ECOLOGY OF PLANKTON

Key words: Phytoplankton, Producer, Productivity

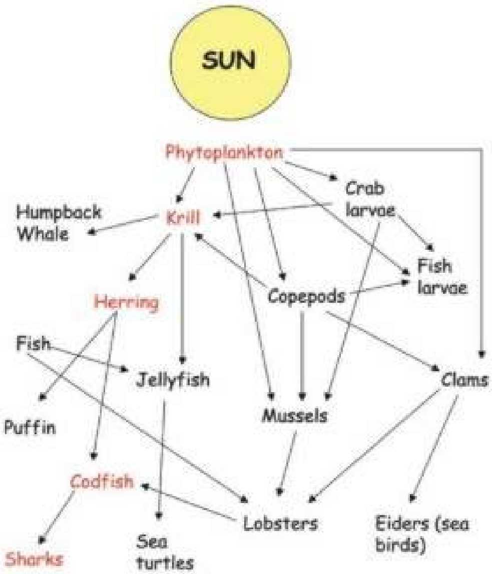

Fig – 19.1

INTRODUCTION

Plankton are those organisms which live suspended in the water of seas, lakes, ponds, and rivers, and which are not able to swim against the currents of water. This latter feature distinguishes plankton from nekton, the community of actively swimming organisms like fish, larger cephalopods, and aquatic mammals. Plankton range in size from ca. 0.2 gm to several meters (large jellyfish), but only the small ones have been the objects of intensive research, the Antarctic krill being the only well-studied plankton organism of > 5 mm.

Plankton form complex biotic communities which are functionally as diverse and show the same richness of interaction as terrestrial communities. Plankton are defined by their ecological niche rather than their phylogenetic or taxonomic classification. They provide a crucial source of food to larger, more familiar aquatic organisms such as fish.

The name **plankton** is derived from the Greek adjective *planktos*, meaning "errant", and by extension "wanderer" or "drifter". By definition, organisms classified as plankton are unable to resist ocean currents. While some forms are capable of independent movement and can swim hundreds of meters vertically in a single day (a behavior called diel vertical migration), their horizontal position is primarily determined by the surrounding currents. This is in contrast to **nekton** organisms that can swim against the ambient flow and control their position (e.g. squid, fish, and marine mammals).

Within the plankton, **holoplankton** spend their entire life cycle as plankton (e.g. most algae, copepods, salps, and some jellyfish). By contrast, **meroplankton** are only planktic for part of their lives (usually the larval stage), and then graduate to either the nekton

or a benthic (sea floor) existence. Examples of meroplankton include the larvae of sea urchins, starfish, crustaceans, marine worms, and most fish.
Plankton abundance and distribution are strongly dependent on factors such as ambient nutrients concentrations, the physical state of the water column, and the abundance of other plankton. The study of plankton is termed planktology and individual plankton are referred to as **plankters**.

Functional groupings:

- **Phytoplankton** (from Greek *phyton*, or plant),

  Autotrophic, prokaryotic or eukaryotic algae that live near the water surface where there is sufficient light to support photosynthesis. Among the more important groups are the diatoms, cyanobacteria, dinoflagellates and coccolithophores.

- **Zooplankton** (from Greek *zoon*, or animal),

  Small protozoans or metazoans (e.g. crustaceans and other animals) that feed on other plankton and telonemia. Some of the eggs and larvae of larger animals, such as fish, crustaceans, and annelids, are included here.

- **Bacterioplankton**,

  Bacteria and archaea, which play an important role in remineralising organic material down the water column (note that the prokaryotic phytoplankton are also bacterioplankton).

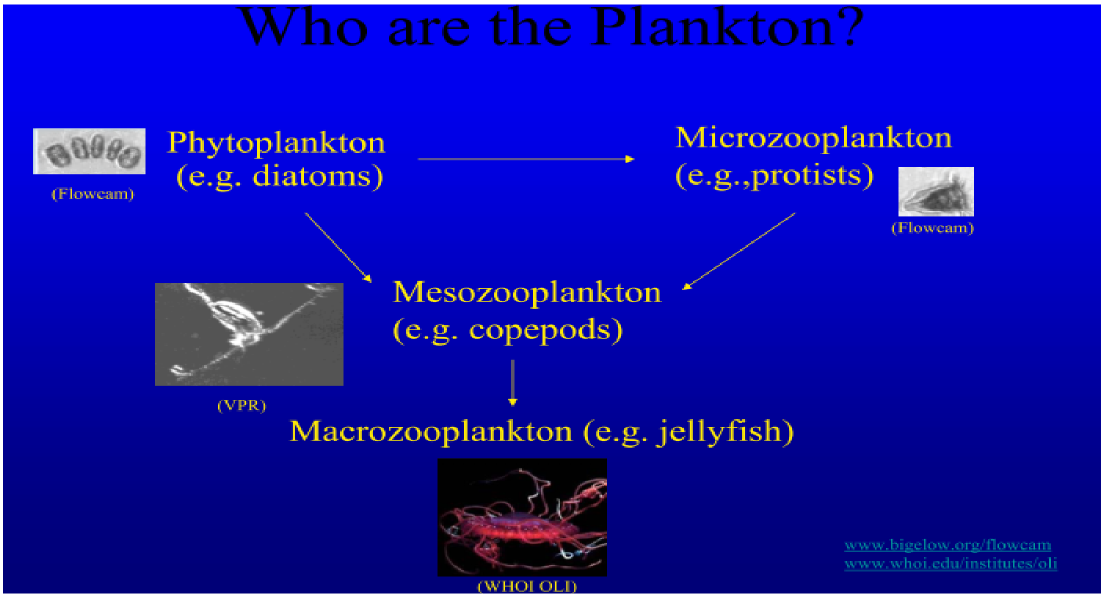

Fig – 19.2

This scheme divides the plankton community into broad **producer**, **consumer** and **recycler** groups. However, determining the trophic level of some plankton is not straightforward. For example, although most dinoflagellates are either photosynthetic producers or heterotrophic consumers, many species are mixotrophic depending upon their circumstances.

Distribution

Plankton inhabit oceans, seas and lakes. Local abundance varies horizontally, vertically and seasonally. The primary cause of this variability is the availability of light. All plankton ecosystems are driven by the input of solar energy (but seechemosynthesis), confining primary production to surface waters, and to geographical regions and seasons having abundant light.

A secondary variable is nutrient availability. Although large areas of the tropical and sub-tropical oceans have abundant light, they experience relatively low primary production because they offer limited nutrients such as nitrate, phosphate and silicate. This results from large-scale ocean circulation and water column stratification. In such regions, primary production usually occurs at greater depth, although at a reduced level (because of reduced light).

Despite significant macronutrient concentrations, some ocean regions are unproductive (so-called HNLC regions). The micronutrient iron is deficient in these regions, and adding it can lead to the formation of blooms of many kinds of phytoplankton. Iron primarily reaches the ocean through the deposition of dust on the sea surface. Paradoxically, oceanic areas adjacent to unproductive, arid land thus typically have abundant phytoplankton (e.g., the western Atlantic Ocean, wheretrade winds bring dust from the Sahara Desert in north Africa). While plankton are most abundant in surface waters, they live throughout the water column. At depths where no primary production occurs, zooplankton and bacterioplankton instead consume organic material sinking from more productive surface waters above. This flux of sinking material, so-called marine snow, can be especially high following the termination of spring blooms.

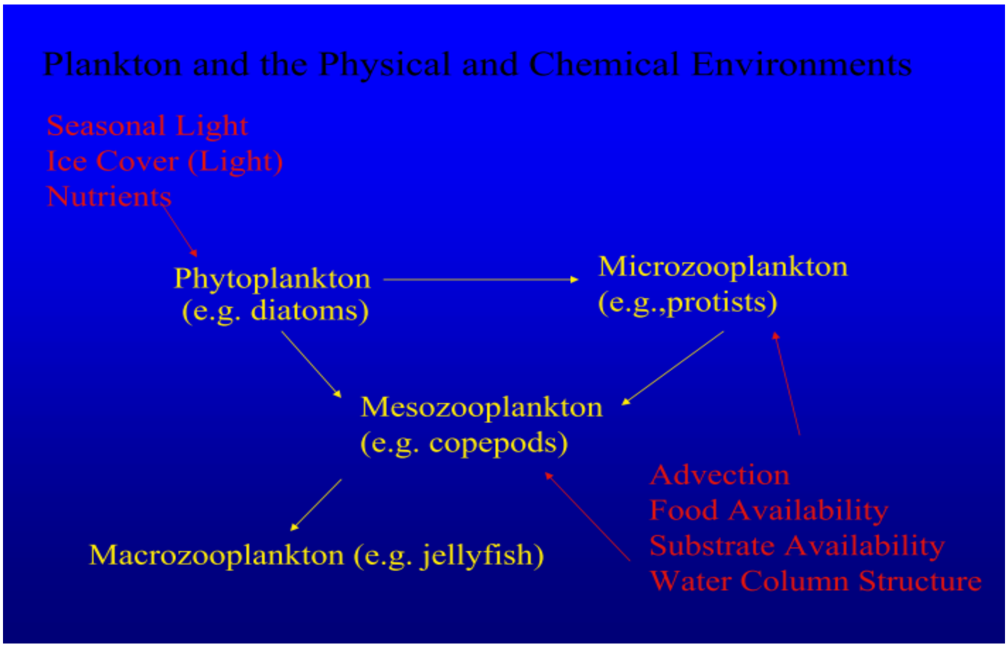

Fig – 19.3

Because of the central role of plankton in the functioning open-water foodwebs and ecosystems, plankton ecology has always been a core discipline of limnology and biological oceanography. Beyond their importance for aquatic systems, plankton are most suitable model organisms for classic topics of general ecology, such as competition, predator-prey relationships, food-web structure, succession, transfer of matter, and energy. Small size, rapid population growth (doubling times < 1 day for bacteria and small phytoplankton to several days or weeks for zooplankton), high abundances (millions per ml for bacteria, millions per 1 for phytoplankton), and a relatively homogeneous distribution in their environment facilitate field and experimental studies. Processes which take years to centuries in terrestrial systems, like competitive exclusion and succession, take only weeks in plankton.

The phytoplankton:

The plantlike community of plankton is called phytoplankton, and the animal-like community is known as zooplankton. This convenient division is not without fault, for strictly speaking, many planktonic organisms are neither clearly plant nor animal but rather are better described as protists. When size is used as a criterion, plankton can be subdivided into macroplankton, microplankton, and nannoplankton, though no sharp lines can be drawn between these categories. Macroplankton can be collected with a coarse net, and morphological details of individual organisms are easily discernible. These forms, one millimetre or more in length, ordinarily do not include phytoplankton. Microplankton (also called net plankton) is composed of organisms between 0.05 and 1 mm in size and is a mixture of phytoplankton and zooplankton. The lower limit of its size range is fixed by the aperture of the finest cloth used for plankton nets. Nannoplankton (dwarf plankton) passes through all nets and consists of forms of a size less than 0.05 mm. Phytoplanktonic organisms dominate the nannoplankton.

Size groups:

Group	Size range (ESD)		
Megaplankton	> $2x10^{-2}$m	(20+mm)	Metazoans; e.g. jellyfish; cteanophores; salps and pyrosomes (pelagic Tunicata); Cephalopoda
Macroplankton	$2x10^{-3}$–$2x10^{-2}$m	(2-20 mm)	Metazoans;*e.g.* Pteropods;Chaeto gnaths; Euphausiacea(krill);
Mesoplankton	$2x10^{-4}$-$2x10^{-3}$m	(0.2mm-2mm)	Metazoans;e.g.copepods; Medusa e; Cladocera; Ostracoda
Microplankton	$2x10^{-5}$-$2x10^{-4}$m	(20-200μm)	large eukaryotic protists;most ph ytoplankton; Protozoa (Foraminif era); ciliates; Rotifera;juvenile m etazoans -Crustacea (copepod nauplii)
Nanoplankton	$2x10^{-6}$-$2x10^{-5}$m	(2-20 μm)	small eukaryotic protists;Small D iatoms;Small Flagellates; Pyrroph yta; Chrysophyta; Chlorophyta; Xanthophyta
Picoplankton	$2x10^{-7}$-$2x10^{-6}$m	(0.2-2 μm)	small eukaryotic protists; bacteria ; Chrysophyta

Femtoplankton	$< 2x10^{-7}m$	(<0.2 µm)	marine viruses

However, some of these terms may be used with very different boundaries, especially on the larger end of the scale. The existence and importance of nano and even smaller plankton was only discovered during the 1980s, but they are thought to make up the largest proportion of all plankton in number and diversity. The microplankton and smaller groups are microorganisms and operate at low Reynolds numbers, where the viscosity of water is much more important than its mass or inertia.

The chief components of marine phytoplankton are found within the algal groups and include diatoms (see phytoplankton video), dinoflagellates and coccolithophorids. Silicoflagellates, cryptomonads, and green algae are found in most plankton samples. Freshwater phytoplankton, usually rich in green algae, also includes diatoms, blue-green algae, and true flagellates.

The zooplankton:

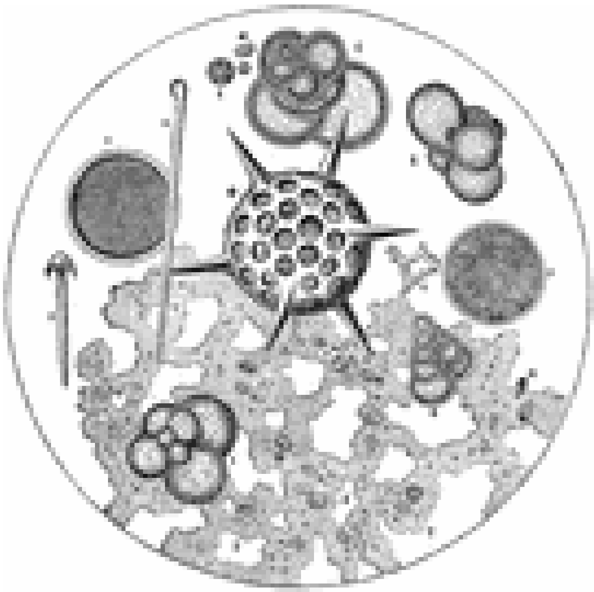

Fig – 19.4

The zooplankton is divided into two groups. **Temporary plankton** consists of planktonic eggs and larvae of members of the benthos and nekton; **permanent plankton** includes all animals that live their complete life cycles in a floating state. The temporary plankton, particularly abundant in coastal areas, is characteristically seasonal in occurrence, though variations in spawning time of different species ensure its presence in all seasons. Representatives from nearly every phylum of the animal kingdom are found in the permanent plankton. Among the protozoans, planktonic foraminiferans and radiolarians are so abundant and widespread that their skeletons constitute the bulk of bottom sediments over wide ocean areas. They are absent in fresh water. The ciliate protozoans are represented mainly by the tintinnids, which are between 20 and 640 microns in size and sometimes occur in vast numbers. Among the planktonic coelenterates are the beautiful siphonophores (*e.g., Physalia,* the Portuguese man-of-war) and the jellyfishes. Planktonic ctenophores, called comb jellies, or sea walnuts, are also common. Freshwater rotifers may be present in plankton in vast numbers during the warmer seasons. A group of organisms that can be found at all latitudes, both in surface water and at great depths, are the marine arrowworms (*e.g., Sagitta*), important planktonic predators. Oysters, mussels, other marine bivalves, and snails begin life as planktonic larvae. The wing snails (Pteropoda) spend their entire life cycles as plankton.

Crustaceans are the most important members of the zooplankton. They are the marine counterparts of insects on land; on land, as in the sea, the arthropods are the most diverse and numerous of all animal phyla. The copepod *Calanus finmarchicus* is important as food for the herring, and the euphausiid *Euphausia superba,* commonly known as krill, is the main food source for blue and finwhales in the Antarctic Ocean. These whales, particularly blue and finback whales, migrate to waters where spawning of these crustaceans occurs; and the rapid growth of these large mammals, feeding entirely on plankton, is impressive.

There is a pronounced tendency for zooplankton to perform diurnal vertical migrations in both lakes and the sea. This migratory behaviour varies with stages in the life cycle, seasons of the year, latitude, hydrographic structure, and meteorological conditions. Generally, the animalsascend toward the surface at sunset from daytime depths. At midnight, if there is no optical stimulus (*e.g.,* moon, artificial light), some of the animals return to the daytime depths, then approach the surface once again just before dawn. As the sun rises, all descend to their daytime level.

Bacteria and fungi:

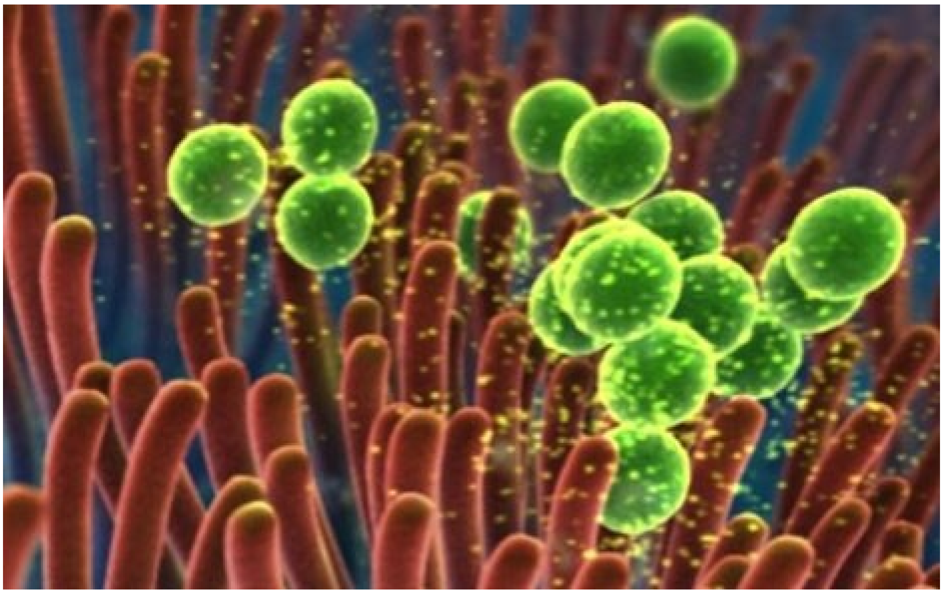

Fig – 19.5

Bacteria and fungi found in water belong by definition to plankton, but, because of special techniques required for sampling and identification, they usually are considered separately. These organisms are important in the transformation of dead organic materials to inorganic plant nutrients. Some of these marine and freshwater microorganisms (including blue-green algae) fix molecular nitrogen from water containing dissolved air, forming ammonia or related nutrients important for phytoplankton growth. Although little is known about the extent of nitrogen fixation, bacteria and fungi always are found in water samples. A peculiar

situation exists in the Black Sea, where water below 130–180 m contains hydrogen sulfide and no oxygen. Under these conditions only bacteria are found.
Ecosystems consist of populations, which in turn consist of individuals that interact with one another and with the environment. Biological interactions in the ocean are not between populations or between trophic levels, as many box-model representations of pelagic food webs might lead us to think. Trophic levels and populations are abstractions, and interactions occur at the level of the individual. "Blind" sampling of bulk properties may result in observed distributional patterns, for example, that cannot be understood and explained from such an approach on its own. The picture must be complemented by approaches that consider the individual in its immediate environment and that provide a mechanistic understanding of the functioning of individuals and of components of the larger systems.

This allows us to build models and to extrapolate observations beyond the system in which the observations were made. Traditionally, scientists who go on cruises and examine distribution patterns of both biota and environmental properties using sampling are considered biological oceanographers, and those who explore the functioning of individuals, for example by conducting laboratory experiments with organisms, are considered marine biologists. We need to combine the two approaches to understand the ecology of the oceans.

The motivation to try to understand the ecology of planktonic organisms is twofold. The first driving force has to do with a simple interest in natural history. It is fascinating to watch the behavior of live plankters under the microscope or—better—free- swimming plankters by video; they have different but often beautiful forms and colors, and even closely related species may behave very differently, which makes identifying live plankton much easier than identifying dead ones. The second reason for examining the adaptations and behavior of plankters is our interest in understanding overall properties of pelagic systems and how the pelagic system relates to the larger- scale issues of fisheries' yield, CO_2 balance, global climate, and others. Understanding the mechanistics of individual behaviors and interactions may allow us to predict rates and to scale rates to sizes, which, in turn, may help us understand the (size) structure and function of pelagic systems and to predict effects of environmental changes and human impacts.

The Encounter Problem:

Life is all about encounters. In the ocean, for example, phytoplankton cells need to encounter molecules of nutrient salts and inorganic carbon; bacteria need to encounter organic molecules; viruses need to encounter their hosts; predators need to encounter their prey; and males need to encounter females (or vice versa). Other important processes in the ocean, such as the formation of marine snow aggregates, likewise depend on encounters, here encounters between the component particles.

All organisms, including plankters, have three main tasks in life, namely to eat, to reproduce, and to avoid being eaten, all related to encounters or avoiding encounters. The behavior, morphology, and ecology of planktonic organisms must to a large extent represent adaptations to undertake these missions, and the diversity of form, function, and behavior that we can observe among plankters must be the result of different ways of solving the problems in the environment in which they live.The pelagic environment seen from the point of view of a small plankter is very different from the environment experienced by humans, and our intuition is often insufficient to allow us to understand the behavioural adaptations of planktonic organisms. Thus, although ornithologists to a large extent may be able to understand the behavior of their study organisms by using common sense, copepodologists rarely can, to rephrase the title of a classical ecology paper (Hutchinson 1951). For example, at the scale of planktonic organisms, the medium is viscous, and inertial forces therefore are insignificant, which makes moving an entirely different undertaking than what we as humans are used to or have seen other terrestrial animals do; the density of water is orders of magnitude higher than the density of air, which makes floatation easier and currents more important; for the smallest pelagic organisms (bacteria), thermally driven Brownian motion makes steering impossible; and most plankton use senses different from, and less far-reaching than, vision to perceive the environment. In addition, the pelagic environment is three-dimensional, whereas humans mainly move in only two dimensions. This implies, among other things, which average distances between a planktonic organism and its target may be very large, maybe thousands of body lengths. Because of the often non-intuitive nature of the immediate environment of small pelagic organisms, we need to appeal to fluid dynamic considerations in order to achieve a mechanistic understanding of the small- scale interactions between plankters and their environment.

In pursuing the encounter problem we can write a very general equation that describes encounter rates

$$E = \beta C1C2 \qquad (1.1a)$$

where E is the number of encounters happening per unit time and volume between particle types 1 and 2, C1 and C2 are the concentrations of these particles, and β is the encounter rate kernel (L3T − 1). Often we are interested in looking at the per capita rate, that is, the rate at which one particle of type 1 encounters a particle of type 2:

$$e = E/C1 = \beta C2 \qquad (1.1b)$$

For example, if particle 1 is a suspension-feeding ciliate and C2 the concentration of its phytoplankton prey, then β is the ciliate's clearance rate, and e its ingestion rate (assuming that all encountered particles are ingested). The clearance rate is the equivalent volume of water from which the ciliate removes all prey particles per unit time. In many suspension-feeding ciliates, the clearance rate can be interpreted directly as a filtration rate; that is, the rate at which water is passed through a filtering structure that retains suspended particles. As a different but similar example: if particle 1 is a fish larva looking for food, and particle 2 its microzooplankton prey, then β is the volume of water that the larvae can search for prey items per unit time; if all encountered prey are consumed, then e is the ingestion rate of the fish larva. We may also see the process from the point of view of the prey, in which case βC1 is the mortality rate of the phytoplankton or microzooplankton prey population through ciliate grazing or fish larval feeding. As a final example: if C1 is the concentration of bacteria, and C2 the concentration of organic molecules on which the bacteria feed, then e is the assimilation rate; it is more difficult to give a physical interpretation of β in this case. However, it is, like a clearance rate, the imaginary volume of water from which the bacterium removes all molecules per unit time. In fact, any encounter problem can be cast in terms of the general equation (eq. 1), but obviously the interpretation or meaning of the terms may be very different. The processes or mechanisms responsible for encounters are contained in the encounter-rate kernel. Obviously, from the examples above, these mechanisms are diverse. Intuitively, encounter rates depend on two factors: the motility of the encountering "particles" and the ambient fluid motion that may enhance encounter rates. Motility encompasses here the diffusivity of molecules, the swimming of organisms, and the sinking of particles. In regard to planktonic organisms, ambient fluid motion essentially means turbulence because planktonic organisms (contrary to benthic ones) are embedded in the general flow. From this consideration, one can see that there may be different components entering into the encounter-rate kernel depending on the specific problem under consideration.

Plankton and biological productivity:

Fig – 19.6

Plankton is the productive base of both marine and freshwater ecosystems, providing food for larger animals and indirectly for humans, whose fisheries depend upon plankton. The productivity of an area is dependent upon the availability of nutrients and water-stability conditions. Currents that flow near continents are important to plankton production in an area. The California Current (a continuation of the Kuroshio Drift from Japan) causes an outland transport of water and combines with a compensating nutrient-rich current along the coast of California to make this area highly productive. The same situation exists along the west coast of southern Africa, which is influenced by the Benguela Current, and off the west coast of South America, influenced by the Peru Current.

In the sea an adequate supply of nutrients, including carbon dioxide, enables phytoplankton and benthic algae to transform the light energy of the Sun into energy-rich chemical components through photosynthesis. The bottom-dwelling algae are responsible for about 2 percent of the primary production in the ocean; the remaining 98 percent is attributable to phytoplankton. Most of the phytoplankton serves as food for zooplankton, but some of it is carried below the light zone. After death, this phytoplankton undergoes chemical mineralization, bacterial breakdown, or transformation into sediments. Phytoplankton production usually is greatest from 5 to 10 m below the surface of the water. High light intensity and the lack of nutrient in the regions above a depth of 5 m may be the causes for suboptimal photosynthesis. Although bacteria are found at all depths, they are most abundant either immediately below great phytoplankton populations or just above the bottom.

As a human resource, plankton has only begun to be developed and exploited. It may in time be the chief food supply of the world, in view of its high biological productivity and wide extent. It has been demonstrated on several occasions that large-scale cultures of algae are technically feasible. The unicellular green alga *Chorella* has been used particularly in this connection. Through ample culture conditions, production is directed toward protein content greater than 50 percent. Although this protein has a suitable balance of essential amino acids, its low degree of digestibility prevents practical use. Phytoplankton may become increasingly important in space travel as a source for food and for gas exchange. The carbon dioxide released during respiration of spacecraft personnel would be transformed into organic substances by the algae, while the oxygen liberated during this process would support human respiration.

Source:
http://nptel.ac.in/courses/120108002/19