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Morphological diversity of benthic Nostocales (Cyanoprokaryota/Cyanobacteria) from the tropical rocky shores of Huatulco region, Oaxaca, México

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Abstract

The supratidal and intertidal zones are extreme biotopes. Recent surveys of the supratidal and intertidal fringe of the state of Oaxaca, Mexico, have shown that the cyanoprokaryotes are frequently the dominant forms and the heterocytous species form abundant and conspicuous epilithic growths. Five of the eight special morphotypes (*Brasilonema* sp., *Myochrotes* sp., *Ophiothrix* sp., *Petalonema* sp. and *Calothrix* sp.) from six localities described and discussed in this paper, are new reports for the tropical Mexican coast and the other three (*Kyrtuthrix* cf. *maculans*, *Scytonematopsis* cf. *crustacea* and *Hassallia littoralis*) extend their known distribution.

Key words: Marine environment, stressful environment, Scytonemataceae, Rivulariaceae

Introduction

The rocky shore is a highly stressful habitat, due to the lack of nutrients, elevated temperatures and high desiccation related to tidal fluctuation (Nagarkar 2002). Previous works on this habitat report epilithic heterocytous species that are often dominant especially in the supratidal and intertidal fringes (Whitton & Potts 1979, Potts 1980; Nagarkar & Williams 1999, Nagarkar 2002, Diez *et al*. 2007). On tropical rocky shores, primary producers such as cyanoprokaryotes, are able to fix atmospheric nitrogen (Nagarkar 2002, Diez *et al*. 2007); they are often the main epilithic components, and are distributed from the subtidal to the supratidal zone (Whitton & Potts 1979, Potts 1980; Nagarkar & Williams 1999, Nagarkar 2002), forming the base of the benthic food web and contributing greatly to the productivity and organization of the marine community in tropical coastal shores (Williams *et al*. 2000, Nagarkar *et al*. 2004).

Despite their ecological and physiological significance, little is known about the diversity of marine cyanoprokaryotes along the Mexican littoral (León-Tejera *et al*. 2009). There are a few reports for this group (León-Tejera *et al*. 2005, González-Resendiz *et al*. 2013) from the Oaxaca coast. The aim of this study is to describe the main morphotypes of supra- and intertidal epilithic heterocytous cyanoprokaryotes for the Tropical Mexican Pacific rocky shore.

Materials and Methods

Study site and sample collection:—Sampling was conducted between April 2004 and August 2014 in the supratidal and intertidal zones of five bays of the Huatulco region, and one site, Panteones beach, in Puerto Angel, located north of Huatulco. San Agustín and Cacaluta are within the Huatulco National Park (PNH); La Entrega, El Arrocito and Tangolunda are situated in Bahías de Huatulco south of PNH (Figs. 1A–1C), all in the tropical Mexican Pacific. Each site was collected between one and six times for a total of 56 samples. The tides of the coast of Oaxaca are mixed, with semidiurnal dominance. Conspicuous cyanoprokaryotic growths (Figs. 1B, 1D–1G) were collected with hammer and chisel along the supra and intertidal fringes, between 0–7 meters above sea level. Each sample was fixed with 4% formaldehyde in seawater and semi–permanent slides in glycerin gel were made.

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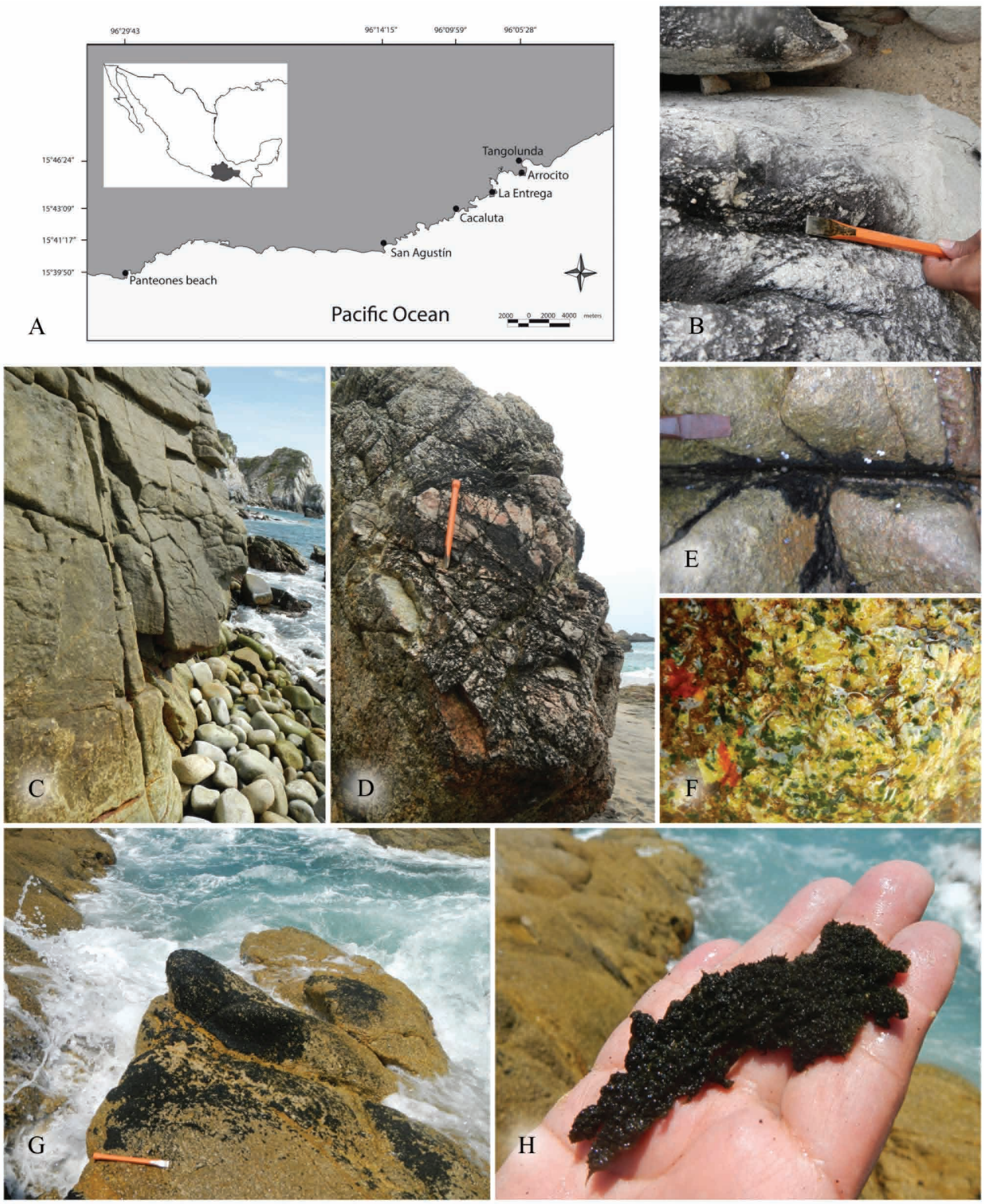

FIGURE 1. A. Map showing study area. B. *Ophiotrix* sp. growth at Cacaluta bay. D. *Hassallia littoralis* growth at El Arrocito bay. E. *Petalonema* sp. growth at San Agustín bay. F. *Kyrtuthrix* cf. *maculans* growth at Panteones beach. G, H. *Brasilonema* sp. growth at Tangolunda bay. B, C, D. Supratidal environments. E, F, G. Intertidal environments.

Sample processing:—Observations and micrographs were made with an Olympus BX51 microscope equipped with a DP12 digital camera. Measurements (n=30) were obtained using SigmaScan Pro© software, automated image analyses (Jandel Scientific, Sausalito, CA). Morphological identification was done in accordance with traditional reference works for Cyanoprokaryotes (Frémy 1929, Geitler 1932, Komárek 2013) and several papers that report tropical and subtropical rocky shore cyanoprokaryote taxa (Umezaki 1961, Whitton & Potts 1979; Sant'Anna 1995, 1997, Thajuddin & Subramanian 1992, Nagarkar 2002, Montoya-Terreros 2003). Systematic arrangement was done using the system of Komárek *et al*. (2014).

FIGURE 2. A–D. *Brasilonema* sp. A. Filaments densely fasciculate. B. False branches. C. Intercalary heterocyte. D. Development of isopolar hormogonia. E–I. *Myochrotes* sp. E. Geminate and simple false branches. F. Filaments constricted, densely entangled and widening towards ends. G. Hormogonia in a row. H. Closed apex closed prior to hormogonia liberation. I. Isopolar filament with variations in diameter. Arrow pointing at crescent-shape hormogonia, ap = apical cell, nc = necridic cell, ihet =intercalary heterocyte. Scale bars: A = 20 µm, D = 20 µm, B, C, E–I = 6 µm.

Results

In 39 of the 56 samples, the dominant growths were heterocytous: eight morphospecies belonging to eight genera and three families. Following are the descriptions of the dominant heterocytous components of the rocky shore mats. Descriptions include taxonomic comments and occurrence.

Family Scytonemataceae
Brasilonema Fiore, Sant'Anna, Azevedo, Komárek, Kaštovský, Sulek *et* Lorenzi (2007: 794)

Brasilonema sp. (Figs. 2A–2D).

Thallus caespitose composed of blackish-green erect filaments densely fasciculate 2–3 cm high, filaments with rarely geminate false branching 9–15 μm wide. Sheaths firm, cylindrical, lamellate, yellowish brown. Trichomes cylindrical constricted or not, at cross-walls 6–10 μm wide, slightly tapered towards the ends also in hormogonia; apical cell colorless, distinctively short and rounded, cap-like. Cells isodiametric in old filaments 5–8 μm long, shorter than wide in apical zones 2–3 μm long, with blue-green, olive-green, granulated content. Heterocytes intercalary, elongated, flattened, discoid or cylindrical 8–15 μm long, 2–3 times longer than wide, one or rarely three heterocytes contiguous or near one another 4.5–6.7 × 1.8–4.8 μm (long × wide). Akinetes not found. Reproduction by isopolar hormogones attached to filaments, sometimes crescent-shape.

Habitat:—Supratidal and intertidal fringes; epilithic on granitic rock.

Notes:—These populations are morphologically closest to *Brasilonema angustatum* Vaccarino *et* Johansen (2012: 1180) but distinctive characters such as heterocyte size and number, apical cell shape, as well as its distribution in a marine biotope, in contrast to the freshwater habitat of *B. angustatum*, probably indicate a new taxon.

Occurrence:—MEXICO. Oaxaca: San Agustín Bay, 15°41' 17.41" N, 96° 14' 15.28" W, *April and May 2004*, *April and December 2010*, *October 2012*, *August 2014*, *L. González-Resendiz* & *H. León-Tejera* (C36, C57, C645, C694, C719, C737, C1313); Tangolunda Bay, 15° 46' 24.79" N, 96° 5' 28.32" W, *August 2014 H. León-Tejera* & *L. González-Resendiz* (C1288, C1289, C1290).

Scytonema sect. *Myochrotes* Bornet *et* Flahault (1887: 86)
'*Myochrotes*' sp. (*sensu* Komárek 2013) (Figs. 2E–2I).

Thallus prostrate, crustose or woolly, blackish-brown, usually up to 1 cm long. Filaments elongated, densely entangled, 3.4–8.6 μm wide, repeatedly falsely branched with divaricated solitary or geminate branches. Sheaths lamellated, yellowish-brown. Trichomes cylindrical, constricted at cross-walls, 2.3–6.0 μm wide, slightly narrowed in central parts of old trichomes. Cells olive-green, shorter than wide, rarely quadrate, 1.5–3.0 μm long. Heterocytes 2.0–2.8 μm long, 4.5–5.8 μm wide, intercalary ± cylindrical to ± quadrate, sometimes wider than vegetative cells. Reproduction by isopolar hormogonia, rarely heteropolar.

Habitat:—Supratidal fringe; epilithic on gneiss rock.

Notes:—Given the complexity the relationships among *Scytonema* Bornet *et* Flahault (1887: 85), '*Myochrotes*' and *Petalonema* Berkeley ex Correns (1898: 321), we consider it necessary to analyze the morphology of populations of other marine localities and perform molecular studies, before assigning a specific epithet. New report of the genus for the coast of Mexico.

Occurrence:—MEXICO. Oaxaca: La Entrega Bay, 15° 44' 37" N, 96° 07' 40" W, *December 2010*, *L. González-Resendiz* & *H. León-Tejera* (C72, C73).

Ophiothrix Sant'Anna, Azevedo, Kaštovský *et* Komárek (2010: 218)
Ophiothrix sp. (Figs. 3A–3F).

Thallus short 100–150 μm high, black epilithic, formed by small groups of short yellowish to brownish filaments irregularly flexuous, creeping on substratum with erected ends forming a wide open "U", 6.5–9.0 μm wide, with false branching of scytonematoid or infrequently coleodesmioid type (almost basically heterocytes). Trichomes, 4.5–6.0 μm wide cylindrical along their whole length, not attenuated towards the ends, constricted at cross-walls; enveloped by a thin, firm lamellate yellowish sheath, closed or open at the apex after liberation of hormogonia. Cells cylindrical, always shorter than wide 1.2–3.0 μm; yellowish, pale blue-green or olive-green; apical cells widely rounded, without calyptra. Commonly hemispherical, barrel-shaped or cylindrical, simple intercalary heterocytes 3.4–4.9 long × 5.0–6.6 µm wide, in filaments as well as in isopolar hormogonia, rarely heteropolar (only at the base of a few hormogonia). Reproduction by isopolar hormogonia formed by necridic cell separation.

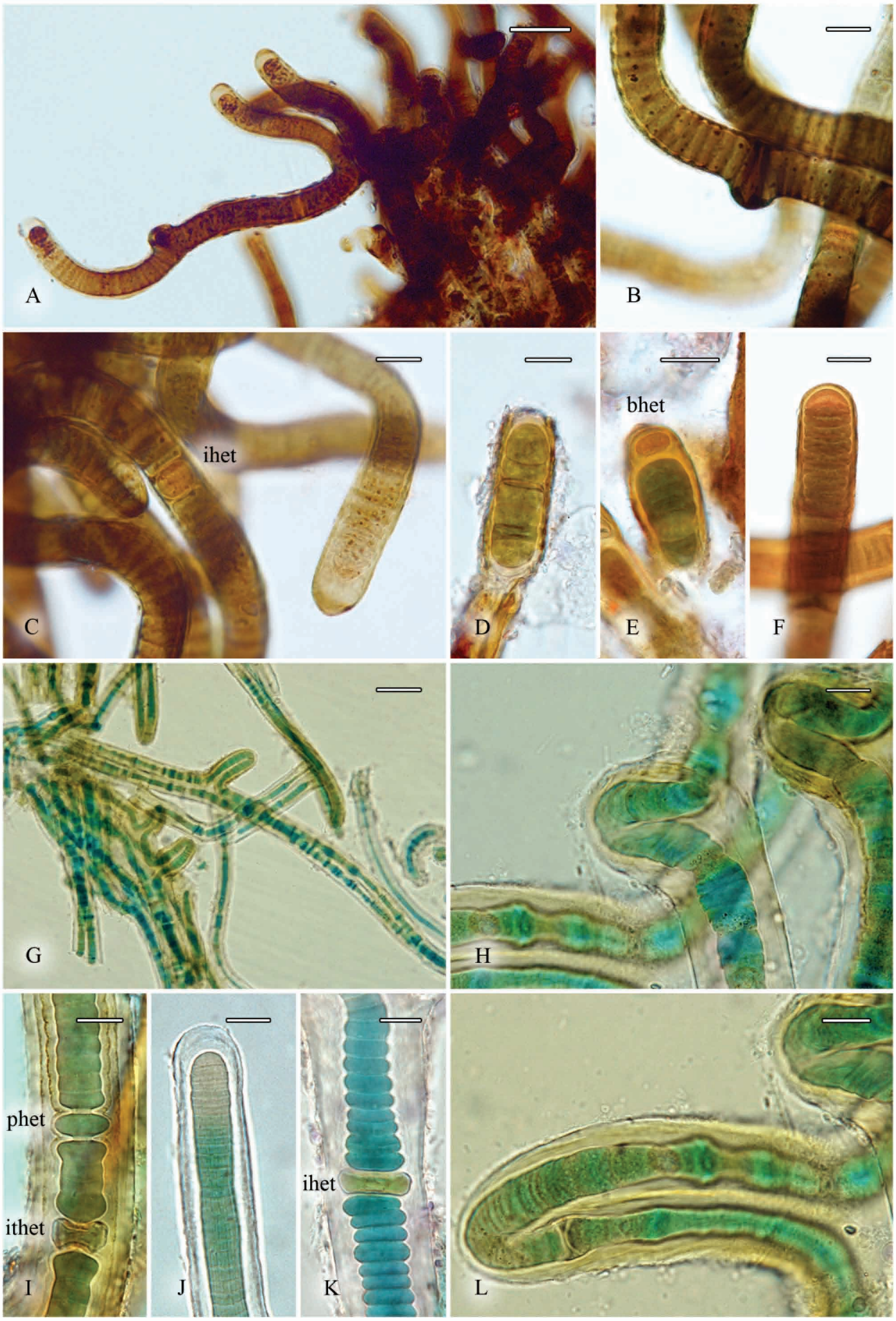

FIGURE 3. A–D. *Ophiothrix* sp. A. Filament with wide "U" shape. B. False branching detail. C. Apex closed and intercalary heterocyte. D. Isopolar hormogonia. E. Heteropolar hormogonia. F. Hormogonia formation by necridic cell. G–L. *Petalonema* sp. G. Thallus showing erect loops. H, L. Filament folds with loops. I. Isopolar hormogonia formation by heterocytes. J. Closed apex. K. Trichomes constricted at cross walls. nc = necridic cell, bhet = basal heterocyte, ihet = intercalary heterocyte, phet = pro-heterocyte. Scale bars: A = 20 µm, G = 30 µm, B–F, H–L = 6 µm.

Habitat:—Supratidal fringe; epilithic on gneiss rock.

Notes:—Our populations resemble *Ophiothrix epibryos* (Komárek 2003: 224) Sant'Anna, Azevedo, Kastovský & Komárek (2010: 220), in particular in the shape of the apex, the lamellated sheath and easily fragmented filaments; on the other hand, they are also similar to the genus *Camptylonemopsis* Desikachary (1948: 46) in the "U" shape of filaments. However, our populations are marine whereas those of both *O. epibryos* and all species of *Camptylonemopsis* are freshwater. We will complete the polyphasic approach given the morphologic convergence with other genera of Scytonemataceae such as *Scytonema* and *Brasilonema*. New report of the genus for the coast of Mexico.

Occurrence:—MEXICO. Oaxaca: Cacaluta Bay, 15° 43' 09.00" N 96° 09' 59" W, December 2010 *H. León-Tejera L. & González-Resendiz* (C48), October 2012 *L. González-Resendiz* & *H. León-Tejera* (C658, C662).

Kyrtuthrix Ercegović (1929: 170)
Kyrtuthrix cf. *maculans* (Gomont) Umezaki (1961: 85) (Figs. 4E–4H).

Thallus crustaceous, flat, firm, forming a blue-green, expanded, but neatly delimited mat of up to 60 µm long, formed by a tight parallel series of isopolar filaments that form loops in the lower part, with narrowed (attenuated) ends towards the upper part. Filaments 10–60 µm long. Sheath firm, colorless, lamellate. Trichomes constricted at cross walls. Cells cylindrical, pyramidal to irregular 3–6 × 2.5–5.0 µm (long × wide). Heterocytes solitary, intercalary, cylindrical to quadrate 5–10 µm diameter. Reproduction by hormogonia.

Habitat:—Supratidal and intertidal fringes; epilithic on granitic rock.

Notes:—Our populations resemble *K. maculans* (Gomont 1901: 210) Umezaki (1961: 85) but its filaments are much shorter and its cell diameter is slightly smaller.

Occurrence:—MEXICO. Oaxaca: San Agustín Bay, 15° 41' 17.41" N, 96° 14' 15.28" W, *December 2010*, *October 2012*, *August 2014 L. González-Resendiz* & *H. León-Tejera* (C59, C61, C695, C700, C707, C708); Cacaluta Bay, 15° 43' 09.00" N, 96° 09' 59" W, *August 2014 H. León-Tejera L.* & *González-Resendiz* (C1319), Panteones beach at Puerto Angel, 15° 39' 50.00" N, 96° 29' 43.93" W, *August 2014 González-Resendiz* & *H. León-Tejera* (C1339, C1340, C1341).

Petalonema Berkeley ex Correns (1889: 321)
Petalonema sp. (Figs. 3G–3L).

Thallus caespitose or cushion-like, 5 mm high, blackish green; filaments isopolar, folds with loops at the base and terminal parts upwards. In old parts, filaments are prostrate on the substrate and then vertically erected 11.7–21.35 µm wide. Sheath thick, lamellated with divergent layers, hyaline to yellowish, apex closed. Ascendant false branches, often in pairs forming loops included within a common sheath. Trichomes coiled, spiral or only curved, 3.5–7.3 µm wide, cylindrical, torulose in parts and constricted at the cross walls. Cells cylindrical or barrel-shaped, green to blue-green 1.5–3.9 µm long. Heterocytes oblong to slightly compressed (1.6) 3.8 long × (4.2) 9.0 wide.

Habitat:—Supratidal and intertidal fringes; epilithic on granitic rock.

Notes:—Although our populations are in morphological accordance with the description of *P. incrustans* Komárek (2012: 143), there are differences in size, growth form and color as well as its distribution in a marine biotope; they were always found in crevices or partially shaded vertical walls. The populations cited here as *Petalonema* sp. probably belong to a new entity.

Occurrence:—MEXICO. Oaxaca: San Agustín Bay, 15° 41' 17.41" N, 96° 14'15.28" W, December 2010, *October 2012 L. González-Resendiz* & *H. León-Tejera* (C57, C58, C719).

Scytonematopsis Kiseleva (1930: 174)
Scytonematopsis cf. *crustacea* Kovácik *et* Komárek (1988: 306) (Figs. 4A–4D).

Thallus caespitose, blue-green, blackish, or yellow-brown. Filaments densely entangled, blue-green, slightly curved, with double and single false branching, 5.1–14.1 µm wide. Young filaments are heteropolar, older ones are isopolar, narrowed at both sides to form a long hair. Sheath in old parts lamellated, hyaline to yellowish, narrower and open in terminal parts.

Trichomes constricted at cross-walls, thickened at the base, gradually attenuated above and ending in long, hyaline cellular hair 5.1–8.3 µm wide. Cells slightly granulated, shorter than wide (2.1–4.5 µm long), also in tapered region of trichome cells. Necridia dark blue-green, biconcave lens-shaped. Heterocytes basal or intercalary, hemispherical, spherical to oval-cylindrical, slightly complanate, solitary 2.9–5.0 µm long. Reproduction by hormogonia. Akinetes not found.

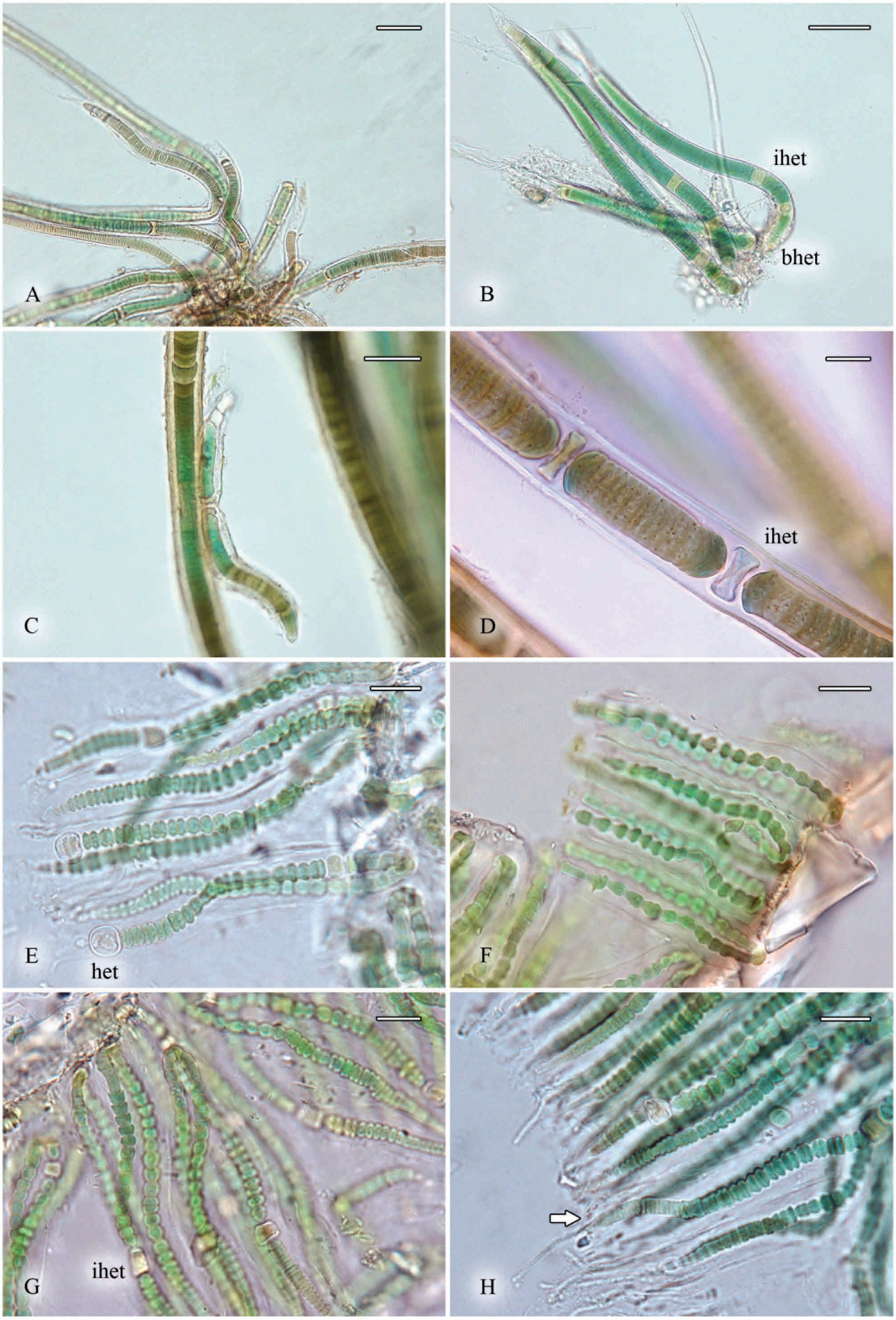

FIGURE 4. A–D. S*cytonematopsis* cf. *crustacea*. A. Thallus with false branching. B. Thallus of isopolar attenuated filaments, basal and intercalary heterocytes. C. Isopolar crescent-shaped development of hormogonia. D. Isopolar hormogonia formation. E–H. *Kyrtuthrix* cf. *maculans* E. Isopolar and attenuated filaments in parallel series. F. Filaments within a firm sheath. G. Epilithic thallus with intercalary heterocytes. H. Cells pyramid-shaped, arrow pointing at heteropolar hormogonia formation. het = heterocyte, ihet = intercalary heterocyte, bhet = basal heterocyte. Scale bars: A = 30 µm, B–C = 20 µm, D–H = 6 µm.

Habitat:—Supratidal and intertidal fringes; epilithic on granitic rock.

Notes:—In the Huatulco material the thallus is smaller than previously reported for the Mexican coast in temperate Guadalupe Island by Setchell and Gardner (1930) as *Calothrix crustacea* Thuret ex Bornet & Flahault (1886: 359).

Occurrence:—MEXICO. Oaxaca: San Agustín Bay, 15° 41' 17.41" N, 96° 14' 15.28" W, December 2010, *October 2012 L. González-Resendiz & H. León-Tejera* (C57, C695, C700, C701).

FIGURE 5. A–C. *Calothrix* sp. A. Entangled filaments. B, C. Curved heteropolar filaments without terminal hair, cells more or less isodiametric. D–H. *Hassallia littoralis*. D. Heteropolar filaments with basal heterocyte. E. Divaricated false branch with basal heterocyte. F. Closed apex. G. Heteropolar hormogonia. H. Terminal widening of the sheath. bhet = basal heterocyte. Scale bars = 6 µm.

Family Rivulariaceae

Calothrix Agardh ex Bornet & Flahault (1886: 345)
Calothrix sp. (Figs. 5A–5C).

Macroscopic green, brown to blackish filamentous mats, epiphytic or epilithic; short, creeping, filaments not branched, up to 20–60 µm long, slightly widened at the base, 3–4 µm, slightly curved or coiled and narrowed towards to the apex, 1–2 µm wide, the ends without terminal hair. Sheaths fine, open at apex, colourless, homogeneous. Trichomes blue-green, 2.2–2.8 µm wide at the base, slightly constricted at cross-walls. Cells 1.5–3.0 µm long, slightly longer than wide almost isodiametric in lower parts. Heterocytes solitary, basal, spherical to ovoid 1.5–2.0 µm diam.

Habitat:—Supratidal and intertidal fringes; epiphytic on *Petalonema* sp. and '*Myochrotes*' sp.; epilithic on granitic and gneiss rock.

Notes:—The filament of the mats are very small. Our material is in accordance with the description of the section *Calothrix* without terminal hair or akinetes, but not with the description of the morphology of any marine *Calothrix* species previously described.

Occurrence:—MEXICO. Oaxaca: La Entrega Bay, 15° 44' 37" N, 96° 07' 40" W, *December 2010 González-Resendiz & H. León-Tejera* (C73); San Agustín Bay, 15° 41' 17.41" N, 96° 14' 15.28" W, *December 2010*, *October 2012 L. González-Resendiz & H. León-Tejera* (C58, C708).

Family Tolypothrichaceae

Hassallia Berkeley ex Bornet *et* Flahault (1886: 115)
Hassallia littoralis González-Resendiz *et* León-Tejera in González-Resendiz *et al*. (2013: 37) (Figs. 5D–5H).

Caespitose, short mats brown to blackish; filaments cylindrical, straight or curved, parallely oriented or intermingled. Falsely branched, branches tightly joined or irregularly divaricated to the main filament. Trichomes 3–6 µm wide, constricted at cross-walls. Cells cylindrical to barrel-shaped, shorter than wide, 3–6 µm wide, 1–3 µm long, with slightly granulated content. Sheaths firm, stratified, amber or dark yellowish-brown, often widening with pronounced, rounded terminals 3–7 µm in diameter. Heterocytes spherical, ovoid to cylindrical. Reproduction by hormogonia. A more detailed description is available in González-Resendiz *et al*. (2013).

Habitat:—Supratidal fringe; epilithic on granitic and gneiss rock.

Notes:—This species has been recorded previously for Tangolunda Bay as a macroscopic black filamentous mat. This report is new for Cacaluta and El Arrocito bays in the same environmental conditions of the type locality, expanding the known distribution on the coast of Oaxaca; always in the supratidal fringe.

Occurrence:—MEXICO. Oaxaca: Cacaluta Bay, 15° 43' 09.00" N, 96° 09' 59" W, *October 2012 H. León-Tejera L. & González-Resendiz* (C660, C661); Tangolunda Bay, 15° 46' 24.79" N, 96° 5' 28.32" W, *August 2014 L. González-Resendiz & H. León-Tejera* (C1295); El Arrocito Bay 15° 45' 40.05" N, 96° 6' 0.95" W, *August 2014 L. González-Resendiz & H. León-Tejera* (C1297, C1299).

Discussion

Taxonomy:—Several of the heterocytous cyanoprokaryotes reported here are morphologically complex and in the midst of a deep taxonomic reevaluation to the degree that many taxa are being transferred to different or newly created families and even orders (Komárek *et al*. 2014). For example, *Brasilonema* was recently separated from *Scytonema* by Fiore *et al*. (2007) based on molecular studies. *Brasilonema* now contains the group of tropical species previously classified as *Scytonema*, particularly from tropical forests (Komárek 2013). No marine species had been previously described. Our samples differ both in morphological and ecological characters not recognized in other species of *Brasilonema*.

'*Myochrotes*' has been considered a section or subgenus of the genus *Scytonema* but recent works sustain that there are enough morphological differences to separate it as an independent genus (Komárek 2013, Komárek *et al*. 2014). Due to the lack of molecular studies this has not been yet validated. Komárek (2013) reports that some authors consider the subgenus or section '*Myochrotes*' as part of the genus *Scytonema sensu lato*, and its morphological features are often similar to those of *Petalonema*, especially those of trichomes and sheaths. Our material from La Entrega Bay is in accordance with the generic description of '*Myochrotes*' *sensu* Komárek (2013) but not with the morphology or ecology of any species previously described.

In *Petalonema* there are numerous populations morphologically convergent with the genera *Scytonema* and '*Myochrotes*'. Thajuddin & Subramanian (1992) and Nagarkar (2002) had reported *S. crustaceum* Agardh ex Bornet *et* Flahault (1887: 85) as a marine species. Recently, Komárek (2012) separated *P. incrustans* (Kützing (1843: 216))

Komárek (2012: 143) from *Petalonema crustaceum* Agardh ex Kirchner in Engler & Prantl (1900: 79) (≡ *S. crustaceum*), both species as non-marine. Our populations are similar in general morphology to *P. incrustans* (a species that has significant differences with the typical *Petalonema*) but they are different in cell dimensions, ecology and geography, therefore they probably belong to a different entity.

The genus *Ophiothrix* Sant'Anna, Azevedo, Kastovský & Komárek (2010: 218) was described and classified as a member of the family Microchaetaceae; in 2014, Komárek *et al*. transferred it to the family Scytonemataceae, where all species are from freshwater habitats. Our populations referred here as *Ophiothrix* are additions for the marine environment.

It is now proposed (Komárek 2013), that the heterogeneous genus *Calothrix* contains several morphotypes, which probably represent separate genera, because the *Calothrix*-complex includes a wide geographic distribution, genetic diversity and therefore represents several genotypes (Komárek 2013). Our populations belong to the group of *Calothrix* species that do not form terminal hairs. According to Komárek (2013) it is probable that populations without terminal hairs belong to another, not yet taxonomically described taxon.

The genus *Kyrtuthrix* has two marine species, with very little morphological differences between them, both being euendolithic or partly epilithic. Our populations are epilithic on granitic rock, as were those of the first report for the Mexican coast (León-Tejera *et al*. 2005). Similar populations were also described from Brazil in Sant'Anna *et al*. (1985) and Crispino & Sant'Anna (2006) for the supratidal fringe and Montoya (2003) for three Peruvian sites of the supra and intertidal fringes. It is important that the Mexican populations of *K.* cf. *maculans* be characterized in detail, using the polyphasic approach. This report increases the number of localities reported for the coast of Oaxaca.

Scytonematopsis crustacea, reported as *Calothrix crustacea* for Guadalupe Island (Setchell & Gardner 1930), and *H. littoralis* (González-Resendiz *et al*. 2013), for the Mexican tropical Pacific) are morphologically and ecologically distinctive. Here we are expanding the distribution record of both species for the tropical coast of México.

It is important to note that marine species of *Brasilonema*, *Petalonema*, '*Myochrotes*', *Ophiothrix* and *Calothrix* cited here should be characterized in detail, using the polyphasic approach, to solve taxonomic uncertainties. Additionally, to help clarify the position and taxonomic relationships of Mexican marine *Scytonematopsis* cf. *crustacea* and *Kyrtuthrix* cf. *maculans*, the use of molecular markers and comparison with populations from other localities is needed.

Ecology:—The greater diversity and abundance of heterocytous populations in the upper and intertidal zones has been attributed to their diazotrophic capacity and stress tolerance, which are lacking in non heterocytous populations (Nagarkar 2002).

Most of the benthic rocky shore mats of the Huatulco coast in Oaxaca are dominated by growths formed by the association of several species belonging to different orders of cyanoprokaryotes, excepting *Brasilonema* and *Kyrtuthrix*, which are usually the only macroscopic species present. Heterocytous cyanoprokaryotes were always a dominant component in our samples and form a crustaceous or an entangled growth form intermingled with Oscillatoriales and Chroococcales. This has been already reported for other rocky shore environments (Whitton & Potts 1979, Sant'Anna 1995, 1997, Nagarkar 2002).

The most dominant species in terms of frequency (number of samples) and distribution (number of localities) was *Kyrtuthrix* cf. *maculans*, followed by *Brasilonema* sp. and *Hassallia littoralis*. It is clear that there is a close correlation between morphology and the environment. For example, the sheaths of all of our species, all exposed to high insolation, are brownish to yellowish. In the most exposed populations of *Kyrtuthrix*, the external part of the sheath covering the tips of the filaments are yellowish whereas the lower part of the sheath is hyaline. Further knowledge of this type of correlation in the supratidal and intertidal fringes will allow better predictions of the morphology of the species inhabiting them and a better understanding of their ecophysiology.

Conclusion

Eight special marine morphotypes are characterized: *Brasilonema* sp., *Myochrotes* sp. (*sensu* Komárek 2013), *Ophiothrix* sp., *Petalonema* sp. and *Calothrix* sp. probably representing new taxa. The majority of these morphospecies are additions for Mexico's cyanoprokaryote diversity as well as the first step in the recognition of new taxa. Most of our material has a morphology slightly different to that of species described from non-marine and temperate biotopes, but the fact that our material comes from tropical marine environments justifies the use of '*sp.*' and '*cf.*' instead of the published specific epithets given in the identification manuals currently available for this type of tropical environment.

For these morphospecies, the application of molecular procedures will derive in a more robust and precise taxonomic delimitation and will allow a better knowledge of the diversity of the cyanoprokaryotes of the tropical rocky shore.

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