Analyses of Ecology’s long-term monitoring data indicate changes in the cycling of organic material might occur that could affect phytoplankton, micro- zooplankton, and benthic communities. The long-term change has potential implications for marine food web structure, energy transfer, particle export, and higher trophic levels such as fish. A testable hypothesis is presented combining observations about the significance of energy flow through the microbial food web that determines the outcome of energy availability for higher trophic levels.

**Introduction**

**Hypothesis**

Nitrogen additions to Puget Sound cause nutrient ratios S/N:P to change and indirectly might create a larger energy flow to higher trophic levels for the marine food web by promoting conditions for increased micro-zooplankton grazing. This has consequences for overall phytoplankton species composition, biogeochemical cycles, higher trophic levels food availability, and benthic-pelagic coupling.

**Results and Discussion**

Long-term increases in nitrogen concentrations (Fig. 1 A) and shifting nutrient ratios (Fig. 1 B) suggest human nitrogen inputs to Puget Sound. Yet, decreasing phytoplankton biomass (Fig. 2) in our monitoring network (Fig. 3) suggests large-scale changes in lower trophic levels of the pelagic food web that match a decline in the marine benthos (Fig. 4 A, B).

- Monitoring of lower trophic food dynamics remains a knowledge gap in Puget Sound and is indispensable to connect water quality to the marine food web!

**Figure 1.** Seasonal patterns of chlorophyll a (left) and ammonium (right). Both chl-a and ammonium are proxies for phytoplankton biomass and their concentration changes can be driven by nutrient availability. Data are from the Washington Department of Ecology’s Environmental Assessment Program, which monitors various water quality parameters in Puget Sound. The sampling frequency is once per month.

**Figure 2.** Mean abundances of the dominant zooplankton species. The dominant copepods (left) and otters (right) are decreasing in abundance, while the dominant micro-zooplankton (middle) are increasing in abundance. Data are from the Washington Department of Ecology’s Environmental Assessment Program, which monitors various zooplankton species in Puget Sound. The sampling frequency is once per month.

**Figure 3.** Mean long-term monitoring locations in the greater Puget Sound area (western Salish Sea). Red dots depict monthly- visited water-column stations. Colored regions illustrate benthic-monitoring regions sampled using a random sampling design.

**Figure 4.** Seasonal patterns of bottom-predominant fish and marine mammals. Both species (left) and marine mammals (right) are decreasing in abundance, while the dominant marine mammals (middle) are increasing in abundance. Data are from the Washington Department of Ecology’s Environmental Assessment Program, which monitors various fish and marine mammal species in Puget Sound. The sampling frequency is once per month.

**Figure 5.** Nitrogen additions to Puget Sound cause nutrient ratios S/N:P to change and indirectly might create a larger energy flow to higher trophic levels for the marine food web by promoting conditions for increased micro-zooplankton grazing. This has consequences for overall phytoplankton species composition, biogeochemical cycles, higher trophic levels food availability, and benthic-pelagic coupling.

**Figure 6.** Changes in the relative importance of spring and late summer phytoplankton blooms. Long-term declines in chlorophyll a (left) are occurring (green) and increasing (blue). The decrease is pronouncedly driven by a decline in the late summer phytoplankton bloom (red), yet spring blooms are increasing (blue). Data are from the Washington Department of Ecology’s Environmental Assessment Program, which monitors various phytoplankton species in Puget Sound. The sampling frequency is once per month.