Chapter 7

Plankton and Periphyton Productivity

7.1 What is Productivity

Productivity is the amount of organics substance acquired by an individual, a population, or a system per unit time.

(1) Categories of Productivity

Productivity falls into two major categories:

1. Primary productivity and
2. Secondary productivity

Primary productivity is exhibited by green plants which are otherwise photo synthetically active. On the other hand, Secondary productivity is exhibited by organisms which are not capable of photosynthesis.

(2) Terminology

Gross Primary Production (GPP): The total amount of organic matter fixed by photosynthetic plant is called Gross production.

Net Primary Production (NPP): Part of gross production is used in metabolic activities by plants through respiration. Gross production minus respiratory loss is called net production.

(3) Primary Production and Net Primary Production

According to Boyd (1979), this is the rate of formation of new organic matter. If Q = primary production (= increase of plant biomass over a period) and T = time, primary productivity is Q/T. Net primary productivity or production is the total

amount of new organic matter created by photosynthesis minus the amount of organic matter used in respiration.

7.2 Measurement of Productivity

When we measure primary productivity, we actually measure net primary productivity. Net primary productivity in water is measured chiefly by:

1. Dark and light bottle method,
2. Chlorophyll a method,
3. Biomass estimation method and,
4. Carbon -14 light bottle method.

Being the cheapest and easiest to operate, only first three methods have been given here.

7.2.1 Dark and Light Bottle Method

(1) Principle

The basic reactions in algal photosynthesis involve uptake of inorganic carbon and release of oxygen, which cen be summarized as:

$$CO_2 + H_2O = (CH_2O)_n + O_2$$

The dissolve oxygen concentration is determined at the beginning and end of incubation period. Productivity is calculated on the assumption that one atom of carbon is assimilated for each molecule of oxygen released.

In light bottle, photosynthesis activity is allowed to occur while in the dark bottle it is restricted. The decrease in the dissolve oxygen in the dark bottle, as compared to initial value represents the amount of dissolved oxygen consumed by the biomass in the bottle through the process of respiration. The increase in dissolved oxygen in the light bottle indicates the amount of dissolved oxygen in water which exceeds oxygen consumption by respiration.

(2) Reagents Required

1. All reagents required for DO estimation.
2. One light and one dark bottle (volume 125 or 250ml).

(3) Procedure

- Select relatively shallow water (photic zone). For euphotic zones, record the depth and measure light penetration.
- Take water sample carefully and uniformly in three bottles for initial DO, light bottle DO and dark bottle DO.
- Add 1ml of $MnSO_4$ followed by 1ml of alkaline iodide (where water volume is 125ml) to initial bottle. Invert it with stopper for 1-2 minutes.
- Fixed the other two bottles (light and dark) under water wherefrom water samples were collected.
- Incubate the bottles under water for desired time which should not be less than 3 hrs.
- After expiry of the desired time, fixed the DO in both the bottles as followed in case of the initial bottles.
- Determine DO values as described earlier.

(4) Calculation

$$\text{Gross primary productivity (GPP)} = \frac{\text{LB}-\text{DB}}{\text{H}} \times 1/1.2 \times 12/32 \times 1000 \text{ mg cm}^{-3}\text{h}^{-1}$$

$$\text{Net Primary Productivity (NPP)} = \frac{\text{LB}-\text{IB}}{\text{H}} \times 1/1.2 \times 12/32 \times 1000 \text{ mg cm}^{-3}\text{h}^{-1}$$

$$\text{Gross respiration} = \frac{\text{IB}-\text{DB}}{\text{H}} \times 1/1.2 \times 12/32 \times 1000 \text{ mg cm}^{-3}\text{h}^{-1}$$

Where,

LB = DO in light bottle

DB = DO in dark bottle

IB = DO in initial bottle

H = Hours of incubation

12/32 = factor to convert oxygen to carbon; under ideal conditions 1mole of O_2 (32g) is released for each mole of carbon (12g) fixed.

1.2 = Photosynthetic co-efficient

Note: During incubation, a measure of temperature, turbidity, and solar radiation (light intensity) should be recorded. These measures help in expressing the productivity for the entire daily photoperiod.

7.2.2 Cholorophyll – a

(1) Introduction

The concentration of photosynthesis pigment is used to estimate plankton productivity. All green plants contain chlorophyll a which constitutes approximately 1 to 2% of dry weight of planktonic algae. It is the main centre of photosynthetic reactions (Buttery and Buzzell, 1977). Algal biomass can also be expressed by multiplying a factor 67 to Chl-a content in terms of ash free weight.

(2) Principle

The pigment (Chlorophyll a) is extracted from the plankton concentrate with freeze cold acetone or methanol and the optical density (absorbance) of the extract is determined with a spectrophotometer. The results are expressed, as if all chlorophyll were chlorophyll-a, as chlorophyll-a equivalent (Golterman et al., 1978).

(3) Reagents

Freeze cooled acetone or methanol.

(4) Apparatus

Spectrophotometer, centrifuge, 25 or 50ml volumetric flask.

(5) Procedure

a) Collection of Chlorophyll Material

A suitable volume of water can be filtered through plankton net. The filtered amount is kept in dark vial. For periphyton, organisms (algae) are collected from a known surface area and kept in dark vial.

b) Pigment Extraction

- Transfer the volume into a centrifuge tube.
- Centrifuge the volume to settle plankton at bottom of the centrifuge tube.
- Decant the supernatant water and raise the volume with cold acetone and transfer to the volumetric flask.
- Wash the tube with acetone two or three times and transfer the solvent to volumetric flask.
- Stopper the flask and keep in a refrigerator in the dark or near 4 ℃.

- After 24 hours, bring out the flask and measure the absorbance at 630nm, 664nm and 750nm.

Note: Every time, before reading the absorbance for different wavelengths, set the spectrophotometer to zero by cold acetone (blank).

c) Calculation for Chlorophyll-a (C_a)

$$C_a = 11.85(OD\ 664) - 1.54(OD\ 647) - 0.08(OD\ 630)\ (APHA, 1998)$$

Where OD 664, OD 647 and OD 630 are the corrected optical densities (with a 1cm light path).

Note: The OD reading 750nm is a correction for turbidity. Subtract this reading from each of the pigment OD values of the other wavelengths before using them into the equation.

d) Chl-a Value for Plankton

$$\text{Chlorophyll} - a(mg/m^3) = \frac{C_a \times \text{extract volume (L)}}{\text{Volume of sample } (m^3)}\ (APHA,\ 1998)$$

e) Chl-a Value for Periphyton

$$\text{Chlorophyll} - a(mg/cm^2) = \frac{C_a \times \text{extract volume (L)}}{\text{Area of the substrate } (cm^2)}\ (APHA,\ 1998)$$

Note: if processing is delayed, keep sample in ice at 4℃ and protect from exposure to light. This way, it can be preserved for 3 weeks.

7.2.3 Biomass (Dry Weight and Ash Free Dry Weight)

(1) Introduction

Biomass is a quantitative estimation of the total mass of living organisms within a given area or volume. It includes the mass of populations or communities but does not give any information on community structure and function. The most accurate methods are Dry weight (DW), Ash free dry weight (AFDW) and volume of living organisms. Expression of biomass in volume has been described earlier.

(2) What is Dry Weight (DW)

Dry weight is the concentrate of inorganic or organic matter at 105 ℃.

(3) Equipment

Oven (max. 105 ℃), porcelain crucible (approximately 30ml capacity), analytical balance (sensitivity 0.1mg), dessicator.

(4) Procedure

- A large number of sample volume is concentrated (either centrifuged or settled gravitationally) to 20ml volume.
- Concentrated sample is taken in a pre-weighed (at 105 ℃) porcelain crucible.
- Dry it at 105 ℃ to constant weight.
- Keep it in a dessicator and then weigh.

(5) Calculation

a) Measurement of DW

$$\text{Planktocic } D_W(\text{mg/L}) = \frac{(\text{Porcelain crucible+sample at 105℃}) - (\text{Porcelain crucible at 105℃})}{\text{Original sample volume in L}}$$

$$\text{Periphytic } D_W(\text{mg/L}) = \frac{(\text{Porcelain crucible+sample at 105℃}) - (\text{Porcelain crucible at 105℃})}{\text{Scrapped surface area (cm}^2\text{)}}$$

b) Measurement of AFDW

The D_w is cooled in a dessicator and ignite in a muffle furnace at 500 ℃ for 1hr. It is then colled and weighed.

$$\text{Planktonic AFDW} = \frac{(\text{Porcelain crucible+sample at 500℃}) - (\text{Porcelain crucible at 500℃})}{\text{Original sample volume in L}}$$

$$\text{Planktonic AFDW} = \frac{(\text{Porcelain crucible+sample at 500℃}) - (\text{Porcelain crucible at 500℃})}{\text{Scrapped surface area (cm}^2\text{)}}$$