

PRIMARY PRODUCTION OF THE WORLD OCEANS AS COMPARED
TO THAT OF THE INDIAN SEAS

During the last two decades several expeditions have collected extensive data from different parts of the world oceans. In addition, through individual efforts intensive data from many isolated regions have also been obtained. The first estimate of the primary production of the world oceans made by Riley (1944) was found to be 10 times higher by Steemann Nielsen after a round the world trip of GALATHEA (Steemann Nielsen and Aabye Jensen, 1957). Several attempts made subsequently at an evaluation of the world primary production indicated that the seas are not more productive than land and the magnitude is only because of the larger area. Recently Koblentz-Miskhe et al. (1970) have reviewed the production of organic matter for the world oceans and got the figure which almost coincides with that of Steemann Nielsen's estimate. According to these authors the world production is $2.5 - 3.0 \times 10^{10}$ tons of carbon per year (gross) and $1.5 - 1.8 \times 10^{10}$ tons of carbon (net) is a more accurate figure. Gulland (1970) while assessing the fish resources of the world oceans has given a brief account of the primary production of the different regions. Gushing (1971)

has estimated the total production in some of the upwelling regions of the world. Thus from the existing literature it is possible to derive a general idea of the magnitude of primary production in all the oceans.

Atlantic Ocean

Studies on primary production have been made by a large number of authors using a variety of methods in different parts of the Atlantic especially the north-eastern region. According to Steele (1965) the annual production is in the range of 50-150gC/m²/year while Cushing considers the possible range as 40-200 gC/m²/year. Assuming an average figure of 100 gC/m²/year, Gulland (1970) has given a figure of 55 x 10⁶ tons of carbon fixation for the north-east Atlantic.

During the survey of GALATHEA the highest rate of 3.8 gC/m²/day and the lowest rate of 0.043 - 0.058 gC/m²/day were observed in the Atlantic (Walvis Bay and Sargasso Sea respectively). The region of Benguela Current was found to be one of the most productive regions with a daily rate of 0.46 - 2.5 gC/m²/day. In the Central part off the west coast of Africa the main areas of high production are the upwelling regions and oceanic areas along the equator. According to the seasonal variations in the rate of upwelling the rate of primary production also varies with

the peak values reaching $5.2 \text{ gC/m}^2/\text{day}$ off Dakar. Outside the peak season the rates fall to $0.2 - 0.4 \text{ gC/m}^2/\text{day}$ (Steemann Nielsen and Aabye Jensen 1957; Serokin and Kliash-terin 1961; Bessonov and Federov 1965). Off the coast of South America measurements have been made by Teixeira and Tundisi (1967). They have reported high values towards the coast decreasing seaward. In July/August higher values were found in the open ocean. El Sayed (1966) reported higher primary production off the Argentinean Coast than in Drake Passage and Weddel Sea. According to Mandelli and Orlando (1966), the Falkland Current is amongst the most productive area of the world oceans and also carries a permanent high phytoplankton biomass. The estimate of annual primary production in the Falkland Current is more than 200 gC/m^2 in the central part between 40° and 44°S and less than half as much in the southern parts (Gulland op.cit.)

The mean value given for the Atlantic by Koblentz-Nishke et al. (1980) is $190 \text{ ngC/m}^2/\text{day}$ and $69.4 \text{ gC/m}^2/\text{year}$, for the Atlantic Ocean, which would amount to a net production of ca 5×10^9 tons per year. Of this the Benguela upwelling region alone accounts for 375 million tons of C/year which is a very high figure compared with those for other upwelling areas and bigger than the estimate for

the Peru/Chile upwelling area (Gushing, 1971). Outside the upwelling areas rate of primary production is at the moderate level typical of subtropical waters i.e., around $50 \text{ gC/m}^2/\text{year}$ (Gulland, 1970).

Primary production in the Mediterranean and Black Sea is generally low, but moderately high in some parts, especially in the Black Sea. Values for the Adriatic Sea also is high with $120 - 364 \text{ gC/m}^2/\text{year}$.

Pacific Ocean

Koblentz-Miskhe (1965 and 1967) has reviewed the data on primary production from the Pacific Ocean. A band of high primary production with rates between 100 and 150 gC/m^2 extends along the North American coast to the tip of the Alaskan Peninsula and along the Aleutian Island chain including much of the offshore area of the Gulf of Alaska. The open oceanic part of the North Pacific is also noticeably more productive ($50-100 \text{ gC/m}^2/\text{year}$) than the tropical and subtropical areas. The Puget Sound has a very high rate of $200-400 \text{ gC/m}^2/\text{year}$. On an average of $150 \text{ gC/m}^2/\text{year}$ for the coastal strip, within 500 m contour the total annual primary production has been computed at 54 million tons (Gulland, op.cit.). Over $600 \text{ gC/m}^2/\text{year}$ has been found in the south-eastern part of the Bering Sea (Ivanenkov, 1961). In the north-west Pacific highest

production rate of $5 \text{ gC/m}^2/\text{day}$ was recorded east of Hokkaido within the zone of convergence of warm and cold water. Taniguchi (1972) has calculated $89 \text{ gC/m}^2/\text{year}$ in the Bering Sea, $156 \text{ gC/m}^2/\text{year}$ in the Oyashio Current and $48 \text{ gC/m}^2/\text{year}$ in the Kuroshio Counter Current. The North Equatorial Current showed the lowest rate of $33 \text{ gC/m}^2/\text{year}$. The waters of the South Equatorial Current ($106 \text{ gC/m}^2/\text{year}$) and the region east of New Zealand ($156 \text{ gC/m}^2/\text{year}$) were found to be more productive.

In the south-east Pacific, Galland (1970) quotes Strickland, Eppley and Rojas de Mendiola that the annual production near the coast of Peru is more than $200 \text{ gC/m}^2/\text{year}$ but suspect that the value will be considerably higher, possibly of the order of $500 \text{ gC/m}^2/\text{year}$. This could be in view of the recent measurement by Ryther *et al.* (1971) in a packet of newly upwelled water in the Peru Current of an average rate of $10 \text{ gC/m}^2/\text{day}$ for five days. Cushing's estimate of total primary production in the Peru Current upwelling is 155 million tons of carbon of which about 45 million tons were estimated to be produced off Chile and the remainder off Peru. The average value for the Pacific Oceans as given by Koblentz-Miskhe *et al.* (1970) is $127 \text{ mgC/m}^2/\text{day}$ and $46.4 \text{ gC/m}^2/\text{year}$. According to these authors the Pacific Ocean is the least productive of all the oceans,

whereas the Indian Ocean is the most productive. At the same time the yield ratio is considerably lower as compared to the Atlantic and Pacific Oceans. The potential yield in relation to primary production in the Indian Ocean and adjacent seas is discussed in the next section.