

Production Biology of Phytoplankton

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LONG-TERM GOALS

To continue to review critically and creatively knowledge about interactions between bulk marine phytoplankton and zooplankton versus the hydrographic and chemical environment, as well as the feedback from the planktonic processes to the abiotic environment. Both existing observations and data collected by current programs are being used. While the emphasis is on regional oceanography, the understanding of the sea itself rather than the biology of marine organisms is at issue.

OBJECTIVES

The FY1999 focus of my work continued to be on regional oceanography, emphasizing the geographic and seasonal distribution of phytoplankton. The study of the distributions in the upper one-quarter to one-third of the photic zone in the subarctic Pacific and the Arabian Sea as viewed from space was completed. The underlying processes were considered principally as problems of population growth, rather than of phytoplankton physiology. Secondly, editing previously commissioned translations about zooplankton physiology and regional oceanography of the Arabian Sea was started in earnest, in order to open windows into a largely unknown marine literature published in Russian.

APPROACH

The report concerns the last year of a three-year grant. A continuation has been granted.

[1] The satellite-related work was based primarily on individual scenes for the entire lifetime of the Coastal Zone Color Scanner (CZCS, late-1978 to mid-1986). The data were rigorously reprocessed with a newly refined filter that had not been used for NASA's Global Data Set, thus avoiding the effect of electronic overshoot. The evaluation of the data, however, relied heavily on existing in-situ observations of hydrography, nutrients, and chlorophyll.

[2] As reported last year, I had financed the translations of four books (mostly with ONR funds, with minor SCOR and U.S. JGOFS support), which I edit. All manuscripts and the chapters of a commissioned book must be revised at least twice.

[3] In February, I was again in India on the occasion of a meeting in Bangalore of the JGOFS Arabian Sea Integration and Synthesis Working Group (overseas travel and per diem costs borne by SCOR).

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With ONR support, I visited again the headquarters of the India-wide Central Marine Fisheries Research Institute in Cochin, to continue trying to bring into useable form a unique, but largely unused set of frequently repeated coastal (shelf and beyond) hydrographic sections from 1972 to 1975. In spite of renewed promises by my colleagues about pursuing the task on their own, I have not heard from them since (there is no e-mail, just airmail). Because the original log sheets were lost in India quite some time ago, I will now try to obtain the only existing copy, which happens to be kept in Bergen (Norway).

WORK COMPLETED

[1] Two manuscripts on satellite-estimated plankton chlorophyll have been published or are in press (see next section).

[2] The translations from the Russian are all completed, although one manuscript is still in the Ukraine and is to be delivered soon.

[a] The editing of one of the translated books was completed, but most figures need to be re-drawn, since the published versions are too reduced and also were printed on poor paper. L.I. Sashina (deceased). 1987. *Reproduction, Growth, and Production of Marine Copepods*. Naukova Dumka, Kiev. 155 pp. with 35 figures and 55 tables. After finishing with the figures in Seattle, the manuscript will be submitted to the publishing house, Universities Press (India) in Hyderabad (Deccan). New title: *Breeding, Growth Rates, and Production of Marine Copepods*.

The editing of the following has been partly done once:

[b] E.V. Pavlova. 1987. *Motion and Energy Metabolism of the Marine Plankton*. Naukova Dumka, Kiev. 212 pp. with 55 figures and 41 tables (partially revised by the author).

[c] L.I. Sashina (deceased). 1985. *Nauplii of Dominant Pelagic Copepods in the World Ocean*. Naukova Dumka, Kiev. 237 pp. with 100 figures and 2 tables.

[d] S.A. Piontkovski and K. Banse (eds.). In preparation. *Synoptic Ecosystem Structure of the Upper Layers of the Open Northwestern Arabian Sea during the Northeast Monsoon of 1990*. This book, mentioned in the FY97 report, about a comprehensive 1990 Ukrainian expedition along a closely-spaced, but large grid of stations, consists now of 17 chapters. The scope of the expedition extended from hydrography through nutrients, phytoplankton, heterotrophic bacteria, zooplankton including stages of copepods, myctophids (including stomach analyses), to squids. The second revisions and figures for 14 chapters are in hand.

[e] T.S. Petipa (ed., deceased) *Mechanisms of Aggregation and of the Functioning of the Plankton Community in Ecosystems of the Indian Ocean*. 17 chapters with numerous figures and tables and a small-format atlas with about 100 black-and-white maps. The translation of this unpublished book manuscript for a similar expedition in 1980 in the same area and season as in [d], with some data for 1983 and 1985, has been completed, but I have not yet seen the work.

RESULTS

[a] The following ms, accepted by the time of the FY 1998 report, has now been published: Banse, K. and D.C. English (1999) *Comparing phytoplankton seasonality in the western and western subarctic Pacific and the Bering Sea*. Prog. Oceanogr. 43: 235-288. (For the abstract, see the FY1998 report.)

[b] In the FY1998 report, the paper by Banse, K., D.M. Bartolacci, D.C. English and M.E. Luther, *Seven Years of Color Scanner-Derived Phytoplankton Pigment for the Arabian Sea and Correlations of 11 Regional Grand Monthly Means with Wind Pseudo Stress, Wind Pseudo Curl and Total Heat Flux*, was stated as having been Accepted Pending Revision. Instead of a revision by the four authors, a reduced ms. is now in press: Banse K. and D.C. English. *Geographic Differences in Seasonality of CZCS-Derived Phytoplankton Pigment in the Arabian Sea*. Deep-Sea Res. II (70 mss. pp.).

Abstract: *In-situ* measurements of phytoplankton chlorophyll in the Arabian Sea were taken largely along temporally and spatially unevenly distributed sections, which were scarce especially prior to the operation of NASA's Coastal Zone Color Scanner (CZCS). Herein, the CZCS pigment observations between late 1978 and mid-1986 north of 10°N, including the outer Gulf of Oman, are depicted for 14 subregions beyond the continental shelves as daily means, often only five days apart. To eliminate bias from electronic overshoot, the data were reprocessed with a more restricted cloud screen than that used for NASA's Global Data Set.

The pattern, derived from the older *in-situ* observations, of one period with elevated chlorophyll almost everywhere during the southwest monsoon (SWM) and one additional late-winter bloom in the north, is confirmed. The differing nitrate : silicate ratios in freshly entrained water in the central and northern Arabian Sea seem to lead to different succession and perhaps to differing vertical fluxes, and during winter favor blooms only in the north. The spatial pigment pattern in the outer Gulf of Oman is not an extension of that of the northwestern Arabian Sea. The physical seasonal forcing explains much of the timing for changes in pigment concentrations, but not the levels maintained over long periods. From the CZCS observations it is unclear whether the period of high phytoplankton productivity expected during the SWM in the open Arabian Sea lasts for about two or four months. During this entire season, chlorophyll values in the upper layers rarely exceed 1 - 2 mg m⁻³ outside the zone influenced by the Arabian upwelling. Near 15°N, however, fluxes into sediment traps at 3 km depth indicate an onset of high primary production very soon after the arrival of the SWM and suggest a long open-sea period of high production. The temporal, partial disconnect during the SWM between pigment changes in the upper part of the euphotic zone and of fluxes into the traps is disconcerting. For future modeling of plankton production in the open Arabian Sea, the use of two size classes of phytoplankton is recommended. The utility of satellite-derived pigment concentrations (as opposed to temporal changes of pigment) for testing such models is questioned.

IMPACT

1. The significance of the two published works named under RESULTS and the earlier regional studies in the Subantarctic parts of the Southern Ocean initiated with NASA support but written up with ONR support, are as follows: [a] The regions were objects of JGOFS field work; our papers will help to set these short-term expeditions (usually during one year) into the long-term context. [b] For a few more years, the CZCS time series will be the longest pigment series available for most of the oceans. Now, for a few offshore regions outside of the North Atlantic, the CZCS archive has been

mined for detailed seasonal descriptions, with weekly or even shorter resolution, and inter-annual differences also have been studied. [c] For these regions, almost monographic evaluations of spatial and temporal changes have been attempted on the mesoscale and larger scales of phytoplankton chlorophyll and the relevant hydrographic, nutrient, and zooplankton data. Some results of the JGOFS field work have been incorporated in these syntheses. It was stressed that the seasonal change of phytoplankton abundance (as chlorophyll) cannot be understood from phytoplankton physiology, i.e., light, mixing and nutrients.

2. The translations from the Russian will be of value by themselves and will provide access to a large body of literature largely unknown among the English-only reading colleagues. The two books by Sazhina have no counterparts in the western literature, and the two regionally oriented books concerned with the Arabian Sea contribute not only historical material, centered on the period 1980-1990, but also will allow three-dimensional modeling of processes. This is not reasonably done when based on the two-dimensional sections run by the JGOFS (and most earlier) expeditions.

TRANSITIONS

As stated under Impact, the new regional and temporal results derived from the CZCS and the accompanying reviews of in-situ knowledge should help the community, especially the JGOFS-focused colleagues, in their integrations and syntheses. Only time will tell whether this will be so.

RELATED PROJECTS

Collaboration with colleagues at India's National Institute of Oceanography in Goa and the Central Marine Fisheries Research Institute in Cochin continues. The focus is on hydrography including regional and temporal distribution of oxygen, as well as nitrogen metabolism on and off the shelf off the west coast of India.

PUBLICATIONS

Banse, K. and D.C. English (1999) *Comparing phytoplankton seasonality in the western and western subarctic Pacific and the Bering Sea*. Prog. Oceanogr. 43: 235-288.

Banse, K. and D.C. English (In Press) *Geographic Differences in Seasonality of CZCS-Derived Phytoplankton Pigment in the Arabian Sea*. Deep-Sea Res. II (70 mss. pp.).