DIATOMS OF THE INDIAN RIVER LAGOON, FLORIDA: AN ANNOTATED ACCOUNT

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ABSTRACT: The Indian River Lagoon, Florida has been touted as the most diverse estuary in North America, yet the biodiversity of most biota is virtually unknown. Diatoms are abundant microalgae in this estuary, in planktonic, benthic, and epiphytic habitats. This account utilizes published records supplemented with personal observations to provide the first comprehensive summary of the diatom flora in this unusual estuary system. Apart from novel and cryptic species, 436 taxa are recorded, in 129 genera. The most diverse benthic genera were Mastogloia (36 taxa) and Nitzschia (24 taxa). Among planktonic genera were 38 taxa in Chaetoceros and 19 taxa in Thalassiosira. Sixty-two genera were represented by one species.

Key Words: Indian River Lagoon, diatom, microalgae, flora

The Indian River Lagoon (IRL) is an elongate subtropical body of water, formed within a barrier island complex, and extending for approximately one-third the length of Florida's east coast. Its exact length varies according to the varying definitions of its geographic limit: the range is 193km to 250km (120mi-155mi). Most commonly, the northern limit is considered to be the Ponce de Leon Inlet at New Smyrna Beach (29° 04.5'N, 80° 55'W), and the southern limit is the Jupiter Inlet in Palm Beach County (26° 56.5'N, 80° 04.2'W). These inlets, plus the Sebastian, Ft. Pierce and St. Lucie inlets, provide the only continuous exchange with the adjacent Atlantic Ocean. The major portions of the IRL are the Mosquito Lagoon, Banana River Lagoon, and the Indian River (including the St. Lucie River). The temperature and salinity structure throughout the length of the lagoon is highly variable on various time scales (e.g., Liu and co-workers, 1998; Niederoda and co-workers, 1995; Smith, 1987, 1993; Virmstein, 1990). Water temperatures vary from 5–35C and salinities range from 0–38 ppt. The transitional climatic zone coupled with high variability in physical-chemical characteristics of the water masses that make up the lagoon allow for a diverse (yet poorly characterized) biota.

This region of Florida represents a significant biogeographic transition zone for both plants and animals, marine and terrestrial (Myers and Ewel, 1990;
Richards, 1995). Biota in the northern portion is more characteristic of the temperate zone (Carolinian province), while the biota of the southern portion have many features and constituents of the sub-tropical and tropical zone (Caribbean province). Recent developmental pressures have been great in the IRL (De Freese, 1995; Larson, 1995) and will likely continue so into the foreseeable future. In addition, the multiple stressors associated with consequences of anthropogenically driven global change (rising sea level, warming, invasive species, etc.) may add to the adaptive demands on IRL biota in future (De Freese, 1991). The IRL has frequently been called the most diverse estuary in North America (e.g., Hart, 1993; Adams, 1995; Herman, 1998). While this may eventually prove to be true, at present it is a spurious appellation. Biodiversity is well known only for a very few groups of organisms, leaving most groups in states of partial or complete ignorance. The most recent summary of IRL biodiversity is found in Richards (1995).

Primary productivity in the IRL is a joint function of the seagrasses, marsh plants, and microalgae. Studies are sparse, but seagrass and marsh productivity appears typical for warm temperate areas (Myers and Ewel, 1990; Dawes and coworkers, 1995). Substantial spatial and temporal variability in productivity is a feature of the IRL (Heffernan and Gibson, 1984). In one study, over 70% of the primary productivity was shown to be due to planktonic microalgae (Jensen and Gibson, 1986), with a 5% contribution by benthic microalgae. The diatoms of this lagoon system are presumably one of the main contributors to microalgal primary productivity, by virtue of their abundance and ubiquity, but comprehensive productivity studies are lacking. Moreover, the contribution to primary productivity by phototrophic and mixotrophic microflagellates (which are often abundant; pers. obs.) is unknown. Plankton chlorophyll ranges exceed two orders of magnitude throughout the lagoon, (<0.1 to >20 µg/l: Youngbluth and co-workers, 1976; Mahoney and Gibson, 1983b; and pers. obs.) of which 40–70% may be diatoms, yet their diversity has been examined only sporadically and incompletely over the last several decades. This is surprising, given the local, regional, and national economic importance and biological significance of the IRL. Several unpublished theses, some preliminary surveys, and studies restricted to single or a few genera constitute most of the available literature. There are also parts of the IRL, such as the Banana River and St Lucie River system, which have never been examined in any detail. Nevertheless, the number of recorded diatom taxa from the IRL is substantial. A series of seasonal samples collected in 1997–2001, an extended sampling series in winter 2000, and an extensive literature search resulted in a significant expansion of the diatom flora from the earlier list of Mahoney and Gibson (1983a).

METHODS—Sample collection—In each season of 1998, 1999, and 2000, and winter/spring of 2001 plankton samples were collected with a 20µm mesh net in the IRL at Vero Beach and at the Sebastian and Ft Pierce inlets; IRL sediment surface samples at Memorial Park, Vero Beach, and at Ft Pierce inlet; and seagrass (Halodule and Syringodium), Rhizophora mangle and Spartina samples (for epiphytes) in the IRL at Oslo Rd. and Memorial Park, Vero Beach. During winter 2000, similar plankton, sediment, and epiphyte samples were collected in the IRL at Eau Gallie Causeway, St Sebastian River, Sebastian Inlet, Vero Beach at Memorial Park and Oslo Rd., ship channel at Harbor Branch Oceanographic Institute, Ft Pierce Inlet, Stuart Causeway, and St Lucie Inlet.
Sample processing—Aliquots of preserved samples were washed free of salt with sequential centrifugation and dilution with deionized water. For light microscopy, samples were processed in two ways: duplicate sub-aliquots were evaporated on hot plates, then heated to oxidize all organic material, then mounted in a high refractive index mounting medium (Hyrax or Naphrax); other duplicate sub-aliquots were boiled for 1 hr in 30% hydrogen peroxide, sequentially centrifuged and washed in deionized water, and mounted in Hyrax or Naphrax. For scanning and transmission electron microscopy, preparation was similar, except sub-aliquots were mounted on copper boats (SEM) or formvar/carbon coated grids (TEM) and coated with Au/Pt or carbon (SEM only).

Sample analysis—For light microscopy, a Zeiss Photomicroscope-II or Nikon LKe with brightfield, phase contrast and interference contrast were used; for electron microscopy, a Zeiss EM9S (TEM), and (for SEM) JEOL 1200EX or JSM6400 were used.

Literature—Few published papers give details on the IRL diatom flora. Several that were used in compiling this list are: Stephens and Gibson (1976, 1979); Tester and Steidinger (1979); Navarro (1982); Mahoney and Gibson (1983a); and Lu (1987). There are pitfalls in accepting such published lists at face value. The skill levels in accurate identification vary among authors, particularly when availability of pertinent monographs is uncertain. Spelling and orthographic errors, and changes in taxon limits and nomenclature all lead to disjuncts and inconsistencies in compiling accurate records. Some of these published records cite species authorities, others do not. I have dealt with these problems by accepting the identifications as stated, but making nomenclatural changes as necessary and including species authorities, deleting species only when egregious mistakes are suspected (e.g., an Antarctic species recorded from the IRL in mid-summer). For common or abundant taxa, synonymous names are included when the previously published name differs from the currently accepted name. Strictly speaking the Tester and Steidinger (1979) paper includes diatom occurrences outside the IRL (about 10 km S of the Ft Pierce Inlet), but I have found nearly all their included species through tidal cycles at the Ft. Pierce inlet, so have included their records.

Taxonomic scheme—Diatom taxonomy is in a state of controversy and ferment: opinions on grouping of species into genera, genera to families, etc. are changing constantly. In general this uncertainty and controversy is avoided by listing taxa alphabetically within defined orders without separation into families, and by briefly comparing the contrasting ordinal scheme as delimited in Round and co-workers (1990) vs. that of Hasle and Syvertsen (1997). This is not a wholly satisfactory arrangement, since an unjustified relationship may be implied, but avoids making decisions that may prove untenable in future. Accordingly, the diatoms are grouped in five orders.

RESULTS—Four hundred thirty-six diatom taxa in 129 genera are designated as present in the IRL. A number of species require explanatory notes, and these are ordered below. In the annotated list, presented as an appendix, the habitus and distribution are briefly indicated for each taxon as two letter codes, as gleaned from other global records.

Habitus:
B = primarily benthic, including epipellic, epilithic, and epipsammic microhabitats;
E = primarily epiphytic on seaweeds and marine higher plants (or, for Protoraphis and Pseudohimantidium, epizoic);
P = primarily planktonic in dominant life form (resting spores may be benthic)

Distribution:
T = primarily a warm-water or tropical taxon;
C = primarily a warm or cold temperate taxon;
W = widespread or cosmopolitan in temperate and tropical waters;  
F = primarily confined to oligohaline (<5 ppt) or fresh water.

DISCUSSION—The reported presence of 436 diatoms from the IRL seems remarkable, but in reality this number does not represent the entire diversity. Although a substantial portion of the planktonic taxa has probably been identified, many of the benthic forms are almost certainly underrepresented. In part this is a result of incomplete and sporadic sampling. The majority of published works on diatoms in the IRL have been based on samples collected at or near the Harbor Branch Oceanographic Institute in Ft. Pierce (e.g., Mahoney and Gibson, 1983a; Navarro, 1982). Likewise, many of the additional new records recorded by me were ancillary to other experiments undertaken in the same general area. The result is that regions of the IRL with major hydrographic and ecological differences from the central IRL have yet to be examined. The Mosquito Lagoon, for example, is clearly differentiated from adjacent areas on the basis of fish and invertebrate biodiversity (Paperno and co-workers, 2001) and the microalgal community surely has unique features as well. Likewise, to the south, the St Lucie River, with its eutrophication stress is likely to harbor species amenable to nutrient-rich areas that are not found farther north. Certainly the chlorophyll levels here (up to 120μg/liter; Doering 1996) indicate a substantial microalgal population whose constituents are unknown. Moreover, there are several novel species from the plankton not included in his account, yet to be described formally. Close examination of diatom communities elsewhere in Florida also has resulted in the discovery of new species (Prasad and co-workers, 1989; 2000): an expected result when the communities are examined in depth.

Several diatom taxa are potentially harmful to humans or marine life. All the *Pseudo-nitzschia* species reported from the IRL (*P. delicatissima*, *P. pseudodelicatissima*, *P. pungens*, *P. seriata*) have been reported to produce domoic acid under some circumstances elsewhere (Hargraves and Maranda, 2002). Domoic acid is a neurotoxin, the cause of amnesic shellfish poisoning (ASP), so far unknown from the east coast of Florida (for domoic acid and *Pseudo-nitzschia* references, see Bates, 2002 or NIEHS, 2002). Domoic acid was responsible for human poisoning events on the Atlantic coast of Canada and the northwest coast of the U.S. At present it is unknown whether IRL strains of these species produce domoic acid, but in most areas these species appear to be benign.

Some of these diatoms are known to produce excreted metabolites that interfere with normal functioning or life cycle events in marine animals. These include *Coscinodiscus centralis*, *Coscinodiscus walesii*, *Cerataulina pelagica*, and *Chae-toceros debilis* (Hargraves and Maranda, 2002). Others, such as the epizoic diatoms *Protoraphis altantica* and *Pseudoheimantidium pacificum*, mechanically reduce the motility of their hosts, thus interfering with reproduction and perhaps increasing their vulnerability to predators.

There are likely invasive species of diatoms in the IRL, although insufficient prior records make an accurate assessment speculative. The intense rates of transit
by recreational and commercial boats, with ballast water discharge and fouling communities, as well as migratory waterfowl, with residual attached biota, provide ample vectors for the introduction of nonindigenous species. Their eventual survival and success is less certain, however, and depends on a number of interacting parameters (Carlton and Geller, 1993; Carlton, 1996). *Coscinodiscus wailesii* is surely an invasive species in the IRL, having appeared on the U.S. east coast in the late 1970's. Many others may be termed “cryptogenic”: they may be recent introductions, but there is insufficient background information to confirm this at present. Examples of cryptogenic species include *Thalassiosira proschkiniae*, previously known from European coastal waters and recently discovered in Narragansett Bay, Rhode Island (pers. obs.), and *Minidiscus comicus*, a tiny species that is apparently widespread but mostly overlooked because of its size (2–5 µm).

The IRL faces increasing anthropogenic pressure, on local, regional and global scales. Recent management initiatives have focused attention on more visually obvious members of the ecosystem: manatees, fish, seagrasses, etc. The stressors for these biota are not always the same as stressors for the microalgae, which form the base of the food web. In order to evaluate the efficacy of management plans for the entire ecosystem, biodiversity at all trophic levels must be examined. The more difficult task for the future is separating local and regional anthropogenic influences on biodiversity, from those associated with broader global climate change.

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LITERATURE CITED


FLORIDA SCIENTIST


Niehs. 2002. University of Miami Marine & Freshwater Biomedical Sciences Center website: www.rims.miami.edu/groups/niehs


APPENDIX

Diatoms from the Indian River Lagoon. See text for notes and abbreviations

COSCINODISCALES

As considered here, the characteristics defining this order are: valve symmetry primarily with no polarities (i.e., oriented around a point rather than a line), and mostly with a marginal ring of various structural processes. In the taxonomic scheme proposed by Round, Crawford and Mann (1990), the species included
here in the Coscinodiscales encompass four different orders. In the scheme followed by Hasle and Syvertsen (1997), this order corresponds to their suborder Coscinodiscineae.

*Actinocyclus normanii* (Gregory) Hustedt
*Actinocyclus octonarius* Ehrenberg
*Actinocyclus octonarius var. crassus* (W. Smith) Hendey
*Actinocyclus octonarius var. tenellus* (Brébiisson) Hendey
*Actinoptychus senarius* Ehrenberg
*Actinoptychus splendens* (Shadbolt) Ralfs
*Aulacodes argus* (Ehrenberg) A. Schmidt
*Aulacoseira islandica* (O. Müller) Simonsen
synonym: *Melosira islandica* O. Müller

*Corethron hystrix* Cleve

*Coscinodiscus centralis* Ehrenberg
*Coscinodiscus grani* Gough
*Coscinodiscus occlus-iridis* Ehrenberg
*Coscinodiscus perforatus* Ehrenberg
*Coscinodiscus radiatus* Ehrenberg *emend.* Hasle et Sims
*Coscinodiscus wailesii* Gran et Angst

*Cyclotella atomus* Hustedt
*Cyclotella choctawatcheeana* Prasad
*Cyclotella meneghiniana* Kützing
*Cyclotella stelligera* Cleve et Grunow
*Cyclotella striata* (Kützing) Grunow
*Cyclotella stylogium* Brightwell

*Detonula pumila* (Castracane) Schütt
synonym: *Schroederella delicatula* Pavillard

*Hyalodiscus scoticus* (Kützing) Grunow
*Hyalodiscus subtilis* Bailey

*Lauderia annulata* Cleve
synonym: *Lauderia borealis* Gran

*Leptocyindrus danicus* Cleve
*Leptocyindrus minus* Gran

*Melosira lineata* (Dillwyn) Agardh
synonym: *M. juergensii* Agardh
*Melosira moniliformis* (O. Müller) Agardh
*Melosira mumuloideas* (Dillwyn) Agardh

*Minidiscus comicus* Takano

*Palmeria hardmanniana* Greville

*Paralia sulcata* (Ehrenberg) Cleve

*Planktonella sol* (Wallich) Schütt

*Podosira hormoidea* (Montagne) Kützing
*Podosira montagnei* Kützing
*Podosira stelliger* (Bailey) A. Mann

(P. W)

(P. W)

(P. W)

(P. C)

(P. C)

(B, W)

(B, W)

(B, W)

(B. W)

(P. F)

(C, P)

(C, P)

(C, P)

(E. C)

(E. C)

(E. C)

(E. C)

(E. C)

(E. C)

(E. C)

(E, T)

(E, T)

(E, T) [note 2]
**RHIZOSOLENIALES**

As considered here, the characteristics defining this order are: valves symmetry organized around a point or annulus, primarily unipolar, and lacking a ring of various structural processes. In the taxonomic scheme proposed by Round and co-workers (1990), the species included here in the Rhizosoleniales encompass two different orders. In the scheme followed by Hasle and Syvertsen (1997), this order corresponds to their families Rhizosoleniaceae and Lithodesmiaceae.

*Dactyliosolen fragilissimus* (Bergon) Hasle  
(synonym: *Rhizosolenia fragilissima* Bergon) (P, W)

*Guinardia delicatula* (Cleve) Hasle  
(synonym: *Rhizosolenia delicatula* Cleve) (P, W)

*Guinardia flaccida* (Castracane) Peragallo (P, W)

*Guinardia striata* (Stolterfoth) Hasle  
(synonym: *Rhizosolenia stolterfothii* Peragallo) (P, W)

*Lithodesmium intricatum* (West) Peragallo (P, C)

*Lithodesmium undulatum* Ehrenberg (P, C)

*Proboscia alata* (Brightwell) Sundström  
(synonym: *Rhizosolenia alata* Brightwell) (P, W)

*Proboscia indica* (Peragallo) Hernández-Becerril (P, T)
synonym: Rhizosolenia alata forma indica (Peragallo) Ostenfeld

*Pseudosolenia calcarea* (Schultze) Sundström (P, W)

*Rhizosolenia bergonii* Peragallo (P, T)

*Rhizosolenia castracanei* Peragallo (P, T)

*Rhizosolenia hebetata Bailey forma semispina* (Hensen) Gran (P, C)

*Rhizosolenia imbricata* Brightwell (P, W)

*Rhizosolenia robusta* Norman (P, W) [note 5]

*Rhizosolenia setigeru* Brightwell (P, W)

*Rhizosolenia styliformis* Brightwell (P, C)

**BIDDULPHIALES**

As considered here, the characteristics defining this order are: valves symmetry organized around a point or annulus, primarily bipolar (but sometimes multipolar), and lacking a ring of various structural processes. In the taxonomic scheme proposed by Round and co-workers (1990), the species included here in the Biddulphiales encompass eight different orders. In the scheme followed by Hasle and Syvertsen (1997), this order corresponds to the suborder Biddulphiinae.

*Amphitretas antediluvianiana* Ehrenberg

  synonym: *Triceratium antediluvianum* (Ehrenberg) Grunow (E, W)

*Auliscus caelatus* Bailey var. *rhapis* (A. Schmidt) Peragallo (B, W) [note 6]

*Auliscus caelatus* var. *strigillata* A. Schmidt (B, W)

*Auliscus pruinatus* Bailey (B, W) [note 7]

*Auliscus punctatus* Bailey (B, W) [note 7]

*Auliscus radiatus* Bailey (B, W)

*Auliscus reticulatus* Greville (B, W)

*Auliscus sculptus* (W. Smith) Ralfs (B, W)

*Bacteriastrium delicatum* Cleve (P, W)

*Bacteriastrium hyalinum* Lauder (P, W)

*Bellerochea horologicalis* von Stosch (P, T)

*Biddulphia alternans* (Bailey) Van Heurck (E, W) [note 8]

*Biddulphia biddulphiina* (J. Smith) Boyer (E, W)

  synonym: *B. pulchella* Gray (E, W)

*Biddulphia reticulata* Roper (E, W)

*Biddulphia tuomeyi* (Bailey) Roper (E, T)

*Cerataulina pelagica* (Cleve) Hendey (P, W)

*Cerataulus smithii* Ralfs (B, W)

*Chaetoceros affinis* Lauder (P, W)

*Chaetoceros affinis var. willei* (Gran) Hustedt (P, W)

*Chaetoceros anastomosans* Grunow (P, W)

*Chaetoceros brevis* Schütz (P, W) [note 9]

*Chaetoceros cinctus* Gran (P, W)

*Chaetoceros coarctatus* Lauder (P, T)

*Chaetoceros compressus* Lauder (P, W)

*Chaetoceros constrictus* Gran (P, C)

*Chaetoceros curvisetus* Cleve (P, W)

*Chaetoceros danicus* Cleve (P, W)
Chaetoceros debilis Cleve
Chaetoceros decipiens Cleve
Chaetoceros diadema (Ehrenberg) Gran
Chaetoceros didymus Ehrenberg
Chaetoceros didymus var. anglicus (Grunow) Gran
Chaetoceros diversus Cleve
Chaetoceros eibeni Grunow emend. Meunier
Chaetoceros gracilis Schütz
Chaetoceros lacinius Schütz
Chaetoceros lauderi Ralfs
Chaetoceros lorenzianus Grunow
Chaetoceros lorenzianus var. forceps Meunier
Chaetoceros messanensis Castracane
Chaetoceros minimus (Levander) Marin, Giuffre, Montressor et Zingone
Chaetoceros muelleri Lemmerman
Chaetoceros neogracilis Van Ladingham
Chaetoceros pelagicus Cleve
Chaetoceros pendulus Karsten
Chaetoceros peruvianus Brightwell
Chaetoceros protuberans Lauder
Chaetoceros pseudocurvisetus Mangin
Chaetoceros simplex Ostenfeld
Chaetoceros socialis Lauder
Chaetoceros subtilis Cleve
Chaetoceros teres Cleve
Chaetoceros tortissimus Gran
Chaetoceros vistulae Apstein
Chaetoceros wighani Brightwell
Climacodium frauenfeldianum Granow
Cymatosira belgica Grunow
Cymatosira lorenziana Grunow
Ditylum brightwellii (West) Grunow
Eucamptia cornuta (Cleve) Grunow
Eucamptia zodiacus Ehrenberg
Eunotogramma laevis Grunow
Eunotogramma maritimum (W. Smith) Peragallo
Eunotogramma rostratum Hustedt
Eupodiscus radiatus Bailey
Helicotheca tamesis (Shrubsole) Ricard
Hemialus hauckii Grunow
Hemialus membranaceus Cleve
Hemialus sinensis Greville
synonym: H. heibergii Cleve
Isthmia enervis Ehrenberg
Lampriscus shadboltianus (Greville) Peragallo
synonym: Triceratium shadboltianum Greville
Lithodesmium undulatum Ehrenberg

(P. W) [note 10]
(P. C)
(P. W)
(P. W)
(P. T)
(P. W) [note 11]
(P. C)
(P. W)
(P. T) [note 10]
(P. T)
(P. F)
(P. W) [note 11]
(B. C)
(B. W)
(P. W)
(P. T)
(P. W)
(B. W)
(B. W)
(B. C)
(B. W) [note 14]
(P. W)
(P. W)
(P. T)
(P. W)
(E, T)
(E, T) [note 15]
(P. C)
Minutocellus polymorphus (Hargraves et Guillard) Hasle, v. Stiosch et Syvertsen

Odontella aurita Agardh
Odontella aurita var. minuscula Grunow
Odontella aurita var. obtusa (Kützing) Hustedt
Odontella longicirrus (Greville) Hoban
Odontella mobilensis Grunow
Odontella regia (Schultze) Hoban
Odontella rhombus (Ehrenberg) Kützing
Odontella sinensis (Greville) Grunow

Pleurosira laevis (Ehrenberg) Compère
Terpsinoë americana (Bailey) Ralfs
Terpsinoë musica Ehrenberg
Triceratium antediluvianum (Ehrenberg) Grunow
Triceratium balearicum Cleve forma biquadrata (Janisch) Hustedt

As considered here, the characteristics defining this order are: bilaterally symmetrical valves, lacking a raphe on either valve, but often with a hyaline sternum (equivalent to the pseudoraphe or axial area of other texts). The areolae are arranged more or less linear fashion in relation to the sternum. The species contained here encompass nine orders in Round and co-workers (1990). This order is subsumed in Bacillariales in the scheme adopted by Hasle and Syvertsen (1997).

Ardissonea fulgens (Greville) Grunow
Ardissonea pulcherrina (Hantzsch) Grunow
Ardissonea robusta (Ralfs) DeNotaris

Asterionellopsis glacialis (Castracane) Round

Bleakeleya notata (Grunow) Round

Catacombus gaillonii (Bory) Williams et Round

Climacosphia elongata Bailey

Delphinicis surirella (Ehrenberg) Andrews
Delphinicis surirella var. australis (Petit) Navarro

Dimeregramma minor (Gregory) Ralfs
Dimeregramma minor var. nana (Gregory) Van Heurck

Falcula media Voigt

Fragilaria capucina Desmazières var. mesolepta Rabenhorst
Fragilaria virescens Ralfs var. mesolepta Rabenhorst

FRAGILARIALES
Glyphodesmis williamsonii (W. Smith) Grunow
Grammatophora gibberula Kützing
Grammatophora marina (Lyngbye) Kützing
Grammatophora marina var. tropica (Kützing) Grunow
Grammatophora oceanica (Ehrenberg) Grunow
Grammatophora oceanica var. macilenta (W. Smith) Grunow
Grammatophora serpentina (Ralfs) Ehrenberg

Hyalosynedra laevigata (Grunow) Williams et Round
Hyalosira interrupta (Ehrenberg) Navarro
   synonym: Striotella interrupta (Ehrenberg) Heiberg

Licmophora abbreviata Agardh
Licmophora abbreviata forma grunowii (Mereschkowsky) Hustedt
Licmophora ehrenbergii (Kützing) Grunow
Licmophora flabellata (Carmichael) Agardh
Licmophora paradoxa (Lyngbye) Agardh
Licmophora remulis Grunow

Lioloma pacificum (Cupp) Hasle

Martyana martyi (Héribaud) Round
   synonym: Opephora martyi Héribaud

Nanofrustulatum shiloi (Lee, Reimer et McEnery) Round, Hallstein et Paasche

Opephora marina (Gregory) Petit
Opephora mutabilis (Grunow) Sabbe et Vyverman
   synonym: Opephora olsenii Möller
Opephora pacifica (Grunow) Petit
Opephora schwartzii (Grunow) Petit

Plagiogramma interruptum (Gregory) Ralfs
Plagiogramma pulchellum Greville var. pygmaea (Greville)
   Peragallo
   synonym: Plagiogramma pygmaea Greville
Plagiogramma rhombicum Hustedt

Plagiogrammopsis vanheurckii (Grunow) Hasle, v.Stosch et Syvertsen
Plagiogrammopsis wallichianum Greville

Podocystis adriatica Kützing
Protoraphis atlantica Gibson

Psammodiscus nitidus (Gregory) Round et Mann
   synonym: Coscinodiscus nitidus Gregory
Pseudohimantidium pacificum Hustedt et Krasske

Pteroncola inane (Giffen) Round
   synonym: Fragilaria hyalina (Kützing) Grunow
Rhabdonema adriaticum Kützing
Rhabdonema arenatum (Lyngbye) Kützing
Rhaphoneis amphiceros Ehrenberg  
Rhaphoneis amphiceros var. geminifera (Ehrenberg) Peragallo  
Rhaphoneis castracanei Grunow  
Rhaphoneis superba Grunow  

Striatella unipunctata (Lyngbye) Agardh  

Tabularia fasciulata (Agardh) Williams et Round  
synonym: Syndra tabulata (Agardh) Kützing  
var. fasciulata (Agardh) Hustedt  

Tabularia parva (Kützing) Williams et Round  
synonym: S. tabulata var. parva (Kützing) Hustedt  

Tabularia tabulata (Agardh) Snoeijis  
synonym: Syndra tabulata (Agardh) Kützing  

Thalassionema frauenfeldii (Grunow) Hallegaard  
Thalassionema nitzschiiodes (Grunow) Mereschkowsky  

Toxarium hemolypondum Grunow  

Trachysphenia acuminata Peragallo  

**BACILLARIALES**

As considered here, the characteristics defining this order are: bilaterally symmetrical valves, and the presence of a raphe on one or both valves. In the taxonomic scheme proposed by Round and co-workers (1990), the species included here in the Bacillariales encompass nine different orders. The order Bacillariales in the sense of Hasle and Syvertsen (1997) would include the order Fragilariales as considered in this work.

Achnanthes brevipes Agardh  
Achnanthes brevipes var. angustata (Greville) Cleve  
Achnanthes brevipes var. parvula (Kützing) Cleve  
Achnanthes citromella (Mann) Hustedt  
Achnanthes curvirostrum Brun  
Achnanthes kwaiatensis Hendey  
Achnanthes longipes Agardh  
Achnanthes manifera Brun  

Amphora angusta Gregory  
Amphora angusta var. ventricosa (Gregory) Cleve  
Amphora arenaria Donkin  
Amphora bigibba Grunow  
Amphora caroliniana Giffen  
Amphora coffaformis Agardh  
Amphora costata W. Smith  
Amphora decussata Grunow  
Amphora exigua Gregory  
Amphora marina (W. Smith) Van Heurck  
Amphora obtusa Gregory  
Amphora ocellata Donkin  
Amphora ostrearia (Brébisson) var. lineata Cleve  
Amphora proteoides Hustedt  
Amphora proteus Gregory
Amphora robusta Gregory
Amphora spectabilis Gregory
Amphora tetrata Ehrenberg

synonym: A. cymbifera Gregory

Anomoeoneis sphaerocephora (Kützing) Pfitzer var. sculpa
(Ehrenberg) O. Mülller

Anorthoneis cyanostoma Cleve
Anorthoneis excentrica(Donkin) Grunow
Anorthoneis hyalina Hustedt

Auricula complexa (Gregory) Cleve

Bacillaria paxillifera (O. Mülller) Hendley

Berkeleya micans (Lyngbye) Gran
Berkeleya rutilans (Trentepohli) Grunow

Caloneis elongata (Grunow) Boyer
Caloneis excentrica (Grunow) Boyer

Campylococcus daemelianus Grunow
Campylococcus immonitatus Ross et Adbin

Capartogramma crassiculida (Grunow) Ross

Climaconeis lorenzii Grunow

Cocconeis brittania Naegeli
Cocconeis convexa Giffen
Cocconeis discusoides Hustedt
Cocconeis heteroidea Hantsch
Cocconeis pellucida Grunow
Cocconeis placenta Ehrenberg
Cocconeis placenta var. englypta (Ehrenberg) Cleve
Cocconeis pseudomarginata Gregory
Cocconeis scutellum Ehrenberg
Cocconeis scutellum var. stauroeiformis W. Smith
Cocconeis woodii Reyes-Vasquez

Cylindrotheca closterium (Ehrenberg) Reimann et Lewin

Cymbella pusilla Grunow

Denticula subtilis Grunow
Denticula thermalis Kützing

Diadesmis contenta (Grunow) Mann

synonym: Navicula contenta Grunow

Dictyoneis marginata (Lewis) Cleve

Diploneis bombus Ehrenberg
Diploneis crablo Ehrenberg
Diploneis gravellana Hagelstein
Diploneis gruendleri (Schmidt) Cleve
Diploneis interrupta (Kützing) Cleve var. caffra Giffen
Diploneis obliqua (Brun) Hustedt
Diploneis smithii (Bréhission) Cleve
Diploneis suborbicularis (Gregory) Cleve var. constricta Hustedt
Diploneis vacillans (Schmidt) Cleve var. renitens Schmidt
Diploneis weissflogii (Schmidt) Cleve

Entomoneis alata (Ehrenberg) Ehrenberg
Entomoneis pulchra (Bailey) Reimer
   synonym: Amphipora conspica Greville

Epithemia sored Kutzing

Fallacia amphipleuroides (Hustedt) Mann
Fallacia forcipata (Greville) Stickle et Mann
Fallacia hyalinula (DeToni) Stickle et Mann
Fallacia litoricola (Hustedt) Mann
Fallacia nummularia (Greville) Mann

Frustulia asymmetrica (Cleve) Hustedt

Gomphonema acuminatum Ehrenberg

Gomphonemopsis littoralis (Hendey) Medlin

Gyrosigma baileyi (Grunow) Cleve
Gyrosigma balticum (Ehrenberg) Raehenhorst
Gyrosigma fasciola (Ehrenberg) Griffith et Henfrey
Gyrosigma hummii Hustedt
Gyrosigma macram (W. Smith) Griffith et Henfrey
Gyrosigma psenonis (Grunow) Hustedt
Gyrosigma variissriatum Hagelstein

Hantzschia virgata (Roper) Grunow

Haslea wasrickae (Hustedt) Simonsen

Lyrella abruptoides (Hustedt) Mann
Lyrella approximata (Greville) Mann
Lyrella atlantica (Schmidt) Mann
   synonym: Navicula lyla Ehrenberg var. atlantica Schmidt
Lyrella clavata (Gregory) Mann
Lyrella clavata var. distenta Hustedt
Lyrella clavata var. indica (Greville) Cleve
Lyrella kennedyi (W. Smith) Stickle et Mann
Lyrella irroroides (Hustedt) Mann
Lyrella lyla (Ehrenberg) Karayeva
Lyrella praetexta (Ehrenberg) Mann

Mastogloia acutisculus Grunow var. elliptica Hustedt
Mastogloia angulata Lewis
Mastogloia apiculata W. Smith
Mastogloia baldikiana Grunow
Mastogloia binotata (Grunow) Cleve
Mastogloia braunii Grunow
Mastogloia citrus (Cleve) DeToni
Mastogloia cribrosa Grunow
Mastogloia crucicula (Grunow) Cleve
Mastogloia decipiens Hustedt
Mastogloia dicephala Voigt

(B. W)
(B. C)
(B. T)
(B. W)
(B. W)
(B. W)
(B. F)
(E. F)
(E. T)
(P. W)
(B. W)
(B. W)
(B. C)
(B. C)
(B. C)
(B. T)
(B. W)
(B. W)
(B. W)
(B. T)
(B. W)
(B. W)

(E. T)
(E. W)
(E. W)
(E. T)
(E. W)
(E. C)
(E. T)
(E. T)
(E. T)
(E. T)
Mastogloia elegans (E, C)
Mastogloia erythraea Grunow (E, T) [note 36]
Mastogloia erythraea var. biocellata Grunow (E, T)
Mastogloia exigua Lewis (E, T)
Mastogloia euxina Cleve (E, T)
Mastogloia exilis Hustedt (E, T)
Mastogloia fimbriata (Brightwell) Cleve (E, T)
Mastogloia grunowii Schmidt (E, T)
Mastogloia hustedtii Meister (E, T)
Mastogloia lanceolata Thwaites (E, W)
Mastogloia minutissima Voigt (E, C)
Mastogloia omissa Voigt (E, T)
Mastogloia ovalis Schmidt (E, T)
Mastogloia paradoxa Grunow (E, T)
Mastogloia pisciculus Cleve (E, T)
Mastogloia pumila (Grunow) Cleve (E, C)
Mastogloia pumila var. papuarum Cholnoky (E, C)
Mastogloia pumila var. africana Giffen (E, C)
Mastogloia pusilla Grunow (E, C)
Mastogloia pusilla var. subcupitata Hustedt (E, T)
Mastogloia schmidtii Heiden (E, T)
Mastogloia smithii Thwaites (E, W) [note 33]
Mastogloia splendidia (Gregory) Ralfs (E, W)
Mastogloia subaffirmata Hustedt (E, T)
Mastogloia varians Hustedt (E, T)
Navicula carinifera Grunow (B, W)
Navicula clamans Hustedt (B, W)
Navicula directa W. Smith (B, C)
Navicula fromenterae Cleve (B, T)
Navicula johannossii Giffen (B, C)
Navicula longa (Gregory) Ralfs (B, T)
Navicula maculosa Donkin (B, C)
Navicula normalis Hustedt (B, C)
Navicula pennata Schmidt (B, C)
Navicula platyventris Meister (B, C)
Navicula pseudocomoides Hendey (B, C) [note 30, 41]
Navicula pseudocrassirostris Hustedt (B, C)
Navicula ramossissima Agardh) Cleve (B, C) [note 30]
Navicula salinarum Grunow (B, W)
Navicula scopulorum Brébisson (B, W)
Navicula tripunctata (Müller) Bory (B, F)
Navicula yarrensis Grunow (B, T)

Nitzschia amphibia Grunow (B, F) [note 38]
Nitzschia brittonii Hagelstein (B, T)
Nitzschia fonticola Grunow (B, F)
Nitzschia frustulums (Kützing) Grunow (B, F)
Nitzschia insignis Gregory (B, W)
Nitzschia lanceolata W. Smith (B, W)
Nitzschia lesbia Cholnoky (B, C)
Nitzschia linearis W. Smith (B, F)
Nitzschia lunella Cholnoky (B, C)
Nitzschia longissima (Brébisson) Ralfs (B, W)
Nitzschia lorenziana Grunow var. subtilis Grunow (B, C)
Nitzschia martiana (Agardh) Van Heurck
Nitzschia obtusa W. Smith forma parva Hustedt
Nitzschia palea (Kützing) W. Smith var. debils (Kützing) Grunow
Nitzschia parvula W. Smith
Nitzschia quickiana Hagelstein
Nitzschia reversa W. Smith
Nitzschia rhopalodiolides Hustedt
Nitzschia sigma (Kützing) W. Smith
Nitzschia sigma var. intercedens Grunow
Nitzschia socialis Gregory
Nitzschia spathulata W. Smith
Nitzschia ventricosa Kitton
Nitzschia vidovicichii Grunow

Parlibellus berkeleyi (Kützing) Cox
Parlibellus delognesi (Van Heurck) Cox
Parlibellus humilifer (Grunow) Cox
Parlibellus tubulosus (Brun) Cox

Petrodictyon gemma (Ehrenberg) Mann
synonym: Surirella gemma Ehrenberg

Petroneis granulata (Bailey) Mann
Petroneis transfuga (Grunow) Mann

Pinnularia gentilis (Donkin) Cleve
Pinnularia robusta Hustedt

Plagirotropis lepidoptera (Gregory) Kuntze
Plagirotropis lepidoptera var. proboscidea (Cleve) Reimer
Plagirotropis seriata (Cleve) Kuntze

Planothidium delicatum (Kützing) Round et Bukhtiyarova
Planothidium hauckium (Grunow) Round et Bukhtiyarova
synonym: Achnanthes lanceolata Brébisson var. elliptica Cleve

Pleurosigma aestivumii (Brébisson) W. Smith
Pleurosigma angulatum (Queckett) W. Smith
Pleurosigma delicatum W. Smith
Pleurosigma elongatum W. Smith var. gracilis Grunow
Pleurosigma formosum W. Smith
Pleurosigma intermedium W. Smith
Pleurosigma rigidum W. Smith

Psammodictyon constrictum (Gregory) Mann
Psammodictyon panduriforme (Gregory) Mann

Pseudo-nititschiae delicatissima (Cleve) Heiden
Pseudo-nitzschiae pseudodelicatissima (Hasle) Hasle
Pseudo-nitzschiae pangens (Grunow) Hasle
Pseudo-nitzschiae serriata (Cleve) Paragallo

Rhopalodia gibberida (Ehrenberg) Müller
Rhopalodia operculata (Agardh) Häkansson
synonym: Rhopalodia musculus (Kützing) Müller

Stauroneis amphoroides Grunow
Stauraphora amphioxys (Gregory) Mann  
synonym: Stauroneis amphioxys Gregory
Stauraphora amphioxys var. producta Grunow

Surirella fastuosa (Ehrenberg) Kützing

Trachyneis aspera (Ehrenberg) Cleve
Trachyneis bruntii (Cleve) Cleve

Tryblionella acuminata (W. Smith) Mann  
Tryblionella acuta (Hantzsch) Mann
Tryblionella coarctata (Grunow) Mann
Tryblionella granulata Grunow) Mann
Tryblionella granulata var. hyalina Amosse
Tryblionella marginulata (Grunow) Mann
Tryblionella marginulata var. didyma Grunow

NOTES

1. According to Håkansson (1996) some identifications of this taxon, including samples from Florida, are in reality Cyclotella littoralis Lange et Syvertsen.
2. The distinction between Podosira and Hyalodiscus is not clear (Round and co-workers, 1990); P. stelliger, for example, is frequently called H. stelliger.
3. According to Hasle (1979) many records of this species may be suspect; it appears to be primarily a benthic species, "possibly... as an epiphyte or trapped by branched larger algae...".
4. There is evidence that at colder temperatures this diatom becomes altered in its morphology and resembles T. gravida (Syvertsen, 1977).
5. This species was recently transferred to a new genus, Calyptrrella, later transferred again to Neocalyptrrella (Hernández-Becerril and Meave de Castillo, 1997).
6. The genus Auliscus is primarily fossil, and rarely seen alive; some have questioned whether it is solely fossil; at least A. caelatus is extant.
7. Auliscus pruinosus and A. punctatus are probably synonymous; see Sullivan, 1987
8. This species has also been called Triceratium alternans and Trigonium alternans. The correct name depends on one's interpretation of the generic limits of the three genera involved.
10. Without the presence of resting spores (in C. lorenzianus only) it is difficult to separate C. decipiens from C. lorenzianus since morphological intergrades are common (see Rines and Hargraves, 1988).
11. There is no consistency to the naming of unicellular Chaetoceros species, and several names have been applied almost indiscriminately; see Rines and Hargraves, 1988.
12. This species is often reported in the literature, but has no taxonomic validity; it is difficult to say exactly what its identity is.
13. The differences between C. pernianus and C. pendulus are not always distinct, and some authors have combined them (see Rines and Hargraves, 1988).
14. Round and co-workers (1990) have questioned whether F. radiatus is extant or only fossil.
15. Proper assignment to a genus depends on whether electron microscope examination shows the presence of ocelli (as in Triceratium), or pseudocelli (as in Lampriscus. See Round and co-workers, 1990, and Navarro, 1981.
16. The generic limits amongst Amphipeitas, Amphitestris, Bidibulbia, Triceratium and Trigonium are confused and complex; see Round and co-workers, 1990.
17. The structure of this species corresponds to Ehrenberg's genus Amphipeitas (Sims, 2001)
18. If one considers the genus Amphipeitas as valid, then this species would be the generitype (Sims, 2001)
19. This species has pseudocelli and non-fuculatate areolae, unlike the type species of Trigonium, and might be better placed in the genus Sheidukovia (P. Sims, pers. com., 801); see Round and co-workers, 1990.
20. Species in this genus were formerly placed in Synedra.
22. Falcula is primarily epizoic on marine zooplankton, Prasad and co-workers (1989) believe this is a misidentification for F. hyalinna Takano.
23. Some species in this genus were formerly placed in Fragilaria.

25. Round and co-workers (1990) do not include this species in *Opephora*, but offer no alternative.

26. Although primarily an epiphyte on seagrasses, this species may also be abundant on the feathers of diving sea birds.

27. This species bears a resemblance to the recently described genus *Reimerothrix* (Prasad and co-workers, 2001), and may be a misidentification for that taxon. *Toxarium kemedyranum* is common in temperate coastal areas, whereas *R. floridensis* has been confirmed only from Florida Bay.


29. Most records throughout the world list *B. paxillifer* (or its synonym, *B. paradoxa*). It seems certain, however, that *Bacillaria* is made up of more than one species, and the one so common in the IRL is probably not *B. paxillifer*.

30. This is a diatom which forms foliose colonies, with the cells in mucilaginous tubes.

31. Round and co-workers (1990) do not distinguish between *Caloneis* and *Pinnularia*.

32. The genus *Clinaconeis* appears to be more diverse in Florida than was previously evident (Prasad and co-workers, 2000).

33. Species of *Fulvia* were formerly in the genus *Navicula*.

34. Species of *Lyrella* were formerly in the genus *Navicula*, primarily in the ‘Lyraeae’, variously called a subgenus, section, or simply, group.

35. Most species of *Mastogloia* are predominantly epiphytic, but may also exist as members of the epipelagic (sediment surface) community.

36. In some species of *Mastogloia* the number of internal marginal siliceous chambers (partecta) is related to valve length. Such is the case, for example, in *M. erythraea* and *M. smithii* (Novarino and Muftah, 1992).

37. This species may be planktonic, benthic, or symbiotic, and has been reported under a variety of names; see Round and co-workers (1999).

38. This is a large genus containing many species which are probably not closely related. A number of *Nitzschia* species have been transferred to other genera, e.g., *Psammodictyon* and *Tryblionella*.

39. The relationship between *N. socialis* and *Bacillaria paxillifer* is unclear. Individual cells of both taxa are similar, and it is becoming apparent that, contrary to conventional wisdom, *Bacillaria* is made up of several undescribed species.

40. *Parlibellus* includes a number of species formerly placed in the large and unwieldy genus *Navicula* (see Cox, 1988). The species listed here all occur primarily within mucilaginous tubes, sometimes branched.


42. It is likely that many records of this species from subtropical and tropical waters are misidentifications of *P. patrimonii* Sterrenburg (see Sterrenburg, 2001).

43. Species of *Petroneis* were formerly in the genus *Navicula* (see Round and co-workers, 1990).

44. The relationship between *P. delicatulum* and *P. hauckiana* is uncertain; see Patrick and Reimer, 1966.

45. Species of *Planothidium* were formerly in the genus *Achnanthes* (see Round and Bulteiyarova, 1996).

46. Some authors (e.g., Patrick and Reimer, 1966) prefer to retain this species as a variety of *P. angulatum* (Queckett) W. Smith.

47. *Psammodictyon* was established by D.G. Mann (in Round and co-workers, 1990) to include the species from the Panduriformes section of *Nitzschia*.

48. *Pseudo-nitzschia seriata* is frequently a misidentified name for other species in this genus of very similar species (see Hasle and co-workers, 1996). These species potentially may produce domoic acid, a potent neurotoxin.

49. This species may be better placed in *Staurophora*, which contains marine/brackish species with one plastid (Prasad and Silva, 2000). *Stauroneis* species usually have two plastids and are freshwater inhabitants. However, the IRL contains numerous adventitious freshwater species. I have not seen living cells, and so the chloroplast number is unknown.

50. *Tryblionella* consists of species formerly in the section *Tryblionellae* of the genus *Nitzschia*. 