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Neomeris annulata Dickie (Dasycladales, Chlorophyceae): a potential new invader from the Red Sea to the Mediterranean Sea

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Abstract – *Neomeris annulata* Dickie is reported for the first time from the Mediterranean Sea (Syria). The most probable hypothesis concerning the origin of these populations is a recent introduction from the Red Sea *via* the Suez Canal. The species is grazer-resistant due to the production of $CaCO_3$ and chemical defenses (sesquiterpenes), and the environmental conditions of the eastern Mediterranean are compatible with the temperature requirements of the species, so the further spread of *N. annulata* in the Mediterranean Sea is to be expected.

***Neomeris annulata* / Chlorophyceae / marine macroalgae / Syria / Mediterranean Sea / introduced species**

Résumé – ***Neomeris annulata* (Dasycladales, Chlorophyceae) nouvelle espèce potentiellement invasive de la Mer Rouge vers la Méditerranée.** *Neomeris annulata* Dickie est signalé pour la première fois en Méditerranée (Syrie). L'hypothèse la plus probable concernant l'origine de ces populations est une introduction récente à partir de la Mer Rouge *via* le Canal de Suez. L'algue est résistante au broutage grâce à la production de $CaCO_3$ et de défenses chimiques (sesquiterpènes) et les conditions environnementales de la Méditerranée orientale répondent aux exigences de température de l'espèce aussi pouvons nous nous attendre à une expansion de *N. annulata* en Méditerranée.

***Neomeris annulata* / Chlorophyceae / macroalgues marines / Syrie / Méditerranée / espèces introduites**

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INTRODUCTION

As part of the RAC/SPA and State Ministry for the Environmental Affairs of Syria Programme '*Development of Marine and Coastal Protected Areas in Mediterranean Region*' (MedMPA Programme) carried out along the coast of Syria, a species of the tropical genus *Neomeris* J.V. Lamouroux (1816) has been discovered in the region of Tartus. This represents the first record of this genus for the Mediterranean Sea. In the present study, the material is identified and described, the ecology of the Mediterranean populations is given, and their possible origin is considered. The possibility of further spread of this species is discussed.

MATERIAL AND METHODS

Two scientific campaigns (8-15 November 2002 & 1-18 August 2003) were carried out along the coast of Syria. In the localities investigated between Ras El Samra in the north and Tartus in the south, *Neomeris* populations were observed on the 14th and 15th of August 2003, at Arwad Island (34° 52' N, 35° 51' E), the only island in Syria (Fig. 1). Located 3 km from Tartus, this small island, less than 1 km in diameter, is wholly occupied by an old attractive city with a fishing, yacht and small trade harbour. Tartus (*ca.* 160 000 inhabitants) is the second largest harbour of Syria next Lattakia. The city has known a substantial growth over the recent years, mainly through exchanges with Lebanon. In August, sea water temperatures ranged from 31°C in surface to 24°C at 63 m deep. Material was collected by snorkelling or scuba-diving and preserved in buffered 5% formaldehyde-seawater. The fixed material was studied under binocular and light microscopes. Specimens of *Neomeris* were sorted and sectioned manually with a razor blade after treatment with diluted HCL solution. Photomicrographs were made using a Coolpix 995 Nikon® digital camera and an Optiphot-2 Nikon® light microscope. The Mediterranean specimens (locality: Arwad Island, Tartus, Syria; date: 14.viii.2003; depth: 2-15 m), dried (Reference: H7199) or preserved in buffered 5% formaldehyde-seawater (Reference: H7200), were deposited in the Herbarium Verlaque, COM, Marseille, France. The Mediterranean collection was compared with an exsiccata from St. Georges Island, Bermuda (no. 49-2053, *A.J. Bernatowicz,* 17.viii.1949) deposited in the Herbarium Huvé, COM, Marseille.

RESULTS

Description of the Mediterranean material

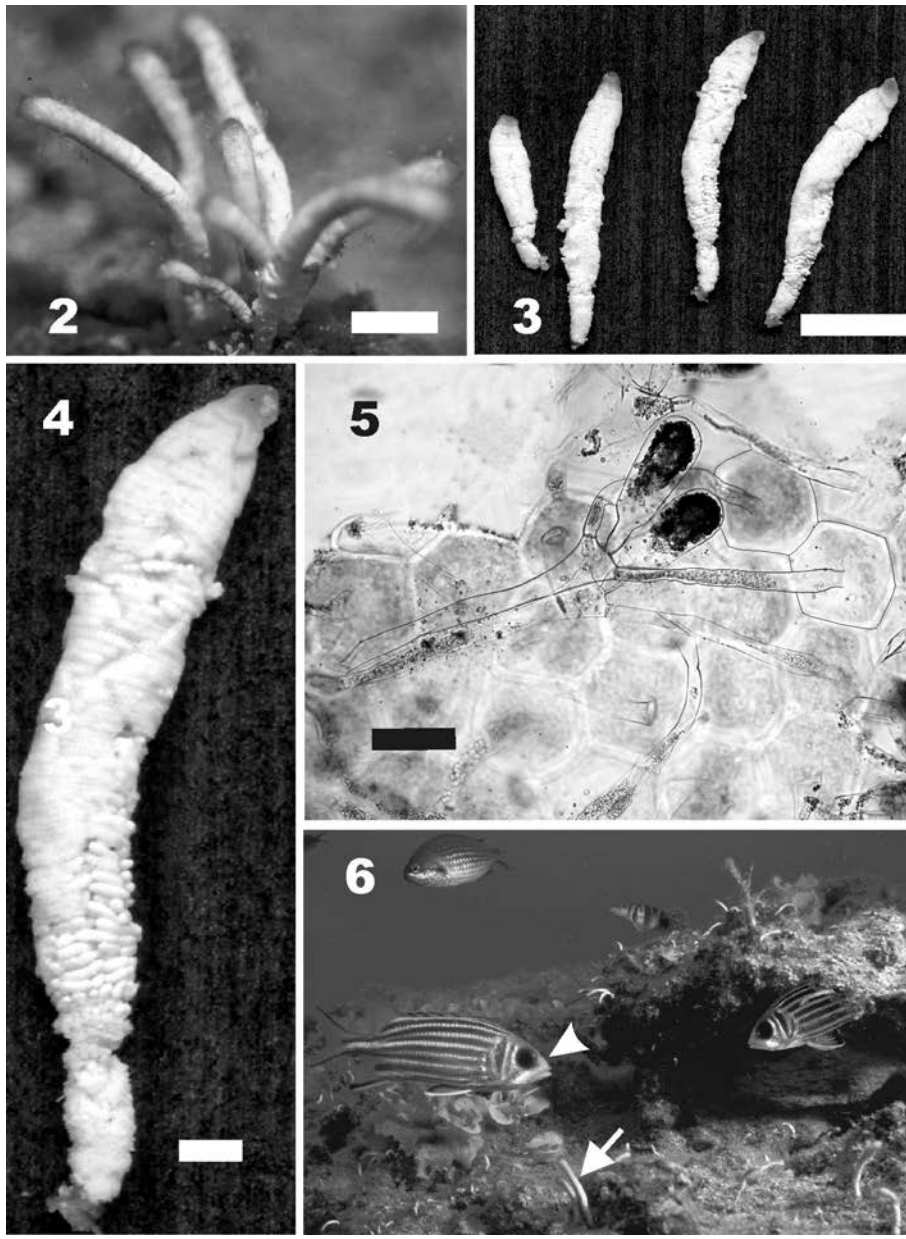
Gregarious plants are sub-cylindrical, 8-25 mm in height and 2 mm in diameter; the thallus is calcified strongly below, less heavily toward the yellowish green apex (Figs 2-4); primary branches are in successive whorls; each primary lateral segment is 13-20 times as long as wide and branches into two secondary segments that expand to form a cortex of pentagonal or hexagonal capitate ends in

Fig. 1. Mediterranean and Red Sea localities of *Neomeris annulata* Dickie: Tartus (Syria, present study), Al Ghardaqah (Egypt; Nasr, 1947; Papenfuss, 1968) and Sinai Peninsula (Lipkin, 1985).

surface view; obovoid or pyriform gametophores develop at the apices of primary segments and are guarded on both sides by the secondary segments with capitate ends (Fig. 5); they are laterally strongly coherent by their calcareous encrustation, thereby giving the plant a transversely annulate appearance in the lower fertile parts; decalcified gametophores with stalks are 65-75 μm in diameter and 154-182 μm long.

Habitat

The alga grows on rock between 2 and 15 m depth, in sunny (sub-horizontal substrates) and shaded places (vertical substrates), in association with *Amphiroa* sp., *Corallina elongata* Ellis *et* Solander, *Jania* sp., *Liagora* sp., *Padina*



Figs 2-6. *Neomeris annulata* Dickie (H7199, Arwad Island, Tartus, Syria**,** 14.viii.2003, 2-15 m deep). **2.** *N. annulata* at the Arwad Island. **3-4**. Habit. **5.** Detail of decalcified primary branches, gametophores and capitate secondary branches. **6**. Shallow photophilic communities of Arwad Island with *N. annulata* (arrow), *Padina* spp. and the Lessepsian fish *Sargocentron rubrum* (Forsskål, 1775) (arrowhead). Scale bars = 5 mm (2); 10 mm (3); 2 mm (4); 100 µm (5).

boergesenii Allender *et* Kraft, *Padina pavonica* (Linnaeus) Thivy, *Sargassum vulgare* C. Agardh and *Stypopodium schimperi* (Buchinger *ex* Kützing) Verlaque *et* Boudouresque (Fig. 6). It was also observed growing on the shells of the following molluscs: the Red Sea migrant *Chama pacifica* (Broderip, 1834) and the Mediterranean species *Hexaplex trunculus* (Linnaeus, 1758). The species was common around the island and locally grew gregariously in colonies.

DISCUSSION AND CONCLUSIONS

The eastern Mediterranean specimens of *Neomeris* are in good agreement with previous descriptions of *Neomeris annulata* Dickie (Howe, 1909; Nasr, 1947; Valet, 1969; Littler *et al.*, 1989; Berger & Kaever, 1992; Littler & Littler, 2000, 2003) and with the herbarium specimens from Bermuda. The distinctive features of *N. annulata* are the discontinuous transverse rows of calcification at the base of the plant, visible to the naked eye, the faceted cortex, and the oblong gametophores laterally coherent by calcification.

The presence of *Neomeris annulata* in the Mediterranean is postulated to be the result of a recent introduction, because its history agrees with the criteria proposed by Ribera & Boudouresque (1995): (1) in the Mediterranean Sea, the species had never been previously observed; (2) the first Mediterranean populations are very confined (Arwad Island) and close to potential sites of introduction (Tartus and Arwad Harbours and berthing facilities of cargo ships). Moreover, it grows in association with several other introduced organisms: *S. schimperi, P. boergesenii*, *C. pacifica* and the fish *Sargocentron rubrum* (Forsskål, 1775), which are regarded as Lessepsian species (Red Sea species introduced into the Mediterranean Sea *via* the Suez Canal) (Verlaque & Boudouresque, 1991; Bitar *et al.*, 2000; Golani *et al.*, 2002; Zenetos *et al.,* 2003). Syria lies within the region of maximum occurrence of Lessepsian species in the Mediterranean (Por, 1990; Verlaque, 1994; Boudouresque, 1999). Consequently, the most probable way of introduction is via the Suez Canal, either directly with the current or transported by ships as fouling, in ballast waters or fixed on animals attached to the hulls (e.g. molluscs).

In tropical seas, *Neomeris annulata* grows on various hard substrata (rocks, coral and shell fragments, mangrove roots and solid substrates over the sandy bottoms), both in sunny and shaded places, from the intertidal zone (in tide pools, near the low water mark) to depths as great as 30-50 m (Berger & Kaever, 1992; Littler & Littler, 2000, 2003). In the Mediterranean, *N. annulata* has been found on bed rock and shellfish, both on sub-horizontal and vertical substrates, between 2 and 15 m depth.

So far, *N. annulata* has not shown invasive behaviour at Arwad, although locally it grows gregariously. However, in its native regions, the species mostly grows in colonies and can be abundant over wide areas (Patel & Francis, 1970; Littler *et al.*, 1989; Berger & Kaever, 1992; Littler & Littler, 2000, 2003).

According to Hoek & Breeman (1990), there are two fundamentally different types of temperature boundaries for species, namely: 1) lethal boundaries and 2) growth and/or reproduction boundaries (Hutchins, 1947). Lethal boundaries are set by the species' ability to survive during the adverse season (i.e. the cold season for a warm-water species). Macroalgal species with tropical to warm

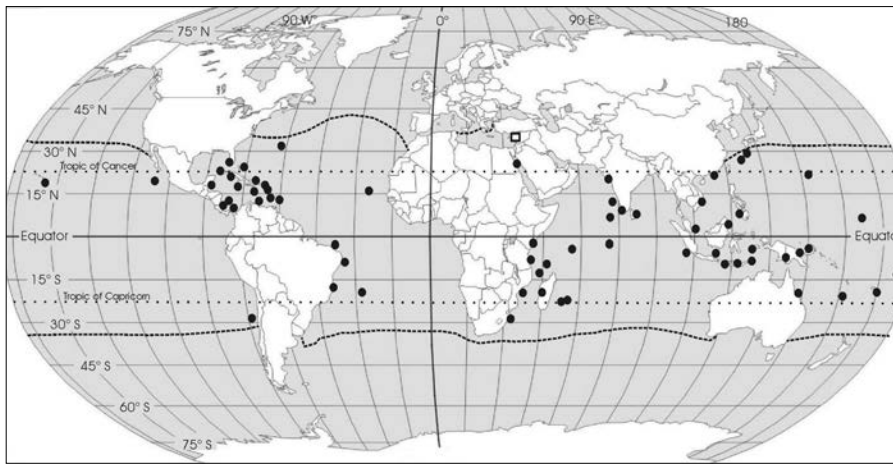


Fig. 7. World distribution of *Neomeris annulata* Dickie according to Howe (1909), Weber-van Bosse (1913), Svedelius (1924), Dawson (1961, 1962), Patel & Francis (1970), Oliveira-Filho (1977), Taylor (1977), Schnetter (1978), Norris & Bucher (1982), Tseng (1984), Berger & Kaever (1992), Tokuda *et al.* (1994), Silva *et al.* (1996), Coppejans *et al.* (2001), Leliaert *et al.* (2001), Costa *et al.* (2002), Guiry & Nic Dhonncha (2004) (dark circles) and present study (open square). Broken line: winter isotherm 15 °C (corresponding to the mean sea-surface temperature of the coldest month) according to Gorshkov (1976, 1979 & 1983).

temperate distribution patterns have a lower temperature tolerance limit of 10 to 15°C (Cambridge *et al.*, 1987, 1990a,b; Breeman, 1988; Pakker *et al.*, 1995) and the winter isotherm 15°C corresponding to the mean sea-surface temperature of the coldest month does correlate well with the world distributional limits of *N. annulata* (Fig. 7). So, the majority of the eastern Mediterranean, where the monthly mean sea-surface temperatures never fall below 15°C in winter, is consistent with the temperature requirement of *N. annulata.*

Moreover, *Neomeris annulata* has some characteristics already found in several invasive species of the Mediterranean (see Boudouresque & Verlaque, 2002). It is grazer-resistant because of the production of $CaCO_3$ and chemical defenses (sesquiterpenes) (Barnekow *et al.*, 1989; Berger & Kaever, 1992; Paul *et al.,* 1993; Meyer & Paul, 1995; Lumbang & Paul, 1996; Pennings *et al.*, 1996). During the vegetative phase, the Dasycladales are known to have a high capability for regeneration from the rhizoid due to the fact that the primary nucleus is always located in this part. Furthermore, Dasycladales can survive in dormancy when the environmental conditions are unfavourable (e.g.: water temperatures too cold) by retracting much of their cytoplasm into the rhizoidal part, which is located in the substratum (Berger & Kaever, 1992; Berger & Liddle, 2003). Finally, Dasycladales have high reproduction capability (Berger & Kaever, 1992).

In conclusion, *Neomeris annulata* can be regarded as a potential invader in the Mediterranean because it seems capable of colonizing, at least, the whole of the eastern Mediterranean basin, except perhaps for the coldest waters of the north-western Aegean Sea.

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