Checklist of Diatoms (Bacillariophyceae) from the Southern Gulf of Mexico: Data-Base (1979-2010) and New Records

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Abstract

The objective of this study was to compile a coded checklist of 430 taxa of diatoms collected over a span of 30 years (1979-2010) from water and net-tow samples in the southern Gulf of Mexico. The checklist is based on a long-term survey involving the 20 oceanographic cruises. The material for this study comprises water and net samples collected from 647 sites. Most species were identified in water mounts and permanent slides, and in a few cases a transmission or scanning electron microscope was used. The most diverse genera in both the water and the net samples were Chaetoceros (44 spp.), Thalassiosira (23 spp.), Nitzschia (25 spp.), Amphora (16 spp.), Diploneis (16 spp.), Rhizosolenia (14 spp.) and Coscinodiscus (13 spp.). The most frequent species in net and water samples were, Actinocyclus senarius, Asteromphalus heptactis, Bacteriastrium delicatulum, Carataula pelagica, Chaetoceros didymus, C. diversus, C. lorenzianus, C. pelagicus, C. pseudocurvisetus, Coscinodiscus radiatus, Cyclotella striata, Diploneis bombus, Guinardia flaccida, Hemiaulus sinensis, Leptocylindrus danicus, Odontella aurita, O. mobiliensis, Paralia sulcata, Proboscia alata, Pseudo-nitzschia pseudodelicatissima, P. pungens, Skeletonema costatum, Thalassiosira eccentrica, T. partheneia, Thalassionema nitzschioides, and Thalassiothrix longissima. Ninety three taxa were new records for this region.

Keywords: Checklist; Marine diatoms; Data-base; Gulf of Mexico

Introduction

Diatoms are the most important primary producers of both marine and freshwater environments. Its role in regulating the ocean’s silicon cycle is considerable [1]. For taxonomists and ecologists these microalgae are useful for monitoring past and present environmental conditions. They are commonly used in studies of water quality, because they are sensitive to many environmental conditions related to water acidification, eutrophication and climate changes. Diatoms have also been used as valuable indicators in historical assessments of water quality [2-6].

Diatoms (Division Bacillariophyta, Class Bacillariophyceae) have been studied since the early nineteenth century when they were popular among microscopists. In the late nineteenth century many European workers produced hand illustrated monographs and descriptions of species which are still as valuable references reviewed in Werner [7]. Hasle and Syvertsen [8] analyzed the new taxonomic information on diatom morphology and presented a revision of the classical identification literature (atlases, floras and handbooks). Krasyesky et al. [9] listed 850 diatom species for the entire Gulf of Mexico; however many of them were insufficiently known or, doubtful entities. Besides, several of the species in this list, have other accepted names according to Guiry and Guiry [10], an on-line resource available since September 2004. As a result, only 575 taxa have valid names.

Diatom studies in Mexican waters were recorded by Schmidt et al. [11] in the “Atlas der Diatomaceenkunde” with illustrations of 313 species from locations in the Bay of Campeche in the southern Gulf of Mexico. Of these, 108 species were assigned to the genus Navicula, 36 to Amphora, 28 to Camyplodiscus and 26 to Triceratium. Additionally, they included some infra-specific taxa that were considered as doubtful cases. Today, many of these names are no longer valid or their taxonomic status has changed. Through the 60’s until the 80’s, Soviet and Soviet-Cuban expeditions in the southern Gulf [12] found out that diatoms were the dominant group. Recently, many researchers reported the taxonomy and distribution of diatoms in this region [13-20]. However, they did not report many of the small and rare species.

This study is part of a large-scale phytoplankton relational database for the southern part of the Gulf of Mexico. The diatom section of this program comprises 434 diatoms with a total of 14801 entries between June 1979 and December 2010. The objective of this study was to compile a checklist of diatom species from the southern Gulf of Mexico and to provide an update of valid taxonomic names for each one.

Materials and Methods

The study area

The study area in the southern Gulf of Mexico (herein referred to as SGM) lies between 24°38’ and 18°15’ N and between 86°15’ and 98°12’ W (Figure 1). The hydrographic conditions in this area are greatly influenced by the Loop Current and the detachment of anticyclonic eddies that migrate westward around the Gulf. These eddies tend to move northwards or southwards, depending on the expulsion of water masses. The south region of Campeche Bay has a predominantly cyclonic circulation mainly associated with the Yucatan Channel waters [21]. The presence of cold winds between October and April causes the formation of cold fronts. The dominant cyclonic circulation and fronts of the rivers create a dynamic system which provides the region with a unique environment. The Coatzacoalcos and the Grijalva-Usumacinta rivers represent approximately 11% of all fluvial discharges into the Gulf of Mexico. There is a notable presence of a permanent cyclonic eddy in the central region and beyond the continental shelf, as well...
as several lagoons that contribute to coastal outwelling [22-24]. More information concerning this area may be found in Yáñez-Arancibia et al. [25]. The Yucatan Shelf is also greatly influenced by an upwelling in the north of Cape Catoche [26,27]. Consequently, while one portion of this water flows towards the west, the other part moves towards the east [28].

This region is a highly productive fishing area, and profitable for the oil industry. Both activities have turned this region into an economically important area, but potentially critical as well due to continuous oil spills and the presence of toxic substances in untreated water that affect this region [29]. It is important to recognize marine diatoms as indicators of modern changes in oceanographic conditions [5], and likewise for oil and gas exploration [30].

Sampling strategy and laboratory analyses

This diatom checklist was compiled from 20 oceanographic cruises between July 1979 and May 2010. Most surveys were done on board the R/V “Justo Sierra”. During this period 647 sites were sampled (sometimes more than once) and the sampling stations covered the entire southern Gulf. Discrete water samples were taken by a CTD Neil Brown with a rosette of Niskin bottles and were preserved with acidified Lugol’s solution. Vertical net samples were collected using 20 µm and 35 µm mesh-sized plankton nets within 5 m from the bottom to the surface were carried out at each sampling site and the samples were preserved with 2% neutralized formaldehyde. Most species were identified in water mounts or on an inverted light microscope. In addition, acid-cleaned samples were mounted in Naphrax [31]. In some cases, transmission or scanning electron microscope allowed us the identification of difficult species of the genera Amphora, Pseudonitzschia, Thalassiosira, Psammodictyon and many small taxa. The reported species composition is based upon the database sponsored by The National Council for the Study and Conservation of Biodiversity (CONABIO) [32,33].

Species identification

The identification of some species was achieved using classic books [8,11,34-42], but specialized literature was needed for specific taxa. In addition, some diatom databases on web sites were also consulted [10,43,44]. Images in several databases illustrated intraspecific variability. Light and eventually electron microscopes were commonly used for routine analyses. In addition databases were used to review valid names to improve their spelling, and to standardize authorized names. Besides, there are pertinent links to obtain additional information, unless they are specifically unauthorized.

This checklist comes from a phytoplankton database that is at a medium stage of development. It contains mainly light micrograph images from 25 oceanographic cruises carried out at the SGM, also electron microscope photographs, light microscope digital images, information about samples, a short description of each species as well as a collection of permanent mounted slides from most net samples. This collection is known as the MEX-UNAM Diatom Collection and is stored at the Instituto de Ciencias del Mar y Limnología from the Universidad Nacional Autónoma de México under curation of the corresponding author.
Habitat | Species |
--- | --- |
FW | Achnanthes curvirostrum |
BW | Achnanthes exigua |
NH | Achnanthes manifera |
FW | Achnanthes ventralis (Krasske) |
FW | Achnanthes exiguum var. heterovalvum (G.Krasske) |
M | Actinoptychus circeius |
M | Actinoptychus curvatulus |
M | Actinoptychus octonarius var. crassus |
M | Actinoptychus octonarius var. ralfsii |
M | Actinoptychus octonarius var. sparsus |
M | Actinoptychus octonarius var. tenellus |
M | Actinocyclus subtilis |
M | Actinocyclus campanulifer |
NH | Actinoptychus minutus |
M | Actinoptychus senarius |
M | Actinocyclus splendens |
NH | Actinoxyphtus vulgaris |
M | Alveus marinus |
M | Amphicocconeis disculoides |
M | Amphora angusta |
M | Amphora arenaria |
NH | Amphora bacillaris |
NH | Amphora bigibba |
NH | Amphora bioculata |
NH | Amphora contracta |
NH | Amphora costata var. inflata |
NH | Amphora decussata |
NH | Amphora laevis |
FW | Amphora ovalis |
FW | Amphora pediculus |
M | Amphora proteus |
NH | Amphora rhombica |
M | Asterionellopsis glacialis |
M | Asterolampra marylandica |
M | Asteromphalus arachne |
M | Asteromphalus cleveanus |
M | Asteromphalus flavellatus |
M | Asteromphalus heptactis |
NH | Asteromphalus ingens |
NH | Asteromphalus robustus |
M | Asteromphalus sarcophagus |
NH | Asteromphalus shadbillianus |
NH | Asteromphalus stellatus |
M | Atthaya septentrionalis |
FW | Aulacoseira granulata |
FW | Aulacoseira granulata var. angustissima |
FW | Aulacoseira italica |
M | Azpeitia neocrenulata |
M | Azpeitia nodulifera |
NH | Bacillaria paxillifera |
M | Bacteriastrium comosum |
M | Bacteriastrium delicatulum |
M | Bacteriastrium elegans |
M | Bacteriastrium elongatum |
M | Bacteriastrium furcatus |
M | Bacteriastrium hyalinum |
M | Bellerochea horologicalis |
M | Biddulphia biddulphiana |
M | Biddulphia rhombus |
M | Biddulphia tridens |
M | Bleakleya notata |
FW | Caloneis amphibiaena |
BW | Caloneis liber |
NH | Campylosidicus brazieriensis |
M/FW | Campylosidicus clypeus |
M | Campylosidicus decorus |
M | Campylosidicus samoenis |
M | Campylosidicus clypeus var. heterovalvum |
M | Cariniasigma rectum |
M | Catacombas gallionii |
M | Cerataulina pelagica |
NH | Cerataulina californica |
M | Cerataulina smithii |
NH | Cerataulina turgida |
M | Ceratoneis closterium |
M | Chaetoceros affinis |
M | Chaetoceros anastomosans |
M | Chaetoceros atlanticus var. neapolitanus |
M | Chaetoceros atlanticus |
M | Chaetoceros borealis |
M | Chaetoceros brevis var. brevis |
M | Chaetoceros coworktus |
M | Chaetoceros compressus |
M | Chaetoceros concavicornis |
M | Chaetoceros constictus |
M | Chaetoceros curvisetus |
M | Chaetoceros didayi |
M | Chaetoceros danicus |
M | Chaetoceros debilis |
M | Chaetoceros decipiens |
M | Chaetoceros dichea |
M | Chaetoceros didymus var. didymus |
M | Chaetoceros difficilis |
M | Chaetoceros diversus |
M | Chaetoceros eileni |
M | Chaetoceros gracilis |
M | Chaetoceros lacinius |
M | Chaetoceros lorenzianus |
M | Chaetoceros messanensis |
M | Chaetoceros minimus |
M | Chaetoceros pelagicus |
M | Chaetoceros pendulus |
M | Chaetoceros perpusillus |
M | Chaetoceros peruvianus |
M | Chaetoceros proburberans |
M | Chaetoceros pseudocurvisetus |
M | Chaetoceros radicans |
M | Chaetoceros rostratus |
M | Chaetoceros seirecanthus |
M | Chaetoceros simplex |
M | Chaetoceros socialis |
M | Chaetoceros subtilis |
M | Chaetoceros subtilis var. abnormis |
M | Chaetoceros tenuissimum |
M | Chaetoceros teres |
M | Chaetoceros tetrastichon |
M | Chaetoceros tortissimus |
M | Chaetoceros wighamii |
M | Chaetoceros willei |
M | Climaciadium frauenfeldianum |
M Climacosphenia moniligera
NH Cocconeis britannica
M/FW Cocconeis placentula var. placentula
FW Cocconeis placentula var. euglypta
M Cocconeis pseudomarginata
NH Cocconeis scutellum
M Corethron hystrix
NH Coscinodiscus jonesianus
M Coscinodiscus alboranii
M Coscinodiscus asteromphalus
M Coscinodiscus centralis
M Coscinodiscus concinnus
M Coscinodiscus gigas
M Coscinodiscus granii
M Coscinodiscus gigas
M Coscinodiscus concinnus
M Coscinodiscus centralis
M Coscinodiscus asteromphalus
M Coscinodiscus jonesianus
M Coscinodiscus alboranii
M Coscinodiscus gigas
M Coscinodiscus granii
M Coscinodiscus rautifolius
M/FW Craticula halophila
FW Craticula exilis
FW Cyclotella choctawhatcheeana
FW Cyclotella litoralis
FW Cyclotella meneghiniana
FW Cyclotella stelligera
FW Cyclotella striata
FW Cyclotella stylocrura
M Cymatodiscus variegatus
M/FW Cymatodiscus pyriformis
FW Cymbella mexicana
M Cyrtosira meneghiniana
M Delphineis angustata
M Delphineis minutissima
M Delphineis ovata
FW Delphineis surirella
FW Denticula kuetzingii
M Deltonula pumila
M Dimeregramma marinum
NH Diaioneis bombus
M Diaioneis coffeiformis
NH Diaioneis contigua var. eugenia
FW Diaioneis craveniana
NH Diaioneis decipiens var. parallela
NH Diaioneis lineata
NH Diaioneis obliqua
M/FW Diaioneis ovata
M Diaioneis papula
FW Diaioneis puella
M/FW Diaioneis smithii
NH Diaioneis subadvena
M Diaioneis vacillans var. renitens
NH Diaioneis vetula
M Diaioneis weissflogii
M Ditylum brightwellii
FW Encyonema minutum var. pseudogracilis
M Entomoneis altata
M Entomoneis gigantea
M Entomoneis paludosa var. paludosa
M Entomoneis pulchra
NH Envekadea pseudocrassirostris
FW Epithemia adnata
M Eucampia cornuta
M Eucampia zodiacus
M Eunotogramma laeve
M Eupodiocystis radiatus
M Exubocellulus spinifer
BW Falloia pygmaea
FW Fragilaria acus
FW Fragilaria brevisvariata
NH Fragilaria goutardii var. goutardii
FW Fragilaria tenera
M Fragilariaopsis doliius
M Fragilariaopsis kerguelensis
FW Gomphonema angustatum
FW Gomphonema affine
FW Gomphonema gracile
FW Gomphonema gracile var. naviculoides
FW Gomphonema intricatum
M Gossleniella tropica
M Grammatophora angulosa
M Grammatophora marina
M Guinardia cylintron
M Guinardia delicatula
M Guinardia flaccida
M Guinardia gracilis
M Guinardia fraccida
M Guinardia striata
FW Gyrosigma acuminatum
M Gyrosigma balticum
M Gyrosigma fasciola
FW Gyrosigma macrura
M Halamphora capilata
M Halamphora clara
BW Halamphora coffeiformis
M Halamphora exigua
FW Halamphora perpusilla
M Halamphora terroris
FW Halamphora veneta
M Haslea frauenfeldii
M Haslea gigantea
M Haslea spicula
M Haslea wawrikae
M Helicodiscus tamesis
M Hemiautus hauckii
M Hemiautus membranaceus
M Hemiautus sinensis
M Hemidiscus cuneiformis
M Hemidiscus cuneiformis var. orbicularis
M Hemidiscus cuneiformis var. ventricosus
M Isthmia nervosa
M Lampriscus shadboltianum
M Leptocylindrus danicus
M Leptocylindrus mediterraneus
NH Leptocylindrus minimus
NH Licmophora abbreviata
NH Licmophora communis
Results and Discussion

Collection and identification techniques

This is the first account of diatoms from the SGM. A total of 430 taxa are recorded and no synonyms are listed in Table 1. The great majority of species are tropical, subtropical or cosmopolitan. Some species have been recorded as brackish-water, fresh water and benthic. Around 45% of the diatoms were identified during analysis of water samples with the inverted microscope (Carl Zeiss ICM405) to identify forms and structures of colonies. The standard phase contrast Carl Zeiss photomicroscope was useful to observe other structures of forms and structures of colonies. The standard phase contrast Carl Zeiss photomicroscope was useful to observe other structures of colonies. The standard phase contrast Carl Zeiss photomicroscope was useful to observe other structures of colonies. The standard phase contrast Carl Zeiss photomicroscope was useful to observe other structures of colonies. 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Identification problems

It was difficult to distinguish closely related species even on permanent mounts since some descriptions were insufficient or inadequate. An example is the characterization of valves; they could be 'rectangular', 'capitate', 'small', 'neat' or 'lanceolate'. Their morphological variation can be very broad, even if the stratification is measured. An electron microscopy is necessary to solve this problem. Diatoms are extremely diverse and there are many species that have not been described yet, the species delimitation is still controversial.

The use of databases

Online databases have been very useful, especially those that provide additional bibliographic information and species distributions. Some online diatom collections and databases offer open access with descriptions, images, environmental and bibliographic data, and in some cases, the use of software for various purposes. It is important to recognize that there is a continuous need to update taxonomy and it requires a careful surveillance. We were able to review all species listed on Table 1 with specialized literature and with online databases since they provided us with the necessary information to take a decision.

A correct identification of every species in a given region is of great importance, since every taxon plays a role in the ecosystem. In particular, small species (3-8 µm) are difficult to identify and an electron microscope is frequently required. On occasions, some of these species may become very abundant and widely distributed; they may even have blooms that affect the ecosystem. In the studied region we found several species with these characteristics: Minidiscus trioculatus, Cyclotella litoralis, Delphineis minutissima, Leptocylindrus minimus, Nitzschia bifurcata, Thalassiosira alleni, and Pseudonitzschia among others. The contribution of river flow and the discharge of several coastal lagoons into the region could explain the presence of fresh and brackish water species along the coast. Examples of these are many species of the genera Amphora, Achnanthes, Cyclotella, Diploneis, Navicula, and Nitzschia.

The potential use of validated diatoms checklists

In the past there was a tendency to erect taxa on the basis of tiny, subtle differences in morphology, sometimes in individual specimens without attempting to establish their stability. On the other hand, in the last 40 years, new genera or living diatoms have been discovered.

Validated and updated checklists are essential for ecological studies involving monitoring assessments or changes in the species composition in a given site. Without these checklists it would be impossible to detect changes in the structure of a community and the use of indicator species would be limited. There is a long-standing debate regarding the ecology of phytoplankton and this has been the controversy underlying a non-uniform distribution of species. A possible answer for the disagreements is that it depends on the spatial scale. With a scale of hundred kilometers, the differences between diatom communities are utterly related to geographic or hydrographic features. We were able to establish four regions in the southern Gulf of Mexico by using species association as part of this checklist [16]. Other authors have identified similar regions but using other organisms as a reference [45]. Another potential use for a diatom database is the detection of non-native species introduced via ship ballast water [30].

There is great risk that human activities could cause a loss in diatom biodiversity, it is fundamental to know about changes in species composition and its implications for ecosystem function. There is an urgent need to understand the marine ecosystems and other problems derive from natural and anthropogenic sources.

This checklist needs to be constantly updated, which is useful as a reference for ecological work considering that diatoms are good indicators of environmental changes. A good knowledge of the species composition is important to be competent in the recognition of changes in the paleo-environment.

Diatom species could indicate substantial differences and the degree of endemism in different regions, since they are indicators of the discharge of rivers and coastal lagoons [4,5]. Furthermore, diatoms are also useful for historical water quality assessments, bio monitoring and climate change,. and additionally a checklist is important for the detection of non-native species, introduced by ballast water.

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