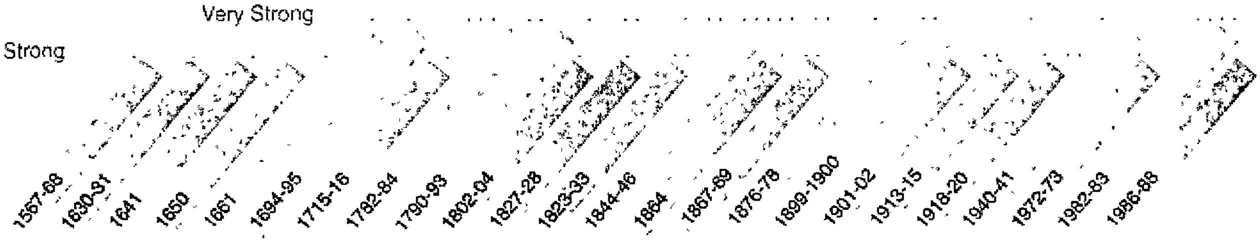


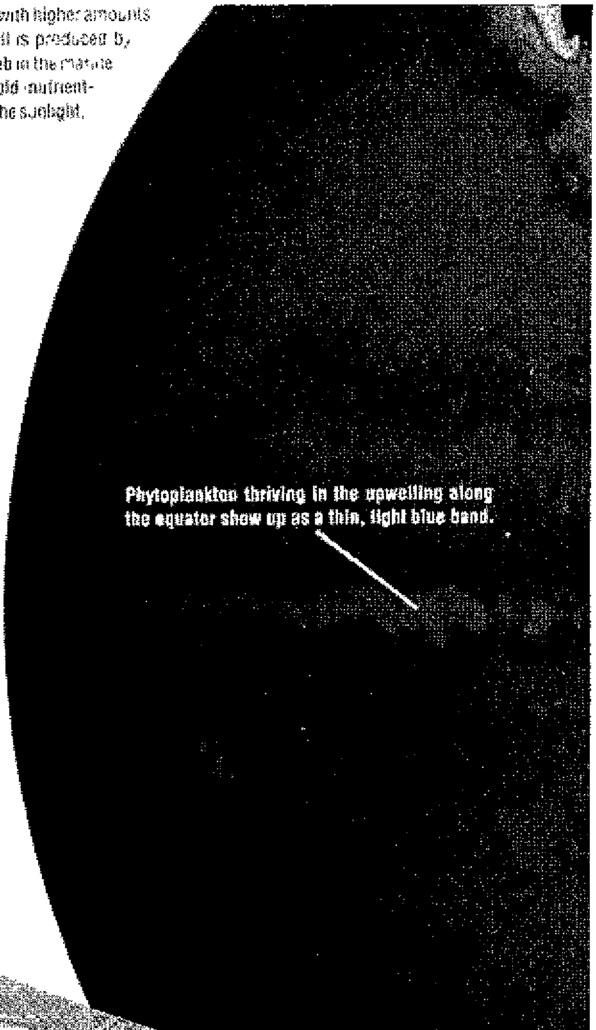
Winds, Upwelling, and the Food Web

To understand how El Niño affects the ocean, we first need to learn about how surface winds move the water during normal years, and how the resulting motions affect water temperatures and amounts of chemical nutrients available to the food web. We will consider two separate regions: the equatorial Pacific extending westward from the Galapagos Islands to beyond the dateline, and the coastal waters off Peru and southern Ecuador.

The easterly winds that blow along the equator and the southeasterly winds that blow along the Peru and Ecuador coasts both tend to drag the surface water along with them. The Earth's rotation then deflects the resulting surface currents toward the right (northward) in the Northern Hemisphere and to the left (southward) in the Southern Hemisphere. The surface waters are therefore deflected away from the equator in both directions and away from the coastline. Where the surface water moves away, colder, nutrient-rich water comes up from below to replace it, a phenomenon known as *upwelling*. Both the equatorial upwelling and the coastal upwelling are concentrated in narrow regions less than

Tropical corals add a new growth band each year (circular inset, upper right). Corals the size of the ones in this picture are old enough to have acquired several hundred of these annual growth bands. The chemical makeup of each band reveals the temperature and saltiness of the water during the year in which it was formed. Scientists depend upon these and other glimpses into the past to infer how El Niño might behave in future climate scenarios.

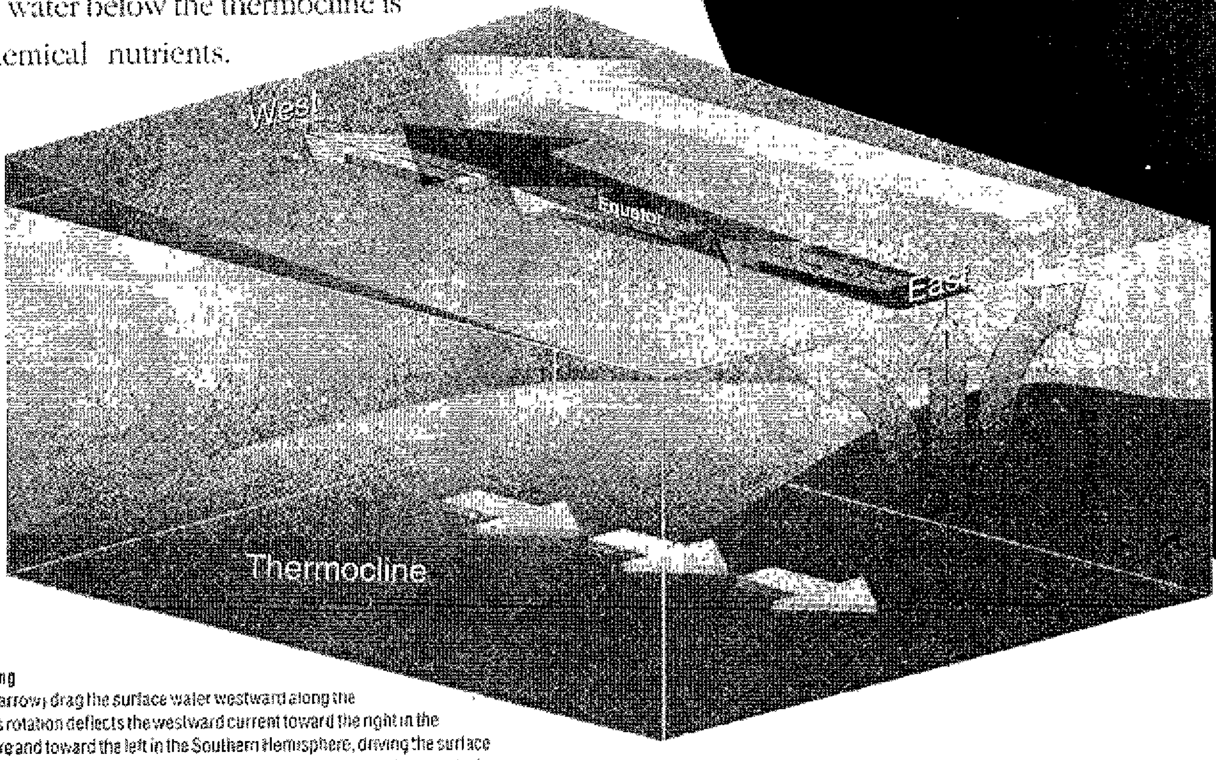
of chlorophyll in the upper layer of the ocean, with higher amounts indicated by the warmer colors. Chlorophyll is produced by phytoplankton, the lowest level of the food web in the marine ecosystem. Phytoplankton "bloom" in the cold nutrient-rich water that rises from the deep ocean into the sunlight, where photosynthesis can take place



100 miles wide which show up clearly in the satellite picture to the right

The winds that blow along the equator also affect the properties of upwelled water. In the absence of the wind, the dividing layer between the warm surface water and the deep cold water, known as the *thermocline*, would be nearly flat; but the winds drag the surface water westward, raising the thermocline nearly all the way up to the surface in the east and depressing it in the west, as indicated in the figure below.

The cold water below the thermocline is rich in chemical nutrients.



Equatorial Upwelling
Easterly winds (red arrow) drag the surface water westward along the equator. The Earth's rotation deflects the westward current toward the right in the Northern Hemisphere and toward the left in the Southern Hemisphere, driving the surface water away from the equator and bringing up water from below (upward arrows). In addition, the winds cause warm surface water to accumulate on the western side of the Pacific. Because of the lower density of the warmer water, sea level is about two feet higher on the western side of the basin than on the eastern side when the winds are blowing at full strength. The thermocline, which marks the boundary between warm surface water and cold, deep water (darker blue) is tilted. It reaches almost up to the sea surface in the eastern equatorial Pacific

Coastal Upwelling (opposite page)
Strong southeasterly winds (red arrow) prevail along the coast of southern Ecuador and Peru. These winds, which blow during both normal and El Niño years, drag the surface water northwestward and cause cold, nutrient-rich water (dark blue) to upwell along the shore of the eastern Pacific