



# Mesopelagic Fish Size Reduction in Response to the Messinian Salinity Crisis

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## Abstract

The Messinian salinity crisis (MSC) has already strongly affected the Mediterranean ecosystems from the beginning of the Messinian. Here, the Tortonian, Messinian, and Zanclean size distributions of the most common mesopelagic fish species are compared in order to test the hypothesis that the MSC impacted the size and hence the biomass of Mediterranean mesopelagic fish in the late Miocene. The results suggest that, with appropriate data, a size reduction can be detected during the Messinian that is possibly connected to the MSC restriction of Mediterranean–Atlantic connection. Indeed, these preliminary data suggest an increase otolith size of *Ceratoscopelus* in the Zanclean.

## Keywords

Otolith • Miocene • Size distribution • Zanclean • Mediterranean

## 1 Introduction

In the Late Miocene, the Mediterranean experienced strong environmental disturbances due to the restriction of the basin's connection to the Atlantic Ocean from the Tortonian/Messinian boundary (7.24 Ma) and the culmination toward the Messinian salinity crisis (MSC; 5.97–5.33 Ma) [1]. Fully marine conditions were established

once more at the beginning of the Pliocene [2]. These events had a profound effect on the marine ecosystems manifesting through massive endemism, extinctions and the final re-introduction of the marine species [3].

Fish respond to the environmental stress through various mechanisms including the distribution range shifts and the lifestyle adaptations [4]. Here, we test the hypothesis that mesopelagic fish size was reduced as a physiological response to the Late Messinian restricted oceanographic conditions in the Mediterranean by comparing the size distribution of the selected species as reflected in the fossil assemblages of the pre-evaporitic Messinian against those for the same species in the Tortonian and the Pliocene.

## 2 Materials and Methods

The size distribution of the typical marine mesopelagic fish species from the Tortonian until the Messinian is obtained by measuring the otolith length of the adult specimens found in six eastern Mediterranean localities (Fig. 1, Table 1).

Otoliths are the aragonitic incremental stone-like structures in the inner ear of Teleost fish that facilitate sound and balance perception [9]. They have species-specific morphology and are commonly found in marine and lake sediments thereby forming a valuable tool for the reconstruction of the past fish faunas [10]. The Otolith length was used here as a direct measure of the fish length and biomass as evidenced by numerous previous studies [11]. Due to space restrictions, only the results for four species are presented here.

## 3 Results

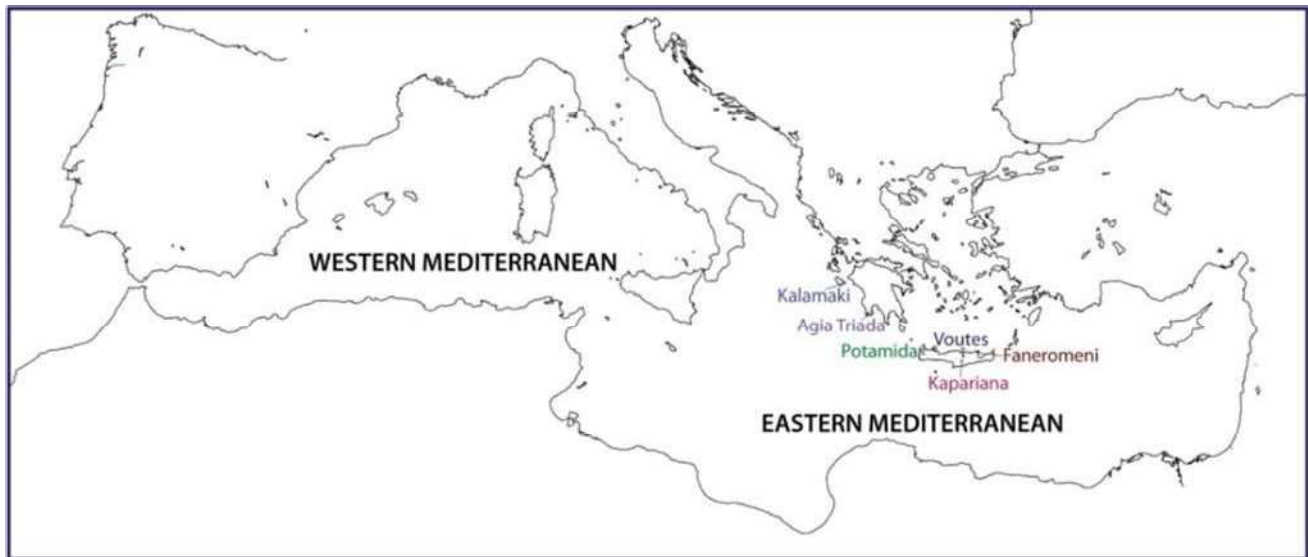
The results pertaining to the most abundant and common species in all assemblages, *Ceratoscopelus maderensis*, support the initial hypothesis. Indeed, both Tortonian and

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**Fig. 1** Map of the Mediterranean Sea with the localities where the material for present analysis was found. Potamida [5], Kapariana, Faneromeni, Kalamaki [6], Voutes [7], Agia Triada [8]

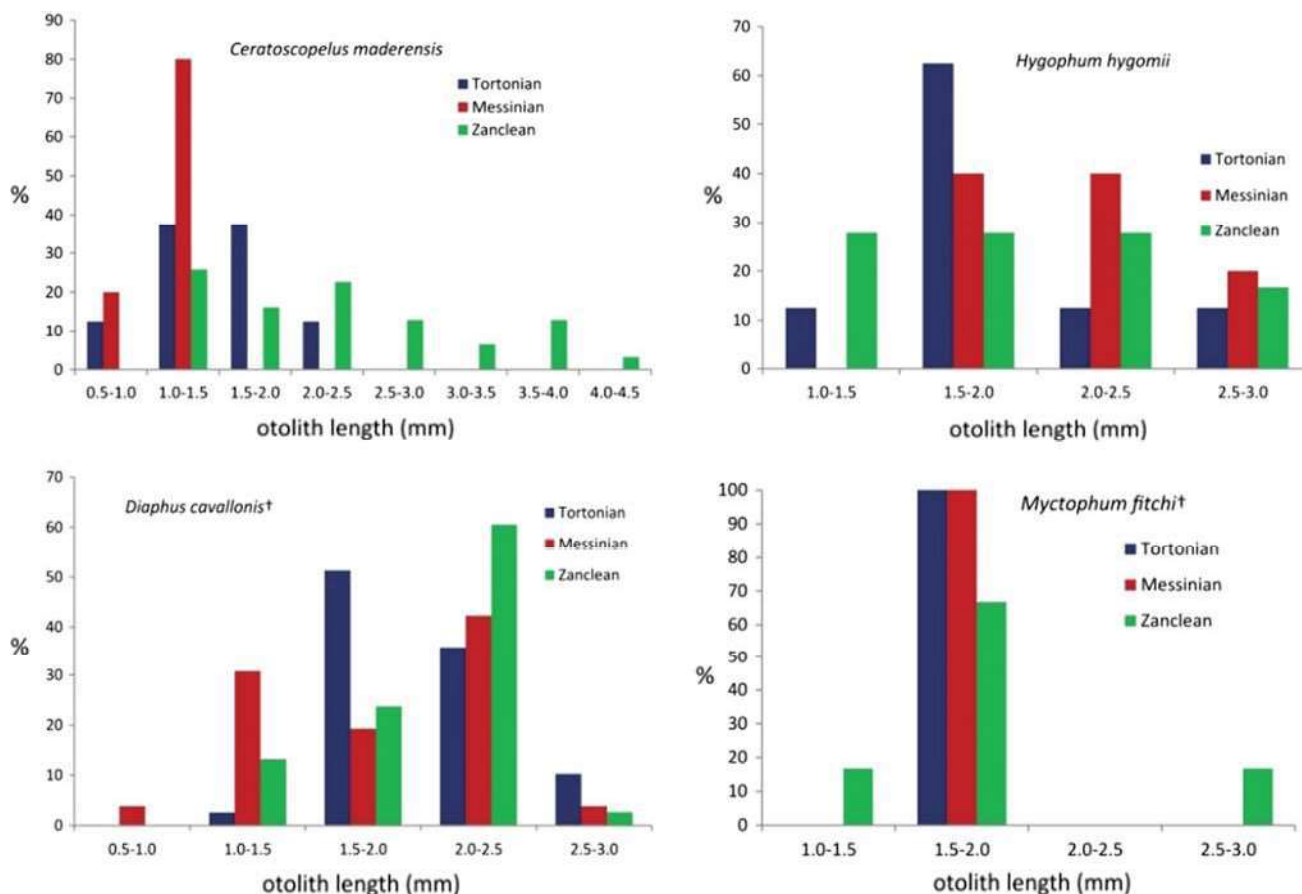
**Table 1** The measured otolith material of the four species presented here

| Species                          | Locality    | Age (Ma)  | Number of specimens |
|----------------------------------|-------------|-----------|---------------------|
| <i>Ceratoscopelus maderensis</i> | Potamida    | 7.36–6.72 | 10                  |
| <i>Ceratoscopelus maderensis</i> | Kapariana   | 6.83–6.64 | 3                   |
| <i>Ceratoscopelus maderensis</i> | Faneromeni  | 6.70–6.64 | 1                   |
| <i>Ceratoscopelus maderensis</i> | Agia Triada | 5.00      | 1                   |
| <i>Ceratoscopelus maderensis</i> | Voutes      | 3.80–3.64 | 30                  |
| <i>Diaphus cavallonis</i>        | Faneromeni  | 7.58–6.72 | 20                  |
| <i>Diaphus cavallonis</i>        | Potamida    | 7.51–6.72 | 37                  |
| <i>Diaphus cavallonis</i>        | Kalamaki    | 6.26–6.09 | 8                   |
| <i>Diaphus cavallonis</i>        | Voutes      | 3.80–3.64 | 38                  |
| <i>Hygophum hygomii</i>          | Potamida    | 7.36–6.72 | 12                  |
| <i>Hygophum hygomii</i>          | Faneromeni  | 7.24–6.83 | 1                   |
| <i>Hygophum hygomii</i>          | Agia Triada | 5.00      | 1                   |
| <i>Hygophum hygomii</i>          | Voutes      | 3.80–3.64 | 17                  |
| <i>Myctophum fitchi</i>          | Faneromeni  | 7.58–7.45 | 1                   |
| <i>Myctophum fitchi</i>          | Potamida    | 7.36–6.72 | 3                   |
| <i>Myctophum fitchi</i>          | Voutes      | 3.78–3.66 | 6                   |

Zanclean specimens are larger than Messinian specimens of this species (Fig. 2). Furthermore, in the Zanclean, the specimens are much larger than the Tortonian ones as well. The same appears to be true for the extinct species *Diaphus cavallonis* although the signal is not as clear as it may be expected. The results for *Hygophum hygomii* and *Myctophum fitchi* are inconclusive probably due to the limited number of the examined specimens (Table 1) (Fig. 2).

## 4 Discussion

Fish size reduction is a well-known physiological response to the environmental disruptions such as the modern climate change. The observations reported here support the validity of the initial hypothesis. However, the results differ depending on the number of the examined specimens and on



**Fig. 2** Otolith size distributions for four very common mesopelagic fish species from the Tortonian until the Zanclean † indicates currently extinct species

whether or not the species was endemic such as *Myctophum fitchi* and *Diaphus cavalloni*, which were probably better-adapted to the Mediterranean restricted conditions than *Ceratoscopelus maderensis* that has a worldwide distribution until today.

## 5 Conclusion

In order to test the hypothesis that the restricted oceanic circulation possibly increasing the stratification and/or the salinity in the Mediterranean just before the MSC onset affected the mesopelagic fish by inducing a reduction in their size, we compared otolith size distributions from typical mesopelagic fish. The results support the validity of this hypothesis, although they seem to vary depending on the number of the measured otoliths and the distribution and ecology of the examined species. Nevertheless, this hypothesis deserves a further inquiry by examining more species and material.

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