UNIVERSITY OF HAWAII
HONOLULU 14, HAWAII

October 15, 1963

L. Fitts: are you in a position to deal with this, or should we send it to Dr Humphrey?

Dr. George Humphrey
C.S.I.R.O.
P. O. Box 21
Cronulla, N.S.W., Australia

Dear George:

Enclosed is a draft for a brief description of the outcome of our Perth primary productivity trials aboard the "Vityaz" in August, 1962. I am hoping that this manuscript may lead to a publication by the four of us who were responsible for the application of the different techniques in the field.

I will appreciate your reading this and suggesting rewrites for any or all paragraphs (referring to them by the number in the left margin). Naturally reorganization would help in some places and perhaps other subjects (or paragraphs) ought to be added. Each of you has received the raw data uniformly tabulated. To get any results useful at all there had to be a great many decisions made, especially in view of the lack of data from the "in situ" measurements at the shallower depths. Also, I'm worried as to what to call the statistics used in Table II. You will note that though in per cent we have referred in one place to this as standard deviation and in another place as "C," which is usually reserved by Americans for coefficient of variation (i.e., $\frac{\text{standard deviation}}{\text{mean}}$).

In connection with Table I, several attempts were made to compose brief paragraphs describing the techniques used. This was rather difficult and the Russian technique just couldn't be described in a brief paragraph. Thus, it was decided to try a table with literature references. This means that the actual technique modifications used are slighted in every case, but I hope their essence is caught in the verbage of the Table under "outstanding features." I'm sure each participant will have comments and improvements for this aspect of the manuscript.

Your response on this in the relatively near future would be appreciated... especially if you have suggestions as to what to do with this manuscript when finished.

Yours sincerely,

Maxwell S. Doty
Professor of Botany

MSD:bf
encl.

Comparison of marine primary productivity techniques

14-X-'63

1 It is becoming increasingly obvious that there are ultimate limits to the world's food production and thus it is becoming increasingly more urgent that this productivity be well known. Various adjectives have been used in subjective appraisals of the food productivity of the "sea," but only recently has a practical technique been devised for its quantitative measurement. Thus, today the basic rate of food production in the sea is measured by experimentally observing the rates that inorganic carbon-fourteen added to sea water becomes organic particulate carbon in phytoplankton algae as a result of photosynthesis.

2 The biological oceanographers of a good many countries now use carbon-14 methods, but each proceeding somewhat differently and using different equipment. In connection with the International Indian Ocean Expeditions (IIOE) intercalibration meetings have been initiated. The authors have represented their countries in one series of such meetings concerning primary productivity measurement at the invitation of Dr. George Humphrey, then President of the Special Committee on Oceanographic Research (SCOR) of the International Council of Scientific Unions. During the meetings the techniques of the individuals were discussed at length and in some cases applied to the same waters in a parallel manner. Aside from informal duplicated reports, only one brief report (Doty, 1962 /in Cyrillic/) has appeared in print concerning the results of the first of these meetings.

3 The most recent primary productivity intercalibration meeting was held aboard the research ship, "Vityaz," of the Institute of Oceanology of the U.S.S.R. working in the Indian Ocean off Fremantle, Western Australia. Individually the authors, none of them working entirely under the conditions usual for application of their technique or with what they considered a complete set of their customary

equipment or sampling gear, measured the productivity of the sea on four different days, August 3, 5, 6 & 7, near the positions given. They used their own equipment and methods (Table I) separately as much as possible. In addition, two other types of measurement were made which at one time or another had been suggested as reference methods for the IIOE phytoplankton primary productivity work.

Table I. The major differences between the different techniques used. The depths from which samples were taken were selected by the participants usually to be equivalent to the filters they used or to achieve the desired sampling of the water. The selection was from curves prepared by the hydrophotometric group aboard the ship of light penetration as a function of depth with deck level light accepted as 100 per cent. An exception was that the Australian group selected depths directly by sampling at depths where the light in the sea balanced the electric output from two photocells, one under the respective incubator filter and one at the sample depth in the sea. In general, the techniques used are described by Sorokin (1958), Vinberg (1960 & 1963), Jitts (1963), and by Saijo (1963).

Technique	Outstanding features
"In situ"	Largely as described by Steemann-Nielsen (1952) in the initial use of the method. Samples brought to surface, inoculated and resuspended in the sea at the sample depths for the incubation period. Water samples used were subsamples of light level samples for the other methods.
Prototype IIOE	Nylon net layers used around bottles submerged in a tray in sunlight to simulate light intensity of five sample depths, otherwise as described by Doty & Oguri (1958, 1959).
American	Nylon net layers used around bottles in ca 1500 foot candles intensity of fluorescent light to simulate five light depths from which the samples were taken. (Doty & Oguri, 1958, 1959)
Australian	Similar to prototype IIOE method but sun lit incubator light intensity adjusted with flat blue glass sheets. Six depths used. (Jitts & Wyrtki, "in press.")
Japanese	Similar to prototype IIOE method but perforated metal screen used to adjust sunlight intensity to that of six sample depths. (Saijo, 1960 & 1963.)
Russian	Samples from many depths incubated in sunlight subdued about 50 per cent by nylon netting. Values thus obtained adjusted for the characteristic "in situ" behavior of plankton in the area. (Koblentz-Mishke, 1960; Vinberg, et al., 1960.)

4 The data obtained were quite incomplete in some instances, but the presentation in Table II is made in order that a gross idea of the degree of variation in results due to the use of the different technique modifications may be presented. Unfortunately it has, thus far, been impossible for this international group to obtain comparative values having any satisfactory confidence level. Satisfactory confidence levels could be attained by repeating the application of the different techniques in a parallel manner at least three to four times more often than has been possible at one time thus far. From the four replicate sets of data available (Table II) it is even difficult to predict the number of replications required to obtain any given confidence level. Nevertheless, the values in Table II permit a first order approximation of the differences to be expected between measurements made by use of these rather different carbon-fourteen techniques.

5 First of all, note the uniformity of the "in situ" measurements (Table II, Column 3) repeated on what would seem to have been the same water mass. This method was selected as the IIOE reference method for it is thought to yield results nearer to the absolute natural rates obtaining in nature than does any other technique. The application of the method was quite unsatisfactory and thus the closeness of the last three of the four measurements cannot be accepted as probably repeatable.

6 In Column 9 of Table II there is given the standard deviation[1/] between the

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1/ Standard deviation in this case was calculated for the data in Table II, using 100 for the "in situ" value, thus the results are in terms of per cent. Standard deviation, non-mathematically described, is the square root of the sum of the squared values divided by one less than the number of values involved.

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productivity measurements made for that day by the different national groups. It is interesting to note the deviation among the six results is about 25 per cent though each result was from use of a different technique. Also each participant

Table II. A summary of comparative values and of statistics from the application of six techniques of measuring primary marine productivity off Perth, Western Australia, in August, 1962. The values for productivity were calculated to terms of milligrams of carbon fixed per 12-hour day per square meter of sea surface by integrating the values obtained by the different methods of Table I for the different depths.

Date	S. Lat. & E. Long.	Mg C/dy/m^2 from "in situ" a/ measurement	Per cent of "in situ" value					
			IIOE prototype	National group results				C % b/
				American	Australian	Japanese	Russian	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
3	32°26' 115°00'	123	75	112	90	146	143 c/	26
5	31°53' 111°43'	196	61	65	59	47	95	30
6	31°01' 112°57'	197	68	55	76	105	91	24
7	21°01' 112°46'	206	86	96	132	76	139	24
Mean		181	.73	.82	.89	.94	1.17	
C %		21.4	14.7	32.3	34.9	45.2	23.8	

a/ Surface fixation estimated as an average of that from the other five techniques, since surface samples were not processed "in situ."

b/ The values in Column 3 were included as 100.

c/ The mean ratio between the results from full sunlight and 50% uniform light incubations on other days was used to obtain a surface fixation rate for this day in full sunlight.

felt serious concern for the lack of adherence to the conventions of his technique and there were many irregularities in the routines of all.

7 Measurements of primary productivity in marine waters vary from perhaps .001 to as much as 100 mg C/hr/m^3 and 1 mg to 20 gm per square meter per day at different times in the different waters found in different geographic areas. In the face of such a wide range of variation (5 decimal places), a coefficient of variation of 25 per cent in one decimal place is, for biological measurements, almost negligible. Sampling in plankton and other biological procedures is not usually this good. It is generally believed that if the authors had been able to adhere to the conventions of their techniques and work in a more truly simultaneous manner, independently, the deviation from the mean found would have been nearer ten per cent than the near twenty-five per cent obtained here.

8 That none of the individual group techniques was conventionally employed in a way standard for the technique was one major fault of this intercalibration session. This is evidenced in the greater coefficient of variation (bottom line of Table II) for the national group sets of results (Columns 5-8) than for the reference method sets of results (Columns 3 & 4). The cause for this was lack of the facilities normal to the techniques for the different groups, or due to time restrictions. Support from the ship was excellent. Again, under normal conditions the individual operators felt the coefficient of variation within their own replicate measurements would be near ten per cent.

9 With only four replications, almost no confidence can be placed in the differences observed between the measurements of the different groups. Though the group techniques all together averaged 91 per cent of the "in situ" values,

six out of 16 times the group results (Columns 5-8) were higher than the correlated "in situ" values. Thus it is hard to say just what their relationship may be. It does appear that the "IIOE prototype" method yields results (Column 4) significantly lower than the others.

10 The internal consistency (C = 14.7%) of the results from the IIOE prototype incubation method, the simplest of all, however, indicates it may merit further attention. It may be that this consistency is an indication that the complexities of the other techniques introduce randomness (or chance variation). It could mean that the IIOE prototype method is undesirably less sensitive than the other methods.

11 If a high correlation prevails between a given group technique and related "in situ" values, then highly significant mean figures for the relationship between the two could be used to adjust values measured by one technique to those obtained by another technique. Another way to do this would be by using the regression of one on the other. Such intercalibration is the goal of these trials, but cannot be accomplished until all participants can apply their own technique completely and do this concordantly with the other participants and with sufficient replication over a sufficiently wide range of water types that satisfactory confidence levels are obtained for whatever relationships are found.

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Your Ref. P/HUM/2
Our Ref. GFH/SOC

19th November, 1963

Mr. H. R. Jitts,
Division of Fisheries and Oceanography,
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P.O. Box 21,
Cronulla, N.S.W.,
Australia.

Dear Harry,

I received from Cronulla a copy of the letter and report sent by Max on October 15. I shall not comment to him until I have your private comments and a copy of anything you have written back to him. I propose to be back on December 15.

Please ask Mr. Rawlings to deal with the enclosed request for apparatus for Grant and Jeffrey. There is no hurry for the information; it is something I shall need to have in front of me early next year.

Yours sincerely,

George

G. F. HUMPHREY

copy on H.O.25, sent to J.R.

1 hw Jitts