Marine productivity, plankton, and food webs

- Primary productivity
  - Patterns, requirements
  - Who does it?
    - Phytoplankton, macroalgae, mangroves, sea grasses
- Macroalgal communities
- Food webs, trophic levels, and energy
  - Zooplankton
  - Energy flow through trophic levels

First, classification:

- "Linnaean" classification
- Categories, from broadest to narrowest:
  - Kingdom
  - Phylum
  - Class
  - Order
  - Family
  - Genus
  - Species
- We identify organisms by *Genus* and *species*

First, classification:

- The five major kingdoms are:
  - Monera
    - bacteria, including cyanobacteria (blue-green algae)
  - Protista
    - single-celled organisms with a nucleus
  - Fungi
    - abundant in the intertidal zone and are important in decomposition
  - Chromista
    - Plants, free-floating or attached to the sea floor
  - Metazoa
    - all multicellular animals in the ocean

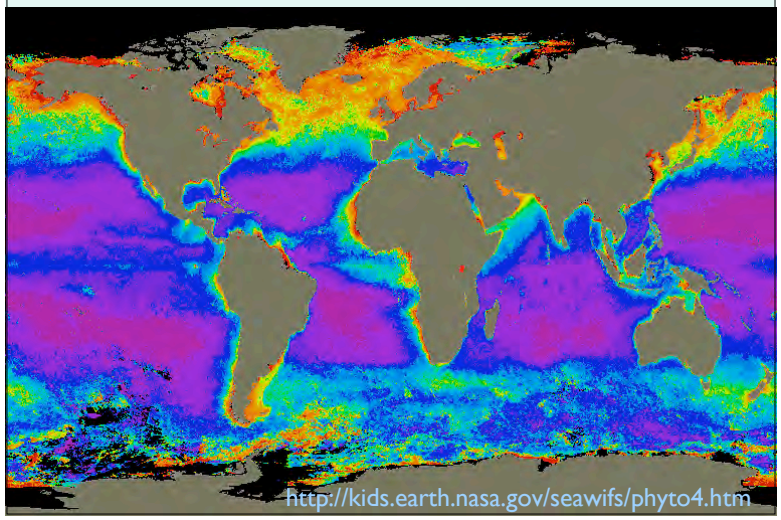
Primary productivity

- Synthesis of organic matter from inorganic
- Done mainly by photosynthesis, a small amount by chemosynthesis
- Requires light, nutrients and other elements
  - Limiting: NO3, PO4
  - Others: Ca, Si, Fe, CO3
- Can also be limited by grazing (heterotrophs)
- Base of marine food web and supports all other life in ocean

Primary productivity

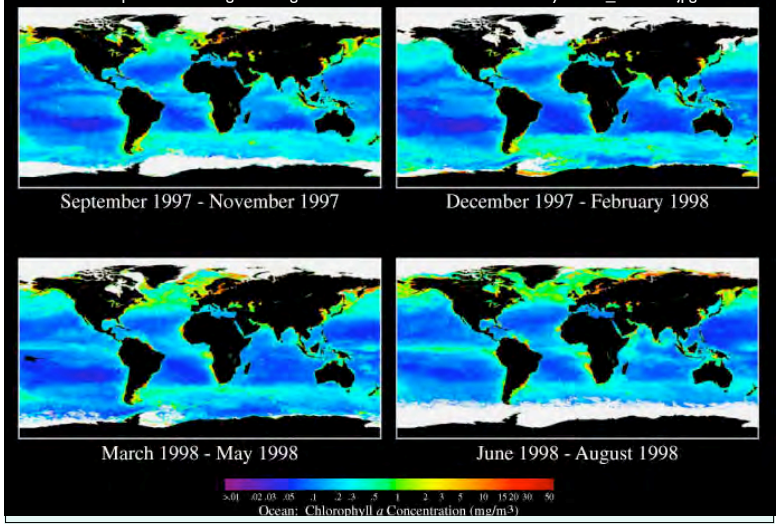
- Measure in g C/m^2/yr or similar types of units
- View from space as ocean color changes
  - Chlorophyll, blooms of CaCO3 phytoplankton
- Marine productivity is comparable in magnitude to terrestrial primary production: 50Gt C/yr
- Main marine producers are phytoplankton
- Compare with veg on land - residence time:
  - Land: 600 Gt C/50 Gt/C/yr = 12 years
  - Ocean: 1 Gt C/50 Gt/C/yr = 1/50 yr = about a week!

Ocean primary productivity

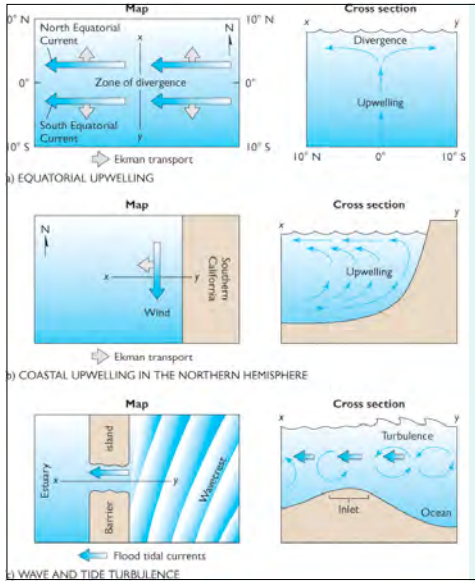


SeaWiFS Seasonal Chlorophyll Composites

http://oceancolor.gsfc.nasa.gov/SeaWiFS/BACKGROUND/Gallery/ocean_seasonal.jpg

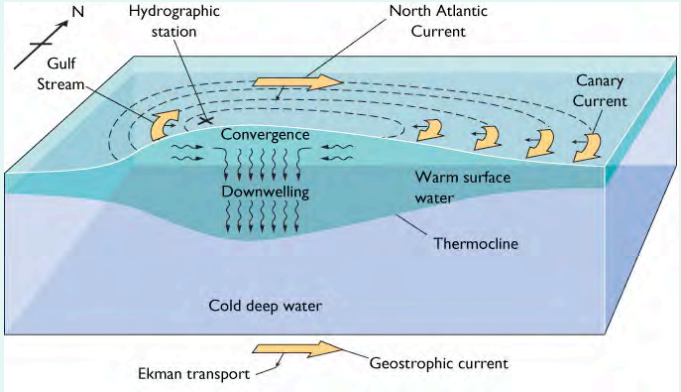


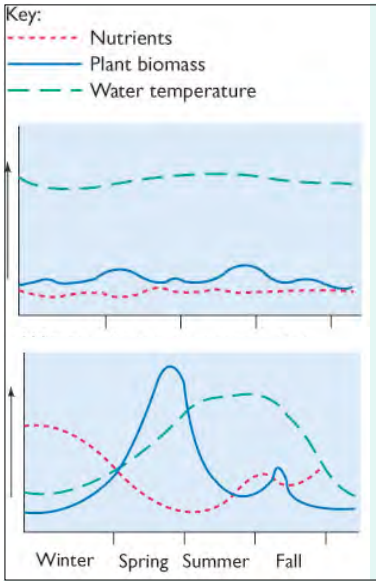
Vertical mixing



- Equatorial divergence and upwelling
- Coastal upwelling
- Strong tidal mixing

Low productivity gyres



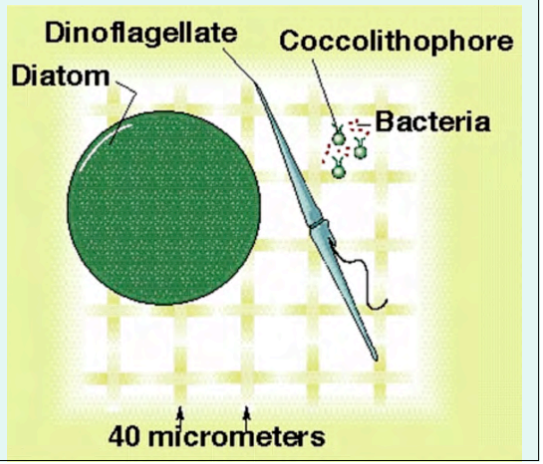


Seasonal cycles

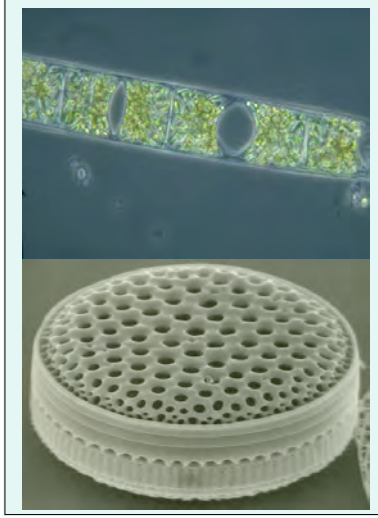
- Tropics: low seasonality in temperature, nutrients, light = low seasonality in productivity
- North Atlantic: strong seasonality in temperature, nutrients, light = seasonal patterns of productivity

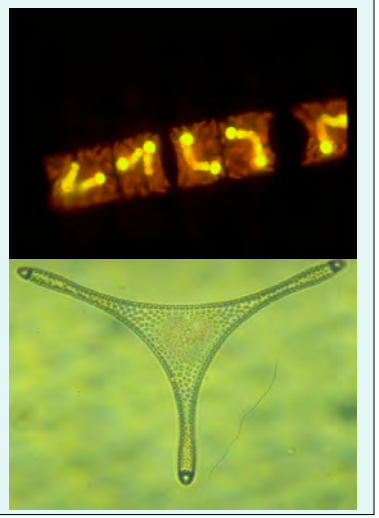
Who are the phytoplankton?

- Diatoms,
- Dinoflagellates
- Coccoliths



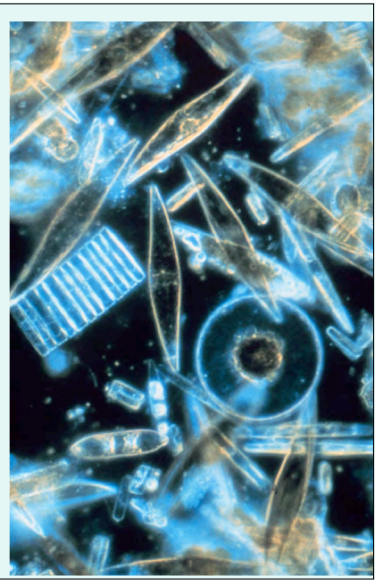
Diatoms



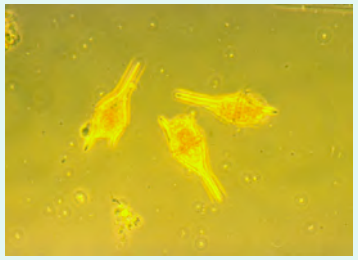


Diatoms

- Rigid cell wall – frustule
- 95% silica
- Frustule
  - Two valves
  - Box and lid
- Size: 10's of microns



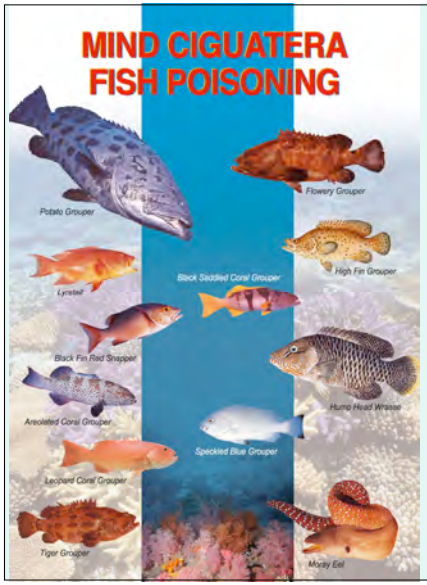
Dinoflagellates

Red tide - Harmful algal blooms

The attack of the killer algae

- Harmful algal blooms (HABs)
  - or "red tides": but not always red, and not related to tides
- Mostly from dinoflagellates, a few diatoms
- Associated with high supply of nutrients and high light (summer)
- Toxins a byproduct of metabolism
  - neurotoxins, paralytic, diarrhetic, amnesic
  - Sometimes fatal!
- indirect poisoning thru food web:
  - people eat fish that eat the dinoflagellates
  - people eat shellfish that eat the dinoflagellates

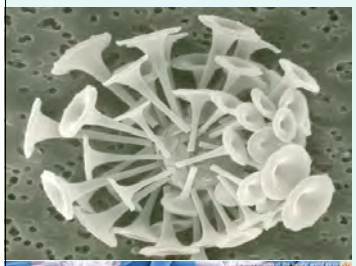
Ciguatera

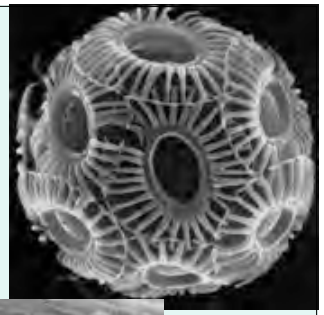
- Neurotoxin found in reef fish
- Especially near disturbed areas
- Cumulative, paralytic
- Can be fatal

More cool things about dinoflagellates

- Two whiplike flagellae
- Release excess energy as light, not heat
  - Bioluminescence
- Symbiotic with corals
  - Provide substantial nutrition, and change internal chemistry to favor calcification

Coccoliths





http://piclib.nhm.ac.uk/piclib/www/downloads.php?view=wall_apes

Coccoliths

http://www.nhm.ac.uk/nature-online/virtual-wonders/vrcocco_ehux.html

- Bloom in response to favorable conditions
- Visible from space as chalky color in ocean

Macrophytes - Larger marine plants

- Multicellular, attached autotrophs
- Small fraction of total primary production, but very important as structure for specific habitats and communities
- Marine macroalgae
  - Kelp, sargassum
- Sea grasses
  - True plants (vascular)
- Mangroves
  - Trees adapted to stand in saltwater
  - Numerous species

Kelp and kelp forests

- Brown algae
- Large, plantlike but structures are different
- Holdfast, stipe and thallus instead of root, stem and leaf
- Pneumatocysts keep afloat
- Habitat for fish, otters, invertebrates

Kelp forests

- 30 – 40 m water depth
  - determined by light availability
- found mainly in areas of upwelling
  - require high nutrient concentrations
- water temperatures cooler than 20°C
- supports diverse community
- provide
  - detritus
  - protection/ hiding place from predators
  - substrate for encrusting organisms
  - food for grazers

Ulva - sea lettuce

- Common in intertidal
- Green - contain chlorophyll
- High light levels

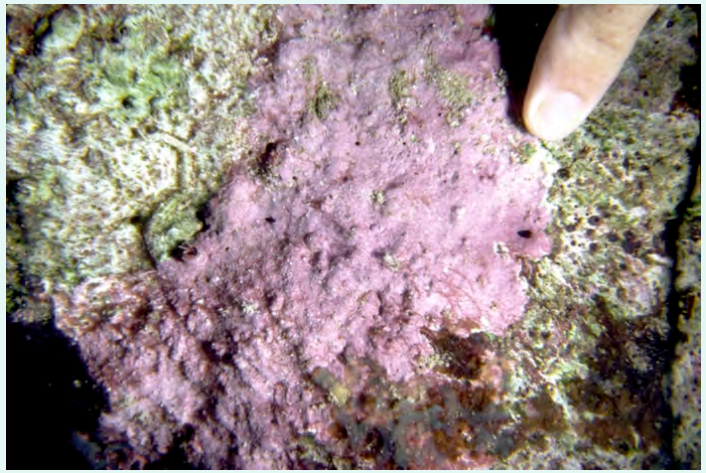
Sargassum

- Free floating (planktonic/pelagic)
- *Sargassum natans* and *S. fluitans*
- Masses drift around
- Provide habitat and food for other species in otherwise unproductive area of the ocean (Sargasso Sea)
  - Eel breeding grounds

Sargassum animals




Encrusting red algae



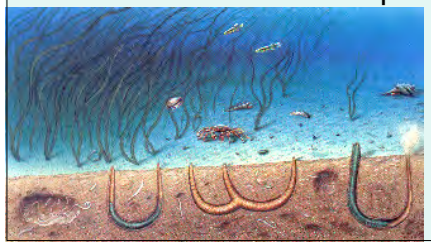
Sea grass beds

- Thalassia (turtle grass)

- Zostera (eel grass)

Sea grass beds

- Productive and diverse
- Used by many species
  - Nurseries
  - Feeding grounds
  - Refuges from predation
  - Substrate
- Trap sediment, minimize erosion



- Infaunal communities
- Epiphytic communities

Mangroves

- tropical and subtropical muddy coasts
- roots can extract freshwater from seawater
- 50 species worldwide
- create habitat for fish, invertebrates, birds
- provide food for fish, invertebrates, birds
- protect coastlines from storms

Mangroves

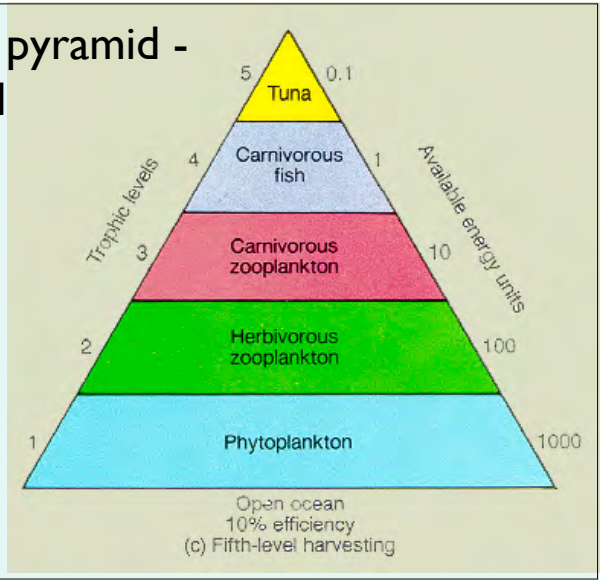
Did mangroves protect shoreline against tsunami damage (2004)?

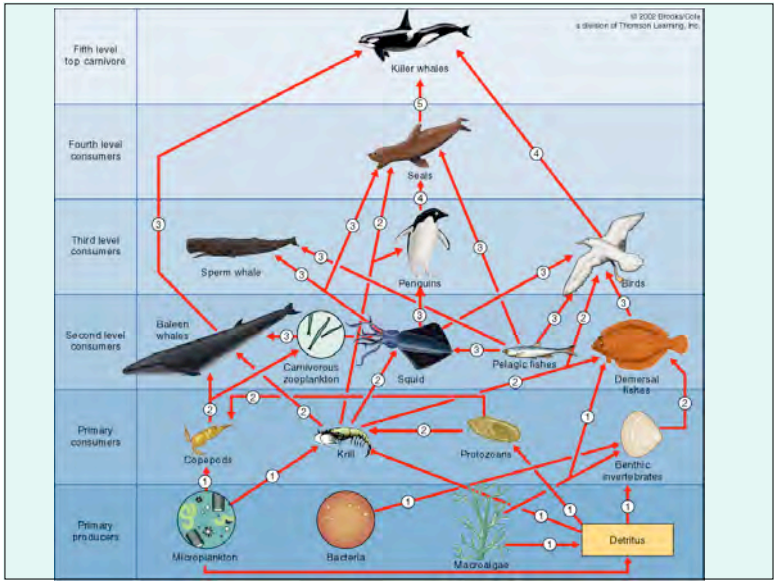
- Extensive development reduced mangrove coverage in SE Asia
  - Shrimp farms
- In areas where mangroves remain, damage and mortality lower than where mangroves removed
- Restoration ongoing but difficult

Mangrove and kelp distribution

- Relate to temperature, water clarity

Trophic pyramid - idealized

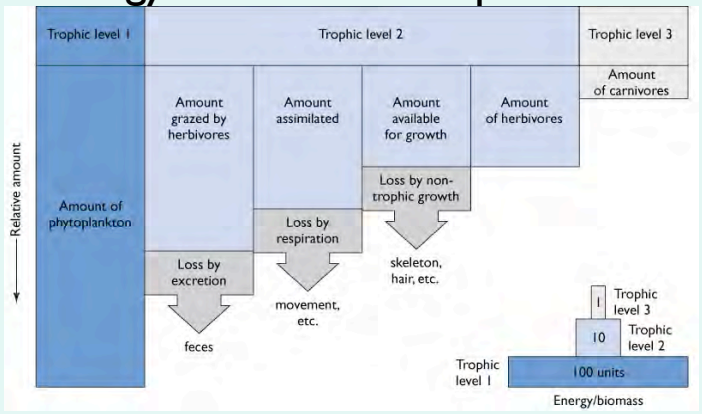




Food chains or food webs

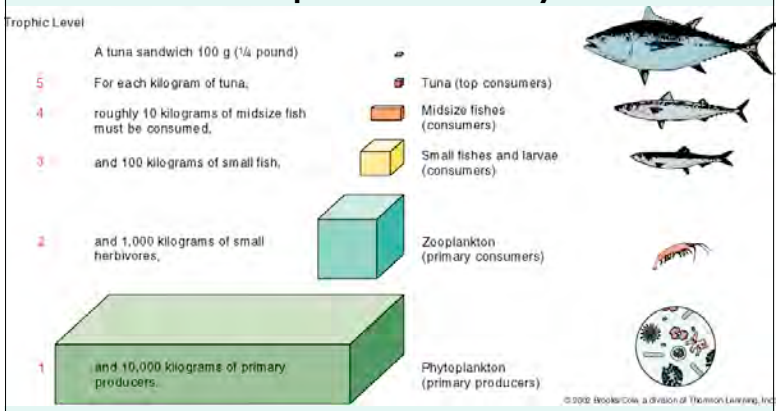
- Transfer energy from one trophic level to another
  - Only about 10-20% of energy is transferred between trophic levels.
- With each higher trophic level:
  - the size of organisms generally increases
  - the reproductive rate decreases
  - The number of organisms decreases
  - the total biomass decreases

Energy loss at each trophic level



- Excretion, respiration, non-trophic growth

Trophic efficiency

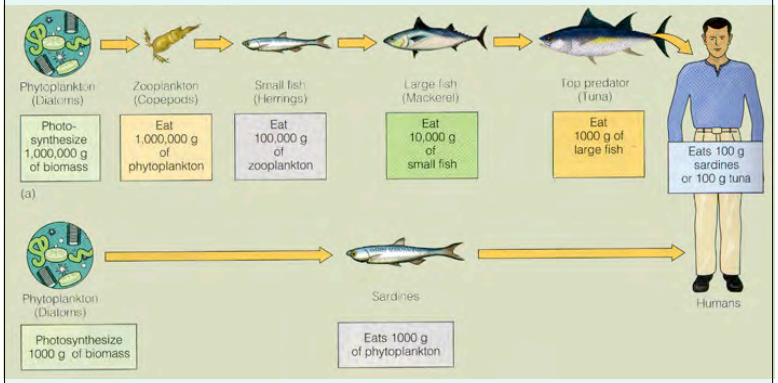


- Only about 10% of the energy at a given trophic level is conveyed up to the next level

Which fish can support the most people? tuna or sardines?

One million grams of phytoplankton needed for 100 grams of tuna

Why it's more sustainable to eat low on the food chain

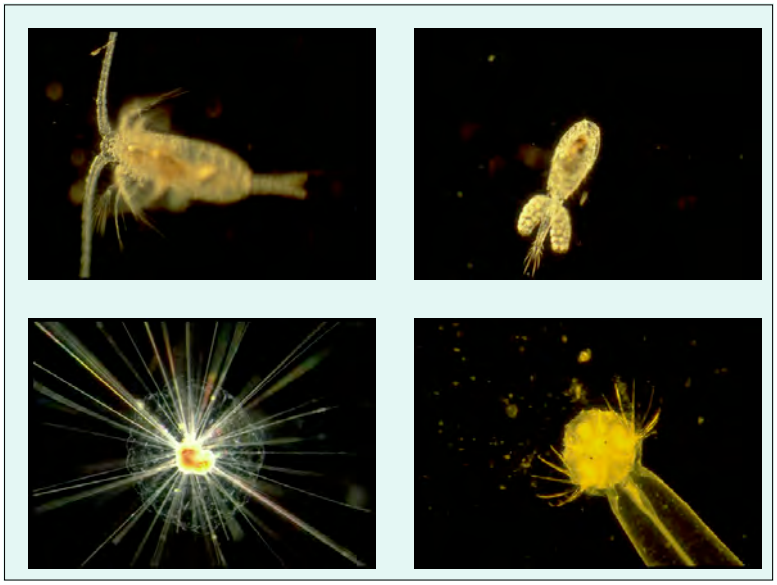


One thousand grams of phytoplankton needed for 100 g of sardines

One million grams of phytoplankton could produce 100,000 g of sardines

Who eats the phytoplankton?

- Heterotrophs
  - Graze on phytoplankton
  - Most numerous primary consumers
- Holoplankton
  - Spend entire lives as plankton
  - Copepods – 70% of zooplankton
- Meroplankton
  - Larval or juvenile stages of benthic or nektonic organisms



Zooplankton

krill

copepod