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The genus *Asterodinium* (Dinophyceae) as a possible biological indicator of warming in the western Mediterranean Sea

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The presence of two dinoflagellate species of the genus *Asterodinium*, which are a priori representative of warm waters, is reported for the first time in the western Mediterranean Sea. *Asterodinium libanum* was identified in the Bay of Villefranche-sur-Mer (Ligurian Sea), while *Asterodinium gracile* is reported in the Tyrrhenian Sea. These findings are discussed in the context of the progressive warming of Mediterranean waters.

Since 1960, a monotonic increase of the temperature has been recorded in the Mediterranean waters, apparently as a result of the combined global warming and local anthropogenic effects (Béthoux et al., 1990; Turley, 1999). Several studies have shown that the marine biodiversity of the Ligurian and Tyrrhenian basins is sensitive to climate change, with tropical species appearing since 1985 (Francour et al., 1994; Astraldi et al., 1995). However most of the studies on changing biodiversity in the Mediterranean Sea, deal with macroscopic species such as fish, invertebrates or macroalgae (Bianchi & Morri, 2000).

During the last century, at least 16 exotic phytoplankton species have become common in European Atlantic waters (Elbrächter, 1999) with the establishment of thermophilic phytoplankton species in the North Sea (Nehring, 1998). However little is known about changes affecting the phytoplankton community of the Mediterranean Sea.

Asterodinium is a distinctive genus of unarmoured dinoflagellates; cells are dorsoventrally flattened, with two characteristic radiating elongate extensions from the hypotheca and three other arms from the epitheca; they present a well-developed nucleus and chloroplasts. The genus was initially reported from the tropical Indian ocean with the description of two species *Asterodinium gracile* and *A. spinosum* (Sournia, 1986). Later, *Asterodinium gracile* and the new species *A. libanum* were reported in Lebanese coastal waters (eastern Mediterranean Sea) (Abboud-Abi Saab, 1989).

The present study reports recent records of *Asterodinium* species in the western Mediterranean Sea and is suggested as possible biological indicator of warming.

Phytoplankton identification was performed as part of two studies. The first study was conducted over two years (1998–2000) at a permanent station (Station B) in the Bay of Villefranche-sur-Mer (Ligurian Sea, north-west Mediterranean Sea). The second study was performed as part of the PROSOPE cruise carried out in September 1999 aboard the RV 'Thalassa' from the Moroccan Atlantic coast to the eastern Mediterranean Sea (Figure 1). Unconcentrated seawater samples were preserved with Lugol's solution and kept in cold and dark conditions until analysis in the laboratory. Subsamples (50–100 ml) were allowed to settle for 24–48 h in Utermöhl chambers and observed by inverted light microscopy.

Three specimens of *Asterodinium libanum* Abboud-Abi Saab have been observed in the Bay of Villefranche-sur-Mer in September 1998 and September–October 1999 at 50 m depth. In September 1999, four individuals of *Asterodinium gracile* Sournia were recorded at four stations in the Tyrrhenian Basin and the Sicilian Strait, mostly in the 70–90 m layer (Figure 2).

The phytoplankton composition of the Ligurian Sea has been extensively investigated in the past. Halim (1960) reported the composition of dinoflagellates from a 3-y study (1952–1954) at the same Station B where we report the presence of *A. libanum* for the first time. The *Asterodinium* genus was described for the first time in 1972 but this genus is distinctive and easily identifiable, thus removing the possibility that Halim (1960) might have misidentified it. For example, Halim (1960) described six new species of *Histioneis*, a genus in the same size range as *Asterodinium* which is also preferentially found in the deep waters of the Bay of Villefranche.

The Tyrrhenian basin has also been intensively investigated, but most of the studies were performed in the Bay of Naples or coastal lagoons. These shallow and eutrophic environments seem to be unfavourable for the development of *Asterodinium* species.

Coinciding with the records of *A. gracile* in September 1999, a climatically-driven ecosystem disturbance was reported in the

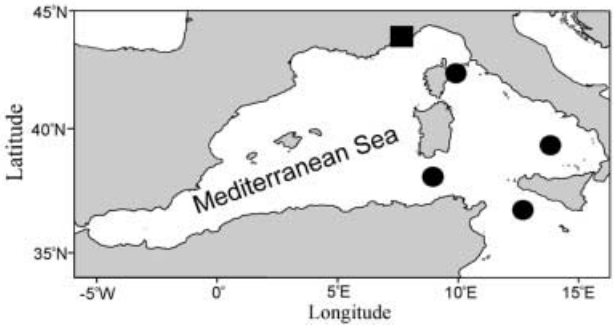

Figure 1. Location of the records of *Asterodinium* Sournia in the western Mediterranean Sea. ■, *A. libanum*; ●, *A. gracile*.

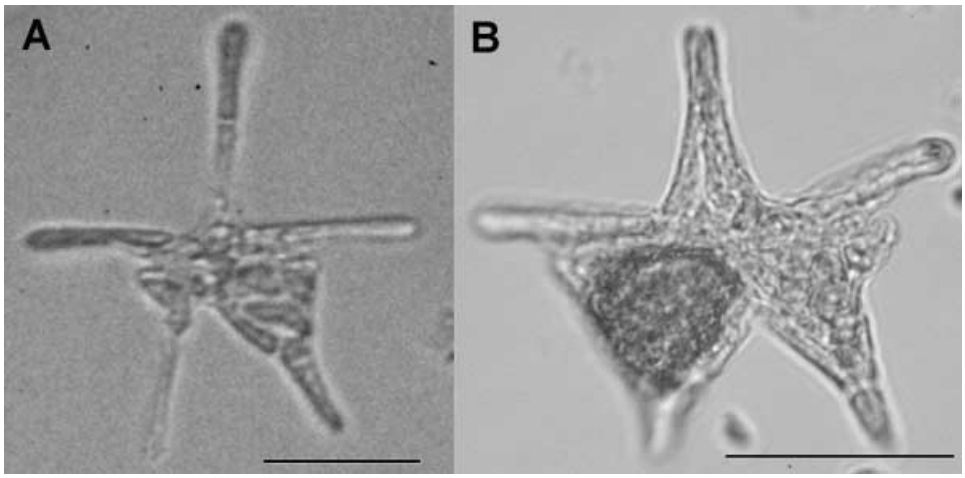

Figure 2. Light microscopy photographs: (A) *Asterodinium gracile* (×400) from the Tyrrhenian Sea; (B) *Asterodinium libanum* (×630) from the Bay of Villefranche-sur-Mer (Ligurian Sea). Scale bar: 20 μm.

north-western Mediterranean, with a deepening of the thermocline and an anomalous increase of summer sea surface temperatures (of 2–3°C); these changes resulted in marked mortality of sessile invertebrates (e.g. sponges and gorgonians) (Romano et al., 2000; Cerrano et al., 2000).

Seawater warming can affect the marine biota by a direct influence of temperature, causing changes in survival, reproductive success and dispersal pattern and an indirect influence due to the change of the ocean circulation patterns (Bianchi & Morri, 2000). Since the completion of the Suez Canal in 1869 and more recently with the reduction of salinity of Bitter Lakes, the introduction of tropical species directly through the Suez Canal or via ballast waters seems to be favoured (Halim, 1990). The progressive warming of the Mediterranean Sea, and possibly the 1999 thermal anomaly might have favoured the increase in abundance of warm-water species such as those of the *Asterodinium* genus.

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