

Short communication

Extensive off-shore meadows of *Penicillus capitatus* (Udoteaceae, Chlorophyta) in the Canary Islands (eastern Atlantic Ocean)

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Abstract

Our finding of extensive off-shore meadows of *Penicillus capitatus* in the Canary Islands is the first direct observation of this species off the eastern Atlantic islands. Populations form scattered patches between 20 and 27 m depths, leading to denser meadows between 28 and 50 m depths. Total population coverage is ca 11.16 ha. Plant morphology, cover and density changed through the year. In September, well-developed individuals were dominant whereas the *Espera*-phase was dominant in January and March. The highest mean cover and density values were 75.42% cover and 1245 well-developed individuals m⁻², respectively. Specimens reach only 6 cm in height, which is shorter than individuals from the Mediterranean Sea and the Western Atlantic, and they often grow intermixed with species of *Caulerpa* and *Halophila decipiens*. It is difficult to determine whether this is a recent introduction, because the species may have been overlooked in the past. Nevertheless, the extensive meadows found in La Palma may be related to recent increases in sea water temperature, and the tropicalization of the marine flora and fauna of the Canary Islands detected during the past decade.

Keywords: Canary Islands; eastern Atlantic Ocean; off-shore meadows; *Penicillus capitatus*.

Penicillus capitatus Lamarck, the type species of the green algal genus *Penicillus* Lamarck, was initially accepted as endemic to tropical and subtropical western Atlantic coasts (Gepp and Gepp 1911, Børgesen 1913), where it usually occurs on sandy bottoms in depths up to 12 m in somewhat exposed to quite sheltered habitats (Taylor 1960, Littler and Littler 2000). Deep water populations, in depths up to 40 m,

have also been reported occasionally (Børgesen 1913). The morphology of plants varies considerably according to habitat conditions, and several *formae* have been described to accommodate the morphological variation observed from exposed to sheltered sites: f. *capitatus*, f. *elongatus* Gepp et Gepp (1911), and f. *laxus* Børgesen (1913), respectively. In the western Atlantic, the species is presently distributed from Florida to Brazil (Guiry and Guiry 2009).

A second species, *Penicillus mediterraneus* (Decaisne) Bornet was established by Bornet (1892) for specimens from France in the western Mediterranean Sea. This species was originally described as *Espera mediterranea* Decaisne (1842), but it was in fact a “filamentous” stage of *Penicillus*, and was thereafter referred to as the “*Espera*-phase” (Meinesz 1980) of *P. mediterranea*. Later, Huvé and Huvé (1964) transferred the species to *Penicillus capitatus* as f. *mediterraneus*, and finally, Friedmann and Roth (1977) suppressed this distinction, after comparing it with specimens from the western Atlantic. In the Mediterranean, *Penicillus capitatus* is presently distributed from Greece to Spain (Gallardo et al. 1993), where it is an infrequent species growing on sandy bottoms of sheltered places up to 5 m deep. Although the “*Espera*-phase” is present throughout the year, the adult phase is very rare and occurs only occasionally (Huvé and Huvé 1964, Meinesz 1980).

In the eastern Atlantic, *Penicillus capitatus* has been reported only twice, as *Penicillus capitatus* var. *mediterraneus*, growing in the low intertidal at Cadiz (Spain), a locality close to the Mediterranean Sea (Seoane-Camba 1965), and during a triangular dredge collection at 50–110 m depths on off-shore sandy and stony bottoms from Porto Santo, Madeira (Audiffred and Prud’homme van Reine 1985, Neto et al. 2001). The finding of extensive off-shore meadows of this species in the Canary Islands growing in habitats deeper than previously reported for the western Atlantic and Mediterranean populations is the first direct observation of populations of *P. capitatus* in the eastern Atlantic islands and presented an opportunity to document these unusual habitats among the scarped volcanic bottoms of the Canary Islands.

Observations were made by SCUBA diving off the north-eastern coast of La Palma (Canary Islands), on off-shore bottoms close to Puntallana (UTM WGM84 28R x:233634; y:3180911; Figure 1). The total extent of *Penicillus* populations was estimated by gvSIG 1.1.2. (gvSIG.gva.es) using maximal and minimal depth values obtained from perpendicular and longitudinal transects to the shore line. To estimate species abundance, data were obtained *in situ* from

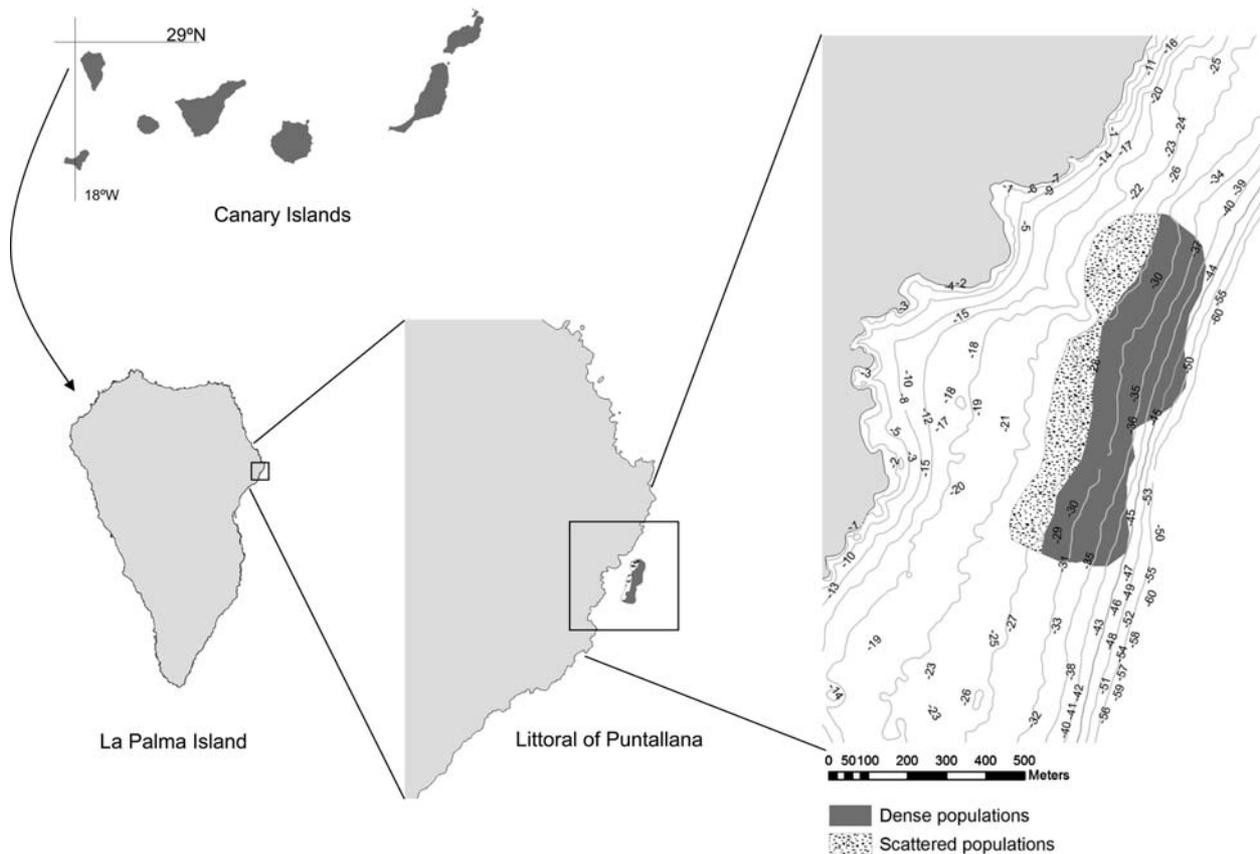


Figure 1 *Penicillus capitatus*: location of the off-shore populations near Puntallana, NE La Palma, Canary Islands.

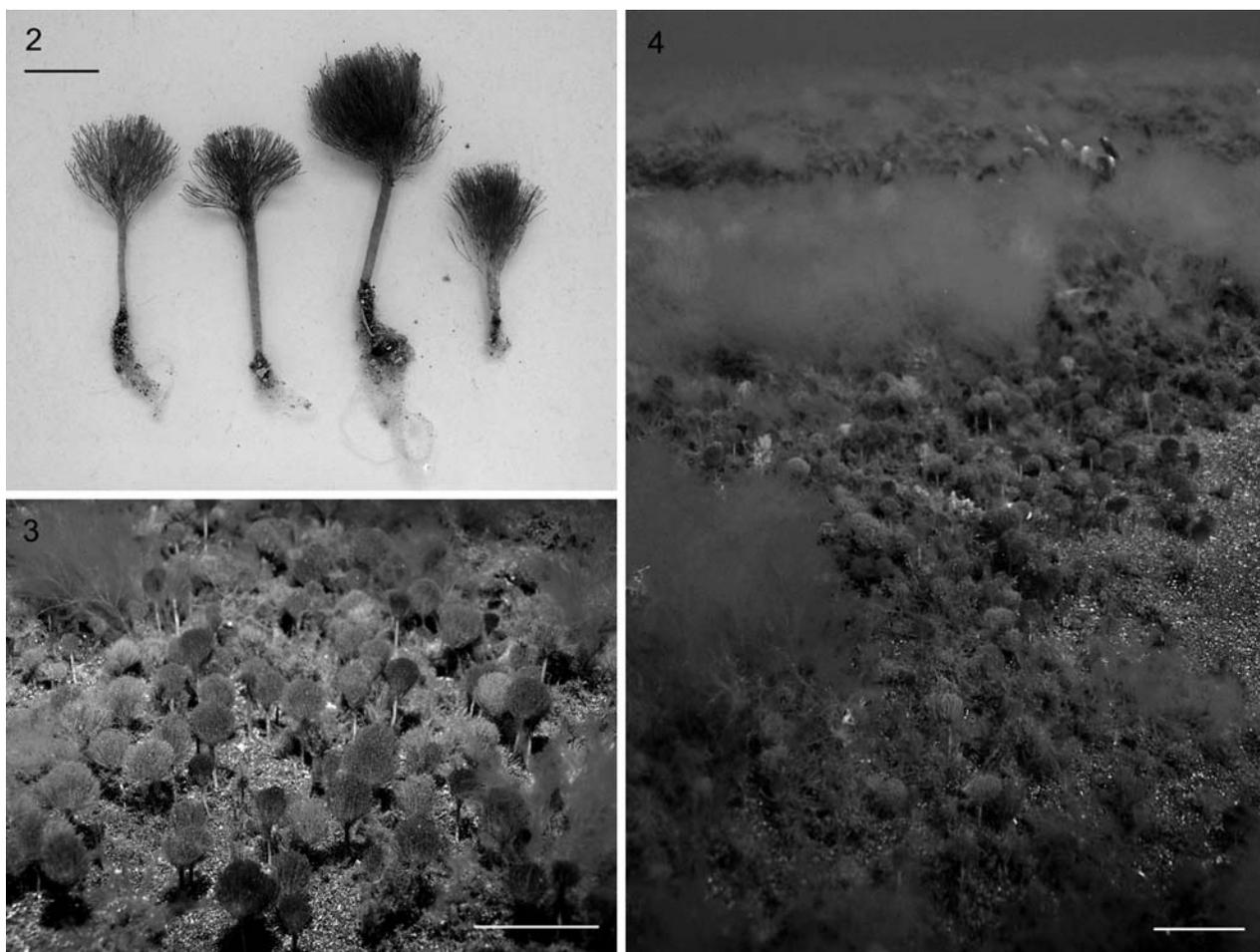
eight quadrats of 25×25 cm at 30–35 m depths, in September 2008, January, March and September 2009. Specimens for morphological studies were also collected. Collections were examined while fresh, and then preserved in 4% formalin in seawater. Microscopic examination was carried out on selected fragments of thalli. Photographs were taken with an Olympus E-520 camera (Tokyo, Japan) with an Ikelite housing and DS160 strobe (Indianapolis, USA). Selected specimens examined are deposited in Herbarium TFC (Departamento de Biología Vegetal, Universidad de La Laguna, Canary Islands) with the numbers TFC Phyc 14433 and 14434.

Littoral habitats of Puntallana are characterized by cliffs, rocky platforms, and beaches composed of small stones. The shallow sublittoral consists of unstable rocky-sandy bottoms that become progressively more stable at depth, forming extensive sandy bottoms (5–20% slope). Populations of *Penicillus capitatus* form scattered patches between 20 and 27 m depths (<1% cover), and progressively form dense meadows up to 50 m depth, where slope increases markedly, restricting growth. The total extent of the populations is about 11.16 ha, of which 4.03 ha are occupied by scattered patches and 7.13 ha by dense beds (Figure 1). Water temperature around La Palma varies between 19°C in March and 23°C in September (Braun and Molina 1988).

Penicillus capitatus is among commonest species in the genus and has been widely described and figured (Gepp and Gepp 1911, Børgesen 1913, Taylor 1960, Huvé and Huvé

1964, Friedmann and Roth 1977, Meinesz 1980, Littler and Littler 2000). Although the size and shape of the capitulum and the lengths of the stipes are variable, diagnostic characters are fairly constant. Specimens examined agree with the forma *laxus*, which is characteristic of sheltered and deep water habitats (Børgesen 1913). Well developed plants are erect, stiff, 2–6 cm long, light green grayish to dark green in color, consisting of a slightly calcified stipe attached by large rhizoidal tufts and a terminal capitulum (Figure 2). Stipes are cylindrical, about 30 mm long and 2 mm in diameter, with a smooth surface. Anatomically, stipes consist of a central region of longitudinally oriented closely compacted medullary siphons and a peripheral region of radially arranged cortical siphons, which become slightly calcified. Siphons are 4–5 times dichotomously branched and end in blunt, flat or rounded tips. The capitulum is loose and lax, forming a proximally attenuate and slightly oblong brush-like to subglobose structure, 10–25 mm long and 8–22 mm wide (Figure 2). The capitulum is composed of slender siphons, 100–190 µm in diameter and up to 25 mm long, constricted above the dichotomies and not tapering at the tips. The “*Espera*-phase” consists of non-consolidated branched siphons up to 20 mm long.

Overall appearance of the populations of *Penicillus capitatus* changed throughout the year due to marked variations in plant morphology, cover and density. In September, well-developed individuals were dominant (Figures 3 and 4), although filamentous individuals (*Espera*-phase) were also



Figures 2–4 *Penicillus capitatus*.

(2) Habits of four liquid preserved specimens (TFC Phyc 14433). (3) Detail of a field population in September, showing light (male) and dark (female) mature specimens. (4) General view of a dense population in September, partially hidden by the cloudy-like habits of *Lophocladia trichoclados* and *Cottoniella filamentosa* which grow as epiphytes on *Penicillus*. Scale bars: Figure 2=1 cm; Figures 3, 4=5 cm.

present. However, the *Espera*-phase was dominant in January and March when stipes of dead specimens persisted. The highest values in cover and density were observed in September 2008 and 2009 [mean cover (\pm SD): 75.42 ± 8.85 , and mean number of individuals m^{-2} (\pm SD): 1245.23 ± 146.09].

Penicillus capitatus shares these sublittoral habitats with several other plant and algal species. The seagrass *Halophila decipiens* Ostenfeld and species of *Caulerpa* [*C. prolifera* (Forsskål) J.V. Lamouroux, *C. racemosa* var. *cylindracea* (Sonder) Verlaque, Huisman et Boudouresque and *C. mexicana* Kützinger] are rhizophytes that occasionally grow in these fine-grained substrata. Some free-living specimens of *Lithothamnion corallioides* P. et H. Crouan occur on the sand, while *Lophocladia trichoclados* (C. Agardh) J. Agardh and *Cottoniella filamentosa* (M.A. Howe) Børgesen grow frequently as epiphytes on *Penicillus* (Figure 4). Small pebbles scattered on the sand are colonized by *Jania adhaerens* Lamouroux, species of *Dictyota*, *Padina pavonica* (L.) Thivy and *Lobophora variegata* (J.V. Lamouroux) Oliveira.

In the Canary Islands, shallow sublittoral bottoms contain extensive areas with sandy-muddy substrata that generally are occupied by seagrasses or green algal meadows. Gener-

ally, shallow beds of the perennial *Cymodocea nodosa* (Ucria) Ascherson occur between 5–35 m depths, and become progressively replaced by the annuals *Caulerpa prolifera*, or in some zones by *Halophila decipiens*, at locales up to 50 m deep (Reyes et al. 1995, Gil-Rodríguez et al. 2007). This pattern of vertical distribution in offshore sheltered sandy bottoms has been recently modified by the arrival of the invasive *Caulerpa racemosa* var. *cylindracea* (Verlaque et al. 2004), which has colonized the upper zone of the annual meadows. The extensive populations of *Penicillus capitatus* off La Palma are also established in this zone, often intermixed with *Caulerpa* species and *Halophila decipiens*.

Specimens of *Penicillus capitatus* from the Canary Islands reach only 6 cm length and are smaller than those from the Mediterranean Sea, which are 9–10 cm long (Huvé and Huvé 1964) and the Western Atlantic, (2-)18(-25) cm long (Littler and Littler 2000). The Canarian meadows of *P. capitatus* reach their maximal development in late summer, following a pattern similar to Mediterranean populations (Huvé and Huvé 1964). This phenological pattern differs from the spring maximal development in western Atlantic populations

(Clifton and Clifton 1999), and suggests a probable temperature dependence. Well developed individuals in Mediterranean and Canarian populations of *P. capitatus* appear during the warmest months of the warm-temperate region (Hoek 1984), whereas in the tropical Western Atlantic they are present through the year. This temporal displacement in the favorable period for populations from different geographical areas has been observed previously for other algal species from the Canary Islands (Tronholm et al. 2008).

According to Clifton and Clifton (1999), the sex of individuals in this dioecious alga can be reliably determined before gamete release based on color of the capitulum (males are distinctly lighter than females). A mixture of both sexes (detected by this differentiation in color) was observed in September in populations from La Palma. As dead plants of post-reproductive *Penicillus* disappear quickly in the field, the decrease in cover observed in January is likely a consequence of sexual reproduction.

It is difficult to determine whether the presence of *Penicillus capitatus* in the Canary Islands is a recent introduction. The species may have been overlooked in the past, since Canarian offshore deepwater habitats have been studied only occasionally (Ballesteros 1993, Sansón et al. 2002, Verlaque et al. 2004, Gil-Rodríguez et al. 2007). Additionally, the occurrence of bushy specimens of *P. capitatus* is strictly seasonal, and makes the detection of field populations difficult during winter to spring months. Future research may help determine whether *Penicillus capitatus* is spreading to other similar habitats in the Canary Islands.

The extensive meadows found off La Palma suggest a relationship to recent increased seawater temperatures. The mean annual water temperature around the Canary Islands increased by 2°C from 1973 to 2006 (Brito 2008). That may have promoted prolific growth of this species. The proportion of tropical elements in the marine flora and fauna of the Canary Islands has recently increased (Brito et al. 2005, Brito and Falcón 2006, Afonso-Carrillo et al. 2007, Cassano et al. 2008), and these changes are hypothesized to be related to global warming (Brito 2008).

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References

Afonso-Carrillo, J., M. Sansón, C. Sangil and T. Díaz-Villa. 2007. New records of benthic marine algae from the Canary Islands (eastern Atlantic Ocean): morphology, taxonomy and distribution. *Bot. Mar.* 50: 119–127.

- Audiffred, P.A.J. and W.F. Prud'homme van Reine. 1985. Marine algae of Ilha do Porto Santo and Deserta Grande (Madeira Archipelago) (CANCAP project Contribution No. 40). *Bol. Mus. Munic. Funchal* 37: 20–51.
- Ballesteros, E. 1993. Algunas observaciones sobre las comunidades de algas profundas en Lanzarote y Fuerteventura (Islas Canarias). *Vieraea* 22: 17–27.
- Børgesen, F. 1913. The marine algae of the Danish West Indies. Part I. Chlorophyceae. *Dansk. Bot. Ark.* 1: 1–160.
- Bornet, E. 1892. Les algues de P.K.A. Schousboe. *Mém. Soc. Sc. Nat. Cherbourg* 28: 165–376.
- Braun, J. and R. Molina. 1988. El mar, el Atlántico en el área de Canarias. In: (L. Afonso, ed.) *Geografía de Canarias. Vol. 1. Geografía Física*. 2 ed. Interinsular Canaria, Santa Cruz de Tenerife. pp. 18–28.
- Brito, A. 2008. Influencia del calentamiento global sobre la biodiversidad marina de las Islas Canarias. In: (J. Afonso-Carrillo, ed.) *Naturaleza amenazada por los cambios en el clima*. Actas III Semana Científica Telesforo Bravo, Instituto Estudios Hispánicos de Canarias, Puerto de la Cruz. pp. 141–161.
- Brito, A. and J.M. Falcón. 2006. Primera cita para Canarias de dos nuevos peces de origen tropical: *Diodon holocanthus* Linnaeus, 1758, y *Canthidermis maculata* (Bloch, 1786). *Rev. Acad. Canar. Cienc.* 18: 89–92.
- Brito, A., J.M. Falcón and R. Herrera. 2005. Sobre la tropicalización reciente de la ictiofauna litoral de las islas Canarias y su relación con los cambios ambientales y actividades antrópicas. *Vieraea* 33: 515–525.
- Cassano, V., M.C. Gil-Rodríguez, A. Senties and M.T. Fujii. 2008. *Laurencia caduciramulosa* (Ceramiales, Rhodophyta) from the Canary Islands, Spain: a new record for the eastern Atlantic Ocean. *Bot. Mar.* 51: 156–158.
- Clifton, K.E. and L.M. Clifton. 1999. The phenology of sexual reproduction by green algae (Bryopsidales) on Caribbean coral reefs. *J. Phycol.* 35: 24–34.
- Decaisne, J. 1842. Mémoires sur les corallines ou polypiers calcifères. *Ann. Sci. Nat. Bot. Sér. 2*, 16: 85–120.
- Friedmann, E.I. and W.C. Roth. 1977. Development of the siphonous green alga *Penicillus* and the *Espera* state. *Bot. J. Linn. Soc.* 74: 189–214.
- Gallardo, T., A. Gómez Garreta, M.A. Ribera, M. Cormaci, G. Furnari, G. Giaccone and C.-F. Boudouresque. 1993. Check-list of Mediterranean Seaweeds, II. Chlorophyceae Wille s.l.. *Bot. Mar.* 36: 399–421.
- Gepp, A. and E.S. Gepp. 1911. *The Codiaceae of the Siboga Expedition including a monograph of Flabellariaeae and Udoteae*. Vol. 62. Leiden. pp. 1–150, 22 pls.
- Gil-Rodríguez, M.C., M. del Arco, W. Wildpret de la Torre, C.L. Hernández-González and R. Haroun. 2007. Biological information and comments on *Halophila decipiens* meadows of the Canary Islands (Hydrocharitaceae, Magnoliophyta). *Vieraea* 35: 77–85.
- Guiry, M.D. and G.M. Guiry. 2009. *AlgaeBase*. World-wide electronic publication, National University of Ireland, Galway. <http://www.algaebase.org>; searched on 06 October 2009.
- Hoek, C. van den. 1984. World-wide latitudinal and longitudinal seaweed distribution patterns and their possible causes, as illustrated by the distribution of Rhodophytan genera. *Helgol. Meeresunters.* 38: 227–257.
- Huvé, P. and H. Huvé. 1964. A propos de *Penicillus capitatus* Lamarck, forma *mediterranea* (Decaisne) comb. nov. (Caulerpale, Udoteacée). *Proc. Int. Seaweed Symp.* 4: 99–111.
- Littler, D.S. and M.M. Littler. 2000. *Caribbean reef plants. An iden-*

- tification guide to the reef plants of the Caribbean, Bahamas, Florida and Gulf of Mexico. Offshore Graphics, Washington. pp. 542.
- Meinesz, A. 1980. Connaissances actuelles et contribution à l'étude de la reproduction et du cycle de Udotéacées (Caulerpales, Chlorophytes). *Phycologia* 19: 110–138.
- Neto, A.I., D.C. Cravo and R.T. Haroun. 2001. Checklist of the benthic marine plants of the Madeira Archipelago. *Bot. Mar.* 44: 391–414.
- Reyes, J., M. Sansón and J. Afonso-Carrillo. 1995. Distribution and reproductive phenology of the seagrass *Cymodocea nodosa* (Ucria) Ascherson in the Canary Islands. *Aquat. Bot.* 50: 171–180.
- Sansón, M., J. Reyes, J. Afonso-Carrillo and E. Muñoz. 2002. Sub-littoral and deep-water red and brown algae new from the Canary Islands. *Bot. Mar.* 45: 35–49.
- Seoane-Camba, J. 1965. Estudios sobre las algas bentónicas en la costa sur de la Península Ibérica (litoral de Cádiz). *Inv. Pesq.* 29: 3–216.
- Taylor, W.R. 1960. *Marine algae of the eastern tropical and subtropical coasts of the Americas*. The University of Michigan Press, Ann Arbor. pp. 870.
- Tronholm, A., M. Sansón, J. Afonso-Carrillo and O. De Clerck. 2008. Distinctive morphological features, life-cycle phases and seasonal variations in subtropical populations of *Dictyota dichotoma* (Dictyotales, Phaeophyceae). *Bot. Mar.* 51: 132–144.
- Verlaque, M., J. Afonso-Carrillo, M.C. Gil-Rodríguez, C. Durand, C.F. Boudouresque and Y. Le Parco. 2004. Blitzkrieg in a marine invasion: *Caulerpa racemosa* var. *cylindracea* (Bryopsidales, Chlorophyta) reaches the Canary Islands (north-east Atlantic). *Biol. Invasions* 6: 269–281.

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