

Halopteris filicina (PHAEOPHYCEAE: SPHACELARIALES), A NEW RECORD FOR MEXICO

***Halopteris filicina* (Phaeophyceae: Sphacelariales), un nuevo registro para México**

RESUMEN. Se presenta el primer registro del género *Halopteris* Kützting para México, el alga parda *Halopteris filicina* (Grateloup) Kützting (Sphacelariales: Stypocaulaceae), especie tipo del género *Halopteris* Kützting. 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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García-Ferrer, Loyda, Citlalli Galicia-García, Yuri B. Okolodkov & Jorge A. Herrera-Silveira. 2019. *Halopteris filicina* (Phaeophyceae: Sphacelariales), a new record for Mexico. *CICIMAR Oceanides*, 34(2): 29-36.

Shelf waters of the Yucatan Peninsula favor proliferation of macroalgae due to shallowness and optimal solar radiation (Robledo-Ramírez, 1996). A total of 225 macroalgal species are known from the littoral of the State of Yucatan, including 91 species of Rhodophyta, 89 Chlorophyta and 45 Ochrophyta (Ortegón-Aznar *et al.*, 2010). Among the most important taxonomic and floristic studies on macroalgae of Yucatan are Taylor (1935), Huerta-Múzquiz (1960), Taylor (1972), Huerta-Múzquiz *et al.* (1987), Mateo-Cid & Mendoza-González (1991), Mendoza-González & Mateo-Cid (1992), Serviere-Zaragoza *et al.* (1992), Ortégón-Aznar (1993), Robledo-Ramírez (1996), Ortégón-Aznar *et al.* (2001), Sánchez-Molina *et al.* (2007), Mateo-Cid *et al.* (2012) and Espinoza-Avalos *et al.* (2015).

In Mexico, Phaeophyceae is represented by 304 species from 54 genera, of which 247 species inhabit tropical waters (León-Álvarez & Núñez-Reséndiz, 2017). In the State of Yucatan, 16 Phaeophyceae species have been found, represented by the families Dictyotaceae Lamouroux (11 species), Sargassaceae Kützting (3), Chordariaceae Greville (1) and Scytosiphonaceae 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* Kützting comprises 14 species: *H. congesta* (Reinke) Sauvageau, 1904; *H. corymbosa* (Dickie) Draisma, Prud'homme & Kawai, 2010; *H. dura* (Ruprecht) Perstenko, 1980; *H. filicina* (Grateloup) Kützting, 1843 (the type species); *H. funicularis* (Montagne) Sauvageau, 1904; *H. hordacea* (Harvey) Sauvageau, 1904; *H. novae-zelandiae* Sauvageau, 1904; *H. obovata* (Hooker & Harvey) Sauvageau, 1904; *H. paniculata* (Suhr) Prud'homme, 1972; *H. platycena* Sauvageau, 1904; *H. pseudospicata* 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. Wynne (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 (García-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 (García-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

Fecha de recepción: 18 de abril de 2020

Fecha de aceptación: 28 de octubre de 2020



Figure 1. Map of the study area; a filled circle indicates the sampling site of *Halopteris filicina*.

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 *H. filicina* is presented below.

Phylum Ochrophyta

Class Phaeophyceae Kjellman 1891

Order Sphacelariales Migula 1909

Family Stypocaulaceae Oltmanns 1922

Halopteris filicina (Grateloup) Kützinger 1843

Bas.: *Ceramium filicinum* Grateloup 1806: (1), fig. 1.

Syn.: *Sphacelaria disticha* Vahl ex Lyngbye 1819: 104, pl. 31A, figs 1-3; *Sphacelaria filicina* (Grateloup) C. Agardh 1824: 166; *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 μm long, 6-20 μm in diameter (Fig. 2a, 3). The medium and supe-

rior zones of the thallus are formed by four thick-walled medullary cells, 37 μm long, 25 μm in diameter, encircled by small cortical cells (Fig. 2c). Cortical cells densely pigmented, 9-26 μm long, 2-13 μm 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 undistinguishable (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 μm in diameter (Fig. 2e). The main axis in the medium zone of thallus is up to 300 μm in diameter; here, cortical cells do not form rhizoids but are surrounded by them (Fig. 2b). The reproductive structure (probably a sporangium) unicellular, 100 μm long, 80 μm 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 (Ramírez & 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),

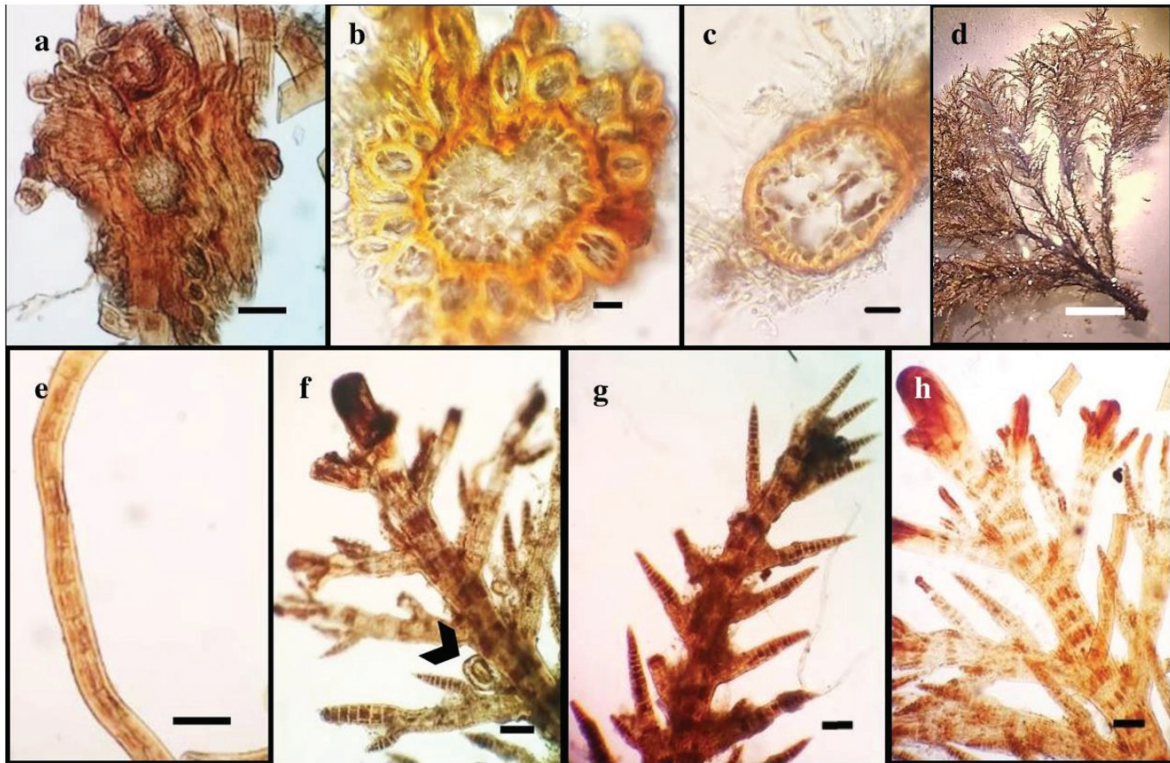


Figure 2. *Halopteris filicina*. (a) Cross-section of thallus showing medullary cells and rhizoids formed by barely visible cortical cells. (b) Cross-section of the medium part of thallus; medullary cells, two layers of cortical cells and rhizoids can be seen. (c) Cross-section of the superior part of thallus showing four medullary cells and a layer of cortical cells. (d) Thallus growing in one plane. (e) A rhizoid fragment. (f) Branch with sporangium; branchlet tips with sphaeci. (g) Branch with alternate ramification. (h) Branches with sphaeci on branchlets. Scale: 1 cm in Fig. (d); 100 μ m in Fig. (a, e-h); 25 μ m in Fig. (b, c).

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, red-dish 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 (Kützinger, 1843) or attached to it by a disc without rhizoids (Womersley, 1987). Ramification is regular (Kützinger, 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 ramification 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 *H. 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-

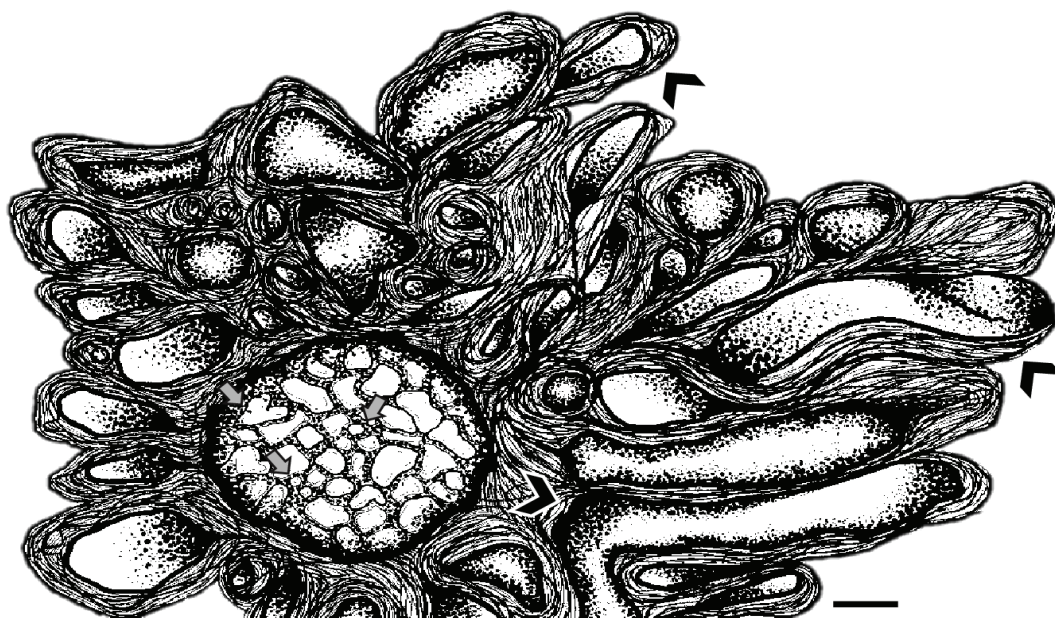


Figure 3. *Halopteris filicina*. Cross-section of the basal part of thallus; medullary cells of different size (gray arrows) and cortical cells that form rhizoids can be seen; some cortical cells are longitudinally divided (black arrowheads). Scale: 25 μ m.

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* Kützinger, 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 to *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.

ACKNOWLEDGMENTS

We are thankful to Ana C. Aguilar-Trujillo from CINVESTAV-IPN and a boat team from Dzilám de Bravo for their help with monitoring, Fany del Carmen Meri-

Tabla 1. Comparison of morphological features between *Halopteris filicina* and *H. scoparia* based on the published literature (Kützing, 1843; Sauvageau, 1900; 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

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

no-Virgilio for logistic support for YBO during his visit to Merida, Ileana Ortigón-Aznar from the Universidad Autónoma de Yucatán, Merida, for help with the literature, Marcia M. Gowing from Seattle, Washington, U.S.A., for improving the English style, and Ismael Gárate-Lizárraga from CICIMAR-IPN, La Paz, Baja California Sur, Mexico, for revising the manuscript, Francisco F. Pedroche from the Universidad Autónoma Metropolitana, Mexico City, for valuable advice and two anonymous reviewers for their critical comments. LGF thanks the Consejo Nacional de Ciencia y Tecnología, Mexico, and the Programa de Maestría en Ecología y Pesquerías of ICIMAP-UV for MSc scholarship.

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