Professor Raymont, to seek any assistance they might require of UNESCO or IOC in arranging facilities with host countries.

COSTED should be informed of these proposals of SCOR and be advised that SCOR will assist COSTED wherever possible but, for the time being at least, SCOR believes that it can most effectively contribute through the UNESCO Division of Oceanography and IOC.

ANNEX IV

SCOR WORKING GROUP 15 (with UNESCO and IAPSO)
PHOTOSYNTHETIC RADIANT ENERGY

RECOMMENDATIONS

The terms of reference given to Working Group 15 by SCOR were:

(i) To identify exactly what measurement of irradiance is required by biological oceanographers;

(ii) To recommend apparatus and procedure for measuring the variable defined above.

The Working Group has confined its activity to the measurements of radiant energy as it relates to the determination of oceanic primary productivity by the C^{14} incubation technique.

With respect to term of reference (i):

The basic recommendation of Working Group 15 is that biologists should measure the total-quanta available for photosynthesis within the wavelength limits 350 to 700 nm. The units of this measurement would be quanta per unit area per sec.

Because of the technical problems associated with the measurement of spherical irradiance (i.e., a measurement giving equal weight to quanta arriving at a point from all possible directions) Working Group 15 recommends a measurement of total downwelling irradiance (in quanta per unit area per sec) on a horizontal flat surface, and within the wavelength limits 350 to 700 nm.

In the event that no quanta meter is available, the subordinate recommendation of Working Group 15 is that biologists should measure total downwelling irradiance (in watts per unit area) on a horizontal flat surface and within the wavelength limits 350 to 700 nm.

With respect to term of reference (ii), Working Group 15 recommends that:

Apparatus recommendation:

I. The radiant-flux sensor for measuring downwelling quantum irradiance should incorporate:

a) A photosensitive device having suitable spectral-sensitivity characteristics and adequate response for the planned application.

b) An optical filter having spectral transmittance such that the product of its spectral transmittance multiplied by the spectral sensitivity of the photosensitive device (multiplied (when necessary) by the spectral transmittance of the collector in C below) imparts equal quantum sensitivity to the combination, within the wavelength limits 350 nm and 700 nm and substantially zero sensitivity at other wavelengths.

c) A white irradiance collector, that is, a radiant flux collector that performs the integration specified in the equation below and that exhibits minimum selective absorption, especially in the spectral region 350 nm to 700 nm.

$$E = 2\pi \int_{0^\circ}^{90^\circ} B \sin \theta \cos \theta \, d\theta \qquad (1)$$

In the equation, E represents the total collected quanta per unit area per sec and B represents the quanta per unit solid angle per unit area per sec arriving from various directions.

II. In the event that no quanta-meter can be made available, the subordinate recommendation of Working Group 15 is that the photosensitive device be fitted with an optical filter (in place of the filter discussed in (b) above) having spectral transmittance such that the product of its spectral transmittance multiplied by the spectral sensitivity of the photosensitive device (multiplied (when necessary) by the spectral transmittance of the white collector), imparts equal energy sensitivity to the combination, within the wavelength limits 350 nm and 700 nm and substantially zero sensitivity at other wavelengths. Recommendations (a) and (c) in this section remain the same.

Procedural recommendations:

I. For measuring downwelling quantum-irradiance in the ocean, Working Group 15 recommends the following procedural details:

a) "Downwelling irradiance" as used herein implies that the underwater irradiance collector is horizontally oriented. When necessary, precautions should be taken to insure horizontal orientation.

b) Measurements of irradiance should be obtained in the vicinity of the phytoplankton samples that are being studied. Both the quanta meter and the phytoplankton samples must be far away from any perturbation of the normal light distribution, due to the presence of the ship or other interfering obstacle.

c) At each location and depth, the measurement of quanta should be sufficiently prolonged to obtain a useful average value.

d) Measurements with a quanta meter should be corrected for the optical immersion effect.

e) The underwater quanta meter should be equipped with a suitable depth transducer.

II. For measuring downwelling quantum-irradiance at deck level, and/or in an incubator, Working Group 15 recommends:

a) A horizontally oriented quantum-irradiance meter mounted in gymbals and located in an open area as free as possible from interference from shadows cast by the ship's rigging or equipment.

b) The quantum-meter should be constructed so that it can be immersed in each section of the deck incubator so that measurements of total quanta available for simulated-in-situ carbon fixation can be made.

c) Measurements of quantum irradiance in each section of a deck incubator, and the incubation of all photosynthesis samples, should be conducted under lighting conditions that closely simulate the natural lighting conditions encountered by the phytoplankton in the ocean at the depth from which they were collected.

Comments on Recommendations

In circulating these formal recommendations to members of the Working Group for signature, the following comments have been offered by individual members.

H. Jitts has commented that Procedural Recommendation I(c) is "weak and unclear". Professor Ivanoff has suggested the inclusion of a numerical specification of accuracy in the measurement of quanta above the surface. N. G. Jerlov and E. Steemann Nielsen have jointly advocated greater technical detail.

These criticisms are in large part corrected by the information given in the section headed, Discussion of State of the Art, which follows.

Y. Ochakovsky has pointed out that under term of reference (ii) (section on Apparatus Recommendation), if no quanta meter can be made available, the energy units in Equation 1, section I(c), will be E, in watts/area and B, in watts/unit solid angle area. Also, in Section I and II of the Procedural Recommendations, if measurements in watts are made, all references to quanta meters and quantum units must be changed to energy units (i.e., watts). Dr Ochakovsky is correct.

Discussion of State of the Art

by

John E. Tyler - Chairman W. G. 15

The concepts and procedures set forth in the above Working Group 15 recommendations were employed successfully during the SCOR DISCOVERER Expedition and an adequate technology exists.

The purpose of this addendum to the Working Group 15 recommendation is to relate and reference this technology.

The conceptual objective of recommendation (i) is to measure the quanta (or energy) available to the phytoplankton. Radiant flux will be "available" to oceanic phytoplankton only if the wavelength distribution of the flux lies within the spectral sensitivity range of the phytoplankton and then only if that flux can be successfully collected, in a geometrical sense, by the phytoplankton.

In order to fulfill this latter conceptual requirement, it is necessary to have detailed information regarding the directional collecting properties of phytoplankton populations. This information is not available and it was therefore necessary for the Working Group to consider measurements that would closely approximate the directional collecting properties of the phytoplankton. The Working Group would have preferred to recommend a measurement of spherical quantum irradiance (as implied in recommendation (i)) but felt that spherical irradiance collectors were not sufficiently well developed.

The radiometric concepts of irradiance, spherical irradiance (and others) are defined and discussed in detail in references (1), (2), (3), and (7). Simple instruments for measuring irradiance and quantum irradiance in the ocean have been described in references (4), (5), and (6).

Detailed data on the spectral quanta (and energy) that penetrates into various types of ocean water are available in the Data Report of the SCOR DISCOVERER Expedition (reference 9, Sections F and G) and in reference (8)). These data are useful in determining the sensitivity requirements of submersible irradiance meters. It has been estimated that irradiance meters for this purpose should be calibrated with an accuracy better than $\pm 5\%$, should exhibit a precision of 1% and that experimental measurements of quanta/m^2 sec (or watts/m^2) in the ocean should have an accuracy better than $\pm 10\%$.

The measurement of irradiance (in any inuts) from shipboard is made difficult by the presence of the ship which casts a large shadow, by the motion of the air-ocean interface which superimposes noise on the measurement and by variations in surface flux due to clouds. No quantitative evaluation of the effects of these problems has been made. Section I(c) of the Prcoedural Recommendations alludes to these problems.

It has been suggested that a continuous record of surface quanta should be made and that underwater measurements of quanta should be averaged over a period at least as long as one ocean-swell period.

Methods for correcting for the optical immersion effect referred to in Procedural Recommendations I(d) are detailed and illustrated in reference (4). The depth transducer referred to in Procedural Recommedation I(e) should have an accuracy consistent with the objectives of the research.

For the experiment on the SCOR DISCOVERER Expedition, a continuous recording of total quanta/m^2 (350-700 nm) was obtained in the simulated-in-situ incubator (under a blue-green filter--see comments below on Section II(c) of Procedural Recommendations), a continuous recording of total quanta/m^2 (350-700 nm) was also obtained at a depth of one of the in-situ incubation bottles, and total quanta/m^2 (350-700 nm) was measured as a function of depth in the ocean in order to locate the in-situ incubation bottles at depths where the available quanta/m^2 was the same as measured under blue-green filters in the various sections of the deck incubator. Additional details of this

procedure are given in the Data Report of the SCOR DISCOVERER Expedition, reference (9), Sections A and Introduction.

Section II(c) of the Procedural Recommendations requires that the spectral and spatial distribution of radiant flux in each incubator section should simulate the natural spectral and spatial distribution of the radiant flux available to the phytoplankton in the natural environment. The spatial distribution of underwater radiant flux has been measured and the data published in references (10), (11), and (12). The spectral distribution of underwater radiant flux is recorded in references (8) and (9) - Sections F and G.

The incubator used in the SCOR DISCOVERER Experiment was divided into sections, each one of which was painted to simulate the measured spatial distribution of underwater radiant flux. (Data for this purpose is available in references (10), (11), and (12).) Each section of the incubator was covered with one or more blue-green glass filters chosen to simulate the spectral distribution of the underwater radiant flux at different depths. Additional details of this procedure are recorded in reference (9), Section B.

Additional references relevant to the DISCOVERER Experiment will be found at the end of the text that precedes each section of the Data Report of the SCOR DISCOVERER Expedition (reference (9)).

Brief reports of the SCOR Working Group 15 planning meetings in 1964 and 1966 and of the sea trials in 1968 are published in references (13), (14), and (15).

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ANNEX V

SCOR WORKING GROUP 27 (WITH ICES AND UNESCO) TIDES OF THE OPEN SEA

Report on 4th Meeting, Wormley, UK, 10 November 1973

Members present: Cartwright, Dohler, Hyacinthe, Radok, Schott, Voit and Zetler. Munk and Teramoto sent their apologies for their inability to attend. M. Demerliac of SHOM, Brest, attended as an observer. Zetler acted as Secretary for the meeting.

Dr David Cartwright, Chairman, reviewed the following changes in membership: Schott for Germany; Eyries replaced by Hyacinthe, with Eyries listed as his alternate; and Zetler as alternate for Munk.

The Chairman read the SCOR terms of reference for the Working Group. There were no comments. The agenda for the meeting was then distributed.

1. Intercalibration Exercise

   (a) The Chairman reported on the mooring cruise (30 October to 7 November 1973) in which eight gauges were deployed on a line west from Brest as follows: