UNIVERSITY OF CALIFORNIA, SAN DIEGO
SCRIPPS INSTITUTION OF OCEANOGRAPHY
VISIBILITY LABORATORY

On the Measurement of Radiant Energy for Correlation with Primary Productivity in the Ocean

FINAL REPORT ON CONTRACT:

N00014-69-A-0200-6017

Department of the Navy

Office of Naval Research

S. I. O. Ref. 70-38 December 1970

INTRODUCTION

Because of the primary correlation between photosynthesis and radiant energy, determinations of oceanic primary productivity must be related to simultaneous measurements of the radiant energy available for photosynthesis. In order for such radiant energy measurements to be significant, they must correlate as closely as possible with the energy utilized by the phytoplankton for photosynthesis.

For reasons which have no scientific basis, it has been common practice in the past to use lux-meters, which are conveniently available, to measure radiant energy for correlation with primary productivity determinations. Lux-meters are designed specifically to have a spectral sensitivity that approximates as closely as possible the spectral sensitivity of the human eye and obviously will yield measurements that have no fundamental relationship with either the absorption or utilization of radiant energy by oceanic phytoplankton.

There is also the important question of directional sensitivity of the detector to radiant energy. Clearly any instrument that is to be employed to obtain correlating information about the energy available to the phytoplankton in the ocean should have a directional sensitivity that relates logically to the directional sensitivity of the plants.

These and other aspects of dossimetry in connection with oceanic primary productivity were discussed at a symposium on the Biological

and Physical Aspects of Light in the Sea, convened in connection with the 10th Pacific Congress in 1961.

Shortly after this Congress the Scientific Committee on Oceanic Research became interested in the problem of dossimetry in relation to oceanic primary productivity and organized Working Group 15, which was given the following frame of reference:

1) To identify exactly what measurement is required by biological oceanographers;

2) To recommend apparatus and procedure for measuring the variable defined above (1).

J. E. Tyler was appointed chairman of this Working Group.

Contract No. N00014-69-A-0200-6017 has regularly supported aspects of the research effort of Working Group 15 which could not be supported by the international sponsoring organizations.

The membership of Working Group 15 between 1964 and 1969 was as follows:

John E. Tyler, Chairman
Visibility Laboratory, Scripps Institution of Oceanography
University of California, San Diego, U.S.A.

Professor Alexandre Ivanoff
Laboratoire d'Océanographie Physique
Universite de Paris, France

Dr. Nils Jerlov
Institute of Physical Oceanography
University of Copenhagen, Denmark

H. R. Jitts
Commonwealth Scientific and Industrial Research Organization
Division of Fisheries and Oceanography, Australia

Dr. E. Steemann Nielsen
Freshwater-Biological Laboratory
University of Copenhagen, Denmark

Dr. Yulen E. Ochakovsky
Institute of Oceanology
USSR Academy of Sciences, USSR

Dr. Yatsuka Saijo
Water Research Laboratory
Nagoya University, Japan

Dr. John H. Steele
Department of Agriculture and Fisheries
Marine Laboratory, Scotland

In 1969 John Steele resigned and was replaced by Dr. Ian Baird of the Marine Laboratory, Department of Agriculture and Fisheries for Scotland.

ACTIVITIES OF WORKING GROUP 15

The first meeting of Working Group 15 took place in October 1964. This was a planning and policy making meeting. The group made the following decisions:

1) We would not try to develop an "equivalent detector," that is, a detector which, per unit of flux input, yields a response equivalent to that of the phytoplankton;

2) We would undertake the development of a radiant energy detector which would measure the radiant energy available for photosynthesis;

3) We would consider only radiant energy in the wavelength region between 350 and 700 nm;

4) We would adopt "watts" or "quanta" as the standard unit for expressing radiant energy (and eliminate any reference to lux or other unit in lumens).

These decisions have since guided the research efforts of the group.

Also at the 1964 meeting a program of research was outlined which involved the construction of instrumentation for underwater light measurements, the design of a deck incubator for simulated-in-situ productivity determinations, studies on the correlation between total energy and measurements which employed narrow-band and/or broadband optical filters, and other studies that related specifically to the assigned problem.

The full "Report of the first meeting of the joint group of experts on photosynthetic radiant energy" was published by the Office of Oceanography, UNESCO, as UNESCO Technical Papers in Marine Science No. 2 (1965).[1]

The second meeting of Working Group 15 took place in August 1966. At this meeting the members reported individually on the research they had undertaken on behalf of the Working Group. Additional research tasks were assigned and a firm date was set for the conduct of sea trials of the radiant energy measuring equipment.

The "Report of the second meeting of the joint group of experts on photosynthetic radiant energy" was published by the Office of Oceanography, UNESCO, as UNESCO Technical Papers in Marine Science No. 5 (1966).[2]

This laboratory agreed to undertake a study of the magnitude of the errors of correlation involved, between the measurement of available radiant energy in air and underwater, to demonstrate the need for proper optical filters in deck incubator design.

This work and the publication of the report[3] were supported entirely by the subject contract. Equation 11 of that report is of special interest to biologists who are undertaking to correlate light measurements with photosynthesis. The report shows that errors as high as 75 percent can easily be made if optical filters are not used in the design of the deck incubator.

In May of 1968 the physicist members, plus one of the biologists, engaged in expeditionary work aboard the ELLEN B. SCRIPPS, a research vessel operated by the Scripps Institution of Oceanography. Much of the work conducted by this laboratory during these sea trials was supported by the subject contract. This includes the modification of instrumentation, organizational efforts, and construction of special equipment, including a catamaran barge which could be used on station to locate instrumentation favorably with respect to the sun.

The "Technical report of sea trials conducted by the Working Group on Photosynthetic Radiant Energy" was published by the Office of Oceanography, UNESCO, as UNESCO Technical Papers in Marine Science No. 13 (1969).[4]

The technical report gives:

1) Chlorophyll concentrations encountered;

2) The results of intercomparison of various instrument measurements;

3) The degree of correlation of narrowband and broadband measurements with total energy available;

4) Performance data on quanta meters;

5) The data obtained on primary productivity by the S.I.S. method.

The spectral irradiance measurements made by this laboratory were published in a separate report: Spectral Irradiance Data, SIO Reference 68-29 (1968).[5]

During April, May, and June of 1970 a major expedition was undertaken by the Working Group. Arrangements were made to use the ESSA ship

DISCOVERER. The subject contract provided essential support for the organization and conduct of this expedition, as well as special modifications to instrumentation employed by this laboratory during the expedition.

An expedition report was issued in September 1970 and is appended.[6]

APPRAISAL OF RESEARCH RESULTS

The research effort conducted by this laboratory alone (excluding for the moment the correlating results obtained by other members of the Working Group) has been eminently successful. Our part in the effort has been the accurate measurement of spectral irradiance underwater and the computation of spectral diffuse attenuation coefficients and reflectance function. During the period from 1966 through 1970, we have accumulated a large fund of such data on a variety of ocean water types. These data define the spectral properties of the radiant energy penetrating into the ocean, they define the spectral properties of the quanta available for photosynthesis, and they specify the spectral properties of the optical signal from the ocean which is available for remote sensing. There is no other instrument that can duplicate the resolution or accuracy of our equipment, although there is a French research instrument that can operate more rapidly and at greater depths than ours.

The combination of our data with the results obtained simultaneously by other Working Group members should represent a major achievement for biologists as well as physicists.

The expedition report, which is included with 40 copies of this Final Report, gives details of the measurements made by the Working Group during the DISCOVERER expedition. The work was planned to provide:

Measurements of primary productivity by three methods;

Measurements of available radiant energy underwater and in incubators;

Measurements of other parameters such as: nutrients, chlorophyll concentration, plankton species, temperature, salinity, and many other parameters that could relate to the central problem of the Working Group.

There were back up measurements planned for all the radiometric measurements in the event of instrument failure and a standard lamp with optical bench was provided in the ship's laboratory to check calibration, linearity, and stability of the various optical instruments.

The results of the expedition are planned to be reported as follows:

1) A data report during 1971;

2) An interpretation of the data in a separate report, planned for 1972;

3) Independent publication of results in the scientific literature. (No dates specified.)

I anticipate that Working Group 15 will complete their work and that the group will be disbanded perhaps during 1972.

BIBLIOGRAPHY

1. "Report of the first meeting of the joint group of experts on photosynthetic radiant energy" - UNESCO Technical Papers in Marine Science No. 2 (1965).

2. "Report of the second meeting of the joint group of experts on photosynthetic radiant energy" - UNESCO Technical Papers in Marine Science No. 5 (1966).

3. "Investigation of errors in the measurement of radiant energy for correlation with primary productivity" - S.I.O. Reference 67-11 (1967).

4. "Technical report of sea trials conducted by the Working Group on Photosynthetic Radiant Energy" - UNESCO Technical Papers in Marine Science No. 13 (1969).

5. "Spectral Irradiance Data" - S.I.O. Reference 68-29 (1968).

6. "Expedition Report S.C.O.R. Working Group 15 DISCOVERER Expedition 1970" - S.I.O. Reference No. 70-25 (1970).

7. "Measurements of Spectral Irradiance Underwater" - J. E. Tyler and R. C. Smith, Gordon and Breach Science Publishers (1970)

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author)	2a. REPORT SECURITY CLASSIFICATION
Visibility Laboratory Scripps Inst. of Oceanography, UCSD San Diego, California 92152	UNCLASSIFIED
	2b. GROUP

3 REPORT TITLE

ON THE MEASUREMENT OF RADIANT ENERGY FOR CORRELATION WITH PRIMARY PRODUCTIVITY IN THE OCEAN

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final Report - from 1966 to 1970

5 AUTHOR(S) (First name, middle initial, last name)

Tyler, John E.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
December 1970	9	6

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
N00014-69-A-0200-6017 b. PROJECT NO.	SIO Ref. 70-38
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

10 DISTRIBUTION STATEMENT

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Office of Naval Research, Dept. of the Navy, Oceanic Biology Branch, Code 408B Washington, D. C. 20360

13 ABSTRACT

The research carried on under this contract has shown that in the determination of oceanic primary productivity, the related measurements of available radiant energy must be made with appropriate consideration for the spectral and directional properties of the measuring and incubating equipment. Instrumentation for measuring spectral irradiance has been modified and used to determine the radiant energy (as well as the total quanta) available for phytoplankton photosynthesis at various depths to 100 meters in the ocean. Simultaneous in situ and simulated-in-situ determinations of the primary productivity have also been made.

This contract was terminated before any analysis of the accumulated data.

DD FORM 1 NOV 65 1473 (PAGE 1)

0102-014-6600

UNCLASSIFIED

Security Classification