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# Revisiting the Eastern Mediterranean coast of Egypt reveals new records and non-indigenous macroalgal species

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## Abstract

This study conducted a comprehensive examination of various seaweed species from the Mediterranean Coast of Egypt, providing detailed descriptions of new records and introduced species based on their morphological characteristics. The results revealed two previously undocumented species in Egypt, *Gigartina pistillata* (S.G. Gmelin) Stackhouse and *Palmophyllum crassum* (Naccari) Rabenhorst, both commonly found in the Mediterranean Sea. Additionally, two red algae *Predaea* sp. and *Callophyllis* sp. were reported for the first time in the Eastern Mediterranean. Among non-native species, *Codium repens* P. Crouan *et* H. Crouan, a widely distributed green alga in the Red Sea and Indo-Pacific Ocean, is recorded as new in the Mediterranean Sea. Furthermore, the non-indigenous brown alga *Padina tetrastomatica* Hauck has been reported for the first time along the Mediterranean Coast of Egypt.

**Keywords:** Non-indigenous species; New records; seaweeds; Southeast Mediterranean Sea; Egypt.

## Introduction

The history of seaweed surveys along the coast of Egypt dates back to 1761 when Forsskål (1775) collected several species from the Mediterranean Sea on his trip to the Red Sea. Later, Delile (1813) collected approximately 23 species from the Mediterranean Sea, particularly Alexandria, including the non-indigenous species (NIS) *Asparagopsis taxiformis* (Delile) Trevisan (= *A. delile* Montagne, Trevisan 1845) and *Achanthophora delilei* Lamouroux [=*A. nayadiformis* (Delile) Papenfuss 1968]. Between 1820 and 1830, Swedish diplomat Dr. Hedenborg collected seaweeds from Alexandria, which were then studied by Areschoug (1871), among which 17 species were identified as NIS that belonged to the Red Sea. Several years later, two prominent phycologists extensively studied the seaweeds of Alexandria and reported several NIS (Aleem, 1951, 1992, 1993; Nasr, 1940; Nasr & Aleem, 1948).

Although macroalgal diversity has been extensively studied and revised in the Mediterranean Sea, there are gaps in seaweed monitoring, particularly for NIS (Bitar *et al.*, 2017; Katsanevakis *et al.*, 2014; Verlaque *et al.*, 2003; Zenetos *et al.*, 2012). According to Loos *et al.* (2024), the eastern Mediterranean basin has the highest number of NIS (77 species, excluding cryptogenic species), resulting from the introduction of species from the Red Sea and Indo-Pacific Ocean via the Suez Canal (shipping or fouling). In this context, the Mediterranean coast of Egypt provides an important habitat for NIS, particularly in Alexandria City, because of its proximity to the Suez Canal, where many species have been reported both historically and recently (Aleem, 1984, 1950, 1948; El Tablawy *et al.*, 2025; Rodríguez-Prieto *et al.*, 2021). The present study examines seaweed species from the Mediterranean coast of Egypt and contributes to the knowledge of seaweeds in the southeastern Mediterranean Sea.

## Materials and Methods

### *Study Area*

The specimens examined in this study were collected during regular surveys along the Mediterranean Coast of Egypt. Specimens were collected from the shores of Abu Qir Bay (31.32361° N, 30.06028° E), located east of Alexandria City. Abu-Qir Bay is a sheltered rocky embayment characterized by chains of naturally exposed rocks, providing suitable substrata for a rich algal flora. Additional samples were collected at Sidi-Barrani City (31.84417° N, 26.02500° E), located on the northwest Mediterranean coast of Egypt.

*Seaweed collection and reference material*

Seaweed samples both in the supralittoral zone and submerged areas down to about 1 m depth were hand-collected monthly between 2020 and 2023 along the rocky shores of Abu-Qir Bay. Samples from Sidi-Barrani were collected using a Van Veen grab sampler at a depth of 85 m using the El-Yarmouk Research Vessel NIOF. Seaweeds were placed in labelled plastic bags containing autoclaved seawater and kept in ice boxes. The samples were transported to the laboratory where they were sorted. Algal samples were preserved in 4% formalin/seawater solution. Hand sections were stained with 1% aniline blue, acidified with 1% HCl, and photographed under a compound microscope (GZM-TR-745 with a 5.1MP mounted digital camera; Gippon Inc., Japan). Voucher herbarium specimens were deposited in the Hydrobiology Lab at the National Institute of Oceanography and Fisheries (NIOF).

## Results and Discussion

**Phylum: Chlorophyta**
**Class: Ulvophyceae**
**Order: Bryopsidales**
**Family: Codiaceae**
**Genus: *Codium* Stackhouse**

The green algal genus *Codium* is among the largest genera, containing 139 species (Guiry & Guiry, 2024). This genus is characterized by spongy fronds and stacked utricles, as described by Stackhouse (1797). Six species have been recorded along the Mediterranean coast of Egypt: *C. bursa* (Linnaeus) C. Agardh, *C. decorticatum* (Woodwrd) M.Howe, *C. effusum* (Rafinesque) Delle Chiaje, *C. taylorii* P.C.Silva, *C. tomentosum* Stackhouse, and *C. vermilara* (Olivi) Delle Chiaje (Aleem, 1993).

***Codium repens* P. Crouan *et* H. Crouan**

Type locality: Guadeloupe, Indias Occidentais
Worldwide distribution: This species is widely reported in the tropical Atlantic, Indo-Pacific Ocean, and Red Sea (Guiry & Guiry, 2024).

Description: Thallus dark-green, robust and thick, approximately 5 cm long, with irregular divaricate branching. Branches were cylindrical to subcylindrical and slightly flattened (Fig. 1A). Utricles are cylindrical to subcylindrical, 80-150 µm in diameter, and 750-900 µm long with rounded apices (Fig. 1B). This specimen agrees well with the description of *C. repens* from Kenya (Van Den Heede & Coppejans, 1996).

Notes: *C. repens* was reported during the summer season. Although absent from Mediterranean Sea records, this species is widely distributed in the Red Sea (Einav *et al.*, 2021) and has been observed along the Red Sea coast of Egypt (Aleem, 1978; Nasr 1947). The current identification of *C. repens* in Alexandria signifies its introduction via the Suez Canal, necessitating genetic analysis to validate this record.

Location: Abu-Qir Bay 31.32361° N, 30.06028° E. This species was found at a depth of about 0.5 m on rocky bottom. Observation dates: June and August 2020 and July 2021.

Voucher specimens: Shabaka_June2020_COD_rep_AQ

**Class: Phaeophyceae**
**Order: Dictyotales**
**Family: Dictyotaceae**
**Genus: *Padina* Adanson**

The genus *Padina* has been subjected to extensive taxonomic revision, resulting in the introduction of new species worldwide (Arraj *et al.*, 2016; Díaz-Martínez *et al.*, 2016; Kyawt Wai & Soe-Htun, 2008; Ni-Ni-Win *et al.*, 2013). Currently, there are 59 accepted species of *Padina* (Guiry & Guiry, 2024). Seven species of *Padina* have been identified in the Mediterranean Sea: *P. boryana* Thivy, *P. boergesenii* Allender *et* Kraft, *P. ditristromatica* Ni-Ni-Win *et* H. Kawai, *P. gymnospora* (Kützing) Sonder, *P. pavonica* (Linnaeus) Thivy, *P. pavonicoides* Ni-Ni-Win *et* H. Kawai, and *P. tetrastromatica* Hauck (Ni-Ni-Win *et al.*, 2011, 2021; Pagana *et al.*, 2023). Two species of *P. boryana* and *P. pavonica* have been recorded on the Mediterranean coast of Egypt (Aleem, 1993).

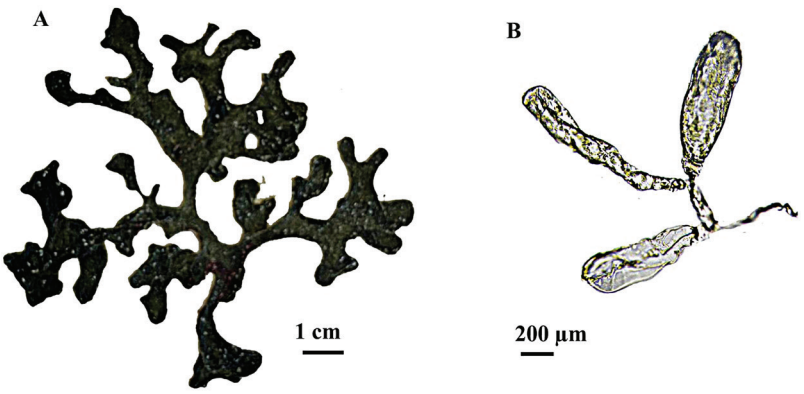


***Fig. 1:*** *Codium repens* P. Crouan *et* H. Crouan. A) General aspect of the thallus, B) Cylindrical utricles with rounded apex.

***Padina tetrastromatica* Hauck**

Type locality: Meith (Maydh), Somalia (Silva *et al.*, 1996:607).

Worldwide distribution: *Padina tetrastromatica* is widely distributed in the Indo-Pacific Ocean and the Red Sea (Guiry & Guiry, 2024). This species has been previously reported in Syria and Italy (Arraj *et al.*, 2016; Einav, 2023; Pagana *et al.*, 2023).

Description: Fresh plants are reddish-brown with fan-shaped and deeply split fronds. Thalli are up to 8 cm in height and 10 cm in width, slightly calcified, and attached by a hard, stupose stipe (Fig. 2A). The stipe was up to 2 cm long and 0.5 cm wide and densely covered with fibrous hairs (Fig. 2B). Tetrasporangial sori were found on both sides of the hairlines without an indusium (Fig. 2C). Soral bands were evenly spaced. Thalli are composed of 3 cell layers at the margin, 3 to 4 layers at the basal portion (Fig. 2D, E).

Notes: *P. tetrastromatica* sporophytes were observed during the summer. The extensive documentation of this species along the Red Sea coast of Egypt (Rashedy *et al.*, 2022) strongly implies that it was introduced via the Suez Canal.

Location: Abu-Qir Bay 31.32361° N, 30.06028° E. This species was found to be densely attached to exposed rocky outcrops. Dates of observation: June and August 2020, July 2021, August 2022, July 2023.

Voucher specimens: Shabaka_June2020_PAD_tet_AQ, Shabaka_July2021_PAD_tet_AQ, Shabaka_Aug2022_PAD_tet_AQ

**Phylum: Rhodophyta**
**Class: Florideophyceae**
**Order: Gigartinales**
**Family: Gigartinaceae**
**Genus*:*** *Gigartina* Stackhouse

***Gigartina pistillata* (S.G.Gmelin) Stackhouse**

Type locality: Doubtful (Dixon & Irvine, 1977: 239)

Worldwide distribution: *Gigartina pistillata* has been reported in the Atlantic Ocean, South Africa, and the Mediterranean Sea (Levantine Basin) (Guiry & Guiry, 2024).

Description: The plant was observed in isolated clumps that were 3 cm in diameter (Fig. 3A). Thalli are blackish, cartilaginous, and dichotomously branched with a uniform diameter of about 0.3 mm (Fig. 3B). The first dichotomy is initiated at a height of 3 mm. Adult plants are approximately 12 dichotomously branched, mainly compressed or flattened, and sometimes subcylindrical. Specimens examined were monoecious. Procarps were formed at the thallus surface close to the apex of the fertile pinnules, whereas spermatangia were produced from the terminal cortical cells (Fig. 3C, D).

Notes: *G. pistillata* was collected from rocky substrates in early spring. This species has not been previously reported on the Mediterranean Coast of Egypt. According to Cormaci *et al.* (2020), the presence of *G. pistillata* in the Mediterranean Sea is questionable because of the limited and potentially ambiguous records. The similarities in morphology between *G. pistillata* and *Chondracanthus teedei*, as well as reports of intermediate forms, suggest the possibility of misidentifications of Mediterranean records (Cormaci *et al.*, 2020). On the other hand, *C. teedei* (=*Gigartina teedei* (Roth) Lamouroux) was reported by Aleem (1993) and Nasr (1940) in Alexandria; the specimens were membranous, with cylindrical thalli and irregularly pinnated branches, resembling the appearance of *Pterocladiella capillaceae* (S.G.Gmelin) Santelices *et* Hommersand.

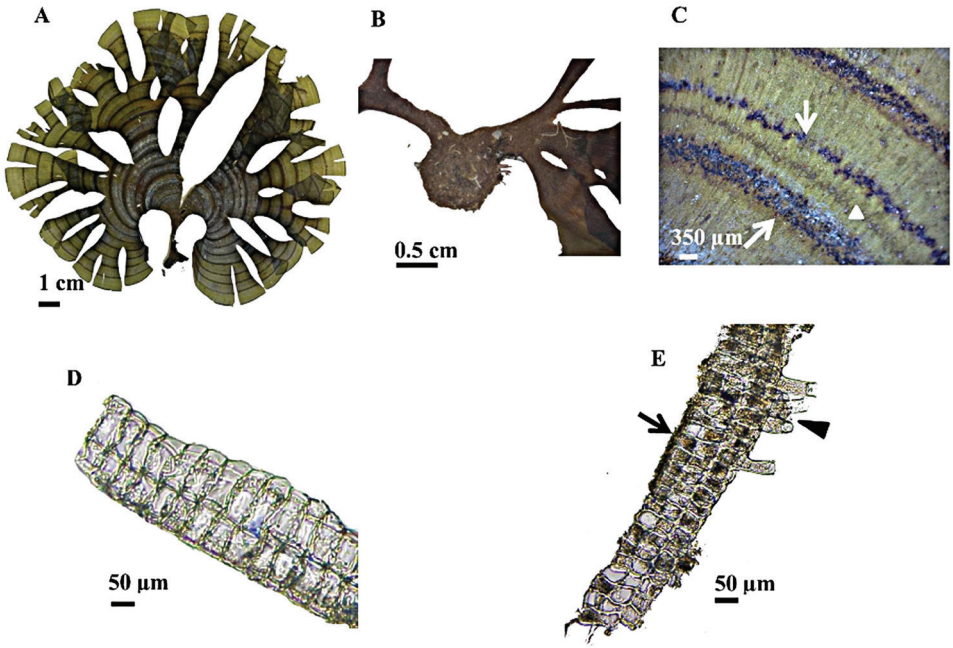


***Fig. 2:*** *Padina tetrastromatica* Hauck. A) Habit of tetrasporophyte, B) Hairs at the basal portion, C) Details of surface view of tetrasporangial sori (arrows) at both sides of hairline (triangle). D) Transverse section (TS) of the marginal part of the thallus, E) TS of the basal portion of the thallus showing moderate calcification (arrow), and rhizoids (triangle).

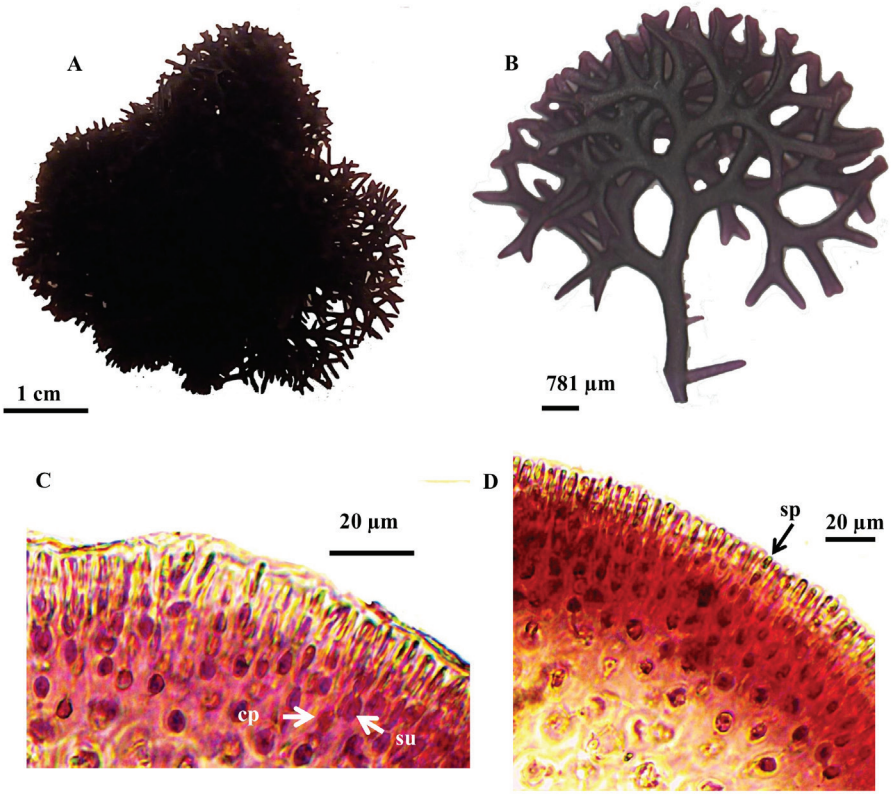


***Fig. 3:*** *Gigartina pistillata* (S.G. Gmelin) Stackhouse. A) Habit of adult plant clumps, B) Thallus morphology, C) Young procarp close to apex of pinnule showing a supporting cell (su) bearing carpogonial branch (arrow), D) Spermatangia (sp) produced from terminal cortical cells.

Location: Abu-Qir Bay 31.32361° N, 30.06028° E. This species was firmly attached to a rocky bottom at a depth of approximately 1 m. Date of observations: from March to May 2020, 2021, 2022, 2023.

Voucher specimens: Shabaka_Mar2020_GIG_pist_AQ, Shabaka_May2021_GIG_pist_AQ

**Class: Florideophyceae**

**Order: Gigartinales**

**Family: Kallymeniaceae**

**Genus: *Callophyllis* Kützing**

The genus *Callophyllis* was established based on two species, *Callophyllis variegata* (Bory) Kützing (originating from Chile) and *C. laciniata* (Hudson) Kützing (=*Metacallophyllis laciniata* (Huson) A. Vergés *et* L. Le Gall) (originating from Europe), as documented by Norris (1957). *Callophyllis* inhabits the cold and temperate regions of both the northern and southern hemispheres, as reported by Arakaki *et al.* (2011). On the other hand, *M. laciniata* is the only species in the genus *Metacallophyllis*, which is similar to several *Callophyllis* spp. in gross morphology (Saunders *et al.*, 2017).

Description: The specimen has a distinct medullary structure consisting of nearly isodiametric cells, which sets *Callophyllis* apart from other kallymeniacean genera. The plant is flat, dark red, and 3-5 cm long. The thallus has a very small holdfast with no stipe and is dichotomously branched two to three times (Fig. 4A, B). The width of the thallus was 2.5-3.0 mm. The margins were proliferous (Fig. 4A, C). The apex of the thallus was roundish. The medulla was composed of multiple layers of relatively large rounded cells (Fig. 4D). The cortex is composed of 2 -3 layers. Cystocarps were scattered over the surface of the blades. The specimens examined from Alexandria were similar to those of *C. hayamensis* Yamada collected in Korea (Lee & Kim, 2014).

Notes: Very few specimens were attached to the bivalve *Mytilus* sp. on rocky outcrops in summer. Based on the general aspects of the genus, this species has not been previously reported on the Mediterranean coast of Egypt. Specimens from Egypt necessitate molecular analysis owing to the challenges associated with morphological differentiation within the genus *Callophyllis*, as well as between *Callophyllis* and *Metacallophyllis.*

Location: Abu-Qir Bay 31°19’25”N 30°03’37”E. This species is epizoic to *Mytilus* sp. Dates of observation: April–June 2020.

Voucher specimens: Shabaka_June2020_CAL_?_AQ

**Class: Florideophyceae**

**Order: Nemastomatales**

**Family: Nemastomataceae**

**Genus: *Predaea* G.De Toni [De Toni fil.]**

The genus *Predaea* is mainly tropical and subtropical, and is well represented by 21 species (Guiry & Guiry, 2024). This genus is characterized by its gelatinous texture, lobed fronds, loosely arranged medullary filaments, and dense dichotomously divided pigmented cortical filaments (Schneider & Wynne, 2007). The genus *Predaea* is represented in the Mediterranean Sea by *P. ollivieri*. Feldmann, and *P. pusilla* (Berthold) J. Feldmann (Athanasiadis, 1988; Conde *et al.*, 1998; Vergés *et al.*, 2004; Verlaque, 1990). These two species have only been reported in the western Mediterranean Sea (Guiry & Guiry,

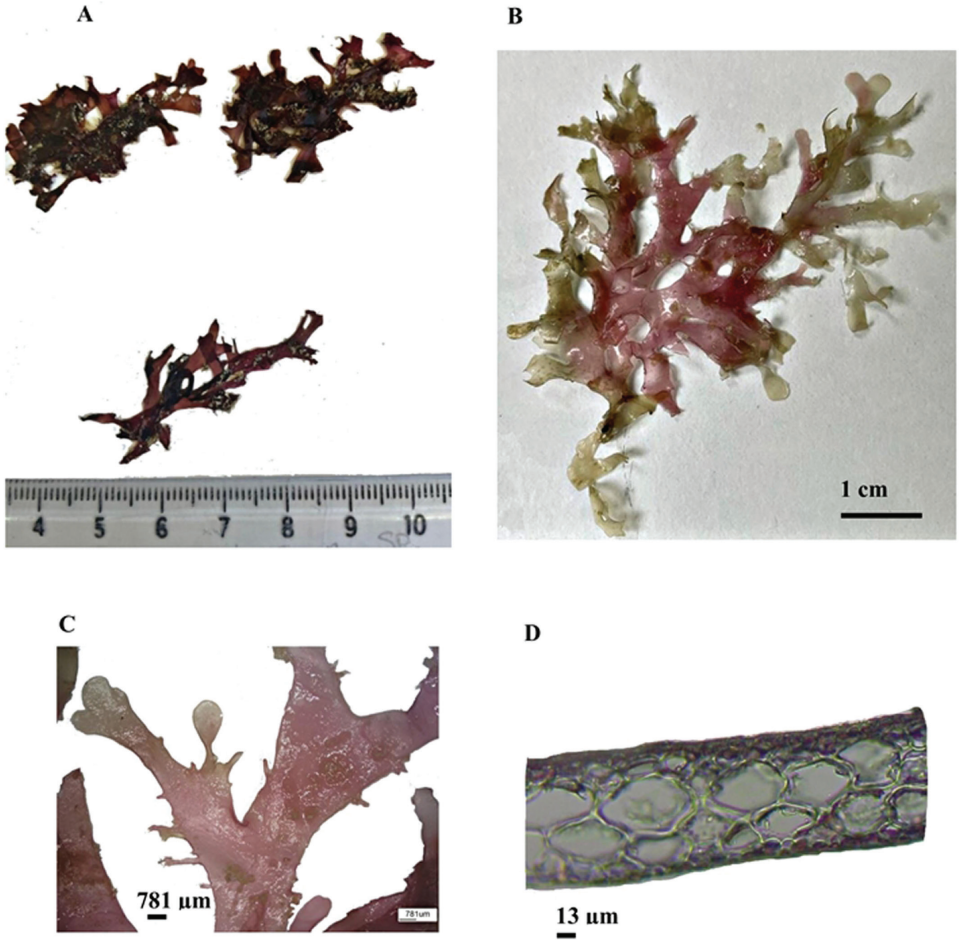


***Fig. 4:*** *Callophyllis* sp. Kützing A) Pressed herbarium sheet of several individuals, B) Habit of plant showing flattened membranous thallus, C) Thallus dichotomously branched with proliferations at the margin of frond. D) Transverse section of the frond showing medulla.

2024). According to a study by Conde *et al.* (1998), *Predaea* is represented by a few voucher specimens because these algae are very difficult to collect as they grow in deep waters.

Diagnosis: The female gametophyte is repeatedly and deeply lobed, 5 cm in length, and narrowed to a short stalk (Fig. 5A). Fresh specimens were rose-red with a gelatinous texture (Fig. 5B). Cortex 101-130 µm and composed of dense fascicles of cortical filaments sub-dichotomous branched, with cylindrical cells. The cortical fascicles were equal in length. A mature carposporophyte with a well-developed goniomoplast was observed (Fig. 5C).

Notes: This species is extremely rare, and was observed only in 2020**.** Female gametophytes were found attached to the fronds of the red alga *Corallina officinalis,* which extensively encrusts rocky outcrops. The distinguishing characteristics used to identify *Predaea* species in the western Mediterranean Sea are derived from female gametophyte structure (Cormaci *et al.*, 2021). In the current study, the presence of this genus in the southeastern Mediterranean Sea is considered the first report; however, molecular analysis is required to confirm this taxonomic identification.

Location: Abu-Qir Bay (31.32361° N, 30.06028° E). This species was observed as an epiphytic species on the shore. Dates of observation: April and June 2020.

Voucher specimens: Shabaka_Apr2020_PRED_?_AQ

**Phylum: Prasinodermatophyta**
**Class: Palmophyllophyceae**
**Order: Palmophyllales**
**Family: Palmophyllaceae**
**Genus: *Palmophyllum* Kützing**

The genus *Palmophyllum* belongs to the palmelloid green algae family, together with *Palmoclathrus* and *Verdigellas*. These genera were classified under the new phylum Prasinodermophyta within Viridiplantae (green plants), with diverging positions before the split of Chlorophyta and Streptophyta (Li *et al.*, 2020). Palmelloid green algae live in deep water with extremely low light intensity, resulting in the dominance of chlorophyll b, which effectively harvests blue-green light in deep water (Ballantine & Aponte, 1996; Leliaert *et al.*, 2011, 2016). These green algae are distinguished by multicellular structures that develop into macroscopic thalli (Zechman *et al.*, 2010). There are currently two accepted species in the genus *Palmophyllum*: *P. crassum* (Naccari) Rabenhorst and *P. umbracola* Nelson *et* Ryan (Guiry & Guiry, 2024). *P. crissum* is a cosmopolitan species, whereas *P. umbracola* is mainly reported in the Western Atlantic Ocean and Southern Hemisphere (Guiry & Guiry, 2024).

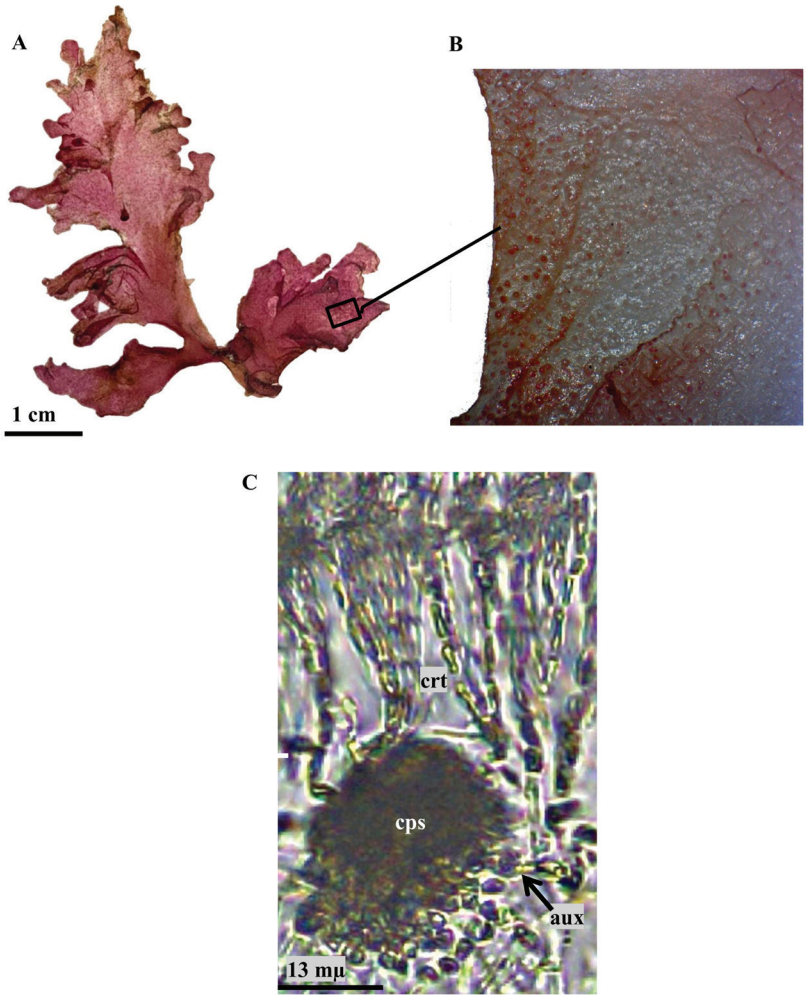


***Fig. 5:*** *Predaea* sp G. De Toni [De Toni fil.]. A) Habit of female gametophyte, B) Surface texture, C) Cortex with mature carposporophytes. crt= cortical filaments, cps: carposporophyte, aux: auxillary cell.

***Palmophyllum crassum* (Naccari) Rabenhorst**

Type locality: Nardo; mixed with fishes; (INA 1996)

Worldwide distribution: This species is widely reported in the tropical and subtropical Atlantic, Indo-Pacific Ocean, and Mediterranean Sea (Guiry & Guiry, 2024).

Description: Thalli up to 5 cm in diameter and 0.5-1.5 mm thick, compact and leathery, with a fleshy consistency (Fig. 6A). Thalli are vivid green in live specimens with spaced zonation, and almost black in dried specimens. The cells in the cross-section are spherical with a diameter ranging from 2-5 µm, irregularly arranged in a gelatinous matrix, and distributed more densely towards the margins (Fig. 6B).

**Notes:** This species was encountered at a single location during surveys along the offshore Mediterranean coast of Egypt**.** Despite being frequently reported in

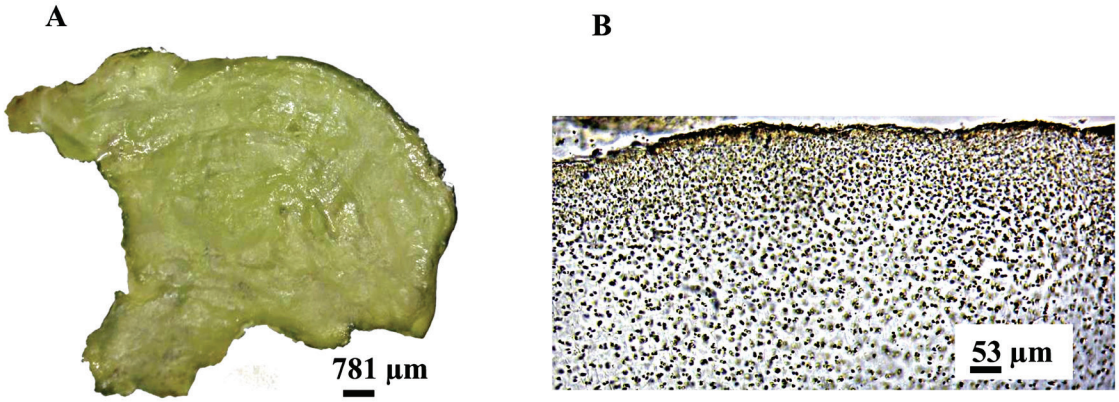


***Fig. 6:*** *Palmophyllum crassum* (Naccari) Rabenhorst. A) Voucher specimen, B) Cross-section showing coccoid cells embedded in gelatinous matrix.

Mediterranean basins (Cormaci *et al.*, 2014), *P. crassum* has not been reported on the Mediterranean coast of Egypt. According to Furukawa *et al.* (2017), the sequencing and structure of the *P. crassum* chloroplast genome are remarkably similar to those of *Verdigellas peltata*, which is a close relative of *P. crassum*. However, there are very few reports on *Verdigellas*, which were mainly collected in the tropical and subtropical Western Atlantic regions (Ballantine & Norris, 1994; Ballantine & Aponte, 1996; Ballantine *et al.*, 2019; Wynne, 2022; Leliaert *et al.*, 2016).

Location: Sidi-Barrani (31.84417° N, 26.02500° E) at 85 m deep. Date of observation: September 2023.

Voucher specimens: Shabaka_Sep2023_ *P. crassum*.

## Conclusion

This research has described, for the first time, several species that represent new records either on the Mediterranean ψoast of Egypt, the Levantine Basin, or the Mediterranean Sea. The results revealed previously undocumented occurrences of two species in Egypt that are widely distributed in the Mediterranean Sea: the red alga *Gigartina pistillata* and the palmelloid green alga *Palmophyllum crassum*. Additionally, these findings include the first report of the gelatinous red alga *Predaea* sp. and the red alga *Callophyllis* sp. in the Eastern Mediterranean Basin. Among the NIS, *C. repens*, a widely distributed green alga in the Red Sea and Indo-Pacific Ocean, represents a new record in the Mediterranean Sea, whereas the brown alga *P. tetrastomatica* was the first reported in Egypt.

Further studies should focus on genetic analysis of newly recorded macroalgal species to confirm their origins and potential ecological impacts. Additionally, regular monitoring of seaweeds along the Egyptian Mediterranean coast is essential for assessing changes in biodiversity and recording NIS to plan conservation policies. Collaboration between regional and international researchers can enhance the management of marine resources.

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