Chapter Overview

- Productivity is the same as photosynthesis, which is affected by sunlight and nutrients.
- Productivity is globally and seasonally variable.
- Feeding relationships are represented by food chains and food webs.
- Oceans are being overfished.

Primary Productivity

- Primary productivity is the rate at which energy is stored in organic matter.
- Photosynthesis uses solar radiation.
- Chemosynthesis uses chemical reactions.
- 99.9% of the ocean’s biomass relies directly or indirectly on photosynthesis for food.

Photosynthesis

\[
\text{Photosynthesis:} \quad \text{Water} + \text{Carbon dioxide} \rightarrow \text{Sugar} + \text{Oxygen}
\]

\[
\text{Respiration:} \quad \text{Water} + \text{Carbon dioxide} \rightarrow \text{Sugar} + \text{Oxygen}
\]

Measurement of Primary Productivity

- Directly – capture plankton in plankton nets
- Measure radioactive carbon in seawater
- Monitor ocean color with satellites
  - Green pigment chlorophyll
  - SeaWiFS
Factors Affecting Primary Productivity

- Nutrient availability
  - Nitrate, phosphorous, iron, silica
  - Most from river runoff
  - Productivity high along continental margins
  - Redfield ratio – C:N:P

- Solar radiation
  - Uppermost surface seawater and shallow seafloor
  - Compensation depth – net photosynthesis becomes zero
  - Euphotic zone—from surface to about 100 meters (330 feet)

Light Transmission in Ocean Water

- Visible light of the electromagnetic spectrum
- Blue wavelengths penetrate deepest
- Longer wavelengths (red, orange) absorbed first
Color in the Ocean

- Color of ocean ranges from deep blue to yellow-green
- Factors
  - Turbidity from runoff
  - Photosynthetic pigment (chlorophyll)
    - Eutrophic
    - Oligotrophic
- Secchi Disk – measures water transparency

Upwelling and Nutrient Supply

- Cooler, deeper seawater is nutrient-rich.
- Areas of coastal upwelling are sites of high productivity.

Types of Photosynthetic Marine Organisms

- Anthophyta
  - Seed-bearing plants
- Macroscopic (large) algae
- Microscopic (small) algae
- Photosynthetic bacteria
Anthophyta

- Only in shallow coastal waters
- Primarily grasses and mangroves

Macroscopic Algae

- "Seaweeds"
  - Brown algae
  - Green algae
  - Red algae
    - Most abundant and most widespread
    - Varied colors

Brown algae (Sargassum)

Brown algae (Macrocystis)

Green algae (Codium fragile)
Microscopic Algae

- Produce food for 99% of marine animals
- Most planktonic
- Golden algae
  - Diatoms – tests made of silica
  - Coccolithophores – plates of calcium carbonate
- Dinoflagellates
  - Red tide (harmful algal bloom)
  - Toxins
  - Fish kills
  - Human illness

Red algae (*Lithothamnium*)

Diatom (*Diploneis*)

Coccolithophore (*Emiliana huxleyi*)

Dinoflagellate (*P. divergens*)
Dinoflagellate (H. whittingae)

Photosynthetic Bacteria
- Extremely small
- May be responsible for half of total photosynthetic biomass in oceans
- Exert critical influence on marine ecosystems

Regional Primary Productivity Variations
- Values range from 1 gC/m²/year to 4000 gC/m²/year based on:
  - Uneven distribution of nutrients
  - Changes in availability of sunlight
- 90% of biomass from euphotic zone decomposes before descending

Regional Primary Productivity Variations
- Only 1% of organic matter is not decomposed in the deep ocean.
- Biological pump – moves material from euphotic zone to sea floor
- Subtropical gyre thermoclines and pycnoclines prevent the resupply of nutrients to the surface.

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

Polar Ocean Productivity
- Antarctic productivity slightly greater than Arctic
- North Atlantic Deep Water upwells near Antarctica
- Productivity decrease from UV radiation – ozone hole
Polar Ocean Productivity
- Isothermal waters – little mixing
- Plankton remain at surface
- Blue whales migrate to feed on maximum zooplankton productivity.

Productivity in Tropical Oceans
- Permanent thermocline is barrier to vertical mixing
- Low rate of primary productivity – lack of nutrients

Productivity in Tropical Oceans
- High primary productivity in areas of
  - Equatorial upwelling
  - Coastal upwelling
  - Coral reefs
    - Symbiotic algae
    - Recycle nutrients within the ecosystem

Temperate Ocean Productivity
- Productivity limited by
  - Available sunlight
  - Available nutrients

Temperate Ocean Seasonal Cycle
- Highly seasonal pattern
- Winter low
  - Many nutrients, little sunlight
- Spring high
  - Spring bloom
- Summer low
  - Few nutrients, abundant sunlight
- Fall high
  - Fall bloom
Comparison of Global Productivities

Energy Flow in Marine Systems

- Biotic community – assemblage of organisms in definable area
- Ecosystem – biotic community plus environment
- Energy flow is unidirectional based on solar energy input.

Energy Flow in Marine Systems

- Three categories of organisms:
  - Producers
    - Nourish themselves with photosynthesis or chemosynthesis
    - Autotrophic
  - Consumers
    - Eat other organisms
    - Heterotrophic
  - Decomposers – break down dead organisms or waste

Consumers in Marine Ecosystems

- Herbivores – eat plants
- Carnivores – eat other animals
- Omnivores – eat plants and animals
- Bacterivores – eat bacteria

Nutrient Flow in Marine Ecosystems

- Biogeochemical cycling
Feeding Strategies

- 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

Trophic Levels

- Feeding stage
- Chemical energy transferred from producers to consumers
- About 10% of energy transferred to next trophic level
- Gross ecological efficiency

Ecosystem Energy Flow and Efficiency

Food Chains

- Primary producer
- Herbivore
- One or more carnivores
Food Webs
- Branching network of many consumers
- Consumers more likely to survive with alternative food sources

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

Marine Fisheries
- Commercial fishing
- Most from continental shelves
- Over 20% from areas of upwelling that make up 0.1% of ocean surface area

Overfishing
- Fish from standing stock – the mass present in the ecosystem at any given time
- Overfishing – fish stock harvested too rapidly, juveniles not sexually mature to reproduce
- Reduction in Maximum Sustainable Yield (MSY)

Exploitation Status of Marine Fish
- 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

- 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
- 1985—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

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