CHAPTER 05

PHYTOPLANKTON FUNCTIONAL TYPES

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What are functional types ?

The term "functional types" emerged from biogeochemical studies. It represents the group of organisms that share common characteristic role in biogeochemical functions. In ecology, a functional type or group represents an aggregation of organisms according to some well-defined property that sets a role or "function" for them in a system. Phytoplankton Functional types (PFT) are defined as a group of organisms (irrespective of taxonomic affiliation) that carry out a particular chemical process such as calcification, silicification, nitrogen fixation, or dimethyl sulfide production; they are also referred to as "biogeochemical guilds". For example, in Nitrogen-Phytoplankton-Zooplankton (NPZ) models, P and Z are representatives of functional types, *i.e.*, producers and consumers. This aggregation is acceptable for some applications, but may be too coarse or even inappropriate for others.

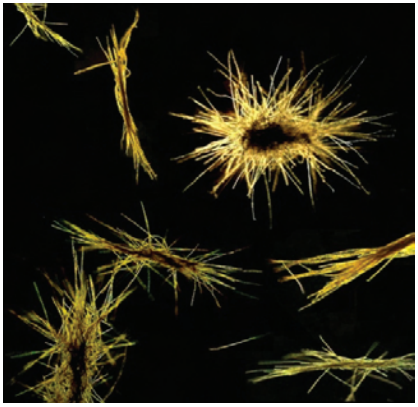
Common Phytoplankton functional types and its Distribution

In pelagic zone, phytoplankton are the dominant diverse group of unicellular microalgae, metabolically and physiologically similar to higher plants. Phytoplankton play a major role in indicating the ecology of the region and it highly contributes as a major primary producer in the food web. These organisms are key partners of carbon and nutrient cycles in the ocean. Diatoms, cyanobacteria, dinoflagellates and coccolithophores are the most dominant phytoplankton taxa in the marine waters. These groups are named as "phytoplankton functional types". Phytoplankton community structures vary from one place to another depending upon various environmental factors resulting in heterogeneous distribution patterns. The major factors that influence the distribution of phytoplankton are: (1) environmental conditions (e.g. temperature and nutrient concentrations), (2) interspecific relationships (*i.e.*, predation and competition), and (3) dispersal (Follows *et al.*, 2007). The distribution and species composition of phytoplankton determines the structure and functioning of the marine food web. Phytoplankton functional types are classified based on size into Pico plankton, Nanoplankton and Net plankton; based on groups, they are classified as Cyanobacteria, PicoEukaryotes, Diatoms and Dinoflagellates; based on ecological functions, plankton are classified as Silicifiers, Calcifiers, Nitrogen fixers and DMS producers.

Phytoplankton based on size classes:

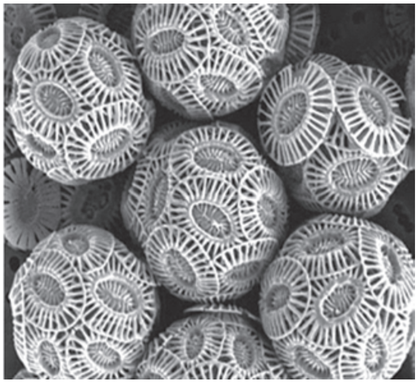
Size of phytoplankton ranges from ~0.6 μm to > 200 μm. The phytoplankton size classes are classified into picoplankton (0.2-2 μm), nanoplankton (2-20 μm) and microphytoplankton (20-200 μm). These broad size classes occupy different physical and chemical niches based on their nutrient-uptake ability, light-harvesting efficiency and sinking rate through the euphotic zone.

Nitrogen Fixers



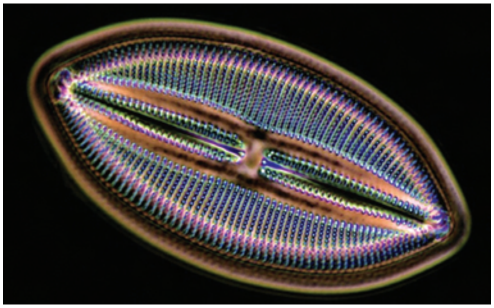
Nitrogen is an essential component for phytoplankton growth. Phytoplankton takes up nitrogen in the form of nitrite, nitrate and ammonia. Nitrogen fixing phytoplankton are also called as Diazotrophs, belong to the class cyanobacteria (blue green algae). For example, *Trichodesmicum*, bloom causing genera of blue green algae (See Image 1, source:https://alchetron.com/Trichodesmium). These organisms are capable of utilizing dissolved nitrogen gas in seawater. These functional types are symbionts, present along with other phytoplankton groups. These groups are known to contribute to nitrogen fixation. When nitrogen fixation is high,the oceanic primary production may vary from nitrogen-limited to phosphorus limited and hence affects the phosphorus cycle.

Calcifiers



Coccolithophores belong to the phylum Prymnesiophyceae. In the process of biomineralization, calcium compounds react with Hydrogen carbonate to form calcium carbonate and dissolved carbondioxide ($Ca + 2HCO_3 \longrightarrow CaCO_3 + H_2O + CO_2$). They produce calcium carbonate shells called coccoliths and are referred to as calcifying phytoplankton. Coccolithophores are the most abundant primary producers and a large contributor to the primary productivity of both the tropical and subtropical oceans. Calcifiers are estimated to produce about 0.6 and 1.2 GT calcite carbon per year. (Coccolithophores: See Image 2, source: http://rwotton.blogspot.in/2016/04/jo-athertons-anthropocene)

Silicifiers



Diatoms possess silica frustules that surround and protect the cells and are commonly known as Silicifeirs. This phytoplankton belongs to the class, Bacillariophyceae. The presence of silica frustules makes this phytoplankton negatively buoyant. They sink into the deeper waters of the ocean contributing to the transportation of carbon and nitrogen from surface to deeper waters. Other phytoplankton such as chrysophytes, silicoflagellates, and xanthophytes are also known to be silicifiers (Brownlee and Taylor,2002). SeeImage3, source:https://sites.google.com/site/botany317/session2/eukaryotes/session3/heterokonts/diatoms).

DMS producers

Phytoplankton taxa of classes: Dinophyceae, Haptophyceae (including Coccolithophores), Chrysophyceae, Pelagophyceae and prasinophyceae are referred to as DMS producers. These phytoplankton populations produce dimethyl sulfoniopropionate (DMSP) a volatile organic compound. The processes related to cell decay and grazing are involved in the transformation of DMSP to Dimethyl sulphide (DMS) in the water. DMS is responsible for the characteristic smell in the seawater. DMS is thought to play a role in the Earth's heat budget by decreasing the amount of solar radiation that reaches the Earth's surface.

Role of Phytoplankton Functional types

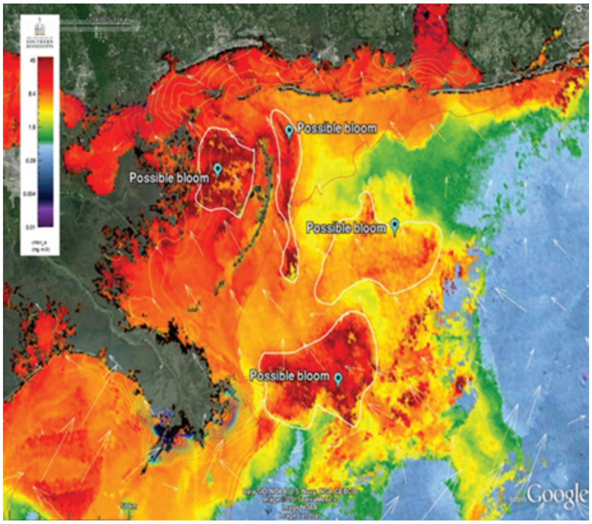
Phytoplankton play an important role in the global carbon cycle. They are responsible for fixing carbon into organic material during the process of photosynthesis. The amount of carbon emission on an annual scale is estimated to about 7 GT per annum and the process is comparable to the net production by terrestrial plants at the global scale (Longhurst, 1995). Phytoplankton functional types are major primary producers involved in the biogeochemical processes of nitrogen, phosphorous and other elements present in the surface waters of the ocean. Phytoplankton are the source of food supply for the fishery resources of the marine ecosystem. Phytoplankton composition influences the food webs and the type of fish that live in a delineated region or environment. For example, some phytoplankton functional types such as flagellates favor the growth of clupeids. Thus, phytoplankton types are also relevant in studies of fish ecology, and hence are an important ingredient in efforts towardsan ecosystem-based strategy for sustainable management of fisheries. Phytoplankton leads to harmful algal blooms, if their occurrence is in very high concentrations. This creates a low-oxygen *i.e.*, hypoxia condition creating negative impact on the fisheries environment. Dinoflagellates and diatoms are the functional types implicate harmful algal blooms in the coastal and oceanic systems.

Studying the phytoplankton diversity in the oceans at large regional scale still remains as an intractable problem. There, the remotely-sensed PFT information serves to be very useful for understanding the various ecological and biogeochemical processes in the ocean. steady rise in sea surface temperature has the potential to extend the geographic ranges of PFTs such as nitrogen fixers and picoplankton, whereas increases in ocean acidity (increase in atmospheric carbon-di-oxide levels), tend to lower the abundance of some other species.

Methods of measuring Phytoplankton Functional types

Phytoplankton identification and characterization are based on several approaches such as using microscopy studies, chromatography techniques for characterizing the functional types based on pigments, cytometry, genetic sequential molecular methods and through remote sensing. Microscopic techniques rely on optical lenses and human eyes or cameras to identify the phytoplankton species. High performance Liquid Chromatography techniques rely on detectors for absorption and fluorescence signals of phytoplankton pigments. Flow-cytometry incorporate photomultipliers or diodes to detect scattering and fluorescence properties of individual phytoplankton cells. Optical properties have the potential to be incorporated with *in situ* technologies, which provides improve space-time coverage in accessing the PFTs in the sea.

Satellite remote sensing datasets are also used to identify and characterize the phytoplankton communities. Mapping and case studies on Harmful algal blooms of Coccolithophores, Diatoms and different species of cyanobacteria at different regional scales were also carried out based on spectral band signals and validated algorithms. Phytoplankton functional types were also studied by determining the size structures of the phytoplankton communities using two approaches: abundance based approach and spectral based approach. Abundance based approach uses the expected size structure of the phytoplankton at a given pixel, based on *in situ* correlations between



size structure and phytoplankton abundance. Spectral-based approaches are more direct, as they rely on observing distinct optical signatures (absorption, reflectance and backscattering). An example ocean colour satellite image from Visible Infrared Imaging Radiometer Suite coupled with modeled data to delineate the possible phytoplankton bloom is presented in the Image 4 (source: Ocean Weather Laboratory).

Each method has both advantages and disadvantages in characterization of phytoplankton communities. Hence, integrated approaches from different methodologies can lead to more comprehensive assessments and understanding of the PFTs on a synoptic scale. In future, expansion and advances in *in situ* sensors and deployment modes emphasizing high resolution time series sites and numerous mobile platforms will be advancing approaches to address the technical limitations to address the technical limitations to study these microscopic organisms.

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