Recent and projected seasonal changes to river flows combine with human pressures to restructure the base of the marine food web in Puget Sound

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Recent and projected seasonal changes to river flows combine with human pressures to restructure the base of the marine food web in Puget Sound.  

Dr. Christopher Krembs, 2018

Greater Puget Sound region

Monthly status and trend assessment of water quality indicators in the larger Puget Sound region, the Straits and coastal bays (37 stations)
Potential climate impacts on regional hydrological, geological, and biological processes...

- What is climate change?
- What is natural variability?
- What are human impacts?

The new frontier in environmental status and trend assessments

Do we have the right tools for effectiveness monitoring?
Climate change is predicted to continue past the Blob, El Niño, La Niña!

**Impacts on hydrological cycle...**
- Amplitude
- Duration
- Seasonal timing
- **Relative timing**
- Life cycles
The timing of processes will be affected by future climate. Snowpack and river flows, upwelled water, and meltwater are shown in the diagram. "Cooled migration corridor" is indicated in the text. Weather and Ocean Patterns are shown with sun and cloud icons. The diagram is drawn by Christopher Krembs.
The timing of processes will be affected by future climate.

Changes to snowpack and river flows:
- Rivers flow, water residence time is low
- Dilutes human pollutants

Weather and Ocean Patterns:
- Ocean
- Total human
- Rivers

Productive foodweb:
- Carbon pump
- Upwelling
cold water natural nutrients

Regeneration

Estuaries and Bays
Basins
Ocean

Drawn by: Christopher Krembs
Climate impacts affect the connectivity of processes in time

Historically peaks of coastal upwelling and the freshet are in sync

The Fraser river (Hope)

Source: Climate Change Impacts in the United States, 2014
Summer droughts increase the human burden on water quality. Changes to snowpack and river flows mean rivers are dry, water residence time is high. This magnifies human pollutants. Weather and ocean patterns, influenced by climate change, affect water temperatures. Warmer water has more time to warm in summer, affecting the productivity of the foodweb. Less desirable foodweb regeneration leads to lower food quality. Upwelling brings colder water and natural nutrients, supporting a productive foodweb.
Temperature changes species composition, food spectrum, the relative timing of life cycles, and the interactions of prey and predator.

### Anchovy
- **<9 °C** – physiological limit
- **>13 °C** – spawning preference

### Herring
- **<10 °C** – spawning
- **12 °C** – optimum somatic growth

### Salmon
- **12-14 °C** – juvenile pacific salmon growth optimum
- **>17 °C** – Coho Chinook salmon avoidance
- **>15 °C** – HABs toxicity
- **<17 °C** – Bull kelp
- **>18 °C** – Oyster spawning
Temperature anomalies span across the land-ocean continuum.

River temperature anomalies, baseline 1999-2016 (°C)

Marine temperature anomalies, baseline 1999-2016 (Thermal energy 0-50m GJ m⁻²)

Stream stations

Marine stations

R² = 0.5276
Si:DIN (silicate to dissolved inorganic nitrogen) is an eutrophication indicator.

Nutrient balance can change the base of the food web, fostering nuisance species.

Flagellates benefit, providing low food quality for fish.
Eutrophication indicators, organic material (information gap)

Undesirable species that tend to float

Noctiluca

Dinoflagellates

Credit: Jim Devereaux

Jellyfish

Macro-algae
Percent significant change in marine indicators since 1999

(Spearman Rank Correl., n=17 years, 10% sign level)

- Non-oceanic nitrate
- Non-oceanic phosphate
- Ratio silicate : nitrogen (DIN)
- Ammonium
- Chlorophyll a
- Near-bottom : surface Chl a (%)

Scale

- 10%
- 20%
- 40%
- 80%
- 160%
- 320%
- 640%

Month

0 1 2 3 4 5 6 7 8 9 10 11 12

Spring  Summer

changed
unchanged
In summer, the relative contributions of WWTPs are highest, and sluggish water exchange can further increase pollutants.

Source: Mohamedali et al., 2011a.
Summary:
Human and climate impacts combine

Land-Ocean-Climate Connection:

• Temperature anomalies stretch across the river-ocean continuum.

• The relative timing of Fraser river and upwelling matters for marine water quality.

• In summer, the base of the marine foodweb (food quality) could change. **Eutrophication indicators are prevalent.**

• **Humans** could have an increasing impact on WQ and the food web during summers. (increased vulnerability because of climate)
Hypothesis: Changes in the lower food web

**HS-1:** Climate change has the effect of magnifying human nutrient contribution to Puget Sound and shifts the food web in the summer months.

**HS-2:** Changes in the nutrient balance affect the growth conditions of the lower levels of the marine food web.

**HS-3:** In summer, the microbial food web has gained importance relative to the productive, diatom-based food chain.

**HS-4:** The organic particle export to deeper water changes in response to shifts in the lower-trophic levels of the food web.