CHAPTER 13
Biological Productivity and Energy Transfer

Chapter summary in haiku form
Primary produce
Sunlight and phytoplankton
Ocean is garden

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
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

Factors Affecting Primary Productivity
• 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

Transmission of Light in Seawater

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

15 Upwelling and Nutrient Supply
• Cooler, deeper seawater is nutrient-rich.
• Areas of coastal upwelling are sites of high productivity.

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17 Upwelling and Nutrient Supply

18 Types of Photosynthetic Marine Organisms
• Anthophyta
  – Seed-bearing plants
• Macroscopic (large) algae
• Microscopic (small) algae
• Photosynthetic bacteria

19 Anthophyta
• Only in shallow coastal waters
• Primarily grasses and mangroves

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• Only in shallow coastal waters
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21 Macroscopic Algae
• “Seaweeds”
• Brown algae
• Green algae
• Red algae
  – Most abundant and most widespread
  – Varied colors

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26 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

27 Microscopic Algae

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**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 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

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

Energy Flow in Marine Systems

Consumers in Marine Ecosystems
• Herbivores – eat plants
• Carnivores – eat other animals
• Omnivores – eat plants and animals
• Bacteriovores – 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

Feeding Strategies

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

Trophic Levels

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
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
• 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

End of CHAPTER 13

Biological Productivity and Energy Transfer