CMFRI

Winter School on

Towards Ecosystem Based Management of Marine Fisheries – Building Mass Balance Trophic and Simulation Models

INFORMATION ONLY

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Technical Notes

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ESTIMATION OF PRIMARY PRODUCTIVITY

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The primary production can be defined as the amount of organic materials, which by the activity of organisms in unit time is synthesized in a unit volume of water by the phytoplankton using the solar energy and extending from the sea surface to the bottom of the euphotic zone. The micro algae remove dissolved carbon dioxide and micro nutrients from the water and using solar energy convert them into complex organic compounds of high potential energy with the help of photosynthetic pigments, the chlorophylls. The primary productivity will be confined practically entirely to that brought about by phytoplankton. The growth and distribution is controlled by many factors which may be physical factors like light, temperature, currents etc., chemical factors like salinity, dissolved oxygen content, pH, nutrients such as nitrite, nitrate, phosphate and silicate and trace elements, organic minerals etc., biological factors like grazing and reproduction, hydrological events like upwelling, sinking, turbulence etc., and seasonal variations like winter, summer, spring and autumn.

The word 'production' is synonymously used for standing crop as well as primary production, which is basically a measure of the photosynthetic activity of the micro algae. Various methods, both direct and indirect, are employed for estimating the productivity of an area. Of the direct methods, which are used in the measurement of primary production, the light and dark bottle oxygen technique (Gaarder and Gran, 1927), ^{14}C technique (Steemen Neilsen, 1952) and chlorophyll estimation (Strickland and Parsons, 1972) are the most popular.

Oxygen Technique

In this technique, samples are collected from various depths in reagent bottles with glass stoppers. Three samples are required from each depth. First bottle (IB) has to be fixed with Wrinkler A & B, second bottle (LB) has to be kept for incubation along with the third bottle (DB) which has to be covered with black paper or black rexene cloth. Both light and dark bottle has to be incubated at least 3 hrs/4hrs/6hrs or 12 hrs depending on the convenience. After the incubation, both the bottles have to be fixed with Wrinkler's solution. All the three bottles have to be titrated against Sodium thiosulphate in a burette, starch will be the indicator and estimate the oxygen content of each bottle. In the dark bottle, only respiration takes place while in the light bottle, both photosynthesis and respiration take place. The oxygen content in the light bottle minus that in the dark bottle represents the gross production. The oxygen content of the light bottle minus that of the initial bottle represents the Net production. The oxygen content in the initial bottle minus that in the dark bottle represents the respiration of all the organisms present.

$$\text{Production (mg C)} = \frac{O_{2\,(ml/l)} \times 0.536}{PQ} \quad \text{or} \quad \frac{O_{2\,(mg)} \times 0.375}{PQ}$$

where, PQ (Photosynthetic Quotient) is taken as 1.25.

Carbon-14 Technique

This technique was introduced by Steemen Neilsen in 1952 on board the Danish research vessel GALATHEA is the most suitable technique for the measurement of primary production in water bodies where the rate of production is very low. Besides, the practical application of the technique in fieldwork is relatively simple. A solution with a definite quantity (1 ml) of $NaH^{14}C0_3$ in sealed ampoules is pippeted out and added to water samples (60 ml) collected from different depths before an experiment. The total CO_2 content of the water has to be estimated. One light and dark bottle of each depth has to be collected and an ampoule of ^{14}C added. After the exposure of samples for a definite period *(in situ* or simulated *in situ* conditions) the samples are filtered in to Millipore or membrane filters. The filters are dried over silica gel and counted in a Geiger Muller Counter. The counts are converted into the carbon equivalent using the formulae,

$$\frac{\text{Activity of the filter (cpm)}}{\text{Activity of the Ampoule (cpm)}} \times \frac{\text{Total } CO_2}{\text{Hrs of incubation}} \quad \frac{12}{44} \times 1.06 = \text{mgC/l/h}$$

By integrating the values for the different depths, production for the water column in $gC/m^2/day$ can be calculated.

Estimation of chlorophylls

Since Chlorophyll *(a, b,* c) are the photosynthetic pigments in phytoplankton, its abundance will give a measure of the presence of primary producers and hence the productivity of an area.

One litre of seawater can be collected from the surface or required depth with the help of a sampler and filtered through Millipore/Sartorius/GFC filter paper (47 mm) and the filter paper is dissolved in 90 % acetone. If the GFC filter paper is used for filtration, the acetone has to be centrifuged and the clear solution is poured to the cuvitte of a Spectrophotometer. In a cuvitte, 90 % acetone is poured for being used as standard and measurement was taken in different wavelengths (630,645,665 and 750). For the estimation of chlorophyll a the below mentioned formulae can be used.

$$\textbf{Chl a (mg/m}^3\textbf{)} = \frac{26.7\,(665_o - 665_a) \times v}{V \times l}$$

Where,

665_0 = before acidification
665a = After acidification

v = volume of acetone added (10 ml)
V = volume of water filtered
I = length and path of the cuvitte

However, Parsons et *al* (1984) has given a revised formula for the estimation of chlorophylls.

Chlorophyll a = 11.85 $_{E664}$ - 1.54 $_{E647}$ - 0.08 $_{E630}$
Chlorophyll *b* = 21.03 $_{E647}$ - 5.43 $_{E664}$ - 3.66 $_{E630}$
Chlorophyll *c* = 24.52 $_{E630}$ - 1.67 $_{E664}$ - 7.60 $_{E647}$

Primary production in special ecosystems

There is great amount of seasonal and spatial variations in the magnitude of primary production in special type of ecosystem such as mangroves, prawn culture fields and sea grass beds.

Mangroves are highly specialised ecosystem in the coastal zone and are the breeding grounds of most of the aquatic organisms. The productivity of the mangroves is very high due to the high quantity of litterfall and organic detritus. Usually mangroove waters are having an average production of 2 - 3 gC/m^3/day depending on the area and season. Mangrooves existing in the island ecosystem are found to be highly productive with an average of 3 - 3.5 gC/m^3/day, especially in the Andaman Nicobar Islands.

The prawn culture fields existing in the estuarine and backwater regions of Kerala indicated moderate to high rates of primary production, ranging from 1 - 3 gC/m3/day depending on the abundance of micro algae. Usually the backwaters and estuaries will have moderate rates of primary production, ranging from 1 - 2 gC/m^3/day during the monsoon season and less than 1.5 gC/m^3/day during the pre and post monsoon periods.

Similar to the mangroves, the sea grass ecosystem occurring in the coastal areas is also found to be highly productive. The productivity of the sea grass beds alone ranges from 3 - 4 gC/m^3/day and when the other primary producers such as benthic and epiphytic algae are included, the daily production may be over 6 - 8 gC/m^3/day revealing that sea grass ecosystem is highly productive in the coastal zone.

Indian Seas

The shelf areas of the Indian seas, which sustain the bulk of the fish production at present, are on the whole having a high rate of primary production. Because of the constant replenishment of nutrients in the surface layers, the shallow waters are generally productive. An average rate of 0.5 to 1.0 gC/m^3/day is observed in the shallow areas most of the time. Rates exceeding 2 gC/m^3/day are found during the southwest monsoon.

In the eastern Arabian Sea, towards the coast of India, the average rate within 50 m depth is about 1.2 gC/m^2/day and for the outer shelf region, the rate is 0.5 gC/m^2/day. The net production (taken as 60% of the gross) from the shelf area on the west coast of India upto 50 m depth has been computed as 30 x 10^6 tonnes of Carbon. Between 50 - 100 m, the net production was only 17 x 10^6 tonnes of Carbon. Thus for the whole continental shelf area on the West Coast, the annual net production is computed as 47 million tonnes of

Carbon. The rate of primary production for the East Coast are 0.65 $gC/m^2/day$ outside the shelf and the annual estimate of net production is 17 x 10^6 tonnes of Carbon (Table 1) totaling 64 million tonnes of Carbon from the entire coastal area, within 100 m depth of the Indian Seas (Nair and Pillai, 1983).

In recent years, various projections of potential yield have been made from the estimates of primary production. The optimum yield from organic production generally varies from 0.3 - 0.4% (in terms of Carbon - 10% of the wet weight 50% of the protein content), the potential exploitable resources for the whole Indian coast is about 3.5 million tonnes. Actually we are exploiting about 1.4 million tonnes only from the coastal region, there is vast scope for further exploitation of the resources.

In view of the declaration of 200 miles Exclusive Economic Zone, having a total area of 2.02 million Sq. km., it would be worthwhile to compute the annual production rate of this area (Fig. 1). The different gradients for the shelf and outside when integrated give a total production of 283 x 10^6 tonnes of Carbon (Gopinathan, 1981).

In view of the distance involved and the sparseness of distribution, a minimum possible exploitation of 0.2% could be expected from the entire EEZ of India. Therefore the exploited yield of the living resources from the EEZ would amount to 5.5 million tonnes, both pelagic and demersal (Nair and Gopinathan, 1981). Since the present yield from the Indian Seas is only 2.7 million tonnes and exploitable potential yield based on catch statistics is 3.92 million tonnes, there is still vast harvestable resources is available in the Indian EEZ, based on the estimates of phytoplankton production.

Indian Ocean and World Oceans

The magnitude of primary production in different areas has been estimated by various authors during different Research Cruises and Expedition Reports. The potential production of the entire Indian Ocean has been computed as 4.1 x 10^9 tonnes of Carbon, which is about 1/5 of the world Oceanic production (Koblanztz Mishke et *al,* 1970). The potential yield from the Indian Ocean has been estimated by various workers which ranges from 14 - 18 million tonnes (Prasad et *al,* 1970; Gulland, 1970).

Based on the different Expedition reports and cruises conducted around the world, the World Oceanic production of phytoplankton in terms of Carbon was estimated as 2.5 - 3.0 x 10^{10} tonnes (Koblanztz Mishke *et al,* 1970). If we apply the optimum conversion efficiency of just 0.1%, the potential yield of harvestable resources will be about 300 million tonnes. The latest reports indicated that the present exploitation from the World Ocean is less than 100 million tonnes. There is still vast scope for further exploitation of the living resources.

TABLE -1

GENERAL LEVEL OF PRIMARY PRODUCTION IN VARIOUS ECOSYSTEMS

Estuaries, backwaters & prawn culture fields	1-3 gC/m^3/day
Mangroves, seaweed & seagrass ecosystems	3-5 gC/ m^3/day
Inshore and coastal areas	1-2 gC/ m^3/day
West coast of India upto 50m	1-2 gC/ m^3/day
West coast of India upto 100 m	0.53gC/m^2/day
East coast of India upto 50 m	0.68gC/m^2/day
East coast of India upto 100 m	0.20gC/m^2/day

Annual Gross Production

West coast upto 50 m	30x$l0^6$T. of C
West coast upto 100 m	17x$l0^6$T. of C
East coast of India upto 50 m	10x$l0^6$T. of C
East coast of India upto 100 m	7x$l0^6$T. of C

Total production of the Indian Seas:
West coast = 47 m.T. plus East coast = 17 m.T.

Indian seas upto 100 m	60 m T. of C
Exclusive Economic Zone of lndia (2.02 m.Sq.km)	283x$l0^6$T. of C

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