Paul R. Pinet

SIXTH EDITION

Invitation to

Oceanography

Chapter 10

Biological Productivity in the Ocean

Ecosystem Model

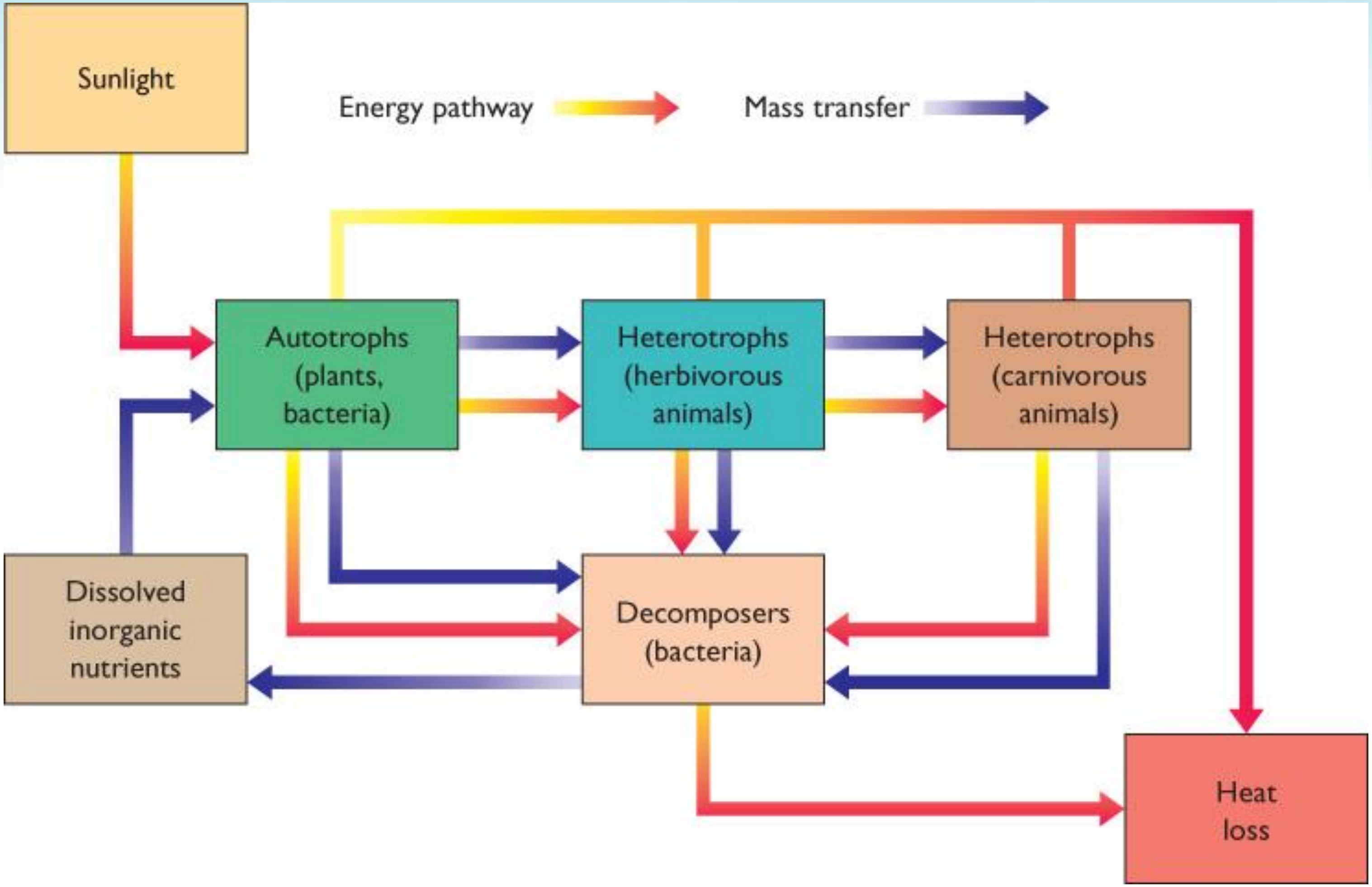


Figure 10.1: Matter is recycled through the ecosystem.

A **food chain** is the succession of organisms within an ecosystem based upon trophic dynamics.

Who is eaten by whom.

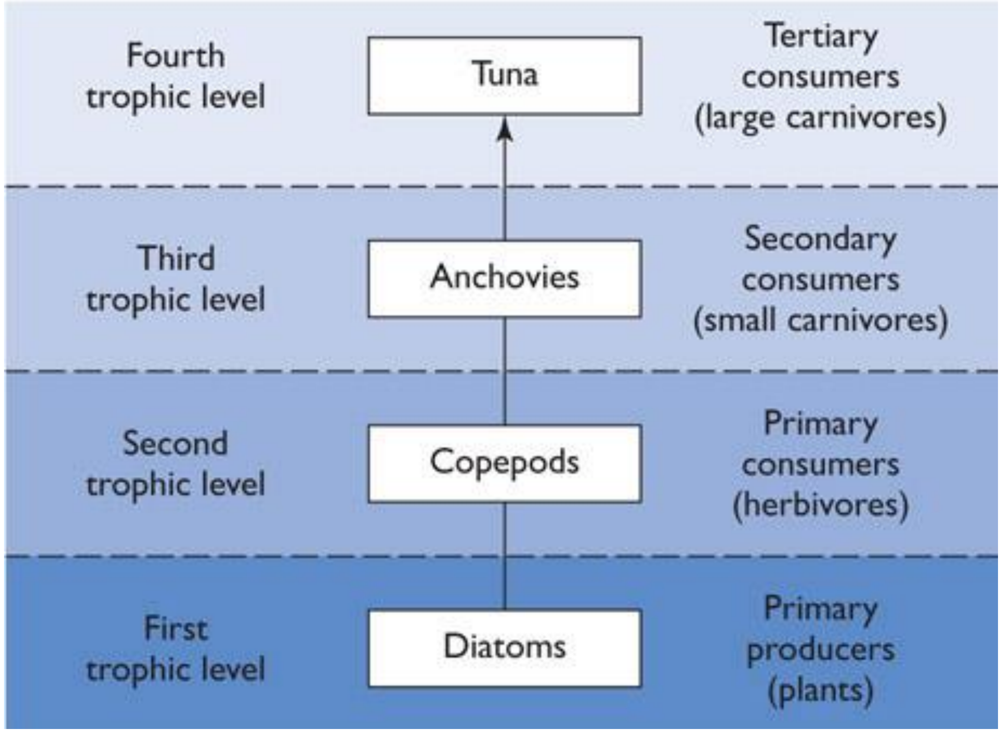


Figure 10.02: This simple food chain consists of four trophic levels arranged in a linear array.

A **food web** consists of interconnected and interdependent food chains

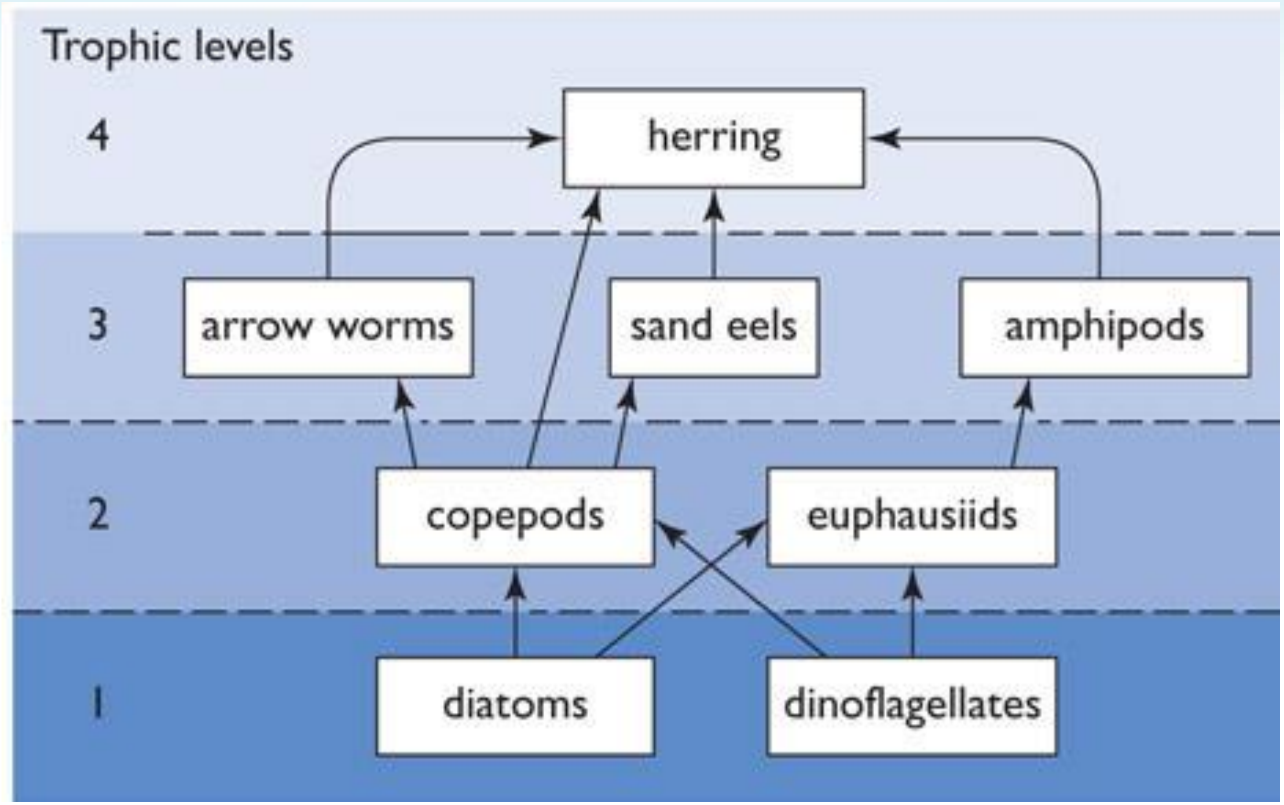


Figure 10.02b: Actual feeding habits are not simple food chains, but food webs, which are networks of interconnected and interdependent food chains.

Food Web/Chain

•An **energy pyramid** represents a food chain (or web) in terms of the energy contained at each trophic level.

- The size of each level in an energy pyramid is controlled by the size of the level immediately below.
- The relationship between the size of levels is a function of energy lost due to heat dissipation at each successively higher trophic level.

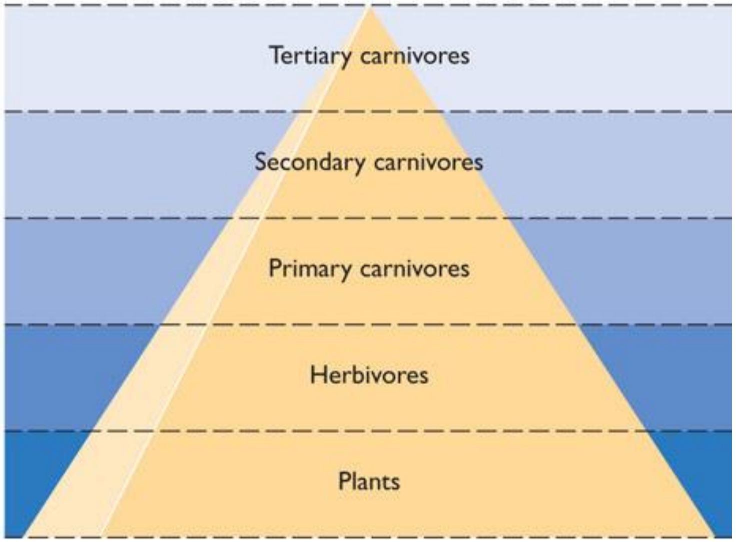


Figure 10.02c: The energy pyramid depicts trophic relationships within a community.

Prey-Predator Relationships

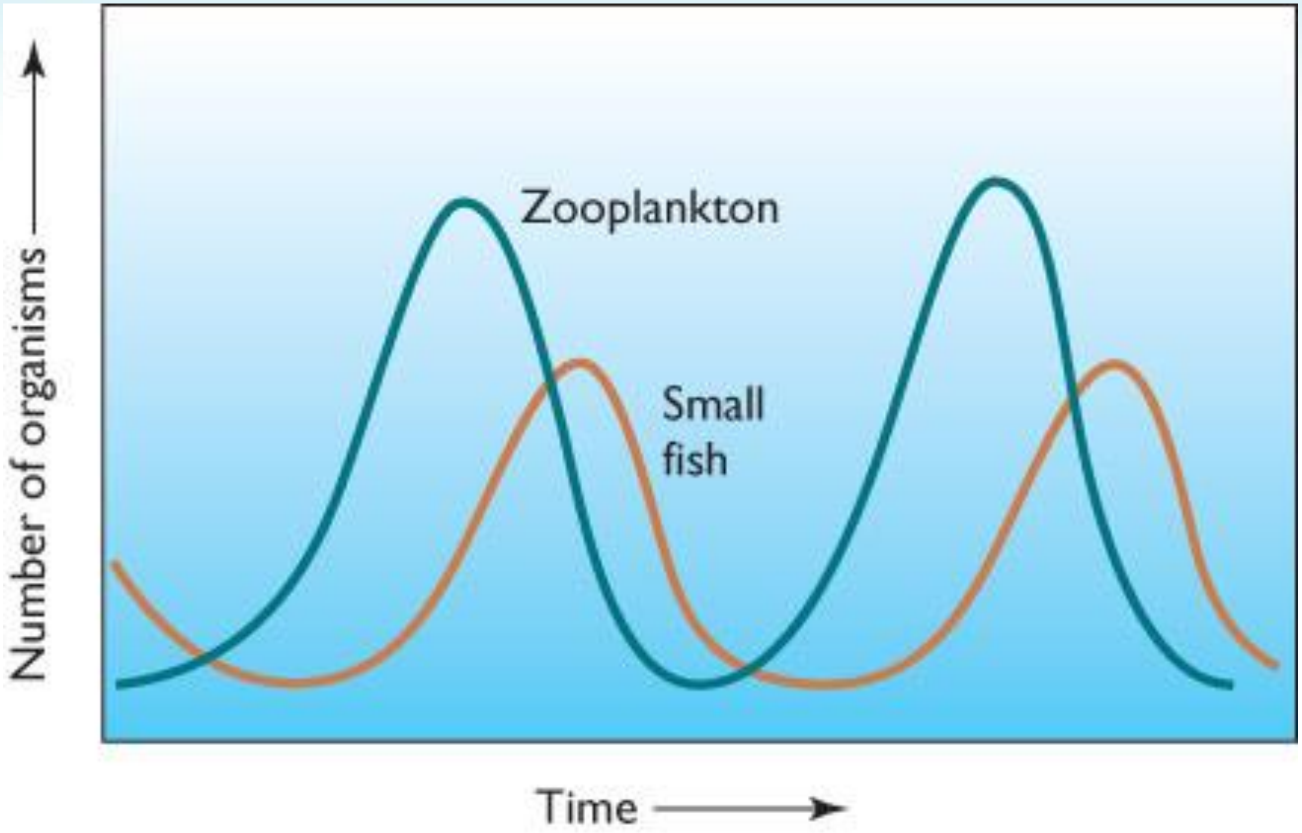


Figure 10.04: The size of a population of small fish, the predators in this model, fluctuates in direct response to the abundance of its prey, zooplankton.

Energy Transfer Between Trophic Levels

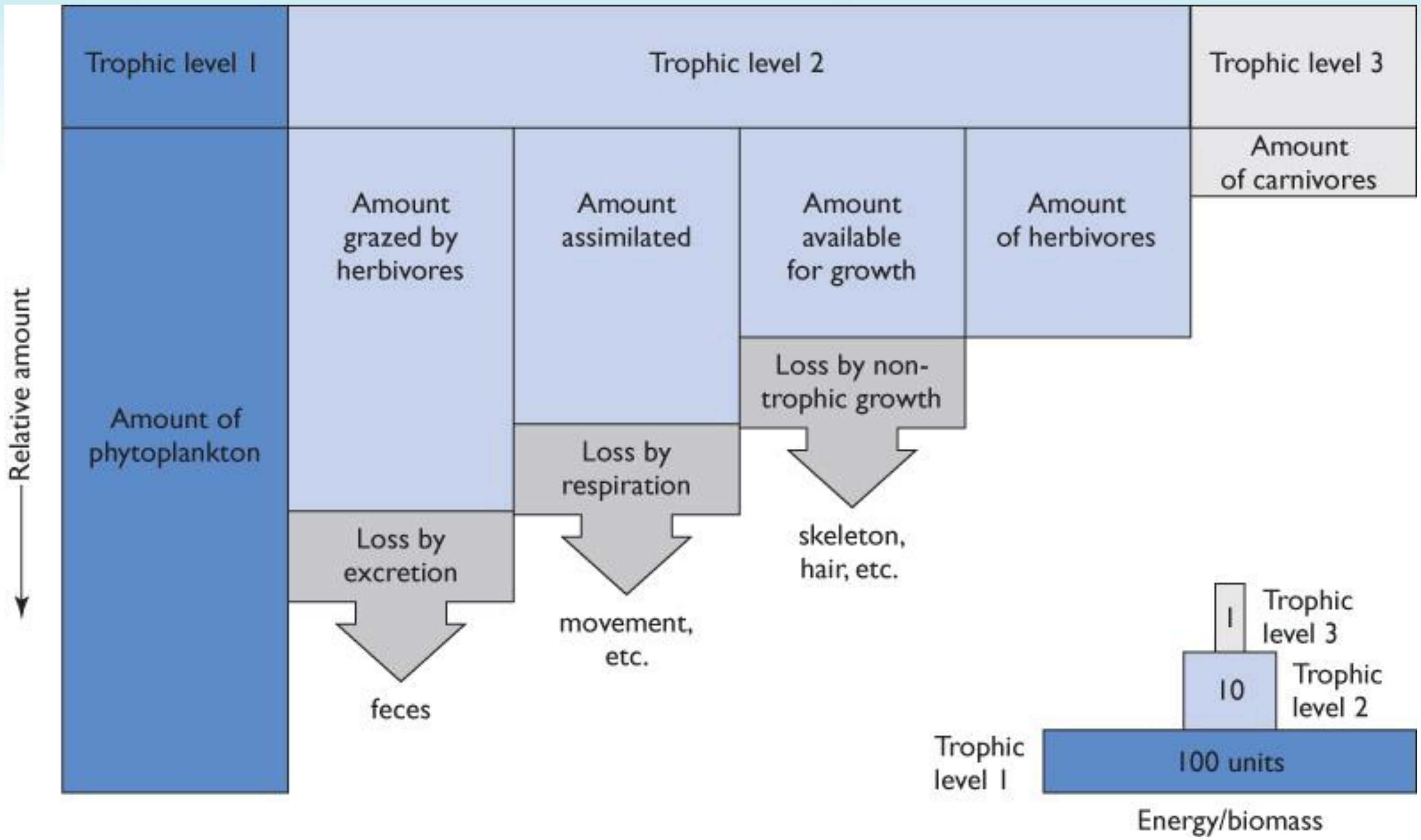


Figure 10.06: This diagram accounts for the energy/biomass distribution shown as an inset in the lower right hand corner of this figure.

Primary production

•the total amount of carbon (C) converted into organic material per square meter of sea surface per year

(gm C/m^2/yr)

Limiting factors

- **Primary factors :**
  Solar radiation
  Nutrient concentrations

- **Secondary factors :**
  Upwelling and turbulence
  Grazing intensity
  Water turbidity

Light Absorption by Seawater

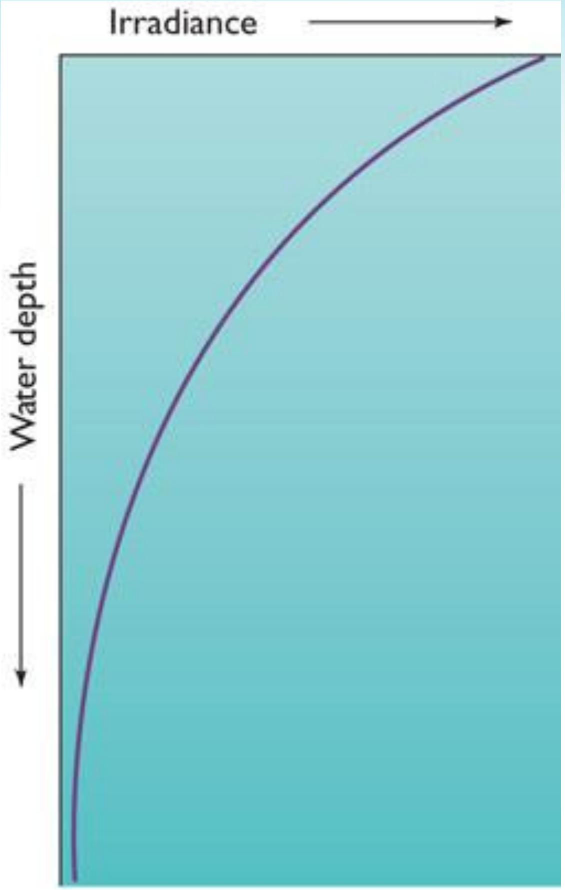


Figure 10.07a: As a result of absorption and scattering, light levels decrease sharply with depth.

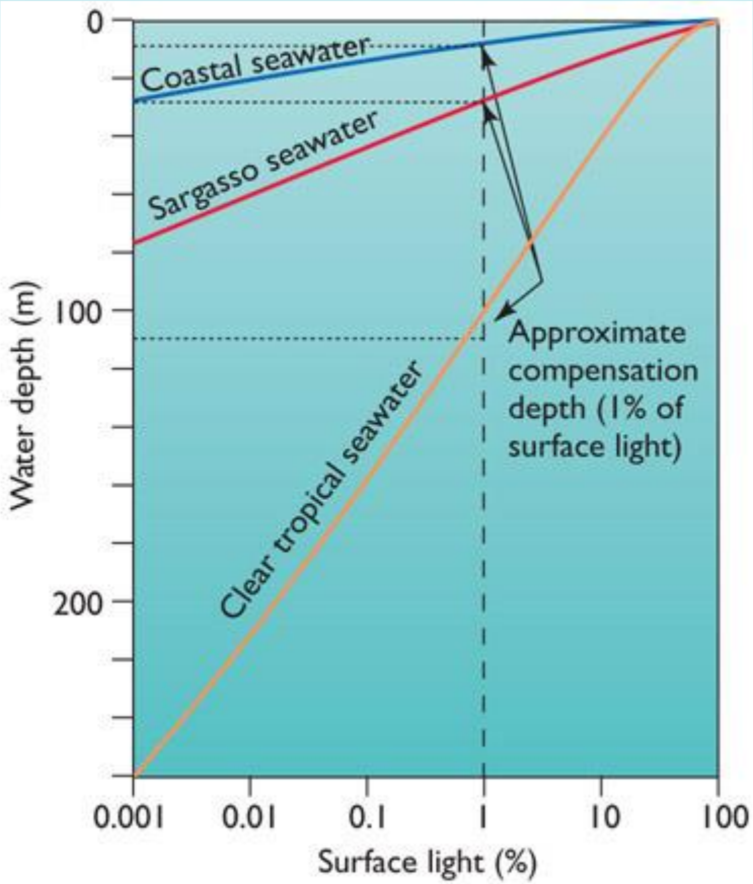
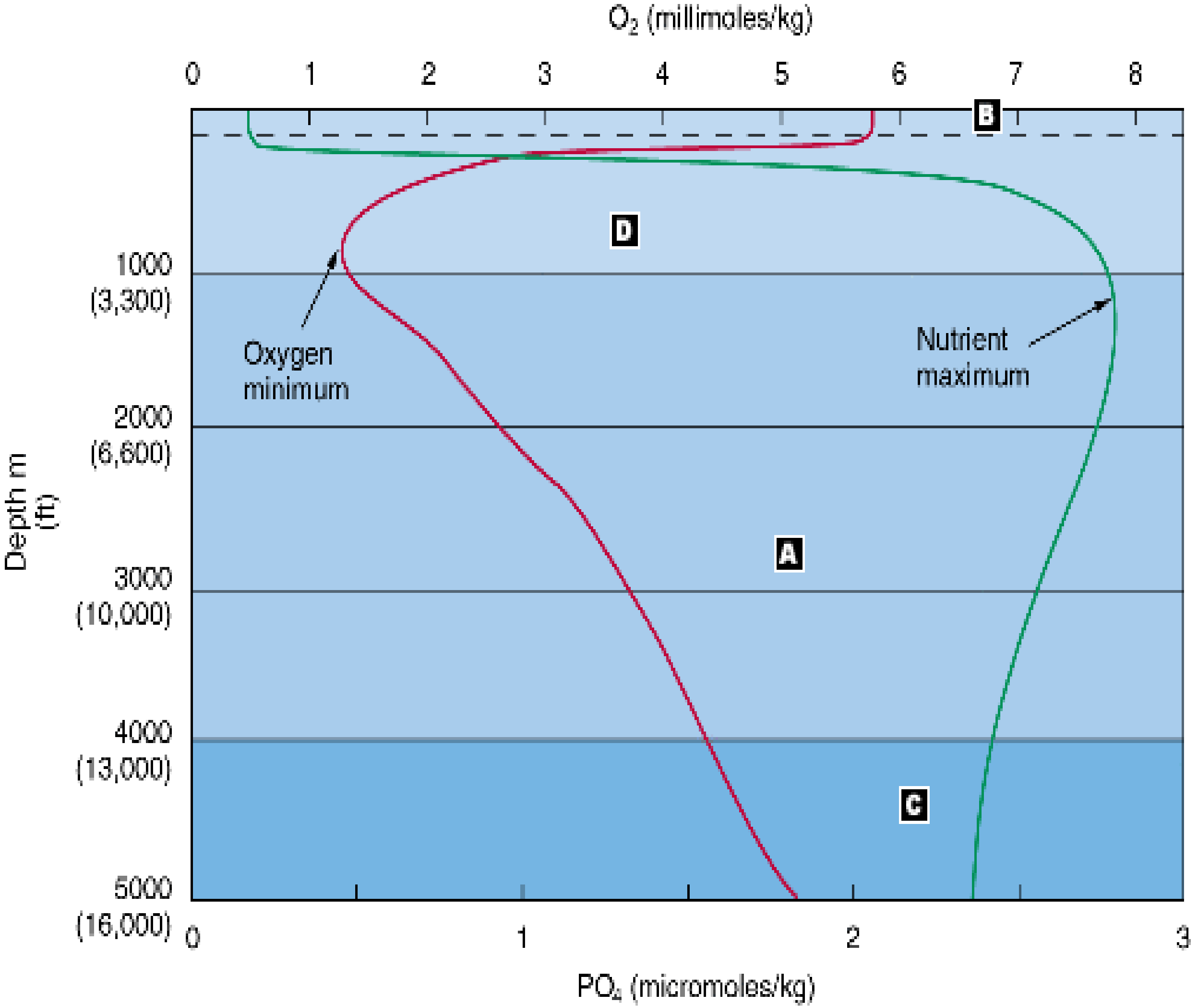


Figure 10.07b: The compensation depth is the point at which the photosynthetic production by plants exceeds their respiratory needs.



O2 (millimoles/kg)
0
1
2
3
4
5
6
7
8
B
D
1000
(3,300)
Oxygen
minimum
Nutrient
maximum
2000
(6,600)
Depth m
(ft)
A
3000
(10,000)
4000
(13,000)
C
5000
(16,000)
0
1
2
3
PO4 (micromoles/kg)

Latitudinal Variations in Primary Productivity

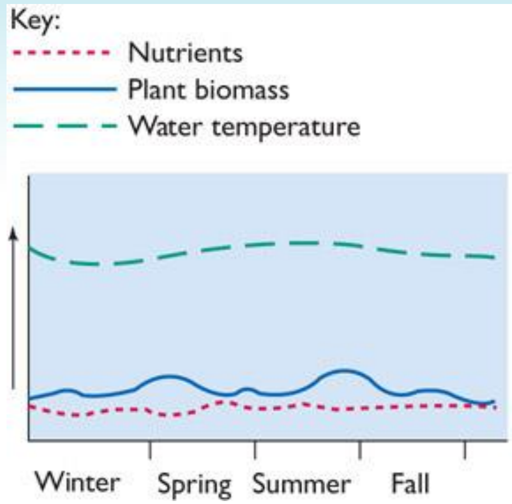


Figure 10.10a: In the tropics, primary production is low throughout the year because a sharp, permanent thermocline prevents the water column from overturning.

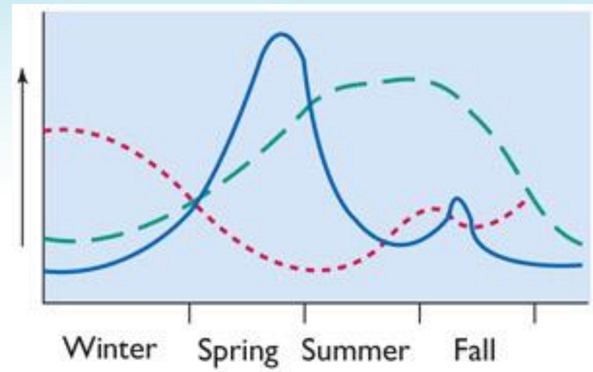


Figure 10.10b: Strong plankton blooms in the spring and weaker plankton blooms in the fall are results of seasonal variations in solar radiation and nutrient infusion.

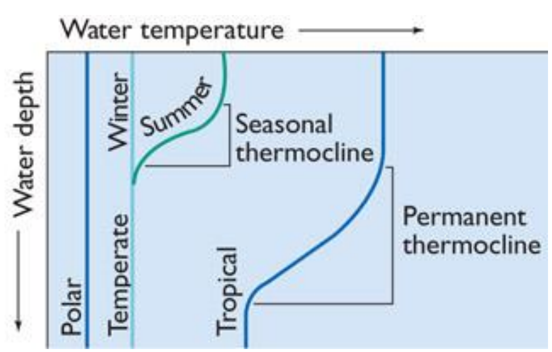


Figure 10.10d: In polar seas, the water column is isothermal.

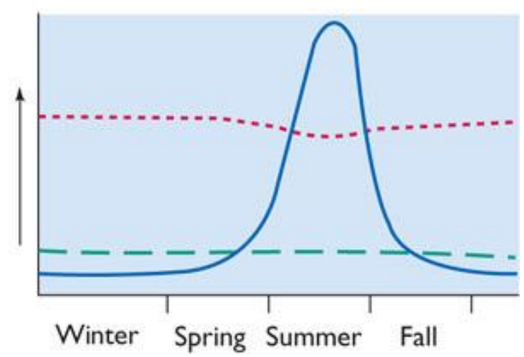


Figure 10.10c: In polar seas, plant production occurs throughout the summer due to high nutrient levels and long daylight periods.

Winter vs. Spring in the North Atlantic: Diatom Bloom

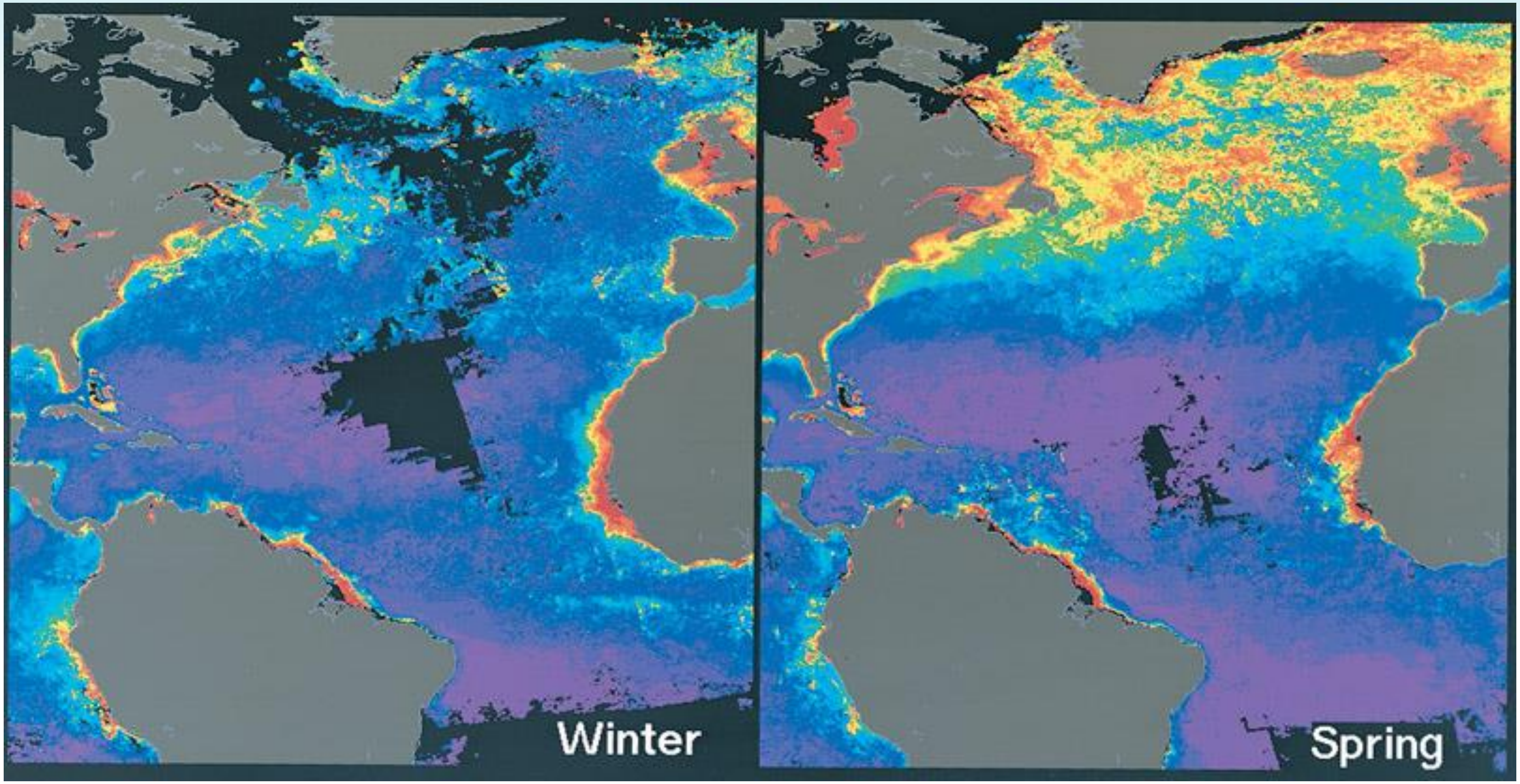


Figure B10.05: These two CZCS photographs, taken at different seasons, reveal variations in plant production in time and space.

Upwelling, Mixing, Turbulence in the Ocean
Conditions that limit light and nutrient availability

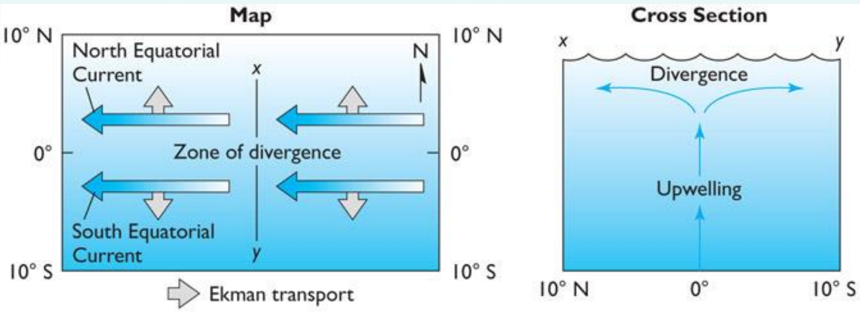


Figure 10.08a: Because of the Coriolis effect, Ekman transport is directed poleward on either side of the equator.

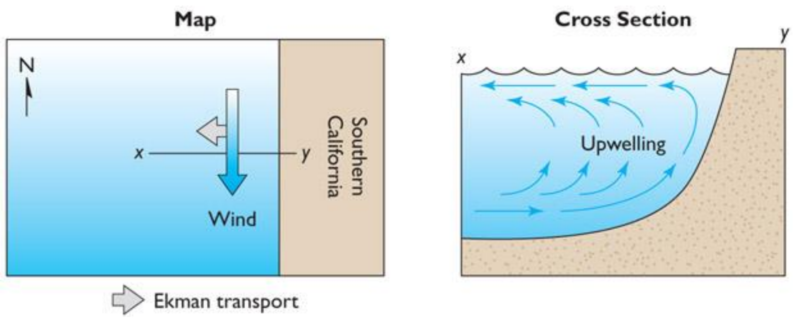


Figure 10.08b: Along the eastern sides of ocean basins, prevailing winds blowing parallel to the shoreline generate Ekman transport away from the coastline.

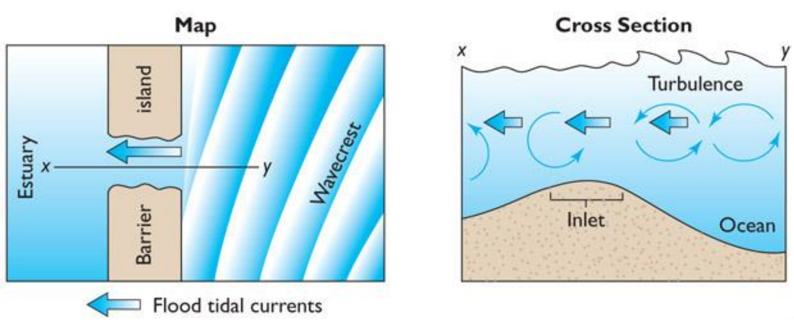


Figure 10.08c: Nutrients can be resuspended from the bottom by flow turbulence induced by waves and strong tidal currents.

FIGURE 10-9

Turbid water. Rivers flowing into the coastal waters of Georgia tend to have high loads of suspended mud. The turbidity of this water greatly reduces light penetration into the water column, which limits the productivity of these waters despite their very high content of nutrients.

10-3 Global Patterns of Productivity

TABLE 10-1

Gross primary productivity.

Quantity (gC/m2/yr)	Ocean Area	Terrestrial Area
<50	Open ocean	Deserts
50–150	Continental shelves	Forests; grasslands; croplands
150–500	Upwelling areas; deep estuaries	Pastures; rain forests; moist croplands; lakes
500–1250	Shallow estuaries; coral reefs	Swamplands; intensively developed agricultural areas

Global Variations in Primary and Secondary Production

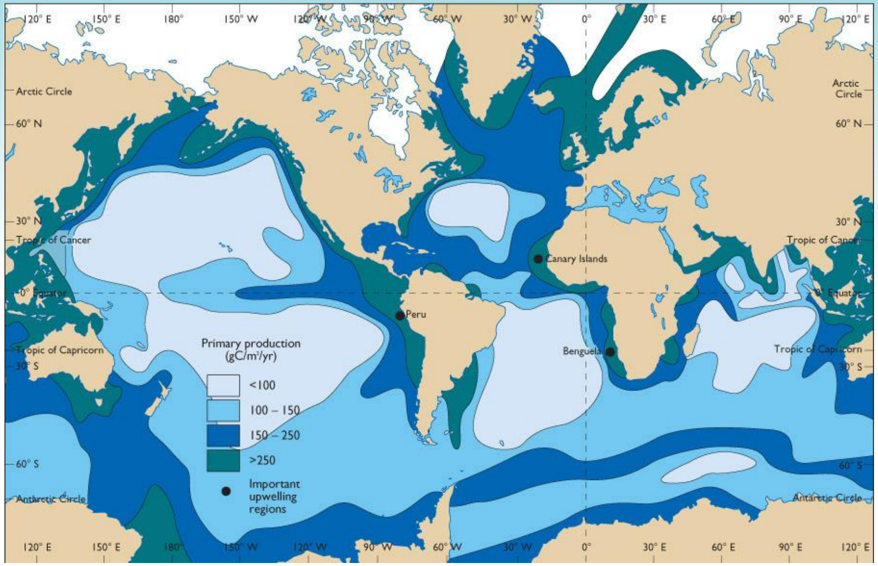


Figure 10.12a: Phytoplankton abound in the surface water of continental shelves and upwelling areas and are scarce in the centers of oceans.

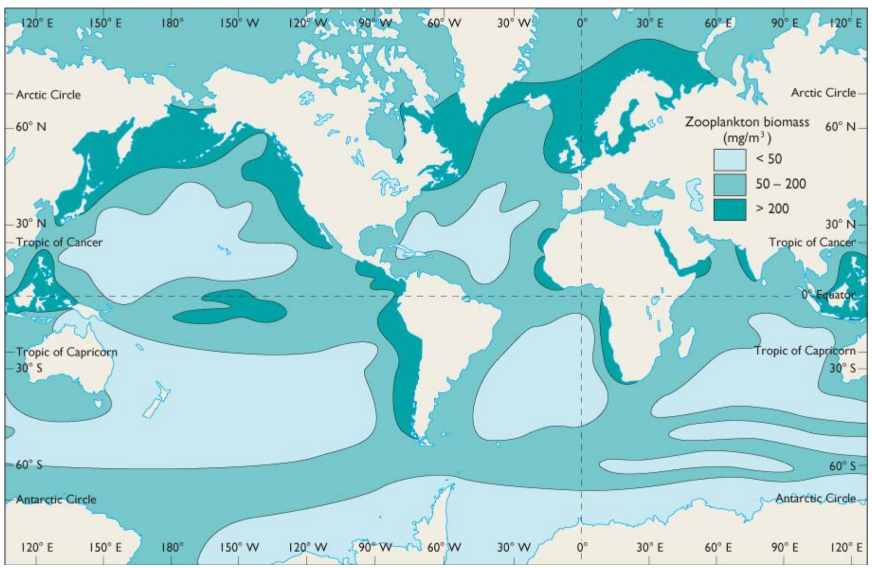


Figure 10.12b: Because zooplankton are dependent on plants for food, their distribution mimics the pattern of primary plant production.

Upwelling in the Equatorial and South Pacific

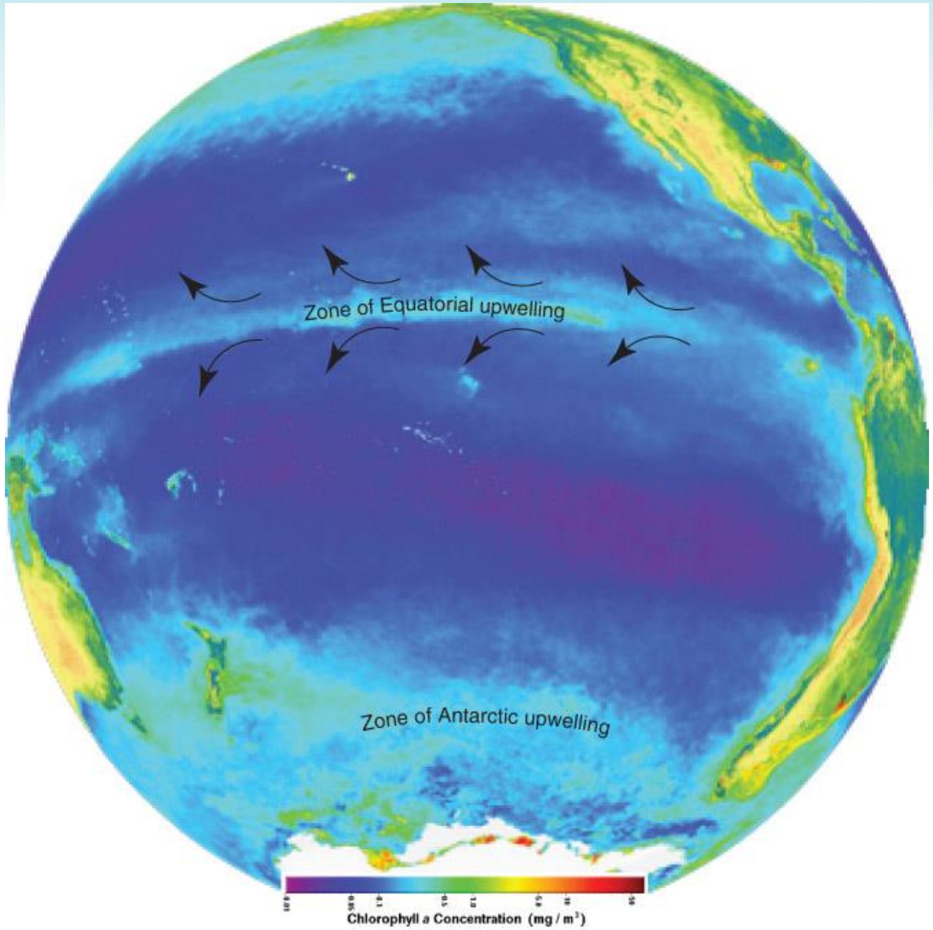


Figure 10.14: A SeaWiFS image of the high (light blue) concentrations and low concentrations of phytoplankton (dark blue).

Coastal Upwelling

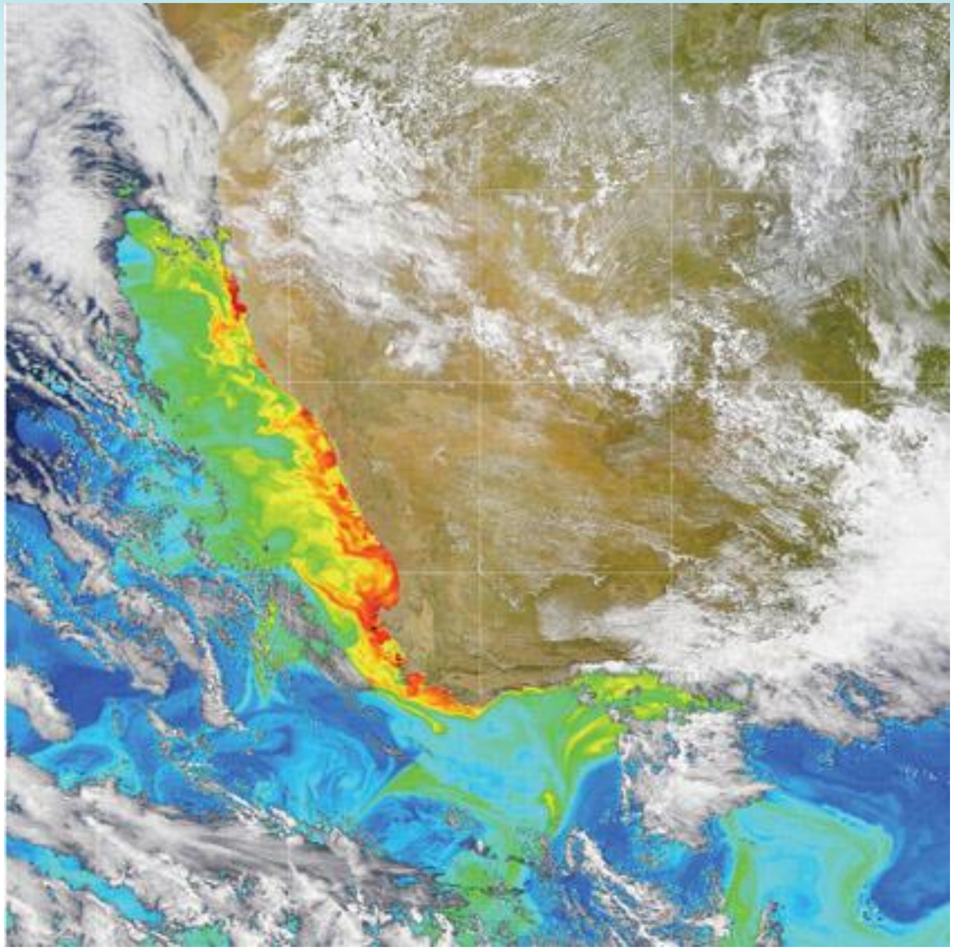


Figure 10.15: A SeaWiFS image of phytoplankton abundances along the Benguela region of South Africa and Namibia.

The Sargasso Sea: a desert in the center of a gyre

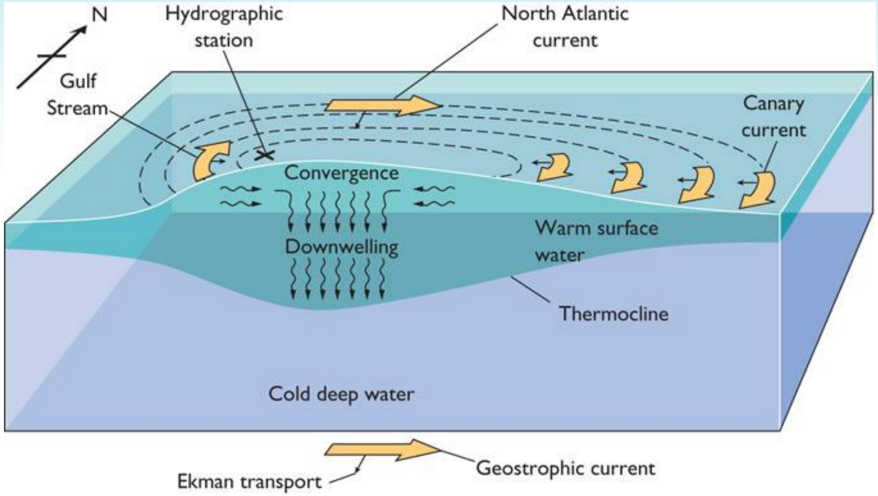


Figure 10.13a: The prevailing currents along with Coriolis deflection direct water toward the center of the gyre in the North Atlantic ocean

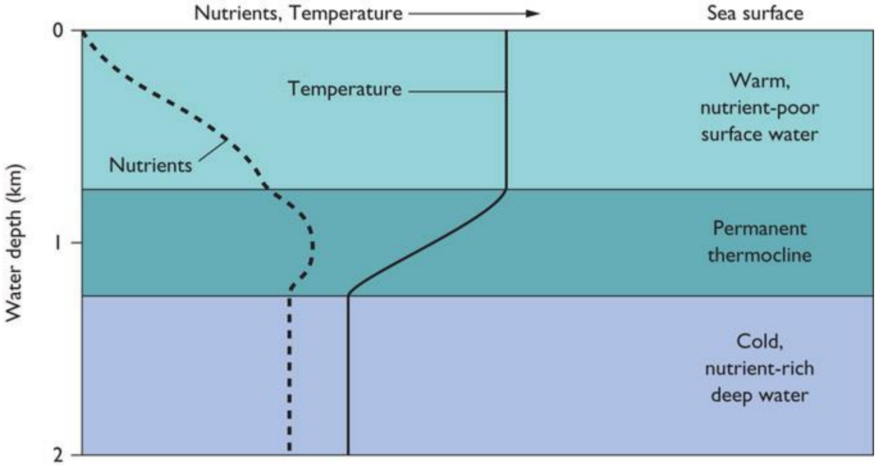


Figure 10.13b: The stratified nature of the water column in the center of the Sargasso Sea does not allow nutrient replenishment of the photic zone.

TABLE 10-2

Global fish production.

Area	Primary Production (gC/m2/yr)	Ocean Area (km2)	Ocean Area (%)	Total Primary Production (tons C/yr)	Total Primary Production (%)	Average Number of Trophic Steps	Material Transfer Efficiency per Trophic Level (%)	Fish Production (tons/yr)	Fish Production (%)
Oceanic	50	325 × ~~106~~ 10^6	90.0	16.3 × ~~109~~ 10^9	81.5	5	10	1.6 × ~~106~~ 10^6	<1
Coastal	100	36 × 106	9.9	3.6 × 109	18.0	3	15	120 × 106	50
Upwelling	300	0.36 × 106	0.1	0.1 × 109	0.5	1.5	20	120 × 106	50

Source: Adapted from J. H. Ryther, *Science* 166 (1969): 72–76.

FIGURE 10-13

Fish production. Estimates of fish populations in a region are easy to calculate, provided reliable data are available for (1) rates of primary production per unit area, (2) the number of steps in the food chain, and (3) the material transfer efficiency between each trophic level. An example of such a calculation is shown at the bottom of the figure.

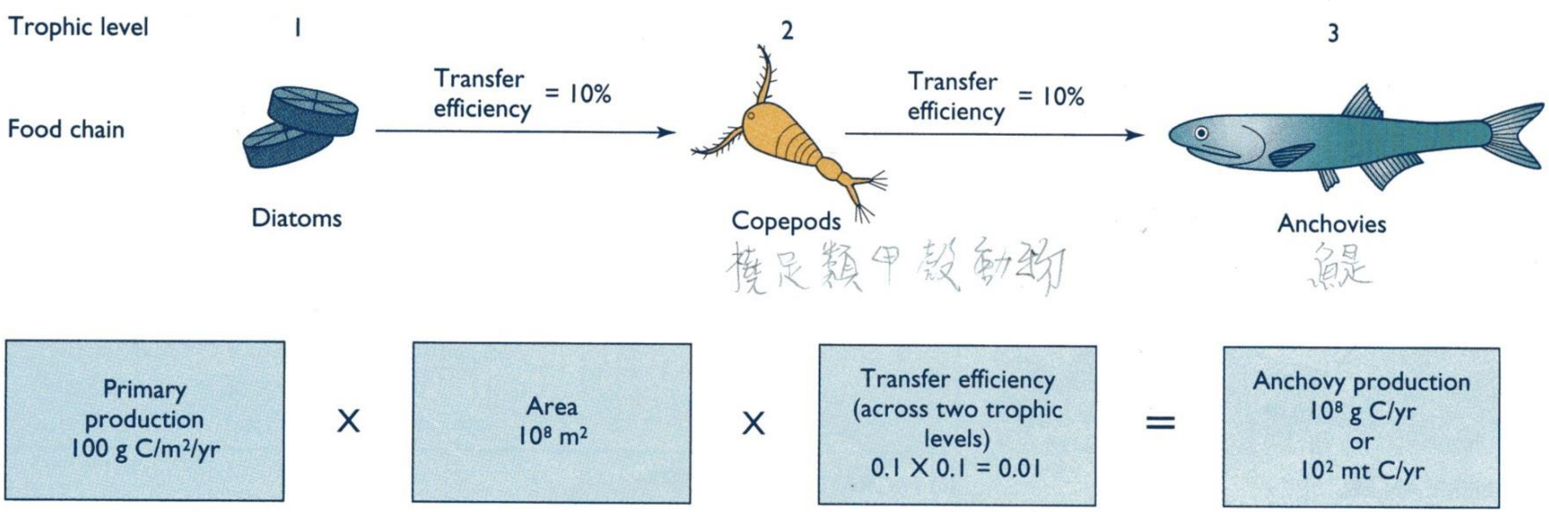
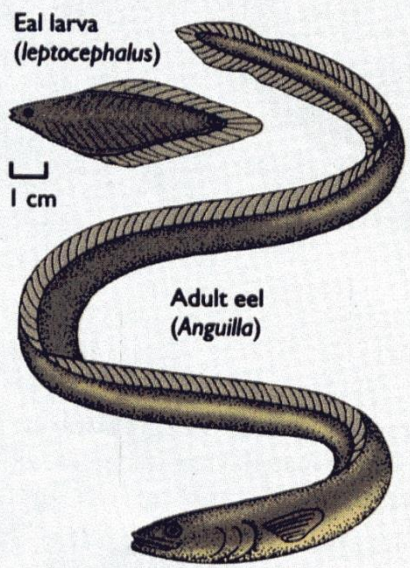


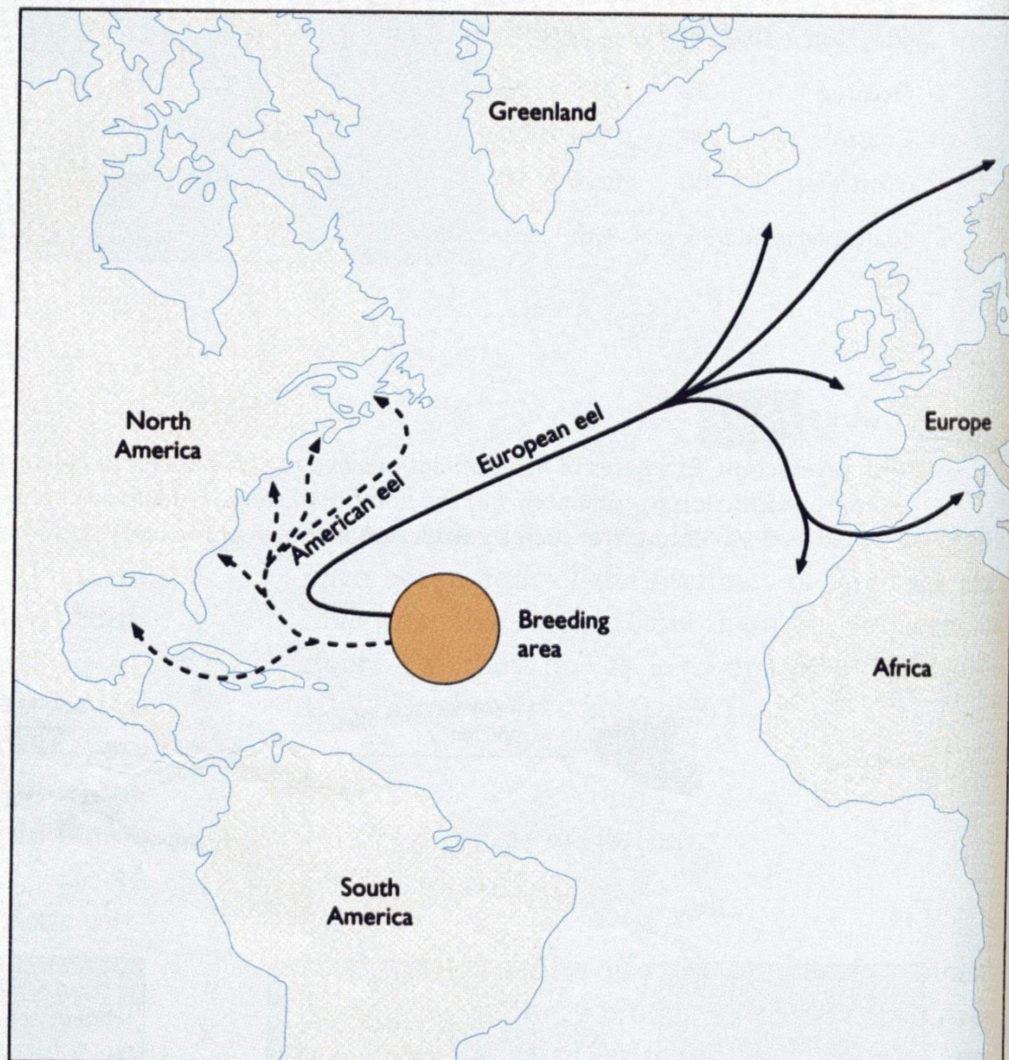
FIGURE B10-7

Eel migration. (a) The eel *Anguilla* inhabits freshwater rivers but breeds and spawns in saltwater. Eel larvae *(leptocephali)* hatch from pelagic eggs in the Sargasso Sea. They have large eyes, transparent bodies, and large surface areas to help them float as they drift with the surface currents. (b) Photograph of the American eel. (c) North American *(Anguilla rostrata)* and European *(A. anguilla)* eels breed in the Sargasso Sea. The pelagic eel larvae drift to their respective shores and then migrate upstream to lakes and ponds. [Adapted from C. E. Bond, *Biology of Fishes* (Philadelphia: Saunders, 1979).]

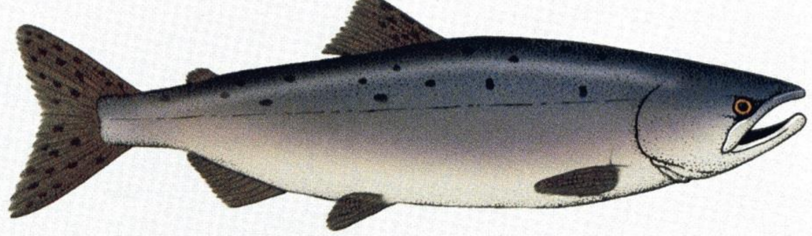


(a) *ANGUILLA*

(b) AMERICAN EEL



(c) MIGRATION ROUTES



(a) NORTH PACIFIC PINK SALMON

(b) NORTH PACIFIC PINK SALMON

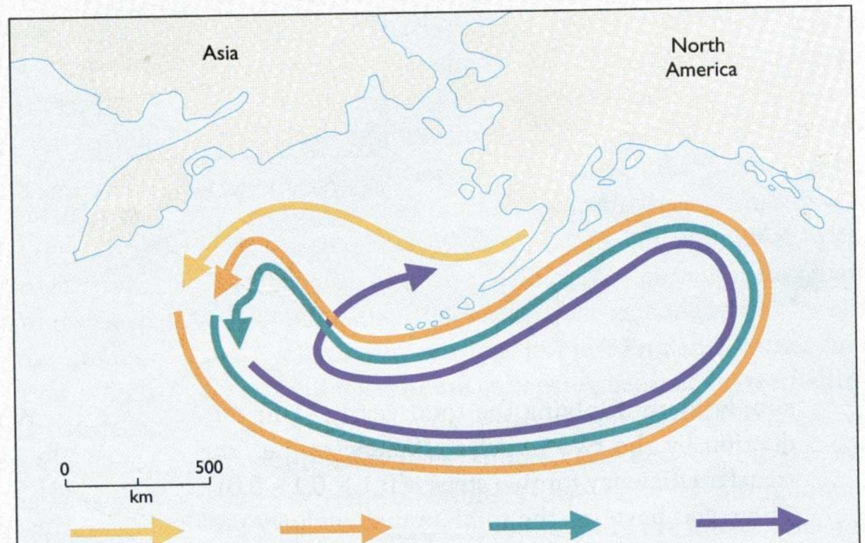


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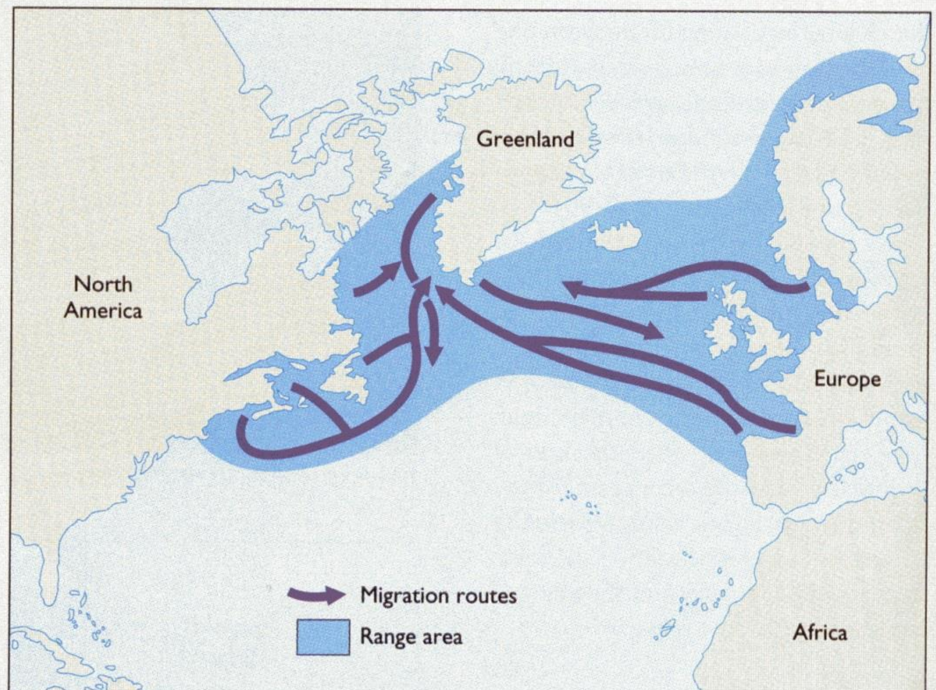
FIGURE B10-9

(a) Atlantic salmon. (b) The Atlantic salmon spend their adult lives in the open ocean and return to their natal streams to spawn. [Adapted from A. Netboy, *The Salmon: Their Fight for Survival* (London: Andre Deutsch, 1974).]

(a) ATLANTIC SALMON



(b) ATLANTIC SALMON MIGRATION ROUTES

The Fishing Population

•Overfishing is removing fish from the ocean faster than they are replaced by reproduction.

•This will eventually lead to the collapse of a fish population if fishing is not regulated.

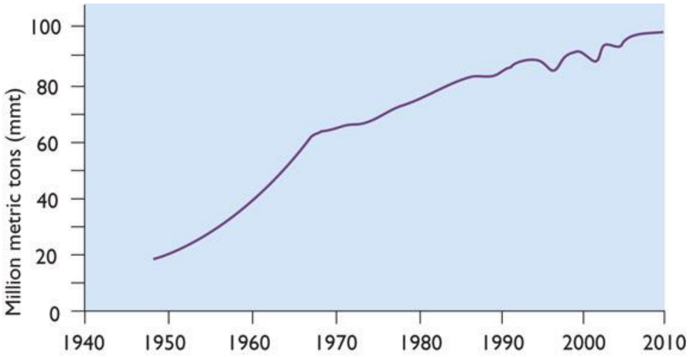


Figure 10.17a: Between 1950 and 1970 the world catch of fish climbed from 20 million tons to 70 million tons. It has since climbed to about 98 million tons.

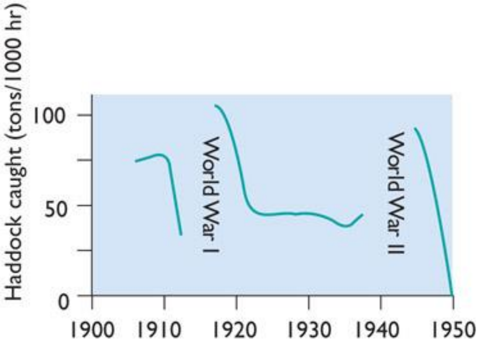


Figure 10.17b: Excessive fishing pressure without proper management can seriously affect a fish stock.

Coastal Upwelling and Normal Water Conditions…
Compare to El Niño conditions…

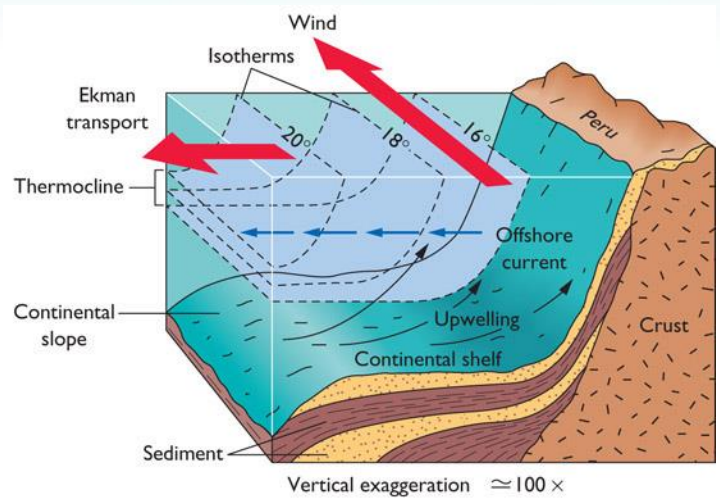


Figure 10.18b: The prevailing winds blow out of the south, parallel to the Peruvian coastline.

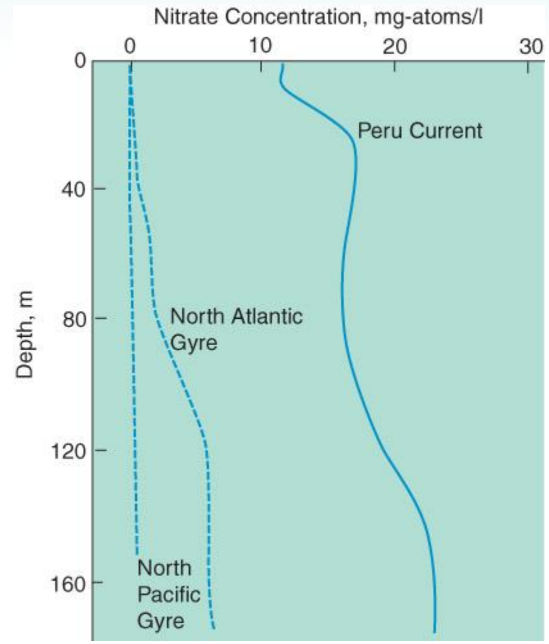


Figure 10.19: A comparison of the vertical distribution of nitrate in upwelling areas (solid curves) and in adjacent non-upwelling central ocean regions (dotted curves).

El Niño Southern Oscillation

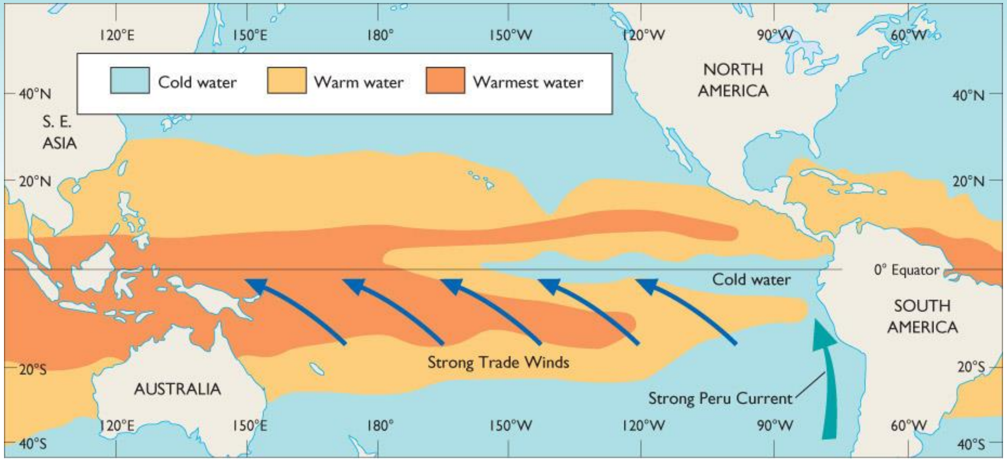


Figure B10.09a: When the trade winds blow strongly, cold, nutrient-rich water occurs at the ocean surface in the eastern equatorial Pacific and offshore Peru.

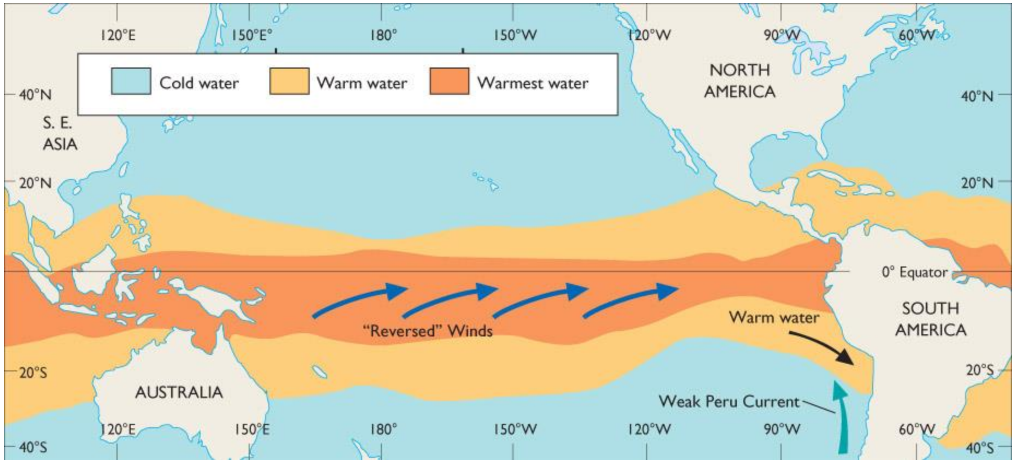


Figure B10.09b: On occasion, normal air-pressure patterns break down.

La Niña

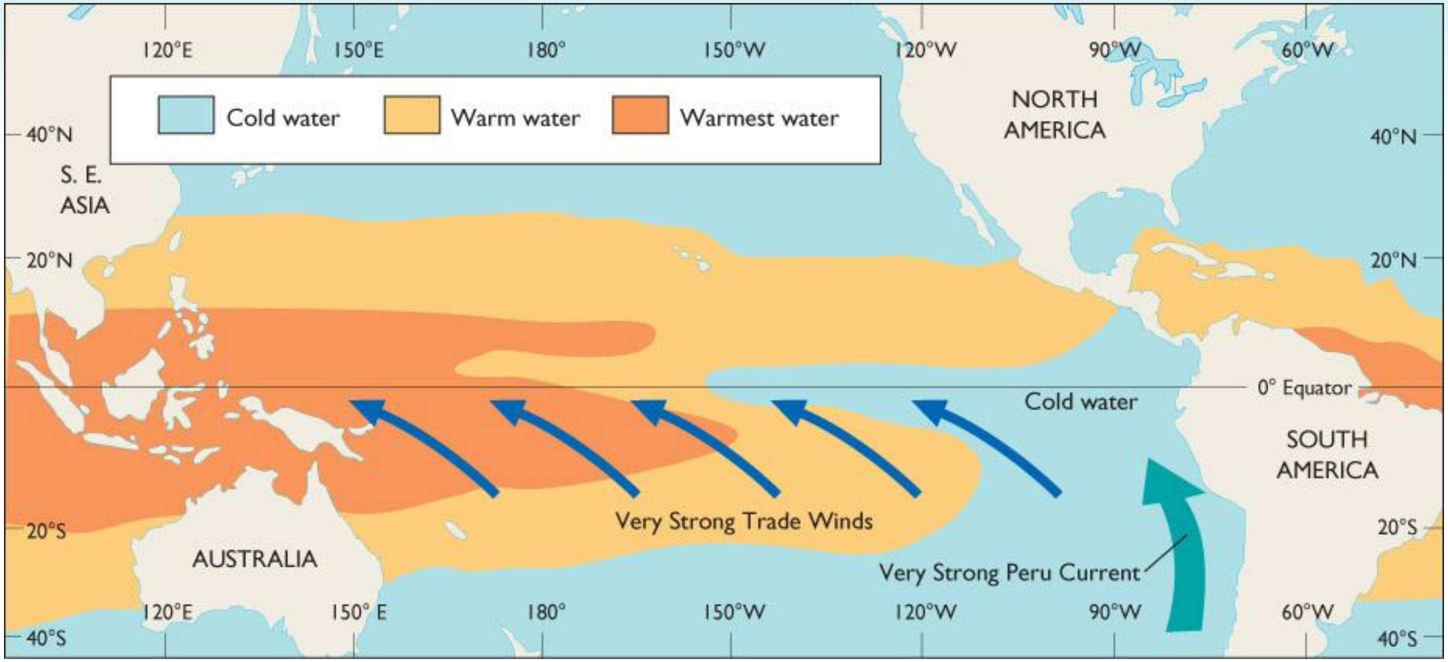


Figure B10.09c: La Niña occurs when sea-surface temperatures are unusually cold and extensive with intensification of the Trade Winds and the Peru current.