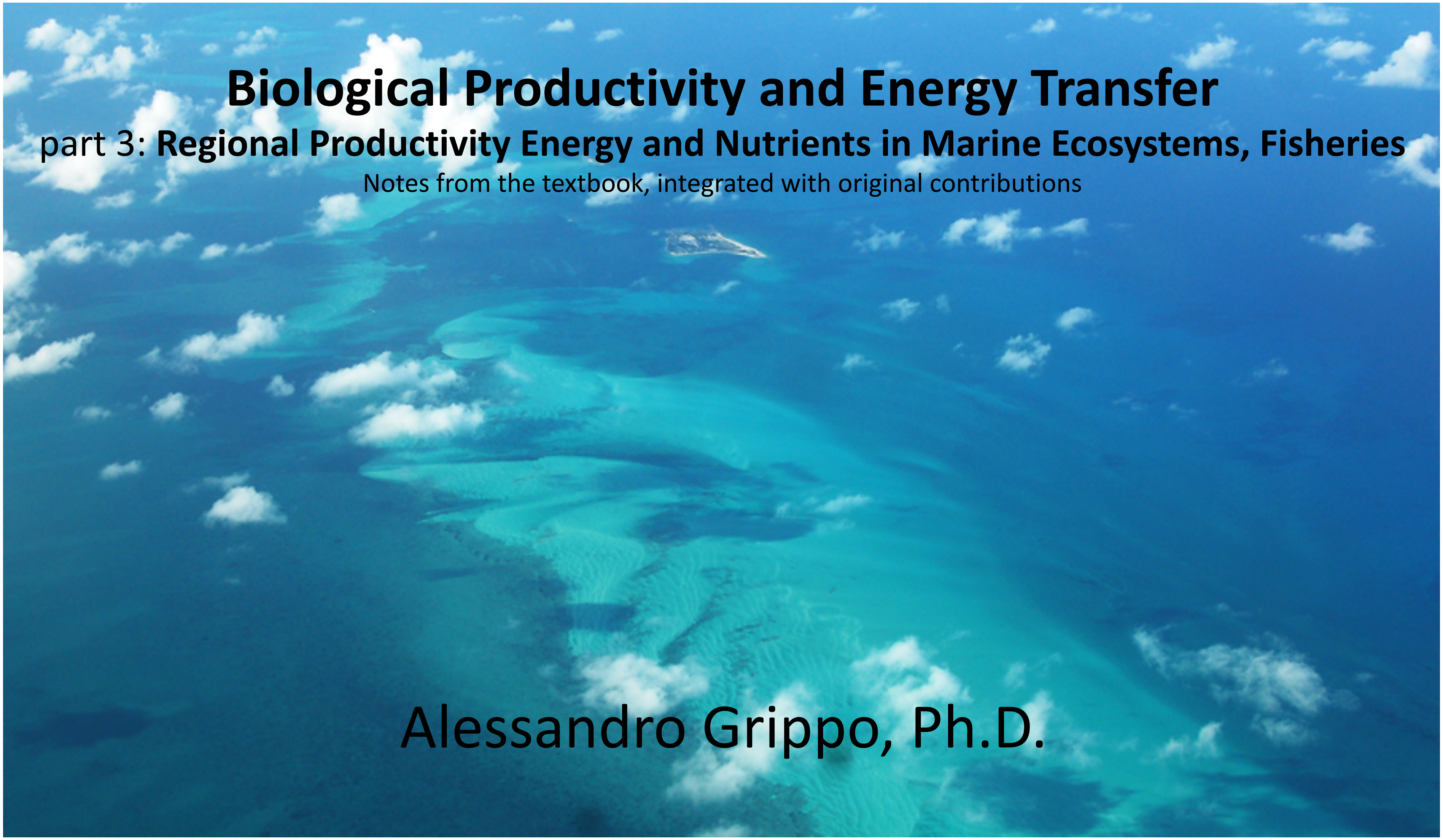
# OCEANOGRAPHY

## Chapter 13

# Biological Productivity and Energy Transfer

part 3: **Regional Productivity Energy and Nutrients in Marine Ecosystems, Fisheries**

Notes from the textbook, integrated with original contributions



Alessandro Grippo, Ph.D.

Shallow tropical waters: carbonate banks, oolitic limestones, low primary productivity

Atlantic Ocean between Florida, U.S.A, and the Bahamas

# How Does Regional Primary Productivity Vary?

- Productivity in the ocean is not constant, but varies dramatically from place to place

- Productivity is measured in weight of carbon in grams (gC) per unit of area (square meters), per unit of time (year)

- Values range from 1 $gC/m^2/year$ to 4000 $gC/m^2/year$ based on:
  - Uneven distribution of nutrients
  - Changes in availability of sunlight

# A biological pump

- Overall, 90% of biomass from euphotic zone decomposes before descending below it
- The remaining 10% sinks to deeper water where about 9% is decomposed
- The remaining 1% reaches the ocean floor and accumulates there
- This removal of organic mater from the euphotic zone is called a **biological pump**

## Why is that removal called a **biological pump**?

- The sinking to the ocean bottom of 1% of the organic matter produced in the euphotic zone "pumps" $CO_2$ and the nutrients from the surface to the bottom waters and sea floor sediments

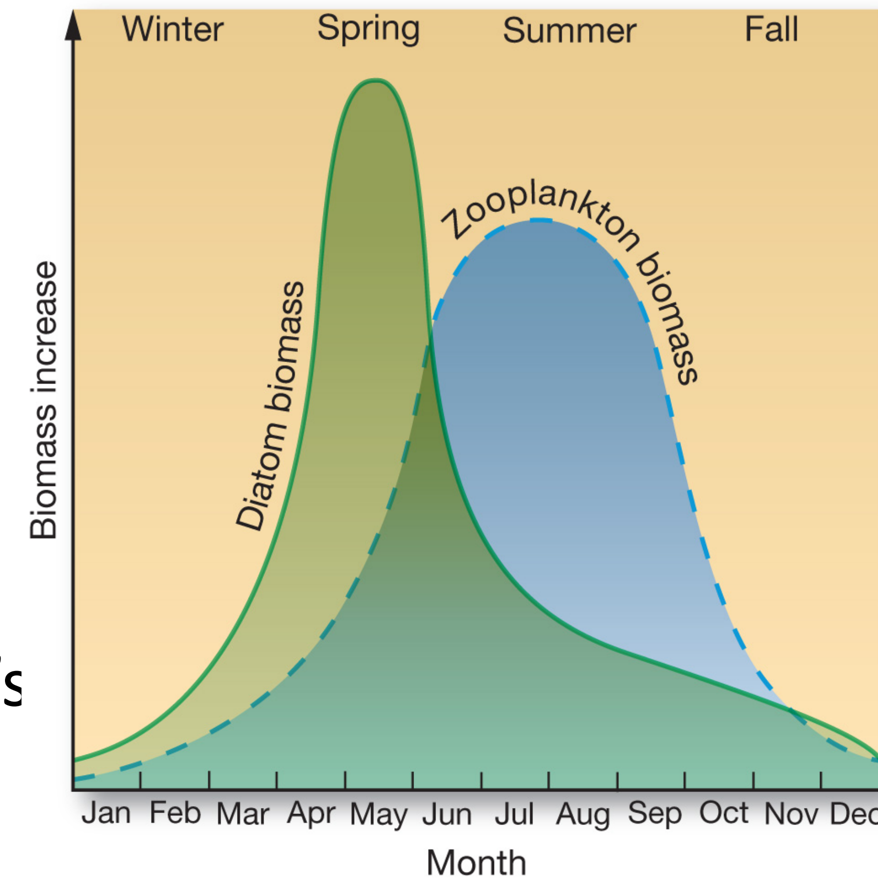
- If those substances cannot come back to the surface, nutrients cannot be resupplied to the sunlit euphotic zone

## Water mixing, the thermocline and the pycnocline

- If a thermocline (and, as a consequence, a pycnocline) exists (warmer waters at the surface, colder at depth), mixing cannot occur and nutrients remain at the ocean bottom
  - In tropical waters, the thermocline is always present
  - In temperate waters, the thermocline is seasonal
  - In polar waters the thermocline is absent

# Polar Ocean Productivity

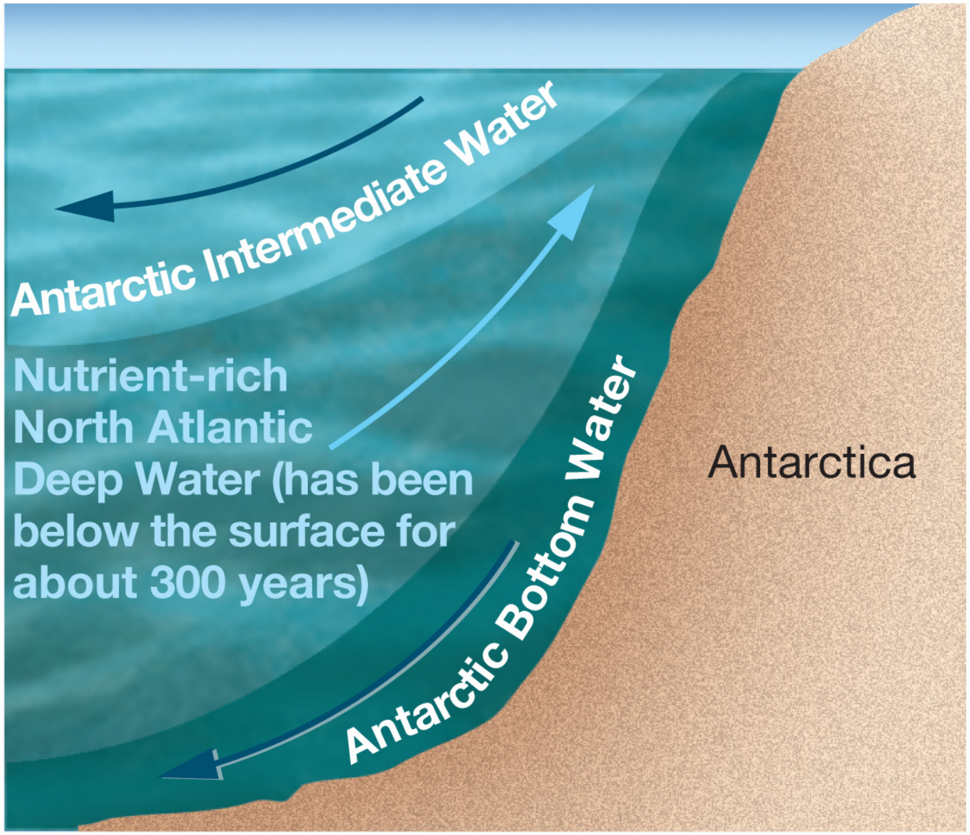
- Winter darkness
- Summer sunlight
- Phytoplankton (diatoms) bloom
- Zooplankton (mainly small crustaceans) productivity follows
- Example: Arctic Ocean's Barents Sea




(a) Barents Sea productivity

# Polar Ocean Productivity

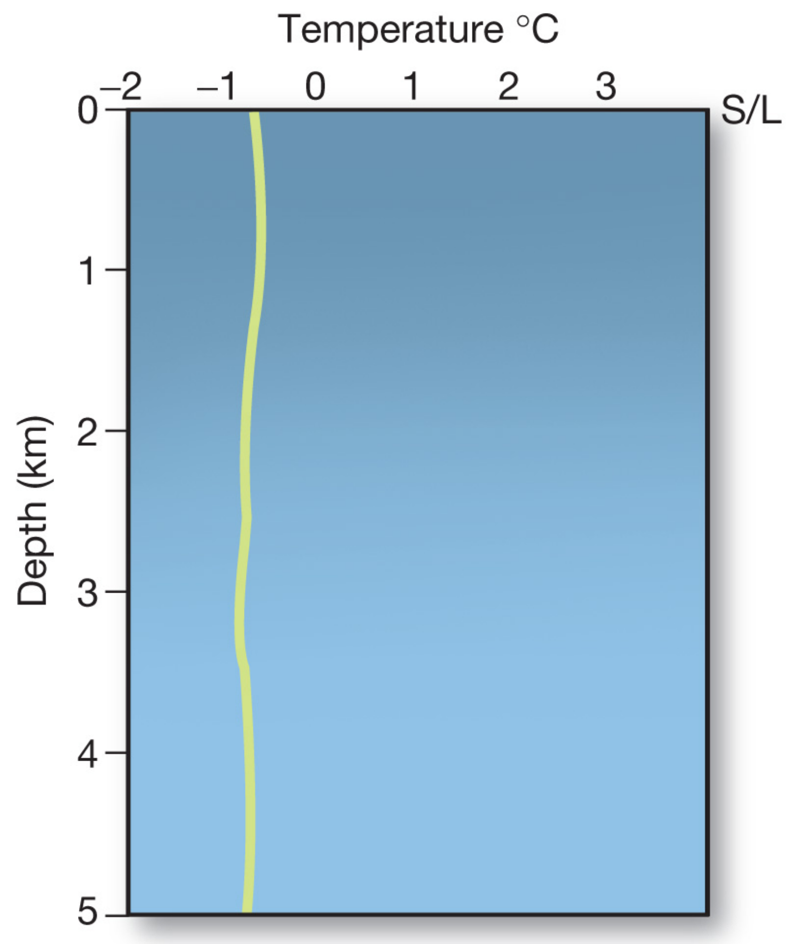
- Antarctic productivity slightly greater than Arctic
- North Atlantic Deep Water upwells near Antarctica
- Productivity decreases from UV radiation – ozone hole




(b) Antarctic upwelling

# Polar Ocean Productivity

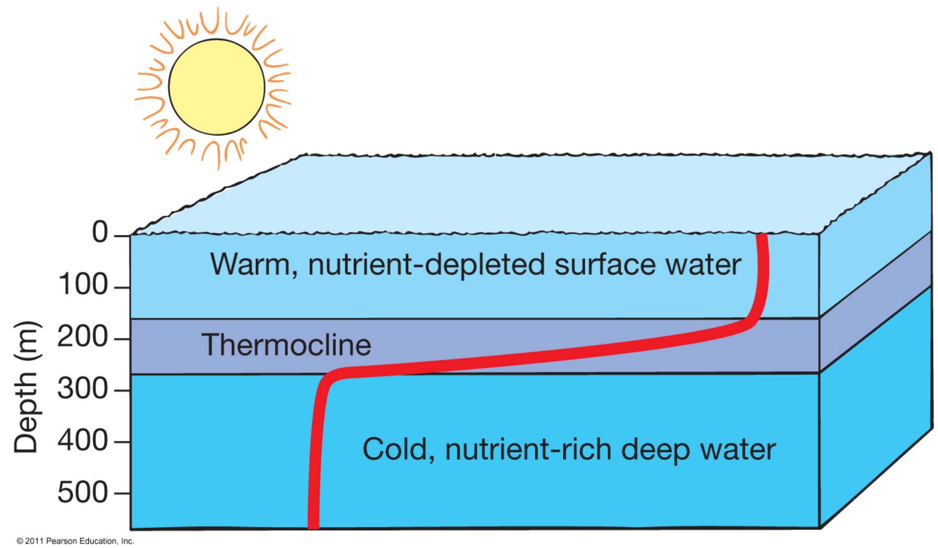
- Isothermal waters
  - Mixing can occur but in summer it is limited by melting of ice
  - Plankton remains at surface
- Blue whales migration timings are set on feeding during maximum zooplankton productivity




(c) Typical polar temperature profile

# Productivity in Tropical Oceans

- A permanent thermocline is a barrier to vertical mixing
- Low rate of primary productivity
  - Caused by lack of nutrients (cannot be recycled to the surface)
  - Opposite of what happens in polar waters where lack of light limits productivity

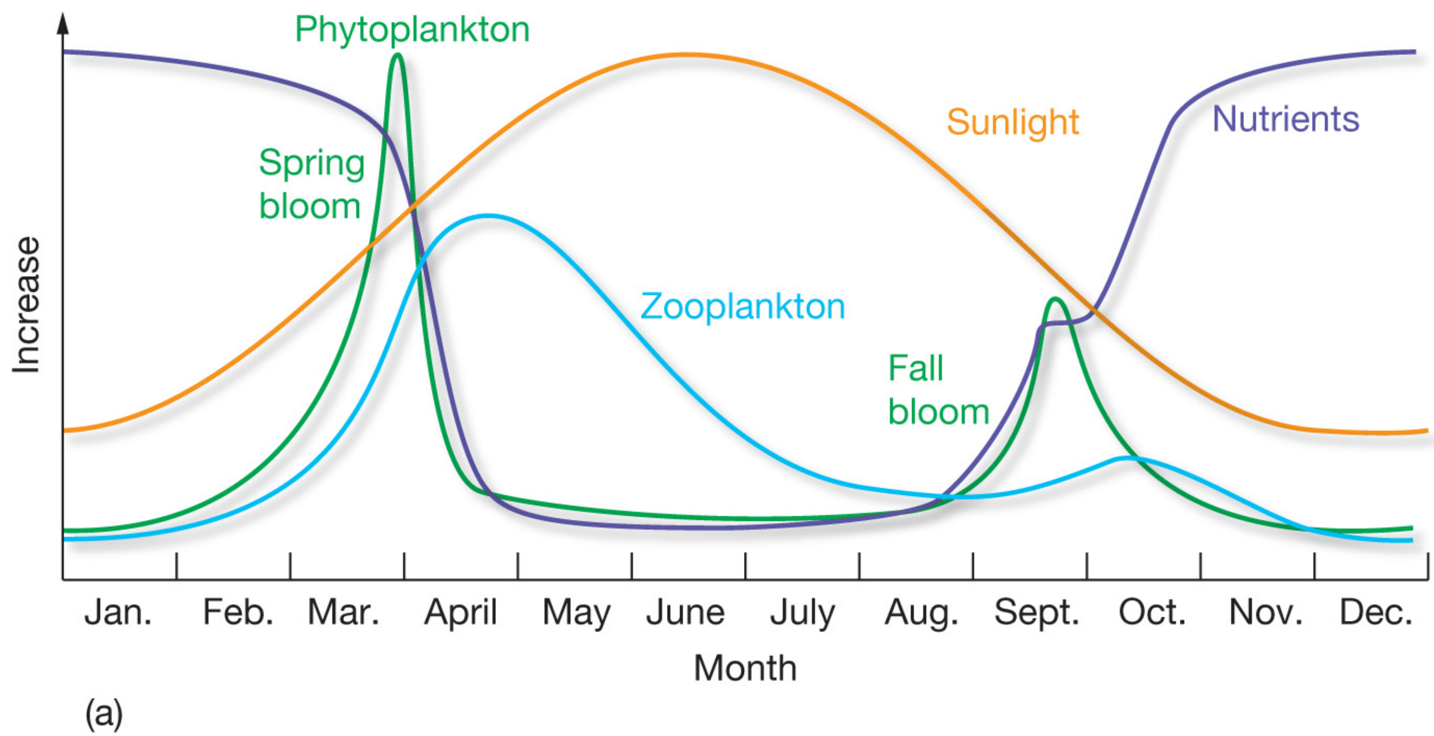


# Productivity in Tropical Oceans

- Generally, primary production in tropical ocean occurs at a steady but rather low rate
- Exceptions, where primary productivity is high in tropical oceans, occur in areas of
  - Equatorial upwelling
  - Coastal upwelling
  - Coral reefs
    - Symbiotic algae
    - Recycle nutrients within the ecosystem

# Temperate Ocean Productivity

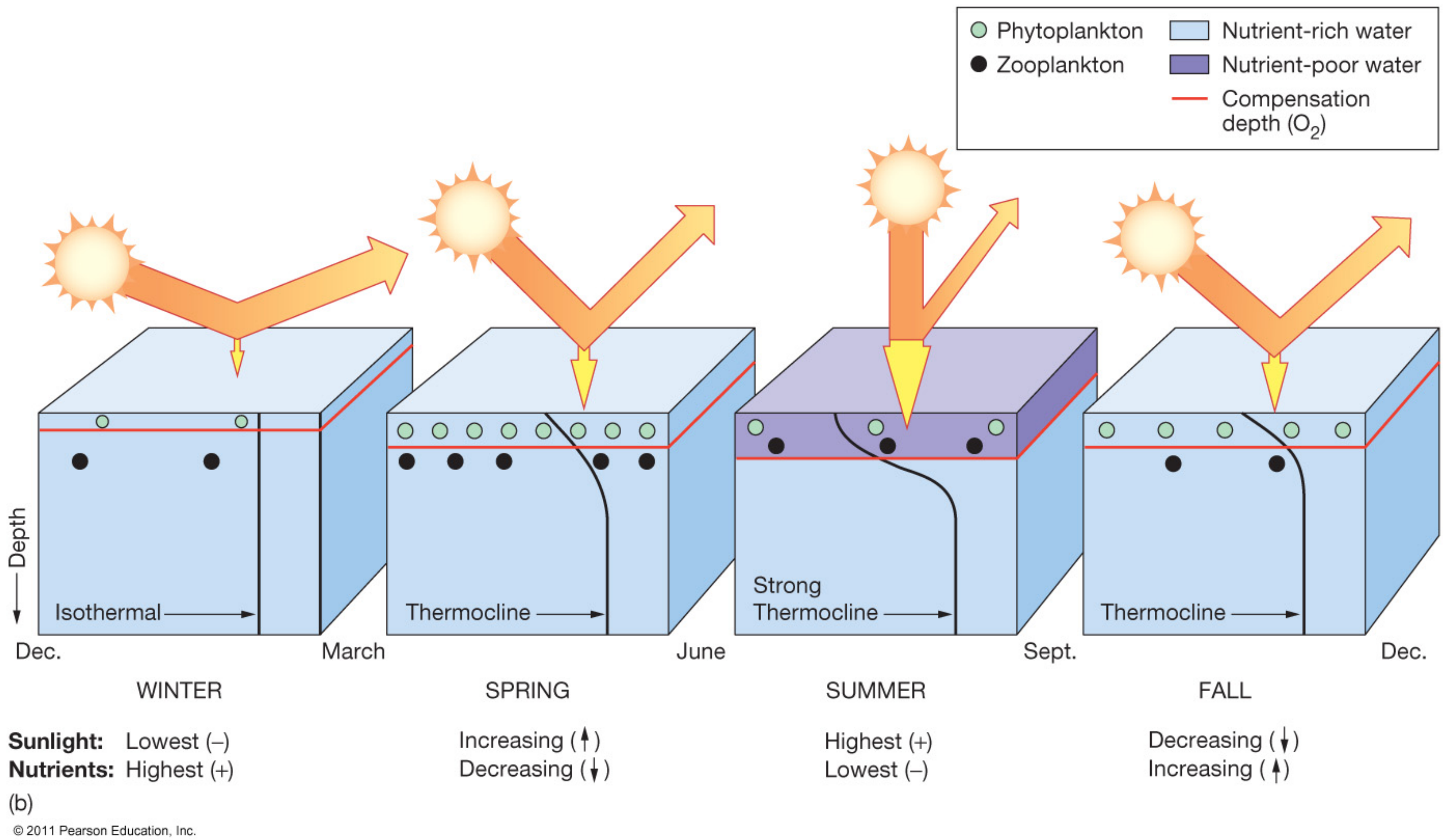
- Productivity limited by both
  - Available sunlight
  - Available nutrients



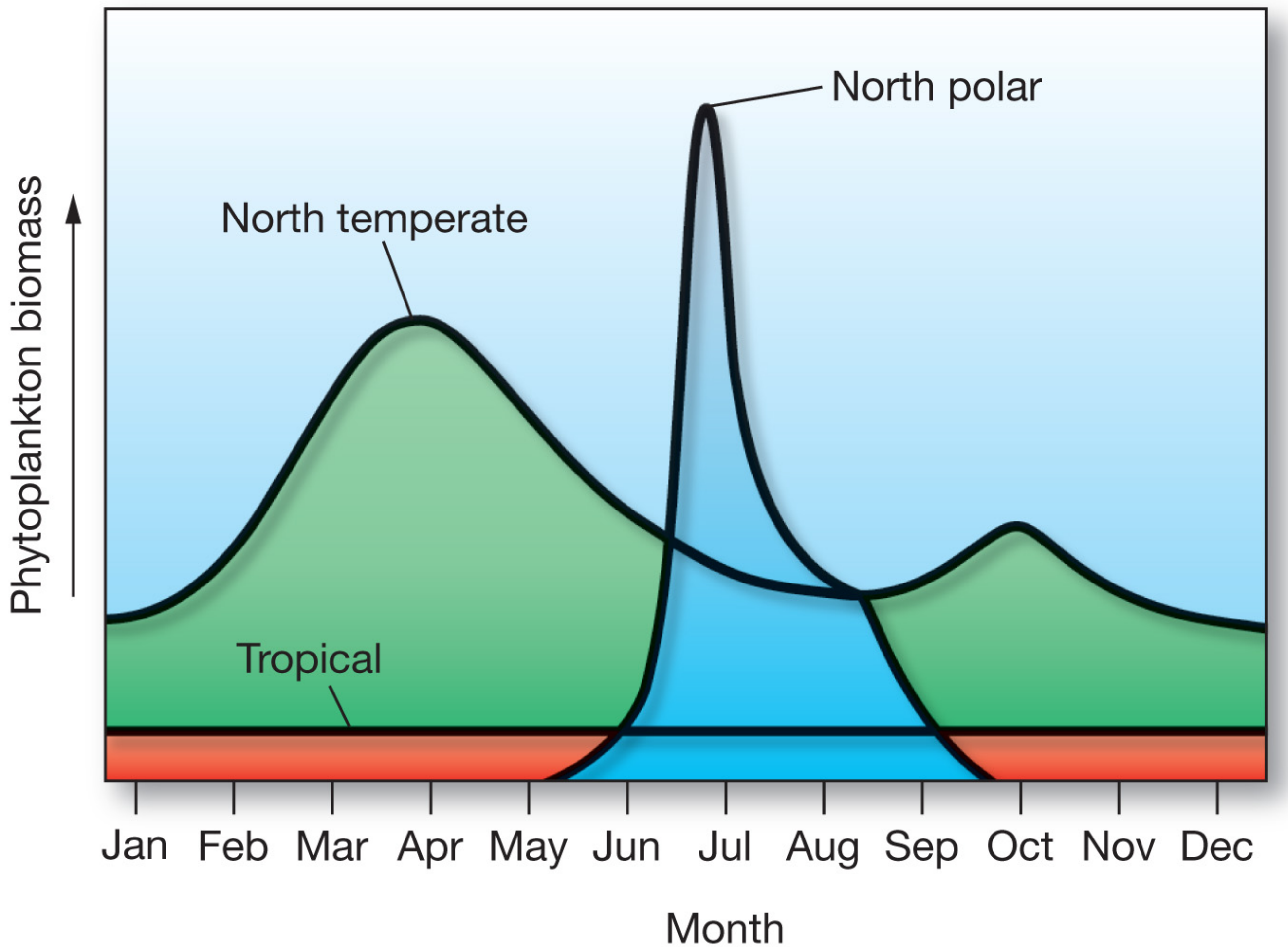
# Temperate Ocean Productivity

- Highly seasonal pattern
- Winter low
  - Many nutrients, little sunlight
- Spring high
  - Spring bloom
- Summer low
  - Few nutrients, abundant sunlight
- Fall high
  - Fall bloom

# Temperate Ocean Seasonal Cycle



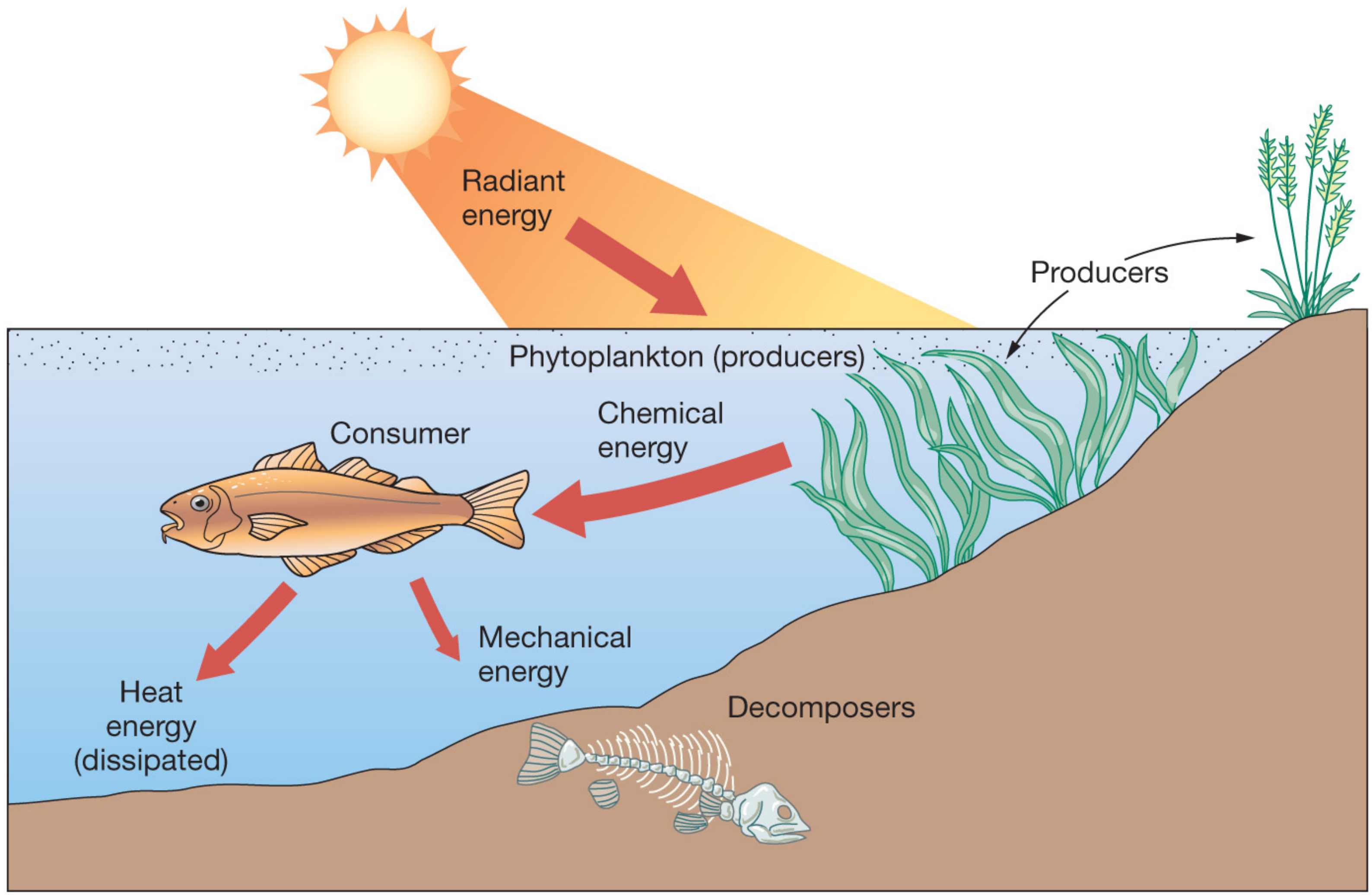
# Comparison of Global Productivities



# How Are Energy and Nutrients Passed Along in Marine Ecosystems?

- Definitions
  - Biotic community – assemblage of organisms in a definable area or habitat
  - Ecosystem – biotic community plus environment
  - The energy flow in marine photosynthetic ecosystems is unidirectional based on a continuous solar energy input

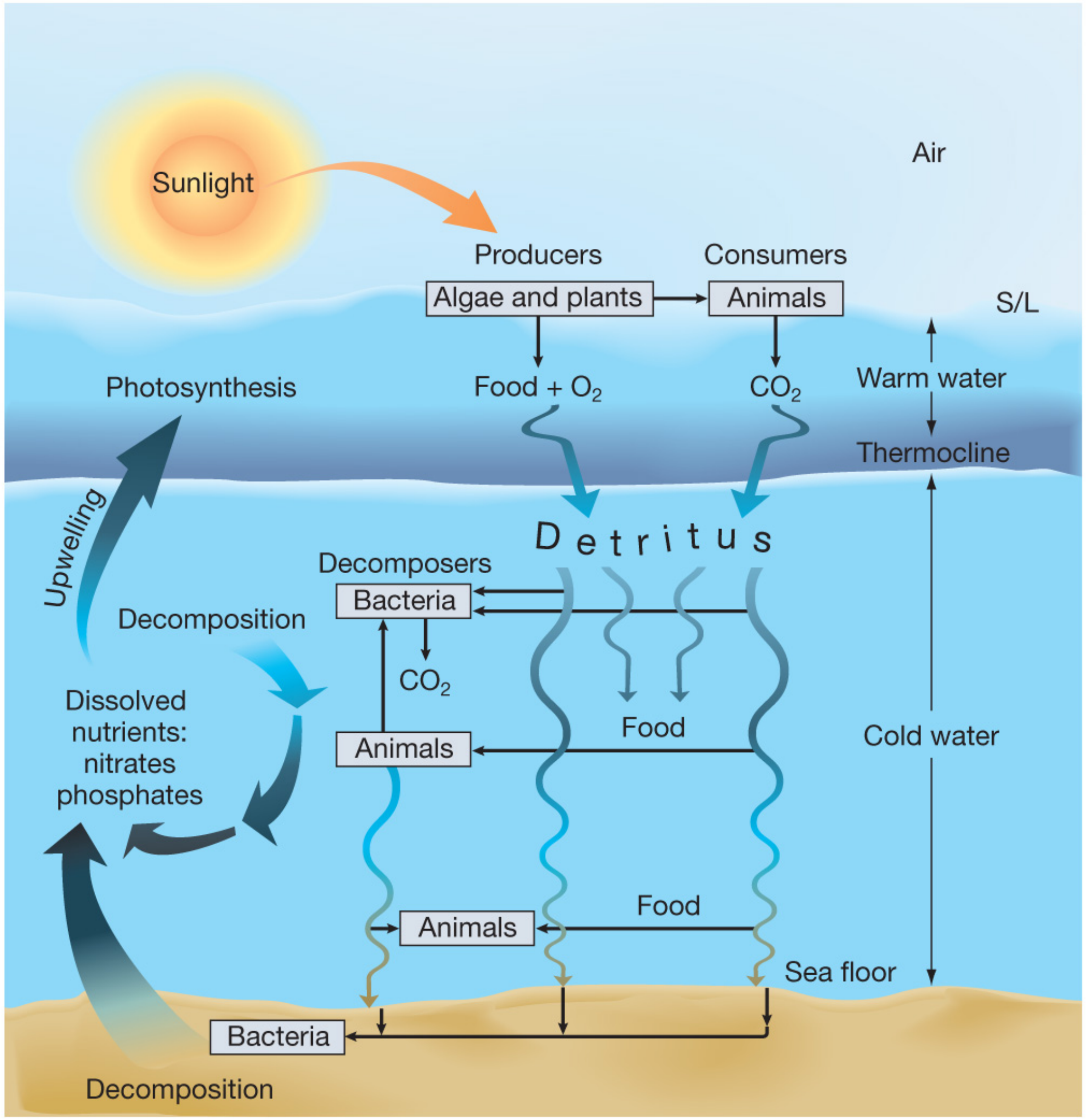
# Energy Flow in Marine Systems



# Energy Flow in Marine Systems

- Three categories of organisms:
  - Producers
    - Nourish themselves with photosynthesis or chemosynthesis
    - Autotrophic
  - Consumers
    - Eat other organisms
      - Herbivores – eat plants
      - Carnivores – eat other animals
      - Omnivores – eat plants and animals
      - Bacteriovores – eat bacteria
    - Heterotrophic
  - Decomposers
    - Break down dead organisms or waste

# Nutrient Flow in Marine Ecosystems: Biogeochemical cycling



# Oceanic Feeding Relationships

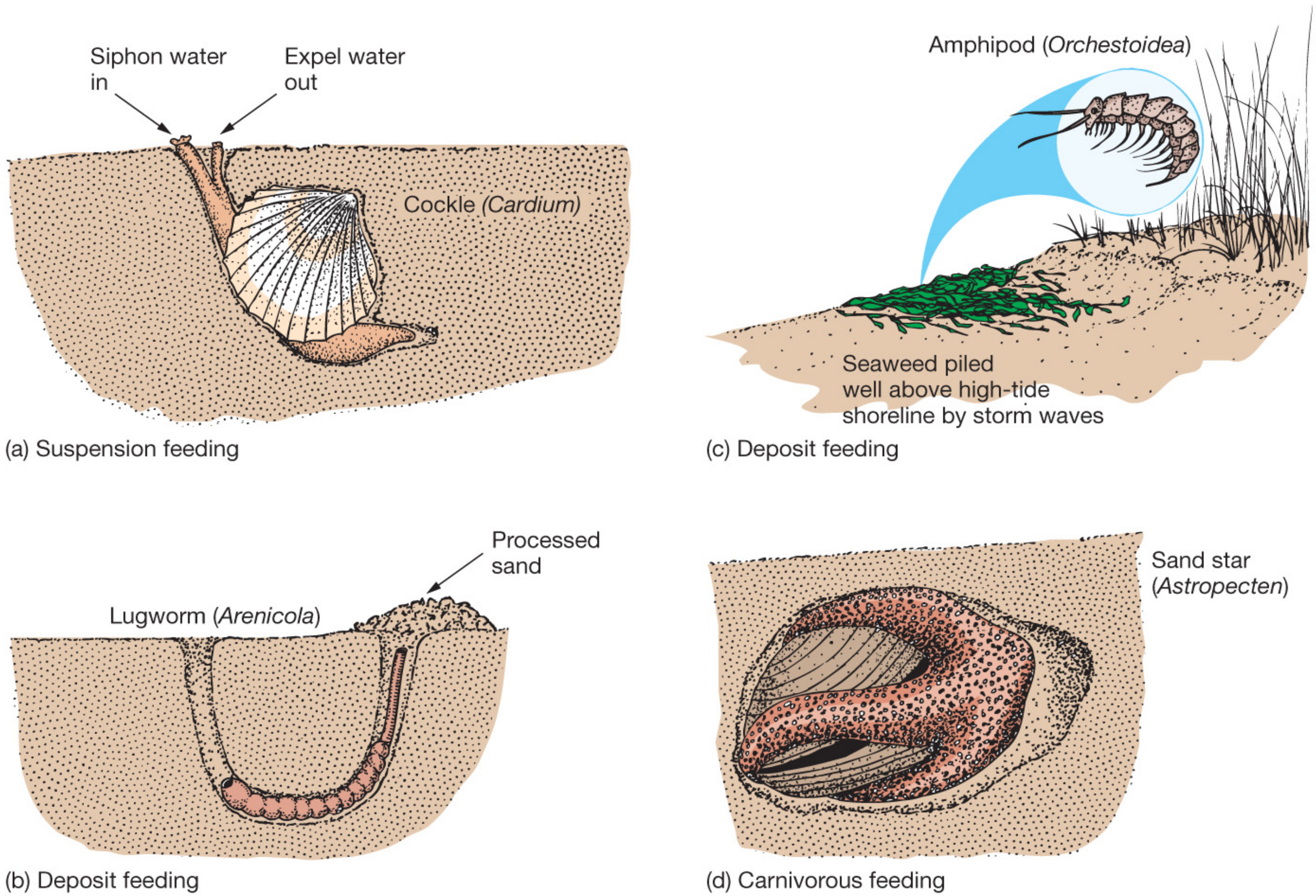
- As producers make food available to consuming animals, said food passes from one feeding population to the next
- On average, only 10% of the energy taken in at any level is passed on to the next
  - Energy is consumed and lost, mostly as heat
- As a consequence, the biomass of producers in the ocean is many times greater than that of the top consumers

# Feeding Strategies

**For most marine animals,**
**getting food takes most of their time**

- Suspension feeding or filter feeding
  - Take in seawater and filter out usable organic matter
- Deposit feeding
  - Take in detritus and sediment and extract usable organic matter
- Carnivorous feeding
  - Capture and eat other animals

# Feeding Strategies



# Trophic Levels

- Trophic levels are the different feeding stages within a community:
  - Diatoms make food, eaten by zooplankton, eaten by carnivores, eaten by big carnivores, and so on

- Chemical energy (from the Sun) is transferred from producers to consumers

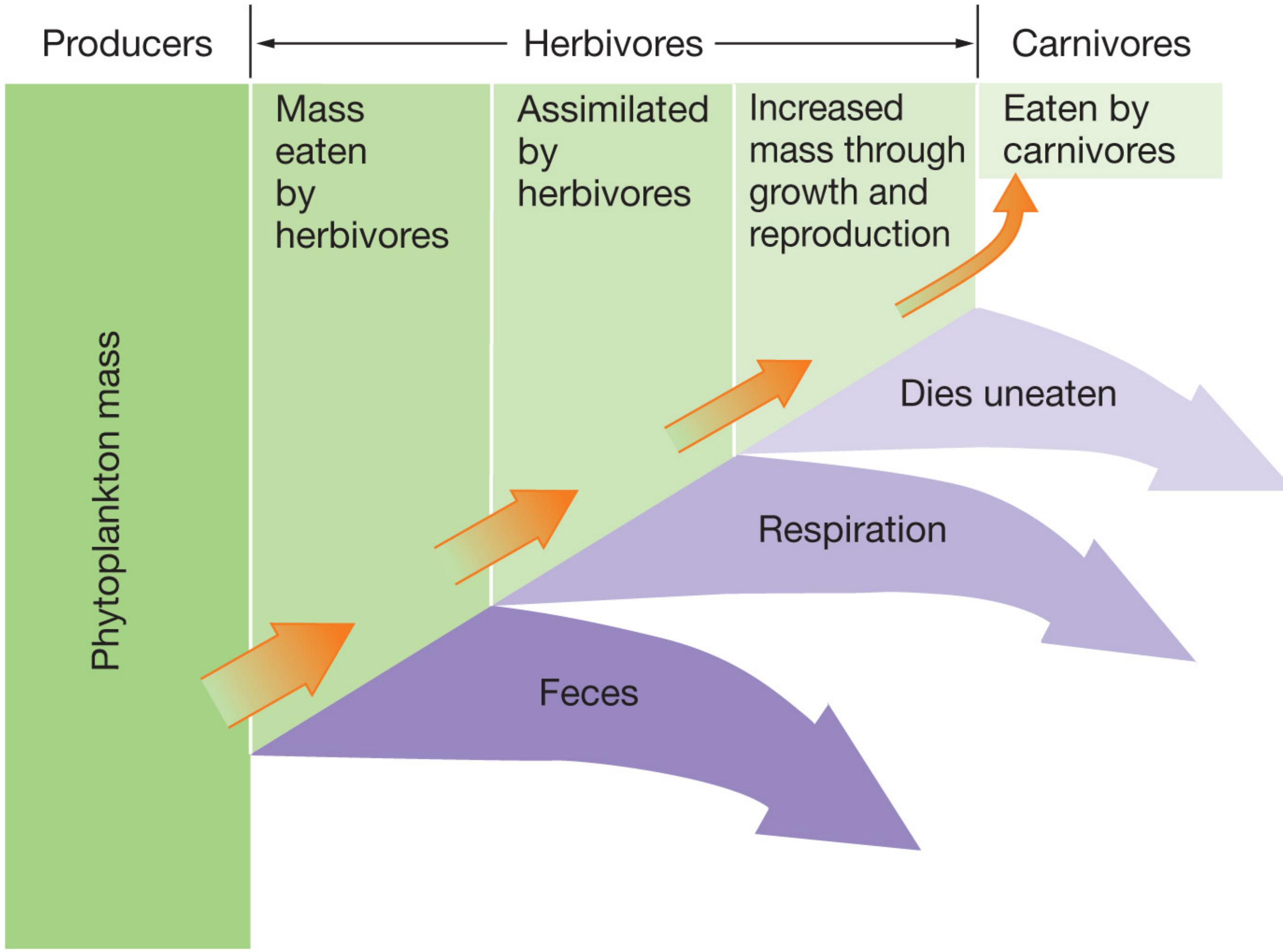
- The transfer of energy between trophic levels is a continuous flow of energy
  - Small-scale recycling, storage, use for internal heat dissipate some energy (entropy increases)

# Transfer of energy

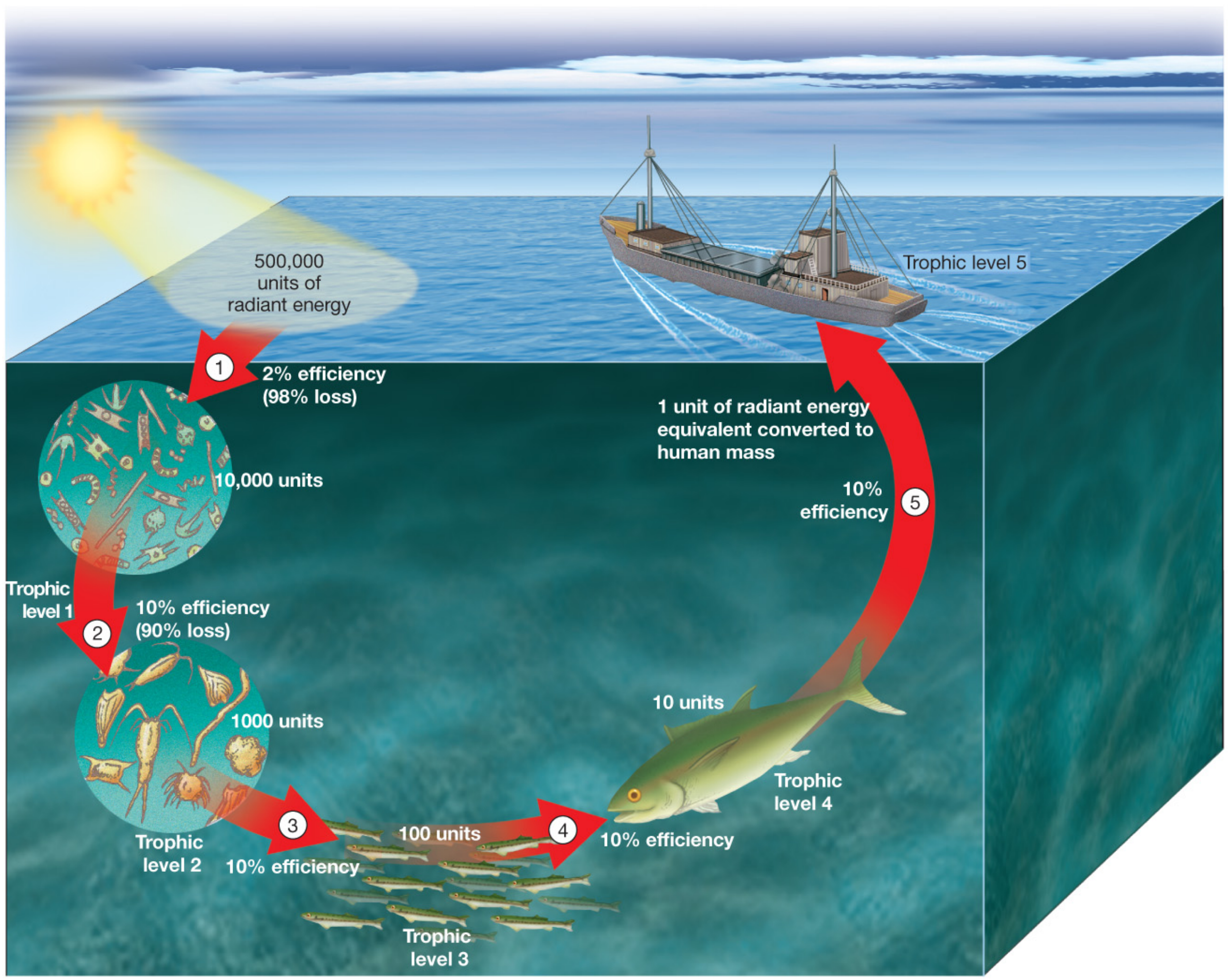
- Transfer of energy is very inefficient
  - about 10% of energy transferred to next trophic level
  - From algae to zooplankton can be down to 2%

- Gross ecological efficiency
  - Ratio, at any trophic level, of energy passed on to the next higher trophic level, divided by the energy received by the trophic level below

# Trophic Levels



# Ecosystem Energy Flow and Efficiency



# Food Chains, Food Webs, and the Biomass Pyramid

- Loss of energy between feeding levels limits the number of feeding populations in ecosystems

- If there were too many levels, not enough energy would be available to support higher and higher trophic levels

- In addition, each feeding population must necessarily have less mass than the population it eats
  - Individuals of a feeding population are, as a result, bigger in size and less numerous than their prey

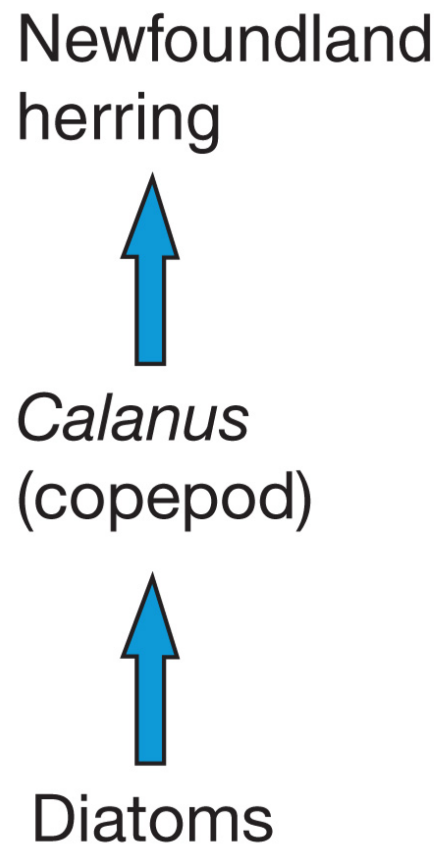
# Food Chains vs. Food Webs

- A food chain is a sequence of organisms through which energy is transferred

- A food web is a more complex system of food chains
  - If animals feed through a food web rather than a food chain, they are more likely to survive

# Food Chains

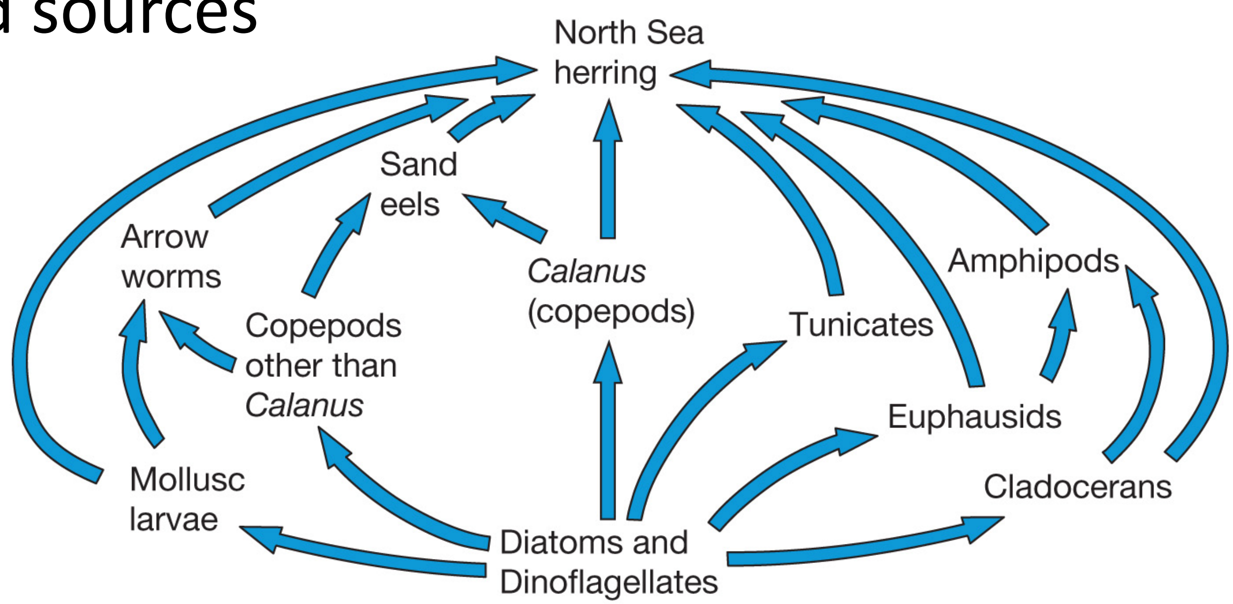
- Primary producer
- Herbivore
- One or more carnivores




(a) Three-level food chain of Newfoundland herring

# Food Webs

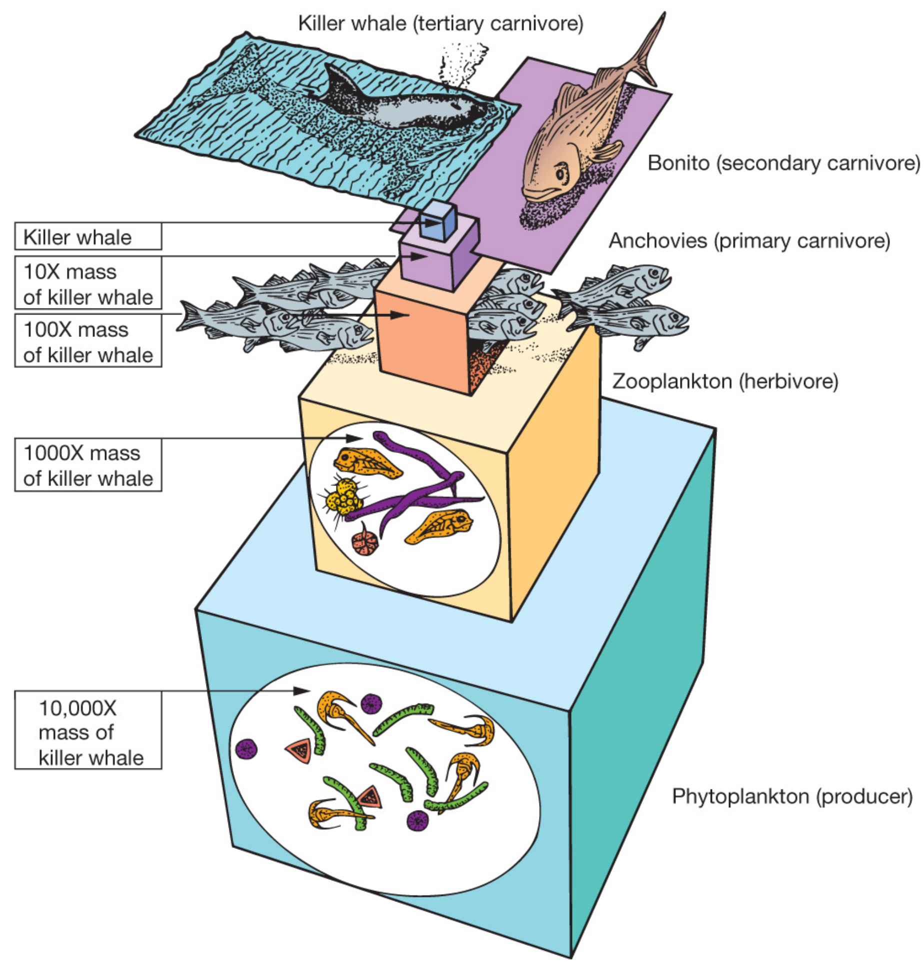
- Branching network of many consumers
- Consumers more likely to survive with alternative food sources




(b) Food web of North Sea herring containing many food chains

# Biomass Pyramid

- The number of individuals and total biomass decreases at successive trophic levels.
- Organisms increase in size.



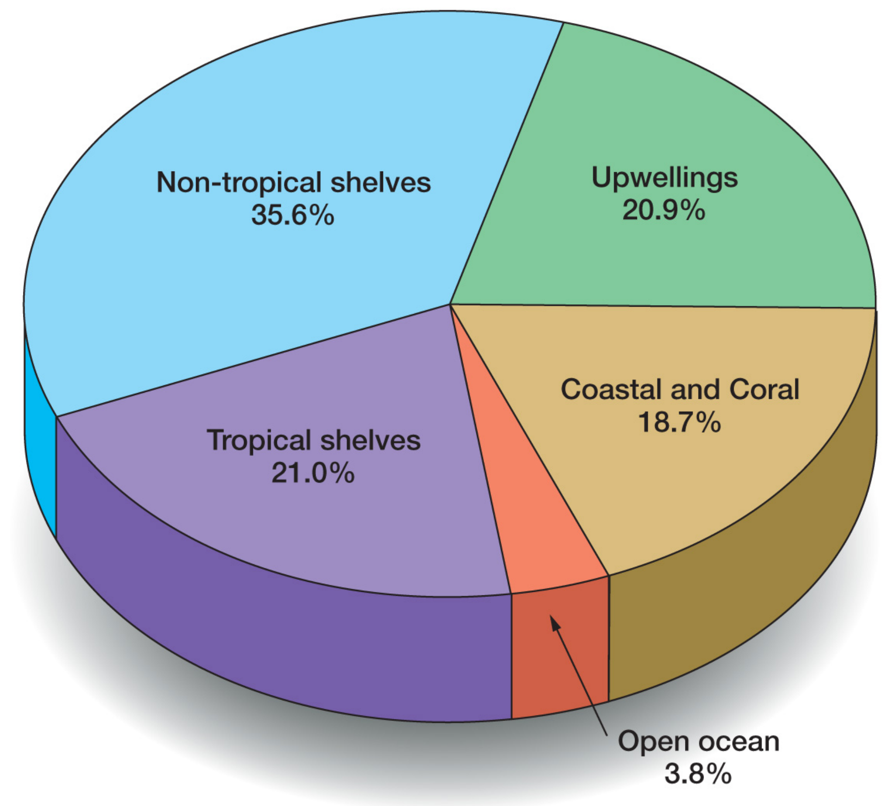
# What Issues Affect Marine Fisheries?

- Humans have used the sea as a source of food for a long time

- Fisheries (fish caught from the ocean by commercial fishers) have provided food fro billions of people
  - Marine resources provided 20% of protein intake for people overall

# Marine Ecosystems and Fisheries

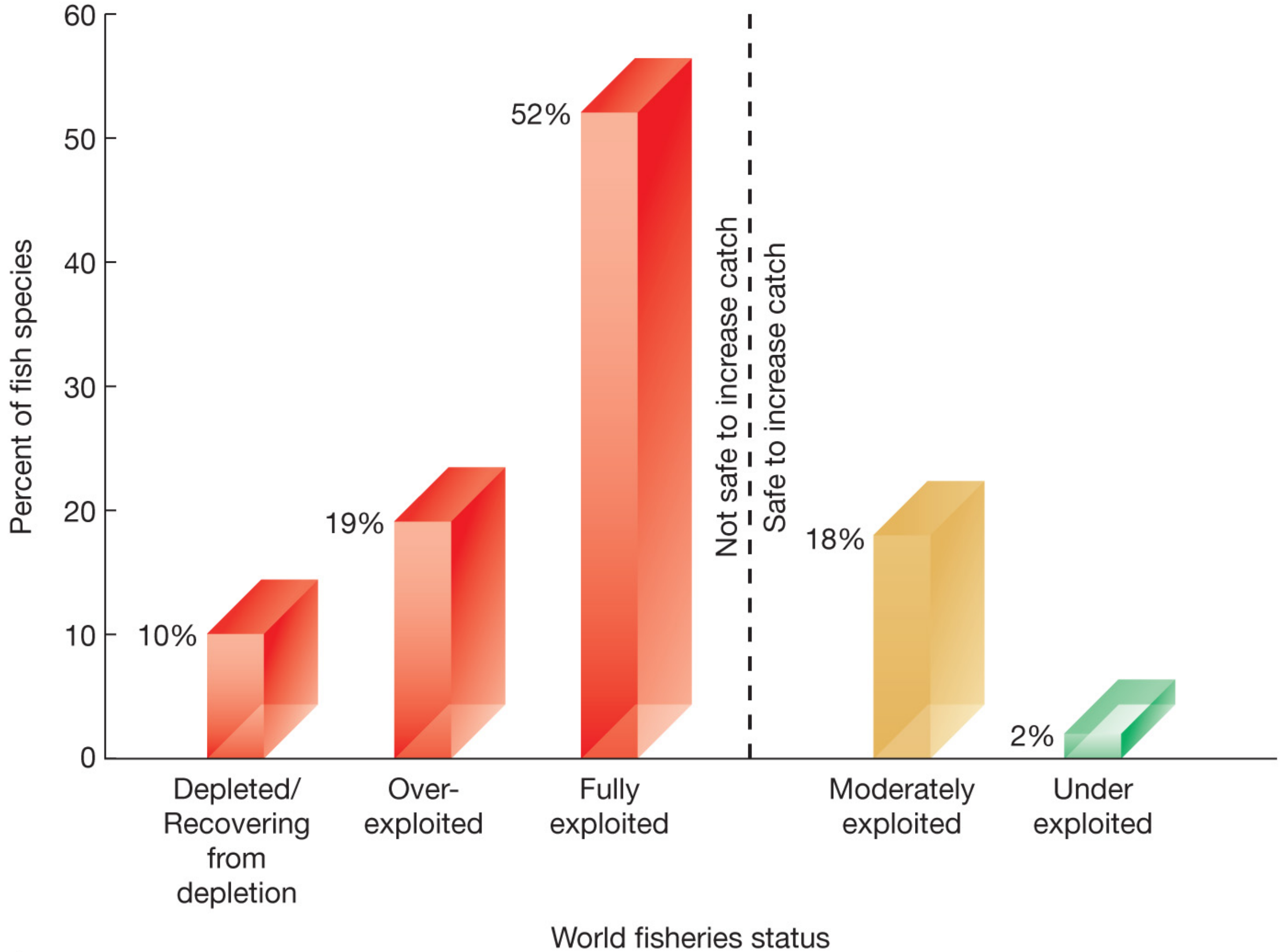
- Most fisheries is drawn from continental shelves
- Over 20% come from areas of upwelling, areas that make up only 0.1% of ocean surface area



# Overfishing

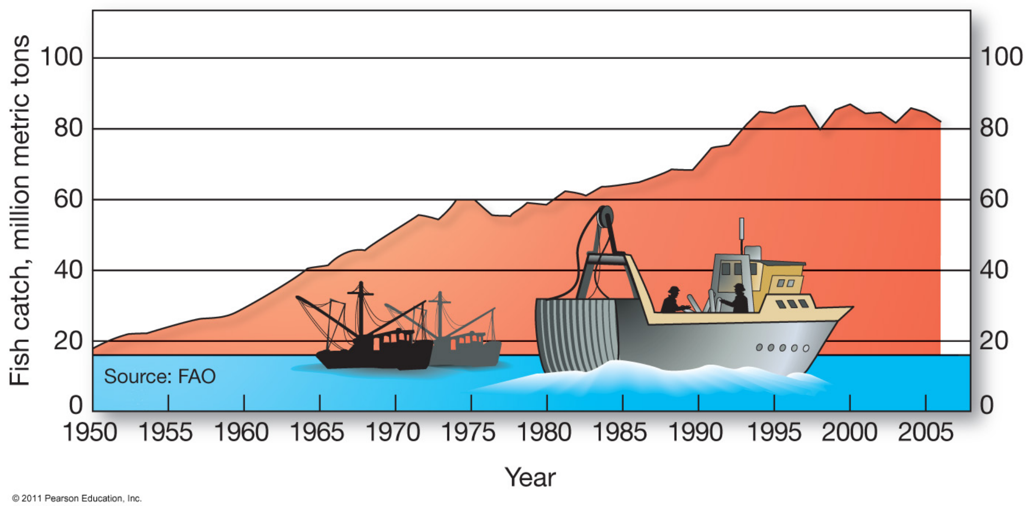
- Fisheries harvest from a population's standing stock
  - the mass present in the ecosystem at any given time
- Overfishing
  - Occurs when the fish stock is harvested too rapidly, and juveniles are not sexually mature to reproduce
- Reduction in Maximum Sustainable Yield (MSY)
  - Maximum amount of fish biomass that can be removed yearly form a stock and still allow a population to be sustained indefinitely

# Exploitation Status of Marine Fish



# Overfishing

- 80% of available fish stock fully exploited, overexploited, or depleted/recovering
- Large predatory fish reduced
- Increased fish production, decreased stocks

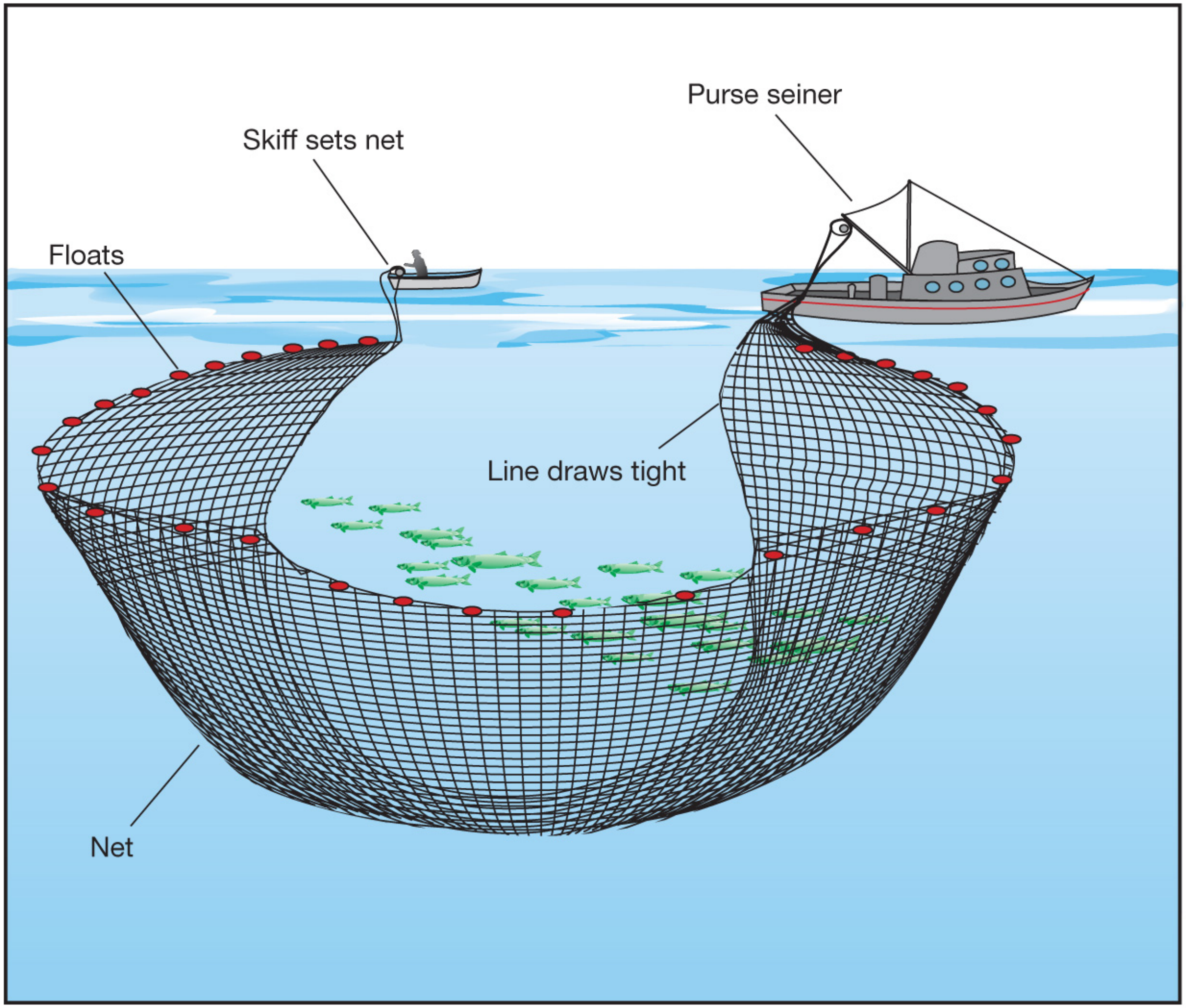


# Incidental Catch or Bycatch

- Non-commercial species are taken incidentally by commercial fishers.

- Bycatch may be up to 8 times more than the intended catch.
  - Birds, turtles, dolphins, sharks
    - Tuna and dolphins swim together
    - Caught in purse seine net
    - Marine Mammals Protection Act addendum for dolphins
    - Driftnets or gill nets banned in 1989

# Purse Seine Net

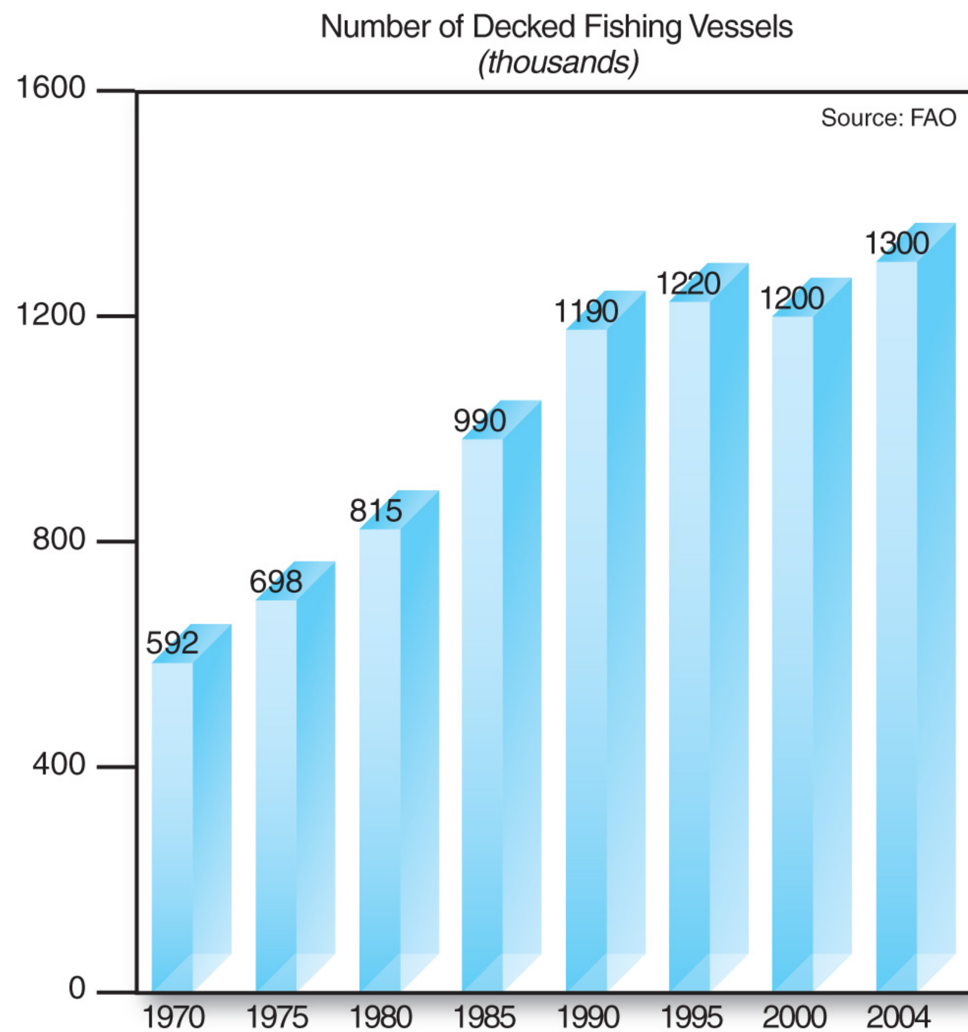


# Fisheries Management

- Regulate fishing
- Conflicting interests
- Human employment
- Self-sustaining marine ecosystems
- International waters
- Enforcement difficult

# Fisheries Management

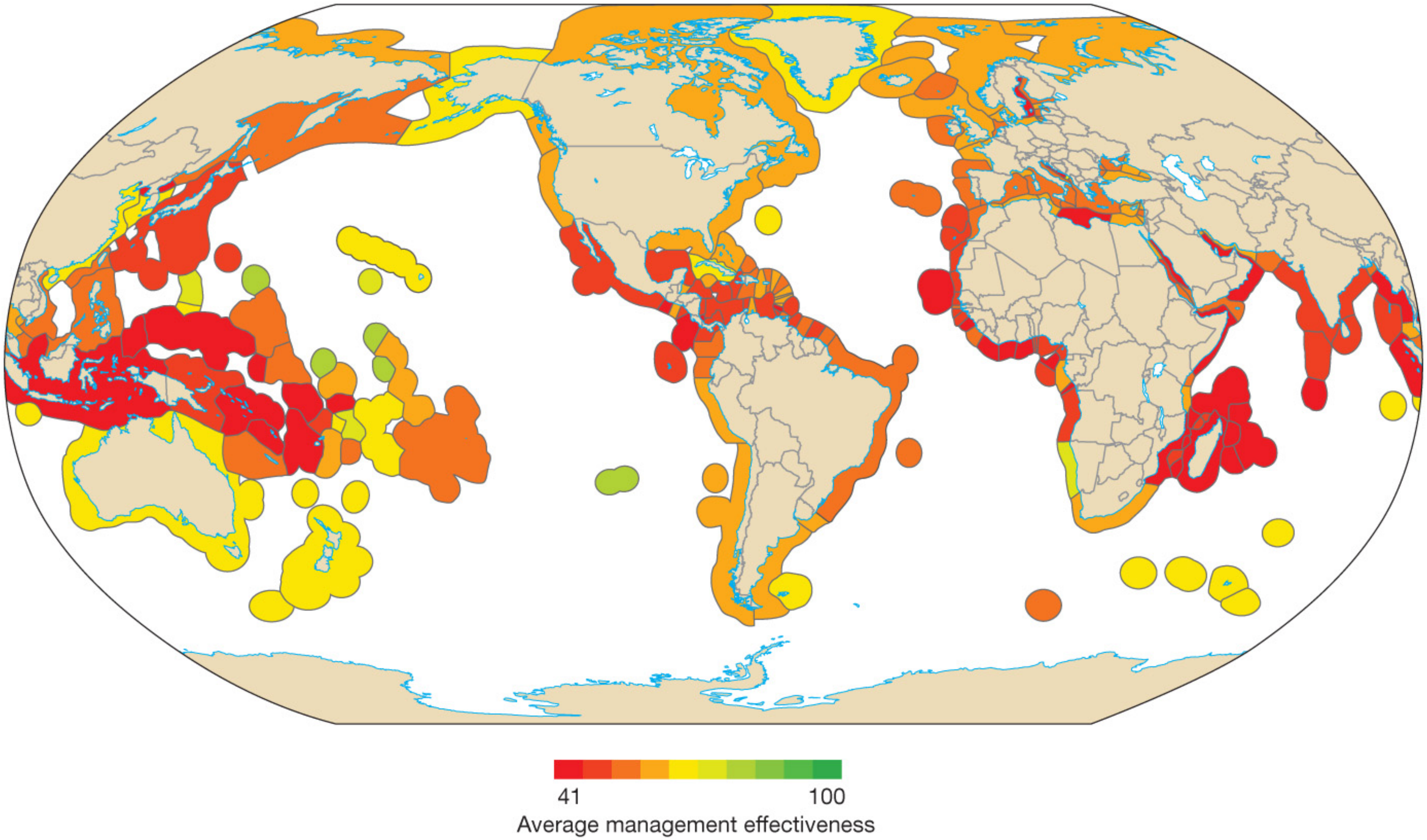
- Many large fishing vessels
- Governments subsidize fishing
- 1995—world fishing fleet spent $124 billion to catch $70 billion worth of fish



# Fisheries Management

- Northwest Atlantic Fisheries such as Grand Banks and Georges Bank
- Canada and United States restrict fishing and enforce bans
- Some fish stocks in North Atlantic rebounding
- Other fish stocks still in decline (e.g., cod)

# Fisheries Management Effectiveness



# Fisheries Management

- Consumer choices in seafood
- Consume and purchase seafood from healthy, thriving fisheries
  - Examples: farmed seafood, Alaska salmon
- Ecosystem-based fishery management
- Avoid overfished or depleted seafood
  - Examples: tuna, shark, shrimp

# Seafood Choices

| Best Choices | Good Alternatives | Avoid |
|---|---|---|
| Arctic Char (farmed) | Clams (wild) | Chilean Seabass/Toothfish* |
| Barramundi (US farmed) | Cod Pacific (trawled) | Cod: Atlantic |
| Catfish (US farmed) | Crab Blue*, King (US), Snow | Crab: King (imported) |
| Clams (farmed) | Crab: Imitation/Surimi | Flounders, Soles (Atlanitc) |
| Cod: Pacific (Alaska longline)* (trap or hook & line-caught) | Flounders, Soles (Pacific) | Groupers* |
| Crab: Dungeness, Snow | Herring: Atlantic/Sardines | Halibut: Atlantic |
| Halibut: Pacific* | Lobster: American/Maine | Lobster: Spiny (Caribbean imported) |
| Lobster: Spiny (US) | Mahi mahi/Dolphinfish (US) | Mahi mahi/Dolphinfish (imported) |
| Mussels (farmed) | Oysters (wild)* | Marlin: Blue* , Striped* |
| Oysters (farmed) | Scallops: Sea | Monkfish |
| Pollock (Alaska wild)* | Shrimp (US farmed or wild) | Orange Roughy* |
| Salmon (Alaska wild)* | Squid | Rockfish (Pacific trawled) |
| Scallops: Bay (farmed) | Swai, Basa (farmer) | Salmon (farmed, including Atlantic)* |
| Striped Bass (farmed or wild*) | Swordfish (US)* | Sharks* |
| Sturgeon, Caviar (farmed) | Tuna: Bigeye, Yellowfin (troll/pole) | Shrimp (imported farmed or wild) |
| Tilapia (US farmed) | Tuna: canned light, canned white/Albacore* | Snapper: Red |
| Trout: Rainbow (farmed) | Yellowtail (US farmed) | Sturgeon*, Caviar (imported wild) |
| Tuna: Albacore US*, British Columbia troll/pole) | | Swordfish (imported)* |
| Tuna: Skipjack (troll/pole) | | Tuna: Albacore, Bigeye, Yellowfin (longline)* |
| | | Tuna: Bluefin* |
| | | Yellowtail (Australia or Japan, farmed) |

**Support Ocean-friendly Seafood**

**Best Choices** are abundant, well-managed and caught or farmed in environmental friendly ways.

**Good Alternatives** are an option, but there are concerns with how they're caught or farmed-or with the health of their habitat due to other human impacts.

**Avoid** for now as these items are caught or farmed in ways that harm other marine life or the environment.

**Key**

*Limit consumption due to concerns about mercury or other contaminants, Visit www.edf.org/seafood

*Some or all of this fishery is certified as sustainable to the Marine Stewardship Council standard. Visit www. msc.org

Seafood may appear in more than one column

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part 3: Regional Productivity Energy and Nutrients in Marine Ecosystems, Fisheries

# The end