2

LITERATURE REVIEW

(a) Tropical Waters :

As compared to the numerous records available for temperate region, only a few studies have been published on the inland waters of the tropics and most of them come from Africa (Eccles 1962, 1964, 1965; Harding 1966; Beadle 1966, Talling 1957,1965, 1966(a), 1969; Talling and Talling 1965; Wood et al 1969; Burgis 1969a, b; Dunn 1969; Dunn et al 1969; Gauf 1969a,b); In India, though there are hundreds of man-made lakes, only a few of them have been studied with reference to their nutrient and salinity cycles, heat budget and/or population dynamics by Ganapati (1940; 1947-48, 1949-50, 1955a, b; 1956; 1957, 1960) and Sreenivasan (1958, 1963; 1964a,b,c; 1965, 1966, 1968a,b,c; 1969, 1970a,b). Still fewer waters have been examined for their biological productivity (Ganapati 1970; Sreenivasan 1963, 1964a,b,; 1965, 5 1968) and Ganapati and Sreenivasan (1966, 1970, 1971). Ganapati and Pathak (1970) have made preliminary measurements of primary production by phyto-plankton in the Ajwa reservoir at Baroda. But they did not estimate the contribution of higher aquatics and periphyton to biological productivity and budget. Misra and Singh (1970) have furnished a very casual review of organic production in aquatic ecosystems in India. In the recent International Symposium on Tropical Ecology emphasizing organic production (1971), seven papers were submitted from India for aquatic production. The papers by Ganapati (1971), dealt with certain aspects of biological productivity in several types of waters.

(b) Methods of Investigation (General) :

Sladeckova (1962) has published a comprehensive review of limnological investigation methods for periphyton (aufwuchs) community. An exhaustive review of literature on measurement of standing crop and productivity of macrophytes has been made by Wetzel (1964). Westlake (1965) has furnished some basic data on the techniques of problems of primary productivity measurements in higher aquatic plants and periphyton.All aspects of primary productivity in aquatic environments are furnished in the proceedings of an IBP/PF symposium (1965). The Manual on Methods of Measuring Primary productivity in aquatic environments has also been subsequently published by IBP/PF, Handbook (1969). As many as 79 preliminary papers for UNESCO-IBP Symposium (1970a) on productivity problems of fresh waters were submitted at Kazimere Dolny in Poland. Another UNESCO-IBP Symposium (1970b) on aquatic macrophytes was held at Bucharest.

The brief but detailed review furnished below on estimation of primary productivity by macrophytes, periphyton and phytoplankton is based essentially on the above exhaustive reviews.

(i) <u>Productivity Measurements on Macrophytes</u> :

Wetzel (1964) has described the earlier quantitative methods of sampling macrophytes for spatial and temporal distribution within lakes. Correlations have been made between the distribution of standing crop of larger hydrophytes and numerous ecological factors. Frequently attempts are made to convert standing crop measurements to rate estimates of productivity simply by integration of the dry weight curve on a seasonal basis (Penfound, 1956). Further conversion is made on the basis of the weight of carbon/area/time.

In recent years, measurements of the chlorophyll content of macrophytes have received attention. Odum, McConnell & Abbott (1958) have correlated the numerous variables of community distribution both spatial and temporal to their ecology. Several methods of estimating the relative rates of photosynthesis of macrophytes <u>in situ</u> have evolved from studies of community metabolism where the larger aquatic plants dominate a particular benthic region. Odum (1956) has described a widely used method of estimating a rough approximation of gross primary productivity of streams from diurnal O_2 curves with correction for oxygen diffusion, 8 where macrophytes are the major producers under certain situations. A similar approach to estimation of the total metabolism uses diurnal fluctuations of CO_2 concentration and pH (Odum 1957, Park, Hood & Odum, 1958). Though these methods of estimation of community metabolism in flowing waters are rough approximations, they represent a definite advance on the problems of <u>in situ</u> measurements in the more difficult environmental situations. Owens and Maris (1964) have determined the rates of oxygen consumption of the major species of the plant community of the River Ivel in order to be able to calculate the oxygen consumption of the plant community and its effect on the oxygen concentration of the river water. The effect of oxygen concentration of the water upon the oxygen consumption of the plant and also the influence of temperature on these rates have been studied. Two inches of the apical portions of excised shoots were used in these studies. They found also that plants in moving water consumed oxygen at a greater rate than those under quiescent conditions. It has been shown that

different parts of the same plant respond differently to changes in the oxygen concentration.

id

Fannier (1958) have noted a marked relation between O_2 consumption and O_2 concentration. They were also able to distinguish two types of plant groups (a) those plants where consumption of O_2 diminished proportionately with decrease in O_2 content and (b) those plants where respiration decreased logarthmically with decrease in O_2 content.

(ii) Investigations employing O_2 concentration changes by macrophytes in the field.

Using apical portions of hydrophytes or whole plants.

The apical portions of hydrophytes were usually removed, placed in flasks of unfiltered surface water and returned for incubation to the depths from which they were taken (Nygaard 1958; Gessner & Hammer 1960). Odum (1957a, 1957b) on the other hand, enclosed whole plants for incubation in large bell jars and withdrew periodically water samples from the chambers for oxygen analysis. Nygaard (1958) proposed similar studies <u>in situ</u> but used a slowly circulating system of water renewal in the experimental vessels.

The above techniques of O_2 measurement have several inherent limitations and sources of error when applied to larger hydrophytes. When apical portions of the submerged hydrophytes are used, they exhibit greater assimilation values and decreased coefficients of respiration than do the basal parts as would be expected. If, on the other hand, the macrophytes are removed from the substratum, brought to the surface to place them into flasks, and returned to their original depth for incubation, these manipulations may cause injury to the plants. (e.g. light injury) (Nygaard, 1958).

"The dependency of truly rooted submergents upon the substratum or on nutrients of the water or both and in what ratios, is still questionable and yet to be fully explained" (Wetzel, 1964). Several other factors can increase the disturbance caused

1 by uprooting the plants and placing them in flasks. Vollenweider and Nauwerck (1961) have drawn attention to possible increase of bacterial populations on the newly provided vessel surfaces when they are exposed to periods greater than six hours. At shallow depth bubble production becomes much more common (Ramsey 1962; Odum 1957a). Again, most species of submerged angiosperms contain large lacunae where appreciable quantities of oxygen are stored and are partially utilized in respiration, especially during periods of darkness (Wetzel, 1964).

(iii) <u>Carbon-14 and light and dark chamber techniques.</u>

Wetzel (1964) found considerable difference between the estimate of photosynthesis obtained by the carbon-14 technique and that obtained by the light and clear chamber method (the Oxygen method) of Odum (1957) and Nygaard (1958). The latter method (which is based on determination of the amount of oxygen evolved) gave the negative results whereas the radio-carbon technique showed a slight but

12 significant net quantity of carbon fixation.

According to Wetzel (1964), the oxygen method (dark and clear bottles) generally gives greater productivity values than the carbon-14 technique because the former is a measure of community metabolism rather than just that of the particular plant species or community under consideration although the larger plants can dominate a particular ecosystem. The flora of the sediments and the ultra-plankton influenced oxygen measurements, even though the water was prefiltered to eliminate the major planktonic organisms. Overestimation by the oxygen method as a result of autosynthetic processes other than those of the macrophytes is one of its major disadvantages.

Also as Wetzel has pointed out, oxygen bubbles are formed frequently within the chambers and trapped among finely dissected leaves even within a relatively brief incubation period in vacuum prefiltered water. Furthermore, most species of

3 submerged angiosperms contain large lacunae where appreciable quantities of O_2 are stored and partially utilized in respiration, especially during periods of darkness.

"Many of these errors are difficult or impossible to circumvent in field investigations, but equipment for C14 determinations may not be available.Also it is often desirable to determine the gross as well as net production. In such circumstances the oxygen method may be used but careful consideration must be given to possible sources of errors and the results must be interpreted with extreme caution" (IBP Handbook No.12, 1969, p.84).

Westlake (1969, p.90-91) has stated that the large diurnal changes in the concentration of oxygen and carbon dioxide accompanied by changes in pH in the natural environment of macrophytic aquatic non-isolated natural communities may be used to estimate primary productivity similar to changes in enclosures used for phytoplankton

4 productivity. Accordingly, this method has been used in this study for the same purpose and it is detailed under "Materials and Methods".

(c) <u>Productivity measurements of Periphyton (Aufwuchs) : General.</u>

'Aufwuchs' is the term applied by Germans to the entire sessile benthic community. Some use the term to indicate attached organisms on submerged macro-flora, while others use the term 'Bewuchs' for attached organisms on glass plates. 'Epiphyte' is used for organisms attached to larger plants both aquatic and terrestrial. 'Epilithic algae' refers to algae attached to rocks; and the term 'epipelic algae' to those seen on the surface of sediments.

'Periphyton' originally included those organisms attached to artificially submerged objects and later included organisms growing on the submerged objects including rooted macrophytes. The sessile organisms are counted per unit area of the artificial substratum. Cooke (1956), Castenholz (1960) and

Sladeckova (1962) have reviewed the subject.

A generally common technique of quantitatively estimating dominant groups of algal periphyton and successional rates of colonization is the method originally adopted by Hentschel, 1915 (Cf. A. Sladeckova 1962). On this method glass plates were immersed for varying periods of time. Numerous types of materials in addition to glass plates have been tested and compared. Butcher (Cf. A. Sladeckova, 1962) summarised the results of using glass slides for 15 years in river conditions relating the distribution of periphytic algae to the degree of eutrophication, to seasonal meteorological variations to variations in and currents. Reimers and Combs 1956 (Cf. A Sladeckova, 1962) traced the seasonal fluctuations of the dry residue, the ash and the organic fractions of periphytic algae using the method of Nelson (1953) where glass slides were suspended in a vertical position along a line from surface to bottom. A high correlation was found between the organic fraction of the periphyton and the temperature, 6 as the growing season progressed. Marked differences in colonization have been found with the position in which the plates are held. Glass is not selective for the attachment of diatoms (Patrick, Hohn, & Wallace, 1954). Grazing can lead to serious alteration of results. Within the limitations of the technique the glass slide method is a useful tool for the estimation of standing crop of a majority of the periphytic organisms (Castenholz, 1961).

Estimations of standing crop of periphytic producers by quantitative measurements of chlorophyll content have been few. Several workers have used slides as a medium for attachment of periphyton and have estimated standing crop by extracting chlorophyll from a known area. Young (1956) used the rate of accumulation of chlorophyll on glass as an index of productivity of a Florida spring. Few attempts have been made to quantify the growth rates of natural populations of periphyton *in situ*.

7 Statistical correlation was found between broad spectrum of "phytopigment units" and organic weight.

Methods for measuring production rate of periphyten :

Wetzel (1969, p.88-90) has dealt with at length, the oxygen methods of measuring production rates *in situ* and has emphasized the difficulties involved in this field of study.

C^{14} techniques have been applied only in a few cases (Vollenweider and Samaan 1958; Eichelberger 1963; and Wetzel 1963, 1964).

(d) Productivity Measurements of Phytoplankton :

The literature relating to the general principles governing biological productivity of phytoplankton in natural waters is numerous. Vollenweider (1969, p.41-60) has briefly described the guiding principles involved in primary production processes by phytoplankton in natural waters and

18 also the methods employed for measuring the production rates. Measurements are made (a) on isolated samples of natural communities and (b) directly in the natural environment i.e. on non-isolated communities taking advantage of the over-all community metabolism (in these two cases oxygen determinations are made by the classic procedure of the 'Winkler Method' and its various modifications). Productivity estimates are also made from changes taking place during longer periods in biomass increases, nutrient depletion and hypolimnetic oxygen consumption. Also, CO_2 system analysis and pH changes are used as the most sensitive indicators of variations of the ecosystem. C^{14} tracer techniques are also employed for the purpose. The details of these techniques are described under the respective headings in the IBP Handbook No.12 (1969).