or, Did the Recent Warm Anomaly Enter Saanich Inlet?

Lead Saanich roles:
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With a CAST OF HUNDREDS

2016 Edition

Adapted for the small screen by

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Some background
Typically, winter winds are Westerly across the North Pacific.

Nutrients are transported from the subarctic Pacific as far south as 30 N, creating a winter chlorophyll maximum (Transition Zone Chlorophyll Front).

Ayers and Lozier (GRL, 2010)
The export of N from the subarctic provides winter feed for many migrating species.
A warm patch forms and persists
Nov 2013 - Jan 2014

Westerlies were halted by a Southerly flow in the NE Pacific, warming the mixed layer over an area of 1.5 million km$^2$.

→ Unique in the record of surface winds and SST.

Ekman transport of nutrients was so weak the TZCF didn’t develop in winter 2014.
The warm anomaly moved toward shore by early 2015, where coastal productivity was impacted.

→ *News reports of seabird and sea lion starvation.*
February 2015 along Line P

Temperature Anomaly (°C - ITS90) w.r.t. 1981-2010 averages

Sigma-t Anomaly (kg/m³) w.r.t. 1981-2010 averages

Dissolved Oxygen Anomaly (μmol/kg) w.r.t. 2001-2010 averages

Distance along Line P (km)

https://www.waterproperties.ca/linep (Marie Robert)
On-line data helps track the warm anomaly:

- Ocean Networks Canada
- Satellite measurements, MODIS
- Lighthouse data (DFO)
- Ocean surveys (DFO)
The anomaly is seen in coastal waters, early 2015.

**Folger, +2.8°C SST**

**Race Rocks Lt.**
2015 warmer than 2014

**Haro Strait,**
+1.3 to 1.6°C in Feb 2015
Warm waters have less oxygen and occur in late summer.

Cooler waters (winter) are better oxygenated.

Warm waters are the densest, entering the Strait as a consequence of coastal upwelling and tidal mixing.

Oxygen declines slightly following basin flushing, except in 2015 when it decreases for 5 months following the summer intrusion.

Lower than "theoretical" minimum (Johannessen et al 2014)
Late summer, basin flushing on weak Neap Tides.

**Summer** upwelling provides saline, low oxygen waters to the shelf

Winter downwelling supplies fresh, cool, oxygenated waters to the shelf

Late winter, mixing of basin waters on Neap Tides.

Hypoxia could develop when winter oxygenation is weak.
Warming and loss of oxygen are common trends in BC coastal waters. Between Mar 2014 and Dec 2015, waters at 95 m warmed by 2.3 °C. 2015-2016 basin warming was 0.3 °C.
Late summer, dense waters approach the sill – **basin flushing on neap tides**.

Rest of the year, waters cross the sill and **transport oxygen to mid depths**.

The density of waters approaching the sill governs oxygen transport into Saanich and SoG.
How climate change may increase hypoxia:

- Recent warming created a less dense winter mixed layer, weakening winter re-oxygenation of inside waters.
- Summer upwelling appears to be strengthening at poleward extremes. Lower oxygen, denser waters may then be transported into BC inlets and straits, increasing water column stratification.
- Changes in Fraser River discharge from spring freshet to winter will affect how estuarine circulation interacts with coastal upwelling and basin flushing.
- Warming waters will increase microbial rates of oxygen consumption in regions with rich organic sediments.