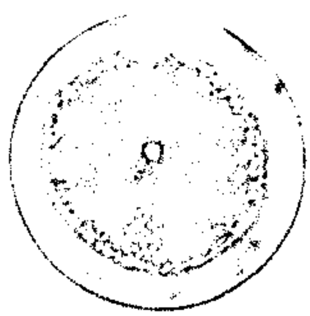
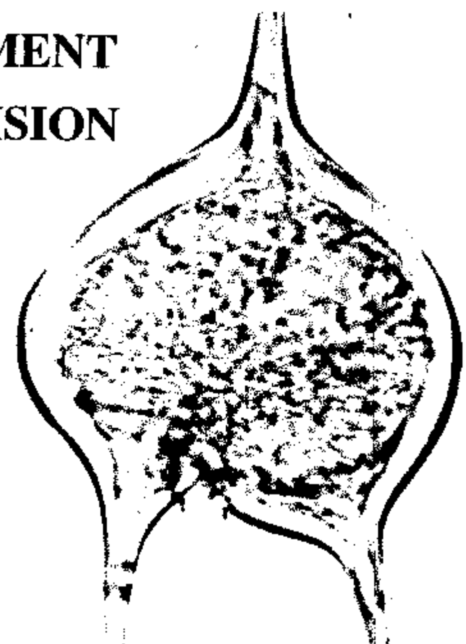
TRAINING MANUAL
ON
PHYTOPLANKTON IDENTIFICATION/TAXONOMY



FISHERY ENVIRONMENT MANAGEMENT DIVISION



ICAR

CENTRAL MARINE FISHERIES RESEARCH INSTITUTE

(I.C.A.R.)

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PREFACE

Phytoplankton or the micro algae are the microscopic plant life of any water body which forms the primary producers synthesizing the basic food, to almost all the animals in an aquatic ecosystem. They form the basic live feed to all the zooplankton and larval forms of Crustaceans, Molluscs and fin fishes. Their importance lies in the fact that they are photosynthesizing organisms and serve as first link in the food chain. They belong to the Class Algae which besides chlorophylls possess other characteristic pigments. Most phytoplankton organisms are unicellular, some are colonial and filamentous in habit. The majority of the phytoplankton are harmless; however, few of them are harmful and cause adverse effects on other aquatic organisms.

Taxonomy and identification of the phytoplankton organisms are a difficult task. Innumerable number of organisms comprise the phytoplankton, from macroscopic forms to picoplankton and the process of identification is long. We have to observe some cell characteristics such as cell wall, cell shape, locomotion, ornamentation of the valves, production of metabolites and mode of reproduction.

This training programme is mainly aimed at the identification of common phytoplankton organisms, isolation procedures, classification, cell characteristics, multiplication and effects of toxic or harmful algal blooms and its impact to other fauna. The Co-ordinator, Dr. C.P. Gopinathan and team members, Dr. M. Rajagopalan, Dr. P. Kaladharan and Dr. D. Prema of the Fisheries Environment Management Division will be taking special interest to cover many areas of interest and application. I hope that this training programme will be beneficial to the participants in their research endeavours.

Dr. Mohan Joseph Modayil,
Director

PHYTOPLANKTON

The term 'plankton' was coined by Victor Hensen in 1887, denotes collectively all free floating and suspended bodies, both plants and animals, living or dead, that essentially move passively in a body of water. The phytoplankters are the microscopic plant life of the sea, which constitute the primary producers synthesizing the basic food. It belongs to the class Algae, which besides chlorophylls posses other characteristic pigments. The important components of phytoplankton are Diatoms (Bacillariophyceae), Dinoflagellates (Dinophyceae), Blue-green algae (Cyanophyceae), Phytoflagellates (Xanthophyceae, Chrysophyceae, Haptophyceae, Cryptophyceae) and Nannoplankters (*Chlorella, Nannochloropsis* etc.). In addition to these, two other Classes namely Silicoflagellates and Coccolithophores also belong to the category of phytoplankton.

In the seawater, the diatoms and dinoflagellates are the more obvious representatives of the phytoplankton, in terms of both cell size and availability when water samples are examined under microscope. Depending on the size grading of phytoplankton organisms, they are grouped under:

1. More than 1 mm : Macroplnkton
2. Less than 1 mm : Microplankton
3. Organisms of 5 –50 μ : Nannoplankton
4. Less than 5 μ : Ultraplankton
5. Less than 1 μ : Picoplankton

Characteristics of Phytoplankton

Most phytoplankton organisms are unicellular. The larger colonial forms possess individual cells that are usually of uniform structure and appearance. Some planktonic green and blue-green algae are of filamentous organisation, and in some diatoms and dinoflagellates chains of loosely associated cells may be formed. Unicellular organisms are identified by recognizing certain cell characteristics, and ease of identification will clearly be limited by cell size and the degree of magnification obtainable. For identification purposes we look for the following with phytoplankton organisms: 1. Cell shape 2. Cell dimensions 3. Cell wall 4. Mucilage layers 5. Chloroplasts 6. Flagella and 7. Reserve substances.

Collection of phytoplankton

The quickest way of obtaining a concentrated sample of phytoplankton is to tow a cone shaped net of bolting silk, through the water. The wider end of the net is kept open by a metal ring and this is attached to tow rope by a rope bridle. The narrow end is closed by a metal or plastic bucket. When towed through water, a backpressure builds up at the opening, which prevents some water flowing through the net. A tapering canvas sleeve allows more effective filtering by reducing the volume of water entering the net. Slower filtration rates are obtained with nets of finer mesh sizes and smaller organisms are collected. Net samples can be collected from various depths. Net samples are inadequate as the basis of quantitative studies due to uncertain nature of the sampling. Flow meters (multibladed propellers with a counter for noting total revolutions) give more accurate information on the quantities of water flowing through the net, but the selective nature of the method of capturing organisms can exclude the nannoplankters.

Preservations

About 5 – 8 % neutral formalin solution can be used although this is not very satisfactory for delicate organisms. Lugol's iodine solution (10 gm of iodine and 20 gm of potassium iodide in 200 ml of Dist. water with 20 gm of Glacial Acetic acid added 2 – 3 days before use) give better preservation of flagellates. Lugol's iodine is added to water samples in a ratio of 1:100 volume of water.

Identification

It is difficult to count and at the same time try to identify organisms with keys and illustrations. Recognition of species is a matter of experience. It is advisable to examine the material before counting and to identify as many of the organisms as possible. It is also useful to prepare a series of pencil or ink drawings of the species observed. Pinned to a board and placed in proximity to the microscope, these drawings will help to speed up the counting process until one is experienced in recognition.

ORGANISMS

1. DIATOMS (BACILLARIOPHYCEAE)

Diatoms constitute the major part of the phytoplankton of the seawater. Their importance lies in the fact that they are photosynthesizing organisms and serve as a vital first link in the food chain, either directly or indirectly of almost every animal in the sea. It is probably true to say that at some times in their life history, all fish, molluscs and crustaceans are diatom feeders, at least in part.

Taxonomy

Diatoms are broadly divided into two major divisions: the CENTRALES or Centricae and the PENNALES or Pennatae, depending on the structure and sculpture on their cell walls.

CENTRALES

Centrales containing the centric diatoms, the valves of which are having radiating sculpture either central or lateral, without raphe and without movement.

CENTRALES divided into 3 sections:

Discoideae

Cells disc shaped, valves circular and surface flat concave or convex.

Example: *Coscinodiscus, Thalassiosira* etc.

Solenoideae

Cells elongate, valves oval or circular in cross section, cylindrical or sub cylindrical with numerous intercalary bands. Cells sometimes united into chains by their valves.

Example: *Rhizosolenia*

Biddulphioideae

Cells box shaped, valves usually oval or polygonal with horns or setae

Example: *Biddulphia*, *Chaetoceros* etc.

PENNALES

The valves not centrally constricted, not arranged in relation to a central point, but to a median line, bilaterally symmetrical and having boat shaped, crescent shaped or linear structure. True raphe or hyaline median line always presents on the valve. Cells capable of spontaneous movement, if a true raphe is present.

PENNALES can be divided into three sections, depending on the presence or absence of raphe.

Araphideae

Raphe is absent, but pseudoraphe usually present.

Example: *Fragillaria, Licmophora*

Monoraphideae

One valve of the cell always with a raphe, the other without raphe or with a rudimentary raphe.

Example *Achnanthes*

Biraphideae

Both valves with developed raphe

Example: *Navicula, Pleurosigma*

REPRODUCTION OF THE DIATOMS

Both vegetative and sexual reproduction met within diatoms.

Vegetative reproduction

It is brought about by the division of a single cell by means of binary fission into two daughter cells. In cell division, the epitheca separates from the hypotheca, each forming the epitheca of the daughter cells in which new hypotheca are formed. With continued and rapid cell division, there will be a progressive diminution in cell size with half of the progeny, but with some species no such diminution is observed, indicating that some adjustment of frustule size must occur at the same time.

Sexual reproduction

It is brought about by the formation of Auxospores. Auxospores are formed invariably by the fusion of gametes, within a single cell or the fusion of two gametes from different cells (conjugation). For thriving the unfavourable conditions, some diatoms especially Centrales forms thick matrix with spines or without spines called statospores or Aplanospores respectively.

2. DINOFLAGELLATES (DINOPHYCEAE)

Dinoflagellates are animal like diversified group of organisms which move around in water with the help of their cilia or flagellae. Among the autotrophic planktonic organisms, Dinophyceae come next in importance to the Diatomaceae. The cells bear paired flagellae which arise in close proximity, usually with one flagellum trailing behind the cell and lying in a groove (sulcus) and the ribbon like transverse flagellum also lying in a groove (cingulum or girdle). The girdle lies between the epicone and the hypocone. Wing like extensions of the body probably assist floatation in some genera (*Dinophysis*, *Ornithocerous* etc.).

Most of the dinoflagellates are harmful to other phytoplankters and aquatic organisms, since they produce some toxins, which act as, poison to others. The discolouration of the water, either red, pink or brown due to the blooming of dinoflagellates are termed as 'Red tide' or red water phenomenon and this causes harmful effects to the fishery. Due to the blooming, there will be deoxygenation, high pH and sometimes-bad smell also effected. The zooplankters as well as the larval forms of fishes will try to avoid the area, otherwise mass mortality may occur in these areas. Incidents of heavy mortality of fishes occurred in several times in the Arabian sea especially in the Lakshadweep area due to the blooming of dinoflagellates such as species of *Gonyaulax*, *Gymnodinium* and *Noctiluca*.

Dinoflagellates are reproduced by binary fission or vegetative cell division and sexual reproduction is lacking in this class.

Taxonomy

Dinophyceae may be divided into two sub classes:

(1) Desmokontae and (2) Dinokontae

Desmokontae

Desmokontae which comprises more of primitive organisms; all are motile unicellular forms, the envelope never appears to consist of the complex series of plates that is characteristic of the higher dinoflagellates. The subclass may be divided into two orders:

1. Desmomonadales

   Consists of naked ellipsoidal cells found in fresh and seawater, are supposed to be most primitive dinoflagellates.

   Example: *Desmocapsa, Haplodinium* etc.

2. Prorocentrales

   These are marine forms and primitive among other marine dinoflagellates.

   Example: *Prorocentrum* spp.

Dinokontae

It includes the main lines of development of the dinoflagellates and show considerable homogeneity. They are the advanced forms of dinoflagellates and have different orders.

Orders

1. Gymnodinales
2. Amphilothalea
3. Kolkwitziellales
4. Dinophysiales
5. Peridinales
6. Rhizodinales
7. Dinococcales
8. Dinotrichales

(Refer Fritsch, F. E. 1935)

3. BLUE GREEN ALGAE (CYANOPHYCEAE or MYXOPHYCEAE)

The members of this class are distinguished from all other algae in being the absence of an organized nucleus, lacking nuclear membrane and chromosomes, instead a central body is present. Besides chlorophylls, the chloroplast contains a blue green pigment known as phycocyanin also present. Planktonic blue green algae are unicellular, colonial or filamentous in habit. Both the cell colonies and the filaments cause extensive 'blooms' under certain marine and fresh water conditions. In the inshore environments, blooming of one filamentous form, *Trichodesmium* spp. is a common phenomenon, causing discolouration of water and sometimes harmful affects to the aquatic organisms. Filamentous blue green algae possess specialised cells called Heterocysts. These are thought to be concerned with nitrogen fixation. The cell of planktonic blue green algae contains conspicuous gas vacuoles, presumably as aids to floatation.

Reproduction in the blue green algae is brought about by vegetative cell division in the filamentous forms by breaking the heterocysts and thus forming 'hormogones'. No sexual reproduction is reported in blue green algae.

Taxonomy

The two important orders, which constitute majority of the marine and fresh water forms, are:

1. Chlorococcales

   Consists of cells united to form chain or colonies.

   Example: *Merismopedia, Synechococcus*

2. Nostocales

   Comprising majority of the filamentous blue green algae.

   Example: *Trichodesmium, Oscillatoria, Nostoc* etc.

4. SILICOFLAGELLATES

Silicoflagellates are small star shaped organisms, characterized by the possession of a skeleton taking the form of framework of silicious rods, arranged in diverse ways and with intervening spaces of definite shape. Outside this skeleton is a delicious layer of cytoplasm and containing a number of bright yellow to brownish yellow discoid chromatophores.

Taxonomy

Mainly four genera are represented:

1. *Dictyocha* 2. *Distephanus* 3. *Ebria* 4. *Mesocena*

5. COCCOLITHOPHORES

Coccolithophores are motile flagellates, with two equal flagella and chiefly differing from one another in the characters of the envelope. The characteristic features of the coccolithophores are that on the surface, there are the depositions of large number of circular bodies or cavities (coccoliths) which consist of carbonate of lime. Important genera are *Coccoliths, Hymnomonas, Pontosphaera, Syracosphaera, Calyptosphaera* etc. In temperate waters, blooming of Coccolithophores causes 'white water' phenomena.

6. NANNOPLANKTERS

Nannoplankters are those organisms, which are measuring less than 50 µ. They form the 'hidden flora' of the sea and playing a significant role in the productivity of the waters. Nannoplankters forms the basic food of almost all the zooplankters and larval stages of fishes, crustaceans and molluscs. Members of Chlorophyceae, Xanthophyceae, Chloromonadineae, Cryptophyceae, Chrysophyceae and Haptophyceae belong to this group. Example: *Chlorella, Nannochloris, Isochrysis, Tetraselmis* etc.

Chlorophyceae - The members of this class are having grass green, pale yellow chromatophores. Starch is the customary form of storage of the products of photosynthesis. The motile cells exhibit the same features and possess a number of equal flagella (commonly 2 or 4) which arise from the front end of the swarmers. Eg: *Chlorella, Nannochloropsis* and *Tetraselmis*

Chrysophyceae – The members of this class are having brown or orange coloured chromatophore, containing xanthophylls and carotene as accessory pigments. The motile cells possess one or two flagella attached at the front end rarely equal. The cells contain one or two parital chromatophores. Sexual reproduction is very rare, however isogamy is recorded in some genera. Eg: *Dicrateria*

Haptophyceae: The members of this class are golden yellow or brown flagellates measuring less than 10 microns. The flagellates will have one to two flagella which arise from the front end. Masking the chlorophyll, carotene and xanthophylls pigments are dominant. The members are widely used in hatcheries as live feed. Eg: *Isochrysis* and *Chromulina*

TOXIC ALGAL BLOOMS

Incidents of phytoplankton blooms, either harmful or harmless, discolouration of coastal waters, either red, pink, brown and green, has been a regular feature along the Indian coasts, especially in the west coast of India. The red tide or red water phenomena are generally intermingled with changes in chemical properties of coastal waters. Introduction of nutrients during the summer monsoon period through river run off and coastal upwelling are major factors influencing the algal blooms. Most cases of blooms have been harmless, since the aquatic fauna will try to avoid the area and fall in fish catches have been reported every time. However, in recent years, a few cases of fish mortality have been reported in the West Coast, due to algal blooms and effects of PSP and DSP depending on the organisms bloomed. Thus the problem of harmful algal blooms along the Indian coast is more serious than apparent and needs urgent attention to check further escalation due to eutrophication.

There are three different types of algal blooms observed in the Indian Seas. They are:

1. Species which produce basically harmless water discolouration, however, under exceptional conditions in sheltered bays, lagoons and stagnant water bodies, blooms can grow so dense that they cause indiscriminate kills of fish and other invertebrates due to oxygen depletion or asphyxiation. (Eg. *Hornellia marina*).
2. Species, which are non toxic to human but harmful to fish, and invertebrates especially in aquaculture systems by damaging or clogging their gills. (Eg. Diatoms like *Chaetoceros* spp., *Asterionella* sp., dinoflagellate *Gymnodinium mikimoti* and species of Coccolithophores.).
3. Species which produce poisonous toxins that, can find their way through the food chain to human, causing a variety of gastrointestinal or neurological illness such as PSP, DSP, ASP, NSP, VSP, CFP etc.

Usually the toxic or non toxic algal blooms occurring in Indian seas due to sudden multiplication of organisms under favourable conditions like dinoflagellates (Dinophyceae), members of green algae (Chlorophyceae), blue-green algae (Cyanophyceae) and diatoms (Bacillariophyceae).

Diatom blooms

In many estuaries and inshore area of the West Coast of India, diatom blooms are observed in upwelled waters rich in nutrients during the monsoon and post monsoon months. Report of blooming of *Fragilaria oceanica* coincides with the abundance of oil sardine in the west coast and blooming of *Hemidiscus hardmannianus* with the abundance of choodai fishery (*Hilsa* sp.) in the east coast. So far no ill effects to human health or to the fishery due to the blooming of diatoms have been reported.

Trichodesmium bloom

The filamentous blue green alga *Trichodesmium* spp is perhaps the most known red tide organisms in the tropical seas. Massive *Trichodesmium* blooms occur in the Arabian Sea during the pre monsoon season every year. Starting in February – March, the bloom persists till April – May then decline. The blooms are generally confined to 5 – 25 m patches and occur generally in long bands parallel to the coast. Warming of surface waters (27 – 32°C) and increase in salinity (30 – 35 %) is thought to be preconditions for the onset of *Trichodesmium* blooms. The nutrient levels have been reported to be generally low during the early phase of the red tide. Phosphate concentrations are very high and Nitrate levels are very low during the early bloom period. Ammonia concentrations increase sharply in the water column after every pulse of the bloom.

There are no cases of fish mortality associated with *Trichodesmium* blooms indicating the non-toxic nature of the blue green algae. However, if there is a bloom, aquatic organisms will try to avoid the blooming area.

Dinoflagellate blooms

Members of Dinophyceae cause the maximum harmful effect to the fauna and responsible for the heavy mortalities of fishes in the West Coast. The Dinoflagellates involved the blooms along the Indian coast are *Noctiluca miliaris*, *Noctiluca scintillans*, *Gymnodinium breve*, *Heterodinium* sp., *Gonyaulax* (*Alexandrium*) spp., *Porocentrum micans*, *Peridinium* spp., *Ceratocorys* sp., *Dinophysis* sp. and *Ceratium* spp.

The blooming of dinoflagellates may not cause toxic effects always and the fish mortality reported by the workers earlier, could be due to sudden depletion of oxygen content in the water column, ammonia toxicity or due to the clogging of gills. Most of the shoaling fishes avoid areas of dinoflagellate blooms. However, the pelagic fishes could not escape these areas and will be trapped and face the consequences.

Dinoflagellate toxins, such as PSP (Paralytic Shellfish Poisoning), DSP (Diarrehetic Shellfish Poisoning), NSP (Neurological Shellfish Poisoning), ASP (Amnesic Shellfish Poisoning), CFP (Ciguatera Fish Poisoning) etc., have been causing great public health concern in several parts of the world.

Paralytic Shellfish Poisoning (PSP)

PSP is a neurotoxin syndrome resulting primarily from the blockage of neuronal and muscular Na^+ channel prevents propagation of action potential, which is essential to the conditions of nerve impulse and muscle contraction. In vertebrates, the peripheral nervous system is particularly affected. Typical symptoms of poisoning include tingling and numbness of the extremities, progressing to muscular paralysis leading to death by asphyxiation in extreme cases. The PSP toxins include saxitoxin and approximately two dozen naturally occurring tetrahydropurine derivatives. Eg. *Alexandrium* spp., *Pyrodinium bahamensei* and *Gymnodinium* spp.

Diarrehetic Shellfish Poisoning (DSP)

Several of the components associated with the DSP toxin complex cause severe gastro-intestinal disturbances in mammals when delivered orally. In humans, typical symptoms following the consumption of DSP toxins contaminated shellfish include acute diarrhea, nausea, vomiting and in some cases abdominal pain. Although no human mortalities from DSP have been reported, the after effects will be prolonged for few more days. Organisms associated with the DSP are species of *Dinophysis* and *Prorocentrum lima*.

Amnesic Shellfish Poisoning (ASP)

This phenomenon was first recognized in 1987 in Prince Edward Island in Canada, where it caused 3 deaths and 105 cases of acute human poisoning following the consumption of blue mussels. The symptoms include abdominal cramps, vomiting, disorientation and memory loss (Amnesia). The memory loss associated with extreme cases of human intoxication from shellfish contaminated by domic acid led to the description of the phycotoxic syndrome known as Amnesic Shellfish Poisoning. Most unexpectedly, the causative toxin is produced by a diatom and not by a dinoflagellate. The diatom species are *Pseudo-Nitzschia multiseries*, *P. pseudodelicatissima*, *P. australis* etc. To date reports of domic acid in seafood products have been mainly confined to North America and Canada.

Neurological Shellfish Poisoning (NSP)

The toxins implicated in neurological shellfish poisoning known collectively as 'brevetoxins' are considered to be primarily ichthiotoxins. In humans, the symptoms of NSP intoxication include respiratory distress, as well as eye and nasal membrane irritation, caused principally the exposure to sea spray aerosols and by direct contact with toxic blooms while swimming. The brevetoxins are also accumulated in shellfish, which when consumed by humans; cause a toxic syndrome somewhat similar to PSP intoxication. Eg. *Gymnodinium breve*.

Ciguatera Fish Poisoning (CFP)

Ciguatera fish Poisoning is a complex syndrome in humans who have consumed certain fish inhabiting or feeding upon coral reef areas, principally in the tropical Pacific and Caribbean region. Symptoms can include gastroenteritis, skin itching, cardiovascular disorders and peripheral neuropathy. The organisms associated with Ciguatera fish poisoning are *Gambieroiscus toxicus* and *Prorocentrum* sp.

Venerupin Shellfish Poisoning (VSP)

Venerupin Shellfish poisoning generally referred to as VSP is also called oyster or 'asari' poisoning. Sporadic or sometimes massive outbreaks of highly lethal food poisoning have followed consumption of oysters and short neck clams (*Tapes japonica*) harvested from certain coastal areas of Japan. Unlike PSP, DSP and NSP, paralytic or neurological symptoms are absent in VSP. Initially gastro intestinal symptoms prevail, followed by damages to liver and kidney. A dinoflagellate belonging to the genus *Prorocentrum* has been suggested to be responsible for the type of poisoning.

Prevention and control of Shellfish Poisoning

Of course, prevention and control and management of toxic algal blooms are not in our hand. However, to some extend, we can avoid the potential blooming conditions in our coastal areas.

- ⇒ Monitoring of shellfish growing waters for toxic dinoflagellates as well as assaying these organisms for toxicity are means for preventing shellfish poisoning
- ⇒ Untreated effluents from factories, industrial areas and other organic wastes should not be discharged into the coastal regions.
- ⇒ Sewage should not be discharged untreated into the sea since it is full of nutrients.

- Eating of uncooked shellfish from endemic areas, since cooking does not completely destroy PSP and NSP and they are rather heat stable.
- Since most of the DSP are concentrated in the hepatopancreas, the removal of this organ is may reduce the toxicity.
- Commercial canning of shellfish is more effective than cooking in reducing PSP toxicity.
- Awareness programmes to the coastal people, especially fisherman and farm owners about the impact of toxic algal blooms.
- Alert the coastal people about the harmful effects of blooming and prevent them for consuming the dead fishes.

Conclusion

The occasional blooming of the toxic or non toxic forms of phytoplankton occurring in the West Coast are confronted with many reasons. Changes in physical and chemical properties of coastal waters associated with monsoon such as nutrient input through river run off, detrital loading, coastal upwelling, reduction in surface salinity and temperature, influence bloom formation.

Incidents such as out break of PSP, detection of DSP, fish and destruction of marine fauna due to toxic algal blooms, indicate the danger to public health and the economic losses caused by some of the blooms. Regular monitoring of shellfish for toxicity would greatly help in avoiding outbreaks of shellfish poisoning. Experience of other countries has shown that toxicity can suddenly appear after periods of non-toxicity. This calls for vigilance to save valuable human lives. For example, it is known that several dinoflagellates can remain for long periods of time in sediments as 'cysts'. The cysts can act as 'seeds' to initiate blooms when favourable ecological conditions prevail. A study of benthos, especially the sediments in different parts of the Indian coast would help identifying areas prone to toxic algal blooms.

Wastes or effluents from the factories and aquaculture industries, which are rich in nutrients, are being discharged into the sea. The effect of these effluents on phytoplankton ecology needs to be investigated. Survey of aquaculture sites for the presence of potentially toxic species and their cysts would greatly help avoiding problems later.

Table- I

Algal blooms observed during 2001-2002					
Sl. No	Period	Location	Algal species	Toxin produced	Harmful effect reported
1	Sept, 1998	Poovar/ Vizhinjam	*Alexandrium polygrama*	PSP	Fish mortality & 7 death
2	Sept, 2001	Calicut	*Prorocentrum micas*	DSP	Nil
3	Oct, 2001	Calicut	*Horneilla marina*	Nil	Fish mortality
4	Dec, 2001	Vizhinijam	*Dinophysis caudata*	DSP	Nil
5	Sept 2 – 23rd 2002	Calicut	*Horneilla marina*	Sulphur oxide radicals	Heavy mortality of fishes and molluscs
6	Sept. 27, 2002	Calicut	*Noctiluca miliaris* and *Horneilla marina*	Ammonia	Nil
7	Nov, 2002	Njarackkal, Kochi	*Gymnodinium* and *Heterodinium*	Nil	Nil

Table – II

Non-toxic algal blooms observed in the off shore waters if west coast of India (FORV *Sagar Sampada*)					
Sl. No	Cruise No.	Date	Time (hrs)	Depth (m)	Organism
1	166	24.06.1998	06.00	90	*Trichodesmium* sp
2	168	23.10.1998	16.00	4200	*Noctiluca miliaris*
3	182	13.03.2000	09.00	540	*Noctiluca miliaris*
4	182	22.03.2000	20.00	2440	*Noctiluca miliaris*
5	183	24.04.2000	16.00	75	*Trichodesmium* sp
6	203	22.05.2002	10.30	72	*Trichodesmium* sp

PLATE – I

Figures 1 – 19

1. *Skeletonėma costatum*
2. *Stephanophyxix palmeriana*
3. *Thallassiosira subtilis*
4. *Thallassiosira subtilis* – Girdle view
5. *Coscinodiscus excentricus*
6. *Coscinodiscus excentrıcus* – Girdle view
7. *Planktoniella sol*
8. *Rhizosolenia styliformis*
9. *Rhizosolenia robusta*
10. *Bacteriastrum hyalinum*
11. *Cheatoceros eibenii*
12. *Eucampia cornuta*
13. *Triceratium reticulatum*
14. *Biddulphia mobiiliensis*
15. *Ditylum brightwelli*
16. *Hemidiscus hardmannianus*
17. *Biddulphia sinensis*
18. *Cerataulina bergonii*
19. *Isthmia enervis*

PLATE - I

D I A T O M S - CENTRALES

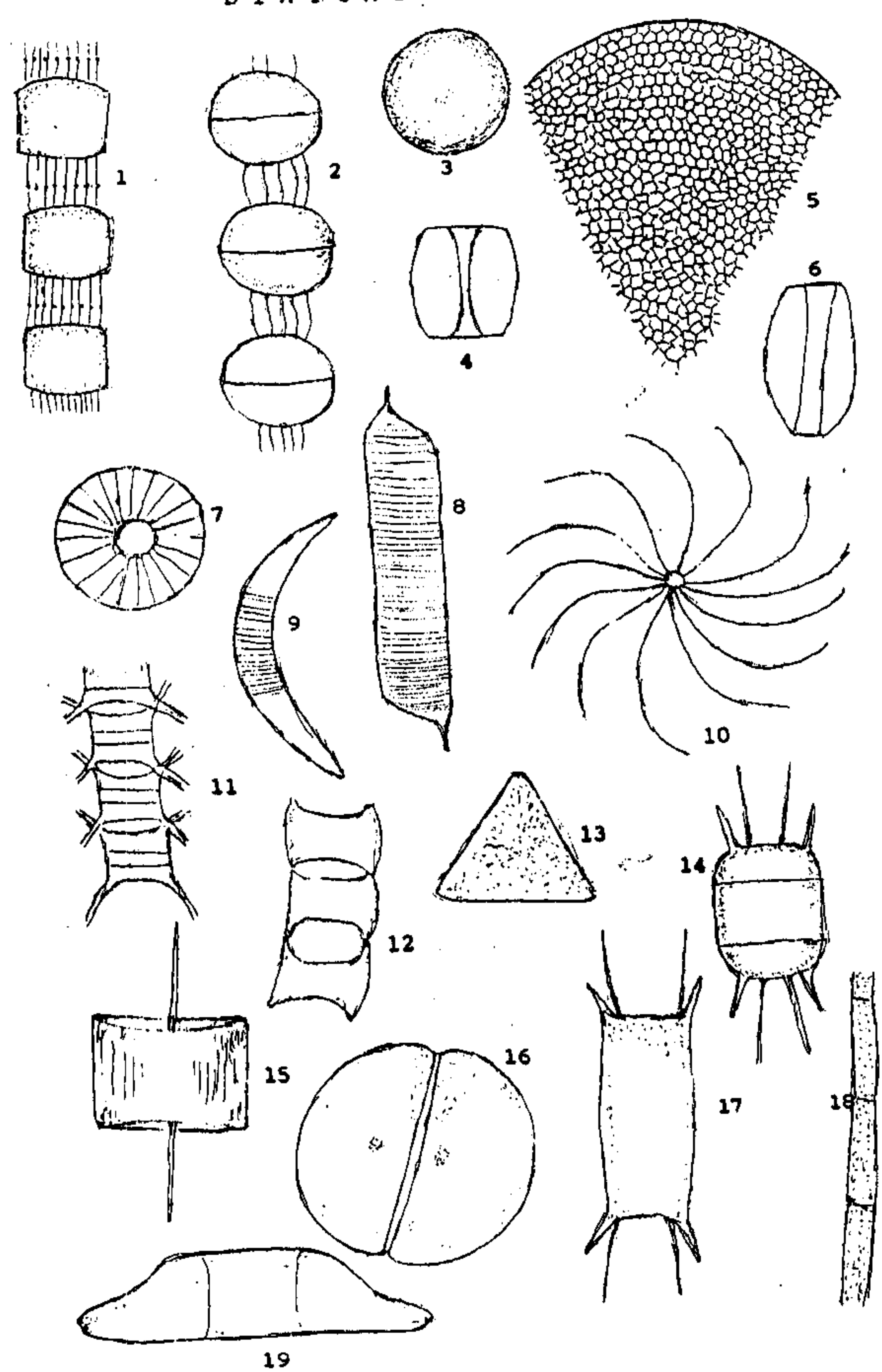


Plate – II

Figures 1- 28

1. *Grammatophora undulata*
2. *Striatella delicatula*
3. *Licmophora abbreviata*
4. *Thalassiosira nitzschioides*
5. *Climacosphenia moniligera*
6. *Fragilaria oceanica*
7. *Rhaphoneis amphiceros*
8. *Synedra formosa*
9. *Thallasiothrix frauenfeldii*
10. *Asterionella japonica*
11. *Mastogloia exilis*
12. *Cocconeis littoralis*
13. *Amphiprora gigantiea*
14. *Amphora liniolata*
15. *Navicula henneydii*
16. *Pleurosigma normanii*
17. *Gyrosigma balticum*
18. *Tropidoneis aspera*
19. *Cymbella marina*
20. *Bacillaria paradoxa*
21. *Nitzschia closterium*
22. *Amphiprora ostrearia*
23. *Nitzschia longissima*
24. *Nitzschia striata*
25. *Surirella eximia*
26. *Nitzschia panduriformis*
27. *Surirella fluminensis*
28. *Campylodiscus iyengarii*

PLATE - II

DIATOMS - PENNALES

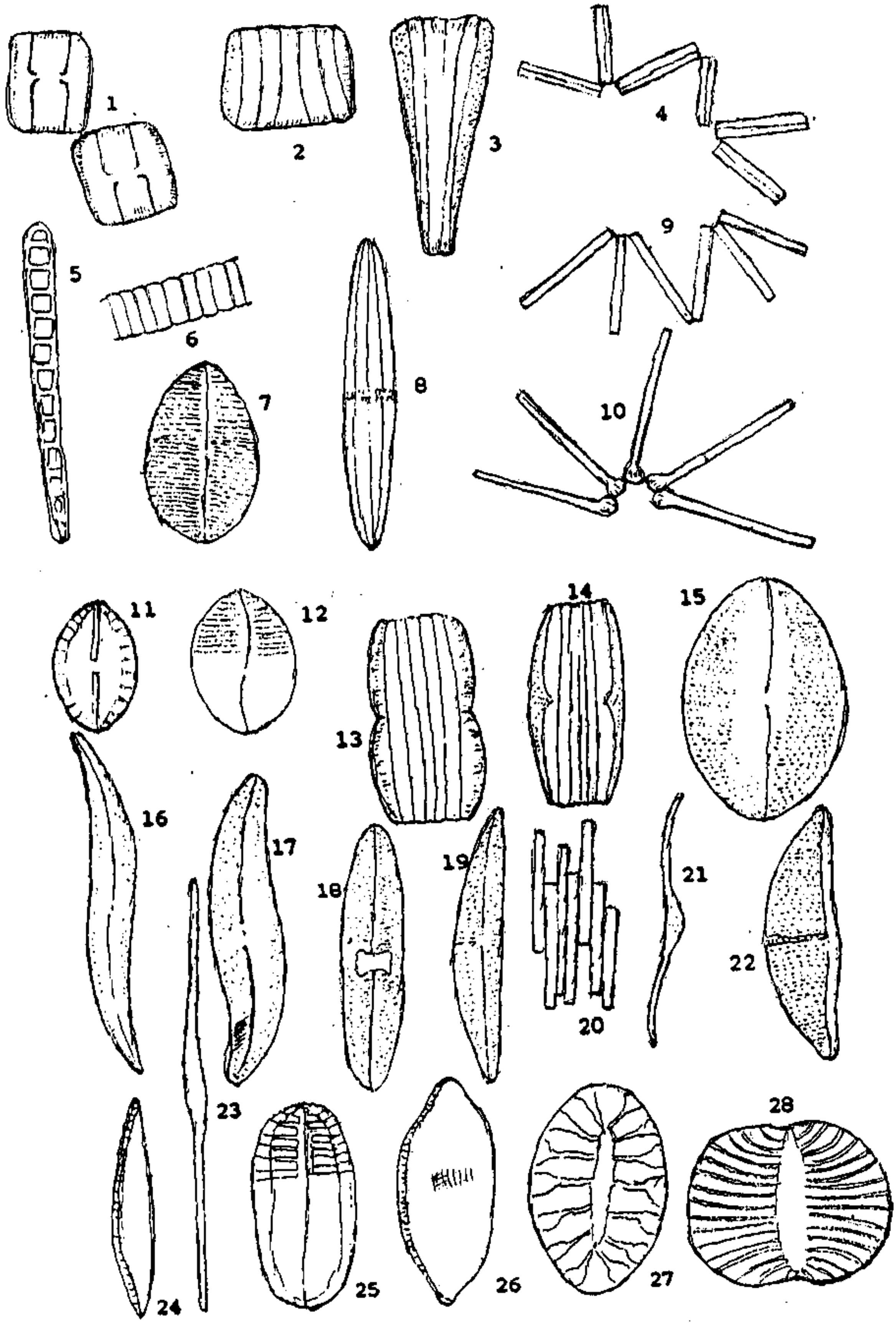


PLATE – III

Figures 1- 23

1. *Prorocentrum micans*
2. *Amphidinium cucurbita*
3. *Ceratium furca*
4. *Ceratium gravidum*
5. *Cochlodinium citron*
6. *Amphisolenia bifurcata*
7. *Oxytoxum milneri*
8. *Ceratium declinatum*
9. *Dinophysis hastata*
10. *Dinophysis caudate*
11. *Oxytoxum scolopax*
12. *Gymnodinium splendens*
13. *Ceratocorys horrida*
14. *Phalacroma doryphorum*
15. *Peridinium claudicans*
16. *Gonyaulax polygramma*
17. *Peridinium elegans*
18. *Podolampas bipes*
19. *Pyrophacus horologium*
20. *Diplopsalis sp*
21. *Ornithocercus magnificus*
22. *Dissodinium lunula*
23. *Polykrikos schwartzii*

PLATE – III
DINOFLAGELLATES

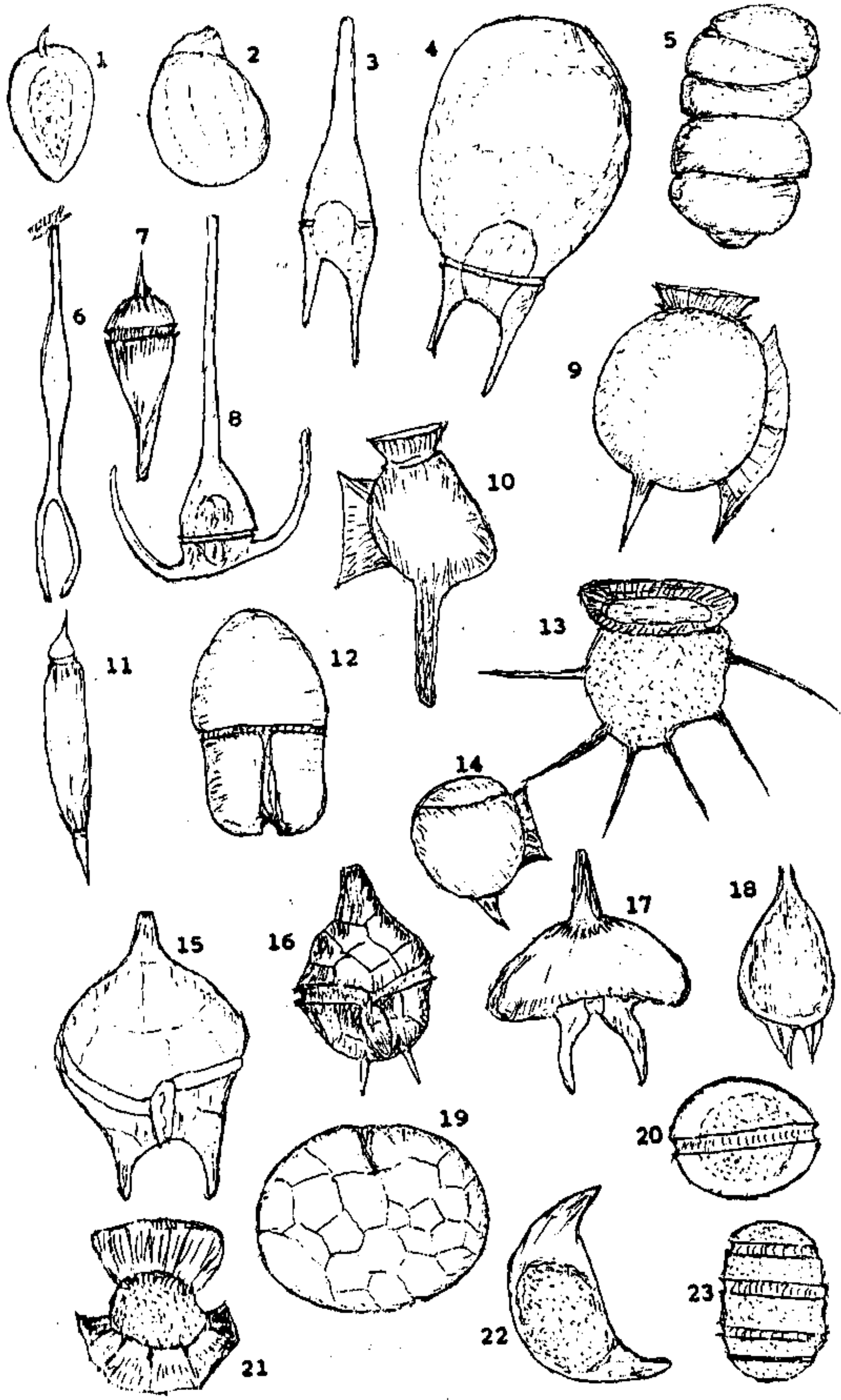


PLATE – IV

Figures 1 -24

1. *Dictyocha* sp.
2. *Coccolithus* sp
3. Blue green algal cell
4. *Distephanus* sp
5. *Trichodesmium theibautii*
6. *Trichodesmium erythreaum*

7-8. *Isochrysis galbana*

9. *Pavlova sp*

10. *Cryptochrysis fulva*

11. *Spirulina sp*

12. *Dicrateria inornata*

13. *Chromulina freibargensis*

14. *Dunaliella sp*

15. *Nannochloropsis salina*

16. *Chlorella marina*

17. *Chlorella salina*

18. *Synechocystis salina*

19- 20. *Dunaliella salina*

21. *Tetraselmis gracilis*

22. *Tetraselmis chuii*

23 –24. *Chaetoceros calcitrans*

PLATE - IV

SILICOFLAGELLATES, COCCOLITHOPHORE
BLUE-GREEN ALGAE & NANNOPLANKTON

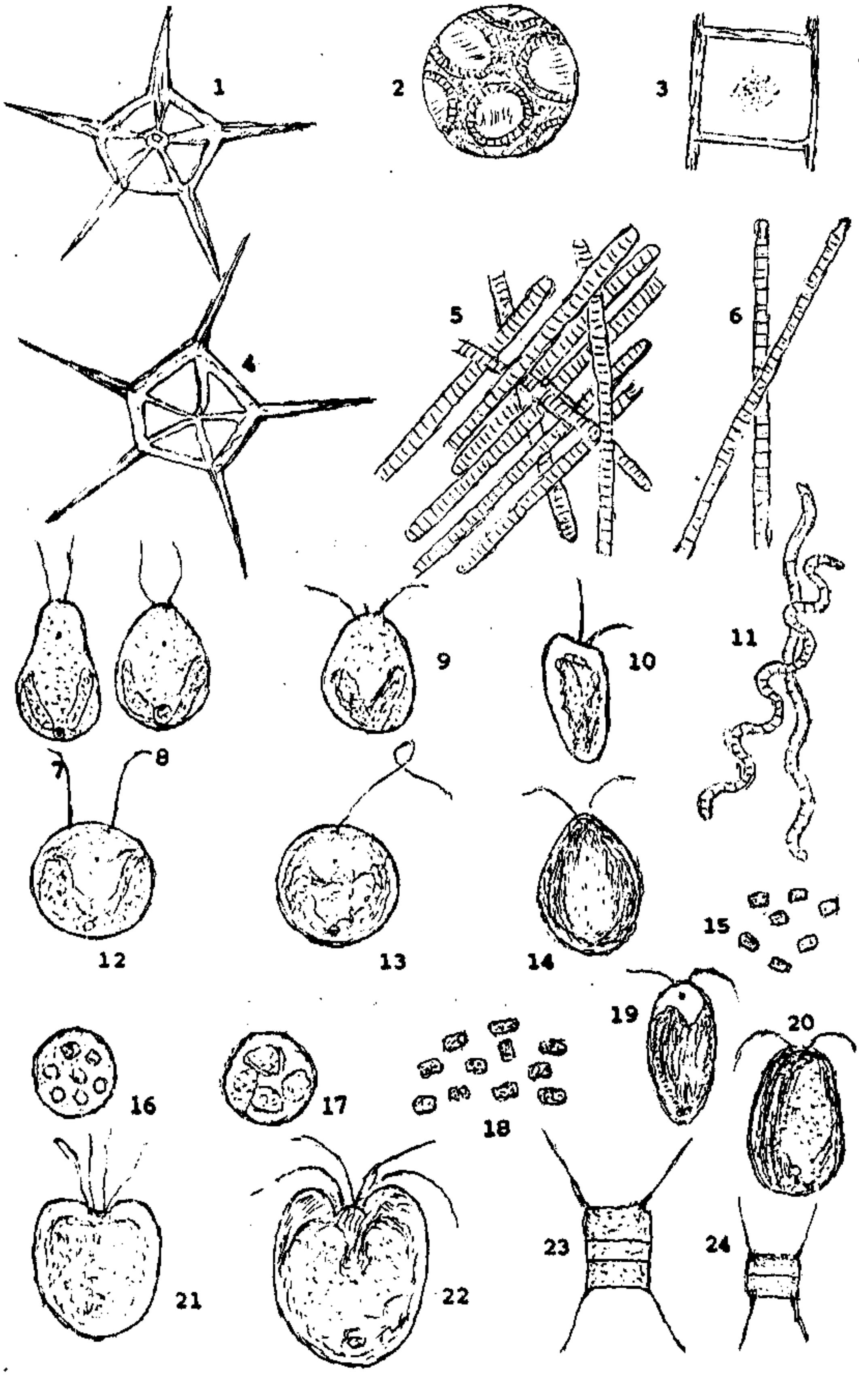
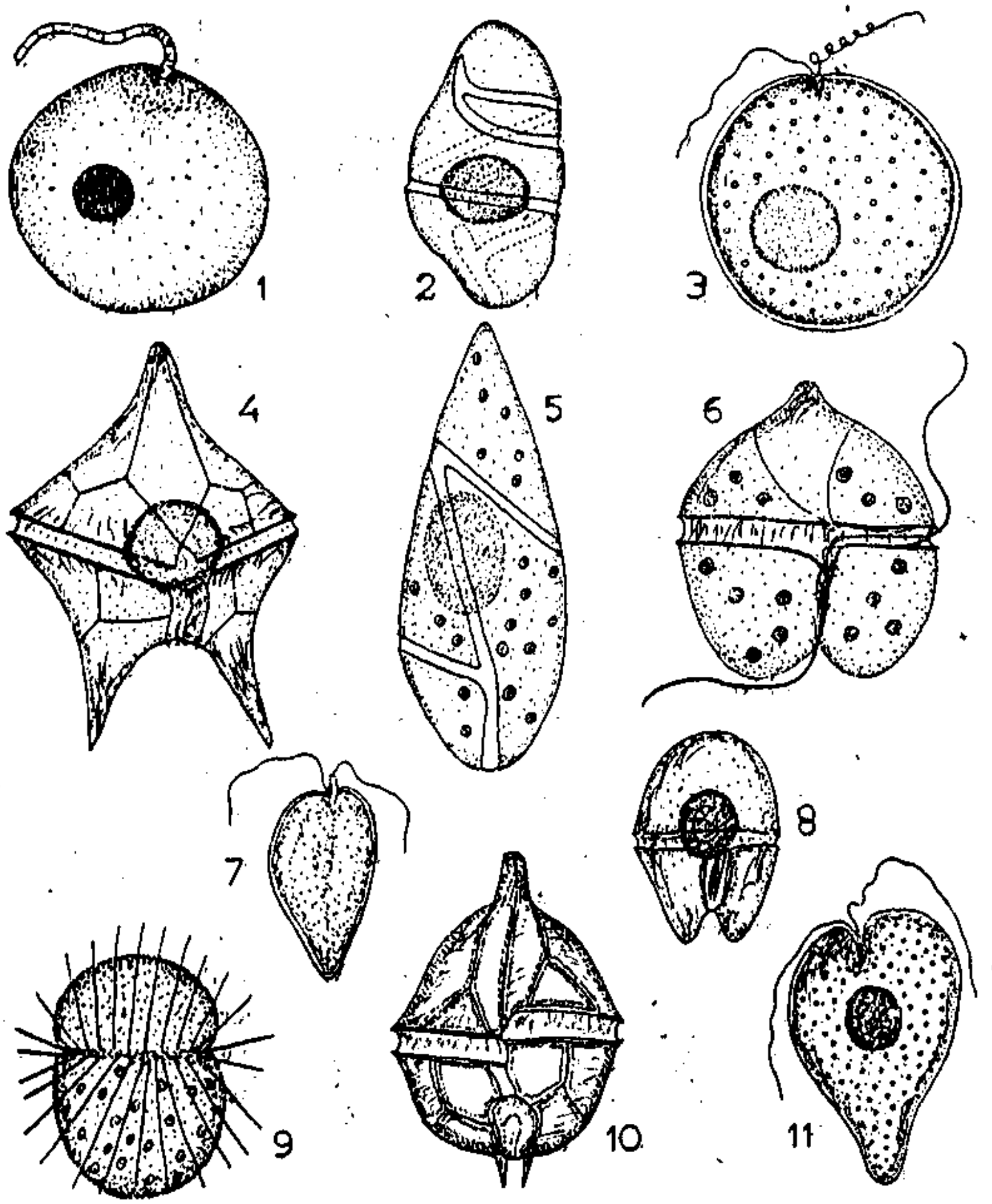


PLATE - V



Common organisms which cause the **'Red Tide'** or red water phenomenon.

1. *Noctiluca miliaris*
2. *Cochlodinium* sp.
3. *Haplodinium* sp.
4. *Peridinium* sp.
5. *Gymnodinium contortum*
6. *Gymnodinium breve*
7. *Prorocentrum micans*
8. *Gymnodinium splendens*
9. *Mesodinium rubrum*
10. *Goniaulax polygramma*
11. *Hornellia marina.*