Low Dissolved Oxygen in Hood Canal

Hood Canal Dissolved Oxygen Program

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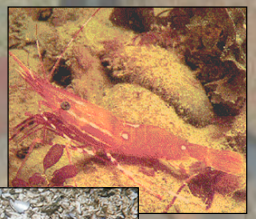
Hood Canal Watershed

- 5 Major Rivers
- 3 Counties
- 54,000 Residents
- 24,800 Homes

The natural resources have great economic, recreational, commercial, and cultural value

- **65-75% of the state's Spot Shrimp are harvested from Hood Canal**
- **500,000-600,000 pounds of Dungeness Crab are harvested annually in Hood Canal**
- **The 2002 Geoduck quota was over 500,000 pounds… valued between $3-5 million**



Source: WA Dept. of Fish and Wildlife

Tuesday, September 16, 2003

Hood Canal marine life struggling for oxygen

By LISA STIFFLER
SEATTLE POST-INTELLIGENCER REPORTER

Yesterday, the state Department of Fish and Wildlife indefinitely closed commercial and recreational fishing throughout the canal for all finfish except salmon and trout, as well as octopus and squid…

Low oxygen in Hood Canal is not a new observation

- **UW: 1950's observations (Collias et al., 1974 Washington Sea Grant)**
- **UW-OSU 1970-80's observations (e.g. Curl and Paulson, 1991, Puget Sound Research Conference Proceedings; Paulson, 1993, Mar. Chem.)**
- **PSAMP comparison of Ecology (90's) and UW (50's) data (Newton et al., 1995, Puget Sound Research Conference Proceedings)**
- **Ecology's *"Washington State Marine Water Quality during 1998 through 2000"* (Newton et al., 2001):**

  "Similar to our previous assessment (Newton *et al.*, 1998a), four observations from the monitoring data indicate the possibility that DO conditions may be deteriorating in southern Hood Canal, that the spatial extent of low DO may be increasing northwards, and that eutrophication could be one of the processes contributing to this change. Impacts of other human activities (e.g., freshwater diversions) as well as natural cycles must also be fully evaluated."

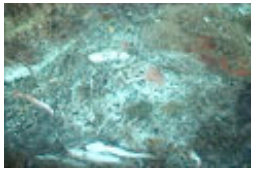
- *Hypoxia more frequent.*
- *Northward increase in the horizontal extent of hypoxia.*
- *High chlorophyll a concentrations observed when nutrient limitation of phytoplankton growth expected.*
- *Nutrient-addition experiments show that primary productivity was increased as much as three-fold (Newton et al., 1995).*

2003

- Low DO was found higher in water column
- Another very sunny summer
- 50,000 Shiner perch fish kill in June
- Very low DO (anoxia) develops
- Substantial biota death observed by divers
- Another fish closure by WDFW in September
- Very large fish kill in October
- HCDOP forms: work with ~20 entities to do what is possible now and draft study plan for future
- Developed a website
- HCDOP Citizen Monitoring begins

Sightings of fish kills on Hood Canal, October 8-10, 2003

WDFW observations W. Palsson



Blackeyed gobies were found dead in a mat of decomposing material.

Dead copper rockfish were encountered mostly in waters between 5 and 40 feet in depth.

An astounding 80 copper rockfish were in this dense school in water depths of less than 20 feet.

This live spot prawn is a very unusual occurrence in shallow waters during the day. Many spot prawn are observed in shallow water during the low dissolved oxygen event and many dead prawns were also observed.

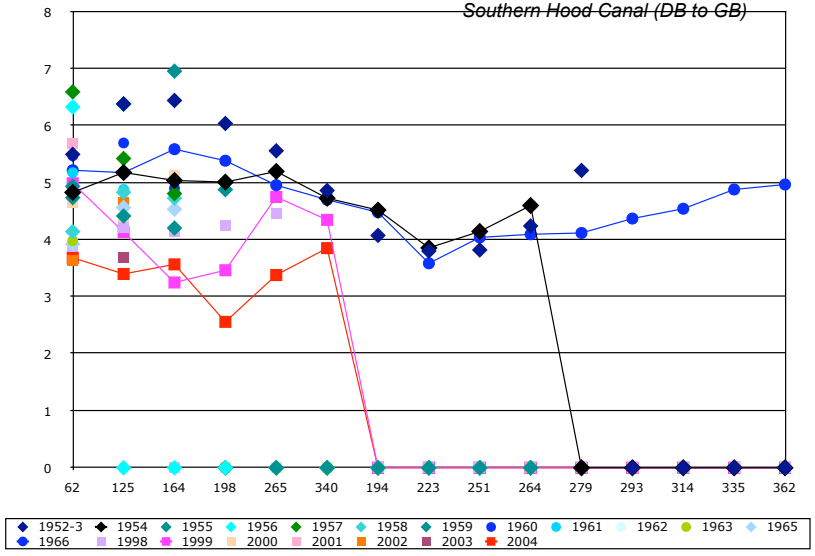
Most wolfeels were out of their dens, which is uncommon. Many were observed in water depth of less than 20 feet.

What we know

- Hood Canal is exhibiting during 2003-04 the lowest oxygen concentrations on record.
- Hood Canal, especially in south, has been showing a gradual increase in severity, persistence, and extent of low oxygen.
- There are likely both human and natural processes involved. Which are most influential needs to be quantified.

Average Dissolved Oxygen Measurements – 1950s - 2004

Southern Hood Canal (DB to GB)

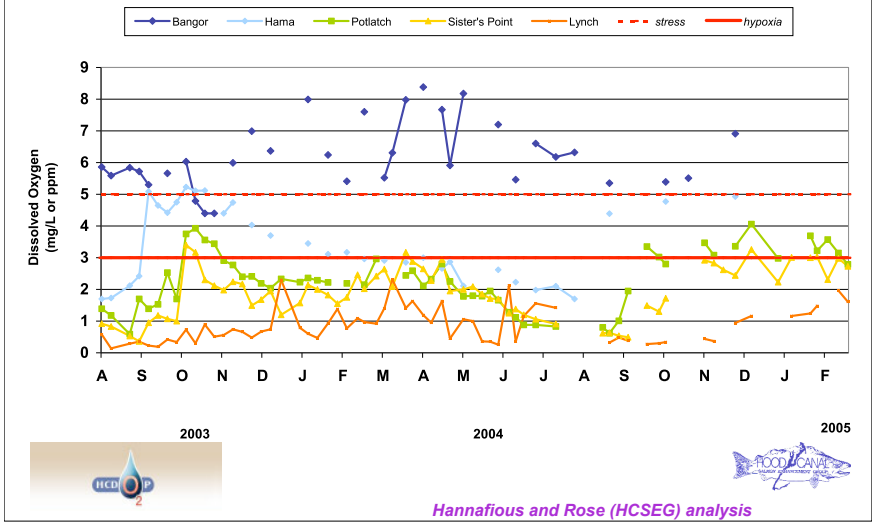


Warner (UW) analysis of PRISM & UW Collias data

Citizen Monitoring Time-series

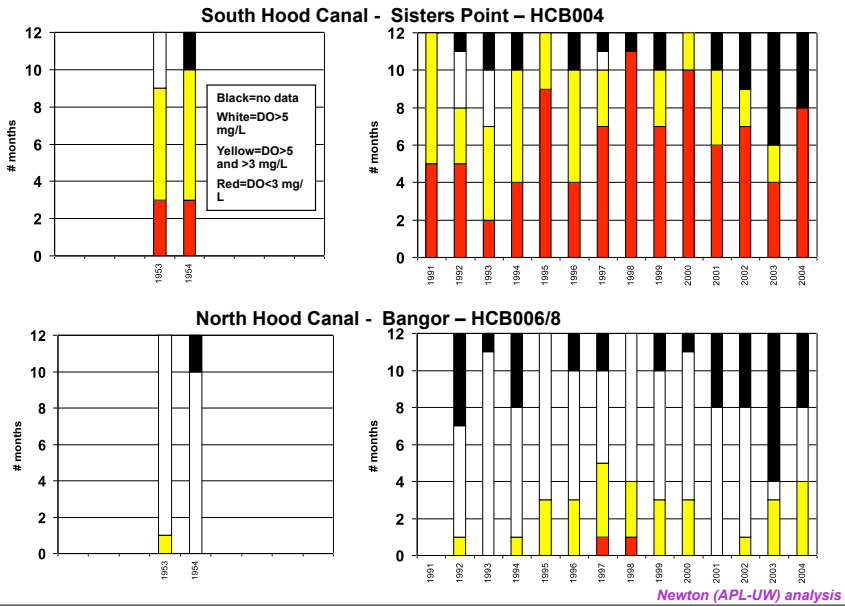
Hood Canal Dissolved Oxygen 2003-05

(center station - bottom samples)

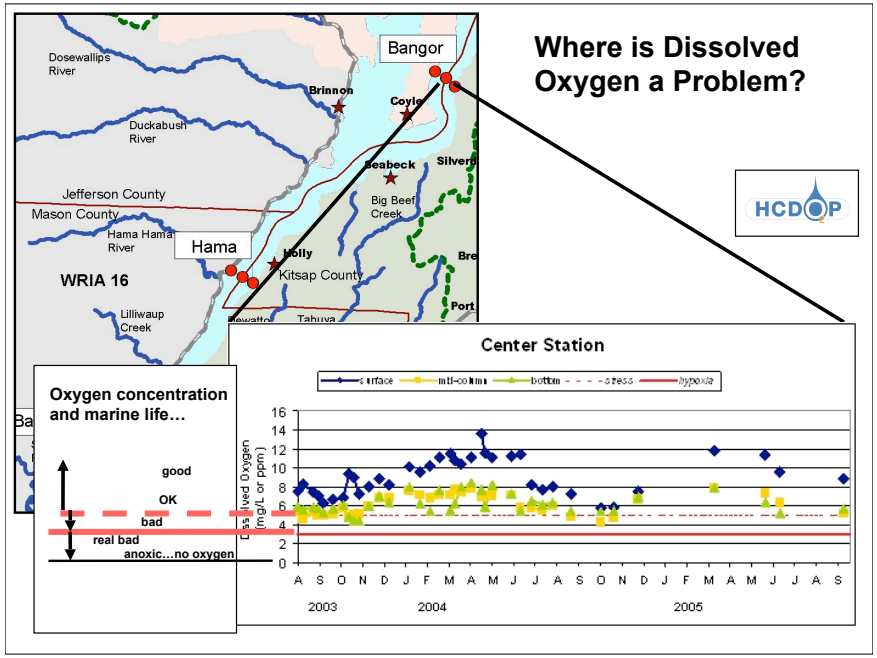


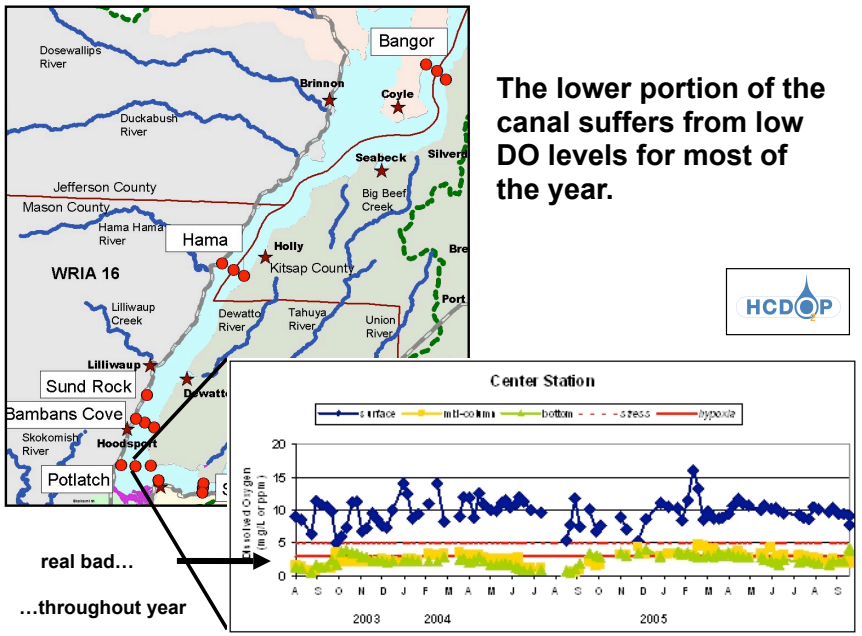
Hannafious and Rose (HCSEG) analysis

UW Historic Data (Collias et al., 1974) *Ecology-PSAMP Monitoring Data*



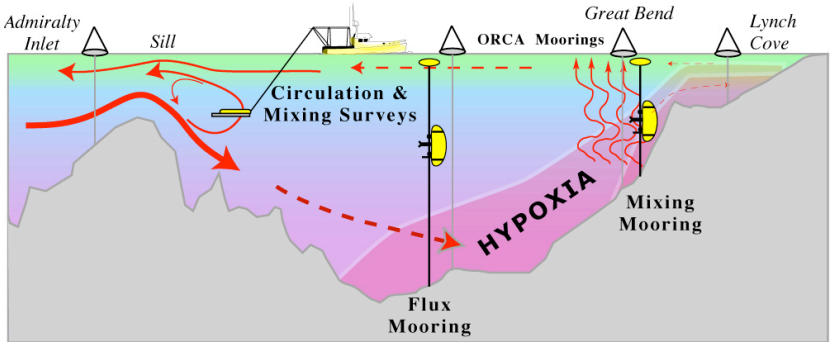
Newton (APL-UW) analysis





The lower portion of the canal suffers from low DO levels for most of the year.

HCDOP



Are we seeing long-term change?

- Area of low oxygen may be spreading north and occupying greater volume.
- Low oxygen present year-round.
- Hypoxia developing earlier in year.
- Biological effects may be worsening.

Source: J. Newton (UW), HCDOP

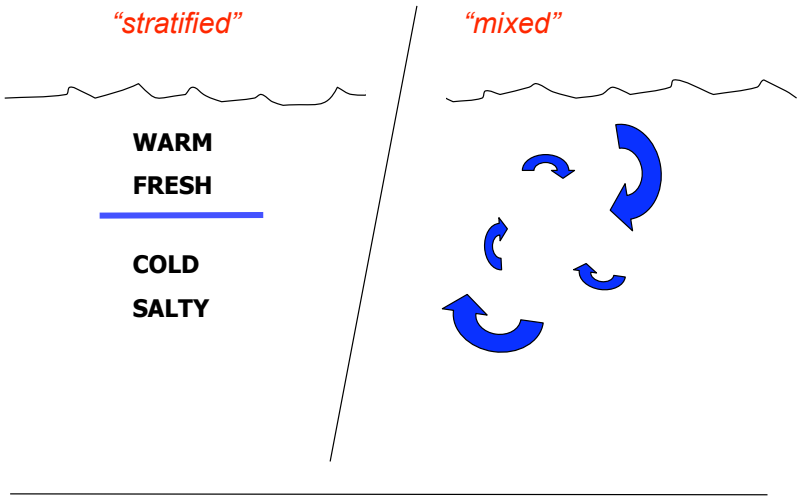
What controls oxygen ?

- Seawater density stratification
- Seawater flushing/circulation
- Organic production and respiration

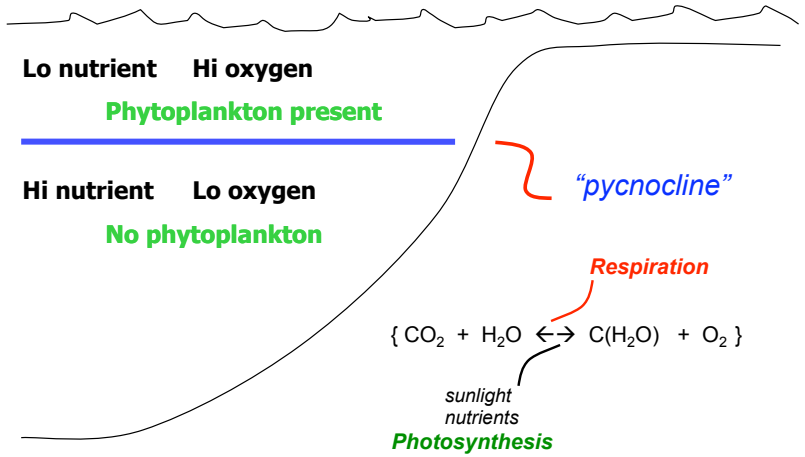
- Eutrophication/nutrient loading
- Organic loading

Start with basics….

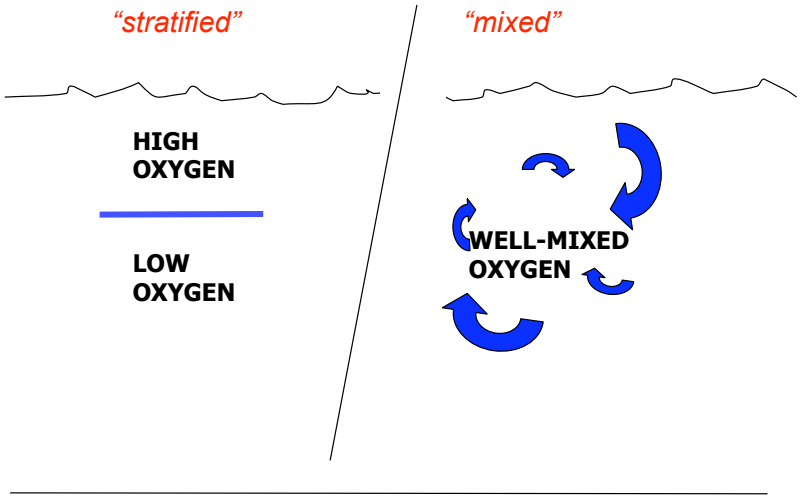
Density *structure can be two different ways:*



Organic (primary) production:



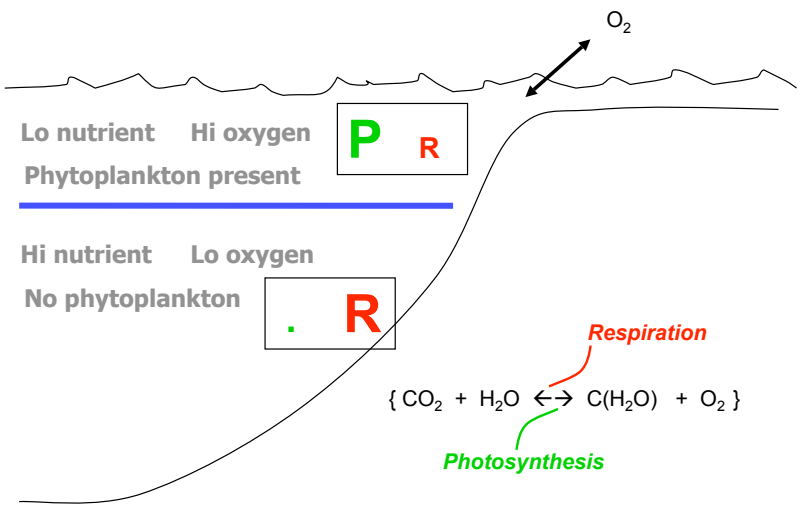
Oxygen *structure can be two different ways:*



So why sub-surface low oxygen ?

- Light + nutrients ➔ algae
- Algae accumulate and eventually settle to seabed
- Organic material decomposition requires oxygen

Which process dominates ?



So why sub-surface low oxygen ?

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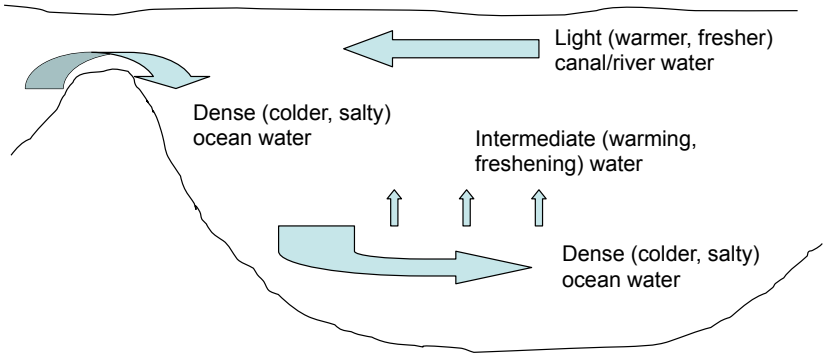
- If water is stable, oxygen consumed at depth
- If water is mixed/flushed, surface oxygen replenishes the deep oxygen concentration

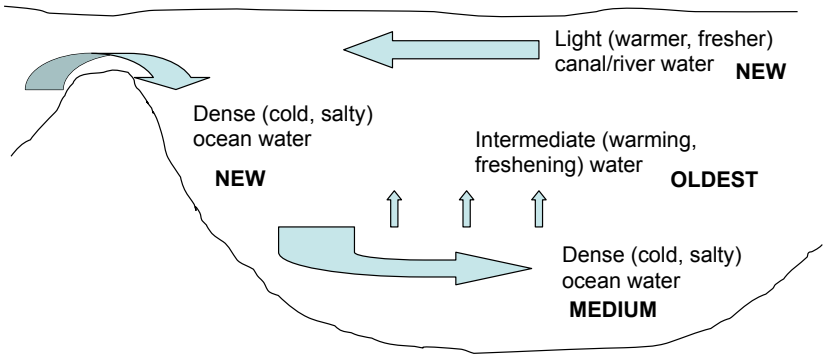
Hood Canal attributes

- **Strong** stratification – distinct layers maintained with different character
  (the deep waters with low oxygen don't get mixed up)
- **High** productivity – high organic load
  (that will be respired away during decomposition)
- **Slow** circulation – long residence time
  (the bulk of the waters are "old"; lots of respiration has occurred w/o PS or air contact)

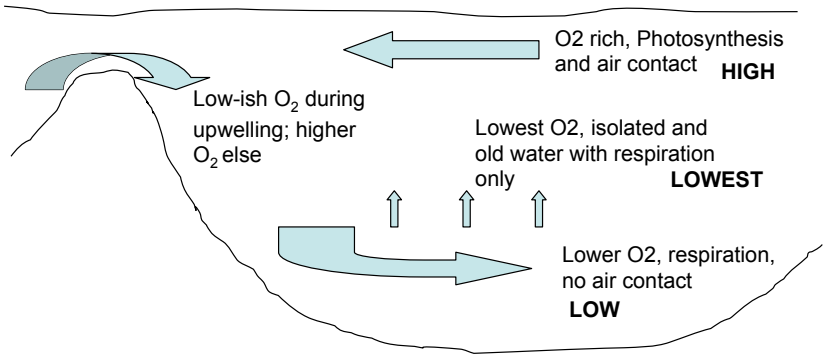
Hood looks like this:



Compare residence times or "age" of waters

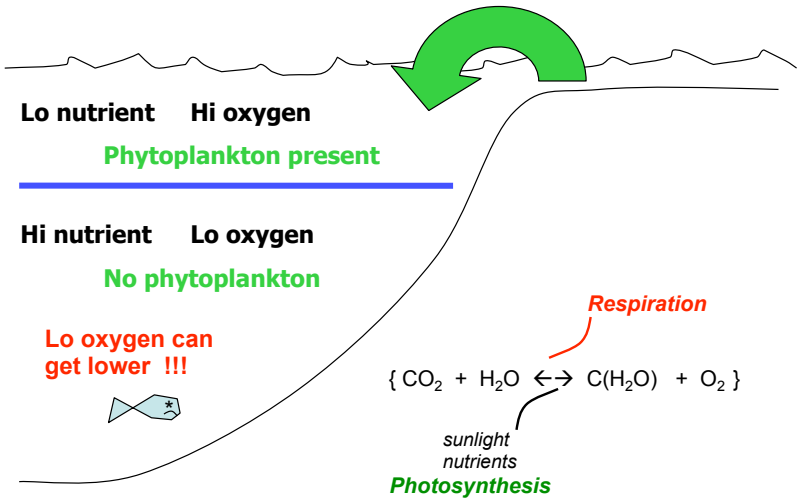


And what about the oxygen ?



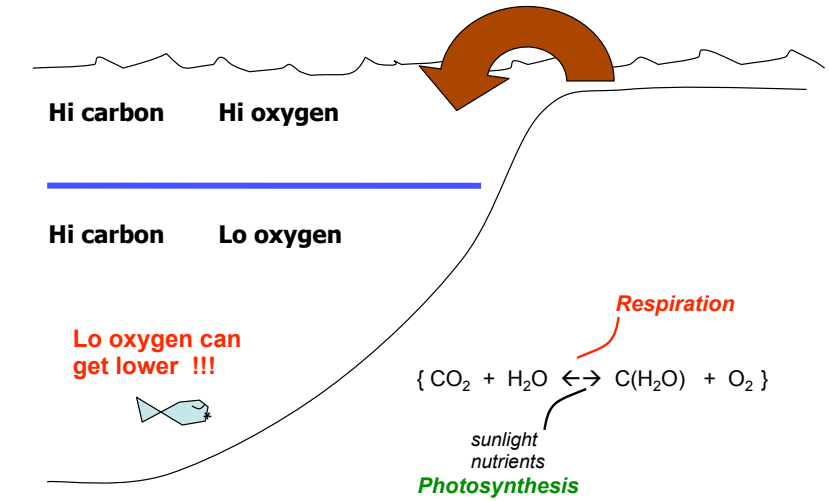
How do humans affect this??

Add "new" nutrients from human activity: stormwater, agriculture, fertilized lawns, sewers, septic tanks, animals, etc.



How do humans affect this??

Add carbon load: carcasses, yard wastes, failing septic tanks, etc.



What controls oxygen ?
WHAT SELECTS FOR LOW OXYGEN?

- Stratification
- Organic production and respiration
- Flushing/circulation
- Nutrient or carbon loading

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What controls oxygen ?
WHAT SELECTS FOR LOW OXYGEN?

- Stratification → STRONG
- Organic production and respiration → HIGH
- Flushing/circulation → SLOW
- Nutrient or carbon loading → OCCURING

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Hood Canal attributes:

- Stratification → STRONG
- Organic production and respiration → HIGH
- Flushing/circulation → SLOW
- Nutrient or carbon loading → OCCURING

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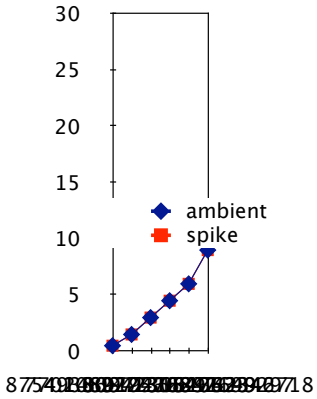
What *could* cause lower oxygen in Hood Canal ?

- **Stronger** stratification – distinct layers maintained with different character
  - Less mixing
- **Higher** productivity – high organic load
  - More nutrients, light, stable environment
- **Slower circulation – long residence time**
  - Less density driven circulation

What about eutrophication?

Nutrient addition causes substantially more primary production

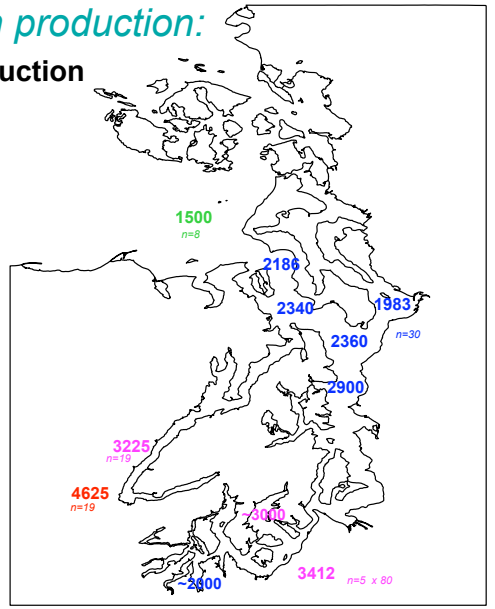


Newton et al., 1995

Hood has high production:

Primary Production
(mg C m^{-2} d^{-1})

>1000-2000
>2000-3000
>3000-4000
>4000-5000

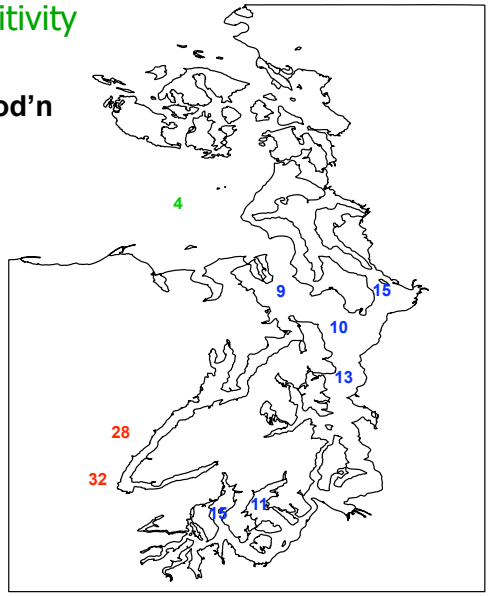


Newton et al., 2000

Nutrient sensitivity

% increase in integrated prod'n

<5
>5-15
>15-25
>25-35



Newton et al., 2000

Hypotheses on possible causes for the lower oxygen concentrations in Hood Canal:

- Changes in production or input of organic matter, due to naturally better growth conditions such as increased sunlight or other climate factors;
- Changes in production or input of organic matter, due to naturally better growth conditions such as increased nutrient availability;
- Changes in production or input of organic matter, due to human-caused loading of nutrients or organic material;
- Changes in ocean properties, such as seawater density that affects flushing of the Canal's waters, oxygen concentration, or nutrients in the incoming ocean water;
- Changes in river input or timing from natural causes (e.g., drought) or from human actions (e.g., diversion) that affect both flushing and mixing in the Canal.
- Changes in weather conditions, such as wind direction and speed, which affect the flushing and/or oxygen concentration distribution.