Halopteris filicina (Phaeophyceae: Sphacelariales), A NEW RECORD FOR MEXICO

RESUMEN. Se presenta el primer registro del género Halopteris Kützing para México, el alga parada Halopteris filicina (Grateloup) Kützing (Sphacelariales: Stypocaulaceae), especie tipo del género Halopteris Kützing. El ejemplar fue encontrado en aguas someras costeras cerca de Uaymitún en el norte de la península de Yucatán en agosto de 2017. La descripción morfológica incluye los datos morfométricos del alga y se comparan con las de H. scoparia (Linnaeus) Sauvageau, debido a que tienen similitudes morfológicas y en distribución geográfica.

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In Mexico, Phaeophyceae is represented by 304 species from 54 genera, of which 227 species inhabit tropical waters (León-Alvarez & Náñez-Reséndiz, 2017). In the State of Yucatan, 16 Phaeophyceae species have been found, represented by the families Dictyotaceae Lamouroux (11 species), Sargassaceae Kützing (3), Chordariaeae Greville (1) and Sctyosiphonaceae Farlow (1) (Mateo-Cid et al., 2012). There have been no records of any species of the family Stypocaulaceae Oltmanns in this state.

The genus Halopteris Kützing comprises 14 species: H. congesta (Reinke) Sauvageau, 1904; H. corymbosa (Dickie) Draisma, Pruds’homme & Kawai, 2010; H. dura (Ruprecht) Perestenko, 1980; H. filicina (Grateloup) Kützing, 1843 (the type species); H. funicularis (Montagne) Sauvageau, 1904; H. hordacea (Harvey) Sauvageau, 1904; H. novae-zelandiae Sauvageau, 1904; H. obotata (Hooker & Harvey) Sauvageau, 1904; H. paniculata (Suhr) Prud’homme, 1972; H. platycena Sauvageau, 1904; H. pseudoplicata Sauvageau, 1904; H. ramulosa Sauvageau, 1904; H. scoparia (Linnaeus) Sauvageau, 1904; and H. virgata (Hooker & Harvey) Adams 1994 (Guiry & Guiry, 2020). H. filicina has been known from the Caribbean Sea, but not from the Gulf of Mexico. Wyne (2011) includes this species in the list of macroalgal species from the tropical and subtropical West Atlantic without giving bibliographic references and collection sites. In this study, H. filicina is reported for the first time in Mexican waters, accompanied with a description, line drawings and light micrographs.

The State of Yucatan is located between another two maritime states: Campeche (the Gulf of Mexico) and Quintana Roo (the Caribbean Sea), with elevations of <350 m (generally, <250 m), mean annual air temperatures between 25°C and 28°C and an annual precipitation of <1500 mm that does not exceed 2200 mm (Fernández-Carnevali et al., 2012). The coastal surface of the state is located between 19°29’N-21°37’N and 87°32’-90°25’W, comprising 646 300 ha, or 15% of the land surface of the state (Garcia-Fuentes et al., 2011); its shelf extends out to 160 km from the coast (Robledo-Ramírez, 1996; Sánchez-Molina et al., 2007). Geologically, the entire Yucatan Peninsula is a great limestone platform formed by a sequence of carbonate rocks and calcareous sediments of marine origin of Cretaceous to Recent age (Butterlin & Bonet, 1960; Bonet & Butterlin, 1962; Weidie & Back, 1985). The Quaternary is observed in coastal areas and corresponds to exposed calcareous deposits after a slight immersion of the peninsula (Garcia-Gil & Graniel-Castro, 2010).

Monitoring along Yucatan coast (approximately 340 km) was performed in August 2017, starting from El Cuyo (station 1) westward to Celestún (station 20). Macroalgae were observed and collected near 20 coastal sites along transects from the beach to 225 m seaward (Fig. 1). A specimen of H. filicina was collected on August 27 near Uaymitún (station 13) at 100 m from the beach (21°19’23.46”N, 89°27’26.02”W) from a sandy bottom at a depth of 1.5 m. The specimen was dried in a botanical press without addition of a fixative agent. It was then transported to the Institute for Marine Science and Fisheries of the University of Veracruz (ICIMAP-UV) in

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Boca del Río, Veracruz, Mexico. Some fragments of the collected specimen were rehydrated, and identification was carried out under a stereoscopic low-magnification Motic SMZ-168 microscope, using specialized literature (Katsaros & Galatis, 1990; Kawai & Prud’Homme van Reine, 1998; Dawes & Mathieson, 2008). The alga fragments were examined in a glycerin-jelly water mountant medium in semi-permanent slides (Tsuda & Abbott, 1985): 15 g of gelatin was dissolved in 90 mL of distilled water at 100°C; then 105 mL of glycerin and 1.5 mL of phenol were added. Photographs were taken using a compound Olympus BX51 (Japan) microscope equipped with a camera lucida and a Sony Cyber-shot 4.1-megapixel digital camera. Taxonomic, morphological and geographic information on \textit{H. filicina} is presented below.

Phylum Ochrophyta  
Class Phaeophyceae Kjellman 1891  
Order Sphacelariales Migula 1909  
Family Stypocaulaceae Oltmanns 1922  
\textit{Halopteris filicina} (Grateloup) Kützing 1843  
Bas.: \textit{Ceramium filicinum} Grateloup 1806: (1), fig. 1.  
Syn.: \textit{Sphacelaria disticha} Vahl ex Lyngbye 1819: 104, pl. 31A, figs 1-3; \textit{Sphacelaria filicina} (Grateloup) C. Agardh 1824: 166; \textit{Sphacelaria sertularia} Bonnemaison 1828: 109.

**Description.** Thallus erect, bush-like, with delicate texture, reddish to brown in color, 7 cm high. Branching alternate and pinnate, growing in one plane (Fig. 2d, f-h), presenting sphaceli at the tip of branchlets (Fig. 2f, h). In the basal part of thallus the number of medullary cells is undetermined; cells angulate, depigmented, 19-27 \(\mu\)m long, 6-20 \(\mu\)m in diameter (Fig. 2a, 3). The medium and superior zones of the thallus are formed by four thick-walled medullary cells, 37 \(\mu\)m long, 25 \(\mu\)m in diameter, encircled by small cortical cells (Fig. 2c). Cortical cells densely pigmented, 9-26 \(\mu\)m long, 2-13 \(\mu\)m in diameter. Extremes of branches and branchlets are formed by a layer of cortical cells (Fig. 2c), and main branches and the medium part of thallus by one or two layers (Fig. 2b). Cortical cells in the basal zone indistinguishable (Fig. 2a, 3). The main axis is up to 1.5 mm in diameter in its basal part, sometimes with small branches; here, cortical cells are covered with ascendant and descendant rhizoidal filaments (Fig. 2a, 3). Rhizoids can divide longitudinally (Fig. 3) down to 60 \(\mu\)m in diameter (Fig. 2e). The main axis in the medium zone of thallus is up to 300 \(\mu\)m in diameter; here, cortical cells do not form rhizoids but are surrounded by them (Fig. 2b). The reproductive structure (probably a sporangium) unilocular, 100 \(\mu\)m long, 80 \(\mu\)m diam., ellipsoidal, axillary, solitary, thick-walled, sessile, (Fig. 2f). Fixation structure formed by a rhizoidal mass.

**Geographic distribution.** The species is rather widely distributed in temperate and tropical waters. In the Pacific, it has been reported from Chile (Ramirez & Santelices, 1991), Hawaii (Abbott & Huisman, 2004) and Japan (Yoshida et al., 2015). In the Atlantic, it is known from the Azores Islands (Tittley & Neto, 1994), the Scandinavian Peninsula (Athanasiadis, 1996), the Bahamas (Ballantine & Aponte, 2003), Florida (Dawes & Mathieson, 2008), Brazil (Menezes-Széchy & Paula, 2010), Spain (Afonso-Carrillo, 2014), the Great Britain (Bunker et al., 2017), Morocco (Moussa et al., 2018) and France (Burel et al., 2019). Furthermore, the species has been found in the Mediterranean: in Egypt (Aleem, 1993), Libya and Tunisia (Ribera et al., 1992), Malta (Cormaci et al., 1997), Slovenia (Rindi & Battelli, 2005), Israel (Einav & Israel, 2008),
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Turkey (Taskin et al., 2008), Spain (Joher et al., 2012), Greece (Tsiamis et al., 2013), Algeria (Ould-Ahmed et al., 2013), Cyprus (Tsiamis et al., 2014) and Italy (Bottalico et al., 2016). In the Indian Ocean, the species has been reported from South Africa (Silva et al., 1996) and the Arabian Sea (Wynne, 2018).

Halopteris species have a thallus of brownish, reddish or olive color, measuring up to 30 cm high, usually growing on rocks in deep water. Their basal parts are small or extended, polystromic, often covered with descendant cortical rhizoids gathered in a mass and adhering to the substrate (Kützing, 1843) or attached to it by a disc without rhizoids (Womersley, 1987). Ramification is regular (Kützing, 1843) to irregular, alternate and pinnate (Yeon-Shim et al., 1995). The thallus is composed of large medullary cells covered with a cortex of small cells, usually interrupted by descendant cortical rhizoids (Womersley, 1987). Most of the above mentioned morphological features were present in our specimen from Yucatan (a basal part covered with rhizoids, a rhizoidal mass as a structure adhered to substrate, alternate and pinnate ramifications and large medullary cells covered with small cortical cells); therefore, there is no doubt about its ascription to the genus Halopteris. Not all morphological traits observed were identical to the published descriptions of Halopteris filicina (Table 1); however, as the only Halopteris species reported from the Caribbean and being morphologically the most similar to H. filicina, our specimen was ascribed to this species.

Dawes & Mathieson (2008) describe H. filicina as densely ramified, without branches in the basal part, adhered to substrate by rhizoids, with multipinnate branchlets, the main axis with four large cells encircled by small cortical cells, sporangia uni- or multilocular, ovoid, sessile or with a short stalk, frequently with small branches along the axis. These traits were observed in the specimen from Yucatan, but the four cells surrounded with small cortical cells of the main axis were observed only in the medium and superior parts of thallus, due to the variable number of cells in its basal part; because of this feature, it is also possible that the specimen belongs to an undescribed Halopteris species. In the basal part, no cortical cells were observed, but near the rhizoidal mass the cortical cells were undistinguishable, due to their forming rhizoids, and the number of medullary cells is variable. Ramification is alternate and pinnate, in one plane, characteristics not mentioned by Dawes & Mathieson (2008).

Katsaros & Galatis (1990) describe H. filicina with a mature thallus consisting of epidermic and medullary cells, the latter being highly vacuolated and non-photosynthetic; the basal part of thallus is surrounded by rhi-
zoids that originate from epidermic cells and divide longitudinally, whereas in the young region of thallus rhizoids continue encircling the main axis, but they do not originate from epidermic cells and do not divide longitudinally. The specimen from Yucatan has medullary and cortical cells, the latter being considered epidermic by Katsaros & Galatis (1990) due to the coverage that rhizoids form. The basal zone of the thallus is covered with rhizoids formed by cortical cells wrapping the thallus up to its medium part, and medullary cells are depigmented, which implies no photosynthetic capacity. Katsaros & Galatis (1990) do not mention undistinguishable cortical cells in the basal part, contrary to our findings.

Among Halopteris species, H. scoparia is the most similar to H. filicina, not only morphologically (Table 1), but also in geographical distribution. Earlier, H. scoparia was ascribed to the genus Stypocaulon Kützing, currently regarded as a synonym of Halopteris (Guiry & Guiry, 2020). The two mentioned species share some morphological features, such as a rhizoidal mass, pinnate ramification, presence of sphaceli at the tip of most branchlets and color. Both species have rhizoids, but only H. scoparia bear filaments on them. Both have plurilocular sporangia, but unlike H. scoparia, H. filicina also has unilocular ones. We cannot be sure that the reproductive structure observed in the examined specimen from Yucatan is a sporangium because we found only one, and it was a single structure, unlike gametangia that are always in axillary groups in Halopteris (Moore, 1951). Therefore, we concluded that our specimen belongs to H. filicina rather than H. scoparia.

Daily, ships transport 3000 to 7000 living species through the world (Carlton, 1999; Gollasch et al., 2002); ships’ ballast water and biofouling together contribute approximately 86.3% of the total number of species (Hewitt & Campbell, 2010). Only in Mexico about 50 million m³ of ballast water are discharged annually (Okolodkov et al., 2007). This might be a vector of unintentional transport of H. filicina to Yucatan coastal waters from elsewhere, via a vessel from overseas that discharged its ballast waters near the port of Progreso with its heavy international traffic and located 23 km from the sampling site. Another possibility for our finding is the passive transport through the system of surface oceanic currents that move clockwise in the North Atlantic from the Mediterranean to the Greater Caribbean and can carry the macroalga from European or African coasts. In addition, the possibility that the specimen from Yucatan could belong to an undescribed species should not be overlooked.

H. filicina has been previously reported from the Greater Caribbean, and other Halopteris species have been observed in the North Atlantic including the Mediterranean, the Pacific, Indian and Arctic oceans. Our finding of H. filicina from Yucatan is a new record of the genus Halopteris in Mexican waters. This species is likely invasive: at least, it has not been previously reported in the Gulf of Mexico. Nevertheless, the observed morphological features of the specimen are not completely identical to those described in the published literature, so it is possibly an undescribed Halopteris species. This could be confirmed by molecular analysis.

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### Table 1. Comparison of morphological features between *Halopteris filicina* and *H. scoparia* based on the published literature (Kützing, 1843; Sauvageau, 1908; Womersley, 1987; Katsaros & Galatis, 1990; Yeon-Shim *et al.*, 1995; Kawai & Prud’Homme van Reine, 1998; Dawes & Mathieson, 2008; Guiry & Guiry, 2020; Lamare *et al.*, 2020) and the specimen of *H. filicina* from Yucatan.

<table>
<thead>
<tr>
<th>Species</th>
<th>Color</th>
<th>Thallus</th>
<th>Ramification</th>
<th>Medullary cells</th>
<th>Sporangium</th>
<th>Gametangium</th>
<th>Rhizoidal filaments</th>
<th>Fixatio structure</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Halopteris scoparia</em></td>
<td>Brown to blackish</td>
<td>Radial growth, up to 15 cm long</td>
<td>Pinnate and alternate</td>
<td>Indefinite number of cells in primary axes, branches and branchlets</td>
<td>Present</td>
<td>Not observed</td>
<td>Plurilocular</td>
<td>Present</td>
</tr>
<tr>
<td><em>Halopteris filicina</em></td>
<td>Brown to blackish</td>
<td>Diffuse growth, up to 10 cm long</td>
<td>Pinnate and regularly alternate to dichotomous</td>
<td>4 cells in primary axes, branches and branchlets</td>
<td>Present</td>
<td>Plurilocular or unilocular</td>
<td>Plurilocular or unilocular</td>
<td>Absent</td>
</tr>
<tr>
<td><em>Halopteris filicina</em> (specimen from Yucatan)</td>
<td>Brown to blackish</td>
<td>Growth in only one plane, 7 cm long</td>
<td>Pinnate and alternate</td>
<td>4 cells in branches and branchlets; indefinite number of cells in the basal part</td>
<td>Present</td>
<td>Uncertain</td>
<td>Not observed</td>
<td>Absent</td>
</tr>
</tbody>
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### REFERENCES


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