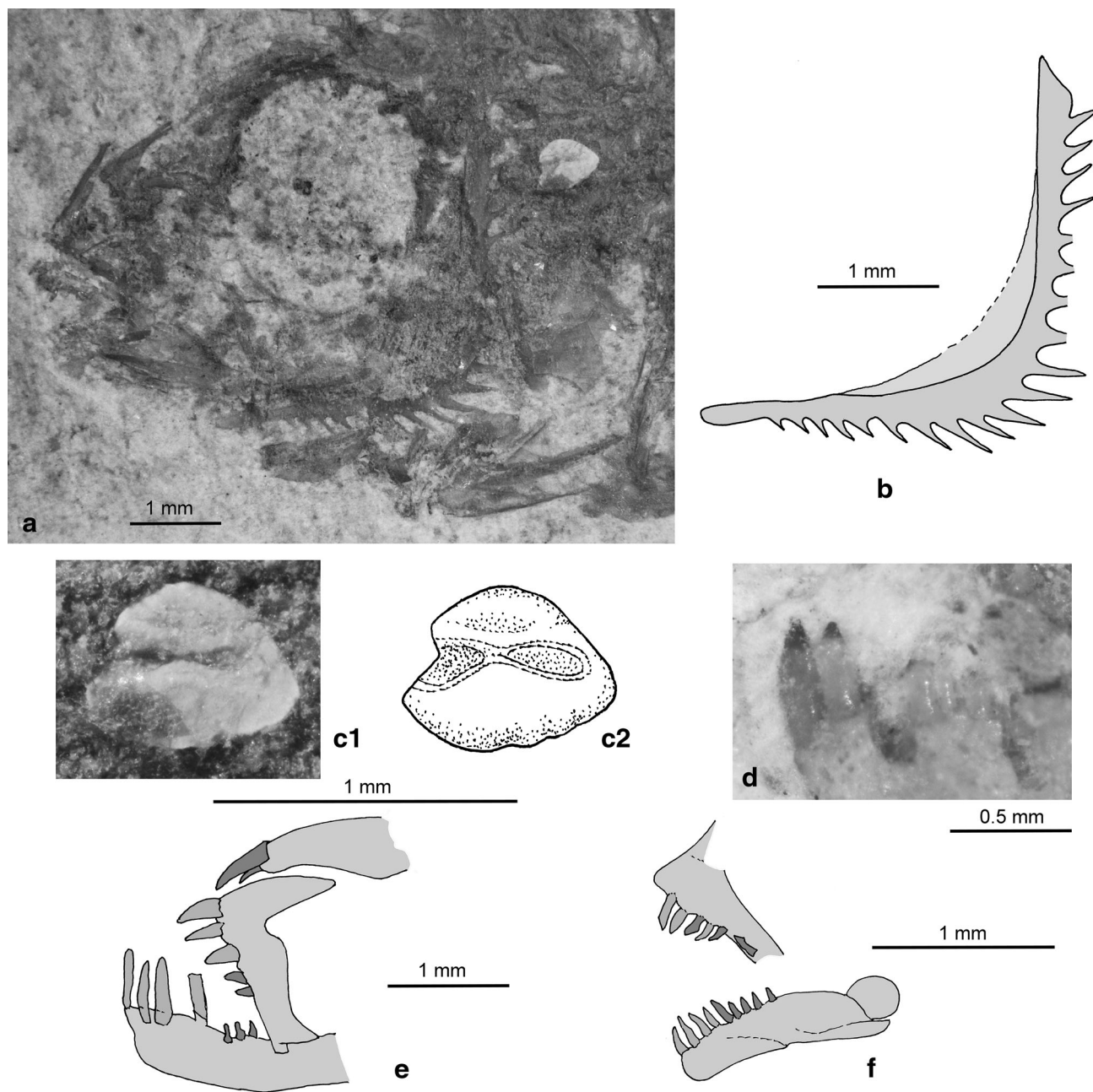


Fig. 4 *Symphodus woodwardi* Kramberger 1891. CNHM 277; **a** head showing the otolith in situ and the preopercle; **b** drawing of the preopercle; **c1–2** photograph and interpretative drawing of the otolith; **f** reconstruction of the oral jaws, *dark gray* are preserved teeth, *medium gray* teeth impressions;

d CNHM 127, photograph of the dentary; **e** CNHM 128 (reversed), reconstruction of the oral jaws, *dark gray* are preserved teeth, *medium gray* teeth impressions

20 long, widely spaced, pointed spines along its posterior and ventral edge; otolith ratio OL:OH = 1.25.

Description Counts and measurements are summarized in Table 2. The body is ovoid, moderately elongate, and laterally compressed.

Neurocranium and suspensorium. The neurocranium is extensively damaged and the individual bones are not recognizable except for the moderately high supraoccipital

crest. Likewise, the bones of the suspensorium are poorly preserved and difficult to interpreted.

Jaws. Both the specimens show partially preserved premaxilla and dentary bearing primarily recurved teeth arranged in a single row (Fig. 4d–f). The premaxilla bears six or seven teeth, slightly decreasing in size posteriorly. The dentary bears six to nine teeth, of which the first three to five are considerably larger than the following ones.

Table 2 Counts and measurements of *Symphodus woodwardi*, *S. salvus*, and *S. westneati* for comparison

	<i>Symphodus woodwardi</i>		<i>Symphodus salvus</i>	<i>Symphodus westneati</i>
	HT CNHM 127/128	CNHM 277	HT (Bannikov 1986)	HT (Carnevale 2015)
SL (mm)	29	20	60	54.5
HL (mm)	10	7	16.5	
Otolith	–	Good	Good	–
Vertebrae	11 + 18 or 19	11 + 18	12 + 18	13 + 18–19
Supraneurals	1	1	1	1
D	XIV + 9 or 10	XIII + 10	XIII + 9	XII + 12
A	III + 12	III + 11	III + 9–10	III + 10–12
P	14	7+	14	14
V	I + 5	I + 5	I + 5	I + 5
C	13	13	13	13
D/Vert	2	2	3	
PMX teeth	7	6 Blade-like	1 Very large anterior + 4–6 conical	4 Conical
Dent teeth	3 or 4 long anterior + 3 small blade-like	5 Long anterior + 4 small blade like	7 Conical	5–6 Conical
Number of preop spines	About 20 (combined)	20	40**	Small serration not reaching ends of limbs
Morphometrics in %SL				
Body depth	30	32.5	32–36	33.7
HL	32	35.5	27–29	31.9
HL:BD	HL > BD	HL > BD	HL < BD	HL < BD
Snouth length	10.5	11	11*	10.7
Upper jaw L	5	6	5.5*	4.6
Orbit diameter	11.5	10.5	7.5*	10.1
Caud pedunc D	15	16	14*	20.2
Predorsal L	40	41	34–36	32.9
Preanal L	58.5	60	62–65	62.1
Prepelvic L	44	45	43*	39.5
Base D	50	49	46–50	50.8
Base A	27.5	26	26*	20.6
1st D spine L	5.5	6	6.5*	11.1
Last D spine L	17	16	16*	17.9
1st A spine L	11	10.5	8*	
2nd A spine L	15.5		12*	17.1
3rd A spine L	18		13.5*	
Longest An ray		16	18	16.1
Caudal fin L	31	31	28*	
P fin L	15.5		19–20	14
P spine L	13	13.5	10.5*	13.4

* Measured from photograph in Bannikov (1986)

** Counted from drawing and photograph in Bannikov (1986)

Table 3 Synopsis of meristic values of fossil and extant species of the genus *Symphodus*. Data from Kramberger (1891), Arambourg (1927), Bannikov (1986), Quignard and Pras (1986), and Michel et al. (1987)

	Vertebrae	Dorsal-fin formula	Anal-fin formula	Upper jaw teeth	Lower jaw teeth	HL-DB relationship
<i>Symphodus bailloni</i>	31–33	XV + 9–11	III + 9–11	3–5	5–8	HL < BD
<i>Symphodus cinereus</i>	30–32	XII–XV + 8–11	III + 7–10	3–14	6–14	HL > BD
<i>Symphodus doederleini</i>	33	XIII–XVI + 9–11	III + 8–10	3–6	6–11	HL > BD
<i>Symphodus mediterraneus</i>	30–32	XV–XVIII + 8–11	III + 8–12	1–5	3–7	HL = BD
<i>Symphodus melanocercus</i>	32	XV–XVII + 6–10	III + 8–11	3–7	6–9	HL < BD
<i>Symphodus melops</i>	32–34	XIV–XVII + 8–10	III + 8–11	4–9	5–11	HL > BD
<i>Symphodus ocellatus</i>	30–32	XIII–XV + 8–11	III + 8–11	4–14	8–26	HL < BD
<i>Symphodus pellegrini</i>	33	XV + 10	III + 9	?	?	HL > BD
<i>Symphodus roissali</i>	29–32	XIV–XVI + 8–10	III + 10	4–10	5–13	HL < BD
<i>Symphodus rostratus</i>	30–33	XIV–XVI + 9–12	III + 9–11	11–21	16–26	HL > BD
<i>Symphodus salvus</i>	30	XIII + 9	III + 10–12	5–7	About 7	HL < BD
<i>Symphodus tinca</i>	32–34	XIV–XVII + 9–12	III + 8–12	3–12	5–24	HL > BD
<i>Symphodus westneati</i>	31–32	XIII + 12	III + 8	4	5–6	HL < BD
<i>Symphodus woodwardi</i>	29–30	XIII–XIV + 9–10	III + 11–12	6–7	6–9	HL < BD

Opercular series. The preopercle is well preserved in CNHM 277 (Fig. 4a, b) and partially exposed in CNHM 127/128. The preopercle shows long vertical and horizontal limbs, bearing together about 20 long and rather widely spaced pointed spines which are more developed at the angle at the convergence of the two limbs; the shortest spines are those emerging along the anterior portion of the ventral margin of the horizontal limb. The other bones of the opercular series are inadequately preserved.

Axial skeleton. The vertebral column is nearly straight and contains 29 or 30 (11 + 18–19) vertebrae. The first two to three abdominal centra are higher than long, while all the subsequent centra are subquadrangular and about as long as high, becoming slightly longer than high in the caudal portion of the body. The neural spines are elongate and slightly curved throughout. Narrow and short parapophyses are recognizable on the posterior three abdominal vertebrae; the length of the posterior most parapophysis is about one-fourth the length of the first haemal spine. The caudal vertebrae bear long haemal spines that are increasingly inclined backwards. Long and curved pleural ribs articulate with the vertebrae three to nine.

Caudal skeleton. The caudal skeleton is well preserved in CMNH 277. The hypural fan consists of fused hypurals 1–2 and 3–4; a short and narrow fifth hypural is not clearly recognizable in the specimen. There are two long and slender epurals, of which the first is the longest. The parhypural is always poorly preserved. There are 13 principal caudal-fin rays and five dorsal and ventral procurrent rays.

Median fins. There is a thin and obliquely oriented supra-neural that inserts just in front of the first dorsal-fin

pterygiophore (Fig. 3b). The dorsal fin is long and high, originating just behind the first vertebra and ending posteriorly at the level of the 21st or 22nd vertebra. It consists of 13–14 pungent spines plus nine or ten rays. The anal fin consists of three robust spines, of which the first is distinctly shorter than the following two, plus 11, or 12 rays. The posterior end of the anal fin is located just below the vertebra 18 or 19.

Paired fins and girdles. The pectoral girdle is always poorly preserved. At least 14 pectoral-fin rays can be clearly recognized in the specimen CNHM 277, and at least seven are exposed in the specimen CNHM 128. The pelvic fin contains one robust and long spine plus five rays.

Otolith (Fig. 4c). The otolith bears the typical appearance of labrid otoliths with a subtriangular outline, a high dorsal rim, and a sulcus with nearly equally long, widened, and deepened ostial and caudal colliculi joint by a narrow collum. The otolith exposed in CNHM 277 is small, about 0.7 mm long, and has a ratio OL:OH of 1.25. The dorsal rim is high, with a distinct, but rounded mediodorsal angle and a faint, obtuse postdorsal angle. The ventral rim is shallow, regularly curving, and faintly undulating in its rear part. The rostrum is short, blunt, and inferior, about 15% of the otolith length. The antirostrum is short and rounded; the excisura is very wide and angular, but not deep. The posterior tip is almost symmetrically developed to the rostrum, without incision at the caudal tip. The inner face is slightly convex with a slightly suprmedian sulcus. Its dorsal margin is nearly straight, with a small indentation at the collum and a widely and strongly incised ventral margin at the level of the collum. The ostium is slightly shorter than the cauda (OsL:CaL = 0.8), but distinctly wider ventrally. The ostial colliculum is deepened. The cauda has the

typical labrid drop-like shape with a rounded, widened tip nearly reaching the posterior rim of the otolith. It is slightly inclined and the colliculum is distinctly deepened. The collum is narrow and shallow. There is a small, ventrally distinctly marked dorsal depression, but no indication of a ventral furrow. We consider this otolith as diagnostically valid despite its small size. There are no isolated labrid otoliths yet recorded from coeval strata of the Paratethys.

Discussion There are three *Symphodus* species recorded from the Miocene of the Paratethys—*S. woodwardi* (Kramberger 1891) from the Sarmatian of the Central Paratethys, *S. salvus* Bannikov 1986 from the Sarmatian of the Eastern Paratethys, and *S. westneati* Carnevale 2015 from the Badenian of the Central Paratethys. For rationale of placement of these taxa within the genus *Symphodus*, see Carnevale (2015). For comparison of meristic values of fossil and extant species of the genus *Symphodus* and distinction of *S. woodwardi* from recent species, see Table 3. *Symphodus westneati* clearly differs from the two Sarmatian species in having a higher number of abdominal vertebrae (13 vs 11 in *S. woodwardi* and 12 in *S. salvus*), less developed serration on the preopercle (vs long spines along the entire length of the preopercle), shorter anal-fin base (20.6% of SL vs 26–28% of SL), and a more elongate first dorsal-fin spine (11.1% of SL vs 5.5–8% of SL). The two Sarmatian species are much more similar. We have deduced some morphometric values from Bannikov's (1986) detailed drawing and photograph and conclude that *Symphodus woodwardi* differs from *S. salvus* in having 11 abdominal vertebrae (vs 12), 11–12 anal-fin rays (vs 9–10), predominantly recurved vs conical teeth, head length larger than body depth (vs body depth larger than head length), about 20 spines along preopercular margin (vs about 40 spines), and otolith with a short rostrum and a low ratio OL:OH = 1.25 (vs long rostrum and OL:OH = 1.85).

The taxonomic placement of the Messinian fossil from Raz-el-Ain, Algeria, referred by Arambourg (1927) to *Symphodus woodwardi* is rather problematic. The specimen is only moderately preserved and part of the skeleton is badly preserved. Even if certain meristic features are identical to those observed in the Sarmatian material of Central Paratethys documented herein, the Messinian specimen exhibits a lower number of anal-fin rays (10 vs 11–12) and head length equal to body depth (vs head length larger than body depth). We prefer to postpone the definition of the affinity of the Messinian specimen until more complete and better preserved material would be available.

Order Gobiesociformes Gill 1872
 Family Gobiesocidae Bleeker 1859
 Genus *Apletodon* Briggs 1955

Apletodon? sp.
 (Figs. 5a–c, 6a–h; Table 4)

Material Three partially complete articulated skeletons from Dolje, Croatia, Sarmatian s.s. (Volhynian), CNHM 273, 25 mm SL (Figs. 5a, 6a, c), CNHM 276 13 mm SL (Figs. 5c, 6d) and CNHM 152, 13 mm SL (Figs. 5b, 6b); all three specimens exhibit otoliths in situ (Fig. 6e–h).

Description Small, slender fishes with head length reaching about one-third of SL. The body is slender, laterally expanded anteriorly, and compressed posteriorly. Counts and measurements are reported in Table 4.

Neurocranium, jaws, and suspensorium. The head is depressed and wide. The bones of the neurocranium and suspensorium are inadequately preserved and difficult to recognize. The right premaxilla is preserved in the specimen CNHM 273 and exposed in medial view (Fig. 6a); it shows a massive, albeit broken, and partially displaced ascending process and what appears to be a triangular postmaxillary process; the actual morphology of this structure, however, is difficult to conclusively define due to its fragmentation. Teeth are not preserved, but a somewhat irregular row of small sockets can be recognized along the oral margin of the premaxilla.

Opercular series. The opercle and subopercle are exposed in the specimen CNHM 276 (Fig. 6d); there are no spines emerging from these bones and their overall morphology is consistent with that of extant clingfishes (e.g., Briggs 1955; Springer and Fraser 1976; Hardy 1983; Hayashi et al. 1986).

Axial skeleton. The axial skeleton is partially preserved in all the available specimens. The larger specimen, CNHM 273, lacks the caudal fin and the hypural plate is incomplete, whereas the anterior portion of the vertebral column of the two smaller specimens is difficult to interpret. Overall, the vertebral column seems to comprise 31–32 (12–13 + 19–20) vertebrae, including the urostylar centrum. The anterior abdominal centra are subrectangular, longer than high, becoming roughly quadrangular at the mid length of the fish and distinctly higher than long in the caudal region. The neural spines of the anterior six to eight abdominal vertebrae are short and more inclined than those of the following vertebrae. The anterior four or five caudal vertebrae bear haemal spines of increasing size not associated with anal-fin pterygiophores. Thin and slender pleural ribs begin on the third abdominal vertebra extending posteriorly to the last abdominal element. The caudal vertebrae show long haemal spines that are increasingly inclined backwards.

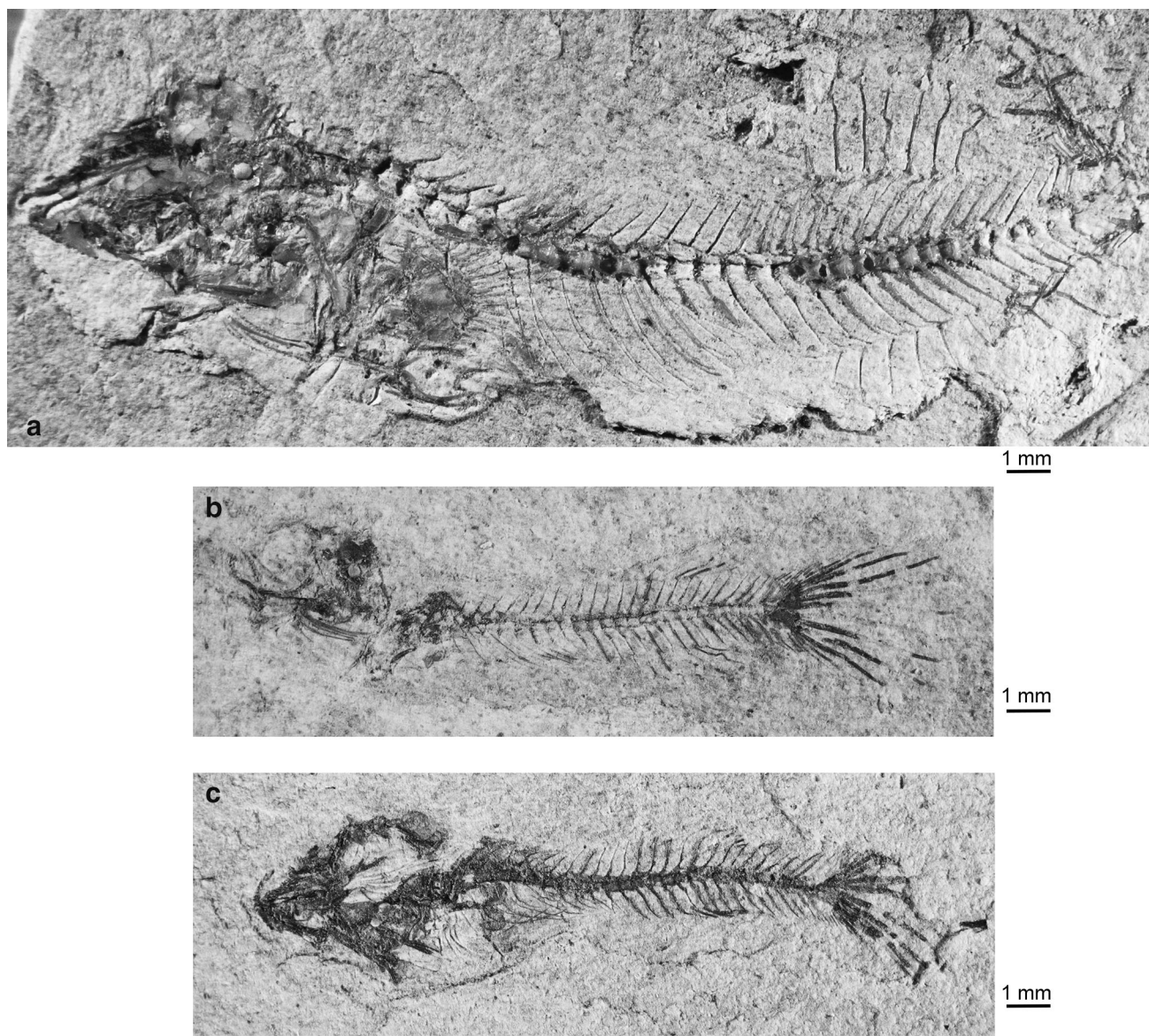
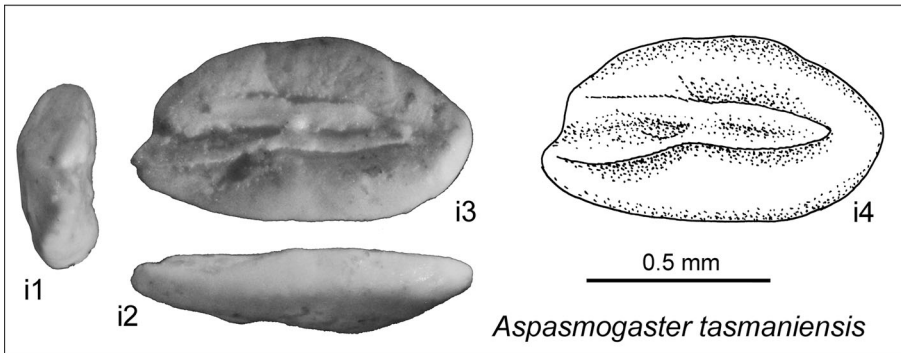
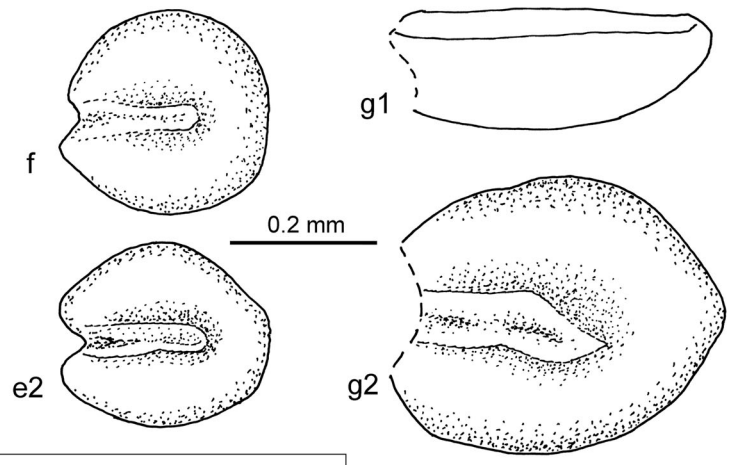
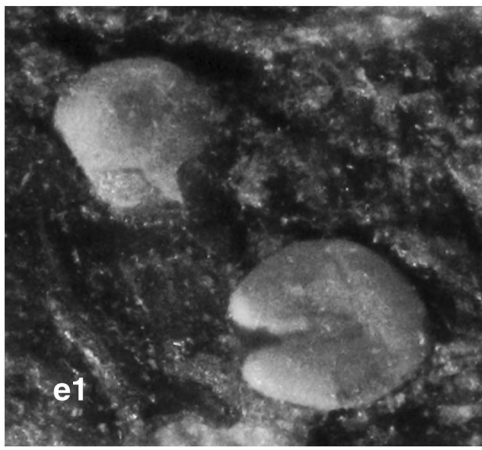
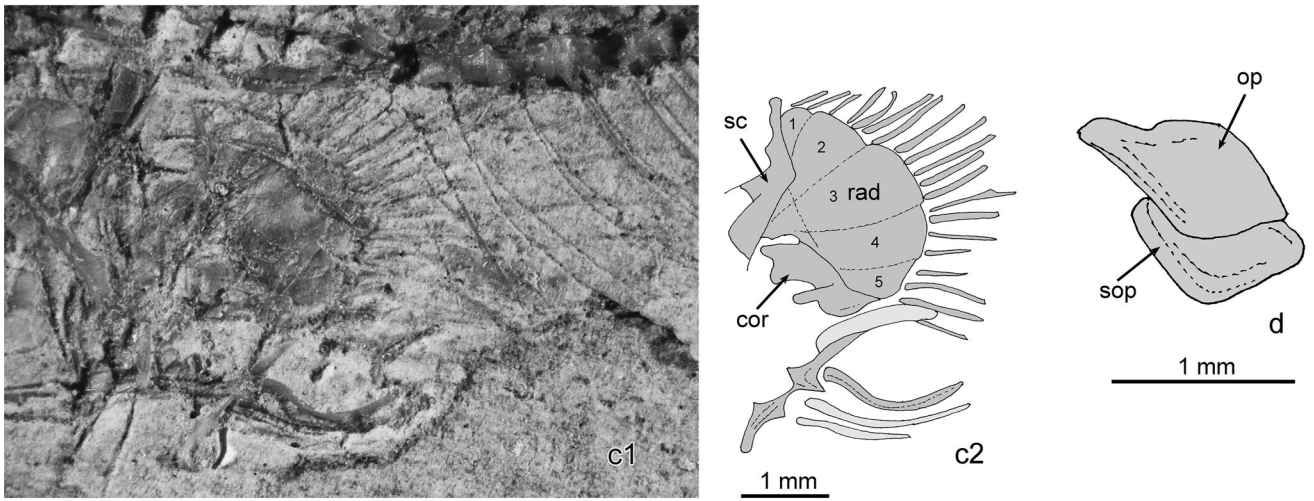
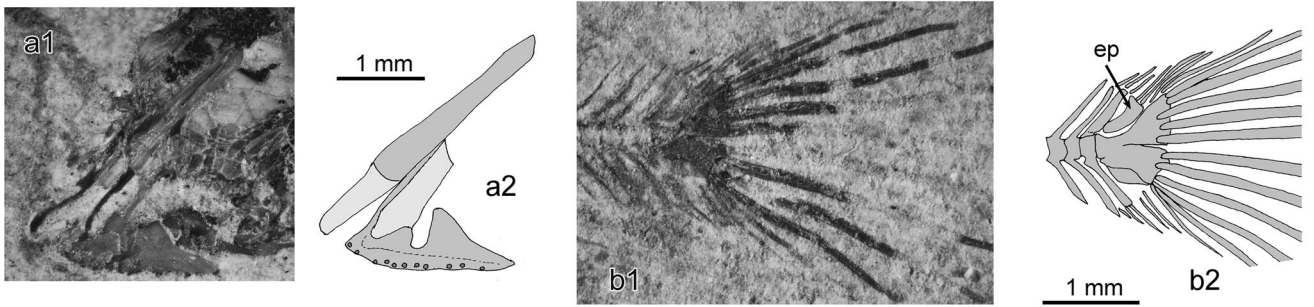


Fig. 5 *Apletodon?* sp., photographs of the articulated skeletons. **a** CNHM 273 (reversed); **b** CNHM 152 (reversed); **c** CNHM 276

Caudal skeleton. The caudal skeleton is moderately well preserved in the specimen CNHM 152 (Fig. 6b). The hypural plate exhibits a median diastema that partially separates the epaxial and hypaxial lobes. The hypaxial lobe of the hypural fan bears a relatively large laminar flange along its anteroventral margin. There is a single, broad epural. The parhypural is not recognizable. Two ventral procurent caudal-fin rays appear to be detached from the caudal skeleton, suggesting that a cartilaginous parhypural was originally present. Altogether, the caudal skeleton is fully consistent with that of extant gobiesocids (e.g., Springer and Fraser 1976; Hayashi et al. 1986; Konstantinidis and Conway 2010). There are ten principal caudal-fin rays and six or seven dorsal and ventral procurent rays.

Median fins. Like in extant clingfishes, the dorsal and anal fins are short and located posteriorly on the body. The dorsal fin contains six to seven rays and originates above the 15th or 16th vertebra terminating just above the vertebrae 23–25. The anal fin contains seven or eight, or, possibly, nine rays, and inserts just under the vertebrae 15–17, i.e., below the first or second dorsal-fin ray and terminates one or two vertebrae behind the dorsal fin. Consequently, there is a well-developed caudal peduncle with a length corresponding to the space occupied by up to six vertebrae.

Paired fins and girdles. The pectoral fin and girdle is partially exposed in the specimen CNHM 273 (Fig. 6c). The pectoral-fin radials are remarkably expanded, and



Aspasmogaster tasmaniensis

◀**Fig. 6** *Apletodon?* sp. **a, c, g, h** CNHM 273 (reversed); **a1–2** Photograph and reconstruction of the premaxilla, light gray represent bone impressions; **c1–2** photograph and reconstruction of the pectoral fin and partially preserved pelvic girdle, light gray represent bone impressions; **g1–2** interpretative drawing of the otolith; **g1** ventral view; **g2** inner face; **h** inner face of the asteriscus; **b, f** CNHM 152 (reversed); **b1–2** photograph and reconstruction of the caudal skeleton; **f** drawing of the otolith; **d, e** CNHM 276; **d** opercle and subopercle; **e1–2** photograph and interpretative drawing of the otolith; **i** otolith of *Aspasmogaster tasmaniensis* (Günther 1861), coll. Schwarzahns (leg. WAM), Recent off SW Australia; **i1–2** photographs; **i1** anterior view; **i2** ventral view; **i3** inner face; **i4** interpretative drawing

supported by short and broad scapula and coracoid. About 20 thin rays articulate with the pectoral-fin radials. The preserved part of the rays is reduced, but based on their impression, it is possible to evidence that these were quite long originally, reaching about 17% of SL. The pelvic fin and the highly diagnostic skeletal elements of the adhesive disk are not preserved in any of the available specimens, except for a few fragments in CNHM 273, which, unfortunately do not allow any detailed analysis.

Otolith (Fig. 6e–g). The preserved otoliths in situ are very small, about 0.5 mm in the specimen CNHM 273 and about 0.3 mm long in the other two specimens. They are nearly circular in outline with a ratio OL:OH of 1.05–1.15; however, the largest specimen, which is anteriorly damaged, must have had a ratio of about 1.25, indicating a certain degree of allometric ontogenetic growth. All the rims are smooth and gently curving without prominent angles. The dorsal rim is slightly more convex than the ventral rim. The anterior rim is marked by a short rostrum and a similarly long antirostrum with a moderately

developed excisura in between. The inner face is flat, even slightly concave towards its center. The narrow sulcus is elevated above the inner face and bound dorsally, ventrally, and posteriorly by a sharp edge towards the depressed inner face, a character diagnostic for gobiesocid otoliths. The sulcus is narrow throughout its length, and the ostium and cauda can be distinguished from each other only by the distinctly deepened colliculi. The ostium opens anteriorly with its colliculum contacting the excisura; the ratio OsL:CaL is 1.5–1.6. The otolith rims are thick and the outer face is convex and smooth, resulting in a ratio OH:OT of 2.3. In two cases (CNHM 273 and 276), the asterisci are also preserved, and in CNHM 273, it could be extracted and cleared for investigation. It is almost as large as the sagitta described above, a condition which is rarely observed in teleost, and almost circular in outline with a slight, excisura-like notch at the posterior rim and a circular crista medial (terminology see Assis 2003).

Discussion These three specimens represent the first fossil members of the family Gobiesocidae in the record, both as skeletal remains or otoliths. There are many highly apomorphic traits that clearly identify them as gobiesocids, including the position of the dorsal and anal fins, the caudal skeleton, the morphology of the pectoral-fin base, and the otolith (Briggs 1955; Springer and Fraser 1976; Hayashi et al. 1986). Unfortunately, the inadequate preservation of the highly diagnostic pelvic fin and adhesive disk prevents any detailed taxonomic identification at the species level. Based on the common size of extant gobiesocids, it is possible to suggest that the largest specimen from Dolje at a size of 25 mm SL possibly represents a fully mature adult individual.

Table 4 Counts and measurements of *Apletodon?* sp

	<i>Apletodon?</i> sp.		
	CNHM 273	CNHM 276	CNHM 152
SL (mm)	25	13	13
HL (mm)	8	4.5	4
Otolith	Moderate	Good	Good
Vertebrae	14 + 18	11–12* + 17	11+* + 18
D	7	6	6
A	8 or 9	5+	7
P	20	–	–
V	3+	–	–
C		10	10
D/Vert	16	15	15–16
Vert/A	17	16	15–16
Last D/Vert			
Vert/last A			
Remarks	Broad, round radial plate	Head severed	Head severed

* Head severed from trunk; precaudal vertebrae may be incomplete

Otoliths of extant gobiesocids have rarely been figured [(Chaine 1958; Lombarte et al. 2006; Nolf et al. 2009 (a re-edition of Chaine and Duvergier's works in one compendium)]. We have, therefore, figured here a further Recent gobiesocid otolith for comparison, *Aspasmogaster tasmaniensis* (Günther 1861) (Fig. 6i). The data so far known show that gobiesocid otoliths add a further well-recognizable apomorphy for the diagnosis of the family, the elevated and sharply bound sulcus. A similar structure also characterizes certain flatfish otoliths with a wide circumsulcal depression. However, these two cases cannot be regarded as homologous, since the elevation of the sulcal area in flatfish otoliths encompasses part of the adjacent portions of the inner face, while this is clearly not the case in gobiesocid otoliths. Otoliths are so far known of only four clingfish genera: *Apletodon*, *Aspasmogaster*, *Diplecogaster*, and *Lepadogaster*. Those of *Aspasmogaster* and *Lepadogaster* differ by their more elongate shape, while those of *Apletodon* and *Diplecogaster* are more compressed (Nolf et al. 2009), similar to the fossils documented herein.

The extant North-eastern Atlantic and Mediterranean members of the Gobiesocidae belong to the subfamily Lepadogastrinae, comprising the genera *Apletodon*, *Diplecogaster*, *Gouania*, *Lepadogaster*, *Lecanogaster*, and *Opeatogenys* (see Conway et al. 2015). The meristics of the specimens from Dolje (e.g., 32 vertebrae, 10 principal caudal-fin rays and dorsal and anal fins separated from the caudal fin and with 6–9 rays each) are consistent with *Apletodon* and *Diplecogaster* (Briggs 1955, 1957, 1986). Following Hofrichter and Patzner (1997) and Fricke et al. (2010), these two closely related genera can be distinguished by certain characters of which two can be expected to be preserved in fossils, including: the presence of caniniform and incisiform teeth in *Apletodon* (only caniniform teeth in *Diplecogaster*), and the first anal-fin ray usually situated below the first and (or) second dorsal-fin rays in *Apletodon* (usually below the third dorsal-fin ray in *Diplecogaster*). Unfortunately, there is no evidence of teeth in the available specimens. The dorsal and anal fins, however, are well preserved, and in all the cases, the first anal-fin ray is located below the first or second dorsal-fin ray. An additional trait is provided by the otoliths. The figures of Chaine (1958) and Nolf et al. (2009) show little detail of the inner face of the otoliths, but sufficient detail of the outline. Otoliths of *Apletodon microcephalus* differ from *Diplecogaster bimaculata* in being more compressed (OL:OH = 1.2–1.3 vs 1.4) and in showing a rectangular to rounded outline (vs subtriangular with a flat ventral and a high dorsal rim). We conclude that the position of the anal fin is consistent with that of *Apletodon*, as well as the otolith outline. Nevertheless, the Sarmatian specimens are only tentatively placed in *Apletodon* because of the lack of

preserved teeth and of the highly diagnostic pelvic fin and adhesive disk.

Conclusions

In this section of our studies about Sarmatian fishes from the Paratethys, we describe taxa that are not reported as isolated otoliths from coeval strata, with the possible exception of “*Scorpaena*” *minima*. This is distinctly different from the subjects of all other papers in this series, in which we were able to correlate otoliths found in situ to isolated otoliths either at the species level or at least at the genus level. However, this observation supports the previous assumptions that otoliths and skeletons from a given region and time interval may not strictly duplicate the number of taxa but also complement each other to some extent (Nolf 1985). The two most interesting taxa examined herein and not reported in the isolated otolith record are the labrid and the gobiesocid and both deserve some special consideration.

Wrasses (labrids) are a large family of shallow water fishes many of which live on coral reefs in the tropics and along the algal and seaweed-rich rocky shores in the temperate seas (Kaufman and Liem 1982; Quignard and Pras 1986). Because of these preferences, they are not particularly common in the fossil record (see Bannikov and Carnevale 2010; Carnevale 2015). Articulated skeletons occur regularly in paleobiotopes associated with reefs or in the vicinity of rocky shores, while such sedimentary environments are not favourable for the preservation of otoliths. The most diverse Paratethyan labrid assemblage has been recorded from the Badenian of St. Margarethen in Austria (Carnevale 2015) and includes four different taxa; the Sarmatian record of these fishes so far has yielded two uncommon species, *Symphodus salvus* from Moldova, in the Eastern Paratethys, and *Symphodus woodwardi* from the Central Paratethys. Labrid otoliths are easy to recognize as discussed above, but have been very rarely observed in the fossil record, and have not been observed yet in Paratethyan deposits.

Clingfishes (gobiesocids) are small fishes primarily inhabiting rocky shores close to the surf zone, large pebbles, and boulder fields, representing some of the very environments of the marine biosphere in which the fossilization is least favourable. A few euryoecious taxa, however, also live on sandy or muddy bottoms, as well as on coralline grounds (see Hofrichter and Patzner 2000). It is not surprising that there is no skeletal or otolith record so far of this group of fishes, even though both are highly diagnostic in appearance. Otoliths are also extremely small and would only be found when fractions smaller than the 0.5 mm mesh size usually applied in the search for otoliths

would be used. In any case, the occurrence of three articulated skeletons of gobiesocids in the diatomite of Dolje is, indeed, a very surprising and spectacular outcome. We assume that paleobiotopes more suitable for clingfishes may have been present in the surroundings of the depositional environment.

Acknowledgements We are very thankful for support in respect to comparative recent material to J. Nielsen and P. Møller (Copenhagen) and A. Allen and S. Morrison (Perth). The research of GC was supported by grants (ex-60% 2015 and 2016) from the Università degli Studi di Torino. We thank G. Marramà (Vienna) and an anonymous reviewer for the constructive contributions during the peer review of the manuscript.

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