Relationship between nutrients and Primary productivity in PS

- Do nutrients limit PP in summer?
- Winter?
Dissolved inorganic nitrogen

Nutrient experiments in Padilla Bay

Nutrient addition experiments

PP and light

From Newton and Van Voorhis 2002
Stratification in the Salish Sea

Stratification rank order:
1. Whidbey Basin
2. Southern Hood Canal
3. Northern Hood Canal
4. South Sound
5. Main Basin
6. Strait of Juan de Fuca

Where does nutrient depletion occur?
Places in the Salish Sea where DIN drops to < 7 μM

Nutrients and eutrophication
• 29 of 41 stations susceptible
• 15% show hypoxia (red) and 20% show DO stress
• Most susceptible stations (36%) in South Puget Sound & Kitsap Peninsula
• Implications for development?

Chlorophyll

b)
Most abundant phytoplankton

- Chain-forming diatoms: *Chaetoceros*, *Thalassiosira*, *Skeletonema*, *Rhizosolenia*, *Detonula*, *Dytilum*, *Thalassionema*, and other species
- Solitary diatoms: *Cylindrotheca*, *Coscinodiscus*
- Dinoflagellates: *Protoperidinium*, *Prorochentrum*, *Ceratium*, *Alexandrium catenella*
- Small flagellates: *Heterosigma akashiwo*,
- Other cool phytoplankton: *Noctiluca scintillans*, *Gyrodinium*, *Syneococcus*
Phytoplankton of Puget Sound: Solitary Diatoms

*Cylindrotheca*  
*Coccosiopsis*

Phytoplankton of Puget Sound: Dinoflagellates

*Ceratium fusus*  
*Alexandrium catenella*

Phytoplankton of Puget Sound: Microflagellates

*Dictyocha*  
*Heterosigma agawashio*  
*Phaeocystis*

Phytodiatom (diploctic) life cycle

Frustule: pure silica coated + layer of organic material.  
Parts: hypotheca, epitheca.  
Auxospore.
Dinoflagellates

Phytoplankton of Puget Sound
Dinoflagellates:
- *Ceratium fusus*
- *Noctiluca miliaris*
- *Protoperidinium divergens*
- *Alexandrium catenella*
- *Gyrodinium britannicum*

Dinoflagellate (haplontic) life cycle

Cyanobacteria
- major forms
  - *Synechococcus* (1-3μm)
  - *Prochlorococcus* (~0.5 μm)
  - *Trichodesmium* (1-3μm)

- In Hood Canal: >70% of cells and ~20% spring biomass is *Synechococcus*
Zooplankton in Puget Sound

Do grazers control productivity?

![Graph showing Chlorophyll levels from Jan-98 to Apr-01](image)

**Chlorophyll**

- **Point Wells**
- **Possession Sound**
- **Admiralty Inlet**
- **West Point**

**Calanoid copepods**

- *Calanus pacificus* (5 thoracic segments)
- *Paracalanus* (4 thoracic segments)
- *Microcalanus* (1 mm)
- *Pseudocalanus*

**Other Puget Sound zooplankton**

- *Acartia*
- *Podon* (a cladoceran)
- *Evadne* (another cladoceran)
Copepod Life Cycle

- Eggs hatch to nauplii
- 6 molt stages (N1 – N6)
- 5 copepodite stages (C1-C5)
- 1 adult (reproductive) stage C6
- C5D’s can overwinter

Predatory copepods

Euchaeta

Mysids and Euphausids (krill)

- Easy to identify because they have eyes
- Mysids are smaller (<4mm) with stalked eyes
- Eat copepods

Saggita the arrow worm

- Phylum Chaetognatha
- Long-lived
  (some species more than one year)
- Eat copepods
  (Calanus and Pseudocalanus)
**Cnidarians and Ctenophores**

- Cnidarians: Collect prey using stinging cells (cnidocytes)
- Ctenophores: Collect prey using sticky cells (colloblasts) or engulf their prey
- Cnidarian jellies
  - Hydrozoans (juvenile phase)
  - Scyphozoans (adult phase)
    - ("True jelly fish")

**Microzooplankton**

- Ciliates and Tintinnids
- Relatively small (20-640μm)
- Can consume up to 90% of PP (Lalli & Parsons, 2001).
- Feed on: detritus, bacteria, naked flagellates, diatoms, other algae
- Tintinnids blooms linked to diatom blooms
- Eaten by meso and macrozooplankton

**Heterotrophic dinoflagellates**

- *Protoperidinium*
- *Gyrodinium britannicum*
- *Noctiluca scintillans* "Red Tide"
  - 200-2000um in size,
  - not photosynthetic – predatory
  - bioluminescent

**Fossil tintinnids** from the Ordovician
- 490 to 443 MBP
- Lorica = organic shell
- Strombidium

**Bloom in East Bay, Orcas Island 1998**
- Bloom off CA coast 1999
- Bloom in East Bay, Orcas Island 1998
- Bloom off CA coast 1999
**Zoea crab larvae**

- Common in spring
- Single spines fore and aft indicate brachyuran (crab) larvae
- Hermit crab larval stages easily misidentified as mysid shrimp

**Polychaete larvae**

**Polydora larva**

- "Bishop’s hat"

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**Is grazing important in Puget Sound?**

- Importance of microzooplankton grazers
  - Numerous
  - Rapid reproduction (can keep up with phytoplankton)
- Method of studying grazing effects
  - Dilution technique
  - Collect water samples to create a dilution series
  - Herbivore dilution allows phytoplankton growth

**Dilution experiments**

- Growth equation: \( \frac{dp}{dt} = \mu p - \chi z p \)
- \( \frac{dp}{dt} = \mu p - \chi z D p = \mu p - g D p \)
- Solution: \( \frac{1}{t} \ln(p(t)/p_0) = \mu - g D \)

- Net Growth Rate (per time)
- Decreasing # of Grazers
- Y-intercept = "infinite dilution"
- Slope = linear relationship with dilutions

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**Dilution factor (fraction SW)**

0 1
Phytoplankton growth and grazing at a station in the San Juan Islands

Growth ($\mu$)
Grazing (g)

Fig. 3 Seasonal cycle in phytoplankton growth (solid bars) and microzooplankton grazing (open bars) in northern Puget Sound (data for total chlorophyll only). Compilation of data from two different years.

Grazing rates high during blooms (periods with high growth rates)

Could grazing contribute to diatom dominance in Puget Sound?