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CONTINUOUS RECORDING TECHNIQUE TO MEASURE OXYGEN RELEASE FROM A SEAGRASS COMMUNITY WITHIN AN ACRYLIC INSULATION CHAMBER

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CONTINUOUS RECORDING TECHNIQUE TO MEASURE OXYGEN RELEASE FROM A SEAGRASS COMMUNITY WITHIN AN ACRYLIC INSULATION CHAMBER

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Abstract

A method for measuring net photosynthesis of a seagrass community is described. A transparent acrylic dome with oxygen, temperature and light probes is placed *in situ* and continuous recordings are made of these parameters. Some of the problems of measuring oxygen release from vascular macrophytes are discussed. Technical descriptions of apparatus used are given.

INTRODUCTION

Numerous mechanical and physiological problems which affect the validity of oxygen techniques for measuring productivity in submerged macrophytes (Vollenweider 1969) have been recognised. During lengthy incubation to measure oxygen release, bacterial populations increase greatly on the surfaces of the enclosing vessels (Zobell and Anderson 1936). Nutrients may be depleted from the enclosed water, limiting photosynthesis. Oxygen super-saturation may also occur and result in the dissolution of gas as bubbles with their subsequent loss from analyses for dissolved oxygen. Carbon dioxide may become limiting. *In situ* the instruments contained by incubation chambers may measure the contribution of other components of the enclosed benthic area and water column as well as the macrophytes' net oxygen release. Internal storage of gases in extensive lacunal spaces by marine angiosperms with utilisation of the stored oxygen is considered an important limitation and source of error in the application of oxygen techniques (Hartman and Brown 1967).

Previous methods used to measure oxygen release include that of Odum (1956 and 1957), who measured what he called the diurnal "upstream-downstream" oxygen concentration in a flowing stream. While this may be satisfactory in a freshwater stream, it is not suitable for the large, shallow areas typical of seagrass meadows where water flow changes direction each tide and continuous diel oxygen concentration could not be measured. There is also the problem of vertical diffusion across the water surface. Nixon & Oviatt (1972) measured diffusion across the water surface using a floating plastic dome and oxygen meter. Neither of these methods make proper allowance for photosynthesis and respiration of plankton or benthic organisms other than the vascular macrophytes. However, Nixon & Oviatt (1972) used "light and dark" bottle incubations to estimate plankton production and respiration and subtracted this from the total community metabolism obtained from the floating dome. Most seagrass meadows are subject to tidal fluctuations of up to 2 m such that dissolved oxygen content of a changing volume of water may not reflect the true release of oxygen from the seagrass community.

Many of these problems can be overcome. Using a large volume/surface area enclosure, the effect of settling bacteria is minimised. Bubbles of gas escaping from the water can be trapped and oxygen volume measured. As a control, a second enclosure can be placed over an adjacent bare area to measure oxygen production or consumption of the contained benthic diatoms and bacteria and water column plankton. This paper describes an apparatus and technique based on these considerations.

Table 1. Oxygen solubility equation and constants.

$$\ln C = A_1 + A_2\,(100/T) + A_3\,\ln\,(T/100) + A_4\,(T/100) + S^{o}/oo\,|B_1 + B_2\,(T/100) + B_3\,(T/100)^2|$$

	$\mu mol\ Kg^{-1}$	$mg\ \ell^{-1}$
A_1	-173.9894	-173.4292
A_2	255.5907	249.6339
A_3	146.4813	143.3483
A_4	-22.2040	-21.8492
B_1	-0.037362	-0.033096
B_2	0.016504	0.014259
B_3	-0.0020564	-0.0017

C = Solubility of oxygen in $\mu mol\ kg^{-1}$ or $mg\ \ell^{-1}$
S^{o}/oo = Salinity in parts per thousand
T = Degrees absolute

METHODS

A pair of large identical acrylic domes was designed to measure the change in dissolved oxygen concentration in seawater over a period of time sufficient for lacunal spaces to equilibrate, i.e. greater than 24 hours. One dome enclosed a seagrass community while the other enclosed a nearby sandy area.

We required almost continuous dissolved oxygen measurements; an electrochemical technique with recordings every two minutes was considered ideal. We used a membrane type electrochemical sensor with an active cell. In this sensor, dissolved oxygen diffused through a membrane and was reduced at the cathode, generating a measurable electric current.

The generated current was directly proportional to the activity of dissolved oxygen in solution and temperature since membrane permeability is dependent upon temperature, and the relationship between activity and concentration for dissolved oxygen in water is a function of temperature.

Temperature and oxygen saturation were measured simultaneously and, by using the temperature coefficient for this particular membrane ($4.2\%\,^{o}C^{-1}$), corrected values as per cent saturation were obtained. These were calculated to absolute units of oxygen concentration ($mg\ \ell^{-1}$) and micro-mole of monooxygen per kilogramme of seawater ($\mu mol\ kg^{-1}$) by the use of a solubility formula given by Kester (1975) (Table 1). The solubility formula also required the measurement of salinity.

The theory of operation, testing and calibration of dissolved oxygen sensors was described by Pijanowski (1975).

Apparatus

Oxygen electrode. Commercially manufactured probes (Model 500 MB) were purchased from Titron Instruments (Melbourne, Vic.). A length of thirty metres of coaxial cable was specified so that recording instruments could be housed this distance or depth from the probe.

Oxygen meter. Meters (Fig. 1) were designed and supplied by L. Stellema, Professional Officer, Department of Aeronautical Engineering, University of Sydney. The meters have a recorder output voltage of 0-100 mV full scale deflection.

Temperature Sensor. A platinum resistance thermometer (Ivor Aanderaa, Mesttum, Norway) capable of measuring temperature to $\pm\ 0.1\,^{o}C$ was used in accordance with the manufacturer's specifications.

Conductivity Sensor. An Aanderaa Current Meter (Ivor Aanderaa, Mesttum, Norway) was used to measure and record temperature and conductivity from which salinity was calculated (Wilson 1975).

Light Sensor. Light was measured as photosynthetically active radiation (PAR) using a Lambda underwater quantum sensor (Lambda Instruments, Lincoln, Nebraska) in units of $\mu\varepsilon\ m^{-2}\ s^{-1}$.

Data Logger. Two Aanderaa twelve channel data loggers were used to record the output voltages from the above instruments onto magnetic tape (Scotch Type 177). The polarizing effect of the generated current in the oxygen electrodes could have confounded the generated current so separate loggers for each probe were used.

Incubation Chambers. Completely submersible chambers were constructed from clear 0.63 cm transparent acrylic (Plate 1). Each consisted of a cylinder with a steel collar attached. The collar was pushed into the sediment. Over the cylinder fitted a dome held in place by galvanised steel clamps. A watertight join was effected by a layer of neoprene around the lip of the cylinder. When the dome was removed all plant material within the cylinder could be easily harvested. A 12 V DC submersible bilge pump (Hanimex Model 682178/6) was attached to mix the contained water and create the necessary flow of water past the oxygen electrode.

Table 2. Oxygen concentrations and rates taken over bare sand and seagrass. Light meter readings taken over seagrass.

1	2	3	4	5	6	7
Time	Bare sand	Rate bare sand	Seagrass	Rate seagrass	Net rate (5 - 3)	Light
	µmol kg^{-1}	µmol kg^{-1} hr^{-1}	µmol kg^{-1}	µmol kg^{-1} hr^{-1}	µmol kg^{-1} hr^{-1}	µε $m^{-2}s^{-1}$
1500	179.81		238.57			1477.00
1600	180.29	0.5	258.67	25.1	24.6	1161.03
1700	180.24	0	291.85	33.2	33.2	647.21
1800	180.96	0.7	308.96	17.1	16.4	222.44
1900	180.45	-0.5	305.51	- 3.4	- 2.9	0
2000	181.73	1.3	300.06	- 5.5	- 6.8	0
2100	183.12	1.4	283.13	-16.9	-18.3	0
2200	182.85	-0.3	254.43	-29.7	-29.4	0
2300	183.92	1.1	220.70	-33.7	-34.8	0
0000	185.48	1.5	200.50	-20.2	-21.7	0
0100	183.92	-1.5	188.89	-11.7	-10.2	0
0200	182.13	-1.8	177.45	-11.5	- 9.7	0
0300	180.39	-1.8	170.00	- 7.5	- 5.7	0
0400	177.90	-2.5	160.51	- 9.5	- 7.0	0
0500	174.11	-3.8	158.80	- 1.7	2.1	0
0600	170.90	-3.2				
0700	168.68	-2.3				
0800	168.23	-0.4	146.76	-12.0	- 6.1	108.80
0900	171.09	2.9	144.16	- 2.6	- 5.5	430.73
1000	176.06	5.0	151.29	7.1	2.1	661.37
1100	175.48	-0.5	161.39	10.1	10.6	924.06
1200	175.26	-0.2	168.27	7.0	7.2	1140.91
1300	174.41	-0.8	180.91	12.7	13.5	1251.95
1400	174.22	-0.2	204.66	23.7	23.9	1434.89
1500	174.57	0.3	230.15	21.0	20.7	1081.29
1600	175.08	0.5	251.17	22.8	22.3	624.11
1700	175.40	0.3	273.93	38.2	37.9	551.45
1800	175.72	0.4	312.16	-15.7	-16.1	214.62
1900	173.74	-2.1	296.44	-7.2	- 5.1	13.04
2000	175.79	2.0	289.86	-55.8	53.8	0
2100	180.69	4.9	223.46	-25.3	-30.2	0
2200	165.69	-15.0	197.08	-10.7	4.3	0
2300	176.78	-4.0	186.38	- 7.0	- 3.0	0
0000	176.31	-0.4	179.42	- 5.0	- 4.6	0
0100	174.76	-1.6	174.39	- 6.7	- 5.1	0

Calibrating the Oxygen Electrode

One of the main sources of error inherent in this measuring system was the fluctuating response of the permeability of the electrode membrane to temperature (Kinsey and Bottomley 1963). The electrode was calibrated to the midpoint of anticipated field temperatures.

Procedure. A zero per cent saturation oxygen solution was made up by dissolving 100 mg sodium sulphite crystals in 5 mℓ of 0.01 molar borax. The electrode tip was placed in this solution for four or five minutes until a stable reading was observed on the oxygen meter. The zero helipot of the meter was then adjusted so that the meter read zero. To set the upper range of the scale (the gain) a constant temperature water bath was used, set at $20^{o}\pm0.5^{o}C$, as it was anticipated that a range of 19^{o} to $21^{o}C$ would be experienced *in situ*. After about two hours the oxygen content of this water was in equilibrium with the atmosphere. A Winkler analysis of this water was performed to determine the exact oxygen concentration (Strickland and Parsons 1972). The oxygen meter was set by the gain helipot so that a full scale deflection was equal to 200% saturation, i.e. 100 mV = 200% saturation. Another Winkler analysis was performed to check that the oxygen concentration in the water bath had not changed. The recorder output of the meter was adjusted by the third helipot, so that it matched the meter. (N.B. The recorder helipot adjustment is independent of the meter gain). To maintain calibration, the oxygen meter was left on and the oxygen electrode kept in water.

Tape Translating

All recorded data were translated on the PDP 11 computer at CSIRO Division of Fisheries & Oceanography, Cronulla. Translations were edited and half-hourly and hourly means were calculated with plots against time. Light readings were plotted as their logarithms to the base 10 against time.

RESULTS

Table 2 presents the results of a preliminary experiment performed on a monotypic seagrass community, *Posidonia australis* Hooker f., and on nearby bare sand. One hourly absolute concentrations of oxygen are presented in columns 2 and 4. Rates of oxygen consumption/release are calculated as the differences between consecutive one hourly means. The net rate (column 4) is the difference between the rate of oxygen consumption or release of oxygen from the seagrass and that of the bare sand. These rates are depicted in Fig. 2. From the net increase in oxygen concentration net photosynthesis may be calculated.

DISCUSSION

Use of this dome technique has provided a satisfactory diel oxygen release curve for the monotypic seagrass *Posidonia australis* community.

In interpreting results of the technique the following limitations should be considered:

1. Oxygen values in the control chamber do not distinguish between respiration and photosynthesis of the epibiota and this problem has yet to be resolved.
2. Nutrients are taken up through roots as well as leaves (McRoy and Barsdate 1973), but depletion of the enclosed substrate and water may not be limiting to photosynthesis in the experimental periods, up to 72 hours.

3. The present technique does not account for internal oxygen recycling by the seagrass. In addition, seagrasses also transport oxygen to their root/rhizome system and probably maintain, for at least part of the time, an oxidised layer around the roots. In most seagrass beds, including the present experimental bed of *Posidonia australis*, the sediments surrounding the roots are strongly anoxic and this could lead to essentially a continuous sink for oxygen that is passed, via the lacunal system, to the roots and subsequently lost across their surface by diffusion (McRoy, personal communication).

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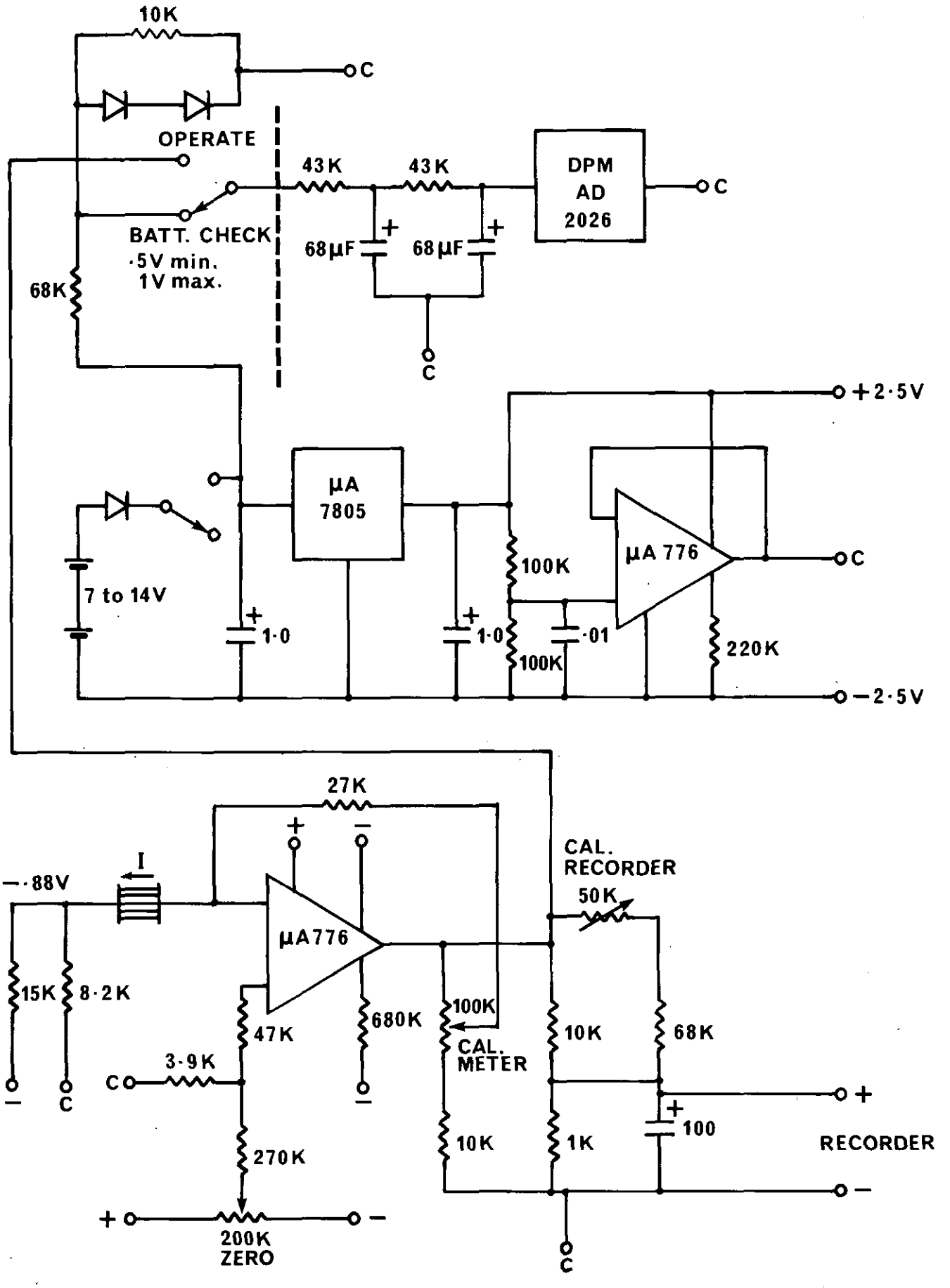

Fig. 1 Electronic circuit diagram for oxygen meter.

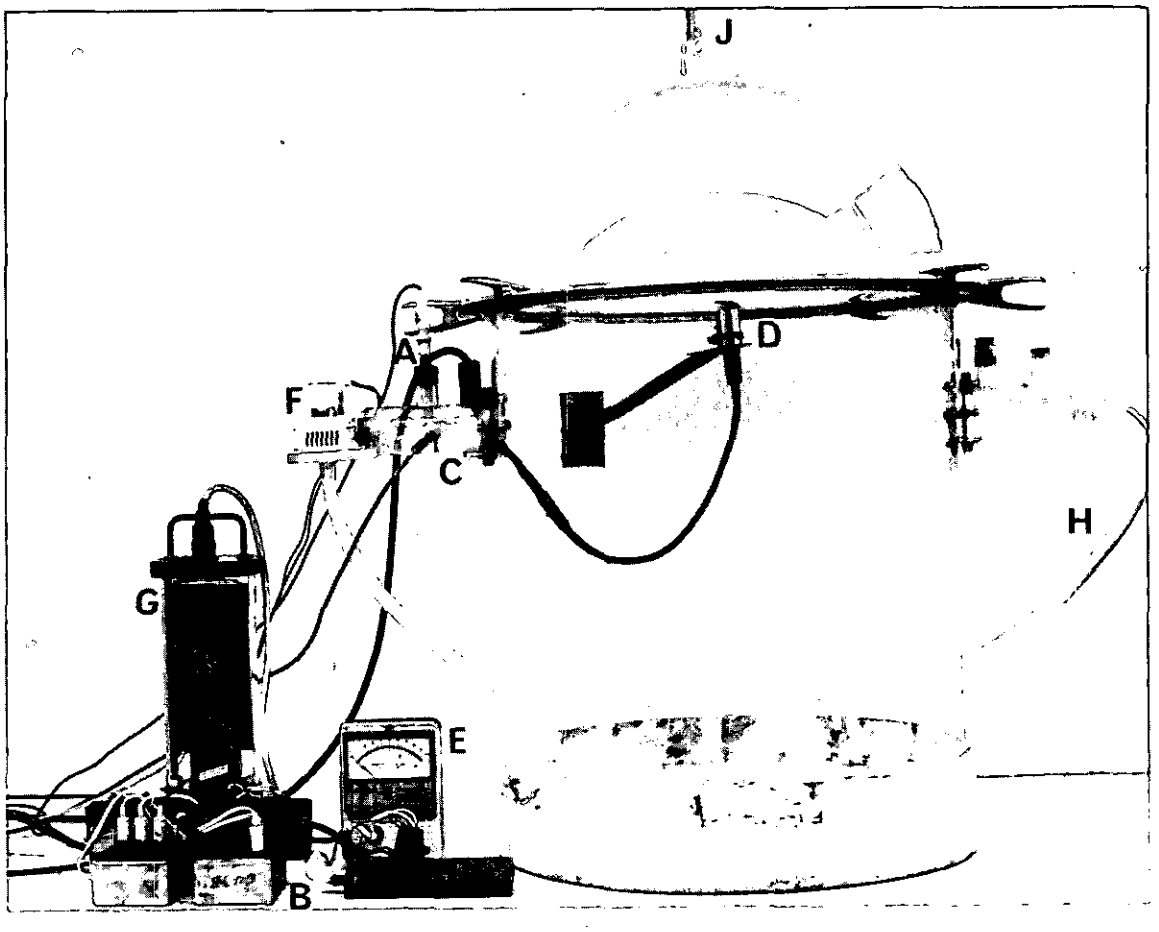

Plate 1 Acrylic dome and instruments.

A. Oxygen electrode
B. Oxygen meter
C. Temperature sensor
D. Light sensor
E. Light meter
F. Submersible pump
G. Data logger
H. Recirculating tube
J. Nipple to remove free gases