

ZOOPLANKTON – STUDY METHODS, IMPORTANCE AND SIGNIFICANT OBSERVATIONS

S. N. Gajbhiye

National Institute of Oceanography
Regional Centre, Lokhandwala Road,
Four Bungalow, Andheri (w), Mumbai – 400 053

INTRODUCTION

The intent of this section is to review briefly current knowledge of the structure and dynamics of the zooplankton and its ecology. Zooplankton are mysids of animal organisms that drift with currents. In an aquatic ecosystem zooplankton form an important link in the food chain from primary to tertiary level leading to the production of fishery. It has been well established that potentials of pelagic fishes viz. finfishes, crustaceans, mollusks and marine mammals either directly or indirectly depend on zooplankton. By virtue of sheer abundance and intermediary role between phytoplankton and fish, they are considered as the chief index of utilization of aquatic biotope at the secondary trophic level. The herbivorous zooplankton are efficient grazers of the phytoplankton and have been referred to as living machines transforming plant material into animal tissue. Hence they play an important role as the intermediaries for nutrients/energy transfer between primary and tertiary trophic levels. Due to their large density, shorter life span, drifting nature, high group/species diversity and different tolerance to the stress, they are being used as the indicator organisms for the physical, chemical and biological processes in the aquatic ecosystem. In the deeper water they occur at different depths and constitute a complicated ecological system worthy of special attention.

DEFINITION OF PLANKTON

It is the plankton with which we are concerned here. This word originates from the Greek meaning "Wandering". Plankton as a term was first used by Victor Hensen (1887) for the aquatic communities of floating and drifting organisms which are carried primarily by movement of water current rather by their own swimming ability. While this is so, it must be remembered that, considering their small size, many plankton animals are strong swimmers and are capable of moving through relatively long distances over a period of time, particularly in a vertical direction. Plankton includes organisms of both plant and animal origin. The plant component of the plankton is called phytoplankton and the animal component is called as zooplankton. There is a third group which can absorb dissolved organic matter called as saproplankton. The majority of phytoplankton belong to Chlorophyceae, Cyanophyceae and Bacillariophyceae.

Their unique ability to fix inorganic carbon to build up organic matter through primary production makes them very important in food web.

Zooplankton consists mostly of invertebrates and larvae, immature stages of both invertebrates and vertebrates. Most of the zooplankton in freshwater are members of three main taxonomic groups i.e. protozoa, rotifera and crustacea. The marine environment differs mainly in having few rotifers or cladocera, more extensive representation of protozoa groups and widespread occurrence of planktonic larvae of sedentary forms ranging from mollusks and malacostracan to chordata. During the decades following Hensen's early investigations, advances in techniques of taxonomy, ecological sampling and chemical analysis provided more detailed information on the ecology of zooplankton.

CLASSIFICATION

1 Based on size

Irrespective of the fact, whether plankton belongs to plant or animal origin, it is divided into two groups.

- (i) **Euplankton** - All true plankton.
- (ii) **Pseudoplankton** – Dead plankton and non-living debris.

Zooplankton are characterized by their faunal diversity compared to phytoplankton and include arrays of animal organisms, varying in size from the microscopic protozoans of a few microns to some jelly fish with tentacles of several metres. No single system of classification has been adopted universally. They have been classified into several groups by size (Cushing *et al.*, 1958).

(i)	Ultraplankton	:	< 5 μ m
(ii)	Nanoplankton	:	5-60 μ m
(iii)	Microplankton	:	1-500 μ m
(iv)	Mesoplankton	:	0.5-1.0 mm
(v)	Macroplankton	:	1-10 mm
(vi)	Megaplankton	:	10 mm

The larger planktonic organisms (20-100 mm) are called micronekton. Depending upon the size (Raymont, 1983), the zooplankton are divided into megaloplankton, macroplankton, mesoplankton, microplankton and nanoplankton.

2 Ecological classification

A. Marine plankton (haloplankton)

- (i) **Neritic plankton** : Those inhabiting waters overlying continental shelves.
- (ii) **Oceanic plankton** : Those inhabiting waters beyond continental shelves.
- (iii) **Brackishwater plankton** : Those inhabiting in brackishwater, also known as hypalmyroplankton.

B. Freshwater plankton : Those inhabiting in freshwater, also designated as limnoplankton (lake plankton), heloplankton (pond plankton) and rheoplankton or potamoplankton (running or lotic water plankton).

3 Based as per depth distribution

- (i) **Pleuston** : Those living at the surface of the sea, part of whose bodies project in to the air. Example – Physalia and velella.
- (ii) **Neuston** : Living in the uppermost part (few to 10 mm) of the surface layer.
- (iii) **Epipelagic** : Living between 0-200 m.
- (iv) **Mesopelagic** : Living between about 200 and 1000 m in daytime.
- (v) **Bathypelagic** : Living below 1000 m.

4 By length of planktonic life

- (i) **Holoplankton (Permanent plankton)** : Those living as plankton during their entire life. Example – Chaetognaths, copepods
- (ii) **Meroplankton (Temporary plankton)** : Those living as plankton during only a part of their life. Example – Eggs and larval stages of fishes

5 By food habit

- (i) **Herbivores** : Those zooplankton feeds on phytoplankton are called as herbivores. Example – Copepods, shrimps
- (ii) **Carnivores** : Those zooplankton feeds on other small zooplanktons are called as carnivores. Example – Chaetognaths, ctenophores, etc.
- (iii) **Omnivores** : Those zooplankton feeds both on phytoplankton and zooplankton are called omnivores.

STUDIES ON ZOOPLANKTON

Studies on secondary production are limited because at present there is no simple *in situ* method for its measurement comparable to the techniques used for measuring primary productivity. The zooplankton patchiness generally renders the extrapolation of the data from a sample to a larger volume of water rather inconsistent notwithstanding this constraints. Secondary production has been measured from the zooplankton biomass values which represent the zooplankton standing stock.

1 Sampling

The sampling design is as important as the analysis and techniques used in the laboratory because field sampling provides the most valuable information for investigating the ecology of plankton in nature.

1.1 Choice of methods

Zooplankton is distributed in the seas as well as in ponds, swamps and rivers. It is almost impossible to sample the entire zooplankton assemblage of particular interest by using a single method. Many factors like sampling gear, frequency of sampling, horizontal and vertical migration of species, influence the distribution of zooplankton. Uniformity in sampling methods is necessary for comparison of data over a wide geographical areas. The zooplankton studies involve collection of samples, fixation and preservation, analysis and computation of data.

1.2 Sample collection

Plankton sampling can be divided into three types :

- (i) By bottle, (ii) With a pump and (iii) With a net

Bottle samples are used for the very small organisms. A water-sampling bottle is lowered into the water, and when it reached the required depth a messenger is sent. However, since only a small volume of water is sampled it is not very useful. Sampling with a pump also is not very useful due to disadvantages and limitations.

Methods of plankton sampling in which nets are common. The basic shape of plankton net is a cone. Various types of nets are used to collect plankton. They are :

- (i) Bongo net, (ii) WP2 net, (iii) Indian Ocean Standard Net (IOSN) and (iv) H.T.net

Most of the sampling methods depend upon the catching power of netting material. The mesh size of the net, towing speed, clogging, patchiness, avoidance etc. will determine the quality and quantity of zooplankton.

In my center and most of the laboratories in India are using Heron Tranter Net for horizontal or oblique hauls

and IOSN nets for vertical haul.

1.3 Flowmeter

It measures the volume of water which passes through a plankton net. The water which is passed over the rotor vanes causes the whole rotor to rotate. The rotor is connected to a gear train so that a given number of rotations is equal to one unit on the dial. Before first use, the flowmeter is calibrated so that one unit of this dial is related to a certain volume of water.

2 Fixation and preservation of sample

Proper fixation and preservation of zooplankton is very important. The sample should be fixed immediately to prevent decay of organisms. The poorly fixed organisms would make their subsequent identification and analysis difficult. Analytical grade buffered formalin (4-5%) is commonly used as fixative. Various type of preservatives are available. The choice is made according to taxonomic group of zooplankton and type of studies to be undertaken. The wide-mouthed polythelene containers with screw lid are recommended for storing the samples. The samples are to be kept in a dark room for subsequent analysis.

3 Analysis

The basic analysis of zooplankton measurement of biomass, enumeration of common groups, percentage composition and species identification. The methods of analysis selected will depend on the objective.

3.1 Biomass

This can be given as one of the following measures.

- (i) Wet weight, (ii) Dry weight and (iii) Volume

Before determining biomass, large organisms such as large medusae, big fish larvae etc. should be removed and recorded separately.

3.2 Population count

This is the most time consuming part of zooplankton analysis. Information on the faunal composition and abundance of different zooplankton can be obtained by counting the organisms present in the sample.

3.3 Volume of water filtered

During the time of collection note the revolution given by the flow meter. Calculate the volume of water filtered (V) using the following equation :

$$V = \frac{A \times R}{K}$$

where

A = Mouth area of the net

R = Revolutions of the flow meter

K = Constant (Calibration value of the flow meter)

The biomass or population have to expressed in terms of cubic meter.

COMPOSITION / COMMUNITY STRUCTURE

The number of species/group or the presence/absence of the species/group in a station in the study area may be due to two factors viz. evolutionary history of the geographic region and the interactions of the species/groups and their relationships to the physical environment (Clifford and Stephenson, 1975). But these factors are not mutually exclusive. Evolution affects the pattern of interactions in a community and the pattern of interactions in a community determine to a great extent the course of evolution.

Two of the special features of the plankton community are the relatively high numbers of omnivorous animals and the filter-feeders. Carnivores are numerous forming about 5 percent of numbers of the zooplankton and volume-wise they are dominant. Planktonic carnivores are usually noticeably larger than the herbivores on which they prey. Protozoans represent by foraminiferans and radiolaria, while medusae, siphonophores and ctenophores contribute as coelenterates. Polyclads form a group of flatworms and they are never common in plankton samples. There are some polychaetes worms which are part of the permanent plankton. Crustaceans forms the major group, normally easily outnumber the remainder of the plankton. Most of the groups of crustacea are reasonably distinctive. Major groups of crustacea are cladocera, ostracods, copepods, mysids, amphipods, cumaceans, various stages of decapods, euphausiids, *Acetes*, *Lucifer* sp., caridean larvae, macruran adults, crabs larvae, stomatopod larvae and other so many larval stages. Gastropod larvae, bivalvae larvae, heteropods, pteropods and cephalopods are the major groups of mollusks. The other groups echinoderms and chordates are represent as cyphonautes larvae, phoronis larvae, sipunculids, brachiopod larvae, chaetognaths, echinoderm larvae, tornaria larvae, larvaceans, thaliaceans, amphioxus larvae, fish eggs and fish larvae. Among all this, copepods generally are regarded as the most important group of planktonic animals and constitute major part of the zooplankton at coastal marine ecosystem. They are so numerous that they have been called the insects of the sea. It has also been said that there are more copepods in the sea than all the rest of the multi-cellular animals put together. Most of the copepods are herbivores. Some species of copepods are carnivores as well as omnivores, but the prevalence of such species in general is very low.

FOOD CHAINS AND ENERGY TRANSFER

The ultimate source of energy for most of life on the earth planet is the Sun. Photosynthetic organisms, such as plants and some bacteria, transform radiant energy into chemical energy for their existence. Some fraction of this energy is passed along food chains in a stepwise fashions to higher trophic levels where secondary food production occurs. A simplified marine food chain consists of

Phytoplankton → Zooplankton → Nekton

As we proceed up the chain, the organisms become larger and less abundant, the bulk of the biomass is concentrated at the base of the chain. The smaller organisms at the base of the food chain comprise a much larger biomass than the larger animals at the top of the food chain. The growth rate of population is also correlated to body size and to trophic level. The smaller organisms are able to double their biomass at much faster rates than the larger animals. Relationships among primary producers and consumers are usually complex. In a food chain, organisms at each level are eaten only by organisms of the next higher trophic level. One example is a grazing food chain, consisting of the following :

Primary producers → herbivores → carnivores

This classic trophic relationship is known on the grazing food chain. As the "term" grazing indicates, this food chain is supported by photosynthesizing plants. More recently another types of trophic interaction, the detritus food chain, has been identified. In this case "detritus" forms a crucial link in the food chain. Essentially all the energy stored in organic matter is consumed by organisms and only a small amount falls to the bottom which is finally buried in sediment for organisms to use it. A small amount of the organic matter in sediment deposits is converted into oil and gas. The main point is that energy is not recycled. It is a one way flow, unlike the recycling of chemical constituents in water.

At each step in a food chain, energy is transferred from one trophic level to the next. Energy is lost at each transfer because organisms use much of the energy they take in for maintenance. Only about 10% of the food intake is available for growth at each trophic level. Thus, 1000 grams of plants support 100 grams of herbivores and 10 grams of carnivores.

So far, we have considered only food chains. Most organisms eat more than one type of food. In turn, each organism is eaten by many predators. The result is more complicated feeding relationships which is called food webs.

To quantify the amount of organic material in an ecosystem we use the concept of biomass, where biomass is the amount of plant or animal material, expressed on the weight of organic carbon, per volume of water or area of bottom. It is similar to the expression used for production. Production expresses how much is being produced, while biomass indicates how much is available to other organisms to eat. Another way of expressing this relationship is the standing crop, which is the difference between the amount produced and the amount consumed.

FOOD AND SURVIVAL STRATEGY

Primary productivity is dependent on light, CO₂, temperature and nutrient elements. The nature and quantity of available fertilizers affect the species composition of primary producers and the rate of primary production. Phosphorous and nitrogen are considered to be the most important fertilizers for increasing density of phytoplankton. At lower concentrations, diatoms are common, but with increase in phosphate concentration, green algae become more frequent, eventually giving way to blue-green algae at the higher concentration.

Zooplankton for their survival do not depend directly upon nutrients, except for microflagellates. The majority of them are affected indirectly by nutrient control of the quality and quantity of their algal, bacterial or detrital food. The predominant feeding method in plankton is the filtering of wide range of living and detrital organic particles, with larger species feeding upon large algae or other zooplankton. To a certain extent, all are size selective feeders, depending upon the dimensions of their food gathering apparatus.

Feeding strategies used by marine organisms vary with depth in the ocean. This is because of the abundance of different kinds of food are greatly different at the various depths. Herbivores dominate near surface waters where phytoplankton are abundant. They decreased markedly in abundance below the pycnocline. Carnivores are most dominant in the middepths, where they can feed on herbivores in the surface zone. Many of the vertically migrating organisms are carnivores. Omnivores occur throughout the ocean, but they are especially common in deeper waters. Many planktonic organisms are suspension feeders, that is, they feed by removing particles suspended in the water.

There are perhaps more than two lakh species of animals and plants living in the sea. The species evince different survival strategies such as body size, food and feeding habits, response to stress and reproduction rates. For prolonged passive suspension in the water column, small body size is preferred. The sinking rates are also reduced by extending appendages provided with setae and fine hairs. The presence of air-filled floats in siphonophores, velilla, porpita and spines in decapods

assist floatation. The oil droplets serve a dual function as food reserve and a buoyancy device. As mentioned earlier zooplankton organisms employ various methods to capture food, but the most common is filter feeding. The herbivores filter the planktonic algae from the water currents generated by tides and waves or by animal itself.

The different filters used by zooplanktonic organisms include mucus nets (salps), meshwork secretions (copepods) and basket work of setae (crustacea). The planktonic crustaceans even use specialized limbs, fringed with setae for filter feeding. In contrast with the relative stability of the sea, the estuaries are dynamic environments, often showing sudden and extensive changes in salinity. The rate and magnitude would depend on the geological, meteorological and hydrographic conditions. The species have to be highly adaptive and are reported to show mechanism to detect changes in salinity and oxygen. Many produce resting eggs to tide over unfavourable conditions. The reproduction rates counter mortality. Several zooplankton species show quick maturation, reproduce early, with shorter generation time and low species diversity.

Zooplankton have different reproductive strategies which influences rate of population increase and hence availability of food. Two different reproductive strategies are used by organisms. One is suited for sparsely inhabited but resource-rich environments, where rapid population growth is advantageous the other appropriate for resource-poor environments already saturated by organisms, where slow population growth is more desirable. The first strategy is used by opportunistic organisms that develop rapidly to take advantage of hazardous environments or variable resource which other organisms can not exploit. Many fishes and invertebrates follows this strategy.

DISTRIBUTION

Planktonic organisms are not distributed uniformly in space. The variability of an ecosystem in space and time is one of its most important features. The physico-chemical boundaries play an important role as there are usually strong gradients in terms of light, temperature and salinity from surface to the bottom layers. The zooplankton exhibit uneven distribution both along the horizontal and vertical planes. It is well known that the zooplankton are abundant at depth during day and their abundance shifts to surface at night. This has been explained on the basis of vertical migratory behaviour. It could be ontogenetic, seasonal and diel migrations. Besides light, food availability, inter and in a specific competition, predation pressure, niche selection, energy conservation and physiological state of zooplankton are other factors responsible for this phenomenon. The diel migration is most common but some planktonic forms don't show migration and occur in discrete depth zones or in the surface layers.

In the deeper marine environment, the zooplankton usually congregate above the thermocline or discontinuity layer which acts as an ecological barrier and results in stratification in distribution. The vertical zooplankton abundance has also been associated with chlorophyll concentration and primary productivity. In addition to vertical gradient, there are also patches in horizontal distribution. The zooplankton patchiness or spatial heterogeneity becomes a dominant character of distribution of some taxa during certain period of the year. The patchiness extends on scales of several meters to hundred or thousands of kilometers. The zooplankton are dispersed according to the scales of ocean turbulence. Since the latter range from small scale eddies to very large gyre, the scales of zooplankton patchiness will be correspondingly varied (Parsons, 1980). The intensity of zooplankton aggregation will depend on their ability to counter dispersion, phytoplankton growth, grazing rates, predator prey relationship and reproduction strategies of zooplankton. The zooplankton patchiness is utilized by higher trophic levels particularly by pelagic fish species and their larvae.

AS INDICATOR ORGANISMS

It is fundamental of ecology that an living organism cannot survive indefinitely in an environment that does not provide its physical, chemical and nutritional requirements. Hence, the presence of a particular species, if it is reasonably abundant, indicates that its environment requirements are being met. Within certain limitations the presence, absence or relative abundance of species may be used as indicators of environmental quality.

The environment of the plankton consists of many factors, each exerting its influence on the organism. Also the zooplankton being passive drifters, they are used as indicators of water masses and their movements, circulation, coastal upwelling, productivity of waters, neritic or oceanic conditions and so on. It is well known that several zooplankton organisms and their species have their main centers of distribution within a specific water mass. Their geographical range would depend on the temperature and salinity tolerance limits. The indicator species could be selected on the basis of adults carried by currents into regions where no recruitment occurs; planktonic larvae carried into regions where the adults do not occur and the species that have their greatest abundance in mixing zones with little recruitment from the outside source. The zooplankton species also serve as indicator of coastal upwelling. The copepod species of family calanidae dominate zooplankton population during upwelling events. The upwelling results in high primary productivity over an appreciable area with high production of herbivorous zooplankton. The zooplankton production and fauna are also indicators of neritic or oceanic conditions. The neritic and inshore waters are

most productive with typical seasonal fluctuations influenced by monsoons and upwelling.

ZOOPLANKTON AND POLLUTION

1 *Ecological aspects*

We know pollution and its disastrous impacts. However, the open sea is still relatively clean. The margins of the seas and most of riverine systems are affected by man, almost everywhere, and encroachment on coastal areas continues worldwide. Habitats are being lost irretrievably to the construction of harbours and industrial installations. Although difficult to quantify, destruction of beaches, coral reefs and wetlands, mangrove forests and increasing shore erosion are evident all over the world. If unchecked, this trend will lead to global deterioration.

Toxic and microbial agents have not so far affected exploitable living resources on a wide scale, although some stocks especially of shellfish in limited areas, have been declared unfit for human consumption. Coastal grounds and shallow waters are being increasingly degraded, and marine resources both wild and farmed, could eventually be damaged on a global scale.

Different pollutants have different effects on living aquatic organisms and on fisheries. Some stimulate the growth of plants and could have beneficial effects if properly controlled. Some are toxic and can kill aquatic organisms or make them unfit for human consumption. Others are innocuous and have little or no effect on the aquatic ecosystem. Most effluents are complex mixtures of a large number of different harmful agents. These include toxic substances of many kinds, extreme levels of suspended solids and dissolved and particulate organic matter. Most effluents also vary in their strength and composition, on a seasonal, diurnal or even hourly basis. There are about four million different chemical substances in existence, a number which increases by about 3,00,000 every year. In order to survive, a living organism must spend its life in an environment which meets its needs, a suitable physical habitat which provides space, shelter and a sufficient supply of food, oxygen and other metabolic requirements. Any of living organism's many individual requirements may be a limiting factor.

Pollution may directly influence one or more components of the dynamic equilibrium of physical, chemical and biological phenomena which give an ecological community its characteristics. Wherever and whenever the input of organic material exceeds the capacity of the system to assimilate it, a number of changes take place. Occurrence of these responses or changes will depend upon the nature and severity of the pollution, and upon the relative susceptibility of the species within the community to specific kinds of

environmental alteration. Living organisms like zooplankton can provide useful indication of these changes and environmental quality of water. There are furthermore, very few organisms whose presence specifically indicates that the water is polluted.

In a severely polluted area the invertebrate fauna including zooplankton is affected by the elimination or numerical reduction of certain species. If the input of pollution ceases, the fauna gradually recovers with the passage of time. A similar process of recovery can be observed with increasing distance from a source of pollution on the concentration of pollutants decreases. The nature of the recovery is a gradual increase in the numbers of species and in the numbers of individuals. However, it is well known that even in the unpolluted environments, the biological community and its physical environment are not well understood and it is therefore extremely difficult to distinguish the consequences of pollution from the response of the community to natural variations in its physical environment.

Effects of pollution on the aquatic ecosystem are the most difficult to establish and evaluate. As mentioned earlier each environment is somewhat different. The species inhabiting any given environment have evolved over long periods of time and each individual species in a community plays its own role. There are many ways in which pollutant might affect a given population without being lethal to the adult organism. The effect may be in form of migration, behaviour, incidence of disease, life cycle, physiological processes, nutrition and food chains, genetic effects and ecological effects.

Zooplankton are used in the pollution assessment and monitoring studies in various ways which include changes in community structure, species diversity, species preference and bioaccumulation of toxicants. Grazing zooplankton accumulate higher concentrations of DDT than is found in the phytoplankton they eat. The top level carnivores accumulate the greatest amount of DDT. Study of the uptake, metabolism and excretion of pollutants and of their distribution in the various body organs and tissues, makes an important contribution to understanding their mechanisms of action. Levels of pollutants in the tissues of living organisms are widely used to indicate the degree of contamination of the watermass in which they live. Pollutants may, over long time periods, accumulate in tissues to levels which may be harmful to the organisms. Since many aquatic species are utilized for human consumption, the public health significance of toxic substances accumulated in their tissue is obvious.

2 *Biological monitoring*

Any surveillance and monitoring system should be established with clearly defined objectives. The

following are the minimum objectives suggested for monitoring.

- (i) Establish present – day base lines
- (ii) Detect and evaluate trends of changes
- (iii) Give advance warning
- (iv) Detect accidental critical events
- (v) Information, storage and retrieval

Monitoring of the biological characteristics of watermass might indicate the occurrence of ecologically significant environmental changes – including the incidence of pollution, which may otherwise be undetected.

In the monitoring programme, sampling stations are surveyed at intervals of between one and six months. Information is gathered on the presence and relative abundance of species and may be used to derive numerical values like species diversity biotic index, to facilitate spatial or temporal comparisons. Significant alterations from previously – established conditions may indicate the need for further investigation and lead to action designed to preserve or improve the existing water quality. Biological monitoring data also can be used to formulate water management strategies notably through the identification of technically and economically feasible water quality objectives.

FUTURE PROSPECTS

Many commercially important pelagic fishes feeds on zooplankton, hence, the study on prevalence and distribution is necessary in assessing the production

potential of a given ecosystem. Investigations on zooplankton have been confined mainly to taxonomy, zoogeography, distribution pattern, community structure and trophic relationships. However, efforts are underway to integrate studies of biological and physical phenomena in the ocean. New techniques either already available or in processes of development are being used for synoptic sampling (acoustics, optical imaging, bioluminescence) and biochemical indicators (digestive enzymes, lipids, genetic markers).

The use of new sampling and analysis technologies in zooplankton research would greatly facilitate rapid data acquisition for evaluation of biological resources and understanding of processes in the ocean.

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