A study of Dinophysiales and Prorocentrales of Atlantic Ocean, Gulf of Guinea, Nigeria

***[1]Kadiri, M.O and [2]Ogbebor, J.U**

[1]Department of Plant Biology and Biotechnology, University of Benin, Benin City, Nigeria.

[2]Department of Environmental Management and Toxicology, University of Benin, Benin City, Nigeria.

**Corresponding author*

DOI: **https://doi.org/10.51584/IJRIAS.2023.8513**

Received: 08 May 2023; Revised: 20 May 2023; Accepted: 23 May 2023; Published: 20 June 2023

Abstract: This study examined the taxonomy, spatial and seasonal occurrences of the Orders Dinophysiales and Prorocentrales in the Atlantic Ocean, from the Bight of Benin to the Bight of Bonny in Gulf of Guinea Nigeria. Samples were collected from Oceanic stations in ten (10) locations drawn from the eight (8) coastal states of Nigeria. Six (6) species of Dinophysiales and 11 species of Prorocentrales were found. Whereas the Prorocentrales comprised exclusively of Prorocentrum species, Dinophysiales consisted of species of Dinophysis (2), Ornitocercus (2), Plalacroma (1) and Ceratocorys (1). The species exhibited differential spatial and temporal variations. Spatially, the distribution of Dinophysiales was generally relatively scanty, with most widely distributed being D. caudata, while D. rotundata and Amphisolenia schauinslandii were rare, while Prorocentrales had a wider distribution with Prorocentrum gracile and Prorocentrum micans as cosmopolitan species and Prorocentrum aporum, P. balticum, P.compressum P. obtusum, P. scutellum and P. rhathymum as restricted species. In terms of seasonal occurrence, D. caudata (Dinophysiales), P. gracile, P. triestinum and P. micans (Prorocentrales) were found at all seasons- dry-wet, wet, wet-dry and dry while D. rotundatum occurred only in the wet season. P. balticum and P. compressum, occurred only in the wet, dry-wet and dry season respectively. Species that were extremely sparse, both spatially and seasonally, were Phalacroma hastatum, Prorocentrum aporum, P. balticum, P. lima and P. compressum. Global distribution of the identified species is also presented. A total of 47.6% of the collection of species identified in this study are known to be toxic and harmful such as Dinophysis caudata, D. rotundata Prorocentrum micans, P. emaginatum, P. lima. P.redfieldii, P.reticulatum and P. rhathymum.

Keywords: Dinoflagellates, Atlantic Ocean, Gulf of Guinea, Phytoplankton, Harmful algae

I. Introduction

Dinophysales and Prorocentrales are both members of the Class Dinophyceae and division Dinophyta or dinoflagellates. *Prorocentrum* Ehrenberg is one of the most diverse and wide spread genus in marine tropical areas (Hernández-Becerril *et al*., 2000). These groups belong to algae causing harmful algal blooms. Harmful algal blooms (HABs) are increasing worldwide in occurrence, geographic expansion and persistence (Anderson *et al*., 2012, Berdalet *et al.* 2016, Heisler *et al* 2008), affecting ecology, economy, ecosystems and health.

Some of these Dinophysiales and Prorocentrales produce toxins which cause harm to human and animals. The major vectors for these toxins are shellfish (Costa 2016, Likumahua *et al.*, 2020). The shellfish consumption when contaminated elicit five different types of syndromes namely, Paralytic Shellfish Poisoning (PSP), Diarrhoetic Shellfish Poisoning (DSP), Neurotoxic Shellfish Poisoning (NSP), Amnesic Shellfish Poisoning (ASP), and Azaspiracid Shellfish Poisoning (AZP). Dinophysales and Prorocentrales produce PSP and DSP. In recent decades, Paralytic shellfish poisoning (PSP) has increased worldwide (Anderson, 2009). Harmful algae produce Paralytic Shellfish toxins (PSTs).

PSTs are divided into three groups namely, carbamoyls with high toxicity (saxitoxin (STX), neosaxitoxin (NEO) and gonyautoxins (GTX1-4)), decarbomoyls with intermediate toxicity (dcSTX, dcGTX and dcNEO); and N-sulfocarbamoyls with least toxicity (C1-4, B1 and B2) (Costa *et al*., 2010). Interconversions of the various toxins is possible both chemically and ezymatically (Falconer, 1993). The symptoms of PSP include weakness, ataxia and paresthesia, dizziness, weakness, drowsiness, incoherence and headache, nausea, vomiting, diarrhea (Hurley *et al*., 2014).

PSTs when ingested by humans and marine mammals culminates in voltage-gated sodium channels blockage, leading to symptoms such headache, nausea, vomiting, diarrhea, muscular paralysis and respiratory difficulty (Costa *et al*., 2010; James *et al*., 2010). DSP results from the proliferation of *Gymnodinium* spp. They produce diarrhetic shellfish toxins (DSTs) such as okadaic acid (OA) and dinophysistoxins (DTXs) as well as pectenotoxins (PTXs) as secondary metabolites, which accumulate in filter feeders, resulting in human poisoning and symptoms of nausea, vomiting, diarrhea, chills and abdominal pain (Li *et al*., 2014, Hu *et al*., 2017, Likumahua *et al.* , 2020)). DSP symptoms include nausea, vomiting, diarrhea, chills and abdominal pain (James *et al.*, 2010).

This study encompasses the seasonal occurrence, spatial distribution and taxonomy of the Orders Dinophysiales and Prorocentrales. There is no previous study on these Orders in the Atlantic Ocean of Nigeria, Gulf of Guinea. This location supports shellfish aquaculture, commercial fishing and tourism, all activities that are usually seriously affected by the presence of these organisms. Fringing records include Kadiri (2001) which has in the collection of marine phytoplankton, listed three species of *Protoperidinium* and Kadiri (2002) lists *Dinophysis caudata* from the Eastern Niger Delta.

The genus *Dinophysis* (Dinophysaceae) Ehrenberg is one harmful dinoflagellate of global significance (Ajani *et al*., 2016). Being cosmopolitan, this genus has over 100 species represented worldwide, several of which have been have been unambiguously found to be toxic, producing diarrhetic toxins (okadaic acid and dinophysistoxins) and pectenotoxins (Reguera *et al*., 2014) in many parts of the world (Taylor *et al.*, 2013; Whyte *et al.* 2014). Similarly, *Prorocentrum* Ehrenberg is one of the most diverse and wide spread genus in marine tropical areas (Hernández-Becerril *et al*., 2000). Thus these genera are the focus of many harmful algal monitoring programs throughout the world. In view of the ecological significance of these microalgae in causing mortality of humans and animals, it is imperative to document their occurrence and taxonomy. This will provide valuable insights to shellfish farmers, public health practitioners, phycologists, hydrobiologists and ecologists.

II. Materials and Methods

Study Area

The study area covered 8 coastal states with 10 regions located in south-south and south-west Nigeria which extends from Lagos State in south-west to Cross River State in south-south (Cross River, Akwa Ibom, Rivers, Bayelsa, Delta, Ondo, Ogun, Lagos – Lekki, Bar beach and Badagry (Fig. 1) along Nigerian coast. The sampling was done in the Atlantic Ocean and the adjoining water bodies.

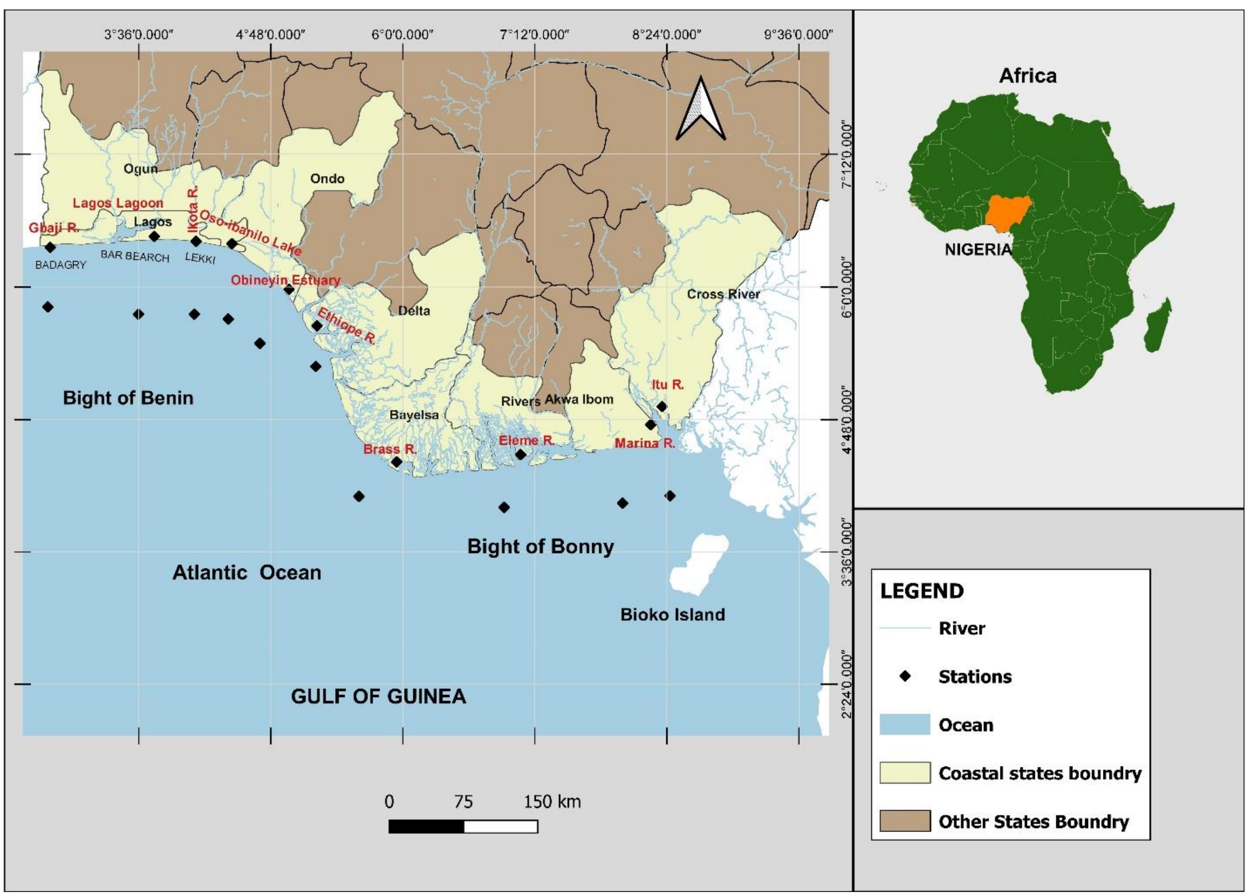


Figure 1: Map of study area: Coastal Area of Nigeria

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue V May 2023

Identification and Enumeration

Identification of algae was done through observation of their gross morphology and with the aid of appropriate text such as Tomas (1997), Botes (2001), Faust and Gulledge (2002); Faust *et al*., (1999). Hoppenrath *et al*. (2009), Al-Kandari *et al*. (2009) and Kraberg *et al*. (2000) and enumeration was done using the Lackey method (1938).

Global distribution of the species were obtained from GBIF (2023) Global Biodiversity Information Facility (GBIF) www.gbif.org and Guiry and Guiry (2023).

III. Results

The results of the study are organized under taxonomy, seasonality, spatial variation and global distribution.

Taxonomic Description of Species

Amphisolenia schauinslandii Lemmermann (Plate C, Fig. 5)

Cells long, thin, straight, not bifurcated, with four antapical spinules; fusiform (inflated in their middle part), slightly widening at the truncate posterior end, with no sub-terminal spine at elbow.

Dimension: 382 -400µm x 14-16 µm. Okolodkov (2014) recorded dimensions of 415-440 µm x 20-25 µm while Gul and Saifullah (2007) reported dimensions of 400.5-420 µm x 36-38 µm.

Spatial occurrence: Bar Beach, Ogun, Rivers

Seasonality: Dry, Dry-wet seasons

Global Distribution: North America: Mexico (Atlantic)

South America: (Brazil), Caribbean Sean

Asia: (China, Taiwan), Indian Ocean, Arabian sea (Pakistan)

Australia,

Africa (Mozambique)

Ornithocercus magnificus **Stein (Plate A, Figs. 6-8)**

Cells bodies are relatively small, sub-circular in lateral view, slightly asymmetrical in relation to the longitudinal axis, directed from the posterior dorsal end to anterior ventral end. The girdle list, with a convex and concave outline is very large with a spreading anterior skirt-like wing. The sulcal list is supported by radial ribs. The girdle list characterizes a convex and concave outline compared to other *Ornithocercus* species (Koffi *et al.* 2015).

Dimension: 96-107 x 55-68 µm

Koffi *et al.* (2015) reported length 88-100 µm x 40-47 µm

Spatial occurrence: Badagry

Seasonality: Dry season

Global Distribution

Atlantic Islands (Canary Islands, Madeira

Europe: Adriatic Sea, Croatia, Mediterranean, Portugal

North America: Mexico (Pacific

Central America: Gulf of California.

South America: Brazil, Colombia.

Indian Ocean Islands: Maldives.

Middle East: Kuwait, Turkey.

South-west Asia: Lebanon

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue V May 2023

Asia: China

Australia and New Zealand: Australia, New Zealand

***Ornithocercus quadratus* F.SChutt (Plate A, Fig. 9)**

Cells are large, sub-oval, slightly deeper than long, epitheca markedly displaced to the ventral side. Cingulum is dorsally excavated and distinctly wider than ventrally. Size: 45 x 37 µm (Koffi *et al.*, 2015). Wilke *et al.* 2018 reports 120-165.0 lm x 100-140 lm

Dimension: 90 x74 µm

Spatial occurrence: Bar Beach

Seasonality: Wet season

Global Distribution:

Atlantic Islands: Atlantic Ocean, Canary Islands, Madeira

Europe: Adriatic Sea, Mediterranean, Portugal

North America: Mexico (Pacific)

South America: Brazil, Colombia

Middle East: Iraq, Turkey

South-west Asia: Lebanon

Asia: China, Taiwan

Australia and New Zealand: Australia

Pacific Islands: Pacific Ocean

Africa: Egypt

***Dinophysis caudata* Saville-Kent (Plate A, Figs. 2,3)**

Cell large, long, widest at the base, irregularly sub-ovate or sub-urceolate, with a long extended anterior ventral process or projection on the hypotheca; a smooth, narrow ridge produced along the dorsal border of the inflated portion of the posterior segment, and two conspicuous fin-like angular ventral plates, with concave, operculum-like, and dilated anterior segment and shagreened posterior segment. *D. caudata* is similar to *D. diegenesis* but differs from it by the reduced hypotheca process of *D. diegenesis* (Faust and Gulledge 2002).

Dimensions: 100.5-112.5µm x 45-48µm. Faust and Gulledge (2002) report dimensions of 70-110 x 37-50 µm. *D. caudata* is very similar to *D. diegensis*, but differ in that the latter has a reduced hypothecal process (Faust and Gulledge 2002).

Spatial occurrence: Delta, BarBeach, Bayelsa

Seasonality: dry- wet, wet, wet-dry, and dry seasons

Global Distribution:

Atlantic Islands: Atlantic Ocean, Canary Islands, Madeira

Europe: Adriatic Sea, Mediterranean, Baltic Sea. Black Sea, Portugal, Britain, France, Romania, Scandinavia, Spain, Croatia,

North America: Mexico (Pacific)

North America: Baja California, Mexico (Atlantic), Mexico (Pacific)

Central America: Gulf of California

Caribbean Islands: Cuba

South America: Brazil, Colombia

Middle East: Iraq, Kuwait, Turkey

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue V May 2023

South-west Asia: Lebanon

Asia: China, Korea, Taiwan

Australia and New Zealand: Australia, New Zealand

Africa: Nigeria; Egypt

***Dinophysis rotundata* C. & L) Plate A Fig 1)**

Syn: *Phalacroma rotundatum* (Claparéde & Lachmann) Kofoid & J.R.Michener

Cell medium sized, broadly rounded in lateral view with convex ventral and dorsal margins, posterior region rounded, ventral plates with two transverse linear thickenings. This species is similar to *D. Rudgei (Phalacroma rudgei)*, but D. rudgei has a more prominent epitheca (Faust and Gulledge 2002)

Our spceis is slightly bigger than that recorded by Faust and Gulledge (2002) with dimensions of 36-56 x 36-46µm.

Dimension: 45-48 µm x 42-46.5µm

Spatial occurrence: Bar Beach

Seasonality: Wet season

Global Distribution:

Atlantic Islands: Canary Islands

Europe: Baltic Sea, Britain, Croatia, France, Germany, Greece, Helgoland, Mediterranean, Netherlands, Norway, Scandinavia

North America: Mexico (Pacific)

South America: Brazil

Middle East: Kuwait

South-west Asia: Lebanon

Asia: China, Korea, Russia (Far East)

***Phalacroma hastatum* Pavillard (Plate A, Figs. 4,5)**

Synonym: *Dinophysis hastata* F.Stein, 1883

Cells are irregularly ovoid or sometimes regularly ovoid, with a sub-truncate anterior end and broadly or narrowly rounded posterior end, terminated with a strong triangular antapical spine directed posteriorly-ventrally or in rare cases backward, often supported by a thick central rib; very short flat or slightly convex epitheca; slightly asymmetrical and more narrowly rounded hypotheca, slightly convex cingulum.

Dimensions: 60-62µm x 43-46µm

Spatial occurrence: Bar Beach

Seasonality: Dry season

Global Distribution:

Asia: Taiwan
Atlantic Islands: Canary Islands, Madeira

Europe: Adriatic Sea, Baltic Sea, Black Sea, Britain, Croatia, Mediterranean, Portugal, Romania, Scandinavia

North America: Mexico (Atlantic), Mexico (Pacific)

South America: Brazil, Colombia

Indian Ocean Islands: Maldives

Middle East: Iraq, Turkey

South-west Asia: Lebanon

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue V May 2023

Asia: China, Taiwan

Australia and New Zealand: Australia

Genus: *Prorocentrum* Ehrenberg

Cell ovate in plate view with slight notch at anterior end, Thecal plates without obvious pores or any ornamentation.

***Prorocentrum aporum* (Schiller) Dodge (Plate C, Figs. 2, 3)**

Cell broadly ovate, strongly constricted laterally, thick and symmetrical thecal plates, without pores.

Dimension: 30-32µm x 26-27µm

Spatial occurrence: Ogun

Seasonality: Dry Season

Global Distribution:

Atlantic Islands: Canary Islands

Europe: Mediterranean, Adriatic Sea, Black Sea, Netherlands, Scandinavia

Caribbean Islands: Caribbean

Middle East: Turkey

***Prorocentrum balticum* (Lohmann) Loeblich (Plate B, Figs. 1)**

Cell small, round to ovoid in valve view, with very minute two apical projections, presence of rimmed pores on the cell surface. Both *P. minimum* and *P. balticum* are small species but *P. balticum* can be distinguished from *P. minimum* by its small size, its almost spherical shape and its two apical projections (Faust and Gulledge, 2002).

Although this species is always confused with *P. minimum, P. balticum* is smaller than *P. minimum* and of different shape (Steidinger and Tangen (1997).

Dimension: 45-48 µm x 42-46.5µm Dodge and Bibby (1973) recorded dimensions of Length =9-10 µm, width =7-20 µm.

Spatial occurrence: Lekki

Seasonality: Wet season

Global Distribution:

Australia and New Zealand: New Zealand

Atlantic Islands: Canary Islands

Europe: Georgia, Latvia, Adriatic Sea, Baltic Sea, Black Sea, Britain, France, Helgoland, Mediterranean, Netherlands, Portugal, Romania, Scandinavia,

North America: Mexico (Pacific)

South America: Brazil

Middle East: Kuwait, Turkey

South-west Asia: Lebanon

Asia: China, Korea, Russia (Far East)

Australia and New Zealand: New Zealand

Antarctic and Antarctic islands: Antarctica/Sub-antarctic Islands

Africa: Egypt

***Prorocentrum compressum* (Baily) Abé ex Dodge (Plate B, Fig.4)**

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue V May 2023

Cell broadly ovate; or elliptical, widest in the middle, surface of plates covered with rows of poroids; thecal plates not spiny; posterior end of cell rounded, anterior end partly depressed but with one or more small spines; small anterior spine(s) present.

Dimensions: 32.5-36µm x 27- 30µm. Gul and Saifullah (2011) recorded dimensions of Length=35-50µm Width: 20-30 µm

Spatial occurrence: Ogun

Seasonality: Dry-wet season

Global Distribution:

Arctic: Svalbard (Spitsbergen)

Atlantic Islands: Canary Islands, Madeira

Europe: Adriatic Sea, Baltic Sea, Black Sea, Britain, Croatia, Mediterranean, Netherlands, Portugal, Romania, Scandinavia.

North America: Mexico (Atlantic), Mexico (Pacific)

South America: Brazil, Colombia.

Middle East: Kuwait, Turkey

South-west Asia: Lebanon

Asia: Taiwan

Australia and New Zealand: Australia, New Zealand.

Antarctic and Antarctic islands: Antarctica/Sub-antarctic Islands

Africa: Egypt

Prorocentrum emarginatum **Y.Fukuyo (Plate C, Fig.1)**

Cells round to oval, asymmetrical slightly, dorsoventrally flattened, smooth thecal surface, deep depression at the anterior end with deep excavation into a V- shaped periflagellar area

Dimension: 37µm x 27µm. Lee and Kim (2009) reported dimensions of L= 33.7–40.9 µm and W= 28.9–38.7 µm

Spatial occurrence: Bar beach

Seasonality: Dry-wet

Global Distribution:

Europe: Mediterranean, Spain

North America: Mexico (Atlantic), Mexico (Pacific

Central America: Belize

South America: Brazil

Indian Ocean Islands: Réunion

Middle East: Saudi Arabia

South-east Asia: Malaysia

Asia: Russia (Far East)

Australia and New Zealand: New Zealand

Pacific Islands: Fiji, French Polynesia, New Caledonia, Ryukyu Islands

Prorocentrum gracile **Schutt (Plate C, Fig. 4)**

Cell slender or elongate, lanceolate with pointed posterior end, rounded anterior end; anterior spine long, sharp, narrow plate in plate view and broad lanceolate in side view.

Spatial occurrence: Cross River, Bayelsa, Ondo, Ogun, Lekki, BarBeach, Badagry

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue V May 2023

Seasonality: Dry-wet, Dry, Wet-dry season, wet season

Dimensions: 84µm x 15µm, 90µm x 24µm (with spine) 75µm x 24µm (without spine). In the pacific coast of Mexico, Cohen-Fernandez *et al.,* (2006) recorded for this species, length of 40-60 µm, width of 23-25 µm and spine length of 8-11 µm, while Dodge and Bibby (1973) reported a length of 40-60 µm and Gul and Saifullah (2011)recorded dimensions of Length: 45-60µm Width: 20-30 µm. This species is similar to *P. micans* but distinguishable by their general shape, a much longer anterior spine and twice as long as broad of *P. gracile*.

Prorocentrum sigmoides is considered to be synonymous with *P. gracile* (Cohen-Fernandez *et al*., (2006)cf Gul and Saifullah (2011). Both species are similar except that *P. gracile* is concavely depressed along one seam margin and in having an apical depression with regular and trichocyst pores (Gul and Saifullah (2011) and possession of a mucron – a small tooth on the antapical part of the cell (Cohen-Fernandez *et al.*,2006).

Global distribution:

Arctic: Svalbard (Spitsbergen)

Atlantic Islands: Canary Islands

Europe: Black Sea, Britain, France, France (Breizh), Mediterranean, Portugal

North America: Baja California, Mexico (Atlantic), Mexico (Pacific), Nova Scotia

Central America: Gulf of California

Caribbean Islands: Cuba

South America: Brazil, Colombia

Middle East: Kuwait, Saudi Arabia, Turkey

South-west Asia: Lebanon

Asia: China

Australia and New Zealand: Australia, New Zealand

Africa: Egypt

Prorocentrum lima **(Ehrenberg) F.Stein (Plate C, Fig. 5)**

Cell medium sized, ovate to oblong/ ellipsoid shape, small to medium size, symmetrical and dorsoventrally flattened. Widest at the mid-region narrow towards anterior end with triangular concavity; smooth thecal plates, cell surface covered with pores; wide V-shaped perflagellar area

Dimensions: 33-50µm x 21-30µm. Luo *et al.* (2018) recorded dimensions of L=37.6–45.3 µm and W=26.4–30.5 µm in northern South China Sea, while Hoppenrath *et al.* (2013) recorded dimensions of 30-57 x 21-46 µm in their review report, while Faust and Gulledge (2002) recorded 32-50 x 20-28 µm as dimensions.

Spatial occurrence: Ogun

Seasonality: Dry-wet season

Global distribution:

Arctic: Svalbard (Spitsbergen)

Atlantic Islands: Bermuda, Canary Islands, Madeira

Europe: Adriatic Sea, Baltic Sea, Black Sea, Britain, France, Germany, Italy, Mediterranean, Netherlands, Portugal, Scandinavia, Spain, Helgoland, Romania

North America: Florida, Maine, Mexico (Atlantic), Mexico (Pacific), Nova Scotia

Central America: Belize, Costa Rica.

South America: Brazil, Colombia.

Indian Ocean Islands: Maldives, Comoros and Mayotte

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue V May 2023

Middle East: Kuwait, Saudi Arabia, Turkey.

South-west Asia: Lebanon.

South-east Asia: Indonesia, Malaysia, Philippines.

Asia: China, Japan, Korea, South China Sea.

Australia and New Zealand: Australia, New Zealand, New South Wales

Pacific Islands: Galápagos Islands, Tahiti

Africa: Egypt

.***Prorocentrum micans*** **Ehrenberg (Plate B, Fig. 5)**

Cell medium to large, elliptical, tear-drop to heart shaped, lanceolate or widest at mid-section, pointed at posterior end and rounded and concave at anterior end. Presence of a well-developed winged apical spine (6-7.5 µm), smooth thecal plates. *P. micans and P. gracile* differ from each other on the basis of body size and pattern of pores which is slightly different. Secondly, *P.* gracile is more elongated than *P. micans and P.micans is broader than P. gracile (*Gul and Saifullah 2011).

Dimensions: 40.5-46.5µm x 24µm (with spine) 39µm x 24µm (without spine);Cohen-Fernandez *et al*., (2006) recorded length of 15-80 µm, width of 15-50 µm and spine length of 7-12 µm in Mexican pacific coast, while Faust and Gulledge (2002) reported 35-70 x 20-50µm and Lee and Kim (2017) reported cell size ranges from small to medium (15- 100 µm), while Gul and Saifullah 2011 recorded dimensions Length: 35-70 µm Width: 22-35 µm Length of spine: 8-12 µm.

Spatial occurrence: Cross River, Akwa Ibom, Rivers, Bayelsa, Delta, Ondo, Ogun, Bar Beach, Badagry

Seasonality: (Dry-wet, wet, wet-dry and dry season)

Global distribution:

Arctic: Svalbard (Spitsbergen)

Atlantic Islands: Canary Islands

Europe: Adriatic Sea, Baltic Sea, Black Sea, Britain, Croatia, France, France (Breizh), Germany, Greece, Helgoland, Ireland, Mediterranean, Netherlands, Norway, Portugal, Romania, Scandinavia, Spain.

North America: Baja California, Mexico (Atlantic), Mexico (Pacific), Nova Scotia, Rhode Island, Virginia

Central America: Gulf of California

Caribbean Islands: Cuba.

South America: Argentina, Brazil, Colombia.

Indian Ocean Islands: Maldives

Middle East:, Iraq, Kuwait, Saudi Arabia, Turkey).

South-west Asia: Lebanon.

Asia: Caspian Sea, China, Korea, Russia (Far East), Taiwan.

Australia and New Zealand: Australia, New Zealand, South Australia

Africa: Morocco, Egypt.

Prorocentrum redfieldii **Bursa (Plate B, Fig. 3)**

Cell Small to medium-sized, globular, lanceolate or sigmoid in shape, bilateral thecate flagellates.

Dimensions: 19.5-21 µm x 9-12 µm

Spatial occurrence: BarBeach, Ogun

Seasonality: Wet, Dry-wet seasons

Global distribution:

Europe: Helgoland, Scandinavia

Asia: Taiwan

Prorocentrum rhathymum **A.R.Loeblich III, Sherley & Schmidt (Plate B, Fig. 6)**

Cell oval to oblong in shape, asymmetric, with rounded margins, circular in outline with thick theca/ thecal plates foveate, periflagellar area wide, shallow and V-shaped; thecal surface smooth, apical apical excavation of the right valve with a characteristic simple apical spine

P. rhathymum was erroneously considered as a synonym of P. *mexicanum* for a long time (Faust, 1990), but differs on the basis of habitat, pore arrangement and number of horned spines. Whereas pores are arranged in organized pattern in the *P. mexicanum*, they are disorganized in *P. rhathymum* (Aligizaki *et al*., 2009). Additionally, *P.rhathymum* species has 2 to 3 horned spines whereas *P. mexicanum* has only one simple spine (Gul and Saifullah 2011). Also *P. mexicanum* is a planktonic, lenticular in lateral view, species which has a centrally located pyrenoid, an areolated valve surface and a large, winged and two or three-pointed apical spine, while *P. rhathymum* is a benthic/epiphytic species with smooth valve surface bearing trichocysts pores and a simple apical spine and no pyrenoid (Corte´ s-Altamirano and SierraBeltra´n, 2003 cf Aligizaki *et al*. 2011).

Dimensions: 27-28µm x 21- 23µm. Gul and Saifullah (2011) reported dimensions of Length= 30-40 µm Width= 18-24 µm

Reports measurements of L= 31.0–33.5 µm, W=23.6– 26.9 µm, while Aligaziki *et al.* (2009) recorded L= 27.4 - 33.3 mm and W= 19.0–22.6 mm.

Seasonality: Dry, Wet, Dry-Wet

Spatial occurrence: Badagry, Lekki, Ogun

Global distribution

North America: Florida, Mexico (Atlantic), Mexico (Pacific)

Central America: Gulf of California

Caribbean Islands: Virgin Islands

South America: Brazil

Europe: Spain

Indian Ocean Islands: Maldives

Middle East: Kuwait

Asia: Korea

Australia and New Zealand: Australia, New Zealand

Prorocentrum scutellum **B. Schroder (Plate B, Fig. 7)**

Cell broadly heart-shaped, with prominent anterior spine or projection, anterior projection a median spine and broad wing; posterior end of cell pointed.

Dimension: 30 µm x 27 µm

Spatial occurrence: BarBeach

Seasonality: Wet-dry season

Global distribution:

Atlantic Islands: Canary Islands

Europe: Adriatic Sea, Baltic Sea, Black Sea, Britain, Croatia, France, Mediterranean, Netherlands, Portugal, Romania, Scandinavia, Spain

North America: Mexico (Atlantic), Mexico (Pacific), Nova Scotia, Baja California Virginia (VA) South America: Brazil

Indian Ocean Islands: Maldives

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue V May 2023

Middle East: Saudi Arabia, Turkey

Asia: Caspian Sea

Australia and New Zealand: Australia

***Prorocentrum triestinum* J. Schiller (Plate B, Fig. 2)**

Cell with distinct small anterior spine, posterior end of cell pointed or acute, Thecal plates not spiny, thecal plates delicate and not spiny. This species is somewhat similar to *P. rotundata* but differ from it in that *P. triestinum* is narrower and has a pointed posterior end

Dimensions: 33-37.5 µm x15-18 µm

Spatial occurrence: Ogun, Lekki, BarBeach, Badagry

Seasonality: Wet, Wet-dry, Dry seasons

Global distribution:

Arctic: Svalbard (Spitsbergen)

Atlantic Islands: Canary Islands

Europe: Adriatic Sea, Black Sea, Britain, Croatia, Italy, Mediterranean, Netherlands, Portugal, Scandinavia

North America: California, Mexico (Pacific)

South America: Brazil, Colombia

Africa: South Africa

Middle East: Kuwait, Turkey

Asia: China, Korea, Russia (Far East), Taiwan

Australia and New Zealand: Australia, New Zealand

***Ceratocorys horrida* Stein (Plate C, Figs 7,8)**

Cell medium sized, angular to round in shape, with 6-8 winged spines of varying lengths, emanating posteriorly from antapical plates and ventrally or dorsally from postcingular plates. Some of the spines are as long as the width of the main body.

Dimension: L- 68µm; W- 83 µm (width plus furthest opposing projections);W- 54 µm (width excluding projections)

Spatial Occurrence: Bayelsa

Seasonality: Wet-Dry season

Global Distribution

Mediterranean
Atlantic Islands: Canary Islands, Madeira

E*urope:* Adriatic Sea, Portugal

N. America: Mexico (Caribbean), Mexico (Pacific)

Western Atlantic: Brazil-Malvinas Confluence

S. America: Brazil, Colombia

Indian Ocean Islands: Maldives

Middle East: Egypt, Saudi Arabia, Turkey

South-west Asia: India, Lebanon

Asia: China, Taiwan

Australia and New Zealand: Australia

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue V May 2023

World: World

Seasonal Occurrence of Dinophysiales and Prorocentrales in Atlantic Ocean, Nigeria

For Dinophysiales, *D. caudata* was found at all seasons- dry-wet, wet, wet-dry and dry while *D. rotundatum* occurred only in the wet season. For Prorocentrales, *P. gracile,* P. *triestinum* and *P. micans* occurred at all seasons. *P. balticum* occurred in the wet season only, while *P. compressum* occurred in the dry-wet period only.

Spatial Occurrence of Dinophysiales and Prorocentrales in Atlantic Ocean, Nigeria

The distribution of Dinophysiales was generally very scanty. The most widely distributed was *D. caudata*, reported in BarBeach, Delta and Bayelsa *D. rotundata* and *Amphisolenia schauinslandii* were both restricted to BarBeach.

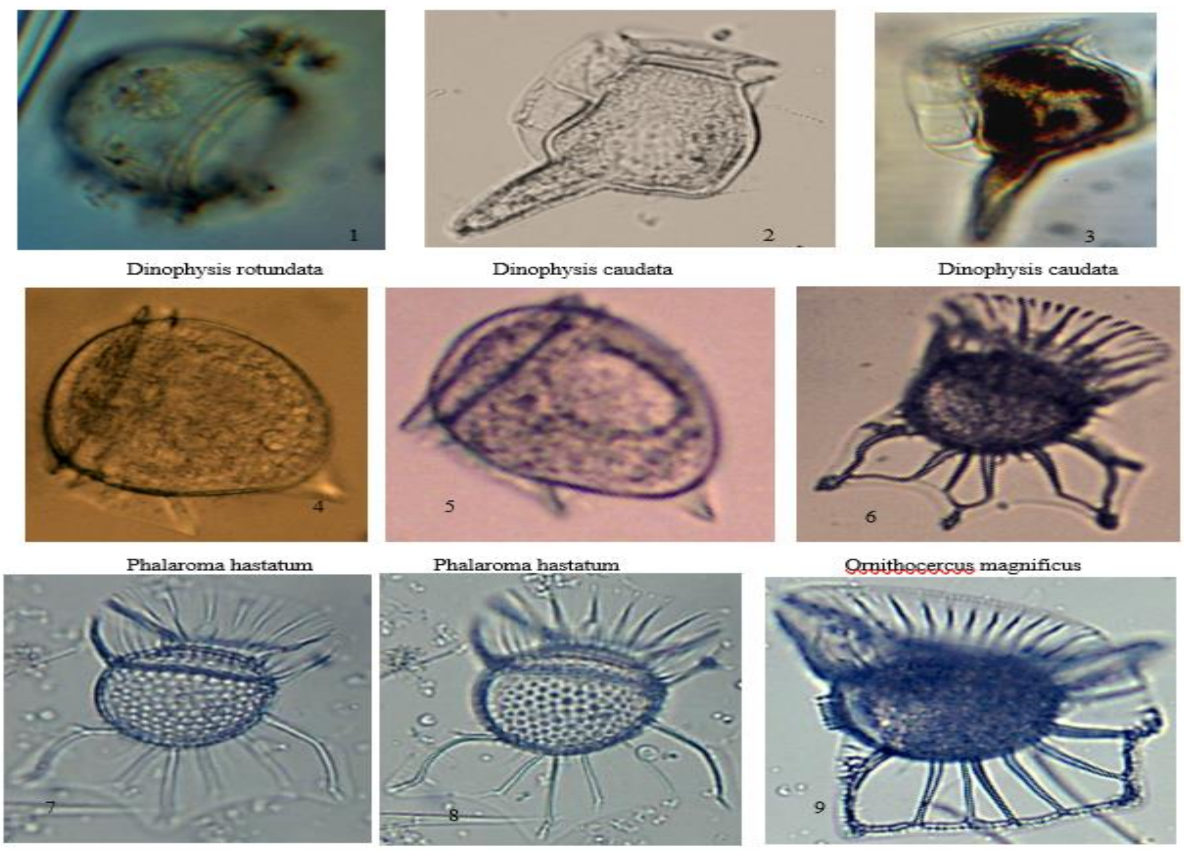
For Prorocentrales, distribution was wider. Species such as *Prorocentrum gracile* and *Prorocentrum micans* were cosmopolitan, occurring at all locations. *P. triestinum* was found in four out of the ten locations. Other species of *Prorocentrum* were less frequent, and restricted to one or two locations

Global Distribution of Species

Generally, the global distribution of the species studied shows that, of the Dinophysiales found, the least distributed was *Amphisolenia schauinslandii*, while *D. caudata* was the most widely distributed. *Ceratocorys horrida* had an impressive global distribution record as well. Within the Prorocentrales, the most widely distributed globally was *Prorocentrum micans,* followed by *P. triestum,* then *P. lima, P. gracile* etc, while *P. obtusum* and *P. redfieldii* had minimal occurrences, with the latter being the least.

It is also very remarkable that records from African region is extremely poor or totally non-existent. The few African records are *Amphisolenia schauinslandii* (Mozambique), *Ornithocercus quadratus* (Egypt), *Prorocentrum triestinum* (South Africa), *P. micans* (Morocco), *P. micans* (Egypt and Morocco). *P. balticum, P. gracile, P. lima, P. compressum* and *P. caudata* were all reported in Egypt.

PLATE A



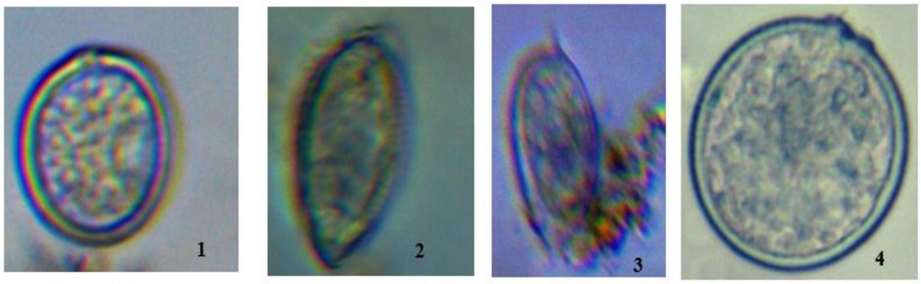
Dinophysis rotundata | Dinophysis caudata | Dinophysis caudata

Phalaroma hastatum | Phalaroma hastatum | Ornithocercus magnificus

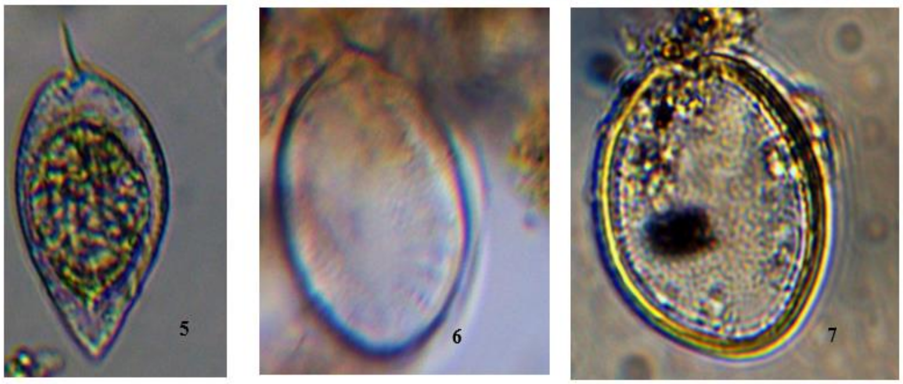
Ornithocercus magnificus | Ornithocercus magnificus | Orninthocercus quadratus

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue V May 2023

PLATE B

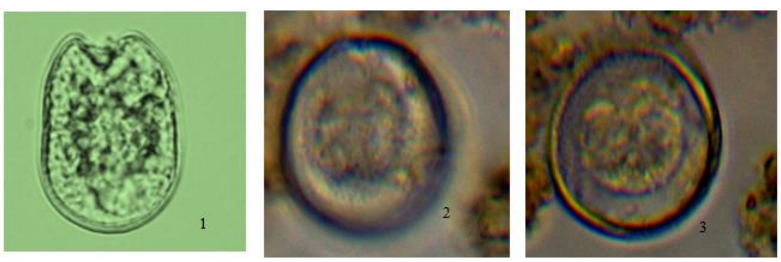


Prorocentrum balticum Prorocentrum triestinum Prorocentrum redfeldii Prorocentrum compressum

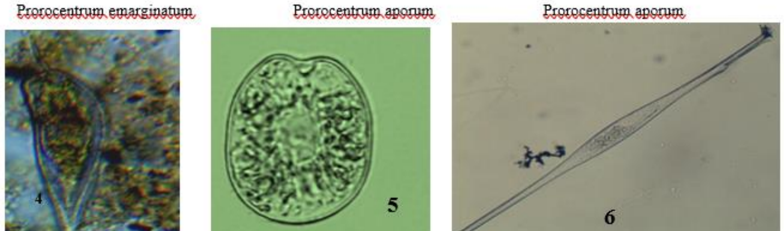


Prorocentrum micans Prorocentrum rhathymum Prorocentrum scutellum

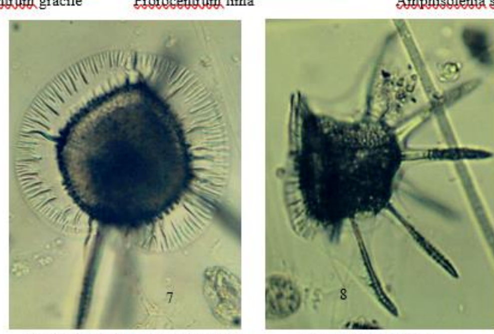
PLATE C



Prorocentrum emarginatum Prorocentrum aporum Prorocentrum aporum



Prorocentrum gracile Prorocentrum lima Amphisolenia schauinslandii



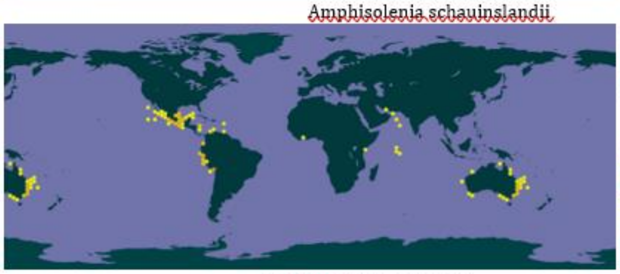
Ceratocorys horrida (apical view) Ceratocorys horrida

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue V May 2023

Global Map distribution of Dinophysales and Prorocentrales

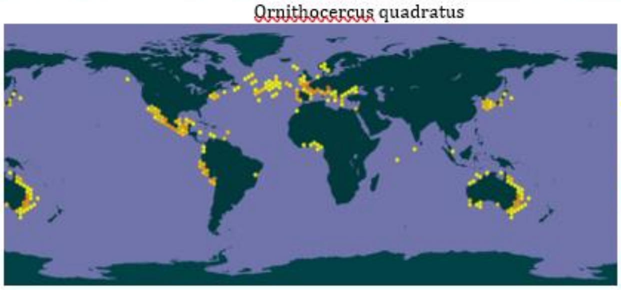
Amphisolenia schauinslandii

Ceratocorys horrida

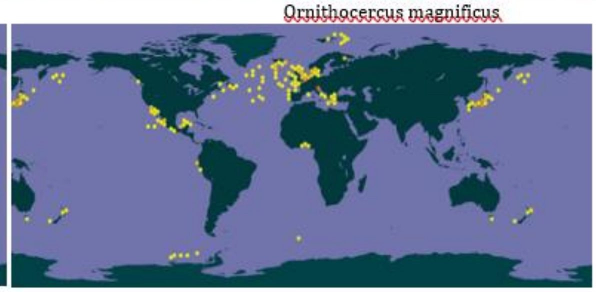


Ornithocercus quadratus

Ornithocercus magnificus



Dinophysis caudata



Dinophysis rotundata

Prorocentrum aporum

Prorocentrum balticum

Prorocentrum compressum

P.obtusum

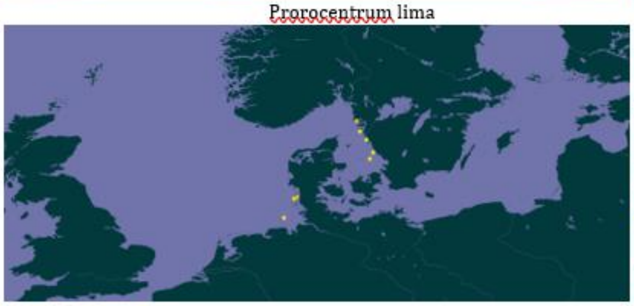
Prorocentrum emarginatum

Prorocentrum gracile

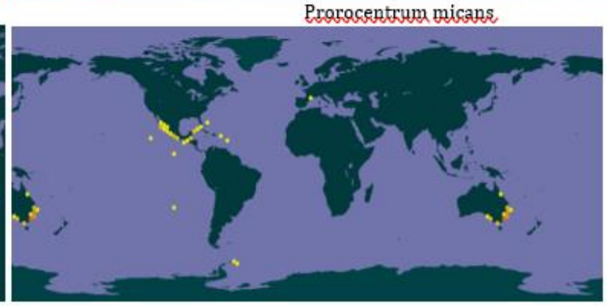
ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS | Volume VIII Issue V May 2023

Prorocentrum lima

Prorocentrum micans



Prorocentrum redfieldii



Prorocentrum rhathymum

Prorocentrum scutellum

Prorocentrum triestinum

IV. Discussion

The diversity of Dinophysiales and Prorocentrales in the Nigeria coastal waters is remarkable.

Gul and Saifullah (2011), who also observed high species diversity of especially *Prorocentrum* in Arabian Sea, ascribing such high diversity to heterogeneity in environment, caused by intrusion of sea water into adjacent waterbodies and vice versa. Other authors implicate high temperature and salinity regimes, both factors which favour the growth of dinoflagellates (Dodge & Marshall, 1994 cf Gul and Saifullah (2011), describing most species except *Prorocentrum gracile,* as eurythermal (wide temperature range) and stenohaline (narrow salinity range). Gomez *et al.* (2008) indicated that species of *Prorocentrum* were encountered in the more eutrophic conditions. Koffi *et al.* (2015), though unusually and surprisingly found some species such as *O. quadratus, O magnificus* in a lagoon in Cote d'Voire, they confirmed that their presence was due to seawater incursion in the dry season.

Amongst the collection of *Dinophysis* of Morton *et al.* (2009), it was observed that *D. caudata* and *D. rotundata,* along with *D. acuminata, D. acuta, D. hastata, D. fortii, D. norvegica, D. tripos* and *D. sacculus* were most common at the Caucasian Coast and *D. caudata* and *D. rotundata* were the most common *Dinophysis* species in the Black Sea. Ajani *et al.* (2016) reported *Dinophysis acuminata, Dinophysis caudata, Dinophysis fortii and Dinophysis tripos*- with *D. acuminat*a and *D. caudata* being most abundant in South-eastern Australia. Highest abundance of *D. acuminata* occurred in the austral spring, whilst highest *D. caudata* occurred in the summer to autumn noting that *D. acuminata* was significantly linked to season, thermal stratification and nutrients, whilst *D. caudata* was associated with nutrients, salinity and dissolved oxygen.

D. caudata has been noted as prevalent in tropical waters, where it probably represents the most abundant species of the genus of all *Dinophysis* spp, and in warm-temperate seas, it is a late season (summer-autumn) species that follows preceding blooms of *D acuminata* and/or D. *sacculus* (Reguera *et al.,* 2014)]. *D. caudata* amongst other dinoflagellates have been described as dominant frequent and subdominant in Malaysian marine and estuarine tropical waters (Naqqiuddin *et al*., 2013; Saifullah *et al*. 2019).

Kudella *et al.* (2010) reported *Dinophysis acuta*, *Dinophysis acuminata*, *Dinophysis caudata*, *Dinophysis fortii*, *Dinophysis sacculus* and *Dinophysis tripos* and species of *Phalacroma rotundatum* (which has been until recently been included in the genus *Dinophysis*) as the most frequently occurring dinoflagellates in Adriatic Sea.

Prorocentrum species, seem to be cosmopolitan (Aligizaki *et al*, 2011). *P. micans* and *P. gracile* were cosmopolitan in the present study, but Bosak *et al.* (2012) reported *P. gracile, P. micans* and *P, rotundata* in Mediterranean bay and a bloom of *P.micans* and *P.gracile* in the summer. *P. micans* according to Carstensen *et al.* (2007) is a very common species in enclosed and semi-enclosed basins or estuarine waters, which may at times be heavily eutrophic, and where it often forms intensive blooms.

Prorocentrum micans has been reported as highly abundant in warm and nutrient-rich waters, such as that of Guanabara Bay (GB) (Barrera-Alba *et al.* 2019). *Prorocentrum micans* was also reported as a producer of putative palytoxin and ovatoxin-a (Ignatiades & Gotsis-Skretas 2010).

P. gracile, *P. compressum,* and *P. micans* have been earlier described as cosmopolitan (Steidinger & Tangen, 1997cf Gul and Safullah, 2011). Gul and Saifullah (2011) found *P. compressum, P. gracile, P. rhathymum* and *P. micans* from the North Arabian Sea shelf of Pakistan, noting that *P. micans* was the only bloom forming species found and *P. compressum* was more common than other species. This latter assertion is however contrary to the situation in Atlantic Ocean, Nigeria, where *P. compressum* was recorded as a very rare species, occurring only in Ogun State.

P. lima was initially described (Ehrenberg, 1860) from the Mediterranean Sea (Gulf of Sorrento, Italy) and has also been recorded in various areas of the world. *P. rhathymum* is a benthic species and occurs preferably in the tropical waters (Licea *et al.*, 2004). Very recently, it was found that this species holds promise as a marine bioresource for antibiotics generally, in particular agents against Vibrio parahaemolyticus (Mussai *et al.*, 2023)

Munir *et al.* (2016) recorded, in Pakistani coastal waters, toxic species of *D. caudata, D. rotundata ,Prorocentrum lima, Prorocentrum emarginatum,* among others and non-toxic species of *P. gracile, P. micans*, *P.compressum* and ichyotoxic species of *Prorocentrum donghaiense*, *P. balticum*, *P. minimum* amongst others, noting that *D. caudata, P. minimum, P. balticum, Prorocentrum donghaiense* were dominant in the dinoflagellate assemblage while *D. rotundata* was rare. This report of *D. rotundata* as rare, is contrary to the observations of the present study where *D. rotundata* occurred in three out of the ten locations and in two seasons.

The two groups of dinoflagellates in this study- Dinophysiales and Prorocentrales have either been earlier reported as co-occurring or successional. The co-occurrence of *Dinophysis* and *Prorocentrum* blooms were previously observed and reported by several studies (Reguera *et al*. 2012, Hattenrath-Lehmann *et al*. 2015), or successional (as the occurrence of a bloom of *Prorocentrum* after *Dinophysis* events in US Gulf of Mexico (Campbell *et al*. (2010), Barrera-Alba *et al*. (2019), Northwestern Mediterranean (Jamet *et al*. 2005).

The scanty spatial occurrence of *P. lima* and in dry-wet season is at variance with its observed all- year round occurrence, with maximum epiphytic abundances at the end of autumn, coinciding with the presence and blooms of *Ostreopsis* spp. in Greek waters, indicating a succession pattern between the toxic dinoflagellates *Ostreopsis* spp and *P.lima* (Aligizaki *et al*. 2011).

There was differential distribution of Dinophysiales and Prorocentrales in different regions within the Atlantic Ocean. The disparity in differential species reported in the various areas in this study can only corroborates the notion of Theriot & Fryxell (1985) that scale in both space and time affects apparent species groupings. The rarity of some of the species found (eg *P. aporum, P. compressum*, *P.scutellum, etc*) can only be explained by observation of Vanormelingen *et al.* (2008) that restricted distribution and differences in species composition between regions are as a consequence of restricted dispersal.

In Nigeria, Kadiri (2011) earlier reported *D. caudata* and *P. micans* in the Atlantic Ocean, while Opute, (1991) recorded *D. caudata, Ornithocercus quadratus, O. steinii* (Dinophysiales) and the Prorocentrales *Exuviella compressa* in Warri Forcados Estuary of Southern Nigeria.

Gomez (2005) listed all the species found in this study among the species in the world oceans comprising 57 species of *Prorocentrum* and 105 species of *Dinophysis.* The observation of similarity of the species in this study and other world oceans is ascribable to the massive movements (eg via ballast water, oceanic current etc) of species between the different oceans of the world (Bailey 2015) and attest to the global distribution nature of species.

Amongst the species reported in this study, 6 are included in e IOC-UNESCO reference list of harmful microalgae. Of the 12 *Dinophysiales* species in the list are *D. caudata, P. rotundatata* (Zingone *et al.*, 2020), and the Prorocentrales are three out of 11, and these are *P. emaginatum, P. lima* and *P. rhathymum* (Hoppenrath, 2020). Although some species listed in this report were not included in IOC-UNESCO toxic list, they can still be considered harmful, as potential toxin producers, as well as other effects such as anoxia, ecosystem alteration, trophic transfer function, water quality deterioration with concomitant increased water treatment costs, food-web alteration, tourism disruption etc when they form blooms.

The composition of the Dinophysiales and Prorocentrales reported in this study, from Nigerian coast, contain harmful and potentially toxic algae communities. Some of the species present with well-expressed toxic potential include *Dinophysis caudata, D. rotundata, Prorocentrum recticulatum* (Reguera *et al*., 2014; Dana *et al*, 2019). Several species of the genus *Dinophysis* produce lipophilic toxins (okadaic acid, its congeners and pectenotoxins).They cause Dierrhetic Shellfish Poisoninig (DSP). *Phalacroma rotundata* is an example of neurotoxic species, producing OA/PTX Lassus *et al.* (2016)

The occurrence of *Dinophysis* spp., has been linked to the accumulation of OA group toxins and DSP in Asia (Mak *et al*., 2005), North America –[Canada(Subba Rao *et al*.,1993); US- Campbell *et a*l., 2010, Fux *et al*, 2011), South America (Garcia *et al*., 2004, Fux *et al*, 2011), Australasia (Madigan *et al.*, 2006), North of Europe (Fux *et al*., 2009) and South of Europe (Mouratidou *et al.*, 2006).

Evidence of Okadaic Acid (OA) and Pectenotoxin (PTX2) attributable to the presence of *Dinophysis* is available in Nigerian coastal waters (Zendong *et al*., 2016). Okadaic acid (OA) and PTX have been reported in *Phalacroma rotundata*. *P. lima* also produces OA while *P. reticulatum* produces yessotoxin (YTX). DTX1 has been reported from *P. lima* (Pan *et al*., 1999). It has been shown that even toxins from *P. lima* can accumulate to significant levels in shellfish locally (Lawrence *et al*., 2000), and hence constitute a public health risk.

Some species produce harmful toxic substances such as *P. lima* and related species have ciguatera and okadaic acid, some populations of *P. minimum* also cause shellfish poisoning (Lee and Kim, 2017). Ajani *et al.* (2013) in a synthesis of harmful phytoplankton species in oyster growing estuaries of 77 New South Wales, Australia, identified *Dinophysis* as one of three potentially high-risk genera for biotoxin events 78 (others being *Alexandrium* and *Pseudo-nitzschia*).

Among the species reported in this study, *Dinophysis caudata* is considered as Diarrhetic Shellfish Poisoning Species (DSP). The production of Diarrhetic Shellfish Toxins (DSTs) has been confirmed in several *Dinophysis* species, including *D. fortii*, *D. acuminata*, *D. acuta*, *D. norvegica*, *D. mitra*, *D. rotundata*, *D. sacculus*, *D. caudata* and *D. tripos*, and in the benthic dinoflagellates *Prorocentrum lima*, *P. concavum* (or *P. maculosum*), *P. micans*, *P. minimum* and *P. redfieldii* (Viviani, 1992). Reguera *et al*. (2014) confirms ten species of Dinophysis—*D. acuminata, D. acuta, D. caudata, D. fortii, D. infundibula, D. miles, D. norvegica, D. ovum, D. sacculus, D. tripos*—and two species of *Phalacroma—P. mitra, P. rotundatum*—have been found to contain DsT. Diarrheic shellfish toxins (DST) and pectenotoxins (PTXs) have to date been found unambiguously in 12 species of *Dinophysis* Ehrenberg. Of these, 7 species (*D. acuminata*, *D. acuta*, D. *caudata*, *D. fortii*, *D. miles*, *D. ovum*, *D. sacculus*) have been associated with DSP events or outbreaks in the world (Reguera et al, 2014).

Blooms of *D. caudata* and its associated toxins (DTs) have been variously reported globally. In Western Europe, serious outbreak of DSP were by *Prorocentrum micans, Dinophysis acuminata* (claiming 5000 victims) in Rias Atlas, Spain, *D. acuminata* (intoxicating 3300 people) in Brittany and Normandy, France and Dutch and *D. acuta* in Skagerrak, Southern Sweden and Norway (Reguera *et al.*, 2014).

D. caudata combined with *D. acuminata* in Uruguay and Argentina (Reguera *et al.*, 2014). *D. caudata* in Uruguay (Mendez *et al.*, 2002) as well as Argentina (Sar *et al.*, 2010) caused DSP oubreaks. DSP shellfish toxicity has been related to elevated abundance of *D. caudata.*

As observed from this study, despite the fact that the proportion of *Dinophysis* spp was small relative to other microplankton or dinoflagellate community, *Dinophysis* produce potent lipophilic shellfish toxins (okadaic acid, its derivatives and the pectenotoxins) and pose a major threat to shellfish aquaculture in Europe, Chile, Japan, and New Zealand (Reguera *et al*., 2012).

Most *Dinophysis* species are often a rare component of the phytoplankton assemblage, occurring at very small concentrations, but the species *D. acuminata, D. acuta*, *D. caudata*, *D. fortii*, *D. norvegica*, *D. rotundata* and *D. sacculus* are able to reach higher concentrations in coastal waters and are responsible for chronic DSP events (Reguera and Pizarro 2000; Trainer *et al.*, 2013). *Dinophysis* are known to exist in thin layers (Reguera *et al*., 2012) that can be dispersed through the surface water column mixed zone during events such as summer storms.

Reports of DSTs in shellfish have been associated with densities of *Dinophysis* as low as a few hundred cells/L (Yasumoto *et al.*, 1985). The appearance of *Dinophysis*, even at low densities such as 200 cells/L, can cause a toxification of shellfish that is enough to affect humans (Trainer *et al.*, 2013, Berdalet *et al.*, 2016). Observations of *Dinophysis* abundance show promise in providing early warning to DSP events (Trainer *et al.*, 2013). Thus precautionary closures/measures need to be taken even when low abundances of *Dinophysis* is observed.

The occurrence of some of the observed species in Nigerian coastal waters is worrisome. The toxins Dinophysistoxin, Okadaic acid, Pectonotoxin and Yessotoxin are all toxins responsible for the Diarrhetic Shellfish Poisoning (DSP). Different algal species producing these toxins were found in the coastal waters. These were, among others, *Dinophysis caudata* (Okadaic Acid, Pentenotoxin (PTX-2) Palytoxin), *Dinophysis rotundata* (Dinophysistoxin-1), and *Prorocentrum lima* (Okadaic Acid, Dinophysistoxin-1, Dinophysistoxin-2, Prorocentrolide). The toxins Saxitoxins and Gonyautoxins cause Paralytic Shellfish Poisoning (PSP) and the causative organisms found in the Nigerian coastal waters. *P. rhathymum* was found to produce haemolytic (Nakajima *et al*., 1981) and/or fast acting methanol soluble toxins (Pearce *et al*., 2005), but not OA or its analogues.

Of special note, is also the occurrence of *Prorocentrum lima* in Nigerian coastal water, which is also worrisome. These are prorocentrolide- and spiro-prorocentrimine- producing organisms (Moglo *et al.*, 2015). These toxins were reported to be very lethal when administered to mouse with an animal lethality of 0.4mg/kg mouse (prorocentrolide) [Torigoe *et al.*1988 Moglo *et al.*, 2015]; and much less toxicity at 2.5 mk/kg mouse (spiro-prorocentrimine). OA diol esters (DTX4) have been reported in *Prorocentrum lima* (Fernandez ;Fux *et al*, 2011). *P. lima* produces okadaic acid, implicated in DSP and ciguatera poisoning (CFP) (Anderson *et al.*2017). *Dinophysis rotundata*, *D. caudata* and *Prorocentrum lima* as the most ubiquitous of the known dinoflagellates associated with diarrhetic shellfish poisoning (DSP).

The destruction of seafood consequent on the syndromes elicited by toxic algae is of global occurrence. Several of the species found in this study have been known to cause harmful algal syndromes and mortality of seafoods in different parts of the world. Morton *et al*. (2009) found that populations of *D. caudata*, *D. rotundata* and *P. lima* cause contamination of wild and aquacultured mussels from the Black Sea with DSP toxins notably, okadaic acid, dinophysistoxin-1, dinophysistoxins-2 and pectenotoxin (Aligizaki *et al*. 2011). In the Gulf of Thailand, food poisoning with diarrhea from mussels collected during the bloom of *D. caudata* (Marrasigam *et al.* 2001) occurred. This species is one of the toxic species that causes DSP. Similarly, Okadaic acid (OA) and dinophysistoxin-1 (DTX1) were detected from *D. caudata* cells in Sapian Bay, the Philippines, Seto Inland Sea, Japan and in Singapore (Marasigan *et al.* 2001)

V. Conclusion

The study addressed the taxonomy, nomenclatural and distributional records of the Orders Dinophysiales and Prorocentrales-dinoflagellates in the Atlantic Ocean (Nigeria) from the Bight of Bonny to Bight of Benin, with varied occurrences, both spatially and seasonality, at different locations and regions within the Atlantic Ocean. Similar species were found between this study and other parts of the world.

Most of the species found in this study cause three (DSP, PSP, CFP) very important of the 5-6 syndromes of harmful algae. In most coastal countries of the world, an intense monitoring program is instituted for the surveillance of toxic algae occurrence and shellfish contamination in order to protect public health via early warning of bloom occurrence and toxins safety limit examination/determination. Since there is great variation in the distribution, composition and seasonality of dinoflagellates including Dinophysiales and Prorocentrales, routine continuous coastal monitoring programmes and comprehensive studies are suggested. This should include rapid development and deployment of new detection methods for individual species, density, diversity of species, toxins and toxicities necessary for the prediction and early detection of the devastating consequences of harmful algal species, inclusive of Dinophysiales and Prorocentrales.

This is the first study simultaneously investigating the taxonomy, diversity and composition of Dinophysiales and Prorocentrales in this area, consequently making it a veritable document for future studies, whether in ecology, environmental science, biotechnology, taxonomy or applied sciences.

Acknowledgements

Tertiary Education Trust Fund (TETFund) which provided the grant (for this work is gratefully acknowledged. Osasere Omoruyi, Timothy Unusiotame-Owolagba, Solomon Isagba and Dennis Umukoro are deeply appreciated for assisting in sample collection.

Funding

This work was supported by the Tertiary Education Trust Fund under Grant National Research Fund (TETF/NRF 2009).

References

1. Ajani, P, Larsson, M.E, Rubio, A, Bush, S, Brett, S, & Farrell H. (2016). Modelling bloom formation of the toxic dinoflagellates Dinophysis acuminata and Dinophysis caudata in a highly modified estuary, south eastern Australia. Estuarine, Coastal and Shelf Science (2016), doi: 10.1016/ j.ecss.2016.10.020
2. Al-Kandari, M., Al-Yamani, F.Y. & Al-Rifaie, K. (2009). Marine Phytoplankton Atlas of Kuwait's Waters. Kuwait Institute for Scientific Research, Safat, Kuwait. 351p.

3. Aligizaki, K., Nikolaidis, G., Katikou, P, Baxevanis, A.D. & Abatzopoulos, T.J. (2009). Potentially toxic epiphytic Prorocentrum (Dinophyceae) species in Greek coastal waters. Harmful Algae 8, 299–311.
4. Anderson, D.M. (2009). Approaches to monitoring, control and management of harmful algal. Ocean & Coastal Management 52(7), 342-347.
5. Anderson, D.M., Cembella, A.D. & Hallegraeff, G.M. (2012). Progress in understanding harmful algal blooms: Paradigm shifts and new technologies for research, monitoring, and management. Annual Review of Marine Science. 4, 143–176.
6. Anderson, D.M., Boerlage, S.F.E., Dixon, M.B. (ed) (2017). Harmful algal blooms (HABs) and Desalination: A Guide to Impacts, Monitoring and Management. UNESCO Manuals and Guides No 78, p480.
7. Barrera-Alba, J.J., Piedras, F.R., Duarte, C.L., Lopes, R.N.T. & Moser, G.A.O. (2019). Morphometric characterization of Dinophysis acuminata/D. sacculus complex in Guanabara Bay, Brazil. Biota Neotropica, 19(3), e20180607. http://dx.doi.org/10.1590/1676-0611-BN-2018-0607
8. Berdalet, E., Fleming, L.E., Gowen, R., Davidson, K., Hess, P., Backer, L.C., Moore, S.K., Hoagland, P. & Enevoldsen, H. (2016). Marine harmful algal blooms, human health and well-being: Challenges and opportunities in the 21st century. Journal of Marine Biological Association UK, 96, 61–91.
9. Botes, L. (2001). Phytoplankton Identification Catalogue-Saldanha Bay, South Africa. GloBallast Monograph Series No. 7, IMO, London, 88 p.
10. Campbell, L., Olson, R.J., Sosik, H.M., Abraham, A., Henrichs, D.W., Hyatt, C.J. & Buskey, E.J. (2010). First harmful Dinophysis (Dinophyceae, Dinophysiales) bloom in the US is revealed by automated imaging flow cytometry. Journal of Phycology 46, 66–75.
11. Carstensen, J., Henriksen, P. & Heiskanen, A.S. (2007). Summer algal blooms in shallow estuaries: Definition, mechanisms, and link to eutrophication. Limnology and Oceanography 52 (1), 370-384.10.4319/lo.2007.52.1.0370
12. Cohen-Fernandez, E.J., Meave, E., Del Castillo, I.H., Ugarte, S. & Pedroche F.F. (2006). Contribution of external morphology in solving a species complex: The case of Prorocentrum micans, Prorocentrum gracile and Prorocentrum sigmoides (Dinoflagellata) from the Mexican Pacific Coast. Phycological Research, 54 (4), 330-340, 10.1111/j.1440-1835.2006.00440.x
13. Costa, P.R., Botelho, M.J., Lefebvre, K.A. (2010). Characterization of paralytic shellfish toxins in seawater and sardines (Sardina pilchardus) during blooms of Gymnodinium catenatum. Hydrobiologia 655, 89–97.
14. Costa, P.R. (2016). Impact and effects of paralytic shellfish poisoning toxins derived from harmful algal blooms to marine fish. Fish 17, 226–248.
15. Dodge, J.D., Bibby, B.T. (1973). The Prorocentrales (Dinophyceae): I. A comparative account of fine structure in the genera Prorocentrum and Exuviaella. Botanical Journal of the Linnean Society, 67 (2), 175–187, https://doi.org/10.1111/j.1095-8339.1973.tb01737.x
16. Draredja, M.A., Frihi, H., Boualleg C. et al. (2020).Distribution of dinoflagellate cyst assemblages in recent sediments from a southern Mediterranean lagoon (Mellah, Algeria) with emphasis on toxic species. Environmental Science Pollution Research. https://doi.org/10.1007/s11356-020-08830-0
17. Faust, M.A. (1990). Morphologic details of six benthic species of Prorocentrum (Pyrrophyta) from a mangrove island, Twin Cays, belize, including two new species. Journal of Phycology 26, 548-558.
18. Faust, M.A. & Gulledge, R.A. (2002). Identifying Harmful Marine Dinoflagellates. National Museum of Natural History, Washington DC. 144p.
19. Faust, M.A. & Larsen, J., Moestrup, J. (1999). ICES Identification Leaflets for Plankton Fiches d'Identification du Plancton LEAFLET NO. 184 Potentially Toxic Phytoplankton 3. Genus Prorocentrum (Dinophyceae) by 'Smithsonian Institution, National Museum of Natural History 4201 Silver Hill Road, Suitland, Maryland 20746, USA Editor J. A. LINDLEY
20. Fernandez, J.J., Suarez-Gomez, B., Souto ML, Norte M, 2003. Identification of new okadaic acid ester derivatives from laboratory cultures of Prorocentrum lima. Journal of Natural Products. 66, 1294–1296.
21. France J, Mozetic P 2006. Ecological characterization of toxic phytoplankton species (Dinophysis spp., Dinophyceae) in Slovenian mariculture areas (Gulf of Trieste, Adriatic Sea) and the implications for monitoring. Mar. Pollut. Bull. 52, 1504–1516.
22. Fux, E., Bire, R., Hess, P. (2009). Comparative accumulation and composition of lipophilic marine biotoxins in passive samplers and in mussels (M. edulis) on the West Coast of Ireland. Harmful Algae 8, 523–537.
23. Fux, E., Smith, J.L., Tong, M, Guzmán, L. & Anderson, D.M. (2011). Toxin profiles of five geographical isolates of Dinophysis spp. from North and South America, Toxicon 57:275-287.

24. Garcia, C, Gonzalez, V., Cornejo, C., Palma-Fleming, H. & Lagos N., (2004). First evidence of dinophysistoxin-1 ester and carcinogenic polycyclic aromatic hydrocarbons in smoked bivalves collected in the Patagonia fjords. Toxicon 43, 121–131.
25. Global Biodiversity Information Facility (GBIF) Secretariat (2020). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2023-04-04.
26. Gómez, F. (2003). Checklist of Mediterranean free-living Dinoflagellates. Botanica Marina 46, 215-242.
27. Gómez, F. (2005). A list of free-living dinoflagellate species in the world's oceans. Acta Botanica Croatica 64, 129–212.
28. Goméz, F. & Boicenco, L. (2004). An annotated checklist of dinoflagellates in the Black Sea. Hydrobiologica 517, 43-59.
29. Gómez, F., Claustre, H. & Souissi, S. (2008). Rarely reported dinoflagellates of the genera Ceratium, Gloeodinium, Histioneis, Oxytoxum and Prorocentrum (Dinophyceae) from the open southeast Pacific Ocean. Revista de Biología Marina y Oceanografía 43(1), 25-40, abril de
30. Gomez, F. in Guiry, MD & Guiry GM (2023). AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org; searched on 04 April 2023.
31. Guiry MD in Guiry, MD, Guiry GM. 2023. AlgaeBase. World-wide electronic publication, National University of Ireland, Galway. http://www.algaebase.org; searched on 4 April 2023.
32. Gul S. & Saifullah, S.M. (2007). Genus Amphisolenia Stein from North-West Arabian Sea Shelf of Pakistan. Pakistani Journal of Botany 39(2), 561-576.
33. Gul, S. & Saifullah, S.M. (2011). The Dinoflagellate Genus Prorocentrum (Prorocentrales, Prorocentraceae) from the North Arabian Sea. Pakistani Journal of Botany 43(6), 3061-3065.
34. Hattenrath-Lehmann, T.K., Marcoval, M.A, Mittlesdorf, H., Goleski J.A., Wang, Z, Haynes, B., Morton, SL, Gobler CJ 2015. Nitrogenous nutrients promote the growth and toxicity of Dinophysis acuminata during estuarine bloom events. Plos One DOI:10.1371/journal.pone.0124148
35. Heisler, J., Glibert, P.M., Burkholder J.M., Anderson, D.M., Cochlan, W., Dennison, W.C., Dortch, Q., Gobler, C.J., Heil, C.A. & Humphries, E., et al. (2008). Eutrophication and harmful algal blooms: A scientific consensus. Harmful Algae 8, 3–13.
36. Hoppenrath, M., Elbrachter, M. & Drebes, G. (2009). Marine Phytoplankton: selected microphytoplankton species from the North Sea around Helgoland Sylt. – Senckenberg, Deutschland
37. Hoppenrath, M. (Ed) (2020). Prorocentrales, in IOC-UNESCO Taxonomic Reference List of Harmful Micro Algae. Available online at http://www.marinespecies.org/hab. Accessed on 2023-04-23
38. Hoppenrath, M., Chome´rat, N., Horiguchi, T., Schweikert, M., Nagahama, Y. & Murray, S. (2013).Taxonomy and phylogeny of the benthic Prorocentrum species (Dinophyceae)—A proposal and review. Harmful Algae 27, 1–28.
39. Hu, T., LeBlanc, P., Burton, I.W., Walter, J.A., McCarron, P., Melanson, J.E., Strangman, W.K., Wright, J.L. (2017). Sulfated diesters of okadaic acid and DTX-1: self-protective precursors of diarrhetic shellfish poisoning (DSP) toxins. Harmful Algae 63, 85–93.
40. Hurley, W., Wolterstorff, C., MacDonald, R. & Schultz, D. (2014).Paralytic shellfish poisoning: a case series. West Journal of Emergency Medicine 15(4), 378-381. doi:10.5811/westjem.2014.4.16279
41. Ignatiades, L. & Gotsis-skretas, O. (2010). A review on toxic and harmful algae in Greek coastal waters (E. Mediterranean Sea). Toxins 2, 1019-1037.
42. Jamet, J.L., Jean, N., Boge, G., Richard, S. & Jamet, D. (2005). Plankton succession and assemblage structure in two neighbouring littoral ecosystems in the north-west Mediterranean Sea. Marine and Freshwater Research 56, 69–83.
43. James, K.J., Carey, B., O'Halloran, J., van Pelt, F.N.A.M. & Škrabáková, Z. (2010). Shellfish toxicity: Human health implications of marine algal toxins. Epidemiological Infections 138, 927–940.
44. Kadiri MO 2001. Some marine phytoplankton species from Atlantic Ocean Nigeria. – Bioscience Research Communication 13: 197–207
45. Kadiri MO 2011. Notes on harmful algae from Nigerian coastal waters. Acta Botanica Hungarica 53, 137-143.
46. Koffi K, Mathieu EW, Siaka B. 2015. The dinoflagellate genera Ornithocercus Stein, Podolampas Stein and Pyrocystis Murray from the Grand-Lahou lagoon complex, Côte d'ivoire Int. J. Biodiversity Conservation 7 (9), 388-393.
47. Kraberg, A, Bauman, M, & Dürselen, C. (2010). Coastal Phytoplankton Photo Guide for Northern European Seas. Verlag Dr., Friedrick Pfeil, München. Germany. 204p
48. Kudela, R.M., Seeyave, S., Cochlan, W.P. (2010). The role of nutrients in regulation and promotion of harmful algal blooms in upwelling systems. Progress in Oceanography 85, 122–135.
49. Lackey, J.B. (1938). The manipulating and counting of river plankton and changes in some organisms due to formalin preservation. U.S. Public Health Reports**,** 53, 343-345.

50. Lawrence, J.E., Grant, J., Quilliam, M.A, Bauder, A.G. & Cembella, A.D. (2000). Colonization and growth of the toxic dinoflagellate Prorocentrum limaand associated fouling macroalgae on mussels in suspended culture. Marine Ecological Progress Series 201, 147-154.
51. Li, X, Li, Z, Chen, J., Shi, Q., Zhang, R, Wang, S., Wang, X., (2014). Detection, occurrence and monthly variations of typical lipophilic marine toxins associated with diarrhetic shellfish poisoning in the coastal seawater of Qingdao City, China. Chemosphere 111, 560–567.
52. Licea, S., Zamudio, M.E., Luna, R. & Soto R. (2004). Free-living dinoflagellates in the southern Gulf of Mexico: report of data (1979-2002). Phycological Research 52: 419-428.
53. Likumahua S, de Boer M.K., Krock, B., Hehakaya, S., Imu, L., Muller, A., Max, J. & Bum, A.G.J. (2020).
54. Variability of dinoflagellates and their associated toxins in relation with environmental drivers in Ambon Bay, eastern Indonesia. Marine Pollution Bulletin 150: https://doi.org/10.1016/j.marpolbul.2019.110778
55. Lee, J., Kim, G. (2017). New Records of two genera Mesoporos and Prorocentrum (Prorocentraceae, Prorocentrales, Dinophyceae) in Korean Waters. Korean Journal of Environmental Biology 35(3), 265-272.
56. Luo, Z, Hu, Z, Tang, Y., Mertens, K.N., Leaw, C.P., Lim, P.T., Teng, S.T., Wang. L. & Gu, H. (2018). Morphology, ultrastructure and molecular phylogeny of Wangodinium sinense gen. et sp. nov. (Gymnodiniales, Dinophyceae) and revisiting of Gymnodinium dorsalisulcum and Gymnodinium impudicum Journal of Phycology 54,744-764.
57. Madigan, T.L., Lee, K.G., Padula, D.J., McNabb, P. & Pointon, A.M. (2006). Diarrhetic shellfish poisoning (DSP) toxins in South Australian shellfish. Harmful Algae 5: 119–123.
58. Marasigan, A.N., Sato, S., Fukuyo, Y, Kodama, M. (2001). Accumulation of a high level of diarrhetic shellfish toxins in the green mussel Perna viridis during a bloom of Dinophysis caudata and Dinophysis miles in Sapian Bay, Panay Island, the Philippines Fish Science 67, 994–996.
59. Méndez, S. & Ferrari, G. (2002). Floraciones algales nocivas en Uruguay: Antecedentes, proyectos en curso y revisión de resultados. **In:** Sar EA, Ferrario ME, Reguera B, (eds.). Floraciones Algales Nocivas en el Cono Sur Americano. Instituto Español de Oceanografía. Madrid, Spain, pp. 271–288.
60. Moglo, J., Benoit, E.A., Zakaria, A. & Iorga B. (2015). Spirolides and Cyclic Imines: Toxicological Profile. **In:** Gopalakrishnakone, P, Haddad Jr, V, Kem WR, Tubaro A, Kim E. (eds.). Marine and Freshwater Toxins. Springer Netherlands. pp. 193-217.
61. Moita, M.T., Vilarinho, M.G. (1999). Checklist of phytoplankton species off Portugal: 70 years of studies. Portugaliae Acta Biologica. Serie B. Sistematica 18, 5-50.
62. Morton, S.L., Vershinin, S., Smith, L.L., Leighfield, T.A., Pankov, S. & Quilliam, M.A. (2009). Seasonality of Dinophysis spp. and Prorocentrum lima in Black Sea phytoplankton and associated shellfish toxicity. Harmful Algae 8, 629–636.
63. Mouratidou, T., Kaniou-Grigoriadou, I., Samara, C. & Kouimtzis, T. (2006). Detection of the marine toxin okadaic acid in mussels during a diarrhetic shellfish poisoning (DSP) episode in Thermaikos Gulf, Greece, using biological, chemical and immunological methods. Science of Total Environment 366, 894–904.
64. Munir, S., Naz, T., Burhan, Z., Siddiqui, P.J.A. & Morton, S.L. (2016). Species composition and abundance of dinoflagellates from the coastal waters of Pakistan. Journal of Coastal Life Medicine4(6), 448-457.
65. Mussai, P., Larsen, J., Alrefaei, A.F. & Jeewon, R. (2023).Ribosomal DNA Sequence-Based Taxonomy and Antimicrobial Activity of Prorocentrum spp. (Dinophyceae) from Mauritius Coastal Waters, South-West Indian Ocean. Marine Drugs 21(4),216. https://doi.org/10.3390/md21040216
66. Nakajima, I., Oshima, Y., Yasumoto, T., (1981). Toxicity of benthic dinoflagellates in Okinawa. Bulletin of Japanese Society for the Science of Fish 47, 1029–1033.
67. Naqqiuddin, M.A., Alim, A., Ghani, I.A., Omar, H. & Ismail, A., (2013). The diversity and density of marine dinoflagellates in the middle zone of the straits of Malacca. Malaysian Nature Journal 65 (2 and 3), 61–80.
68. Okolodkov, Y.B. (2014). Dinophysiales (Dinophyceae) of the National Park Sistema Arrecifal Veracruzano, Gulf of Mexico, with a key for identification. Acta Botanica Mexicana 106, 9-71.
69. Opute, F.I. (1991). A check-list of the freshwater, brackish and marine phytoplankton of the Warri/Forcados estuary of southern Nigeria. Nigerian Journal of Botany 4, 222-237.
70. Pan, Y., Cembella, A.D., Quilliam, M.A. (1999). Cell cycle and toxin production in the benthic dinoflagellate Prorocentrum lima. Marine Biology 134, 541-549.
71. Pearce, I., Handlinger, J.H. & Hallegraeff, G.M. (2005). Histopathology in Pacific oyster (Crassostrea gigas) spat caused by the dinoflagellate Prorocentrum rhathymum. Harmful Algae 4, 61–74.
72. Reguera, B. & Pizarro, G. (2000). Planktonic dinoflagellates that contain polyether toxins of the old “DSP complex”. **In:** Botana, L. M. (ed.). Seafood and Freshwater Toxins: Pharmacology, Physiology, and Detection. Marcel Dekker Inc. New York, USA, pp. 257–287.

73. Reguera, B., Riobo, P., Rodriguez, F., Diaz, P., Pizarro, G., Paz, B., Franco, J.M. & Blanco. J. (2014). Dinophysis toxins: causative organisms, distribution and fate in shellfish. Marine Drugs, 12 (1),394-461.
74. Reguera, B., Velo-Suárez, L., Raine, R., Park, M.R. (2012). Harmful Dinophysis species: A review. Harmful Algae, 14, 87-106.
75. Sar, E.A., Sunesen, I., Lavigne, A. & Goya, A. (2010). Dinophysis spp. asociadas a detección de toxinas diarreicas (DSTs) en moluscos y a intoxicación diarreica en humanos (Provincia de Buenos Aires, Argentina). Revista de biología marina y oceanografía. 45: 451–460.
76. Shultz, D., Campbell, L., Kudela, R. (2019). Trends in Dinophysis Abundance and Diarrhetic Shellfish Toxin Levels in California Mussels (Mytilus californianus) from Monterey Bay, California. Harmful Algae 88,1-50. DOI 10.1016/j.hal.2019.101641
77. Steidinger, K.A., Tangen, K. (1997). Dinoflagellates, In: Tomas C.R (Ed), Identifying Marine Phytoplankton. Academic Press, San Diego, pp387-589.
78. Subba, Rao, D., Pan, Y., Zitko, V. & Mackeigan, K. (1993). Diarrhetic shellfish poisoning (DSP) associated with subsurface bloom of Dinophysis norvegica in Bedford Basin, eastern Canada. Marine Ecology Progress Series 97, 117–126.
79. Saifullah, A.S.M., Kamal, A.H.M., Idris, M.H. & Rajaee, A.H. (2019). Community composition and diversity of phytoplankton in relation to environmental variables and seasonality in a tropical mangrove estuary. Regional Studies in Marine Science 32,100826
80. Taylor, M., McIntyre, L., Ritson, M., Stone, J., Bronson, R., Bitzikos, O., Rourke, W. & Galanis E. (2013). Outbreak of diarrhetic shellfish poisoning associated with mussels. Marine Drugs. 11(5), 1669-1676.
81. Tomas, C. R. (1997). Identifying Marine Diatoms and Dinoflagellates. AP, San Diego, CA, p. 858.
82. Torigoe, K., Murata, M., Yasumoto, T. & Iwashita, T. (1988). Prorocentrolide, a toxic nitrogenous macrocycle from a marine dinoflagellate, Prorocentrum lima. Journal of American Chemical Society 110,7876-7877.
83. Theriot, E., & Fryxell, G. (1985). Multivariate Statistical analysis of net diatom species distributions in the Southwestern Atlantic and Indian Ocean. Polar Biology 5:23- 30.
84. Vanormelingen, P, Verleyen, E. & Vyverman, W. (2008). The diversity and distribution of diatoms: from cosmopolitanism to narrow endemism Biodiversity Conservation 17,393–405.
85. Whyte, C., Swan, S., Davidson, K. (2014) Changing wind patterns linked to unusually high Dinophysis blooms around the Shetland Islands, Scotland. Harmful Algae 39,365-373.
86. Wilke, T., Zinssmeister, C., Hoppenrath, M. (2018). Morphological variability within the marine dinoflagellate Ornithocercus quadratus (Dinophysales, Dinophyceae) – evidence for three separate morphospecies Phycologia 57 (5), 555–571.
87. Yasumoto, T., Murata, M., Oshima, Y., Sano, M., Matsumoto, G. & Clardy, J. (1985). Diarrhetic shellfish toxins. Tetrahedron 41, 1019–1025.
88. Yñiguez, A. T., Lim, P. T., Leaw, C. P., Jipanin, S. J., Iwataki, M., Benico, G., & Azanza, R. V. (2021). Over 30 years of HABs in the Philippines and Malaysia: What have we learned?. Harmful Algae, 102, 101776.
89. Zendong, S.Z., Kadiri, M., Herrenknecht, C., Nézan, E., Mazzeo, A. & Hess, P. (2016). Algal toxin profiles in Nigerian coastal waters (Gulf of Guinea) using passive sampling and liquid chromatography coupled to mass spectrometry. Toxicon, 114:16-27.
90. Zingone, A. & Larsen J. (Eds) 2020. Dinophysiales, in IOC-UNESCO Taxonomic Reference List of Harmful Micro Algae. Available online at http://www.marinespecies.org/hab. Accessed on 2020-06-23