Reviews

Underwater irradiance as a factor affecting primary production

OCEANOLOGIA, No. 38 (3)
pp. 419–422, 1996.
PL ISSN 0078–3234

by Jerzy Dera, Dissertations and monographs IO PAS, 7, 1995; 110 pp. (68 + 42 in Appendix), 14 figures (13 + 1), 44 tables (4 + 36).

Professor Jerzy Dera's monograph deals with the important question of light and photosynthesis in the sea. Its principal objective is to outline the current state of knowledge about the inflow of solar radiation to the sea and its effect on the primary production of marine phytoplankton. The second, more utilitarian aim is to gather together a set of practicable mathematical formulas enabling the quantities of solar energy entering the sea, absorbed by marine phytoplankton and then utilised in photosynthesis, to be assessed. To achieve these aims Prof. Dera has made full use of the contemporary subject literature, and by selecting of appropriate illustrative material has described the state of research into light and photosynthesis which the Institute's scientists – himself included – have reached.

In the first section – 'The inflow of sunlight to a basin' – the author discusses in outline the factors responsible for the solar radiation energy reaching the three successive levels of the atmosphere-sea system: the upper boundary of the atmosphere, the layer just above the sea surface and that just below it. The problem is straightforward only with respect to the first of these levels, since the portion of solar energy entering the atmosphere is controlled merely by the geometry of the Sun – observation-point-on-Earth system. The author gives equations enabling these incoming downward irradiances (spectral and total, *i.e.* the light energy over the entire spectral range of solar radiation) and their daily doses for any observation point and any time to be determined from the known 'solar constant' and its spectral distribution. The determination of transmittances of the incoming solar radiation flux through the atmosphere and across the surface of a water basin is a very complex problem. Both of these processes display strong spectral selectivity, even when the sky is cloudless and the water surface smooth. The occurrence of clouds and the ruffling of the sea surface merely complicate the matter further. Thus it is impossible to provide a simple mathematical apparatus describing this transfer spectrally. The author does not consider these problems in detail here, and refers readers to the relevant literature. Instead, he concentrates on the following aspects:

- semi-empirical models describing the transmittances of total irradiances through a cloudless atmosphere;
- empirical expressions modifying these transmittances for a real atmosphere depending on the type of cloud cover;
- empirical relationships between the proportions of VIS energy (400–700 nm) in the total downward irradiances incident on the sea surface and the real transmittances of the atmosphere;
- empirical relations between VIS irradiances just above and just below the sea surface;
- mean relative spectral distributions of downward visible irradiance.

Clearly, by making use of these semi-empirical or empirical models and relationships the absolute spectral distributions of visible irradiances penetrating the sea can be defined approximately from actinometric data, for example, or very roughly on the basis of the cloud cover characteristics.

The coverage of solar radiation transfer into the water in Section 2 – 'Transmittance of irradiance into the water body' – is also brief, but nevertheless ample, based as it is on spectral models. The author has limited his analysis to the VIS spectral interval, which in the water is practically the same as the photosynthetically available radiation (PAR).

In this section, the author demonstrates by means of examples the spectral characteristics of underwater irradiance fields (the downward irradiance spectra at different depths or the corresponding spectra of the diffuse irradiance attenuation function) in various regions of the world ocean and discusses the reasons for their differentiation. There are two principal reasons. One is the origin of the optically active admixtures in seawater, which has led to its division into Case 1 Waters (mostly oceanic regions), where the admixtures are autogenic, and Case 2 Waters, *e.g.* the Baltic, where allogenic components additionally occur. The other, more significant reason for the differentiation in the optical properties of seawaters is the varying 'fertility' of the marine environment as a result of chlorophyll concentrations differing by as much as 3 or 4 orders of magnitude. Prof. Dera moves on to the various optical classifications of natural waters, focusing on the bio-optical classification of both Case 1 and Case 2 Waters, worked out by himself and the team of marine optics specialists at the Institute of Oceanology. He presents the mathematical formulas of these classifications, which enable a number of different optical properties of seawater, including the absorption of light by phytoplankton, to be assessed on the basis of assumed concentrations of chlorophyll. In the conclusion to this section he also draws atention to the short-term fluctuations of irradiance in the sea, which could have an indirect effect on photosynthesis.

The author begins Section 3 – 'The relation between irradiance and the characteristics of photosynthesis' – with a brief presentation of the photosynthetic primary production in the sea as a complicated function of its four most important abiotic factors, *i.e.* the underwater light field, the temperature of the water, its nutrient content and dynamic mixing. He then gives an in-depth analysis of the relations between the various characteristics of photosynthesis and underwater irradiance, and discusses two ways of describing the effect of irradiance on the rate of photosynthesis. The first, 'non-spectral' method is based on the analysis of this rate as a function of the summed underwater irradiances in the PAR spectral range, that is, the 'photosynthetic light curves'. In the second, 'spectral' method, this rate is expressed as a function of the irradiance spectrum, the absorption of the phytoplankton being studied and the photosynthetic quantum yield. The complete mathematical description corresponding to both these methods of describing photosynthesis is given together with the appropriate empirical parameters determined either for the Baltic (the non-spectral description) or seas in general (the spectral method).

In the conclusion (Section 4 – 'Final remarks') the author summarises the current state of knowledge on the influence of irradiance on photosynthesis in the sea, briefly characterising the problems already solved and the significance of the results and practical applications, *e.g.* in remote sensing methods of assessing the photosynthetic production of seas. He also draws attention to questions as yet unresolved, indicating that in the near future our knowledge of marine photosynthesis will undergo a very considerable expansion as a result of the use of modern methods based on active *in situ* fluorimetry.

The aims which Prof. Dera set out to achieve in this book have been achieved with distinction. Concisely but very readably, he has outlined the currently accepted model describing irradiance and its relationships with the characteristics of photosynthesis in seawater. At the same time, the mathematical formulas contained in the monograph make up an entire algorithm enabling the magnitudes characterising the inflow and utilisation of solar radiation energy in photosynthesis in different types of seas to be estimated on the basis of meteorological data and assumed concentrations of chlorophyll. This task is considerably facilitated by the appropriate tables contained in the Appendix. As a result, the algorithm can be handled also by non-specialists in marine optics.

This monograph is essential reading for marine physicists, chemists and biologists, and also students of oceanography.

Bogdan Woźniak