Chapter

Zooplankton Productivity Evaluation of Lentic and Lotic Ecosystem

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Abstract

The present study reveals the correlation of zooplankton productivity of lotic and lentic water ecosystem. The biological rhythms are useful tool to determine the zooplankton production. Planktons enrich the trophic level of lentic and lotic ecosystems. The relationship of primary productivity of any aquatic ecosystem depends on the biological biodiversity. Estimation of zooloplankton productivity of any water system helps to analyse its richness of species as biological population which are sustainable in it by the adequate amount physicochemical parameters. It is observed in most of the water system the quality of physical, chemical and biological phenomena are depends directly or indirectly correlation to establish diverse life as suitable habitat. To identify the current problems on lentic and lotic water system correlation studies will be more helpful, it is need of hour to give more attention on limnology because most of the biodiversity polluted due to industrialisation and anthropology. To develop advanced monitoring tools to address it on time to time problems of water system as key indicators and to conservation strategies towards the sustainable developments.

Keywords: ecological adaptation, climate change, conservation, river basin, physicochemical, heavy metal, sediments, microorganisms, water quality, water pollution, anthropology, diversity

1. Introduction

Water is one of the most significant resources on earth and is fundamental to all kinds of life since it is necessary for the survival and well-being of all living things [1]. The presence of planktonic organisms is the distinctive peculiarity of all aquatic ecosystems, whether they are lentic or lotic. Planktons are typically regarded as a measure of the water column's fertility [2]. Studies on fresh water sources, whether they are man-made or natural, have become increasingly important in recent years, mostly due to their variety of uses.

In aquatic system, surface water called as inland water ecosystem and classified into lotic and lentic system. The land surface habitats for free water and will be categorised as lotic or lentic system. In the inland water system, act as fundamental habitat as ecological constraints to divide in to as lotic and lentic system [3]. Lentic water ecosystem exhibits discrete habitat as aquatic matrix in the terrestrial system, whereas in lotic water ecosystem shared continuous habitat with the linkage of various basins in unidirectional flow in the dendritic structure of river networks. These ecosystems act considerably different in physical, chemical and biological characteristics (**Table 1**). Lotic water ecosystem significantly differentiated when compare to lentic water ecosystem, which possess relative affinity with terrestrial waters. In the lotic water ecosystems, waters flow establish it continuous, definite and unidirectional approach in the form of measurable, constant flow, wherein lentic water ecosystems, waters not exit in any flow in the continuous, definite and any direction in the given medium as staging structure. In lotic water ecosystem, flow of water source towards flat surface, whereas in lentic system water equally stored as per the specific landscape, terrestrial system and topography of the diversity. The lotic water system walks their path in the narrow form, shallow level, broader surface, relatively rapid, slow moving and deeper in nature. Lotic water system will be diverse and area specific in their structure, reaching small area as a spring in a centimetre wide exhibit like a major river which covers kilometre width. These water systems showed main difference in the communities, they move as per the velocity and along with lotic communities. These systems depends which are the organisms occupied the ecosystem and richness of diversity exist in the ecological niche. In this context, the plant diversity in lotic community is lower compared to community of lentic water system while small components of lotic community exhibit similar environment in the lentic community. These plants have adaptive evolutionary significance to cope up with the environmental force and various conditions that brings by running water. Such biological adaptations have placed different type of species successfully to take advantage in the lotic water system as one of the ecological niche. In this aquatic ecosystem, water differs in their stability, persistence basically, determining the structure of population and their genetics, size of geographical range and rate of speciation in lentic and lotic lineages [4]. Whereas the pattern of this phenomenon is remain incomplete and not understood, the compatibility of such traits preparedness with all the ability of species to develop as new populations to bring it as significant differences in the system [4]. Due to water current velocity, affect the processing time directly, in indirect approach leaf fragmentation is common to renew the dissolved oxygen and supporting for microbial diversity. The contrasting feature of geological activities and ecological strength of these water systems exhibited relative index of evolutionary and biogeographical differences in the species in different habitats [5]. Species taxa is depends on geological period and they were ecologically unstable due to adoptive condition to lentic habitat and found less population and greater area of geography when compare to the range of lotic relative species, such pattern observed through the range of selected taxa, specific regions and ecosystem [6, 7].

Ecosystem of lentic and lotic significantly differ basically in the local environmental conditions (For example, presence or absence of flow, time of water residence) and property of physical connectivity. While lotic water system not suffer much from fragmentation and deviation than the lentic water system, climate-induced changes from permanent to temporary locales will reduce the connectivity in the equal landscape ecosystem in in lotic system. In these environment exhibits harsh conditions for specific plant species, in those larger plants more prone, herbaceous species adjust with such conditions and acts as more favourable for the lotic community. It was noted that they were more tend to available physical conditions to adopt such water. Algal species can adapt to all sorts of places, surfaces and hence, they take significance as successful feature of the lotic water system. All the algal species have developed genetic ability with evolutionary changes to adapt over the period of their times to

Sl. No.	Characteristics	Lotic system	Lentic system	References
1	Water flow	Water flows in a continuous and definite direction (flowing waters/running waters/moving waters)	Absent; water do not flow in a continuous and definite direction (standing waters/static waters/still waters/ stationary waters)	[3–8]
2	Morphometry of water body	Linear, longer, narrower and shallower basin with more complex perimeter	Circular and deeper basin with less complex perimeter	
3	Width of water bodies	Relatively narrow	Relatively broad	
4	Depth of water	Shallower	Deeper	
5	Landscape position	Natural placement	Lower in the catchment	
6	Regional distribution and function	Dictated by geomorphology	Influenced by regional demand for dam related ecosystem services	
7	Permanence	Can last many thousands of years	Usually only last for a few hundred to a few thousand years	
8	Source of water	Fed by lower order streams and diffuse inputs; fed by rains, precipitation, snow melt and springs	Fed by higher order streams, surface water dominated; in addition to ground water, lotic waters from rivers, streams and creeks drain into lakes and ponds to form a lentic environment	
9	Current velocity	High	Low	
10	Water retention time/ water residence time (how long it holds water)	Sometimes there is a lot of water like after a heavy rain; sometimes there is a very little water during drought; will dry up and many organisms will diev	Last longer and organisms can continue to live despite the shortened supplies	
11	Dissolved oxygen content	Usually high in dissolved oxygen; higher percentage of dissolved oxygen in water, due to water flowing	Lower percentage of dissolved oxygen, especially in deeper water	
12	Salt content	Lower salt content	Higher salt content as water evaporates over time	
13	Adaptability of creatures	The creatures that live here must adapt to their past-paced environment	The creatures that live here must also adapt to their environment	
14	Speciation rates	Low	High	
15	Geographical range size	Higher	Lower	
16	Species diversity	Higher	Lower	
17	Stability	High	Low	

Table 1.
Characteristics of lotic and lentic aquatic systems.

prevent and overcome against water current from sweeping it completely. Dry season disturb the fauna and flora which occurs in both the aqua system globally and it can be strongly affect the communities. Whereas the drying effect depends on ecosystem and their relationship with local species ability strengthens the community, dryness is completely different with climate and their community responses between lentic and lotic water system comparatively [8].

Researchers predicted that drying of fauna and flora in aquatic communities may effect strongly in isolated lentic water system compare to scattered lotic system, if provided support of hydrological connectivity in higher level reduce the drying effect passively rather than dispersers, because such sources may potentially greater in recolonizing ability of the species in the ecosystem. Whereas such variation, strongly combine the quality characteristics to make the healthy habitat of running waters compare to still waters. Flow of water should be unidirectional also observed that spatial and temporal heterogeneity in all the scales (microhabitats) in potent level and high degree [8].

There are two sorts of natural freshwater bodies: lotic and lentic. Running water is referred to as lotic since the entire body of water moves in that direction. Brooks, streams, rivers, and springs, which are representative of the lotic bodies in India, may be included in these [9]. Lentic ecosystems such as pools, ponds, swamps, bogs, lakes, exhibit a wide range of chemical, physical and biological characteristics (**Figures 1**–**3**). In general, they have different zonation, unlike the rapid and the pool zones of the lotic system with different specialised lentic community.

Limnology is the study of all aquatic systems, both lentic and lotic fresh, fresh, and saline including lakes, wetlands, marshes, bogs, ponds, reservoirs, streams, rivers, oceans, etc. about their physical, chemical, and biological characteristics [10].

The physical, chemical, and biological properties of lakes vary greatly. They differ physically in terms of temperature, water circulation, and light intensity. They differ biologically in terms of biomass, population size, and growth as well as chemically in terms of nutrients, major ions, and pollutants [11]. Management of freshwater bodies should aim to maintain high productivity level of water bodies with provision for a

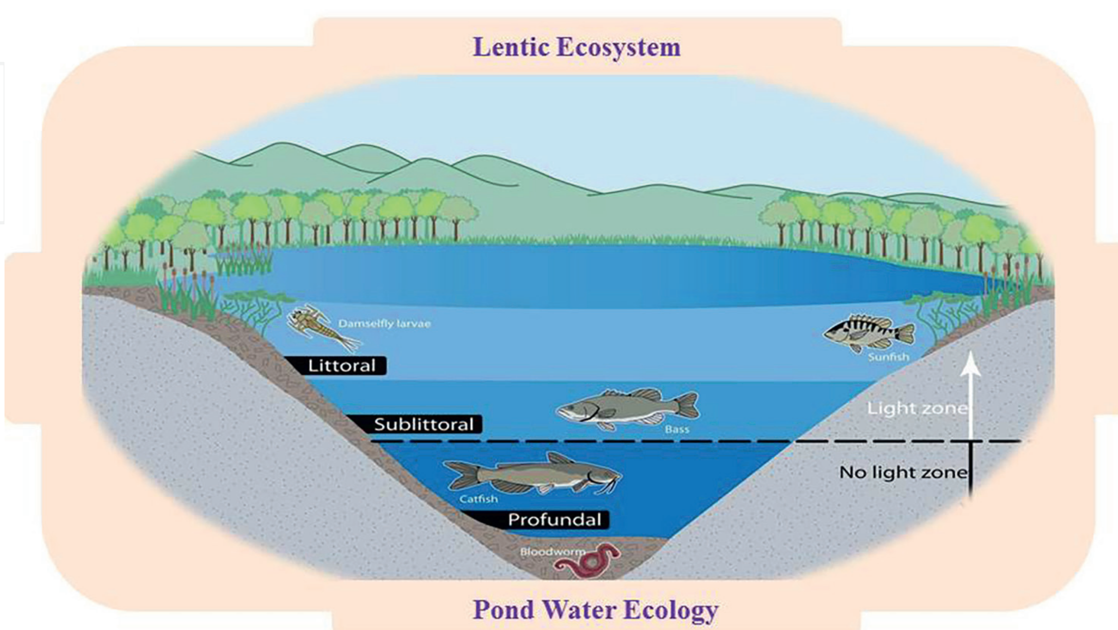

Figure 1.
Types of lentic system and their morphology.

Figure 2.
Anatomy of the aquatic ecosystem represents the zones and species diversity.

high rate of harvest of plants and animals for human use. The amount of solar energy trapped by the autotrophic organisms is known as production. The amount of solar energy trapped by the autotrophic organisms in unit time is known as productivity. The amount of plankton present in the water body decides the productivity of that water body [12]. Primary productivity is inversely related to the nutrient concentration, indicating that when the nutrient status is low, both primary productivity and fish output decline. There is only one primary production peak in reservoirs during the summer or early summer, according to numerous researchers who have examined the primary productivity of water bodies in different places and at different times of the year [10].

Zooplanktons are a crucial component of the aquatic ecology. Zooplanktons are essential components of the food chain and biogeochemical processes. They serve as helpful indicators for environmental changes [13]. Water currents carry zooplankton from lentic to lotic systems, and the energy in their tissues can affect the amount of resources available downstream, influencing ecological functions and the community structure of lotic consumers [14]. Zooplanktons are influenced by a wide range of environmental variables, such as pH, temperature, salinity, oxygen, and others [13].

2. The lentic ecosystems

The term lentic (meaning 'to make calm') is used for still waters of lakes and ponds, which offer environmental conditions, which differ sharply with that of the streams [15, 16]. Lentic aquatic systems contain stagnant waters. These are formed

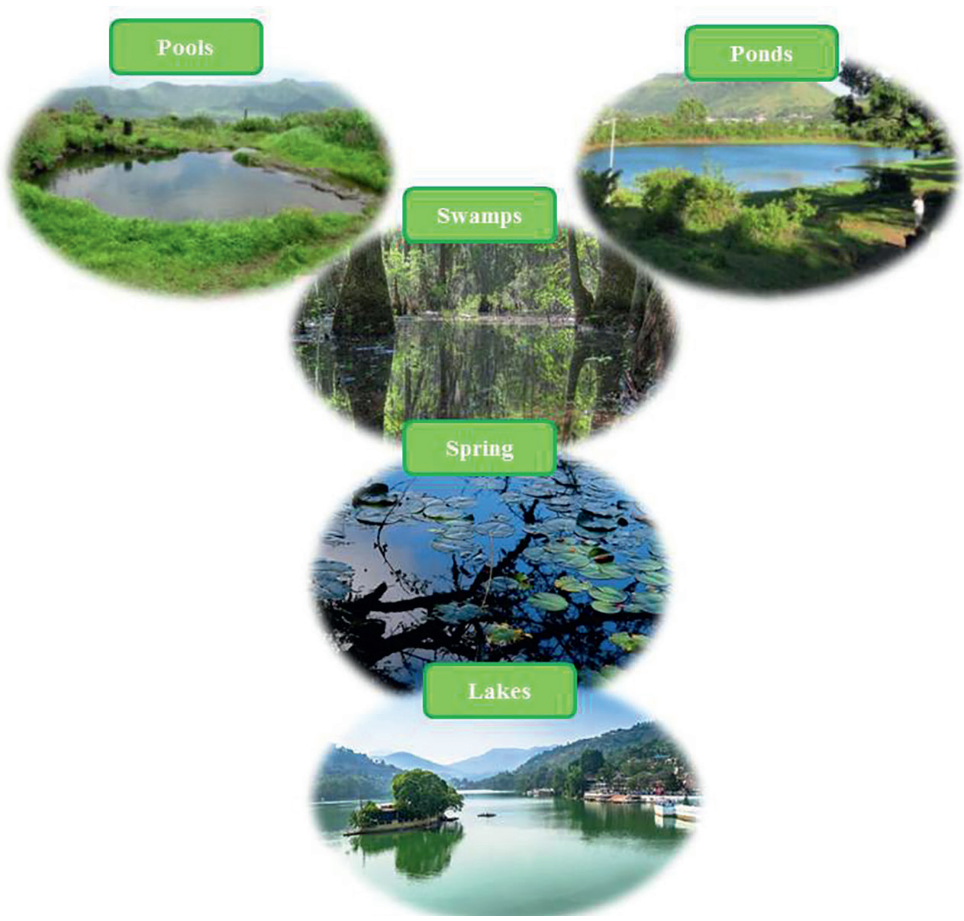

Figure 3.
Types of lotic system and their morphology.

usually in large or small depressions formed on earth's surface where water is collected and cannot flow out. These water bodies include ponds, lakes, swamps etc. As a result, the lentic systems are closed systems; most aquatic life rarely leaves them after entering. Within the lentic body, they must endure, deteriorate, and decompose. They eventually transform into swamps or marshy wetlands before becoming dry lands with time. The depth to which light can penetrate depends on the turbidity. The temperature varies with depth and the season. The oxygen level of the lentic ecosystem is considerably lower than that of the lotic because only a small portion is in direct contact with the atmosphere and because decomposition proceeds intensively at the bottom.

2.1 Zonation in lentic systems

The bodies like ponds and lakes have three zones (**Figure 3**):

- Littoral Zone
- Limnetic Zone
- Profundal Zone

2.1.1 Littoral zone

The area of shallow water is where light can reach the ground. This area is often identified by the presence of rooted plants because it receives a lot of sunlight. This might not apply to "managed" or "man-made" lakes or ponds.

2.1.2 Limnetic zone

The compensation level is the area of open water up to the depth of effective light penetration. The depth at which the rate of respiration and photosynthesis are equal is known as the compensation level. This depth will typically be at the point when light intensity is 1% of that of full sunlight. Only planktons, nektons, and occasionally neustons make up the community in this zone. Small, shallow ponds lack this zone. The term "Eutrophic Zone" refers to the entire lighted stratum, including the littoral and limnetic zone.

2.1.3 Profundal zone

This is the deep bottom region, past the point at which light can effectively penetrate. Ponds frequently lack this zone.

3. The lotic ecosystem

Running water is referred to be lotic (from the Greek word lavo, which means "to wash"), in which the entire body of water moves in one direction. These could include springs, rivers, streams, and lakes. A tiny natural body of water is referred to as a brook, whereas a comparatively big natural body of water is referred to as a river. The stream is typically described as being larger than a brook but smaller than a river. Water from the earth, which appears on the surface as a stream in the spring, is a problem [15, 16]. The current's speed, which can produce either slow-moving or fast-moving streams with highly different features, essentially determines the lotic [17]. Plant and animal communities in slow-moving streams typically resemble those in lentic (lake and pond) habitat. According to Tokeshi and Pinder [18], algae and plants are crucial to lotic systems as a source of energy, for building microhabitats that protect other animals from predators and the current, and as a food source [18, 19].

4. Physico-chemical characteristics of lentic ecosystems

Closed systems are lentic systems. Due to the lack of an exit for the water body, persistent substances, such as the byproducts of the decomposition and mineralisation of organic matter and the degraded or partially degraded pollutants that are released into these aquatic bodies, continue to exist in the system. The biotic communities are significantly impacted by this. Due to the lack of water movement, the physico-chemical environment of lentic aquatic systems is exceptional. The following list of key characteristics of lentic water bodies includes:

4.1 Water quality

Physical–chemical study of a water sample provides a picture of the physical and chemical components, however this analysis simply provides a numerical value. To determine the precise quality of water, an indexing method called the "Water Quality Index (WQI)" has been devised. WQI provides information on the whole aquatic system's quality. "A rating of water quality, which shows the composite influence of different water quality criteria on the overall quality of water," is how the term "water quality index" is defined [20]. Physical, chemical, and biological characteristics of water must all be considered when evaluating its quality because they are interconnected [21]. The majority of the water in the lentic system comes from rainfall, surface runoff, or subsurface water sources. The makeup of these sources does not alter all that much over time. As a result, the water quality in lentic systems has essentially not changed over a lengthy period of time.

4.2 Seasonal changes

A lentic body's positive association with seasonal variations in the physicochemical properties of water affect how productive it is. The make-up of the living community is significantly impacted by the seasonal variations in water quality. A significant increase in phytoplankton is seen during periods of intense sunlight, which is also accompanied by a striking decrease in the concentration of numerous plant nutrients.

4.3 Assessment of productivity

The entire surface area of the water body is more significant than the water volume or the depth of the water body when determining the productivity of a lentic water body. The productivity is based on the combined length of the limnetic and littoral zones. Even if some lentic bodies' profundal zones are nutrient-rich, productivity is scarcely impacted by a lack of sunlight.

4.4 Stratification and water movement

One of the most significant characteristics of a lentic water body is the stratification phenomena, often known as vertical zonation. The variation in density brought on by the varied heating of lake waters causes stratification to exist. If the temperature stays consistent at more than $4.^{0}$ C when there are significant breezes present, the lake water is well mixed. This is seen in lakes and ponds where the static waters are often deeper, measuring more than 6 to 8 metres. Because of stratification, the lentic water's many strata range in temperature, oxygen concentration, and nutrient status [22]. The lake is stratified into the epilimnion, hypolimnion, and thermocline when the temperature is not constant due to density differences. Lakes are categorised into amictic, meromictic, holomictic, oligomictic, monomictic, dimictic, and polymictic lakes based on their circulation patterns. Thus, the temperature and wind pattern have a significant impact on how the water moves. Water in lakes frequently moves in multiple directions.

4.5 Effect of light

The depth to which light can penetrate depends on the turbidity. The temperature varies with depth and the season. The spectral makeup and intensity of the light there govern how deep rooted macrophytes and associated algae can develop on suitable surfaces.

A lake can be separated into tropogenic zone and tropolytic zone based on the amount of light it receives. The primary production of a lake is influenced by light, and phytoplankton in turn affects the depth of light penetration. The oxygen level of the lentic ecosystem is considerably lower than that of the lotic because only a tiny fraction is in direct contact with the atmosphere and because decomposition occurs intensively at the bottom.

5. Physico-chemical characteristics of lotic ecosystems

5.1 Currents and stream pattern

Running waters' gradient and substrates have an impact on the current's speed. Wind has little effect on currents in running waterways, in contrast to lentic waters. The properties of the drainage basin are what determine how water, dissolved chemicals, and suspended particles travel continuously downstream. According to this gradient, there are numerous stream patterns, including dendritic, rectangular, radial, trellised, parallel, annular, deranged, and pinnate. The risks of soil erosion are determined by the stream pattern.

5.2 Light

Light is important to lotic systems, because it provides the energy necessary to drive primary production via photosynthesis, and can also provide refuge for prey species in shadows it casts. The amount of light that a system receives can be related to a combination of internal and external stream variables [23]. The presence of turbidity has a significant impact on how well light penetrates moving waters. There is a loss due to water absorption in addition to scattering by particles. A sufficient amount of light can reach the substrate and enable photosynthesis if the water is transparent or hollow. The availability of light may also be affected by seasonal and nocturnal circumstances because the angle of incidence—or the angle at which light strikes water—can cause light to be reflected back into space [24].

5.3 Temperature

Temperature is a crucial abiotic component for most lotic species since they are poikilotherms, whose internal temperature fluctuates with their surroundings. Water can be heated or cooled through surface radiation, conduction to or from the air, and other nearby substrates [24]. The absence of temperature-related stratification means that a stream's temperature follows that of the surrounding air because of increased interaction with it. Numerous variables, including as the source, depth, substrate, tributaries, exposure, and time of day, affect the temperature of lotic water. The contribution of surface and ground waters to stream flow varies depending on a number of variables, including the geology and temperature of the area. Running water fuelled mostly by surface runoff has variable flow and may spate after each significant downpour, whereas running water fed primarily by ground water often has regular flow.

5.4 Dissolved gases

The most prevalent and significant dissolved gas in flowing water is oxygen. Due to turbulence and mixing, there is a high concentration of oxygen. Organic contamination is typically indicated by low concentration. However, the oxygen concentration in the diurnal basis varies. Current, water temperature, and the presence of breathing plants and animals all affect how much oxygen is present. The carbon-di-oxide concentration of the moving waters tend to be sparse due to constant turbulence of water and its frequent interaction with air [3].

6. Distribution of planktonic forms in lentic and lotic systems

Plankton distribution patterns and environmental conditions are closely connected. Climate, water, temperature, light intensity, nutrient concentration, river shape, discharge, water residence time, precipitation, and biotic variables are examples of potential physical, chemical, and hydrological elements [25]. All the creatures suspended in unrestricted water are referred to as plankton. Aquatic organisms that drift passively and have limited ability to move in opposition to the movement of the water mass make up the plankton. Compared to benthic or nektonic species, planktonic organisms have a short life cycle and high metabolic activity, which allows them to respond to any pollution challenge quickly and dramatically [26]. Hence, study of planktonic community is of crucial importance in understanding pelagic productivity and pollution impacts [2].

Phytoplankton and zooplankton are two types of plankton. All suspended microalgae in a body of water that belong to all taxonomic algal groups are referred to be phytoplankton [27]. The primary producers in aquatic habitats and the foundation of the food chain are phytoplankton and other aquatic plant life [28]. Zooplankton, the animal element of the plankton, is a vital component of a freshwater ecosystem's food chain since it occupy a central position between of autotrophs and other heterotrophs. All varieties of aquatic bodies exhibit zooplankton abundance due to energy transfer occurring at various trophic levels [9].

Pelagic creatures known as zooplankton are those that are unable to hold their location by swimming against the physical movement of water [29]. They were found in practically all water bodies, including rivers, streams, lakes, reservoirs, ponds, irrigation canals, rice fields, and temporary water bodies. They lived in both freshwater and saltwater. By regulating phytoplankton production and modifying the pelagic ecology, zooplankton play a crucial role in the pelagic food web. They are heterotrophic animals unable to produce organic materials on their own [30].

Water currents transport zooplankton from lentic to lotic systems, and the energy in their tissues can change resource availability downstream, changing ecosystem functioning and the community structure of lotic consumers [31]. As essential biotic components of the food webs in any body of water, zooplankton diversity and abundance play a crucial role in the establishment of water quality and trophic levels as well as serving as the subject of bioindication and environmental condition monitoring [32]. The zooplankton community is quite susceptible to changes in the environment. Therefore, they are of ecological relevance because changes in their abundance, species diversity, or community composition can give key signs of environmental change or disturbance [10].

7. Primary productivity of lentic and lotic ecosystem

Any aquatic ecosystem's main production is based on the diversity of planktonic organisms. A water body's primary productivity estimate can be used to determine how much biological population it can support through respiration. It is the most significant biological phenomenon, on which all forms of life are directly or indirectly dependent [11]. The amount of primary production must be determined in order to gauge a reservoir's bioactivity. Production is the measure of how much solar energy is captured by autotrophic organisms. Productivity is the solar energy captured by autotrophic organisms per unit of time [33]. The rate at which radiant energy is stored by a producer's photosynthetic and chemosynthetic processes is referred to as primary productivity [34]. The most significant biological phenomenon in nature is primary productivity, which is directly or indirectly dependent on the entire biodiversity. Through the process of photosynthesis, primary producers generate organic matter from inorganic nutrients. Primary producers need essential nutrients to live and grow such as nitrogen, phosphorus, magnesium, calcium, iron, zinc, etc. in sufficient amount. Phytoplankton, Macrophytes, and Periphyton are the main producer in lake and reservoir [35].

Primary producers require appropriate amounts of key nutrients including nitrogen, phosphorus, magnesium, calcium, iron, and zinc to survive and flourish. The primary producers in lakes and reservoirs include phytoplankton, macrophytes, and periphyton [36]. The balance between gross photosynthesis, respiration, and other plant losses, such as death, is referred to as net primary productivity. There are several characteristics of primary production in aquatic ecosystems that are different from those in terrestrial systems. Contrary to nutrients, which may go through multiple cycles, the movement of energy through an ecosystem is a one-way process. The primary productivity is the foundation of all food chains and food webs in each ecosystem, and it also produces 70% of the world's atmospheric oxygen. Note that the efficiency with which energy is converted by organisms into other forms (chemical energy) and the quality of incident solar energy per unit area of the ecosystem are the two main concerns of ecologists interested in ecoenergetics and the study of productivity, which is currently receiving much attention in ecology [37].

The productivity of a water body is determined by the quantity of plankton present within. When compared to lotic water, lentic water has the highest primary productivity. This suggests that lentic water has more planktonic activity. The "light and dark bottle method" was used to determine the primary organic output of the river water. The method of measuring the production and consumption of oxygen using light and dark bottles and Winkler's titration was initially put forth by Gaarder and Gran in 1927 [38]. It is the most typical technique for assessing output and productivity in the aquatic environment. The amount of dissolved (or free) oxygen in water or wastewater is measured. The amount of dissolved gas (oxygen) per litre of water is known as the dissolved oxygen concentration. In this method, productivity is calculated by evaluating the dissolved oxygen content (**Figure 4**).

8. Water productivity calculation

The following formulas were used to compute Gross Primary Productivity (GPP), Net Primary Productivity (NPP), and Respiration:

$$\textit{Gross Primary Productvity} = \frac{LB - DB}{\mathrm{T}} \mathrm{X} \frac{0.375}{PQ} \mathrm{X}\, 1000mg\,/\,\mathrm{L}\,/\,\mathrm{h}$$

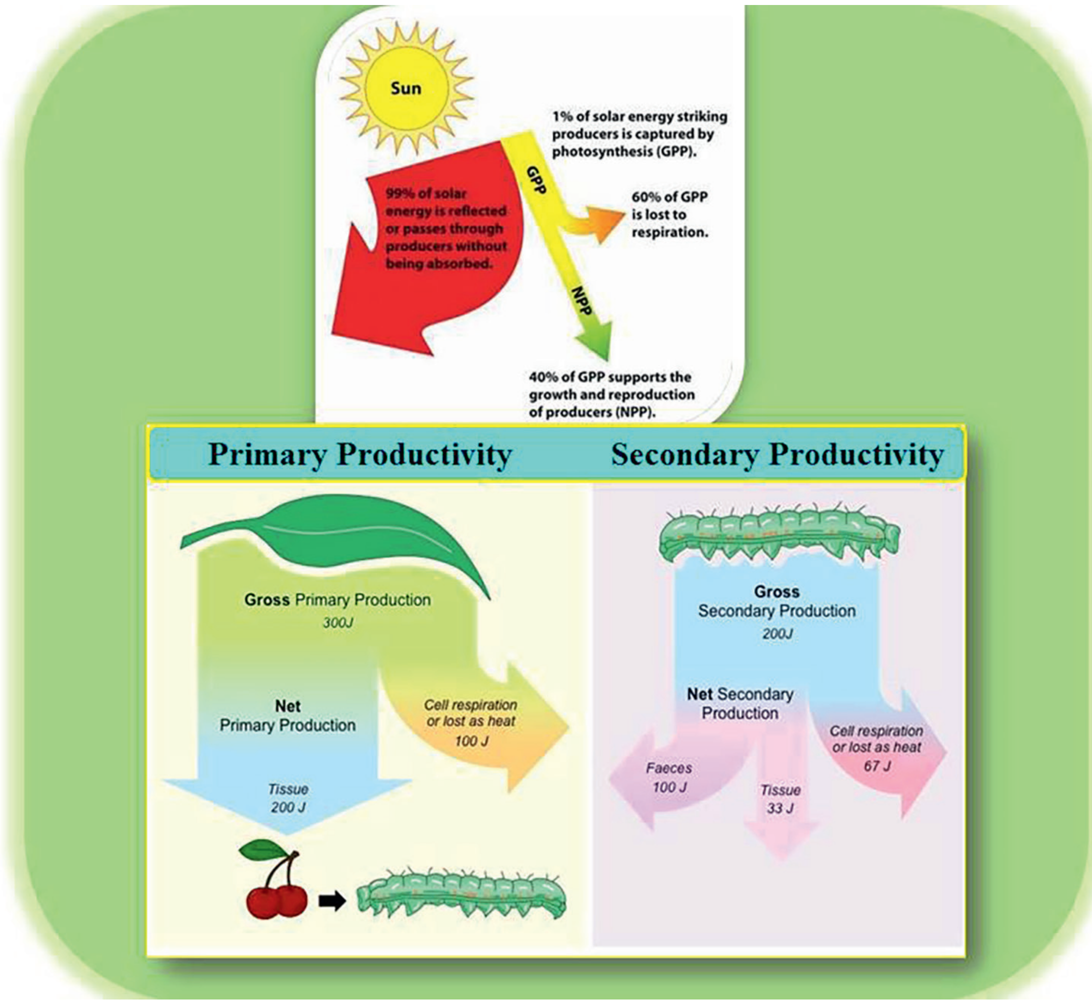

Figure 4.
Schematic representation of productivity of aquatic system.

$$Net\ Primary\ Productvity = \frac{LB - IB}{\mathrm{T}} \mathrm{X} \frac{0.375}{PQ} \mathrm{X}\, 1000 mg\,/\,\mathrm{L}\,/\,\mathrm{h}$$

$$Respiration = \frac{IB - DB}{\mathrm{T}} \mathrm{X} \frac{0.375}{PQ} \mathrm{X}\, 1000 mg\,/\,\mathrm{L}\,/\,\mathrm{h}$$

Where:
LB = Light bottle,
DB = Dark bottle,
IB = Initial bottle,
T = Time of incubation,
PQ = Photosynthesis Quotient = 1.25,
RQ = Respiratory Quotient =1 and.
The value 0.375 represents a constant to convert Oxygen value to Carbon Value.

9. Conclusion

The zooplankton's role in lentic and lotic water system to improve the water quality, act as basal organism in food chain and maintain the environmental conditions.

The existence and richness of zooplanktons relationship associated with water quality in both the water system. Zooplankton communities such as cladocerans, copepods, rotifers, etc., are held responsible to set biological parameters due to their central role in aquatic habitat in food webs along with the phytoplankton's (primary producers) and reach to higher level trophic system and to become important in energy flow and in nutrient cycle of aquatic systems. The many research study showed the correlation between dominant species along with the measured environmental parameters, whereas many tools, methods and protocols like cluster analysis, population metrics, limnology, etc., will help us to know the lentic and lotic water assemblages of zooplankton. This chapter emphasised that zooplankton community establish the structure of water system, environmental conditions and reflects the health of lentic and lotic ecosystem, hence they play significant role in biomonitoring, biodegrading and bioremedial of any water ecosystem health.

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