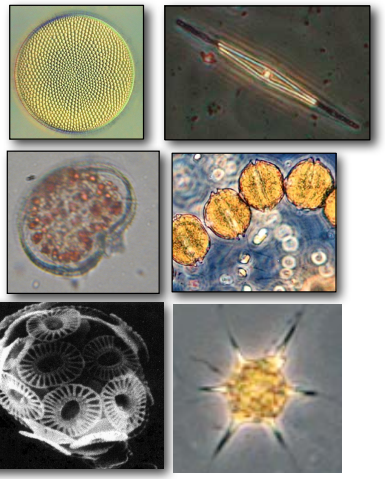
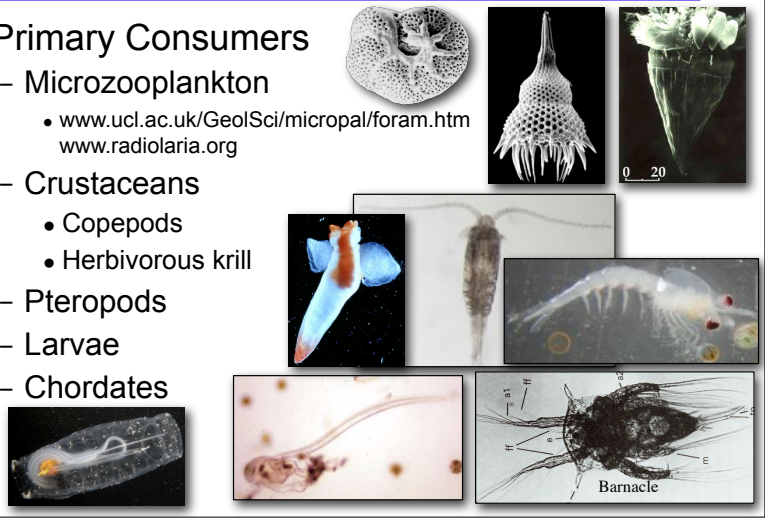
Pelagic Food Web: Review

- Primary Producers
  - Diatoms
  - Dinoflagellates
  - Microflagellates



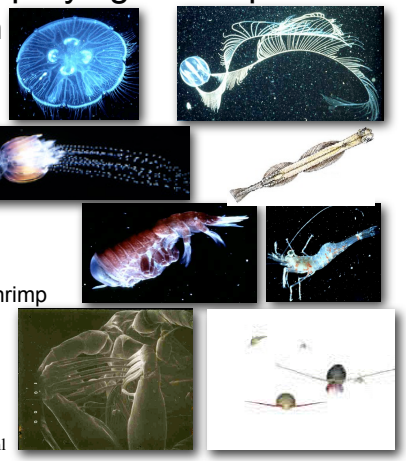
Pelagic Food Web: Herbivores

- Primary Consumers
  - Microzooplankton
    - www.ucl.ac.uk/GeolSci/micropal/foram.htm
      www.radiolaria.org
  - Crustaceans
    - Copepods
    - Herbivorous krill
  - Pteropods
  - Larvae
  - Chordates



Pelagic Food Web: Carnivores

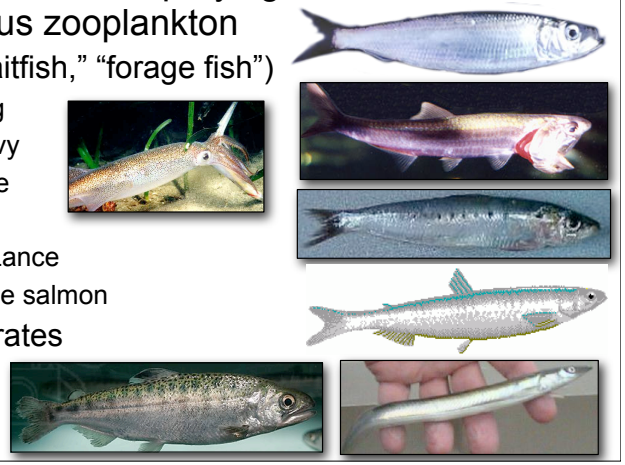
- Secondary consumers preying on zooplankton
  - Gelatinous zooplankton
    - Medusae
    - Ctenophores
    - Siphonophores
    - Chaetognaths
  - Crustaceans
    - Carnivorous krill
      - Amphipods & juveniles shrimp
    - Predatory copepods
  - Fish larvae & juveniles



http://jaffeweb.ucsd.edu/pages/celeste/copepods.html

Pelagic Food Web: Carnivores

- Tertiary consumers preying on herbivorous & carnivorous zooplankton
  - Fish (“baitfish,” “forage fish”)
    - Herring
    - Anchovy
    - Sardine
    - Smelt
    - Sand Lance
    - Juvenile salmon
  - Invertebrates
    - Squid



Pelagic Food Web: Carnivores

- Tertiary consumers preying on herbivorous & carnivorous zooplankton
  - Planktivorous Fish
    - Pink salmon
    - Sockeye salmon
    - Pollock
    - Hake
    - Cod
    - Dogfish
    - Lanternfish

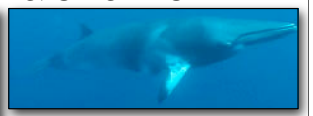




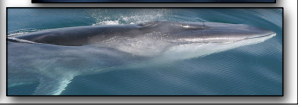


Pelagic Food Web: Carnivores

- Predators on krill zooplankton & small fish
- Mammals
  - Baleen whales
  - Filter feeders
    - Blue
    - Minke
    - Humpback
    - Right
    - Fin
    - Sei



Pelagic Food Web: Carnivores

- Predators on krill zooplankton & small fish
- Diving birds
  - Puffins
  - Murres
  - Auklets
  - Guillemots
  - Grebes
  - Pelicans
  - Albatrosses






Pelagic Food Web: Carnivores

- Predators on small fish
  - Coho salmon
    - Chum salmon
    - Chinook salmon
    - Mackerel
- Top predators
  - Tuna
  - Sharks
  - Billfish







Pelagic Food Web: Carnivores

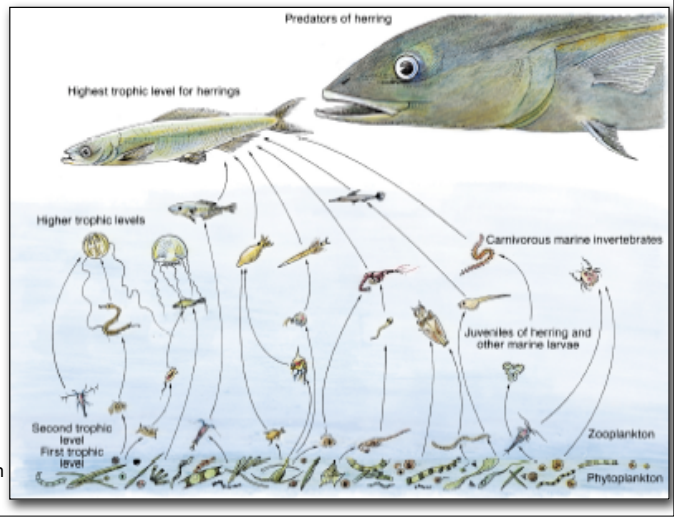
- Top predators: Mammals
  - Seals
  - Sea lions
  - Toothed whales
    - Orca
    - Porpoise (dolphin)
    - Sperm





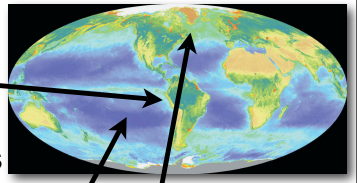
Generic Food Web

- 5. Large fish, birds, mammals
- 4. Small fish (herring, smelt)
- 3. Carnivorous zooplankton (medusae, amphipods, some copepods, fish larvae)
- 2. Herbivorous zooplankton (copepods, larvae)
- 1. Phytoplankton



Food Webs in Different Zones

- Differences dictated by two properties:
  - Amount of primary productivity
  - Type of phytoplankton
- Upwelling zones
  - High productivity
  - Large, fast-growing diatoms
- Neritic zones & temperate oceanic zone
  - Moderate productivity
  - Large diatoms mixed with dinoflagellates
- Low-latitude oceanic zone
  - Low productivity of small microflagellates

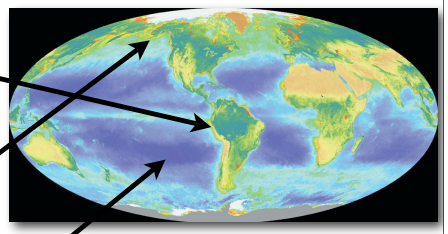


Productivity in Ocean Zones

Table 14.1 World Ocean Primary Productivity

Area	Primary Productivity ($gC/m^2/yr$)	World Ocean Area (km^2)	World Ocean Area (%)	Total Primary Productivity (metric tons carbon/yr)
Upwellings	640	0.36×10^6	0.1	0.23×10^9
Coasts	160	54×10^6	15.0	8.6×10^9
Open oceans	130	307×10^6	85.0	39.9×10^9
All ocean areas	135	361×10^6	100.0	48.73×10^9

- Upwelling zones have highest productivity
  - Nutrient supply
- Coasts (& temperate oceans) next
- Low-latitude open ocean lowest



NOTE: Biomass used here as an indicator of productivity

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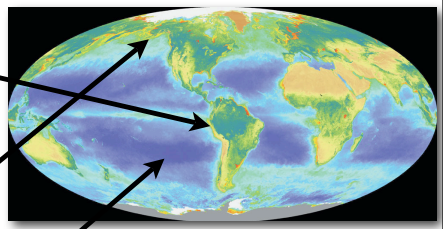
- Upwelling zones still provide <1% of total ocean production
  - Small area
- Coasts (& temperate oceans) next, open ocean highest because of area



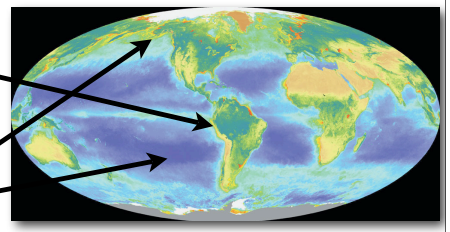
NOTE: Biomass used here as an indicator of productivity

Productivity in Ocean Zones

Table 14.4 Oceanic Food Production

Area	Plant Production (metric tons of carbon/yr)	Efficiency of Mass and Energy Transfer per Trophic Level	Trophic Level Harvested	Estimated Fish Production (metric tons/yr)
Open ocean	39.9×10^9	10%	5	4.0×10^6
Coastal regions	8.6×10^9	15%	4	29.0×10^6
Upwelling areas	0.23×10^9	20%	2	46.0×10^6

- But upwelling zones provide 58% of total fish production
- Coasts (& temperate oceans) 37%, open ocean 5%
  - Why?



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Productivity in Ocean Zones

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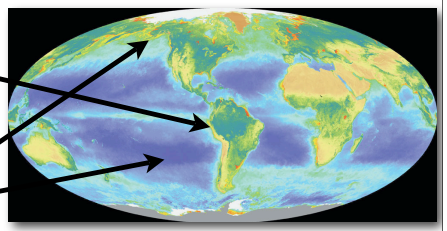
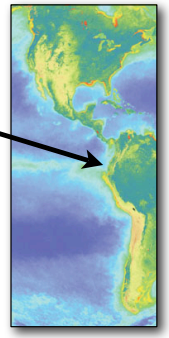
- Upwelling zones have:
  - Shorter food chains
  - Greater trophic efficiency
- The main difference is in the food chains

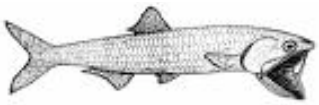


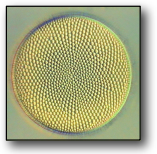
NOTE: Biomass used here as an indicator of productivity

Food Webs in Upwelling Zones

- Peru a special case
  - Primary producers large, fast-growing diatoms
  - Primary consumer Peruvian anchovy
    - An unusual herbivorous fish
  - Result: fishery harvest @ trophic level 2
  - Dense, compact area of production
    - Efficiency = 20%
    - Less energy expended to search for food
    - Harvestable fish production = 20% of primary production

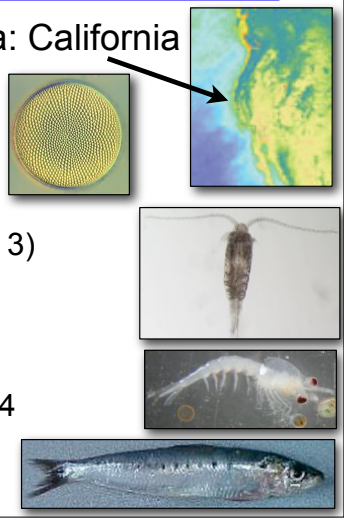






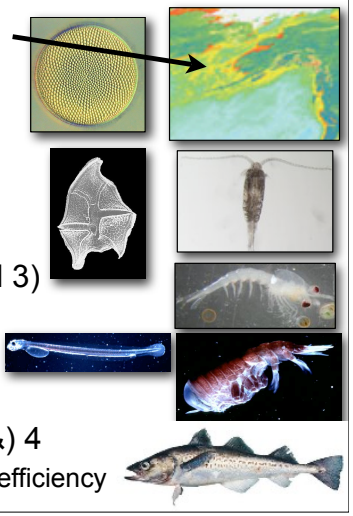
Food Webs in Upwelling Zones

- More typical upwelling area: California
  - Primary producers
    - Large, fast-growing diatoms
  - Primary consumers (level 2)
    - Copepods & krill
  - Secondary consumers (level 3)
    - Anchovies & sardines
  - Tertiary consumers (level 4)
    - Mackerel, salmon
  - Fish harvest from levels 3 & 4
    - Estimated global production 46 * 10^4 - 10^5, not 10^6



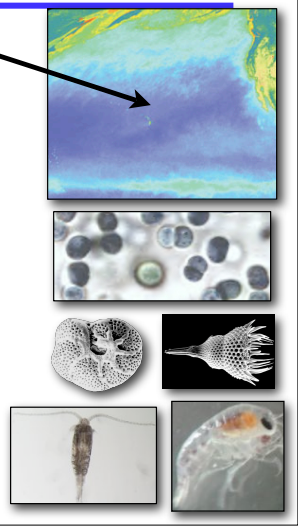
Food Webs in Neritic Zones

- Example area: Bering Sea
  - Primary producers
    - Nutrients not as abundant
    - Diatoms & dinoflagellates
  - Primary consumers (level 2)
    - Copepods & krill
  - Secondary consumers (level 3)
    - Carnivorous ZP & juvenile fish
  - Tertiary consumers (level 4)
    - Pollock, salmon
  - Fish harvest from levels (3 &) 4
    - Food less concentrated, 15% efficiency



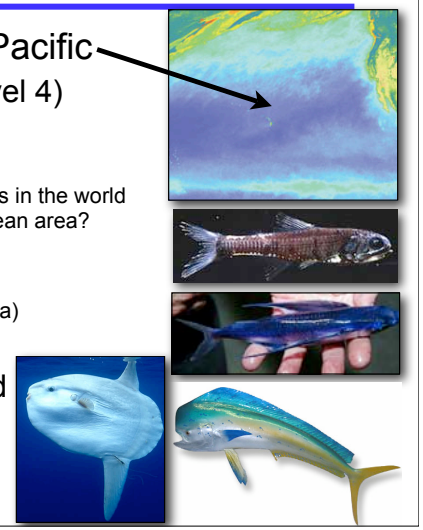
Food Webs in Oceanic Zones

- Example area: North Pacific
  - Primary producers
    - Nutrients scarce: microflagellates
    - Nitrogen fixing cyanobacteria
    - Productivity sustained by nutrient regeneration near surface
  - Primary consumers (level 2)
    - Microzooplankton
  - Secondary consumers (level 3)
    - Carnivorous copepods & krill
    - Same size as herbivorous species that live in more productive waters



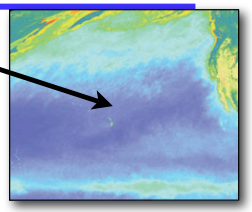
Food Webs in Oceanic Zones

- Example area: North Pacific
  - Tertiary consumers (level 4)
    - Small oceanic fish
      - Lanternfish (myctophid)
        - » Most abundant fishes in the world because of open ocean area?
      - Flying fish
      - Dorado (mahi mahi)
      - Ocean sunfish (mola mola)
  - Mostly not significant commercially harvested species
    - Too expensive to catch for market value



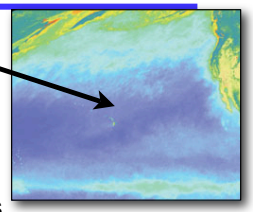
Food Webs in Oceanic Zones

- Example area: North Pacific
  - Top predators (level 5)
    - Large oceanic fish
      - Tuna
      - Swordfish, marlin
      - Sharks
  - Significant commercially harvested species
    - Valuable enough to justify expense of fishing far from shore
    - They save fishermen the work of scouring the sea to catch smaller fish
    - Highly mobile, energetic migrators



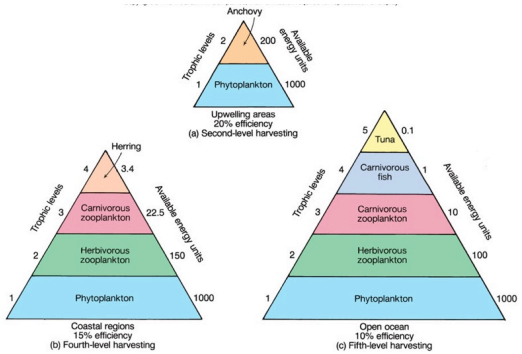
Food Webs in Oceanic Zones

- Example area: North Pacific
  - Five-level food chain
  - Lower trophic efficiency (10%)
    - Energy expended to find widely dispersed food by energetic migrators
  - Result:
    - Classic food-chain model of 10% loss at each trophic level
    - Harvestable fish production is 10^{-5} times primary production
  - Combination of:
    - Low primary productivity, small phytoplankton, widely dispersed food



Food Chain Productivity

- Trophic pyramid is a simple (simplistic) model
  - Illustrates underlying principles of:
    - Number of trophic levels
    - Differences in trophic efficiency
  - This diagram does not include diff-erences in primary productivity



Food Chain Productivity

- Upwelling
  - 1000 * (0.2) = 200
  - 1000 * $(0.2)^2$ = 40
- Neritic
  - 1000 * $(0.15)^3$ = 3.4
- Oceanic
  - 1000 * $(0.1)^4$ = 0.1