

# Development of Mediterranean cold-water coral ecosystems since the late glacial

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**Abstract:** Based on all available ages obtained on the dominant framework-building scleractinian cold-water coral species *Lophelia pertusa* and *Madrepora oculata* collected in the entire Mediterranean Sea (compiled from literature review and own studies), we discuss the basin-wide occurrences of these species emphasising their spatial and temporal development during the late glacial and Holocene. We show that these species became abundant since the deglacial (<14ka) and their Late Pleistocene and Holocene proliferation or demise significantly differed between the eastern and western Mediterranean Sea sub-basins, depending on regional (sub-basin-related) environmental conditions, like the availability of food or bottom water oxygenation. In combination with the corals' preference to settle in intermediate depths, a strong relationship between Mediterranean cold-water coral development and intermediate water mass circulation is suggested, though resulting regionally in different parameters influencing the corals' prosperity.

**Key words:** Cold-water corals, Mediterranean Sea, Holocene, Levantine Intermediate Water

## INTRODUCTION

Cold-water corals are common in the temperate Mediterranean Sea, where they currently thrive in intermediate water depth. Numerous cold-water coral carbonate structures on the seafloor indicate their prosperity in the past. Former studies dealing with the past development of cold-water corals in this marginal sea discussed their occurrences in a rather generalised manner for the entire basin (e.g. McCulloch et al., 2010) or trace their appearance through time on a locally restricted setting (e.g. Malinverno et al., 2010, Fink et al., 2012, 2013).

As the Mediterranean sub-basins were affected by basically different events since the last glacial (e.g. anoxic formation of sapropel S1 in the east; variability of the inflow of Atlantic surface waters in the west), which resulted in different paleo-environmental conditions, this study outlines for the first time the prosperity of cold-water coral ecosystems on a regional sub-basin scale.

## DATA AND RESULTS

Eighty-one cold-water coral ages obtained on the reef-forming scleractinian coral species *Lophelia pertusa* and *Madrepora oculata* collected in the entire Mediterranean Sea were compiled from literature (references see caption of Fig. 1), and complemented by nineteen new radiocarbon ages of coral specimens sampled in the Alboran Sea and in the Strait of Sicily (Fig. 1). Becoming abundant in the deglacial (after ~14ka), cold-water corals seem to have thrived throughout the entire Holocene. However, by grouping the coral dates according to their sampling area (Alboran Sea, Strait of Sicily, Eastern and Western

Mediterranean Sea) distinct age cluster and regional differences appear.

## DISCUSSION

Whereas in the western Mediterranean Sea the initial deglacial cold-water coral growth was forced by increased primary production and well ventilated intermediate water masses prevailing during the formation of the so-called organic rich layer 1 (ORL1, ~14.5 to 8.2ka), favourable conditions for cold-water corals in the eastern basin were established only during the Younger Dryas (YD, 12.9 to 11.7ka). However, in the Alboran Sea, as the westernmost part of the Mediterranean Sea, the YD is characterised by an absence of cold-water corals probably induced by enhanced inflow of Atlantic waters during this cold event, which led to environmental instabilities.

During the deposition of sapropel S1 in the deep eastern Mediterranean Sea, dysoxic conditions prevailing in intermediate water depths caused a temporal coral demise in the eastern basin (~11.5 to 5.9ka). Moreover, the impaired formation of both, Levantine Intermediate Water (LIW) in the east (during S1 deposition) and Winter Intermediate Water in the west (after ORL1 deposition), had a negative impact on the prosperity of western Mediterranean coral ecosystems during the Mid Holocene (8.2- ~6ka).

Along with the onset of LIW formation (~ 6ka) cold-water corals re-colonised the entire Mediterranean Sea and thrived there throughout the Late Holocene until today.

## CONCLUSIONS

This detailed comparative study between the western and eastern Mediterranean sub-basins indicates that the development of cold-water corals during the late glacial and Holocene relies on a rather complex pattern, precluding any generalised basin-wide approach to describe their occurrence through time. Their proliferation or demise rather depends on different regional (sub-basin-related) environmental conditions, mainly driven by the intensity of the intermediate water circulation, which is linked to climatic conditions.

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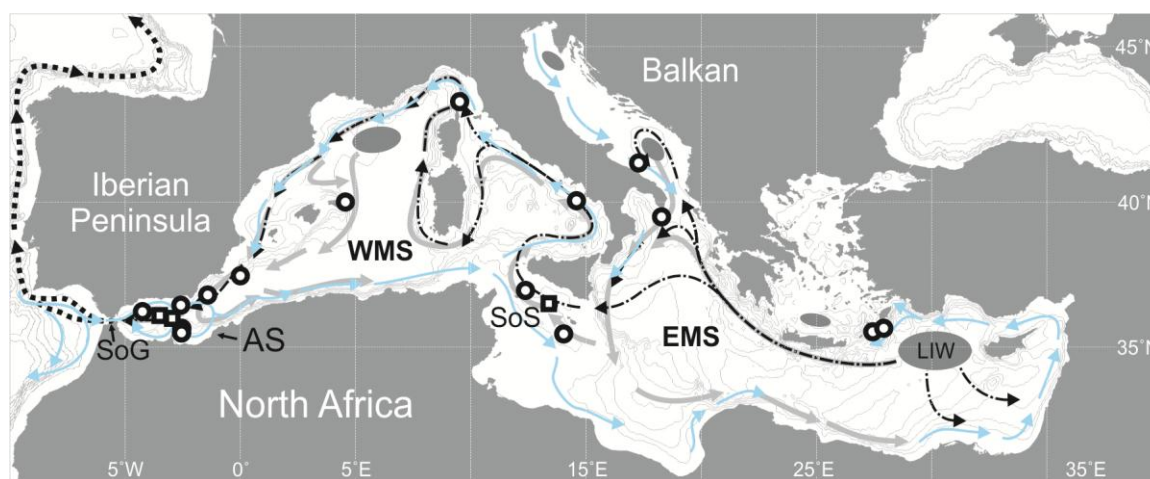


FIGURE 1: Overview map of the Mediterranean Sea. Displayed is the general ocean circulation pattern in the Mediterranean Sea (modified after Millot and Taupier-Letage, 2005). Blue arrows: Surface water circulation. Dashed-dotted black arrows: Intermediate water circulation. Thick grey arrows: Deep water circulation. Dotted black arrows: Mediterranean Outflow Water (MOW). Highlighted in grey are the areas of modern dense (deep- and intermediate) water formation. Displayed are the sampling sites of this study (squares) and reference locations (circles; data from Schröder-Ritzrau et al., 2005; Malinverno et al., 2010; McCulloch et al., 2010; Angeletti and Taviani, 2011; Frank et al., 2011; Taviani et al., 2011; Fink et al., 2012; 2013. Abbreviations: AS-Alboran Sea, EMS-Eastern Mediterranean Sea, WMS-Western Mediterranean Sea, SoS-Strait of Sicily, SoG Strait of Gibraltar.