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PRIMARY PRODUCTIVITY ON GEORGES BANK WITH AN EXPLANATION OF WHY IT IS SO HIGH

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ABSTRACT

Primary productivity on Georges Bank is calculated at 400-500 $gCm^{-2}yr^{-1}$ based on 11 cruises covering three years. Values remain high from spring until late fall. This high productivity appears to be maintained by mixing on top of the Bank and by upward transport of deeper nutrient-bearing oceanic water along both edges.

Georges Bank is one of the most productive fishing areas in the world, yet there have been few studies of the environmental factors supporting the fish production. The only previous attempt to estimate the primary productivity cycle on Georges Bank was made using the oxygen production technique on surface samples (1).

During 1975-1976 six cruises were conducted on Georges Bank and surrounding waters (Figure 1) by United States and other International Commission for Northwest Atlantic Fisheries nation vessels. An additional five cruises were made in 1977-1978 by United States and Soviet vessels.

Water samples were taken at 0, 10, 20, 50, 75, and 100 meters for salinity, temperature, dissolved oxygen, chlorophyll, and nitrate, using PVC Niskin bottles. In addition, there were from 4 to 11 stations per cruise at which primary productivity was determined using the ^{14}C technique. All analyses were carried out using standard oceanographic techniques (2).

Vertical distributions of temperature and dissolved nitrate concentration along 68^{o}W longitude (Figure 1), from a cruise in November 1975, illustrate some persistent features of the hydrography of Georges Bank.

1. The water on the shallow top of the Bank is well-mixed throughout the year, presumably by winds and tidal action.

2. There is a region of strong gradients on the south side of the Bank, representing the transition to oceanic Slope Water conditions.

3. Another frontal region exists to the north, usually with weaker gradients, into the waters of the Gulf of Maine.

4. Nitrate, which is representative of all dissolved nutrients, is low - sometimes undetectable - on top of the Bank. It increases both north and south with highest values in the deeper water. In the winter nitrate values on the Bank increase to about 10μg-at N/ℓ.

There is a supply of nutrient-rich oceanic water at depths of 150 meters or more on both sides of Georges Bank. This is because warm, relatively saline, nutrient-bearing Slope Water flows intermittently through the Northeast Channel (sill depth ~ 230 m) into the Gulf of Maine where it underlies the colder, less saline shelf waters (3).

There is some evidence, notably in the temperature and nitrate sections (Figure 3), of upwelling of this deep water on both sides of Georges Bank. This feature is not always present in our data but appears regularly in a series of monthly averages drawn on the basis of Soviet hydrographic data covering 12 years (4).

Chlorophyll distribution (not shown) is in sharp contrast to that of nutrients. The highest values of chlorophyll are found over the central portion of the Bank, with very low values in the Gulf of Maine and particularly in the Slope Water. There is a seasonal fluctuation in chlorophyll on Georges Bank, ranging from about 1 mg/m^3 in winter to 15-20 mg/m^3 in late spring, but the geographical pattern is consistent throughout the year although patches of high chlorophyll concentration are found in the Gulf of Maine during the spring.

Primary productivity measurements were made at 100%, 50%, 25%, 10%, and 1% light penetration depths. The appropriate light levels were obtained using neutral density filters in an on-deck simulated <u>in situ</u> incubator. The actual sampling depths for the different light levels was determined either by Secchi disc or by direct measurements using a Lambda submarine photometer. Incubations were approximately 4 hours starting in the morning and running until after noon. From our data we have estimated the primary productivity on a m^2 basis for Georges Bank. The primary productivity data for each station during each cruise was integrated over the depth of the photic zone. The average value of $gC/m^2/hr$ for each cruise was then converted to $gC/m^2/day$ based on the average day length during that cruise. The resulting cycle of primary productivity is shown in Figure 2. It does not agree well with the spring bloom-fall bloom pattern proposed earlier for Georges Bank (1). Our data show an increase in the spring to a high level of productivity (ca 2 gCm^2/day) which is maintained throughout the summer and into the late fall with a decline to low winter values in November-December. It must be pointed out that there is a large variance associated with our estimates (approximately half the mean values shown) because of the relatively few observations for such a large area (ca 53,000 km^2) and the patchiness of phytoplankton blooms. However, the consistently high values over the three years of sampling indicate that a valid picture of the productivity cycle has been observed.

Integrating these values over the year yields a value of 400-500 $gC/m^2/yr$, making Georges Bank one of the most productive areas of the ocean. Some other coastal marine values are (all in $gC/m^2/yr$): Long Island Sound, 250; Florida mangrove swamp, 400; North Sea, 90. On land, an oak/pine forest is rated at 500 and an alfalfa field at 1500 $gC/m^2/yr$ (5).

We propose a two-part mechanism for the high productivity of Georges Bank, rooted in its unique topography and hydrography: the shallow, well-mixed region on top of the Bank and the frontal regions along both edges (6).

In winter, light levels are low and the critical depth, above which photosynthesis balances respiration, is shallow. Productivity is at a minimum (7). In spring the insolation increases and the photic zone and critical depth deepen. When the critical depth reaches the bottom, photosynthesis exceeds respiration and the spring bloom commences. As solar warming continues, in most areas a thermocline develops to restrict the flow of nutrients regenerated in the bottom sediments from reaching the phytoplankton population near the surface, and production drops. This does not happen on Georges Bank because the intense vertical mixing prevents such stratification. The supply of nutrients continues throughout the summer ensuring high rates of primary production. Not until late fall - early winter does insolation decrease sufficiently for the depth of the photic zone to shoal above the bottom. When the mixed depth exceeds the depth of the photic zone, production drops to low winter levels. The other mechanism that is at work apparently year-round is the supply of nutrients from the deeper waters on both sides of the Bank, suggested in Figure 1.

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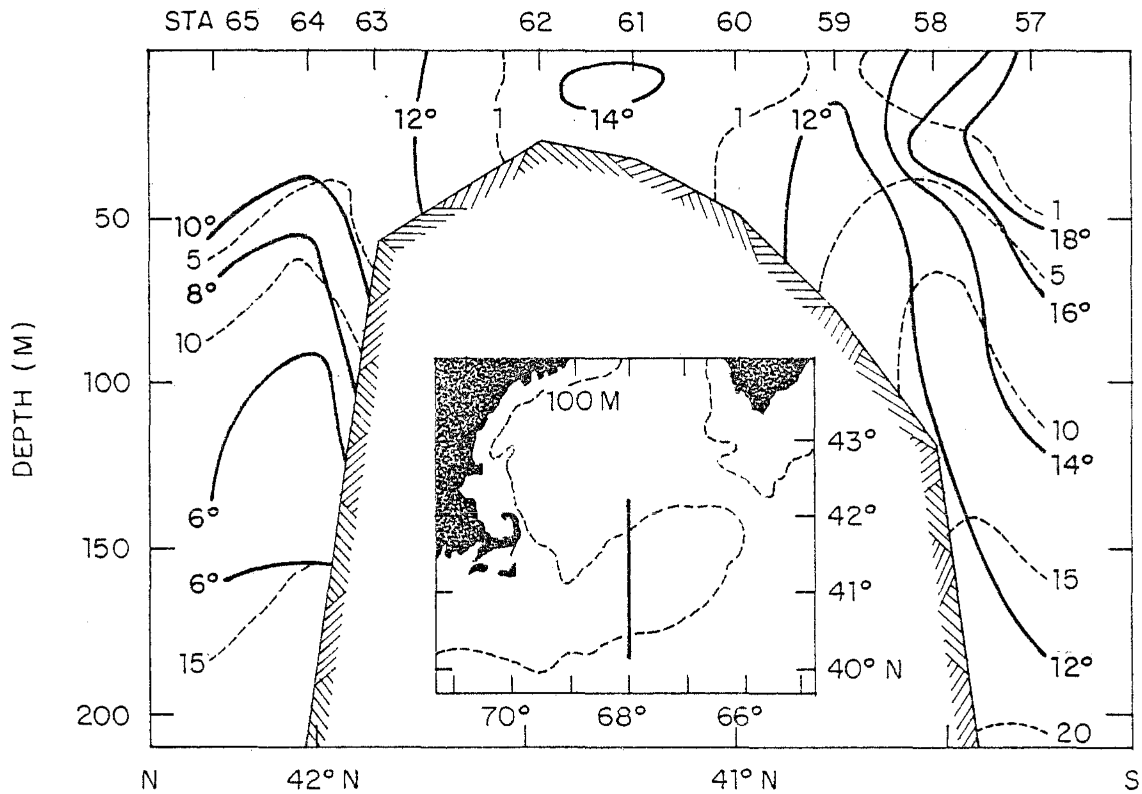
FIGURES

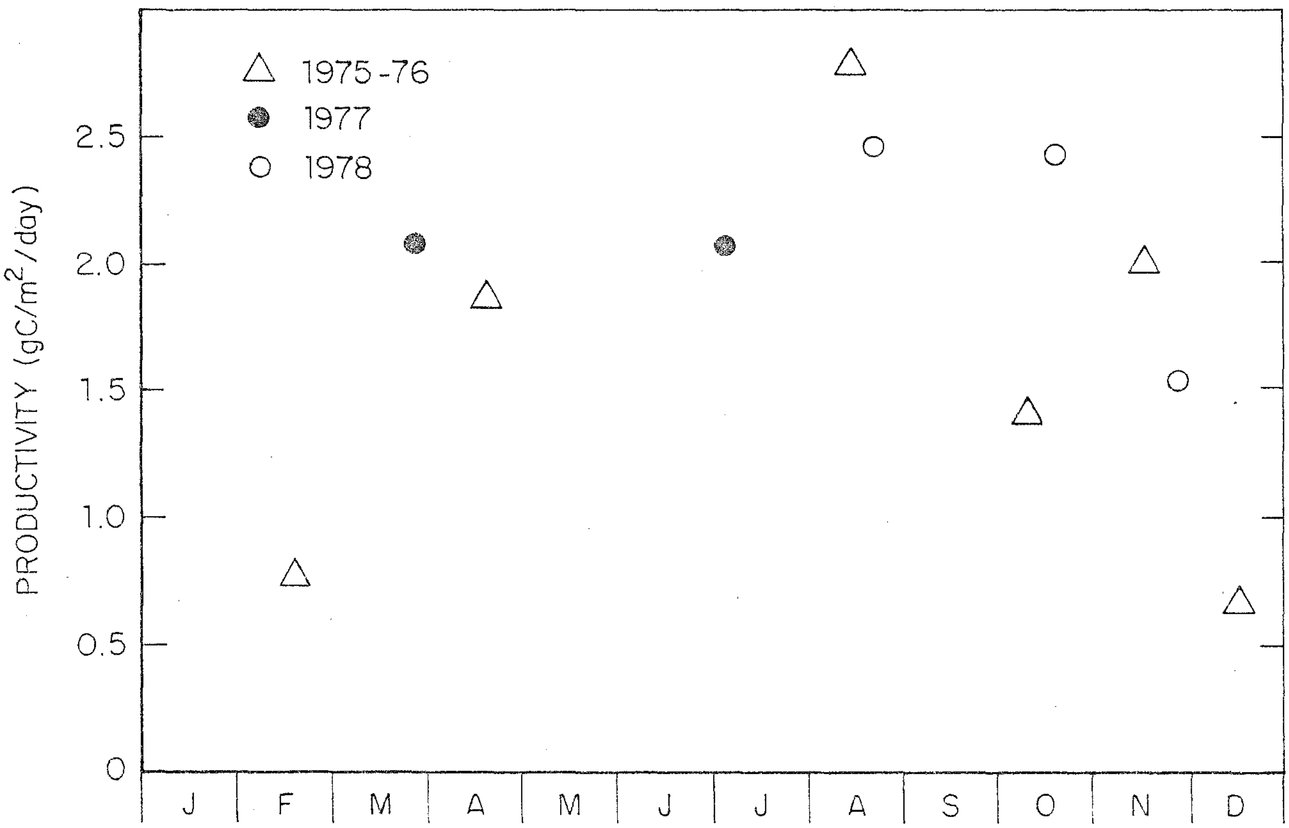
Figure 1. Vertical section through Georges Bank at 68^{o}W showing distribution of temperature (heavy lines, ^{o}C) and nitrate (light lines, μgA/ℓ) measured from R/V ANTON DOHRN (Federal Republic of Germany) in November 1975. Vertical exaggeration about 2000:1. Heavy line on inset map shows location of section.

Figure 2. Mean primary production (gC/m^2/day) versus time of year for 11 cruises on Georges Bank between late 1975 and late 1978. Each point is a mean of from 4 to 11 individual determinations. Standard deviation varied from 0.36 to 2.02 gC/m^2/day, with an average of 1.0



STA 65
64
63
62
61
60
59
58
57
DEPTH (M)
50
100
150
200
12°
1
14°
1
12°
10°
5
8°
10
6°
6°
15
1
18°
5
16°
10
14°
15
12°
20
100 M
43°
42°
41°
40° N
70°
68°
66°
N
42° N
41° N
S

Figure 1.



1975-76
1977
1978
PRODUCTIVITY (gC/m2/day)
2.5
2.0
1.5
1.0
0.5
0
J
F
M
A
M
J
J
A
S
O
N
D

Figure 2.