

BIOGEOCHEMICAL RESPONSES TO CHANGES IN CLIMATE AND OCEAN CIRCULATION

Physical oceanographers and meteorologists have long recognized the need for continuous observations in order to characterize and understand climate and ocean variability. The need to observe biological and chemical processes in the ocean at appropriate temporal scales was recognized several decades ago, but these types of studies are rare. For example, while the coastal upwelling

process and its biological and chemical consequences have been studied extensively, the experiments have been sporadic in space and time. Input parameters needed for modeling coastal ecosystems have been marginally available and long-term data sets for model validation and for characterizing climate change are lacking.

The primary focus of these studies is on phytoplankton—the microscopic plants at the base of the Monterey Bay ecosystem. The mean and fluctuating components of phytoplankton biomass, production, and species composition are of primary interest, as are the physical, chemical, and biological processes responsible for the mean and fluctuating components. For

central California, studies by MBARI have used bi-weekly to monthly ship expeditions, together with continuous observations from moorings and drifters, to determine mean seasonal ecosystem conditions. Satellite observations of sea surface temperature and ocean color provide a synoptic spatial view of physical and biological properties. The results reveal the

processes regulating biological production in a coastal upwelling ecosystem, and provide data for model input and validation. Additionally, a long-term technical goal is to transition the shipboard measurements to autonomous platforms such as moorings, drifters, and autonomous underwater vehicles (AUVs).

Based on this time series, the mean seasonal conditions have been established for a number of parameters (Figure 2), allowing interrelation of variables to be examined. There is clear physical-biological coupling in the time series, which is obvious in the seasonal cycle. There is a maximum in nutrients, centric diatoms (the phytoplankton responsible for most of the production), chlorophyll, and primary production associated with the upwelling season. The so-called oceanic and winter seasons also have defining characteristics. Deviations from mean conditions are also of great interest. Chlorophyll levels dropped during the warmer El Niño years (-19% in 1992 and -21% in 1997), and rose during the colder La Niña years (+19% in 1991 and +11% in 1994). Phytoplankton biomass dropped by 15% in 1992 and 27% in 1997, and rose by 29% in 1995, a year in which the average temperature was close to the climatological mean, 13.5 °C. Perhaps the most exciting but still uncertain aspect of the time series is the apparent long-term trend in the data. Sea-surface temperature has gradually risen over the course of the 10-year study, while nitrate, chlorophyll, primary production, and centric diatoms are decreasing (Figure 2). The abundance of the small phytoplankton that dominate in offshore waters, and the rate of metabolism of plants are increasing. If real, these trends reflect the impact of climate change on the biological productivity of the coastal ocean.

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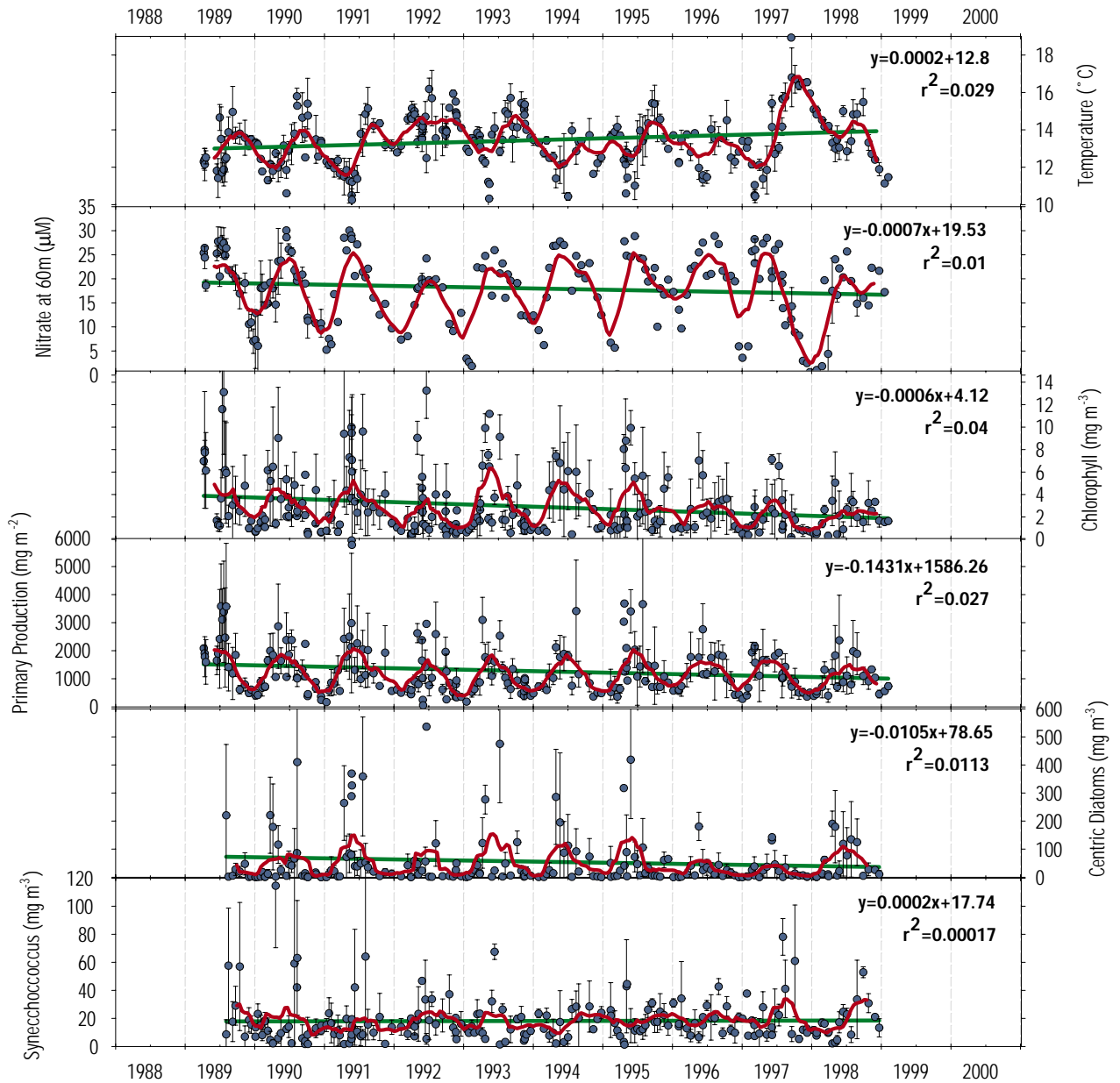


Figure 2. Time series of properties from Monterey Bay, California, from 1989 to 1998. During the period of study, sea surface temperature (SST) increased at a rate of 7.3°C per 100 years. The rates have accelerated during the course of the century from 0.4°C (100 yr^{-1}) for the period 1900-1994, to 1.2°C (100 yr^{-1}) for the period from 1949 to 1994, to 2.9°C (100 yr^{-1}) for the period 1971 to 1994. Accompanying the temperature increase are decreases in nitrate concentration at 60 m, chlorophyll concentration, primary production, and centric diatoms. The abundance of small phytoplankton (eg. *Synechococcus* sp.) and the rate of metabolism (productivity index) for the plants (not shown) have apparently increased in response to higher temperatures.