

ECOLOGICAL AND MORPHOLOGICAL STUDIES ON GENUS *CAULERPA* FROM THE EGYPTIAN RED SEA COASTS

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Abstract

Ten species of the tropical genus, *Caulerpa*, have been investigated in 29 sites on the Egyptian Red Sea coasts during the period of 1994-1999. These were *C. fastigiata* Montagne, *C. lentillifera* J. Agardh, *C. mexicana* (Sonder) J. Agardh, *C. racemosa* (Forsskål) J. Agardh, *C. peltata* Lamouroux, *C. scalpelliformis* (R. Braun) C. Agardh, *C. serrulata* (Forsskål) J. Agardh, *C. sertularioides* (Gmelin) Howe, *C. taxifolia* (Vahl) C. Agardh, and *C. webbiana* Montagne. The study describes how their morphology and growth vary along the gradient of habitat conditions. An identification key, original descriptions, illustrations and biogeographical data are also added.

The locality type of the species is the Indian Ocean. *C. racemosa* and *C. serrulata* are the most common, while other species were frequent or rare, forming small dense patches where appeared. Six of the identified species were found in the Suez Canal, three of which overrunning the eastern Mediterranean. *C. serrulata* seems to prefer habitat of open waters, and thus may be excluded from migration through the canal.

The species of *Caulerpa* prefer growing on sand or mud, dominating several photophilic and sciaphilic biotopes in the infralittoral, frequently inhabiting the littoral zone where the bottom never exposed to air. When found on hard substrates, the species inhabited the area covered by a layer of sand. The length of rhizoids seems to be dependent upon the depth of sand in which the plant anchored. Successful growth of species was observed in nutrient rich bottoms, and sites protected from waves. The variability in species morphology in relation to habitat conditions is evident and reflects differences in light.

Key words: *Caulerpa*, caulerpales, chlorophyta, Egypt, morphology, Red Sea.

Introduction

The genus *Caulerpa* comprises over 73 species that frequent the quiet shallow waters of the tropics (Dawes, 1998). Thirteen species of this tropical genus were recorded from the Red Sea. Papenfuss (1968) listed 10 species while cataloguing the benthic algae from different parts of the Red Sea. Taylor (1967) added two other species, namely *C. ambigua* Okamura and *C. fastigiata* Montagne, which were collected by Papenfuss in 1962 from Dahlak Archipelago off the Ethiopian coast. Lipkin (1973) added the thirteenth species to the list when he collected *C. taxifolia* (Vahl) C. Agardh from el-Tor on the coast of Sinai.

Publications dealing with the species of *Caulerpa* in the Red Sea refer mainly to their taxonomy (e.g., Zanardini, 1858; Nasr, 1947; Taylor, 1967; Rayss and Dor, 1963). A general knowledge of the habitats of these species can be derived from the works of El-Manawy (1992, 1999), El-Manawy and Gab-Alla (2000), Hegazy (1992), and Lipkin (1973). The morphology of the thallus of *Caulerpa* varies very considerably according to species (Dawes, 1998). Moreover, the form of the thallus of a species may also vary when grow in different habitat conditions, and *C. cupressoides* and *C. racemosa* (Chapman and

Chapman, 1973) particularly illustrated this. Such phenomenon is resulted in subdivision of species into varieties or forms (Meinesz, 1980).

The present study deals with the distribution of *Caulerpa* species along the Egyptian Red Sea coasts. Particular emphasis has been placed on determining the effects of habitat conditions on the morphology of the species. An identification key, original descriptions, illustrations and biogeographical data have been also considered.

Materials and Methods

The investigated area (Fig. 1) extends from Port Said at 31.15 N, 32.20 E to el-Dibia Island at 22.39 N, 36.51 E. Twenty-nine sites were chosen to represent a variety of habitats in which the species of *Caulerpa* live. Botanical and ecological information had been accumulated in various sites through which the senior author visited during the

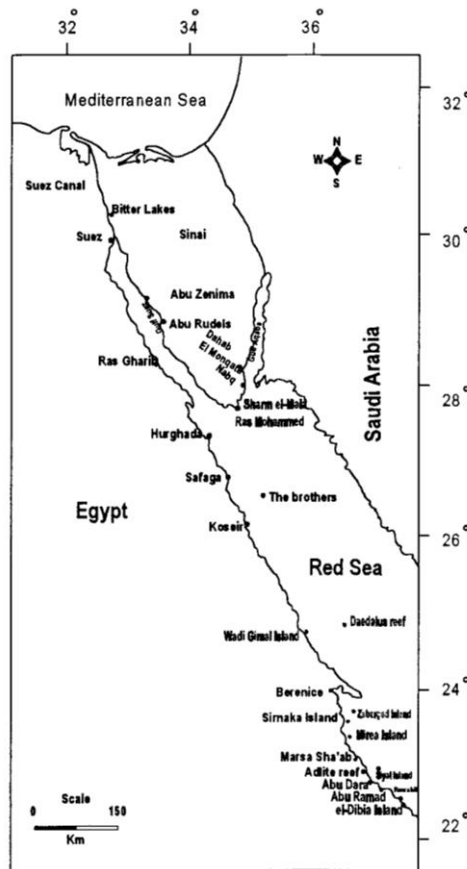


Fig. 1. The Red Sea and the investigated sites

period of 1994-99. Algal collections were carried out at random, by snorkeling, sometimes by diving, and covering different habitats at each site. Algal materials were preserved as herbaria and in 4% formalin for further identification. Records of site, depth, habitat types, and the general ecological conditions are included with all voucher specimens. All the drawings are original and made by the authors using Camera Lucida.

Results

The genus *Caulerpa* is easily distinguished from the other algae as its thallus consists of a "rhizome", which creeps over the sand or mud, rooted into them by means of numerous rhizoids terminated with a group of fixative filaments. The stolon gives rise to numerous, erect, assimilators or "fronds". The frond consists of a central axis with lateral branchlets or ramuli, the form and arrangement of which varies very considerably according to the species and their habitats.

Identification key of *Caulerpa* Lamouroux from the Egyptian coasts

1. Frond and stolon are morphologically similar. *C. fastigiata*
1. Frond and stolon are markedly different. 2
2. Frond form dichotomously straps with dentate margin. *C. serrulata*
2. Frond does not form straps. 3
3. Ramuli are clavate, peltate or spherical. 4
3. Ramuli are pinnate, with cylindrical or compressed pinnules. 6
4. Ramuli are peltate; forming stalked discs. *C. peltata*
4. Ramuli are spherical, clavate. 5
5. Ramuli are spherical, crowded (grape-like), with constricted stalks. ... *C. lentillifera*
5. Ramuli are clavate, not crowded, with non-constricted stalks. *C. racemosa*
6. Pinnules arranged in dense whorls, cylindrical, stiff, and mucronate. *C. webbiana*
6. Pinnules arranged in two opposite rows in one plane (distichous). 7
7. Pinnules are cylindrical of regular diameter throughout. *C. sertularioides*
7. Pinnules are slightly or strongly compressed. 8
8. Central axis is broader than the length of pinnules; apices of pinnules are round, smooth or dentate. *C. scalpelliformis*
8. Central axis is markedly narrow than the length of pinnules; apices of pinnules are apiculate or acuminate. 9
9. Pinnules are wide at the middle part, overlapped, distinctly constricted at the base, and apiculate. *C. mexicana*
9. Pinnules are sickle-shaped, rarely overlapped, slightly constricted at the base, and acuminate. *C. taxifolia*

Caulerpa fastigiata Montagne. (Fig. 2, a).

The stolons and fronds are morphologically similar; the diameter is being 1.1-2.4 mm for both. The stolon is rarely branched, may reach a length of 25-45(75) cm. The fronds are 3-6 cm in length, irregularly or sub-dichotomously branched. Frond apices are round or slightly tapering into blunt tips.

C. fastigiata was rare, forming small dense patches on reef front and frequently developed on shaded areas in a depth between 2-3 m of the infralittoral. Uncommon, this species was found forming a mat-like on sandy bottoms in the upper-, mid-, lower-littoral zones of a mangrove swamp. The plants in this case were much thinner, trapping large amount of sand. It was found only during summer in the southern coast.

Locality: el-Dibia, Nabq mangrove, Mirrear, and Siyal.

***Caulerpa serrulata* (Forsskål) J. Agardh. (Fig. 2, b & c).**

Records under other synonyms

Fucus serrulatus Forsskål, 1775.

Caulerpa freycinetii var. *serrulata* (Forsskål) Zanardini, 1858.

The prominent characters of this alga are the strap-like fronds. Stolons are 2 mm thick, sparsely to richly branched, fastened to substrate by numerous rhizoids that may reach a length up to 6 cm. There are two forms of this species. The first with yellowish green erect fronds, which are dichotomous and spirally twisted, having serrate margin, narrow (1-1.2 mm), 2-3 cm in length, and born on short cylindrical stipes (2-5 mm). The second form with dark green fronds that are dichotomous in one plane, with serrate margins, broader than the former (2-3 mm), 8 cm in length, and born on compressed stipes (3-18 mm).

C. serrulata was the most common among *Caulerpa* in the Red Sea. It inhabited different photophilic and sciaphilic biotopes, growing on various sandy and muddy substrates in bottoms and on reefs situated in both mid-littoral and infralittoral zones. It was found in many cavities, gullies and fissures on reef flat; and frequently growing in association with seagrasses such as *Cymodocea rotundata*, *Halophila stipulacea*, *Halodule uninervis*. *C. serrulata* also inhabited the organic substrates in upper infralittoral of mangrove swamps, creeping with other organophilic algae between the pneumatophores of *Avicenia* and *Rhizophora*.

The thalli of this species were vigorous with long stolons, fronds and rhizoids in nutrient rich sandy or muddy bottoms. On sand covered corals, thalli were less branched, shorter, and became much smaller in exposed situations. A marked variation in both color and morphology was observed when the species growing in different light conditions. The first form, described above, dominated the shallow well-illuminated waters, while the second occupied the shaded areas or found in deeper depths.

Locality: Abu Dara, Abu Ramad, Abu Rudeis, Abu Zenima, Adlite reef, Berenice, Dahab, el-Dibia, el-Tor, Hurghada, Koseir, Marsa Sha'ab, Mirrear, Nabq, Ras Gharib, Ras Mohammed, Ruwabil reef, Sharm el-Maia, Shora el-Monqata, Siyal, Suez, The brothers, and Zabargad.

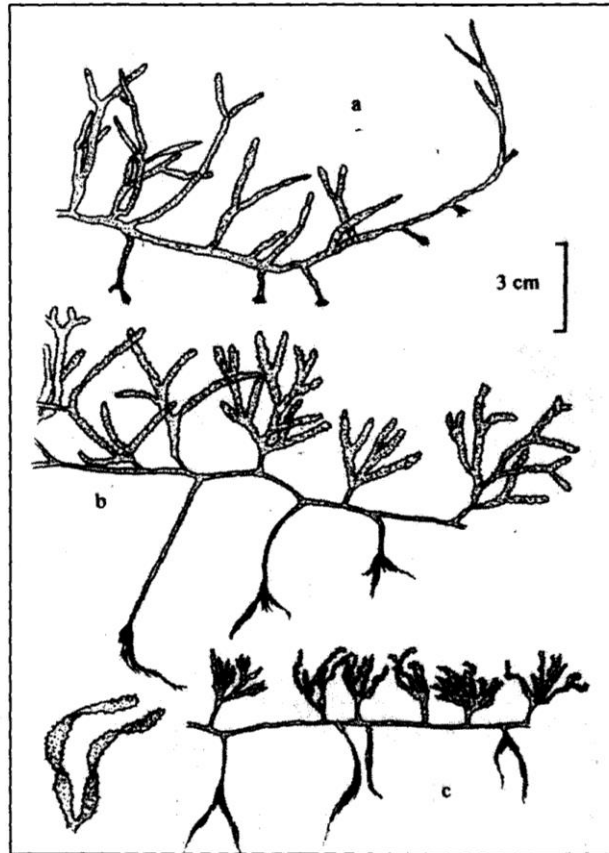


Fig. 2. a. *C. fastigiata* Montagne. b, & c. two forms of *C. serrulata* (Forsskål) J. Agardh.

***Caulerpa lentillifera* J. Agardh. (Fig. 3, a & b).**

Records under other synonyms

Caulerpa microphysa (Weber) Taylor. Børgesen, 1925.

The prominent character of this alga is the grape-like looking of their fronds. Stolons are branched, up to 2 mm in diameter, fastened to substrates by slender rhizoids. Erect fronds are simple or branched, with central axes, of 1-mm diameter, carry very dense spherical ramuli. Ramuli are 1 mm diameter, radially arranged, born on short constricted stalks.

C. lentillifera was found in many sites in lower littoral and upper infralittoral zones. It inhabited the sand-covered solid substrates in reef cavities in both dim and moderate light, and this bearing little variation in plant morphology. Fronds with very dense vesicles were observed in moderate light, while the plant born much less vesicles in dim light.

Locality: Abu Dara, Adlite reef, Berenice, Bitter Lakes, el-Dibia, el-Tor, Koseir, Marsa Sha'ab, Mirear, Ruwabil reef, Sirnaka, and Suez.

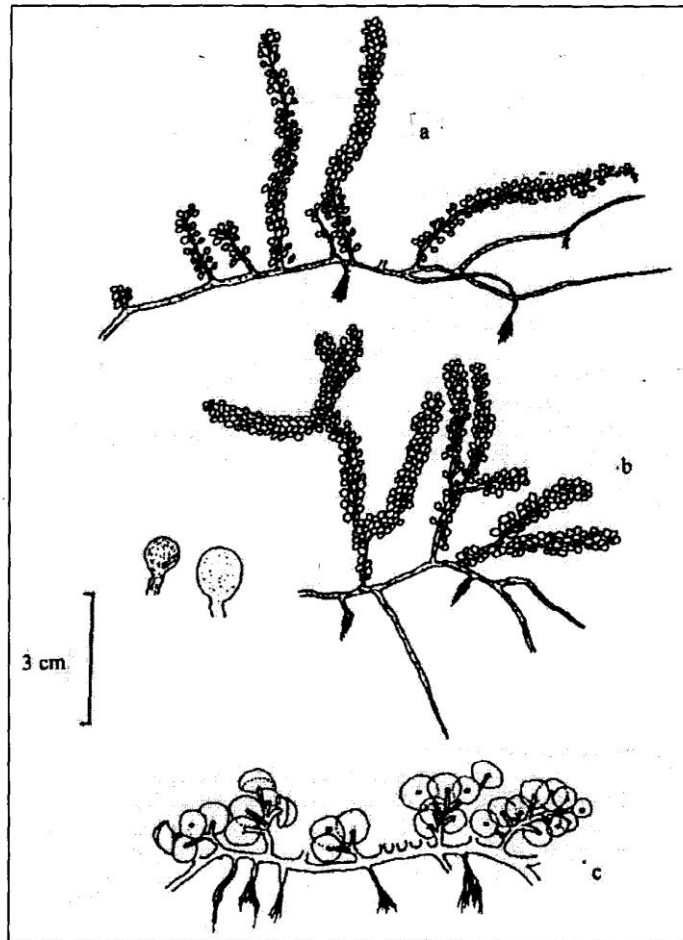


Fig. 3. a & b. simple and branched thalli of *Caulerpa lentillifera* J. Agardh.
c. *Caulerpa peltata* Lamouroux.

***Caulerpa peltata* Lamouroux. (Fig. 3& c).**

Records under other synonyms

Caulerpa chemnitzia var. *peltata* (Lamouroux) Zanardini, 1858.

Caulerpa racemosa var. *peltata* (Lamouroux) Eubank. Papenfuss, 1968.

The prominent character of this alga is the flat discs or peltate ramuli on narrow stalks. Stolons are rarely branched, up to 1.7-2.3 mm broad, fastened to substrates by short slender rhizoids. Erect fronds are 1.4-2.8 cm long, simple, sometimes branched, and richly

placed on the stolon. The discs are 5-7 mm in diameter with smooth margins, generally in alternate disposition on the central axis of the frond. Both central axis and stalks are about 1-1.2 mm in diameter.

C. peltata was found in many sites, growing on sand covered hard substrates. It occupied the shaded areas in crevices, fissures, and gullies of the reef flat in the infralittoral zone. It was also found exposed to direct sunlight in the shallow waters of the lower littoral. In the latter habitat, the discs tend to be thicker and smaller than the typical *peltata* ramuli born in shaded areas.

Locality: Abu Rudeis, el-Tor, Hurghada, Mirear, Ruwabil reef, Ras Mohammed, Safaga, Sirnaka, and Zabargad.

***Caulerpa racemosa* (Forsskål) J. Agardh. (Fig. 4, a, b & c).**

Records under other synonyms

Caulerpa racemosa var. *lamourouxii* (Turner) Weber van Bosse, 1898. Papenfuss, 1968.

Caulerpa racemosa var. *lamourouxii* f. *requienii* (Montagne) Weber van Bosse, 1898.

Caulerpa racemosa var. *turbinata* (J. Agardh) Eubank. Papenfuss, 1968.

Stolons are richly branched, 2-4(5) mm in diameter, fastened to the substrate by numerous rhizoids. Their length has an average of 50-80 cm, and may reach a few meters. Erect fronds are 1-5(7) cm long, simple or branched, bearing 4-8 pairs of pyriform vesicles of 1-3(4) mm diameter. There are many specimens with different aspects of vesicles. On some, the vesicles are crowded, radially arranged, and having rounded apices. On others, the vesicles are sparse, oppositely arranged, and having flattened apices. Moreover, a third form is found carrying fronds with the two previous aspects in addition to others lacking vesicles on the same stolon.

C. racemosa was very common in the Red Sea and Suez Canal, found as pure stands or mixed with other seaweeds and seagrasses. It inhabited sands and mud in both lagoons and open coasts, in infralittoral zone of a depth varies between 60 cm to several meters. It rarely found at 30 m of water depth. The characteristics of the thallus vary considerably according to the substrate, depth, light, nutrient level, and exposure to waves. Dense growths were observed in nutrient rich bottoms in the protected sites; stolon was more branched, thicker and longer, measuring a length of about two meters. Well-developed fronds and long rhizoids were also evident in these habitats. In rocky habitats, the plants were small, and became much smaller but stout in exposed situations.

In shallow waters, where illumination was extremely high, the fronds appeared to be pale in color. The color is turned to dark green when other seaweeds such as *Sargassum*, *Turbinaria* and *Padina* shade the thalli. The first form of dense vesicles was found in lagoons and shallow areas, while the second form occurred in reef cave, gullies and fissures. The third form occurred on the illuminated edgeways of a reef cave, its stolon was found extending down to a dim area inside this cave.

Locality: Abu Ramad, Abu Rudeis, Bitter Lakes, Daedalus reef, Dahab, el-Tor, Hurghada, Koseir, Marsa Sha'ab, Nabq, Port Said, Ras Gharib, Ras Mohammed, Ruwabil reef, Sharm el-Maia, Shora el-Monqata, Sirnaka, Suez, The brothers, Wadi Gimal, and Zabargad.

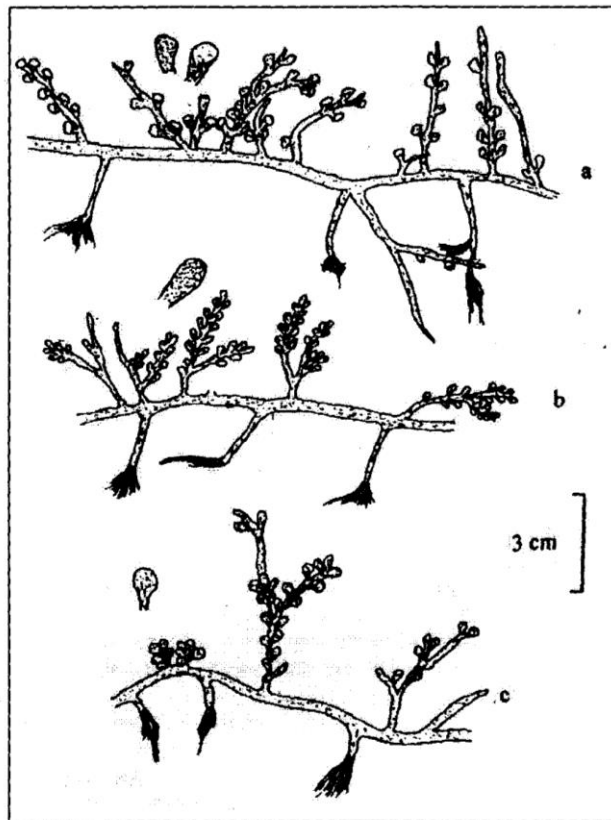


Fig. 4. a, b & c. three forms *Caulerpa racemosa* (Forsskál) J. Agardh.

Caulerpa scalpelliformis (R. Braun) C. Agardh. (Fig. 5, a).

Records under other synonyms

Caulerpa scalpelliformis var. *denticulata* (Decaisne) Weber, 1898. Papenfuss, 1968.

Stolons are poorly branched, 1-1.5 mm in diameter, fastened to substrate by cylindrical rhizoids of 0.3-1(2.3) cm long. Erect fronds are pinnate, compressed, 3-8(14) cm in length, 0.7-1 cm broad, having short cylindrical stipes, and richly placed on the stolon. The central axis of the fronds are wider (6mm) than the pinnule length (3-4 mm). The pinnules are lanceolate, non-contracted at the base, having rounded smooth or denticulate apex.

C. scalpelliformis was found in many sites along the Red Sea and Suez Canal. It inhabited the sandy covered hard substrate in infralittoral at 2-4 m water depth, and may penetrate sandy area from nearby reef. In sand, the length of rhizoids may reach to 2.3 cm. The species was also found in back reef pools of the lower littoral in association with *Caulerpa racemosa* and *Digenea simplex*. In exposed shallow habitats, the fronds were

short, somewhat succulent, had pinnules with prominent denticulate apex. The erect fronds, in the infralittoral reef gullies, were much longer, reached a length of up to 14 cm, and had pinnules with smooth apex.

Locality: Abu Zenima, Adlite reef, Berenice, Bitter Lakes, Dahab, Koseir, Marsa Sha'ab, Nabq, Port Said, Safaga, Suez, and Wadi Gimal.

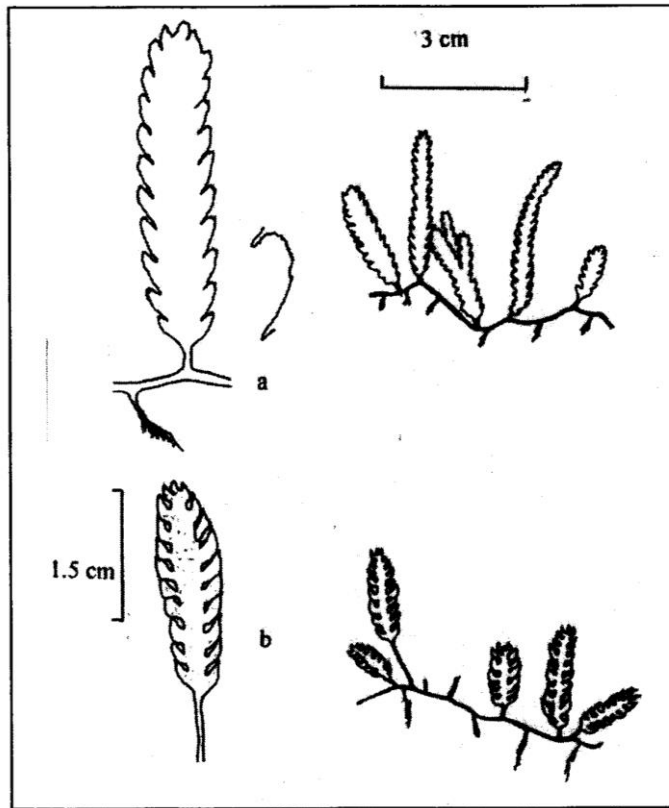


Fig. 5. a. *Caulerpa scalpelliformis* (R. Braun) C. Agardh.,
b. *Caulerpa mexicana* (Sonder) J. Agardh.

***Caulerpa mexicana* (Sonder) J. Agardh. (Fig. 5, b).**

Records under other synonyms

Caulerpa taxifolia var. *crassifolia* C. Agardh. Muschler, 1908.

Caulerpa crassifolia (C. Agardh) J. Agardh. Nasr, 1939.

Stolons are richly branched, 0.5-1 mm in diameter, and fastened to substrate by many slender rhizoids. Erect fronds are pinnate, strongly compressed, rarely branched,

1.3-2.3(4) cm high, 4-8 mm wide, with short cylindrical stipes. Pinnules are dense, 2-3 mm long, 1-1.5 mm wide, oppositely placed along a central axis of 1-2 mm broad. Pinnules are lanceolate, wider at middle or sub-apical parts, having acuminate apex and contracted base. The widest parts are generally overlapped.

C. mexicana was found in many sites along the Red Sea and Suez Canal. It formed small patches in both lower littoral and upper infralittoral zones. It was found attached to hard substrates, shaded by *Laurencia papillosa*, *Sargassum ilicifolium*, and *Turbinaria triquetra*, or living cracks and gullies with other sciaphilic seaweeds. The alga was rarely found growing with *Halophila stipulacea* on sandy or muddy substrates. The morphology of the *C. mexicana* showed very little change when occurred in a habitat of dim light; the fronds and pinnules become longer and thinner than the specimens found in more light.

Locality: Abu Dara, Adlite reef, Bitter Lakes, Hurghada, Koseir, Port Said, Shora el-Monqata, Sirnaka Island, Siyal, Suez, and Zabargad.

***Caulerpa sertularioides* (Gmelin) Howe. (Fig. 6,a).**

Records under other synonyms

Caulerpa plumaris (Forsskål) C. Agardh, 1822.

Stolons are 5-10 mm in diameter, sparsely branched. Fronds are pinnate, rarely branched, 1-3.5(5) cm high, 6-10 mm wide, with short stipes. The central axis is slightly compressed, 3-5 mm wide. Pinnules are cylindrical of regular diameter throughout, 160 µm thick, up-curved, with mucronate tips.

C. sertularioides formed small dense patches on both solid and soft substrates in reef pools, seagrass flat, mangrove channels of mid-littoral and infralittoral zones. When found in well-insolated shallow waters, the plants were small and slender.

Locality: Adlite reef, Berenice, Bitter Lakes, Nabq, Ruwabil reef, and Sharm el-Maia.

***Caulerpa taxifolia* (Vahl) C. Agardh. (Fig. 6, b).**

Records under other synonyms

Caulerpa mexicana (Sonder) J. Agardh, Eubank, 1946.

Stolons are 5-10 mm in diameter, sparsely branched. Fronds are compressed, pinnate, 2-4(5) cm high, 5-7(10) mm wide, with short stipes. The central axis is about 5 mm wide. Pinnules are gradually tapering to an acuminate apex, slightly contracted at the base, 3-6 mm long, 140 µm thick, up-curved, and rarely overlapped.

C. taxifolia formed small dense patches in association with *Codium dwarkense*, *Digenea simplex*, *Halimeda tuna*, and *Turbinaria triquetra* on the edgeways of cliffs, gullies, and ledges of the reef in infralittoral zone. In these sciaphilic habitats, the plumes were thin and long, but rarely reached to 7 cm in height. In shallow depth between 3-5 m, where the alga was found on sand nearby reef, the habitat was more lightened and the plumes were shorter but reached 7-10 mm wide.

Locality: Abu Dara, Berenice, Daedalus, el-Tor, Nabq, Ruwabil reef, and Suez.

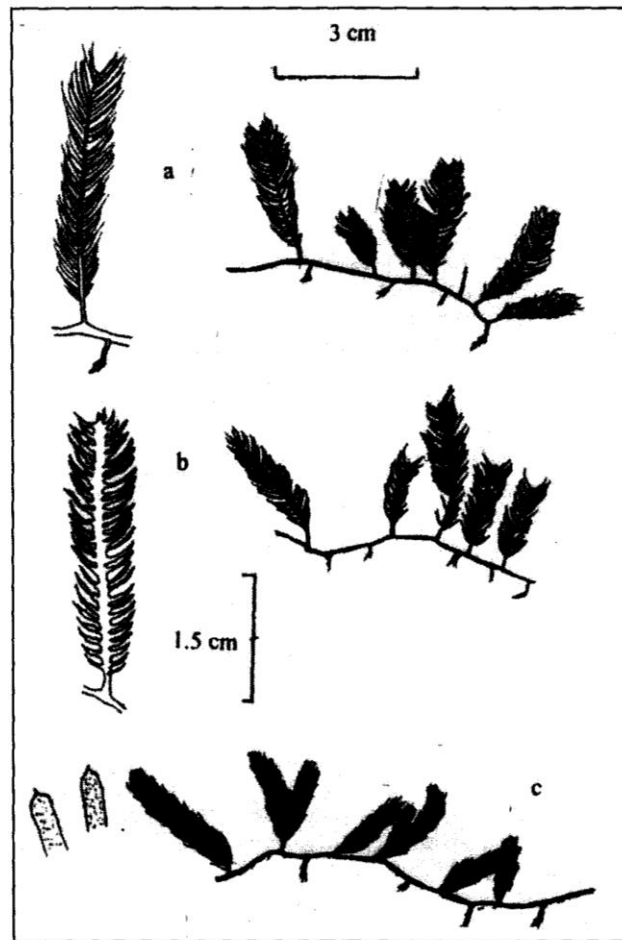


Fig. 6. a. *Caulerpa sertularioides* (Gmelin) Howe. b. *Caulerpa taxifolia* (Vahl) C. Agardh. c. *Caulerpa webbiana* Montagne.

***Caulerpa webbiana* Montagne. (Fig. 6, c).**

The prominent characters of this alga are the cat-tail-like fronds. Stolons are 1-1.3 mm in diameter, sparsely branched, firmly attached to substrates by short slender rhizoids. Fronds are cylindrical in appearance, due to the dense verticillately arranged pinnules, and so it is not easy to follow the central axis. Five to six pinnules are found in each whorl. Pinnules are cylindrical, stiff, mucronate, 3-6 mm long, 130 μ m thick

C. webbiana was found along the coast of Red Sea and Bitter Lakes, forming small dense patches where appear. It exclusively inhabited the shaded hard substrates, very firmly rooted and difficult to separate from other algae. It was found in the infralittoral,

generally in sheltered habitats but also found in areas exposed to strong surf. When growing in more light, the plant produces branched fronds, sometimes with branched pinnules.

Locality: Abu Ramad, Abu Ramad, Abu Rudeis, Bitter Lakes, Ras Mohammed, Safaga, Shora el-Monqata, Suez, and Wadi Gimal.

Discussion

Ten species of *Caulerpa* were identified from the Egyptian coast of Red Sea. Almost all species are included in the previous checklists. *Caulerpa fastigiata* was only the species that identified as a new record for the study area. This species has been reported by Taylor (1967) from the Ethiopian coast, and is never reported in the other parts of Red Sea. *C. ambigua*, *C. cupressoides*, *C. prolifera*, and *C. selago*, were previously reported by Papenfuss (1968) and Taylor (1967) however, they were not found in the course of this study.

The locality type of the investigated species situated in the Indian Ocean, as they are known along the coasts of East Africa: Somalia (Sartoni, 1978); Kenya (Taylor, 1967; Moorjani, 1977; Coppejans and Beeckman, 1989, 1990); Tanzania (Jaasund, 1977; Taylor, 1967); Mozambique (Taylor, 1967). *C. racemosa* and *C. serrulata* are the most common species in the Red Sea, occupying 21 and 23 of the investigated sites, respectively. *C. lentillifera*, *C. mexicana* and *C. Scalpelliformis* were frequent in 12 sites. The two latter species with *C. racemosa* seem to reach the northern limits in the shores of the Suez Canal and overrunning the Eastern Mediterranean (Aleem, 1992; Hamel, 1931; and Rayss, 1941). Three other species, *C. lentillifera*, *C. sertularioides*, and *C. webbiana*, were reported in this study from the Bitter Lakes, and may penetrate into the Mediterranean in the future. However, the very common *C. serrulata* was not found in the Suez Canal. It seems to prefer habitat of open waters in the sea, and thus may be excluded from migration through the canal, which is of just 250-m wide and 25-m depth.

C. peltata, *C. webbiana*, *C. taxifolia*, *C. sertularioides*, and *C. fastigiata* were rare, forming small dense patches where appeared, and occurring in 9, 8, 7, 6, and 4 sites, respectively. Each site contained two to six species of *Caulerpa*. Recently the *C. taxifolia* is introduced into the northern Mediterranean at Monaco, and is well established and spread along the coasts of France and Spain (Meinesz and Hesse, 1991). This species reaches its northern limits in the shores of the Red Sea at Suez, but not found in any part of the Suez Canal. The characteristics of its thallus at Monaco are markedly different from those found during this study; the fronds may reach a length greater than 40 cm; the length of stolons vary from 50 to 80 cm; the rhizoids reach a length of 5-10 cm.

Although *Caulerpa* is well known to be one of the psammophytic macroalgae (Dawes, 1998; and Round, 1981) inhabiting unconsolidated sediments, it is also found on hard substrate. The sediments, in the study area, are composed of sand and/or mud, occurring in the open coasts, lagoons, seagrass beds, mangrove swamps, back-reef pools, and reef channels. Hard substrata range from horizontal to gently sloping rocks and reefs. When found on hard substrates, the species inhabited the area covered by a layer of sand. The length of rhizoids seems to be dependent upon the depth of sand in which the plant anchored. The length of *C. serrulata* rhizoids, as an example, was 0.5-1 cm in thin sand, reaching a length of 2.3 cm in heavy sand.

According to their preference to the type of substrate, the species of *Caulerpa* may be assembled into three groups. The first comprising *C. fastigiata*, *C. lentillifera*, *C. peltata* and *C. webbiana* that found attached to hard substrate. Uncommon, *C. fastigiata* was found forming a mat-like on a sandy bottom channel of a mangrove swamp. The second group including *C. mexicana*, *C. scalpelliformis* and *C. taxifolia*, which are principally found attached to hard substrate but may penetrate sandy areas from nearby reef. The third group comprising *C. racemosa*, *C. serrulata* and *C. sertularioides*, which grow where there is plenty of sand or mud in both lagoons and reef flats. Successful growth of these species was observed in nutrient rich bottoms, and in sites protected from waves.

The species of *Caulerpa* in the Red Sea dominated the zone of infralittoral, generally at 2-3 m, sometimes more deeper, but rarely to about 30 m water depth. Some species frequently inhabited the littoral zone and grow where the bottom never exposed to air, as in tidal channels of the mangrove swamps and back-reef pools. The *Caulerpa* is thus appeared as a submergent plant. *C. fastigiata* inhabited the upper-, mid-, lower-littoral and the upper infralittoral zones. *C. serrulata* and *C. sertularioides* were found in both mid-littoral and infralittoral. *C. mexicana*, *C. lentillifera*, *C. peltata* and *C. scalpelliformis* occurred in lower littoral and upper infralittoral, while *C. racemosa*, *C. taxifolia*, and *C. webbiana* occupied the infralittoral only. *C. mexicana* and *C. serrulata* were also found growing deepest in the Red Sea; they were dredged from a depth of about 100 m and 120 m, respectively (Lipkin, 1973).

The salinity range in the study area was comparatively narrow and did not depart from 27-43 ‰. It was measured as 37-41 ‰ in sites of the Red Sea, 42-43 ‰ in the Bitter Lakes, and as 27-31 ‰ at Port Said. Presence of various species of *Caulerpa* in this range indicates a good tolerance. Horstmann (1983) found that a salinity of 30-40 ‰ is good for the optimum growth of *C. racemosa*. He stated that the irreversible depression of growth occurs when the salinity decreases to below 20 ‰.

Water temperatures were measured as an average for winter and summer. They were as 16 and 26°C in Red Sea, 17 and 28° C at Bitter Lakes, and 14 and 27°C at Port Said. Dense growth of many species of *Caulerpa* was observed during July-August when the water attained value of 25-28°C, and this is in a close agreement with the result given by Trono and Ganzon-Fortes (1981) and Horstmann (1983) on cultures of *C. lentillifera* and *C. racemosa*.

The species of *Caulerpa* in the Red Sea occupied different photophil and sciaphil biotopes from shallow to deep water, and from exposed to sheltered situations. They prefer living in shaded areas such as crevices, cliffs, fissures, gullies, overhangings, and ledges, in association with the other sciaphilic species of seaweeds such as *Halimeda* *anaea*, and *Udotea argentea*. In shallow waters, *Caulerpa* may hideaway from intense solar radiation by occupying the areas between other larger algae such as *Laurencia papillosa*, *Sargassum ilicifolium*, and *Turbinaria triquetra*. *C. racemosa* and *C. serrulata* were only the species that dominate both highly illuminated and shaded habitats. Their frond color appeared to be pale in strong light, turned to dark green when other seaweeds or seagrasses shade the thalli. Horstmann (1983) referred the pale color of *C. racemosa*, under intense radiation, to the retraction of the chloroplasts from the assimilatory structures into the stolons.

Variations in species morphologies that occur between locations with similar hydrographic conditions usually reflect differences in light (Vadas and Steneck, 1988). *C.*

racemosa, *C. scalpelliformis* and *C. serrulata* showed marked variations in their morphology when grows under different light intensity. In photophilic biotopes, the fronds of *C. serrulata* appeared to be shorter, densely and spirally twisted. In sciaphilic biotopes, the fronds were longer, flat, thin, and untwisted. In both biotopes, the frond margins have well-developed teeth, and this is in a close agreement with the observations of Lipkin (1973) but in contrast with the observations of Nasr (1947). Nasr observed plants with poorly developed teeth in shaded habitats. The fronds of *C. scalpelliformis*, in high illumination, were short, somewhat succulent, had pinnules with very prominent denticulate apex, and this is the same as variety *denticulata* (Decaisne) Weber van Bosse (Papenfuss, 1968). In shaded habitats, fronds were much longer, had pinnules with smooth apex, and this is similar to the characteristics of the variety *typica* Weber van Bosse. *C. scalpelliformis* showed the same variations along the Mediterranean coast (Rayss, 1941).

The great variability in morphology of *C. racemosa* is a well-known phenomenon. Weber van Bosse (1898) described more than 20 intraspecific taxa and since then, new forms have been added by various authors. Doubts have been expressed whether all these forms constitute genuine taxonomic units as experimental works by Tandy (1934) and Nasr (1947) suggest that, by changing external conditions, different varieties as described from natural habitats, can be produced on the same stolon. Papenfuss (1968) listed five varieties of *C. racemosa* from the Red Sea, few of which have the same characteristics of specimens observed during this study. Specimens with the fronds that richly branched with many vesicles densely arranged around the central axis appeared under high illumination in shallow waters; and this is the typical species *racemosa* (Forsskål) J. Agardh (Børgesen, 1932). In shades, the fronds bear much less vesicles, which were oppositely arranged on the central axis; and this similar to variety *lamourouxii* (Weber van Bosse, 1898; Papenfuss, 1968). In this habitat, many fronds on the same stolon may also lack vesicles and, hence, create an ecological form known by Weber van Bosse (1898) as variety *lamourouxii* f. *requienii*. Other specimens had vesicles of flattened apex and record as variety *turbinata* (J. Agardh) Eubank (Papenfuss, 1968).

C. fastigiata, *C. lentillifera*, *C. peltata*, and *C. webbiana* showed no marked changes in their morphology in relation to light conditions. The thallus was much thinner, forming a mat-like when occurring in littoral zone, while typical thallus was found in the infralittoral, and this fits well for the materials collected by Coppejans and Beeckman (1990) from Kenya. *C. lentillifera* bears much less vesicles in dim light, while *C. webbiana* bears branched fronds, sometimes with branched pinnules, when growing in more light. The discs of *C. peltata* tend to be thicker and smaller in diameter when exposed to direct sunlight. Many authors (e.g., Papenfuss, 1968; Coppejans and Beeckman, 1989) regard this species as a variety of *C. racemosa*, while others (e.g., Muschler, 1908; Børgesen, 1925) treat it as a distinct species. The typical flat discs with the absence of any intermediate transition form between *C. racemosa* and *C. peltata* may constitute the main reason for justifying the present material as a distinct species as do Børgesen.

Little changes in morphology are also noticed for *C. mexicana*, *C. sertularioides*, and *C. taxifolia*. In dim light, *C. mexicana* and *C. taxifolia* became longer and thinner. In contrast, *C. sertularioides* became small and more slender in well-insolated shallow waters. Papenfuss (1968) regards *C. taxifolia* as a synonym for *C. mexicana*. In the present collections, it is always easy to distinguish the two species from each other. The pinnules of the former are gradually tapered into an apical point, being sickle-shaped,

while the pinnules of the latter are more compressed, wider at the middle, and with marked spine at the apex.

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دراسات بيئية ومورفولوجية على جنس *Caulerpa* المنتشر على السواحل المصرية للبحر الأحمر

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يهدف البحث إلى دراسة أنواع الكوليريا المنتشرة على سواحل مصر المطل على البحر الأحمر وإلقاء الضوء على أماكن تواجدها واختلافاتها المورفولوجية في الظروف البيئية المتباينة . وقد تم التعرف على عشر أنواع منها خلال دراسة تسع وعشرون محطة في الفترة بين عام ١٩٩٤ إلى عام ١٩٩٩ . وعضدت النتائج بمفتاح تعريف ووصف ورسوم أصلية لهذه الأنواع ، إضافة إلى توزيعاتها الجغرافية القريبة في سواحل المحيط الهندي . وقد أظهرت الدراسة تغيرا ملحوظا في الشكل الظاهري لبعض الأنواع عند تواجدها في الأعماق والأماكن المختلفة في درجة إضاءتها . وكان كل من نوعى *C. serrulata* و *C. racemosa* هما الأكثر شيوعا في أماكن الدراسة بينما كانت باقى الأنواع ذات تردد متوسط أو قليلة الانتشار بين المحطات . وناقشت الدراسة هجرة بعض الأنواع للبحر المتوسط ، ولوحظ تواجد ست أنواع من الكوليريا في قناة السويس ، استطاع ثلاثة منها الوصول إلى شرق البحر المتوسط . وعلى الرغم من سيادة طحلب *C. serrulata* في كثير من محطات البحر الأحمر إلا أنه يمكن استبعاده من الهجرة خلال قناة السويس حيث يبدو هذا الطحلب محبا لبينات المياه المفتوحة في البحار . وتفضل أنواع الكوليريا القاع الرملى والطمى المتواجد في عدد من الأماكن المضاءة والضعيفة في إضاءتها في أعماق مختلفة بمنطقة ما تحت الجذر . والقليل منها يعيش في أسفل منطقة المد والجذر بالأماكن التي لا تتعرض للجزء كالكبرك المرجانية الصغيرة . وقد وجدت هذه الأنواع منشرة بكثرة على الشعاب المسطحة الصلبة وبين شقوقها وكهوفها عندما تكون هذه الشعاب مغطاة بطبقة من الرمل . ولوحظ زيادة طول الطحالب وأشباه جنورها عندما يزداد عمق الطبقة الرملية أو محتواها الغذائى أو عندما تكون في أماكن محمية من فعل الأمواج . ووجد أن اختلاف الشكل الظاهري للعديد من الأنواع يعتمد على شدة الإضاءة .