Can long term-nitrogen increases affect pelagic food web processes and the vertical structure of biogeochemical processes in Puget Sound?

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Can long term-nitrogen increases affect pelagic food web processes and the vertical structure of biogeochemical processes in Puget Sound?

1. Nitrate concentrations are increasing. Large flagellate blooms occur near the surface.

2. Phytoplankton biomass is declining!

3. Large *Noctiluca* blooms
   Micro-zooplankton grazing (200µM) is important!

HS: Are energy and material cycling through the lower pelagic food web changing?
   Benthic species match observations in the water.

Lower food web dynamics remain a knowledge gap in Puget Sound, yet is indispensable to connect water quality to the marine food web.
Nitrate concentrations are increasing (non-oceanic cause)

\[ y = 0.2007x - 402.49 \]
\[ R^2 = 0.4003 \]

Marine long-term monitoring locations in the greater Puget Sound area (southern Salish Sea).

Red dots monthly-visited water-column stations.
Si:N nutrient ratio is falling (eutrophication indicator)

Lower Si:N ratios can favor non-silicified phytoplankton taxa

Large and abundant flagellate blooms at the water surface

Nitrogen increases are driving the decline in the Si:DIN ratio!

\[ y = -0.9223x + 1855.4 \]

\[ R^2 = 0.3423 \]
Phytoplankton biomass: a 14-year decline (0-50m)

The Puget Sound-wide decline in phytoplankton biomass relative to baseline conditions (1999-2008) does not follow the pattern of a bottom-up nutrient control.

\( y = -5.5987x + 11251 \)

\( R^2 = 0.5312 \)
Inter-annual variability in phytoplankton biomass could explain changes in macro-nutrients?

Chlorophyll a inter-annual anomalies (mg Chl $a$ m$^{-2}$, 0-50m)

Nitrate anomalies ($\mu$M, 0-30m)

$y = -19.507x + 20.642$

$R^2 = 0.6486$

Spearman Rank Corr. Coef. $p<0.05$

Micro-zooplankton (<200 $\mu$m)

Micro-zooplankton grazers can remove the entire diatom standing stock each day!

(e.g., Verity et al., 1996a; Suzuki et al., 2002)

Balance between microzooplankton grazing and phytoplankton growth in Dabob Bay (Hood Canal)...


What controls phytoplankton inter-annual variability could also control nutrients in Puget Sound surface water?
*Noctiluca* blooms are large (eutrophication indicator)

**A strong competitor to copepods that feed on diatoms!**

**Food:** No food preference! *(Diatoms, flagellates, detritus, nauplii, copepod and fish eggs...)*

*Note: Blooms of *Noctiluca* are linked to massive fish and invertebrate kills.* *(Okaichi & Nishio, 1976; Fukuyo et al., 1990)*

*Noctiluca* rapidly recycles sinking fecal pellets and retains nutrients in the surface. *(Kiørboe, Thomas 2003)*
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Some juvenile salmons peak in June in PS  
King County 2004, Juvenile salmon composition, timing, distribution and diet in marine nearshore waters of central Puget Sound in 2001-2002
Grazing is reflected in the seasonality of Phytoplankton biomass and NH$_4$ in Puget Sound.
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Chl a summer peak loses its strength. Question: Top-down control or abiotic factors?

**Note:** NH₄ max also decreases in late summer; average is unchanged.
Surface material eventually sinks to the bottom and feeds the benthos. Why micro-zooplankton grazers do matter!

Are micro-grazers changing the organic particle export to the benthos (the benthic-pelagic coupling)?
Could micro-grazers change particles from fast-sinking nutrient-rich fecal pellets to slow-sinking nutrient-poor loose aggregates?

Decadal decline in benthic abundance and taxa richness

Partridge, V. Characterizing changes in Puget Sound benthic infaunal invertebrate assemblages: A functional approach

Are these signs of a reduced particle export to the benthos?
Hypothesis for combining a series of recent observations affecting energy transfer to higher trophic levels

Increases in nitrate conc. in PS could be caused by a top-down control on phytoplankton biomass.

Is Noctiluca a harbinger of a food web shift towards increased microzooplankton grazing?

POSTER:
Krembs, C. Changes in nutrient ratios drive changes in pelagic and benthic assemblages, and benthic-pelagic coupling in Puget Sound: A compelling hypothesis linking water quality and the benthos.