

Geographical variations in productivity

The environmental factors such as light, temperature and nutrients interact with each other in the marine environment and play a major role to produce the geographical and latitudinal variations in productivity.

Temperate seas

In the temperate zone seas, the amount of light varies seasonally. As a result, the amount of solar energy entering the water varies, which alters the temperature in the upper water layers. The thermal structure of the water column, therefore, changes seasonally. In the summer months, the sun is high, days are long, and the upper layers heat up and become less dense than underlying layers. In other words, the water column is thermally stratified and no mixing occurs. In the fall, the amount of solar energy entering the water column decreases, days become shorter, upper layers cool, and thermal stratification decreases. Finally, a point is reached where the temperature of the surface layers has been reduced to such an extent that the density of the layer is little different from that of the underlying mass. At this point, mixing can occur when ever sufficient wind is available. In winter, usually the storm season in the temperature zone, the sun is lowest on the horizon, solar energy input to the water is at a minimum, thermal stratification is at a minimum or absent, and mixing occurs. With the onset of spring, the days become longer, the solar energy increases, the upper layers begin to rise in temperature, and the system moves toward reestablishment of thermal stratification.

In contrast to the tropics, all the major factors that affect productivity change seasonally in temperate seas. This is reflected in the change in production over the year, with a major peak in spring, a lesser peak in the fall, and low productivity in winter and summer. We may explain this as follows: The low winter productivity is the result of low light levels due to the low position of the sun on the horizon and because the winter storms mix the isothermal water column and carry plant cells below the critical depth. In the spring, the increased light and solar energy increase the temperature of the upper layers. With increasing temperature come increasing differences in density between upper and lower layers. Under such conditions the wind cannot mix the water to as great a depth as in winter; at some point, algal cells are no longer carried below the critical depth. Since nutrients in upper layers have been replenished during the winter mixing, conditions are good for phytoplankton growth, and we observe the spring bloom. As spring passes into summer, the water column becomes more thermally stratified, mixing with lower levels ceases, and light conditions reach optimal levels. Because mixing ceases due to stratification, nutrient replenishment ceases and production falls, even though light levels are optimal. With the advent of fall, the thermal stratification begins to break up and nutrients are returned to upper levels. If, in the fall, the mixing alternates with calm weather such that the plants spend more of their time in the upper layers and are not carried below the critical depth, a small bloom will occur because of the increased nutrients. This bloom declines in late fall, due to decreasing light and increased mixing. In the winter, low light levels

and deep mixing of the water column keep productivity low. You will note that there are differences in the seasonal cycle curves between the temperate North Atlantic and North Pacific. These differences are the result of somewhat different hydrographic conditions, coupled with different nutrient concentrations and availability.

Tropical seas

In the tropical seas, the upper waters are well lighted throughout the year because the sun does not show marked changes in height above the horizon. Light conditions are, therefore, optimal for phytoplankton production. At the same time, the continual input of energy from the sun maintains the surface layers of water at temperatures much higher than those in deeper waters. This means there is a great difference in density between surface and deep waters; hence, mixing does not occur. This thermal stratification extends throughout the year. In the tropical seas, the light conditions are optimal for high productivity. Because the sun's energy creates a thermal stratification in the water column that prevents mixing and the upward transport of nutrients, however, the productivity is low but constant all year. Tropical seas are very clear and have the deepest compensation depths, but they are that way because there are few phytoplankton in the water column due to the low nutrient content.

POLAR SEAS

In Polar areas, productivity is restricted to a single short period in the polar summer, usually July or August in the Arctic. At this time, the snow cover on the ice has disappeared, allowing sufficient light to enter the water through the ice to permit phytoplankton growth. In areas outside of the permanent ice pack, breakup of the ice at this time opens the leads, allowing sufficient light to enter the water and permitting phytoplankton growth. Following this single burst of growth, the production quickly declines. Nutrients are not limiting and the water column is never strongly stratified. The reason for the lack of production at other times is due primarily to lack of light. Light intensity is insufficient for a fall bloom, and during the long winter, light is either absent or prevented from reaching the water column by a layer of snow over the ice pack.

PRODUCTION FOR SEVERAL DIFFERENT GEOGRAPHICAL AREAS

Location	Productivity in g C/m ² /year
Long Island Sound (temperature inshore)	380
Continental shelf	100 160

Tropical oceans	18 50
Temperate oceans	70 -120
Antarctic oceans	100
Arctic Ocean	<1