Palaeogeography, Palaeoclimatology, Palaeoecology 471 (2017) 134–143

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

journal homepage: www.elsevier.com/locate/palaeo

Fish otoliths in superficial sediments of the Mediterranean Sea

Chien-Hsiang Lin [a,*], Marco Taviani [b,c,d], Lorenzo Angeletti [b], Angela Girone [a], Dirk Nolf [e]

[a] Dipartimento di Scienze della Terra e Geoambientali, Università degli Studi di Bari Aldo Moro, Via E. Orabona, 4, 70125 Bari, Italy
[b] ISMAR-CNR, Bologna, Via Gobetti 101, 40129 Bologna, Italy
[c] Stazione Zoologica Anton Dohrn, Villa Comunale, 80121 Napoli, Italy
[d] Biology Department, Woods Hole Oceanographic Institution, 266 Woods Hole Road, Woods Hole, MA 02543, USA
[e] Institut Royal des Sciences Naturelles de Belgique, 29, Rue Vautier, 1000 Brussels, Belgium

ARTICLE INFO

Article history:
Received 26 September 2016
Received in revised form 7 December 2016
Accepted 18 December 2016
Available online 23 January 2017

Keywords:
Pleistocene
Recent sea bottom
Taphonomy
Taxonomy
Ecology
Biogeography

ABSTRACT

Otoliths represent a significant biogenic carbonate component in marine sediments that may provide valuable information for paleoenvironmental and biogeographic reconstructions. In spite of their importance, relatively little is still known about the taxonomic composition, abundance and early taphonomic characteristics of recent otolith death-assemblages, which would add to their value to interpret situations in the geological record. Here we present data on the distribution of fish otoliths from bottom sediments collected in the central Mediterranean Sea ranging in depth from 51 to 3300 m. The preservation of otoliths ranges from fresh semi-translucent (white) specimens to dull-coloured (dark) ones, although whitish specimens are predominant across all the samples. This diversity in lustre and colour and at times texture reflects the degree of early taphonomic processes undergone by these aragonitic bodies *post-mortem* under submarine conditions, never being exposed to diagenetic processes on-land. In general, a correlation with depth is observed, with best preservation observed in otoliths sampled at depths <500 m, while more degraded specimens occur deeper. In the upper depth range (<500 m), a substantial number of benthic and benthopelagic taxa is counted with respect to mesopelagic taxa, which prevail from 500 down to 3300 m. The taxonomic composition and relative abundance of each taxon of otolith death-assemblages at various depths conform well to the distribution of related Mediterranean modern fish communities. The occurrence of pre-modern subfossil taxa in the death-assemblages is evidenced at some bathyal sites by the overwhelming presence of many highly-degraded (worn, chalky, opaque and patinated) otoliths and locally extinct species. This is the case of *Protomyctophum arcticum*, a mesopelagic myctophid absent in the modern Mediterranean Basin that represents an Atlantic Pleistocene 'cold guest' fish in the Pleistocene of this basin.

1. Introduction

Saccular fish otoliths represent a significant biogenic component of marine sediments although their major abundance is documented from the Cenozoic onwards (Nolf, 1985, 2013). They may at times even predominate in fossil assemblages, and this is especially true in hemipelagic and bathyal situations where other skeletal macrocomponents could be less represented in the sediments. Otoliths hold an important and independent role to achieve paleoenvironmental reconstructions since they are shed by mobile organisms from a variety of taxa living in different parts of the water column, from surface down to the benthic layer, in a wide bathymetric range and responding to a vast spectrum of salinity and oxygen content (e.g., Limburg et al., 2015). Besides their value as ecological indicators, these mineralized skeletal parts prove useful also as archives to unravel delicate ecological as well as oceanographic problems (e.g., Brickle et al., 2016; Iacumin et al., 1992; Zazzo et al., 2006). Finally, their ecostratigraphic value is also significant (Kotlarczyk et al., 2006).

Since otoliths are calcified as metastable aragonite and more rarely as vaterite (Gauldie, 1993; Kalish, 1993), they are easily and quickly exposed to post-mortem taphonomic processes that could alter their texture until their ultimate dissolution (Cherns and Wright, 2009; Flügel, 2010). Otolith survival in the fossil record, therefore, largely results from certain ambient conditions, such as burial in fine-grained sediments. This explains also why fossil otoliths are more commonly found in muddy and mudstone lithologies deposited in outer-shelf to bathyal conditions (e.g., Brzobohatý et al., 2003; Girone et al., 2010; Lin et al., 2016b; Nolf and Steurbaut, 2004; Radwańska, 1992; Schwarzhans, 1985; Stringer, 1998), although they have been reported as abundant also from considerably shallower settings, such as the Eocene shallow neritic otolith assemblages from the Anglo-Belgian-Parisian Basin (Nolf, 1972; Nolf and Cappetta, 1976; Nolf and Lapierre,

* Corresponding author.
E-mail address: r97b41028@gmail.com (C.-H. Lin).

http://dx.doi.org/10.1016/j.palaeo.2016.12.050
0031-0182/

1979; Priem, 1906; Stinton, 1975) and the US Gulf Coast (Müller, 1999; Nolf and Stringer, 2003; Stringer, 2016).

All fossil assemblages are time-averaged (Kidwell, 2002; Kidwell and Flessa, 1995), and, in the case of otoliths, these are spatial-averaged vertically as well, since skeletal parts are added from different depths of the water column and from the sea-bottom. Furthermore, such otolith assemblages not necessarily reflect the ambient fish population only, since extra material may have been introduced into the burial place by a number of processes, both biological (feeding) and physical (turbidites, currents) (Nolf, 1985; Nolf and Brzobohaty, 1992; Schwarzhans, 2004). Therefore, there are a number of caveats to consider when approaching the study of recent death-assemblages with the scope of inferring valuable ecological information of paleobiological soundness. In general, the basic tenet of solving with confidence the paleoenvironment stays with the taxonomic resemblance between fossil and modern populations and upon the actualistic assumption of comparable ecological requirements between modern and fossil representatives. The reliability of such approach obviously diminishes with increasing geological age as well as with the intensity of taphonomic processes undergone by any fossil fauna (e.g., Behrensmeyer et al., 2000; and Elder and Smith, 1984, 1988 for fish remains).

A number of otolith-based paleoecological and biogeographic reconstructions could be tracked in the literature regarding the Cenozoic marine record of the Mediterranean region (e.g., Agiadi et al., 2011, 2013; Bassoli, 1906; Carnevale et al., 2006; Girone, 2000, 2003, 2005, 2007; Girone et al., 2006, 2010; Hoedemakers and Batllori, 2005; Lin et al., 2015, in press; Nolf et al., 1998; Nolf and Cappetta, 1988; Reichenbacher and Cappetta, 1999). Little is known, however, regarding the distribution of otoliths in superficial sediments of the Mediterranean Sea, which can further assist any paleoecological reconstruction in the basin since valuable information can be gained through the simple comparison of fossil assemblages with modern counterparts of known ecological niche. Here we present the first comprehensive study of otolith death-assemblages from bottom sediments in the Mediterranean Sea over a consistent bathymetric range from subtidal to bathyal depths. Our exercise sets a Mediterranean baseline to investigate the temporal relationships between otolith occurrence in sediments and fish distribution in the most recent past, in analogy with the scant literature on the subject (e.g., Elder et al., 1996; Gaemers and Vorren, 1985; Lin, 2016; Lin et al., 2016a; Schwarzhans, 2013, with references therein). Goals of this study are the evaluation of the ecological consistency between time-averaged death-assemblages and present fish distribution in the Mediterranean and to provide some qualitative information on taphonomy of otoliths under submarine conditions. This study offers the unique possibility to check the sea bottom otolith assemblages with respect to the formidable biogeographic changes that the Mediterranean fish population is experiencing at dramatic pace because of invasive species and meridionalization process (Azzurro, 2008; Galil, 2000; Kalogirou et al., 2012).

2. Materials and methods

2.1. Sediment sampling and otolith preparation

Sediments analyzed in this study for their otolith content are from a part of the marine sample collection stored in the repository of the Institute of Marine Sciences, National Research Council (ISMAR-CNR) in Bologna, Italy, formerly Laboratorio di Geologia Marina. Such samples were collected during several oceanographic cruises since the early '70s of the past century (Sartori, 1977) up to present. The large majority of samples was obtained by means of modified Van Veen grabs and chained geological dredges carried out onboard R/V *Bannock*. The rest were obtained by a few Van Veen large volume grab stations collected in 2014 by R/V *Urania* (cruise COCOMAP14). The area taken into consideration is a large sector of the central Mediterranean Sea and includes Tyrrhenian, Ionian and Adriatic Sea sites (Fig. 1, Table 1).

A total of 49 samples has been analyzed in the present study (Table 1, Appendix 1). Samples were weighed dry, and then two 50 g-subfractions per sample were taken and stored separately for archive purpose, except for samples from cruises T73 and COCOMAP14. Sediment samples were then wet-sieved over a 500 μm-mesh screen. All the otoliths were picked out from the 500 μm residue and grouped into two classes, i.e., identifiable and unidentifiable, irrespective to their preservation state. Whenever possible, otoliths have been identified at species level. The unidentifiable class is largely composed by juvenile and poorly-preserved specimens. The study material is deposited in the Institut royal des Sciences naturelles de Belgique, Brussels, Belgium (IRSNB) and a voucher collection is hosted in the ISMAR-CNR repository in Bologna.

2.2. Quantitative analyses

Otolith abundance was computed as otolith count/sediment weight (kg), and then plotted versus depth and locality. The otoliths and taxa were counted to indicate abundance and richness (Lin et al., 2016a).

Each taxon is recorded with its depth range to evidence distribution versus bathymetry. For convenience, samples $<$500 m depth were pooled together in each 100 m interval, while samples $>$500 m depth were pooled together in each 500 m interval. Taxa were further divided into pelagic and benthic-benthopelagic groups and treated separately to assess the dominance of any given taxon (see Lin et al., 2016a for details).

2.3. Multivariate statistics

The multivariate analysis was based upon the use of the PAST software; the UPGMA algorithm and the Correlation distance coefficient have been adopted for this study (Hammer et al., 2001). The otolith count of each taxon was transformed as a proportion to the total otolith count within each interval. Hierarchical cluster analysis was performed to classify all the intervals in order to find out how they are grouped; this analysis was based on both the taxonomic composition (quality) and relative abundance (quantity) within any given interval, in order to compare their similarity and difference with respect to the depth. Following Lin et al. (2016a), analyses based on all-taxa (pelagic plus benthic-benthopelagic taxa) and on benthic-benthopelagic taxa alone were conducted.

3. Results

3.1. Preservation status

An in-depth study of otolith taphonomy would unavoidably require a set of complex petrographical and chemical analyses complemented by detailed optical and SEM microscopy inspections to evaluate mineralogical and chemical compositional changes (Dufour et al., 2000), dissolution patterns and other circumstances affecting the overall modification of the original otolith sample. This approach is beyond the purposes of the present paper, and we limit our observations to a few qualitative features.

As noted by Schwarzhans (2013), the appearance and coloration of an otolith change during the fossilization process. The freshest otoliths display a semi-translucent lustre, turning progressively dull white with time. Otoliths could get yellowish, greyish, or brownish hues, in response to specific situations, such as the type of the embedding sediment or in response of their prolonged exposure on the sea bottom. All such situations are observed in the otolith specimens examined in this study, providing an indirect clue about relative aging of taphonomic processes, although only direct radiometric dating, when applicable, could in principle provide unquestionable ages. Otoliths also display considerable differences in their texture up to highly degraded chalky specimens and dark-patinated ones found especially at deeper stations.