



Piacenzian otolith assemblages from northern Italy (Rio Merli section, Emilia Romagna)

Angela GIRONÈ

A. Girone, Dipartimento di Geologia e Geofisica, Università degli Studi di Bari, via E. Orabona 4, I-70125 Bari, Italy; girone@geo.uniba.it

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ABSTRACT - The Middle Pliocene sediments from the Rio Merli section (Ravenna, Emilia Romagna-Northern Italy) provided otoliths representing at least 39 teleost taxa. The otolith assemblages recognised at various stratigraphic intervals of the section were studied in their taxonomic, palaeoecological, and stratigraphical features. The studied material furnishes additional taxonomic comments for taxa subject to discussion. The analysis of these assemblages in their composition and structure allows comparison of palaeoecological significance of the Pliocene otolith assemblages with regard to well-known Pleistocene and Recent assemblages. The available palaeoecological data based on molluscan assemblages allow further comparison of the palaeoecological changes of the otolith assemblages. The teleostean fauna from Rio Merli includes species reported previously in the Pliocene and Pleistocene deposits of the Mediterranean area, but about 40% are represented by species unknown for the Middle Pliocene, and in several cases, they registered the first appearance of taxa, mainly with temperate and subpolar-temperate affinities, in this basin. The studied Middle Pliocene assemblages clearly show transitional biogeographic affinities with the Zanclean and the Upper Pliocene and Pleistocene fauna of the Mediterranean realm. The compositional modifications seem to be closely related to gradual climate changes that took place during this unit time.

RIASSUNTO - [Associazioni ad otoliti del Piacenziano della sezione di Rio Merli (Emilia Romagna, Italia settentrionale)] - La sezione di Rio Merli, costituita da peliti omogenee e scarsamente stratificate, affiora in comune di Brisighella (Ravenna, Emilia Romagna) ed è riferibile al Pliocene Medio (Piacenziano). L'analisi di undici bulk samples raccolti lungo la sezione ha permesso di riconoscere 39 taxa di teleostei e di fornire un ulteriore contributo per meglio definire la composizione e la distribuzione stratigrafica della fauna a teleostei durante il Pliocene Medio. L'analisi, non solo della composizione tassonomica, ma anche di alcuni aspetti composizionali e strutturali della componente bentonica e bentonectonica di tali associazioni, permette di definire il significato paleoecologico delle associazioni ad otoliti nel Pliocene Medio e di confrontarle con quelle ben note del Pleistocene e del Mediterraneo attuale. La composizione e struttura delle associazioni bentoniche e bentonectoniche, riconosciute nei primissimi metri della sezione, sono indicative di un ambiente di sedimentazione compreso tra l'epibatiale superiore e il circolitorale profondo. Verso l'alto, le associazioni ad otoliti non mostrano una netta variazione paleobatimetrica poiché, sebbene si osservi un incremento della componente a carattere batiale, rispetto a quella a più larga distribuzione circolitorale/batiale, la componente circolitorale non mostra variazioni di dominanza. I dati ottenuti dallo studio delle associazioni ad otoliti ben si confrontano con quelli, già disponibili in letteratura, ottenuti dall'analisi paleoecologica delle associazioni ad invertebrati bentonici, sebbene queste sembrano indicare una più chiara variazione paleobatimetrica nell'intervallo superiore della sezione.

La fauna a teleostei riconosciuta lungo la sezione di Rio Merli, sebbene includa specie già conosciute in depositi del Pliocene (inferiore e superiore) e del Pleistocene del Mediterraneo, è rappresentata per ben il 41% da taxa ancora sconosciuti nel Pliocene Medio ed in alcuni casi questi dati registrano la prima comparsa di taxa, in particolare di alcuni ad affinità temperata e subpolare-temperata, nel bacino del Mediterraneo. Le associazioni ad otoliti esaminati nel presente lavoro mostrano caratteristiche biogeografiche di transizione tra quelle della fauna del Zancleano e quelle del Pliocene superiore e Pleistocene del Mediterraneo. Tali variazioni composizionali sembrano essere in stretta correlazione con i cambiamenti climatici registrati durante questo intervallo di tempo.

INTRODUCTION

During recent years, studies on otolith assemblages have improved the stratigraphic, palaeoecological and palaeobiogeographic knowledge about the Pliocene and Pleistocene Mediterranean teleost faunas. Overviews of the otolith-based reconstruction of the Pliocene fauna have been published by Nolf et al. (1998) mainly regarding the Lower Pliocene fish fauna. More recently, the study of otolith assemblages from the Vrica section (southern Italy) (Girone et al., 2006) improved the knowledge about the Late Pliocene fish fauna; the previous data on fish fauna from the Vrica section was concerned mainly with the osteological material from the sapropel layers (Landini & Menesini, 1978) that were essentially composed of pelagic taxa. Between the well-documented Early Pliocene (Zanclean) and, partially, Late Pliocene (Gelasian) time units, there is

still a marked gap in the available data comprising the Middle Pliocene (Piacenzian), an interval during which important climatologically changes took place in the Mediterranean realm.

From this point of view, the otolith assemblages from the Rio Merli section, Middle Pliocene in age, have been analysed to improve the knowledge about the teleostean fauna of this poorly known time-unit. In particular, they provide new data concerning the stratigraphical distribution and palaeobiogeographic meaning of particular taxa. Moreover, the analysis of these assemblages in their composition and structure, in particular the benthic and benthopelagic assemblages, allows determination of the palaeoecological significance of the Pliocene otolith assemblages with regard to Pleistocene and Recent assemblages. The available palaeoecological data based on the invertebrate macrofauna associations allow comparison of the otolith

data and to test the sensitiveness of the otolith assemblages as palaeoecological indicators during the Pliocene.

MATERIALS AND METHODS

The Rio Merli section (X: 724.329; Y: 4899.989), about 30 m thick, is located in the Brisighella area (Ravenna, Emilia Romagna) (Fig. 1) and belong to the "Argille azzurre di Riolo Terme Fm" (Ceregato, 2002). It consists of poorly stratified and homogeneous clays becoming well laminated at the top (Fig. 1). According to biostratigraphical analysis on the foraminifera assemblages, the section is referable to the Middle Pliocene (*Globorotalia bononiensis* biozone) (Ceregato, 2002).

In the present work, eleven bulk samples previously collected for the study of invertebrate macrofauna (Ceregato, 2002) have been analysed for otoliths. The analysis identified ten otolith assemblages useful to interpret the faunal composition and to define the stratigraphic distribution of particular taxa. Sample 11, from the top of the section consisting of a laminated layer and was poor in otoliths.

The coarser fraction of the bulk samples (>500 µm mesh) was sorted for otoliths with the purpose of quantitative analyses. To provide a standardized view of the relative abundance of each taxon, percentage values are used. Although many of those percentages are not statistically significant (see total numbers of specimens), they at least provide a standardization to compare trends that differentiate the successive samples.

The abundance and dominance of each taxon for each sample were calculated following the criterion proposed for the bivalve group by Di Geronimo & Robba (1976); the right and left sagittae of each taxon per sample are counted separately. The abundance is given by the recognised larger number of sagittae (left or right) plus the half of the number of the smaller group of sagittae. If the obtained number is a decimal number, it is rounded up. The calculations were carried out separately for the pelagic and benthic-benthopelagic groups (Tab. 1).

The palaeoecological analysis has been carried out on the benthic and benthopelagic assemblages that, as demonstrated in several applications on shelf and deep-sea Pleistocene assemblages (Girone, 2003, 2005), may provide more precise palaeoenvironmental reconstruction with respect to palaeobathymetric method based on entire assemblages (pelagic and benthic-benthopelagic assemblages) proposed by Nolf & Brzobohaty (1994), mainly for the Pliocene and Pleistocene assemblages very rich in still living species. In this approach, among all the various factors affecting the distribution of fishes, depth is the only one taken into account and attributes related to the associations (abundance, dominance and structure of fish populations) are not considered. The analysis of the structure of fish populations, beside taxonomic composition, is a good tool for the interpretation of deep benthic and benthopelagic associations. In

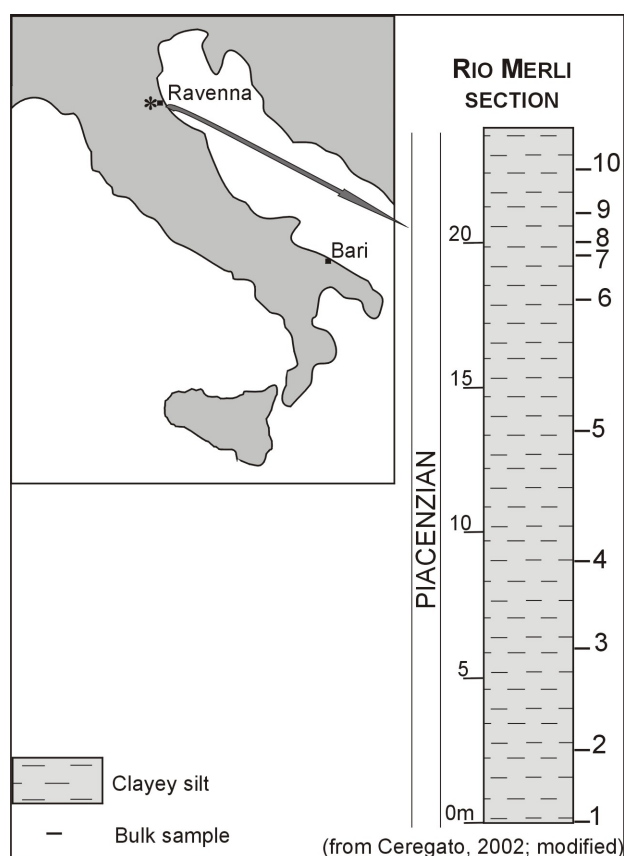


Fig. 1 - Location of the study area and the Rio Merli section (from Ceregato, 2002, modified).

particular, the distribution of fishes size and the bigger-deeper phenomenon are significant aspects in the palaeoenvironmental analysis. For example, the macrourid fishes, characteristic of different depth in the bathyal setting at adult stage, may occur in shallower assemblages at juvenile stage. Moreover, fishes may change life habit during the growth: some of them, pelagic in juvenile stage, show benthopelagic habit, in the adult stage, in well defined environmental settings, and therefore, they have different ecological meaning (Di Geronimo et al., 2003; Girone, 2003, 2005).

The previous palaeoecological analysis conducted by means of molluscan associations suggest a circalittoral-bathyal environment in the lowermost part of the section evolving to a deep bathyal environment (Ceregato, 2002; Ceregato et al., 2005). The same author interpreted the laminated layer, at the top of the section, as an anoxic layer (Ceregato, 2002).

COMPOSITION AND PALAEOECOLOGY

The otoliths provided by the eleven bulk samples represent at least 39 taxa of teleostean fishes. A list of all otolith-based species from the Middle Pliocene of Rio Merli with their occurrence in the samples is given in Tab. 1. The otoliths are mostly well preserved, and the features are quite distinct and allow reference to species or genus level. Some otoliths could only been

List of the taxa from Rio Merli section		SAMPLES										
taxa in bold: living taxa disappeared from the Mediterranean *: extinct taxa		1	2	3	4	5	6	7	8	9	10	11
PELAGIC TAXA												
CLUPEIDAE	Clupeidae ind.				1,3	1,1						
ARGENTINIDAE	<i>Argentina sphyraena</i> (Linnaeus, 1758)	1,96		1,6					2,6			
STERNOPTYCHIDAE	<i>Maurolicus muelleri</i> (Gmelin, 1789)	3,9	8,7	3,3	6,5	4,4	10,8		7,7		30	54
	<i>Polyipnus</i> sp. (3)		8,7	4,9	10	8,9	5,4		2,6			
PHOTICHTHYDAE	<i>Vinciguerrria poweriae</i> (Cocco, 1838)		2,2		6,5		2,7		2,6	23		
	<i>Vinciguerrria</i> sp.			4,9				25				
MYCTOPHIDAE	<i>Benthoosema glaciale</i> (Reinhardt, 1837) (4)	9,8	26	6,6	20,7	6,7	10,8		41	7,7	30	
	<i>Ceratoscopelus maderensis</i> (Lowe, 1939)	23,5	15,2	32,7	24,6	44,4	21,6	25	18	46		
	<i>Diaphus rafinesqui</i> (Cocco, 1838)			1,6	1,3		2,7		2,6			
	<i>Diaphus</i> aff. <i>splendidus</i> (Brauer, 1904)				2,6							
	<i>Diaphus</i> aff. <i>*cavallonis</i> Brzobohaty & Nolf, 2000	7,8	2,2	4,9	1,3	6,7	2,7					
	<i>Diaphus</i> ind.	13,7	4,3	9,8	1,3	7,7	5,4	12,5		15,3		
	<i>Electrona risso</i> (Cocco, 1829)	2		1,6	1,3	1,1	2,7	25	2,6			
	<i>Hygophum benoiti</i> (Cocco, 1838)		2,2									
	<i>Hygophum hygomi</i> (Lutken, 1892)	11,7	8,7	11,4	11,6	4,4	10,8		7,7		10	
	<i>Myctophum punctatum</i> (Rafinesque, 1810)					4,4	8,1	12,5				
	<i>Notoscopelus resplendens</i> (Richardson, 1845) (5)	7,8	15,2	4,9	5,2		13,5					
	<i>Notoscopelus</i>					4,4			12,8			
	<i>Scopelopsis *pliocenicus</i> (Anfossi & Mosna, 1976)	11,7	6,5	6,6	1,3	2,2						
BREGMACEROTIDAE	<i>Bregmaceros</i> sp.	5,9		4,9	3,9	3,3	2,7			7,7	30	45,8
total specimens		51	46	61	77	90	37	8	39	13	20	24
BENTHIC AND BENTHOPELAGIC TAXA												
CONGRIDAE	<i>Pseudoplichthys splendens</i> (Lea, 1913) (2)	5		5,9								
	<i>Rhynchoconger *pantanelli</i> (Bassoli, 1906) (1)			5,9								
MORIDAE	<i>Laemonema</i> sp. A (6)					5,88						
GADIDAE	<i>Gadiculus argenteus</i> Guichenot, 1850	20	10,3	35	24,4	35,3	47,1	40,9	27,3	60	50	
	<i>Gadiculus *labiatus</i> (Schubert, 1905) (7)	25	20,7	35	36,6	23,5		9,09	30,3	20	28,6	80
	<i>Micromesistius poutassou</i> (Risso, 1826)	5	27,6		9,76	11,8	17,6	36,4	24,2		7,14	20
	<i>Merluccius merluccius</i> (Linnaeus, 1758)		6,9						6,06			
	<i>Phycis musicki</i> Cohen & Lavenberg, 1984 (8)					5,88			3,03			
MACROURIDAE	<i>Trachyrincus scabrus</i> (Rafinesque, 1810)						5,88					
	<i>Coryphaenoides *sicilianus</i> (Schwarzhans, 1986)		3,45		2,44							
	<i>Nezumia aequalis</i> (Gunther, 1878) (9)						5,88					
BYTHITIDAE	<i>Grammonus</i> sp. (10)	5	3,45									
	Bithitidae ind.	15	10,3	12	7,32		11,8					
	<i>Carapus</i> sp.		6,9									
	<i>Echiodon</i> sp.	5										
TRIGLIDAE	<i>Lepidotrigla cavillone</i> (Lacepede, 1801)				2,44							
ACROPOMATIDAE	<i>Parascombrops *mutinensis</i> (Bassoli, 1906)	5	6,9			5,88		13,6			7,14	
CARANGIDAE	<i>Trachurus</i> sp.				2,44							
CEPOLIDAE	<i>Cepola rubescens</i> (Linnaeus, 1766)									20		
	<i>Owstonia *neogenica</i> (Nolf & Cappetta, 1989)	10										
BLENNIDAE	<i>Blennius</i> sp. (11)				2,44							
GOBIDAE	<i>Deltentosteus</i> sp.				2,44				6,06			
	Gobidae ind.	5		5,9	4,88	5,88	11,8		3,03		7,14	
	<i>Lesueurigobius</i> aff. <i>friesi</i> (Malm, 1874)		3,45									
	<i>Lesueurigobius</i> sp. ind.				4,88	5,88						
total specimens		20	29	17	41	17	17	22	33	5	14	5

Tab. 1 - Systematic list of teleost taxa from Rio Merli section. Relative abundance of each species and total number of specimens per sample.

identified to family level such as Clupeidae, Bithitidae and Gobiidae due to their preservation and/or small size. Juvenile specimens of macrourids, gobiids, and some populations of myctophids are dominant in the assemblages of the Rio Merli section.

The pelagic group is generally richer in specimens than the benthic and benthopelagic ones. However, the abundance of both benthic-benthopelagic and pelagic assemblages decrease upward in the section (Tab. 1).

The myctophid family shows the highest diversity with eleven taxa of which the extant *Ceratoscopelus maderensis* and *Benthosema glaciale* (Pl. 1, fig. 5) are the most abundant, followed by *Hygophum hygomi*. In the benthic-benthopelagic group, the gadiforms are well diversified. In particular, the gadids *Gadiculus argenteus* (Pl. 2, fig. 7), *Gadiculus labiatus* (Pl. 2, fig. 9) and *Micromesistius poutassou* are the most common and abundant.

Based on their modern environments, the benthic-benthopelagic taxa of Rio Merli section can be included in three main ecological groups (Fig. 2): the bathyal group, the shelf group, and the large bathymetric distribution group (eurytopic). In all benthic and benthopelagic assemblages from Rio Merli section, the dominance value of the entire bathyal group varies from about 30% to about 80% (Fig. 2), generally increasing in the assemblages towards the upper part of the section.

The gadids *Gadiculus argenteus* and *Micromesistius poutassou* are the principal components of this group and, according to the data from the Recent and Pleistocene assemblages, these taxa are characteristic species of upper continental slope assemblages in the bathymetric range between 200 and 400 m (D'Onghia et al., 1998; Girone, 2005). In the bulk samples they are represented by medium-large size specimens; several larger specimens have been recognized in the outcrop. The bathyal group also includes the extant macrourids *Nezumia aequalis* (Pl. 3, fig. 4) and *Trachyrincus scabrus* (Pl. 3, fig. 13) and the extinct species *Coryphaenoides sicilianus* (Pl. 2, fig. 11). In the modern environment, *Trachyrincus scabrus* is considered characteristic species of deep sea bathyal assemblages (below 400-500 m). In Pliocene and Pleistocene assemblages it shows a similar life habit but juvenile specimens have been found in associations indicative of shallower upper bathyal setting (Nolf &

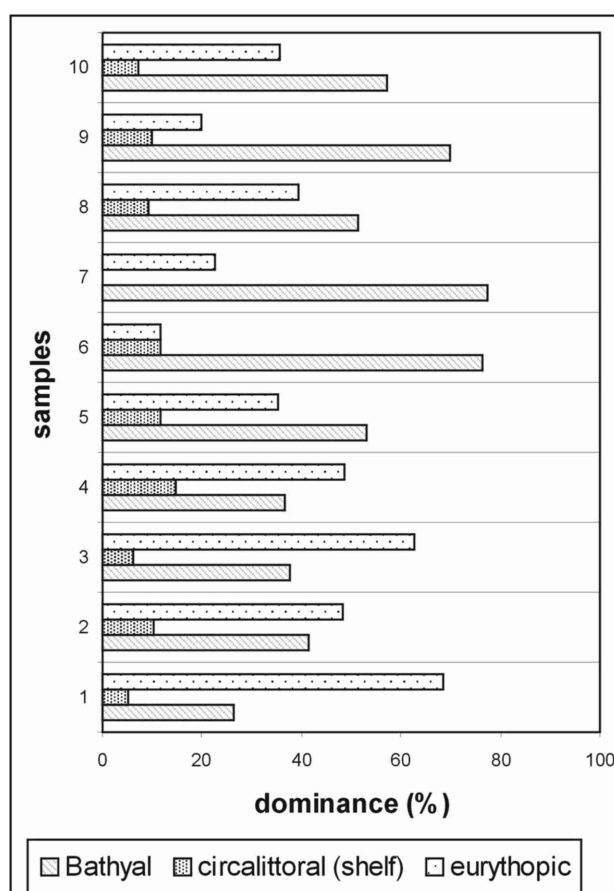


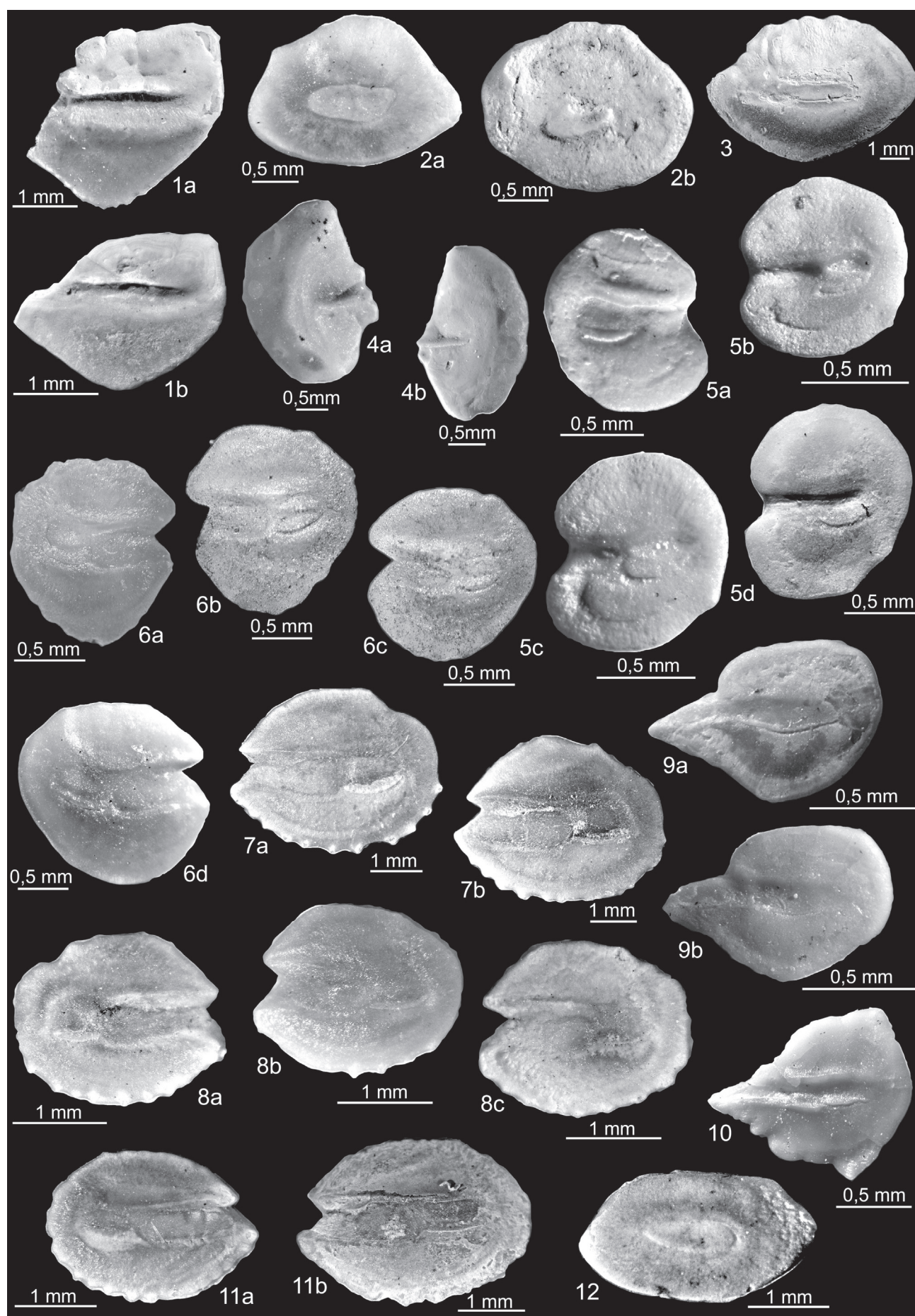
Fig. 2 - Distribution of benthic and benthopelagic fishes based on modern environments in the Rio Merli section.

Cappetta, 1989; Di Geronimo et al., 2003). The extinct species *Coryphaenoides sicilianus* had probably a similar life habit (Nolf & Cappetta, 1989; Girone, 2005). In the screenwashed samples *Trachyrincus scabrus* and *Coryphaenoides sicilianus* are represented by very uncommon and juvenile specimens even though several larger specimens of *Trachyrincus scabrus* were also collected from the surface of the outcrop along the upper interval of the section showing an higher frequency and abundance of this species also at adult

EXPLANATION OF PLATE 1

All figured specimens are deposited in the collections of "Dipartimento di Geologia e Geofisica dell'Università di Bari". In the captions, L stands for left otolith and R for right otolith.

- fig. 1 - *Argentina sphyraena* (Linnaeus, 1758), R; a: sample 1, b: sample 3.
- fig. 2 - *Pseudophichthys splendens* (Lea, 1913), L; a: sample 1, b: sample 3.
- fig. 3 - *Rhynchoconger pantanelli* (Bassoli, 1906), R; sample 3.
- fig. 4 - *Polyipnus* sp.; a: L, sample 4, b: R, sample 3.
- fig. 5 - *Benthosema glaciale* (Reinhardt, 1837); a: L, sample 4, b: R, sample 4, c-d: R, sample 8.
- fig. 6 - *Hygophum benoitii* (Cocco, 1838), L; a: Recent, Mediterranean sea, R, b-c: Recent, Mediterranean sea, L, d: sample 2.
- fig. 7 - *Diaphus cavalloni* Brzobohaty & Nolf, 2000; R, Saint Martin du Var (France) Lower Pliocene, IRSNB collection.
- fig. 8 - *Diaphus* aff. *cavalloni* Brzobohaty & Nolf, 2000; a: L, sample 4, b-c: R, sample 1.
- fig. 9 - *Vinciguerrria poweriae* (Cocco, 1838); R, sample 4.
- fig. 10 - *Maurolicus muelleri* (Gmelin, 1789); R, sample 4.
- fig. 11 - *Diaphus* aff. *splendidus* (Brauer, 1904); sample 4, a: L, b: R.
- fig. 12 - *Grammonus* sp.; R, sample 2.



stage. In the sample 6, *Trachyrincus scabrus* is associated with the Recent *Nezumia aequalis* reported in the modern associations in a bathymetric range between 200 and 1000 m. The palaeoecology of this taxon is poorly known.

In the lower and middle interval of the section several specimens of the extinct species *Coelorinchus arthaberi* (Schubert, 1905) have been picked on the surface, but not in screenwashed samples. This species, known in the Mediterranean area from the Miocene (Langhian) to the Middle Pliocene, has been generally found in bathyal assemblages.

The group of eurytopic taxa, which show dominance value generally decreasing upward, include *Lepidotrigla cavillone* (Pl. 3, fig. 6), *Pseudophichthys splendens* (Pl. 1, fig. 2), Bithitidae, and the gadid *Merluccius merluccius*. The extinct species *Gadiculus labiatus* has been also included in this group. This species is known in fossil assemblages from the Miocene up to Middle Pliocene and has been reported in a wide range of environments.

The palaeoecological analysis shows the presence of a shelf group, which is frequent along the entire sections but with dominance values lower than about 15%. Gobiid taxa, *Cepola rubescens* (Pl. 3, fig. 10), and the carapids *Carapus* and *Echiodon* mostly compose this group.

The composition and structure of the analyzed assemblages compare well with Pleistocene assemblages from several southern Italian fossil deposits (Girone, 2000, 2005; Di Geronimo et al. 2003) indicating an upper slope transitional to shelf-margin setting at about 250 m depth, in the lowermost part of the section. Like the Pleistocene assemblages, the Rio Merli associations are characterized by the co-occurrence of typical shelf benthic taxa and dominant gadids like *Gadiculus argenteus* and *Micromesistius poutassou*, that without the typical deep upper bathyal taxa as *Coelorinchus coelorinchus* (at adult stage), seems to be more indicative of the uppermost part of the continental slope. From the sample 5, the dominance of the group of bathyal species increases upward even though the dominance values of shelf group show the similar trend of the lower assemblages (except for sample 7). However if the structure of the assemblages

is unvaried, some variations can be observed in the composition of the shelf and bathyal groups. From the sample 6 up to sample 10, the shelf group is composed by very juvenile and unidentifiable gobids (except for sample 7 and sample 9). The assemblage of the sample 7 is lacking of the shelf group but in the assemblage of sample 9 the shelf group is reduced to just one juvenile specimen of *Cepola rubescens*. At the same time, the bathyal group include the deepest bathyal taxa as *Laemonema* sp. A which, on the basis of the available data from Pleistocene assemblages, seems to be characteristic of bathyal settings deeper than 400 m (Girone et al., 2006) and, the above mentioned, *Trachyrincus scabrus*. The increased dominance of the group of true bathyal species and the variations registered in the composition of this group could be indicative of deeper setting even though the unvaried structure of the assemblages does not clearly pointed out any important depth increase.

REMARKS ON TAXA REQUIRING COMMENTS

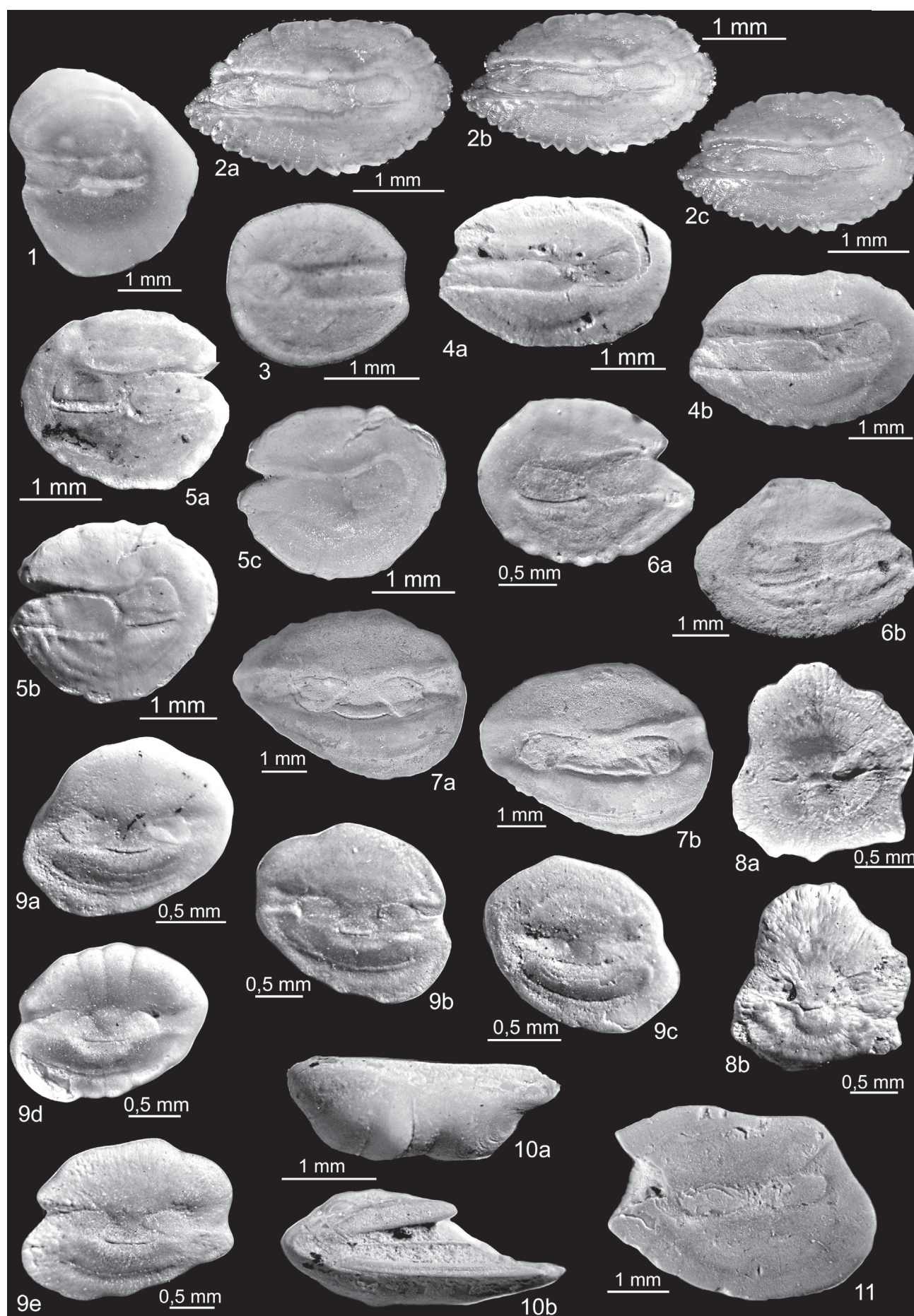
Rhynchoconger pantanelli (Pl. 1, fig. 3). In the Mediterranean area, this extinct species is known from the Upper Miocene up to Upper Pliocene (Nolf & Steurbaut, 1983; Nolf et al., 1998; Nolf & Brzobohaty, 2004; Girone et al., 2006). The species is also reported from the Lower and Middle Miocene of Aquitaine and from Middle Miocene of Romania and Austria (Steurbaut, 1984). Today, the genus *Rhynchoconger* is absent from the Mediterranean, but it has been reported in all oceans (Smith, 1989).

Pseudophichthys splendens (Pl. 1, fig. 2). Recently, Nolf & Girone (2006) had the opportunity to consult a extensive series of otoliths of this amphi-Atlantic species. They concluded that all otoliths from the Mediterranean Pliocene previously attributed to *Japonoconger caribbeus* (Smith & Kanazawa, 1977) belongs to *P. splendens*. The species was already known in the Lower and Middle Pliocene of the Mediterranean basin (Nolf & Cappetta, 1989, Nolf et al., 1998), but it had never been found in the Upper Pliocene and Pleistocene deposits.

EXPLANATION OF PLATE 2

All figured specimens are deposited in the collections of "Dipartimento di Geologia e Geofisica dell'Università di Bari". In the captions, L stands for left otolith and R for right otolith.

- fig. 1 - *Electrona risoi* (Cocco, 1829); R, sample 7.
- fig. 2 - *Notoscopelus elongatus elongatus* (Costa, 1844); R, Recent from Ionian Sea.
- fig. 3 - *Scopelopsis pliogenicus* (Anfossi & Mosna, 1976); L, sample 1.
- fig. 4 - *Notoscopelus resplendens* (Richardson, 1845); R, a: sample 4, b: sample 6.
- fig. 5 - *Myctophum punctatum* (Rafinesque, 1810); sample 5, a: L, b-c: R.
- fig. 6 - *Diaphus rafinesqui* (Cocco, 1838); L, a: sample 6, b: sample 8.
- fig. 7 - *Gadiculus argenteus* (Guichenot, 1850); L, sample 1.
- fig. 8 - *Bregmaceros* sp.; R, sample 5.
- fig. 9 - *Gadiculus labiatus* (Schubert, 1905); sample 3, a: R, c: L, sample 4, b: L, d: R, e: R.
- fig. 10 - *Laemonema* sp. A; R, sample 5, a: ventral view, b: inner view.
- fig. 11 - *Coryphaenoides sicilianus* (Schwarzahns, 1986); L, sample 2.



Polyipnus sp. (Pl. 1, fig. 4). Twenty-six otoliths, generally worn, are comparable with those of the Recent genera *Polyipnus* and *Ichthyococcus*. However, the more convex posterior part of the inner surface and the less considerable height of the fossil otoliths are quite distinct features that identifies them as *Polyipnus*. Fossil specimens of the Recent extra Mediterranean genus *Polyipnus* are known in the Upper Miocene deposits from northern Italy (Nolf & Steurbaut, 1983) and in the Middle Pleistocene deposits from southern Italy, where Girone & Varola (2001) reported the Recent Atlantic *P. polli* Schultz, 1961 (pl. 1, fig. 2). The general shape of the Pliocene specimens is comparable with that of Pleistocene and Recent *P. polli*, but the sulcus, in better preserved specimens, is completely lacking the anterior colliculum.

Benthoosema glaciale (Pl. 1, fig. 5). In the lowermost samples of the section, the population of *B. glaciale* is mostly composed of juvenile otoliths comparable with those of the Recent species especially by their characteristic sulcus. These juvenile fossil otoliths are often lacking the typical spines that characterize the ventral margin of *B. glaciale* otoliths. However, in the sample from the middle-upper part of the section the population also contains well-preserved adult specimens with features almost identical with those of Recent *B. glaciale* otoliths. Therefore, all otoliths of *Benthoosema* from the Rio Merli section are assigned to the Recent *B. glaciale*.

Diaphus aff. *cavallonis* (Pl. 1, fig. 8). Fifteen relatively small otoliths have been compared with those of the fossil species *Diaphus cavallonis* Brzobohaty & Nolf, 2000 (Pl. 1, fig. 7), known in the Mediterranean realm from the Tortonian to the Middle Pliocene. Compared to the diagnosis of *D. cavallonis* given by Brzobohaty & Nolf, 2000, the otoliths from the Rio Merli section are characterized by relatively high and irregular elliptical shape. Between the rostrum and the posterodorsal angle, their dorsal rim shows a regular curving but with a feeble obtuse angular expansion, which is well visible in large otoliths of the type series of *D. cavallonis*. Moreover, the ventral rim of the Rio Merli specimens is less stretched obliquely towards the

rostrum than in typical *D. cavallonis* otoliths. These differences may be related to size: in small and medium sized specimens of *D. cavallonis* salient structures are more blunt.

Notoscopelus resplendens (Pl. 2, fig. 4) This species, today reported in tropical-subtropical areas of all oceans, is very common in the Upper Miocene and Lower Pliocene deposits of the Mediterranean area (Brzobohaty & Nolf, 1996). From the Upper Pliocene on, it seems to be replaced by the Recent Mediterranean species *N. elongatus* (Girone et al., 2006). *N. resplendens* differs from *N. elongatus elongatus* (Pl. 2, fig. 2) by its shorter otoliths with a more marked postero-dorsal angle.

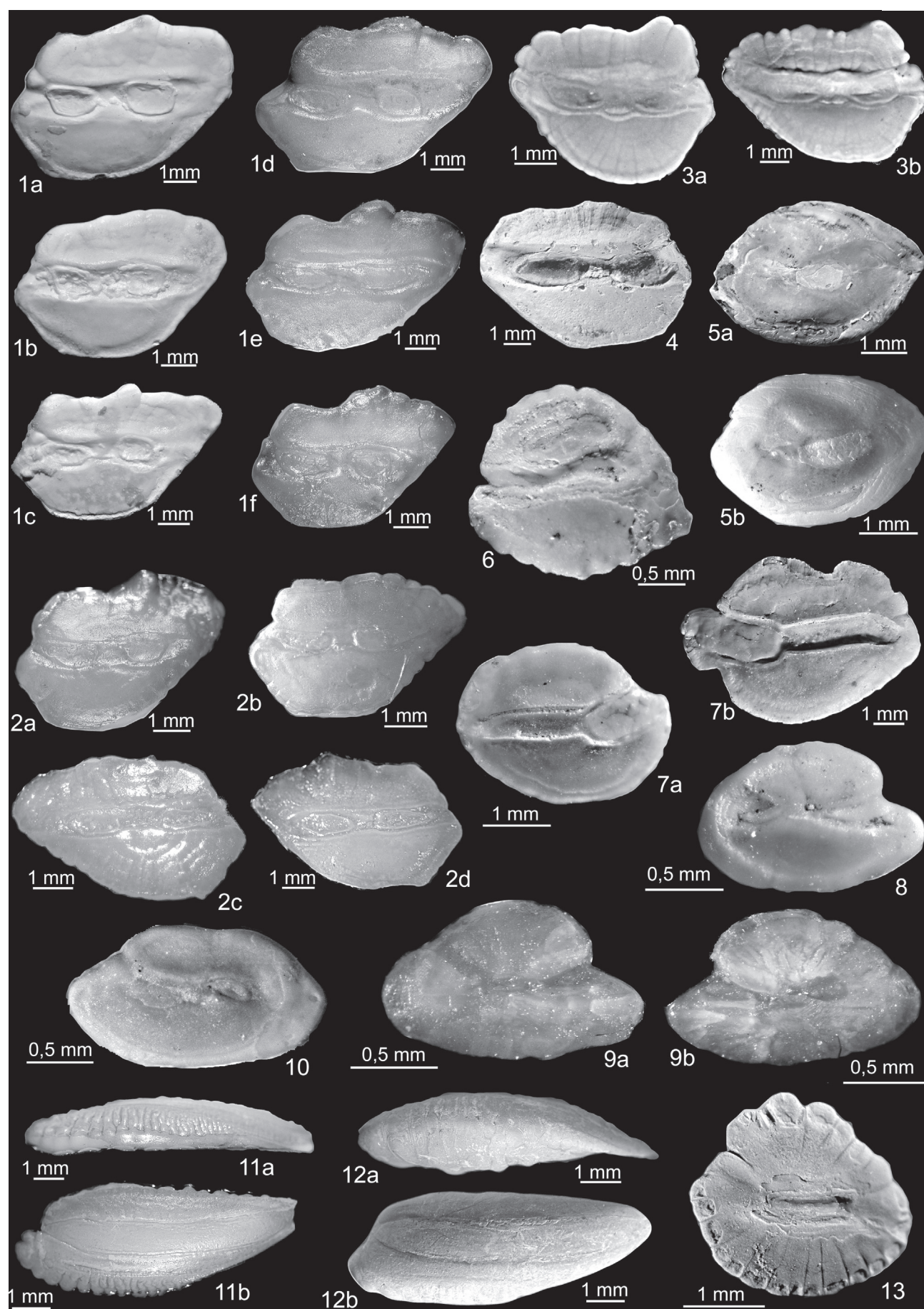
Laemonema sp. A (Pl. 2, fig. 10). One otolith from sample 5 is assigned to this taxon. The less gentle shape and other features permit reference to the genus, which had not been considered Mediterranean taxon. Recently, Matallanas (1985) reported the first record of north Atlantic *Laemonema latifrons* Holt & Byrne, 1908 in the Recent Mediterranean. As a fossil, the Atlantic species *L. aff. yarrelli* (Lowe, 1841) has been already reported in the Tortonian sediment from Montegibbio (northern Italy) by Nolf & Steurbaut (1983). The Pliocene otolith does not match those of the Tortonian species and the Recent *L. yarrelli*, but it is well comparable with the Pleistocene taxon *Laemonema* sp. A found in various deep water otolith assemblages by Girone et al. (2006). The latter taxon, as discussed in Girone et al. (2006), may be related to *L. latifrons*.

Gadiculus labiatus (Pl. 2, fig. 9). *G. labiatus* generally shows a marked intraspecific variability. In the samples from Rio Merli, otoliths of *G. labiatus* are very common, and they mostly have a characteristic round and higher shape than the Recent *G. argenteus* (Pl. 2, fig. 7). However, one specimen from sample 4 (Pl. 2, fig. 9e) is rather elongated and shows an irregular shape. Such morphology has been also observed in *G. labiatus* populations from Lower Miocene of both the North Sea Basin and the Aquitaine Basin (Steurbaut, 1984; Nolf, 1985) but was never observed in the Pliocene populations.

EXPLANATION OF PLATE 3

All figured specimens are deposited in the collections of "Dipartimento di Geologia e Geofisica dell'Università di Bari". In the captions, L stands for left otolith and R for right otolith.

- fig. 1 - *Nezumia aequalis* (Gunther, 1878); R, a-c: Recent, NW Atlantic, d-e: Recent, Mediterranean Sea (off Messina).
- fig. 2 - *Nezumia sclerorhynchus* (Valenciennes, 1838); a-b: R, Recent, Mediterranean Sea (off Messina), c-d: L, Recent, Ionian Sea.
- fig. 3 - *Nezumia ornata* (Bassoli, 1906); L, Le Puget Sur Argens, Lower Pliocene, IRSNB collection.
- fig. 4 - *Nezumia aequalis* (Gunther, 1878); L, sample 6.
- fig. 5 - *Owstonia neogenica* (Nolf & Cappetta, 1989); R, sample 1.
- fig. 6 - *Lepidotrigla cavillone* (Lacepede, 1801); R, sample 4.
- fig. 7 - *Parascombrops mutinensis* (Bassoli, 1906); a: L, sample 5, b: R, sample 1.
- fig. 8 - *Blennius* sp.; L, sample 4.
- fig. 9 - *Blennius ocellaris* (Linnaeus, 1758); Recent, Ionian Sea, a: L, b: R.
- fig. 10 - *Cepola rubescens* (Linnaeus, 1766); R, sample 9.
- fig. 11 - *Phycis blennoides* (Brunnich, 1768); R, Recent, Ionian sea, a: ventral view, b: inner view.
- fig. 12 - *Phycis musicki* Cohen & Lavenberg, 1984; R, sample 5, a: ventral view, b: inner view.
- fig. 13 - *Trachyrincus scabrurus* (Rafinesque, 1810); R, sample 6.



Phycis musicki (Pl. 3, fig. 12). Two juvenile specimens (samples 8 and 5) belong to the genus *Phycis*. Well-preserved adult *Phycis* otoliths from the Piacenzian of the Mediterranean area, are not available; all collected specimens belong to juvenile or subadult fish. Recent *P. blennoides* otoliths of comparable size are thinner and have a more salient anterior margin (Pl. 3, fig. 11). The Piacenzian fossils are quite similar to otoliths of the fossil *P. musicki* reported from the Middle Miocene deposits of southeastern France, Poland, Portugal, and Romania, and from the Upper Miocene to Lower Pliocene of the Mediterranean area (Steurbaut, 1984 with bibliography; Nolf et al., 1998). The specimens found in the Lugagnano, previously identified as *P. blennoides* (Girone, 2000), also belong to *P. musicki*.

Nezumia aequalis (Pl. 3, fig. 4). One specimen can be referred to this taxon. In the fossil deposits of the Mediterranean area, three species are represented: the Recent Mediterranean species *N. sclerorhynchus* (Pl. 3, fig. 2) and *N. aequalis* (Pl. 3, fig. 1) and the extinct *N. ornata* (Pl. 3, fig. 3). The otolith of *N. aequalis* and *N. ornata* are both higher than otoliths of *N. sclerorhynchus* but, at the same time, the otoliths of *N. aequalis* are more elongated than the ones of fossil species. Moreover, a wider and deeper sulcus seems to characterize the otoliths of *N. aequalis* with respect to those of *N. sclerorhynchus*. These features are well distinguishable in the specimen from the Rio Merli for which it is worth noting that the outline is eroded (mostly along the posterior margin); consequently, the otolith may actually be more elongated.

Otoliths of *N. aequalis* are apparently not very common in the fossil deposits mostly from the Middle Pliocene to Pleistocene: the occurrence from Rio Merli section represents the first fossil record referable to this time unit.

Recently, Brzobohaty (1995) assigned specimens from Miocene deposits (Langhian) of central Paratethys to *N. aequalis*. The same author refers to this taxon the specimens previously described by Anfossi & Mosna (1969; 1972) and Schwarzhans (1978) from the Miocene (Tortonian) and Lower Pliocene deposits of Italy, respectively. More recently, Nolf & Brzobohaty (2004) reported *N. aequalis* from the Lower Miocene (upper Burdigalian) of the Mediterranean realm.

Grammonus sp. (Pl. 1, fig. 12). Beside 13 bythitid otoliths, which small size does not permit any genus or specific identification, 3 otoliths from samples 1 and 2 seem to belong to the genus *Grammonus*. They have been compared with the otoliths of the Recent species *G. ater* living in the Mediterranean and reported as fossil from the Middle Pleistocene of southern Italy (Girone & Varola, 2001), as *Oligopus ater*. The Pliocene specimens show a general outline quite similar to the ones of *G. ater*, but their postero-dorsal angle is more developed giving an rectangular shape to the dorsal rim. In *G. ater*, the dorsal rim is more regularly curved. The sulcus has the same width but seems to be shorter. The dorsal area, slightly depressed, is larger than the ventral one, like it is in *G. ater*. Although the Pliocene

specimens show well-defined features, the poor knowledge of Recent bythitid otoliths does not allow identification at the species level. The specimens from the Rio Merli section, however, show reasonable similarity to Lower Pliocene specimens figured by Nolf & Cappetta (1989) from the southeastern France.

Blennius sp. (Pl. 3, fig. 8). One specimen is ascribable to this genus. The sulcus is not clearly open along the posterior rim and is characterized by a well-developed collicular crest curving in the posterior part of the cauda. The ostium is not strongly incised and is filled with elongated colliculum that is thick along the lower margin. These features exclude the Recent Mediterranean *Blennius ocellaris* (Pl. 3, fig. 9) where otoliths of similar size are characterized by a deep cauda and an ostium lacking colliculum. In the Recent species, the cauda opens clearly on the posterior rim and is characterized by thin linear collicular crista. Fossil *Blennius* otoliths are not very common due to their ecology: they are rocky shore fishes that occur only very occasionally in the low relief sand and mud environments where fossil otolith associations are commonly preserved. There are various Pliocene records of blennids treated in open nomenclature, but occurrence of Recent species *B. ocellaris* have been reported only in the lower Pleistocene (Santerian) by Nolf & Girone (2000).

DISCUSSION AND CONCLUDING REMARKS

The otolith assemblages from the Rio Merli section are almost homogenous in their composition and structure. The benthic and benthopelagic assemblages from the lower and middle interval of the section are mainly composed of taxa characteristic of the upper bathyal zone like *Gadiculus argenteus* and *Micromesistius poutassou*, associated with deep shelf (e.g. gobiid group, *Cepola rubescens*, *Carapus*, and *Blennius*) and eurytopic taxa. *Trachyrincus scabrus* and *Laemonema* sp. A, the more characteristic taxa of the deep bathyal environment, are uncommon in the screenwashed samples but larger specimens of *T. scabrus* were also collected from the surface of the outcrop along the upper interval of the section. The lowermost otolith assemblages from Rio Merli are quite comparable with other Plio-Pleistocene assemblages at the transition of upper bathyal to deep shelf environments (Di Geronimo et al., 2003; Girone, 2005) and are in agreement with the data obtained by molluscan assemblages (Ceregato, 2002). The molluscan assemblages, however, indicate a significant deepening upward in the section. On the basis of otolith assemblages, this is not clearly pointed out. It is evident that the dominance of the group of the bathyal species increases upward but no important variations can be registered for the dominance values of the shelf group. The very low abundance and diversity of these assemblages do not allow definite conclusion.

Although the teleostean fauna from Rio Merli includes many species already reported in the Plio-Pleistocene deposits of the Mediterranean area, about

40% is represented by species reported for the first time in sediments of Piacenzian age. Some (e. g. *Benthosema glaciale*, *Hygophum benoiti*, Pl. 1, fig. 6, *Myctophum punctatum*, Pl. 2, fig. 5, and *Lesueurigobius* aff. *friesii*) represent the first appearance of these taxa (Tab. 2) in the Mediterranean basin.

The main characteristic of the Rio Merli teleostean fauna is the co-occurrence of typical Lower Pliocene Paleomediterranean and subpolar-temperate taxa like *Benthosema glaciale* and *Myctophum punctatum*. Although still living in the Recent Mediterranean, these species seem to enter the basin during the Middle Pliocene. This subpolar-temperate group becomes very common and abundant in Upper Pliocene and Pleistocene otolith assemblages and today survives in

the Mediterranean realm, being especially abundant in the western part of the basin (Nafpaktitis et al., 1977).

At the same time, the extant oceanic taxa *Pseudophichthys splendens*, *Notoscopelus resplendens*, and *Diaphus splendidus*, very common in the Miocene and Lower Pliocene assemblages, seem still characterize the Middle Pliocene teleostean assemblages, even if they generally disappear in the Upper Pliocene-Pleistocene assemblages. Among these taxa inhabiting mainly tropical-semisubtropical oceanic areas today (Nafpaktitis et al., 1977), only *D. aff. splendidus* (Pl. 1, fig. 11) has been reported in the Upper Pliocene and in the Lower Pleistocene (Santernian) Mediterranean realm (Nolf & Girone, 2000; Girone et al., 2006). Extinct species like *Owstonia neogenica* (Pl. 3, fig. 5)

List of nominal species from Rio Merli section	Miocene	Zanclean	Piacenzian	Gelasian	Pleistocene	Recent
M*: Z*: taxa recognised in Miocene or Zanclean sediment of extra-Mediterranean area. R*: living taxa disappeared from the Mediterranean Sea Pl(I): taxa reported only in Lower Pleistocene (Santernian)						
<i>Pseudophichthys splendens</i> (Lea, 1913)	-	Z	P	-	-	R*
<i>Rhynchoconger pantanelli</i> (Bassoli, 1906)	M	Z	P	G	-	-
<i>Argentina sphyraena</i> (Linnaeus, 1758)	M*	Z	P		Pl	R
<i>Maurolicus muelleri</i> (Gmelin, 1789)	M	Z	P	G	Pl	R
<i>Vinciguerria poweriae</i> (Cocco, 1838)	?M	?Z	P	G	Pl	R
<i>Benthosema glaciale</i> (Reinhardt, 1837)	-	Z*	P	G	Pl	R
<i>Ceratoscopelus maderensis</i> (Lowe, 1939)	-	Z	P	G	Pl	R
<i>Diaphus rafinesqui</i> (Cocco, 1838)	-	Z	P		Pl	R
<i>Diaphus</i> aff. <i>splendidus</i> (Brauer, 1904)	-	Z	P	G	Pl (I)	R*
<i>Diaphus</i> cf. <i>cavalloni</i> Brzobohaty & Nolf, 2000	M	Z	P	-	-	-
<i>Electrona risso</i> (Cocco, 1829)	-	Z	P	G	Pl	R
<i>Hygophum benoiti</i> (Cocco, 1838)	-	-	P	G	Pl	R
<i>Hygophum hygomi</i> (Lutken, 1892)	M	Z	P	G	Pl	R
<i>Myctophum punctatum</i> (Rafinesque, 1810)	-	-	P	G	Pl	R
<i>Notoscopelus resplendens</i> (Richardson, 1845)	M	Z	P	-	-	R*
<i>Scopelopsis pliogenicus</i> (Anfossi & Mosna, 1976)	M	Z	P		Pl	-
<i>Bregmaceros</i> sp.	-	Z	P	G	Pl	-
<i>Laemonema</i> sp. A	-	-	P	?	Pl	R
<i>Gadiculus argenteus</i> (Guichenot, 1850)	M	Z	P	G	Pl	R
<i>Gadiculus labiatus</i> (Schubert, 1905)	M	Z	P	G	Pl (I)	-
<i>Micromesistius poutassou</i> (Risso, 1826)	-	Z	P	G	Pl	R
<i>Merluccius merluccius</i> (Linnaeus, 1758)	M	Z	P		Pl	R
<i>Phycis musicki</i> Cohen & Lavenberg, 1984	M	Z	P	-	-	-
<i>Trachyrincus scabrus</i> (Rafinesque, 1810)	M	Z	P	G	Pl	R
<i>Coryphaenoides sicilianus</i> (Schwarzahns, 1986)	-	Z	P	G	Pl (I)	R
<i>Nezumia aequalis</i> (Gunther, 1878)	M	-	P			R
<i>Grammonus</i> sp.	-	Z	P	-	-	-
<i>Lepidotrigla cavillone</i> (Lacepede, 1801)	-	Z	P			R
<i>Parascombrops mutinensis</i> (Bassoli, 1906)	M	Z	P	G	Pl(I)	-
<i>Cepola rubescens</i> (Linnaeus, 1766)	M	Z	P		Pl	R
<i>Owstonia neogenica</i> (Nolf & Cappetta, 1989)	-	Z	P	-	-	-
<i>Lesueurigobius</i> aff. <i>friesi</i> (Malm, 1874)	-	-	P		Pl	R

Tab. 2 - Stratigraphic and geographic distribution of the nominal taxa from Rio Merli section.

and *Rhynchoconger pantanelli*, can also be included in this group. *Owstonia* is a taxon with Indo-Pacific distribution well known in the Mediterranean realm from the Zanclean up to the Piacenzian (Nolf & Cappetta, 1989; Nolf & Cavallo, 1994). *Rhynchoconger* is distributed worldwide (Atlantic and Indo-Pacific) but disappeared from the Mediterranean realm during the Upper Pliocene.

On the basis of these analyses, the teleostean fauna from the Middle Pliocene deposit of the Rio Merli shows transitional biogeographic affinities with the Zanclean and the Upper Pliocene and Pleistocene fauna of the Mediterranean realm. These gradual modifications seem to be closely related to slow climate changes that took place during this interval of time.

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REFERENCES

- Anfossi G. & Mosna S. (1969). Otoliti del Bacino terziario ligure-piemontese (Tortoniano e Miocene superiore). *Atti dell'Istituto Geologico della Università di Pavia*, 20: 23-49.
- Anfossi G. & Mosna S. (1972). Otoliti del Pliocene inferiore di Lugagnano (Piacenza). *Atti dell'Istituto Geologico della Università di Pavia*, 23: 90-118.
- Brzobohaty R. (1995). Macrouridae (Teleostei, Otolithen) im Oligozan und Miozan der Zentral Paratethys und ihre palaogeographische Bedeutung. *Jahrbuch der Geologischen Bundesanstalt*, 138: 615-637.
- Brzobohaty R. & Nolf D. (1996). Otolithes de myctophidés (poissons téléostéens) des terrains tertiaires d'Europe: revision des genres *Benthoema*, *Hygophum*, *Lampadena*, *Notoscopelus* et *Symbolophorus*. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Sciences de la Terre*, 66: 151-176.
- Brzobohaty R. & Nolf D. (2000). *Diaphus* otoliths from the European Neogene (Myctophidae, Teleostei). *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Sciences de la Terre*, 70: 185-206.
- Ceregato A. (2002). Paleocomunità batiali a molluschi del Pliocene del Bacino Padano. Doctoral Thesis in Paleontology, Università di Modena, Bologna, Firenze e Roma: 97pp.
- Ceregato A., Scarponi D., & Raffi S. (2005). Deep sea faunas in the Middle Pliocene of Northern Italy: the *Korobkovia oblonga* – *Jupiteria concave* paleocommunity. *Epitome*, 1: 273.
- Di Geronimo I., Di Geronimo R., Girone A., La Perna R. & Rosso A. (2003). Autochthonous and allochthonous assemblages from Lower Pleistocene sediments (Palione river, Sicily). *Bollettino della Società Paleontologica Italiana*, 42 (1-2): 133-138.
- Di Geronimo I. & Robba, E. (1976). Metodologie qualitative e quantitative per lo studio delle biocenosi e paleocomunità marine bentoniche. *Il Paleobenthos in una prospettiva paleoecologica, Gruppo informale di Ricerca coordinata, C.N.R., Rapporto di lavoro*, 1: 1-35.
- D'Onghia G., Tursi A., Maiorano P., Matarrese A. & Panza M. (1998). Demersal fish assemblages from the bathyal grounds of the Ionian Sea (middle-eastern Mediterranean). *Italian Journal of Zoology*, 65: 287-292.
- Girone A. (2000). Studio delle associazioni a otoliti in Sezioni pleistoceniche dell'Italia meridionale. PhD Thesis, Bari University: 1-86.
- Girone A. (2003). The Pleistocene bathyal teleostean fauna of Archi (Southern Italy): palaeoecological and palaeobiogeographic implications. *Rivista Italiana di Paleontologia e Stratigrafia*, 108 (3): 493-500.
- Girone A. (2005). Response of otolith assemblages to sea-level fluctuations at the Lower Pleistocene Montalbano Jonico section (southern Italy). *Bollettino della Società Paleontologica Italiana*, 44 (1): 35-45.
- Girone A., Nolf D. & Cappetta H. (2006). Pleistocene fish otoliths from the Mediterranean basin: a synthesis. *Geobios*, 39 (5): 651-671.
- Girone A. & Varola A. (2001). Fish otoliths from the Middle Pleistocene deposits of Montalbano Jonico (Southern Italy). *Bollettino della Società Paleontologica Italiana*, 40 (3): 431-443.
- Landini W. & Menesini E. (1978). L'ittiofauna plio-pleistocenica della sezione Vrica (Crotone - Calabria). *Bollettino della Società Paleontologica Italiana*, 17 (2): 143-175.
- Matallanas J. (1985). First record of the North Atlantic Morid fish, *Laemonema latifrons* Holt & Byrne, in the Mediterranean. *Journal of Fish Biology*, 26 (3): 289-290.
- Nafpaktitis B.G., Backus R.H., Craddock J.E., Haedrich R.L., Robinson B.H., Karnella C. (1977). Fishes of the Western North Atlantic. *Memoir Sears Foundation for Marine research*, 7: 1-299.
- Nolf D. (1985). Otolithi piscium. In Schultze H.P. (ed.), *Handbook of Paleoichthyology*, Gustav Fischer Verlag, Stuttgart, 10: 145 pp.
- Nolf D. & Brzobohaty R. (1994). Fish otoliths as paleobathymetric indicators. *Paleontologia i evolucion*, 24(25): 255-264.
- Nolf D. & Brzobohaty R. (2004). Otolithes de poissons du Miocène inférieur piémontais. *Rivista Piemontese di Storia Naturale*, 25: 69-118.
- Nolf D. & Cappetta H. (1989). Otolithes de poissons pliocènes du Sud-Est de la France. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, Sciences de la Terre*, 58 [1988]: 209-271.
- Nolf D. & Cavallo O. (1994). Otolithes de poissons du Pliocene inférieur de Monticello D'Alba (Piemont, Italie). *Rivista Piemontese di Storia Naturale*, 15: 11-40.
- Nolf D. & Girone A. (2000). Otolithes de poissons du Pléistocene inférieur (Santernien) de Morrona (Sud Est de Pisa). *Rivista Piemontese di Storia Naturale*, 21: 3-18.
- Nolf D. & Girone A. (2006). Otolithes de poissons du Pliocene inférieur (Zanclean) des environs d'Alba (Piemont) et de la cote ligure. *Rivista Piemontese di Storia Naturale*, 27: 77-114.
- Nolf D., Mané R. & Lopez A. (1998). Otolithes de poissons du Pliocene inférieur de Papiol, pres de Barcelone. *Palaeovertebrata*, 27 (1-2): 1-17.
- Nolf D. & Steurbaut E. (1983). Révision des otolithes de téléostéens du Tortonien Stratotypique et de Montegibbio (Miocène supérieur d'Italie septentrionale). *Mededelingen van de Werkgroep voor Tertiaire en Kwartaire Geologie*, 20 (4): 143-197.
- Schwarzshans W. (1978). Otolithen aus dem Unter-Pliozän von Süd-Sizilien und aus der Toscana. *Berliner Geowissenschaftliche Abhandlungen, Reihe A: Geologie und Palaeontologie*, 8: 1 – 52.
- Smith D.G. (1989). Family Congridae. In Bohlke E.B. (ed.), *Fishes of the Western North Atlantic. Memoir Sears Foundation for Marine Research*, 1 (9): 460-567.
- Steurbaut E. (1984). Les otolithes de téléostéens de l'Oligo-Miocène d'Aquitaine (Sud-Ouest de la France). *Palaeontographica A*, 186 (1-6): 1-162.

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