

New Records of Marine Diatoms for the American Continent Found on Stone Scorpionfish *Scorpaena mystes* (Scorpaenidae) in Mexican Shores

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Abstract

The survey of new benthic substrata is expected to yield new records of diatom taxa. A particular type of substratum is the skin of the Stone scorpionfish *Scorpaena mystes* Jordan & Starks, 1895 that, because of its benthic form of life, represents a potential colonizing surface for various organisms, including epizoic and opportunistic diatom taxa (epibiotic community). Thus, a floristic survey of diatoms was carried out by sampling the epibiotic community from *S. mystes* specimens collected in the east coast of Baja California Sur (Gulf of California). Thirty diatoms are new records for Mexican littorals. Twelve of these taxa had not been hitherto recorded for American coasts. Micrographs, and morphometric and distribution data on these taxa are provided.

Keywords

Epibiotic, Floristics, Mexican Littorals, Species Richness, Stone Scorpionfish

1. Introduction

A recent surge of floristic studies reviews on benthic diatoms from Mexican littorals has yielded an extensive species list [1] that has kept on growing on the

basis of ex-professo studies, particularly for the Mexican northwestern [2] [3]. In this way, the survey of new substrata in the Mexican coasts promises still more new records of benthic diatom taxa. In particular, live substrata represent a rich source of epiphytic and epizoic diatoms. The latter comprises a wide array of host species that include invertebrates such as copepods, ciliates, bryozoans, hydrozoans, holothurians and vertebrates such as dolphins, whales, manatees and turtles [4] [5]. Out of these, the less studied is fish, and most research has been done on freshwater species [6] [7] [8] [9] [10]. For the marine environment, and in particular for epizoic algae on fish, Ballantine *et al.* [11] carried out the only study with three species of scorpaenids, recording only ten diatom taxa.

The body form of scorpaenids fishes provides them with camouflage, which is enhanced by skin ornaments, and a brown layer over the skin made from hydrozoans, filamentous algae, diatoms and other organisms that grow mainly on the cephalic region [12]. Thus, the benthic habit of the stone fish *Scorpaena mystes* Jordan & Starks, 1895, and its idleness, make it an ideal live substratum for testing various hypothesis on the relation animal host/epizoic diatom, but the scarcity of basic studies such as diatom floristics limits the spectrum of said hypotheses. However, several benefits have been noted for these epizoic diatoms, such as protection against grazing, availability of growing nutritional supplements, and an elevated position that also reduces the risk of being resuspended when growing on sediments [13] [14] [15].

Current observations by the first author of a rich diatom flora found within the epibiotic community growing on *S. mystes* suggested that new taxa could be found on this poorly explored substrate. Thus, the objective of this paper is to report new records of diatom taxa for Mexican waters and the American continent from the epibiotic community of *S. mystes* specimens collected in the central zone of the east coast of the Gulf of California (Santa Rosalia, Baja California Sur).

2. Materials and Methods

Twenty scorpion-fish specimens were captured during April 2016 off the coast of Santa Rosalia, Baja California Sur, Mexico which is located at 27°19'N, 112°15'W (Figure 1). Fish specimens were caught manually with hand-held spears using semi-autonomous diving equipment (hookah) at an approximate depth of 20 m. Specimens were identified as *S. mystes* following Grove and Lavenberg [16].

Diatoms and other organisms (macroalgae mainly) were separated from the skin of the fishes using a tooth-brush to generate a compound sample from the twenty specimens. The brushed-off material was placed in a 250 mL flask and preserved in commercial 70% ethanol. Afterwards, in order to eliminate organic matter which would preclude visibility of the diatom frustules, the compound sample was oxidized by adding 3 mL of 70% nitric acid to 2 mL of sample, heating with a burner to boiling point and until emission of gas subsided indicating end of

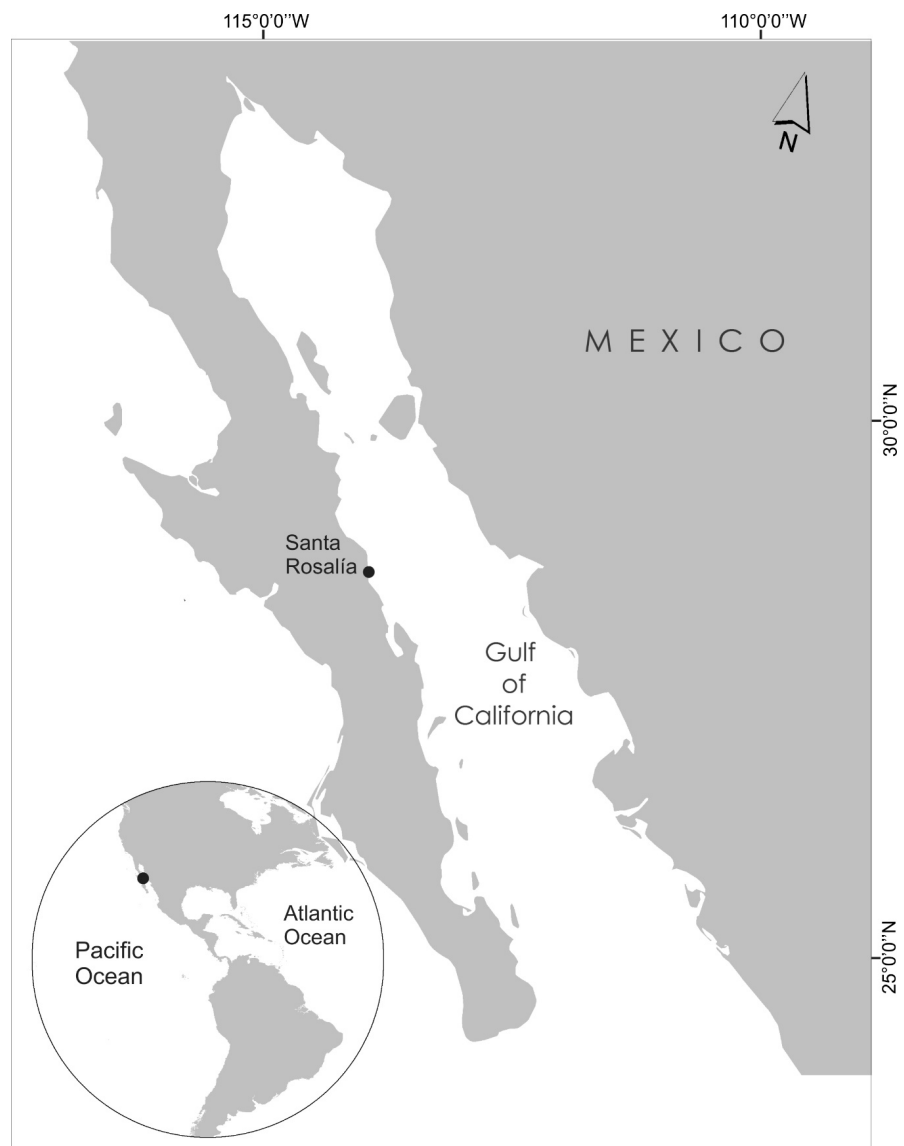


Figure 1. Location of sampling site off Santa Rosalia, Baja California Sur, Mexico.

reaction (ca. 3 min.). The oxidized sample was rinsed repeatedly with purified water until reaching a circumneutral pH. Then, twelve permanent slides were mounted using Zyraz[®] (RI = 1.7) (made and distributed by Prof. Bill Daily of the University of Pennsylvania).

The mounted slides were observed under a Zeiss[®] Axio Lab A1 compound microscope (Zeiss, Germany) with phase contrast optics and equipped with a Canon EOS Rebel T5i camera (Canon, Japan). Identification of the taxa was done specifically using the reference that appears in its corresponding description. A formal list of the diatom taxa was constructed following Round *et al.* [17], and including information on synonymy, references, distribution, and morphometrics, which in several taxa refer to a single found specimen. Nomenclatural updates were done according to AlgaeBase [18], the Catalogue of Diatom Names, California Academy of Sciences

(<http://researcharchive.calacademy.org/research/diatoms/names/index.asp>), and <http://www.marinespecies.org/> [19].

3. Results

Thirty benthic diatom taxa, including species and varieties, are presented here as new records for the Mexican littorals, along with twelve taxa not recorded before for the American continent. These taxa belong to the Bacillariophyceae (21 species), Coscinodiscophyceae (6 species), and Fragilariophyceae (3 species), that comprise nine orders, 14 families and 20 genera, with 30% of the species belonging to *Amphora* (6) and *Navicula* (3).

In what follows, taxonomic data, reference, synonymy, basionym, distribution, morphometric information, and illustrations are provided. Taxa without a previous record in the American continent are designated with an asterisk (*).

COSCINODISCOPHYCEAE Round & Crawford

Order Biddulphiales Krieger

Family Biddulphiaceae Kützing

Biddulphia juncta (A. Schmidt) A. Mann* (Figure 2M)

Morphometric data. Length 85 µm; width 78 µm; 3 areolae in 10 µm.

Synonyms. *Triceratium junctum* A. Schmidt, *Amphipentas juncta* (A. Schmidt) De Toni.

Literature. Schmidt's Atlas [20], pl. 98, Figures 1-3 (as *T. junctum* A. Schmidt)

Distribution. Asia (China, Taiwan and Philippine Islands as *T. junctum*).

Biddulphiopsis membranacea (Cleve) von Stosch & Simonsen (Figure 2J)

Morphometric data. Length 101 µm; width 48 µm; 19 areolae in 10 µm.

Basionym. *Biddulphia membranacea* Cleve.

Literature. Stidolph *et al.* [20], pl. 21, Figure 7.

Distribution. South America (Colombia, Galapagos Islands), Barbados, Oceania (Guam), West Indian Archipelago and Africa (Mozambique).

Trigonium arcticum (Brightwell) Cleve (Figure 2B)

Morphometric data. Length 111 µm; width (side) 104 µm; 19 areolae in 10 µm.

Synonyms. *Triceratium arcticum* Brightwell, *Biddulphia arctica* (Brightwell) Boyer.

Literature. Peragallo & Peragallo [21], pl. 104, Figure 1. Stidolph *et al.* [20], pl. 7, Figure 139-140.

Distribution. Asia, Europe, Antarctic and subantarctic islands.

Comments. A marine littoral species, epiphytic or attached to various substrata.

Order Coscinodiscales

Family Coscinodiscaceae

Thalassiosira maculata cf. Fryxell & Johansen (Figures 2C-E)

Morphometric data. diameter 22 µm; 22 areolae in 10 µm.

Literature. Hustedt [22], p. 112, Figures 26-28, Foged [23], pl. 6, Figure 1.

Distribution. Antarctic, Africa.

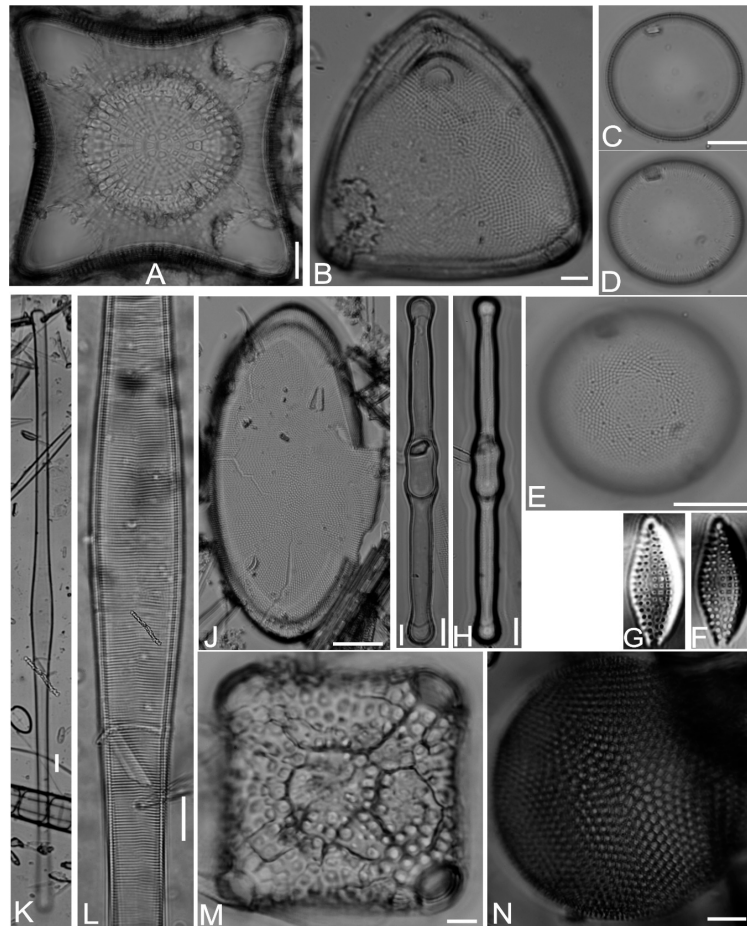


Figure 2. A. *Amphitetras subrotundata*, B. *Trigonium arcticum*, C-E. *Thalassiosira maculata* cf., F-G. *Rhapsoneis hungarica*, H-I. *Grammatophora undulata* var. *gallopagensis*, J. *Biddulphiopsis membranacea*, K-L. *Ardissonaea fulgens* var. *gigantea*, M. *Biddulphia juncta*, N. *Shionodiscus bioculatus* cf. Scale bar: 10 μm .

Comments. This taxon is considered to be restricted to the southern hemisphere, frequently found in subantarctic and antarctic waters, becoming more abundant southward.

***Shionodiscus bioculatus* cf. (Grunow) Alverson, Kang & Theriot (Figure 2N)**

Morphometric data. diameter 70 μm ; 4 areolae in 10 μm .

Synonyms. *Coscinodiscus bioculatus* Grunow, *Thalassiosira bioculata* (Grunow) Ostenfeld, *Coscosira bioculata* (Grunow) H. Heiden.

Literature. Hustedt [24], p. 331, Figure 168.

Distribution. Europe, Asia, Arctic, Canada.

Order Triceratiales Round & Crawford

Family Triceratiaceae (Schütt) Lemmermann

***Amphitetras subrotundata* Janisch (Figure 2A)**

Morphometric data. Length 80 μm ; width 90 μm ; 4 areolae in 10 μm .

Literature. Schmidt's Atlas (1874-1959), pl. 99, Figure 24, Stidolph *et al.* [20], pl. 5, Figures 108-112.

Distribution. Asia, Europe, USA, Arctic.

FRAGILARIOPHYCEAE Round

Order Ardissonales Round

Family Ardissonaceae Round

Ardissonea fulgens var. *gigantea* (Lobarzewsky) De Toni (Figures 2K-2L)

Morphometric data. Length 340 µm; width 13 µm; 18 striae in 10 µm.

Synonyms. *Synedra gigantea* Lobarzewsky.

Literature. Peragallo & Peragallo [21], pl. 79, Figure 6 [as *Synedra fulgens* var. *gigantea* (Lobarzewsky) H. Peragallo & M. Peragallo], Lobban & Schefter [20], pl. 1, 16, Figures 1-2, 6-8.

Distribution. South America (Brazil), Oceania (Guam), Gulf of Mexico Kraysky *et al.* 2009.

Order Rhapsoneidales Round

Family Rhapsoneidaceae Forti

Rhapsoneis hungarica Pantocsek (Figure 2F & Figure 2G)

Morphometric data. Length 28.33 µm; width 9.16 µm; 8 - 9 striae radiating in 10 µm.

Synonyms. *Sceptroneis hungarica* (Pantocsek) G. Andrews.

Literature. Pantocsek, J. [25], Teil I, p. 34; pl. 3, 25, pl. 25, Figure 224; pl. 3 Figure 30.

Distribution. Europe, USA.

Order Striatellales Round

Family Striatellaceae Kützing

Grammatophora undulata var. *gallopagensis* Grunow (Figure 2H & Figure 2I)

Morphometric data. Length 125 µm; width 11 µm, Van Heurck [26] report 27 striae in 10 µm.

Literature. Van Heurck, H. [26], pl. 53 bis, Figure 20.

Distribution. Europe (Belgium).

Comments. In both data bases consulted, AlgaeBase and Worms the status of this taxon is considered uncertain (unassessed).

BACILLARIOPHYCEAE Haeckel

Order Achnanthes Silva

Family Achnantheaceae Kützing

Achnanthes apiculata (Greville) Riaux-Gobin, Compère, Hinz & Ector* (Figure 3A & Figure 3B)

Morphometric data. Length 28 - 47 µm; width 17 - 26 µm, Rapheless valve: (9) 11 - 12 striae in 10 µm, Raphe valve: 18 - 20 striae in 10 µm.

Synonyms. *Stauroneis apiculata* Greville

Literature. Riaux-Gobin *et al.* [27], p. 111; Figures 1, 58-61.

Distribution. USA. Cuba, Africa.

Comments. According to Riaux-Gobin *et al.* [27] this taxon may belong to the genus, *Schizostauron*, however, they choose *Achnanthes* after Ross [28], who

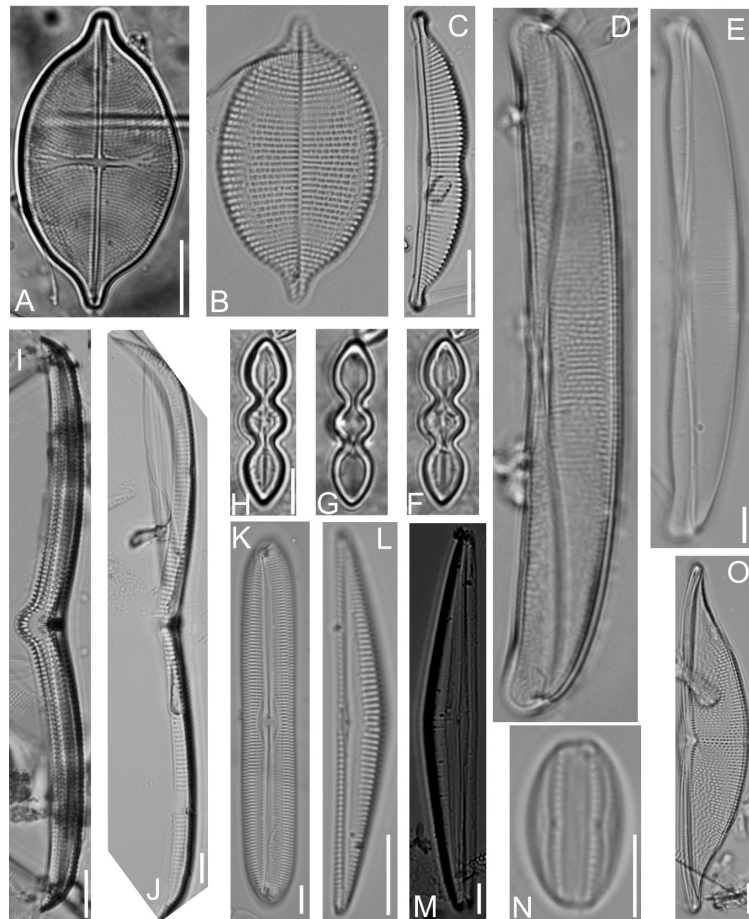


Figure 3. A-B. *Achnanthes apiculata*, C. *Halamphora subangularis* cf., D-E. *Amphora formosa* var. *studeri*, F-H. *Caloneis egena*, I-J. *Amphora arcus*, K. *Caloneis liber* var. *umbilicata* cf., L. *Amphora cymbamphora*, M. *Seminavis basilica* cf., N. *Amphora helenensis*, O. *Amphora arcuata*. Scale bar: 10 μ m.

includes the *Schizostauron* forms in *Achnanthes*. Thus, we decided for *Achnanthes apiculata*, as proposed by Riaux-Gobin *et al.* [27].

Order Naviculales Bessey

Family Diploneidaceae D. G. Mann

Diploneis ingens (A. Mann) Van Landingham* (Figure 4A)

Morphometric data. Length 105 μ m; width 59 μ m; 7 - 8 striae in 10 μ m.

Synonyms. *Navicula ingens* Mann.

Literature. Mann, A. [29] p. 105; pl. 22, Figure 8 (as *Navicula ingens* Mann).

Distribution. Philippine Islands.

Family Amphipleuraceae Grunow

Halamphora subangularis cf. (Hustedt) Levkov (Figure 3C)

Morphometric data. Length 38 μ m; width 9 μ m; 9 - 10 dorsal striae in 10 μ m.

Synonyms. *Amphora subangularis* Hustedt.

Literature. Levkov, Z. [30], vol. 5, pl. 110, Figure 15; Hustedt [22], p. 39, pl. 13: 16-17; Simonsen [31], p. 628: 1-2; both as *Amphora subangularis* Hustedt.

Distribution. Europe, USA.

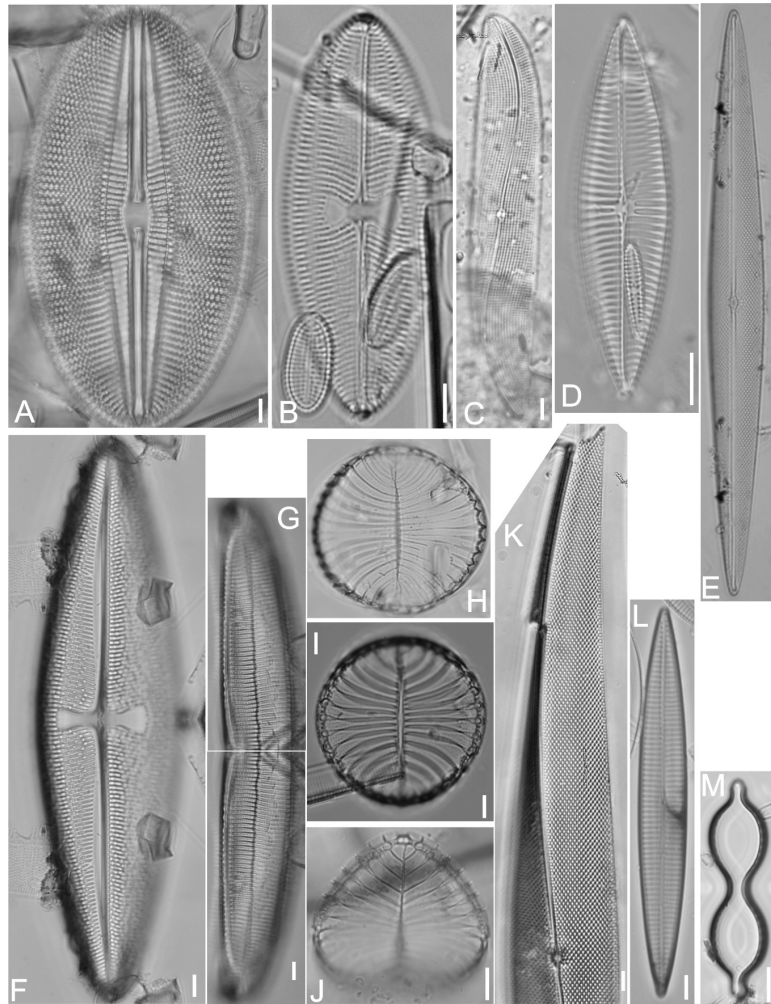


Figure 4. A. *Diploneis ingens*, B. *Trachyneis aspera* var. *oblonga*, C. *Gyrosigma hummii*, D. *Navicula transitans*, E. *Pleurosigma patagonicum* var. *paucistriatum*, F. *Trachyneis aspera* var. *robusta*, G. *Amphora compacta*, H-J. *Coronia decora*, K. *Pleurosigma delicatulum*, L. *Navicula halinae*, M. *N. permulsa* (cingular band). Scale bar: 10 μm .

Comments. Siqueiros Beltrones *et al.* [32], figure 164, reported a specimen as *Amphora angulosa* Gregory, albeit for the Pacific coast of the Baja Peninsula that coincides in all morphological traits with Levkov's description and ours. Hustedt's description, however, reports 22 - 23 striae/10 μm .

Family Diadesmidaceae D. G. Mann

Caloneis egena (A. Schmidt) Cleve (Figures 3F-H)

Morphometric data. Length 25 μm ; width 5.8 μm .

Synonyms. *Navicula egena* A. Schmidt.

Literature. Witkowski *et al.* [33], p. 164, pl. 160, Figures 13-14.

Distribution. Europe, Oceania, Gulf of Mexico, Thailand.

Caloneis liber var. *umbilicata* cf. (Grunow) Cleve* (Figure 3K)

Morphometric data. Length 145 μm ; width 22 μm ; 10 striae in 10 μm .

Basionym. *Navicula maxima* var. *umbilicata* Grunow.

Synonyms. *Navicula liber* var. *umbilicata* (Grunow) Grunow.

Literature. Cleve, P. T. [34], 26(2): 1-194, p. 55, pl. 5.

Distribution. Europe, Caribbean sea (Puerto Rico).

Family Naviculaceae Kützing

***Navicula halinae* Witkowski* (Figure 4L)**

Morphometric data. Length 68 µm; width 8 µm; 11 - 12 striae in 10 µm.

Literature. Witkowski *et al.* [33], p. 281, pl. 130 Figures 1-4.

Distribution. Africa (Atlantic coast of Namibia).

***Navicula permulsa* Hustedt (Figure 4M)**

Morphometric data. Length 60 µm; width 15 µm; 5 - 6 striae in 10 µm.

Literature. Schmidt's Atlas [35], pl. 394, Figure 22.

Distribution. South America (Galapagos).

Comments. Although only the cingular bands are depicted in the plates, complete valves were observed and measured, but could not be found again for photographic recording.

***Navicula transitans* Cleve (Figure 4D)**

Morphometric data. Length 75 µm; width 18 µm; 7 - 8 striae in 10 µm.

Literature. Witkowski *et al.* [33], p. 309, pl. 127, Figures 6-8.

Distribution. Europe, North America (USA, Canada), Indian Ocean, West Africa and Russia.

***Seminavis basilica* cf. *Danielidis* (Figure 3M)**

Morphometric data. Length 68 µm; width 9 µm; 28 - 30 dorsal striae in 10 µm, 30 - 32 ventral striae in 10 µm.

Literature. Danielidis & Mann [36], p. 22, Figures 1-19.

Distribution. Europe, USA.

***Trachyneis aspera* var. *robusta* (Petit) Cleve* (Figure 4F)**

Morphometric data. Length 50 - 62 µm; width 20 - 25 µm; 11 - 12 striae in 10 µm.

Synonyms. *Stauroneis robusta* Petit.

Literature. Peragallo & Peragallo [21]: p. 151, pl. 29, Figures 8-9 (as *Trachyneis robusta* Petit).

Distribution. Europe (New Zealand, Italy).

***Trachyneis aspera* var. *oblonga* (J. W. Bailey) Cleve (Figure 4B)**

Morphometric data. Length 168 µm; width 39 µm; 9 - 10 striae in 10 µm.

Basionym. *Stauroptera oblonga* J. W. Bailey.

Synonyms. *Trachyneis oblonga* (J. W. Bailey) H. Peragallo & M. Peragallo, *Stauroneis oblonga* (Bailey) Ralfs.

Literature. Peragallo & Peragallo [21], p. 192, pls. 25-48.

Distribution. Europe, Asia, Australia, New Zealand, Canada.

Family Pleurosigmataceae Mereschowsky

***Gyrosigma hummii* Hustedt* (Figure 4C)**

Morphometric data. Length 99 µm; width 17 µm; 14-15 striae in 10 µm.

Literature. Hustedt, F. [22], p.33, pl. 10, Figure 2.

Distribution. USA.

***Pleurosigma delicatulum* W. Smith* (Figure 4K)**

Morphometric data. Length 226 µm; width 26 µm; 10 - 11 striae in 10 µm.

Synonyms. *Gyrosigma delicatulum* (W. Smith) Griffith & Henfrey, *Pleurosigma angulatum* var. *delicatulum* (W. Smith) van Heurck.

Literature. Peragallo & Peragallo [21], p. 166, pl. 32, Figures 14-15.

Distribution. Europe, USA, Canada, South America (Brazil, Colombia) Africa, Asia.

***Pleurosigma patagonicum* (Ferrario & Sar) Sterrenburg & Sar var. *paucistriatum* Sar, Sterrenburg & Sunesen (Figure 4E)**

Morphometric data. Length 128 µm; width 12 µm; 20 - 21 transversal striae in 10 µm, 16 - 17 oblique striae in 10 µm.

Literature. Sar, E. U, Sterrenburg, F.A.S., A. S. Lavigne & I. Sunesen [37]. Bol. Soc. Argent. Bot. 48(1): 17-51.

Distribution. South America (Argentina).

Order Surirellales

Family Surirellaceae Kützing

***Coronia decora* (Brébisson) Ruck & Guiry (Figure 4H & Figure 4J)**

Morphometric data. Length 34 µm; width 35 µm; 7 - 8 ribs in 10 µm.

Synonyms. *Campylodiscus decorus* Brébisson.

Literature. Witkowski *et al.* [33], p. 412, pl. 214, Figure 15, Stidolph (1980), p. 403, pl. 14, Figure 10; Lobban *et al.* [38], p. 469, pl. 64, Figures 5-6 (in all cases as *C. decorus* Brébisson).

Distribution. Europe, USA, South America, Asia, Oceania.

Order Thalassiophysales D. G. Mann

Family Catenulaceae Mereschkowski

***Amphora arcus* Gregory* (Figure 3I & Figure 3J)**

Morphometric data. Length 116 - 121 µm; width 5 - 9 µm; 11 - 13 striae in 10 µm.

Literature. *Sensu* Witkowski *et al.* [33], p. 129, pl. 165 Figure 15.

Distribution. Europe.

***Amphora arcuata* A. Schmidt (Figure 3O)**

Morphometric data. Length 75 µm; width 13 µm; 15 - 16 striae in 10 µm.

Synonyms. *Amphora acuta* var. *arcuata* (A. Schmidt) Cleve.

Literature. Schmidt *et al.* [35], pl. 26, Figures 27-29; Peragallo & Peragallo [21], pl. 49, Figures 27, 28.

Distribution. Europe, USA, Oceania, Puerto Rico, Virgin Islands.

***Amphora compacta* A. Mann* (Figure 4G)**

Morphometric data. Length 174 µm; width 26 µm; 7 - 8 dorsal striae in 10 µm, 8 - 9 ventral striae in 10 µm.

Literature. Mann, A. [29], p. 19; pl. 3, Figure 6.

Distribution. Philippine Islands.

***Amphora cymbamphora* Cholnoky* (Figure 3L)**

Morphometric data. Length 9 µm; width 5 µm; 14 dorsal striae in 10 µm, 15 - 16 ventral striae in 10 µm.

Literature. Witkowski *et al.* [33], p. 136, pl. 164, Figures 26-28.

Distribution. Oceania, South Africa, Baltic Sea.

***Amphora formosa* var. *studerii* Janisch* (Figure 3D & Figure 3E)**

Morphometric data. Length 71 - 89 μm ; width 9 - 13 μm ; 14 dorsal striae in 10 μm , 13 - 14 ventral striae in 10 μm .

Basionym. *Amphora studerii* Janisch

Literature. Peragallo & Peragallo [21], p. 214; pl. 47, Figure 18.

Distribution. Europe.

***Amphora helenensis* Giffen (Figure 3N)**

Morphometric data. Length 12 μm ; frustule width 9 μm ; valve width 3 μm ; 20 - 21 dorsal striae in 10 μm , 18 - 19 ventral striae in 10 μm .

Literature. Witkowski *et al.* [33], p. 140, pl. 163, Figures 31-33.

Distribution. Europe, South Africa, Atlantic, Canada, Oceania.

4. Discussion

The relative high number of new records for Mexican littorals and those that are new for the whole American continent (12), indicate that much work is yet to be done on floristics of benthic marine diatom. Thus, further surveys that include new substrata where these microalgae may thrive will eventually yield a reliable basis to undertake related studies on ecology and biogeography, both at regional and at worldwide scale. A balance between these findings and an analysis of the overall species richness currently underway, will surely permit addressing questions such as, are exclusively epizoic diatom aggregations lacking on these fish? What characteristics favor the establishment of unique epizoic diatom aggregations? And, how do these rich diatom aggregations compare floristically with hosts from other localities?

Due to the relevance currently recognized on biodiversity data in terms of conservation policy and potential anthropogenic impact in Mexico and worldwide, species inventories are regaining attention. Studies on benthic diatoms, and in particular those on benthic forms, exhibit an underestimation of their geographic distribution, both regionally and worldwide, that is a function of the lack of research, which undermines the reliability of biogeographical analyses [34]. For example, *Biddulphia juncta* (A. Schmidt) A. Mann (Figure 2M), *Achnanthes apiculata* (Greville) Riaux-Gobin, Compère, Hinz & Ector (Figure 3A, Figure 3B), *Diploneis ingens* (Mann) Van Landingham (Figure 4A), *Amphora compacta* A. Mann (Figure 4G), and *Navicula permulsa* Hustedt (Figure 4J) had been recorded for a single continent. Several of these for the Philippine Islands, bringing into mind the observation by Mann [29] on the striking similarity between the diatom flora of these islands and the coasts of Campeche, Mexico. His main concern was the remoteness and isolation between these localities. Our study poses similar questions which require ex-professo biogeographical theory.

Derived from this and other recent efforts on the floristics of benthic diatoms from Mexican coasts, the list of new records incorporated to the overall checklist

by López-Fuerte and Siqueiros-Beltrones [1] has increased substantially up to 88 from 2013 to 2017, and to 329 new regional records for the coasts of the Baja California Peninsula from 1999 to date. On a worldwide basis these inventories account for just >1% of the total diatoms recorded for the whole planet, and around 3.3% of the species recorded for Mexico [1] [36] [37]. Thus, if we considered that most of the littorals in Mexico have not been surveyed for benthic diatoms, it is to be expected that the species richness is considerably higher. This may be supported by the fact that the recent new records mentioned above originate from previously unexplored areas, such as the Mexican Caribbean [12] [38] and from the Mexican NW [2] [3] [39], as well as from unexplored substrata such as blades of the kelp *Eisenia arborea* Areschoug [32].

5. Conclusion

The new records of taxa collected from the skin of the stonefish in this study are more indicative of scarce floristic research than as representatives of an epizoic relation, *i.e.* a product of an increasing survey comprising many more substrates and regions. Also, they inhabit a compound substrate where the main component is the skin of the fish, but other forms such as macroalgae and invertebrates are surely attached to it and diatoms to them, thus making up an epibiotic community. Moreover, many of the recorded taxa have been observed on other substrata elsewhere and may not be considered epizoic *sensu stricto* but are opportunistic as are the general natures of benthic diatoms. Notwithstanding the latter, said taxa have not hitherto been recorded elsewhere for Mexican littorals and constitute new additions to the benthic diatom flora of the region, inasmuch as many of the recorded taxa have been observed on other substrata found elsewhere.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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