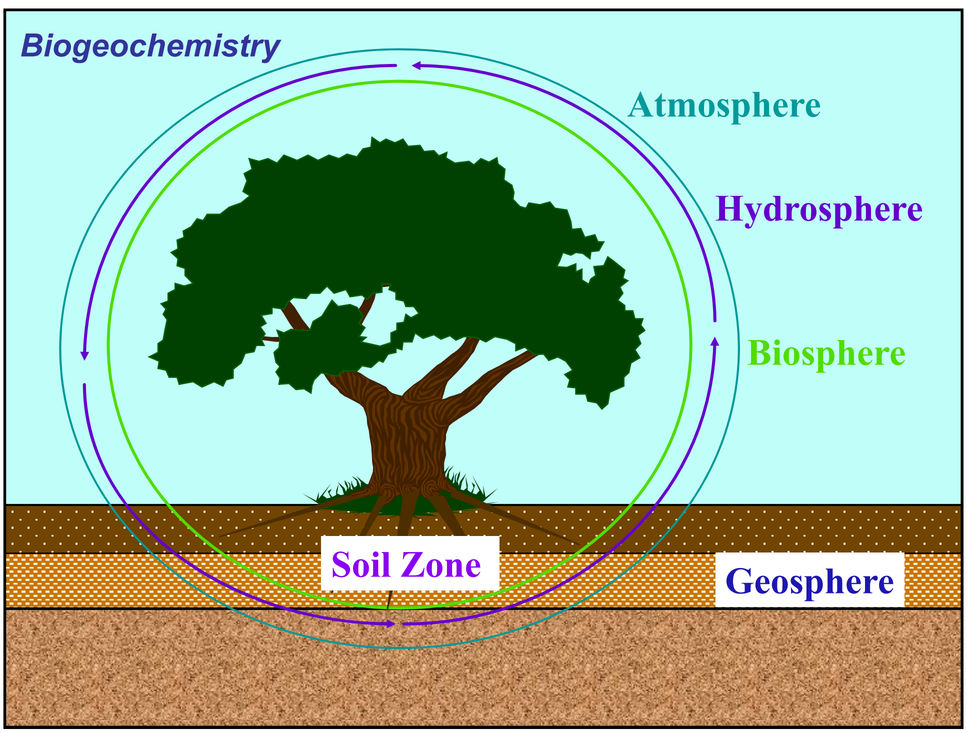
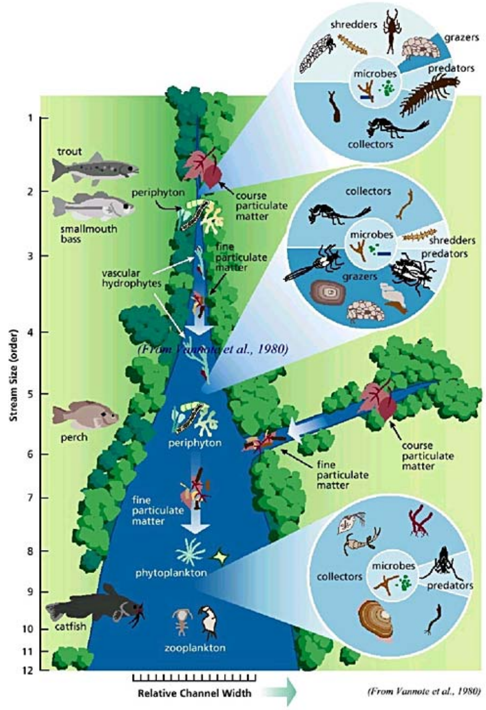
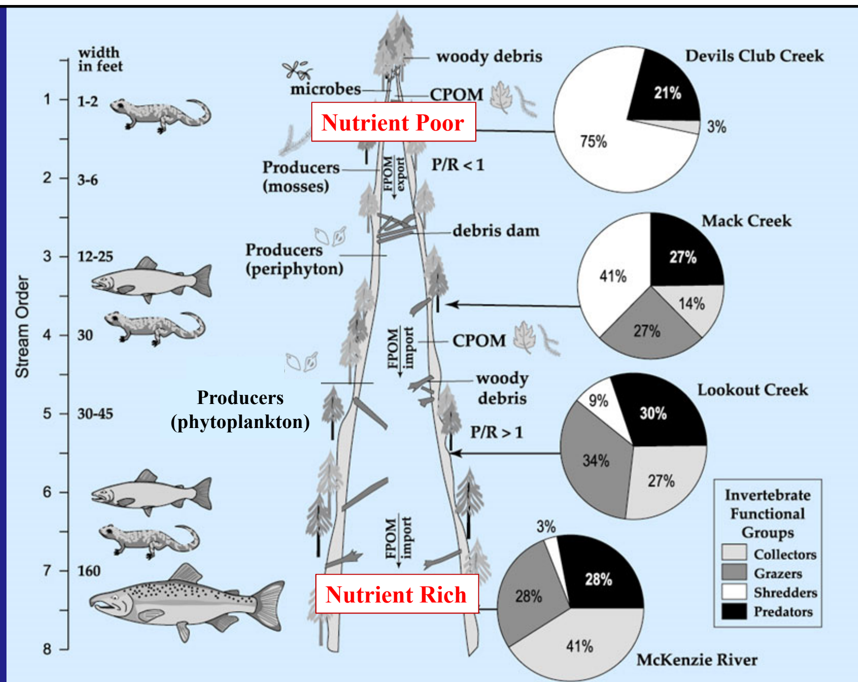

Water Quality Aspects of Aquatic Habitats
Nutrients
Dissolved Oxygen
Temperature
Light - Turbidity
Reliable Flows
Habitat Structure
Pollutants


Biogeochemistry
Atmosphere
Hydrosphere
Biosphere
Soil Zone
Geosphere



River Continuum Concept

As you move from upstream to downstream, the physical (width, depth, velocity, sediment load), chemical (nutrients, pH, specific conductance) and biological (type and availability of food resources and higher level consumers) factors change in a relatively predictable progression.



FPOM is fine particulate organic matter; CPOM is coarse particulate organic matter; P/R is the production/respiration

Nutrients

Nitrogen & Phosphorus

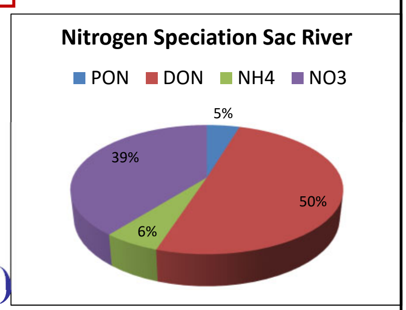
Nitrogen

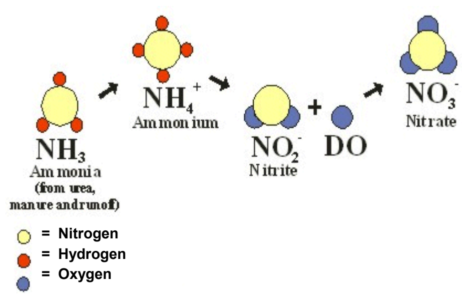
Organic forms

- particulate (PON)
- dissolved (DON)

Ammonium (NH_3/NH_4^+)

Nitrate (NO_3^-)/Nitrite (NO_2^-)





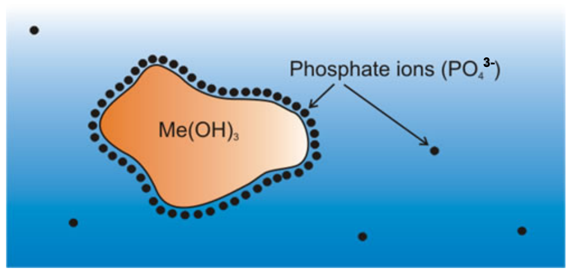
Phosphorus

Organic forms

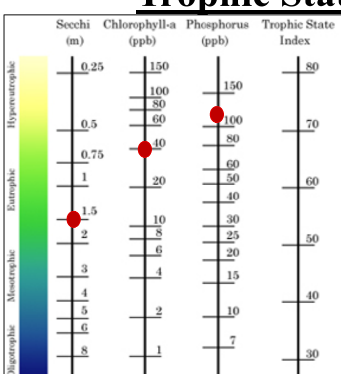
Adsorbed to particles

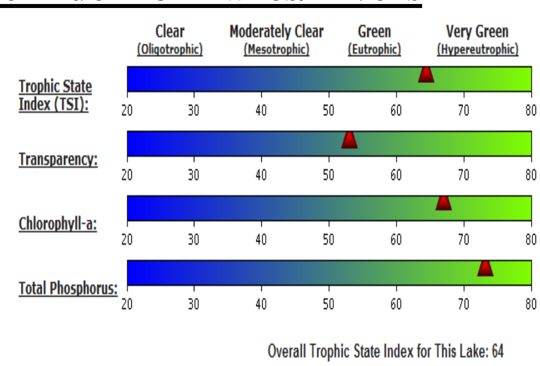
Dissolved phosphate (PO_4^{3-})

Organic P



Trophic State Index for Lakes/Rivers



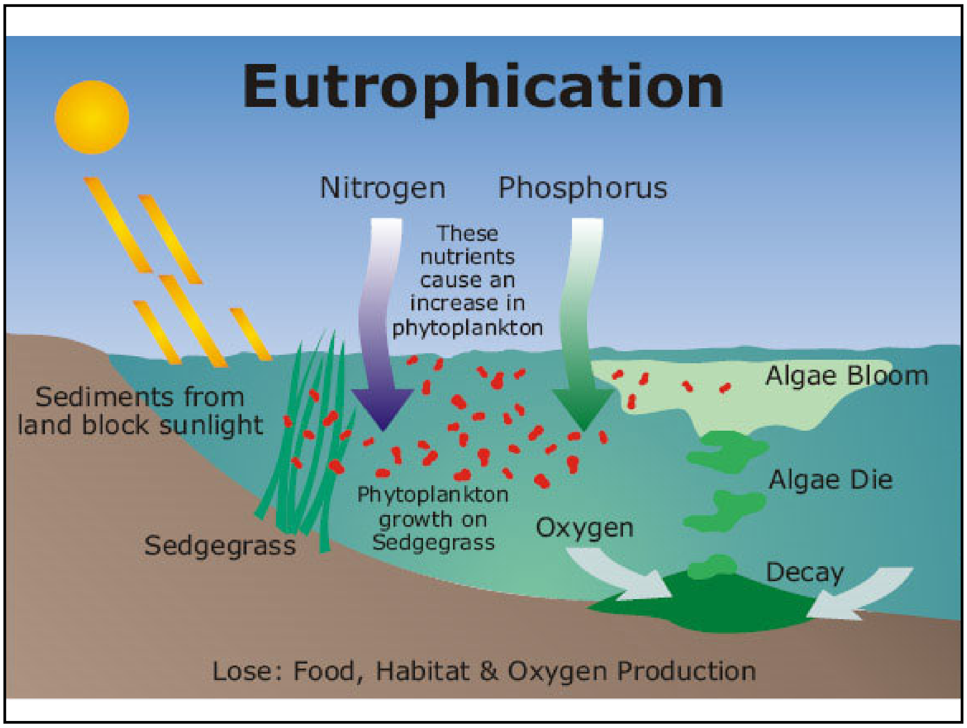


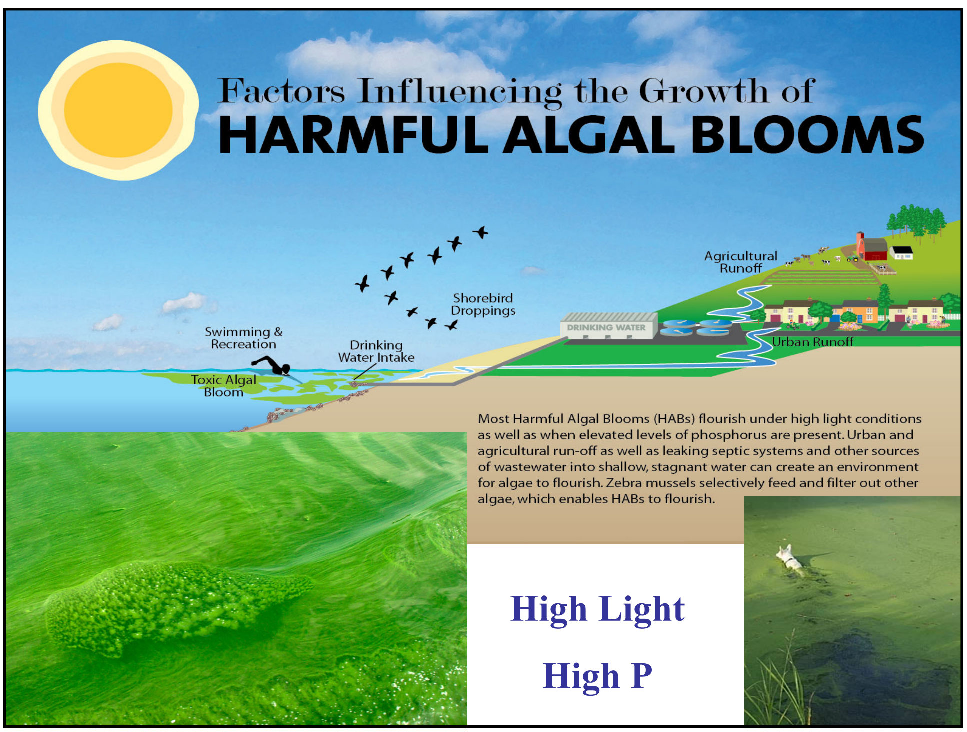
Low
Oligotrophic

Medium
Mesotrophic

High
Eutrophic

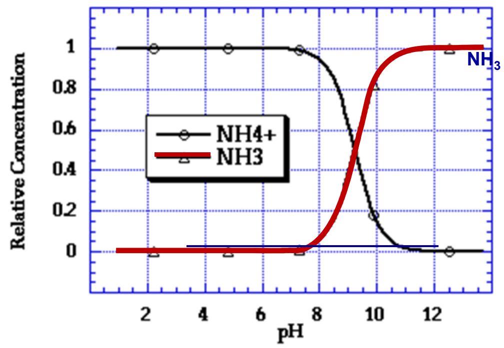
Very High
Hypereutrophic


Eutrophication
Nitrogen
Phosphorus
These nutrients cause an increase in phytoplankton
Algae Bloom
Sediments from land block sunlight
Algae Die
Phytoplankton growth on Sedgegrass
Oxygen
Sedgegrass
Decay
Lose: Food, Habitat & Oxygen Production


Factors Influencing the Growth of
HARMFUL ALGAL BLOOMS
Agricultural Runoff
Shorebird Droppings
DRINKING WATER
Swimming & Recreation
Drinking Water Intake
Urban Runoff
Toxic Algal Bloom
Most Harmful Algal Blooms (HABs) flourish under high light conditions as well as when elevated levels of phosphorus are present. Urban and agricultural run-off as well as leaking septic systems and other sources of wastewater into shallow, stagnant water can create an environment for algae to flourish. Zebra mussels selectively feed and filter out other algae, which enables HABs to flourish.
High Light
High P

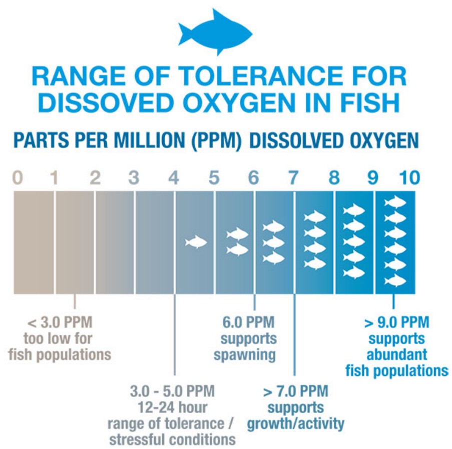
Ammonia (NH_3) Toxicity – Aquatic Ecosystems

Criterion Duration	2013 Final Criteria TAN at pH = 7 & 20 °C
Acute (1-hr average)	**17 mg N/L**
Chronic (30-d rolling average)	**1.9 mg N/L**
TAN = NH_3 + NH_4^+	



Dissolved Oxygen (DO) is the amount of oxygen that is present in the water. It is measured in milligrams per liter (mg/L), or the number of milligrams of oxygen dissolved in a liter of water.

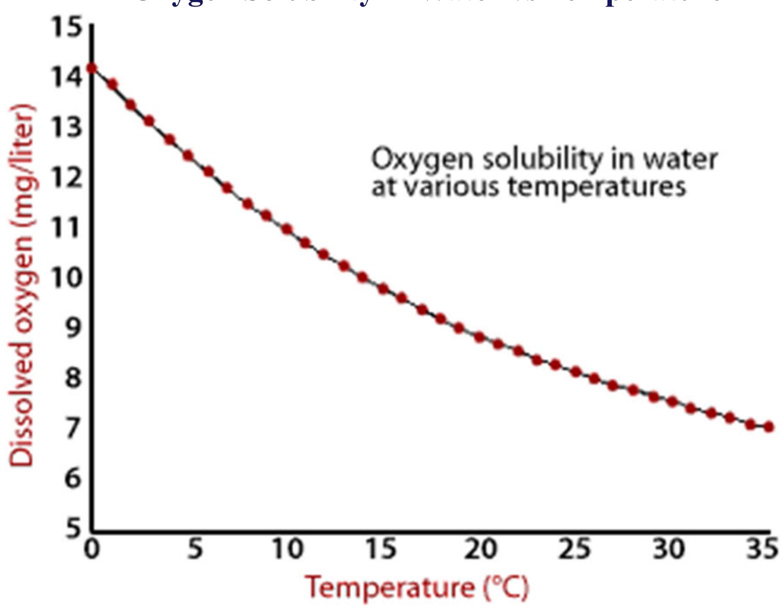
Dissolved Oxygen Stress to Aquatic Organisms



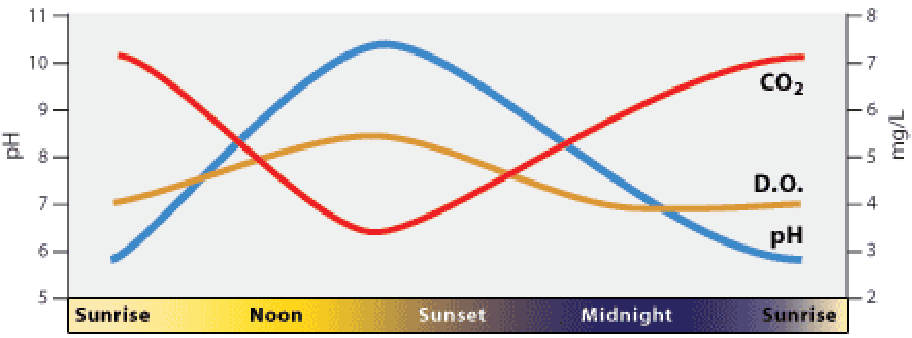
DO Concentration is a function of:

1. Elevation
2. Temperature
3. Salinity
4. Barometric Pressure
5. Time of Day

Oxygen Solubility in Water vs Temperature



Diel Dissolved Oxygen Dynamics



Algae Photosynthesis

HCO_3^- + H_2O → (CH_2O) + O_2 ++ OH^-

Bicarbonate ion	Water	Carbohydrate	Oxygen	Hydroxyl ion

Organic Matter Respiration

$$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O + \text{energy}$$

Respiration →

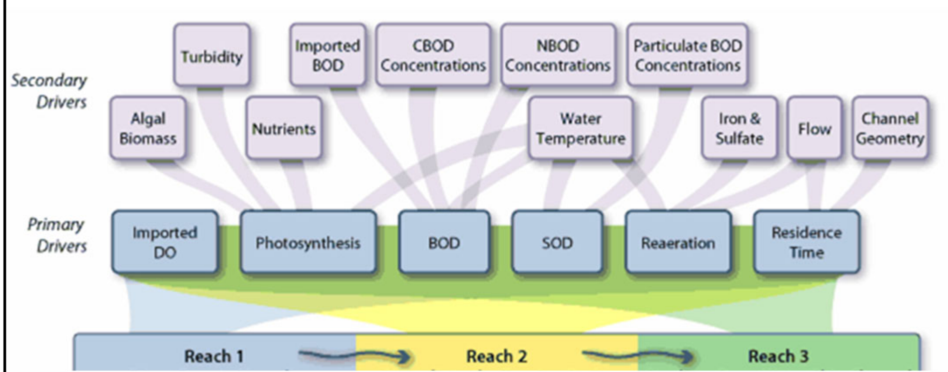
← Photosynthesis

Nitrification

$$2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 2H_2O + 4H$$

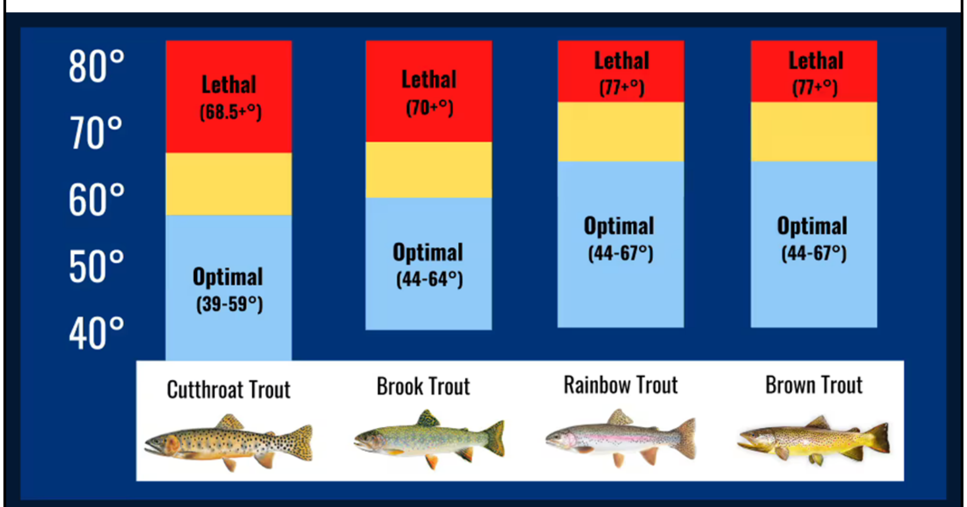
$$2NO_2^- + O_2 \rightarrow 2NO_3^-$$

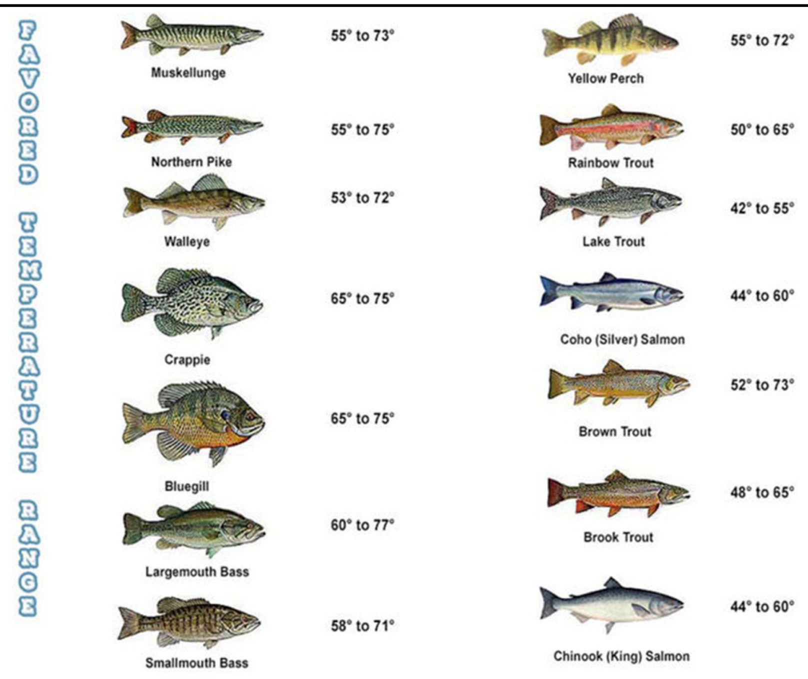
Dissolved Oxygen Conceptual Model for River Systems



Dissolved Oxygen

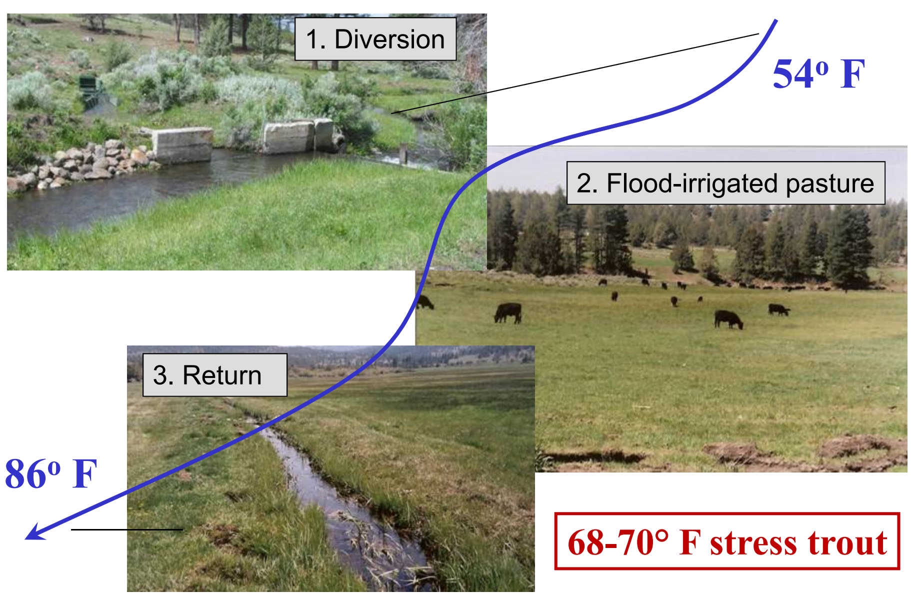
Stream Temperature – Heat Pollution





Source: Bass Pro Shops

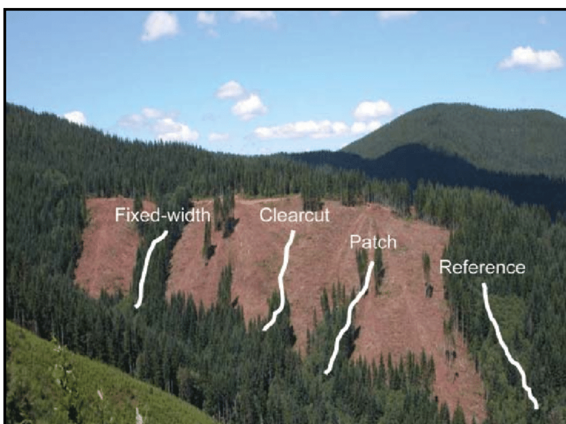
Stream Temperature – Heat Pollution



68-70° F stress trout

Grazing and Stream Temperature

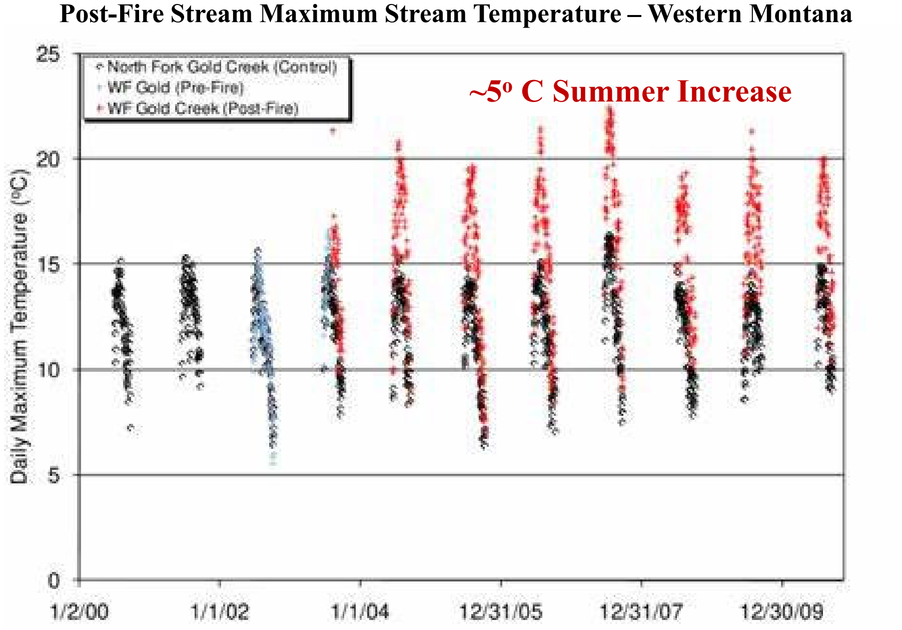
Excessive Grazing ⟶ Reduced Shade

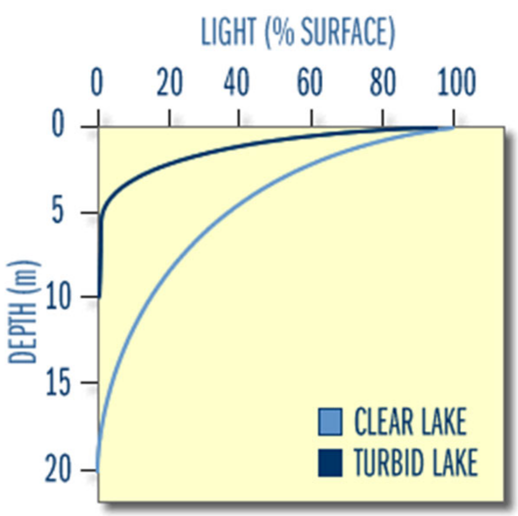


Wildfire Disturbance

Clearcut Harvesting

Post-Fire Stream Maximum Stream Temperature – Western Montana





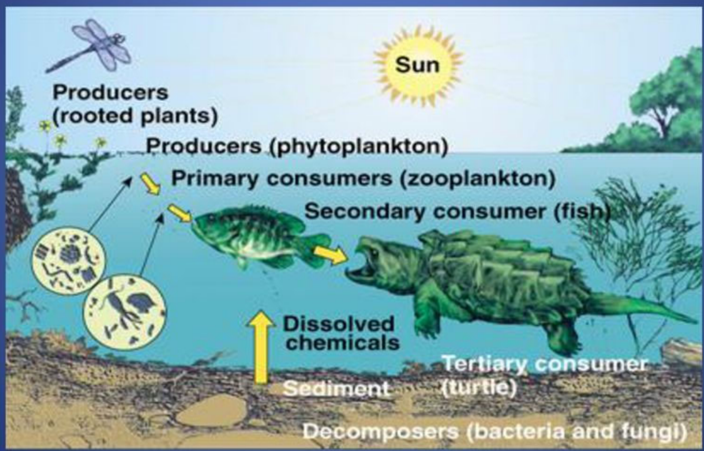
LIGHT VERSUS DEPTH PROFILES FOR A CLEAR LAKE ($k=0.2\ M^{-1}$) AND A TURBID LAKE ($k=0.9\ M^{-1}$).

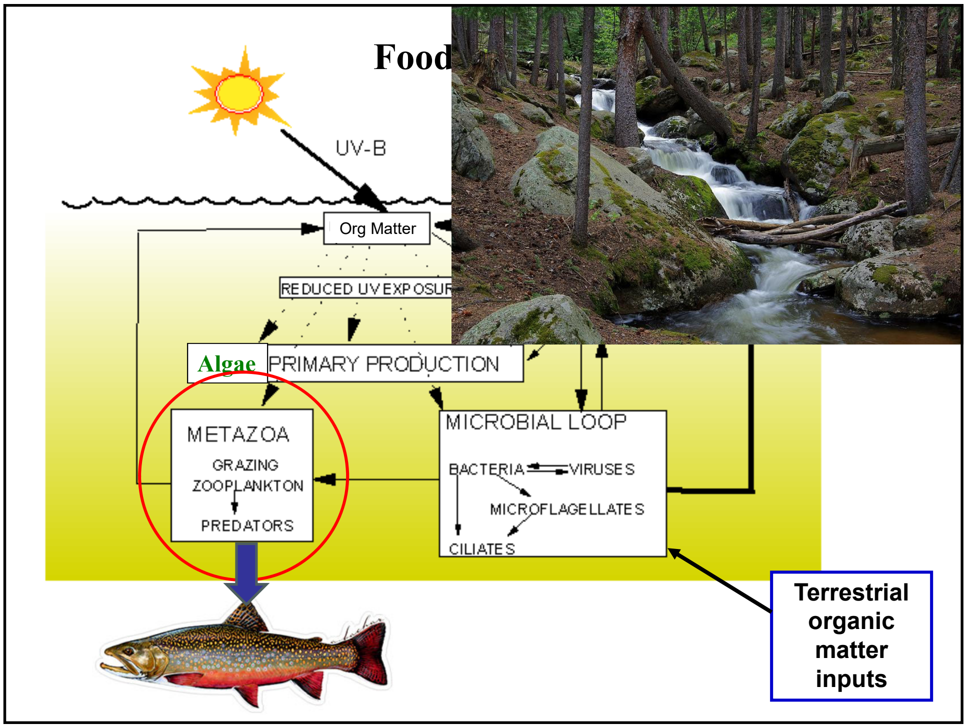
Photic Zone

Depth to 1% light extinction

Major Components of Ecosystems

Major components of aquatic ecosystems.



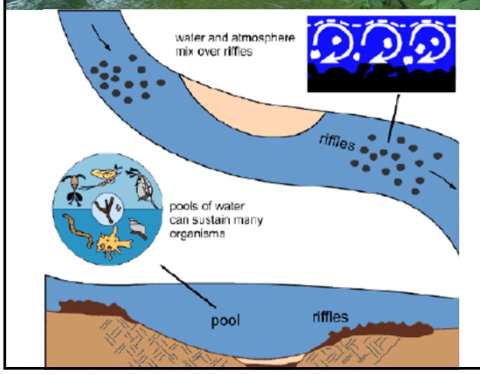


California's Mediterranean Climate

Winter Feast **Summer Famine**

Winter: cold-wet **Summer: warm-dry**

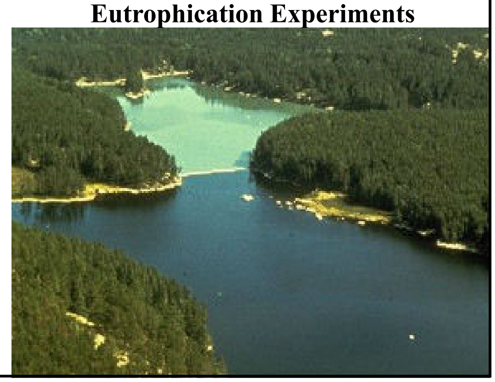
Stream Habitat



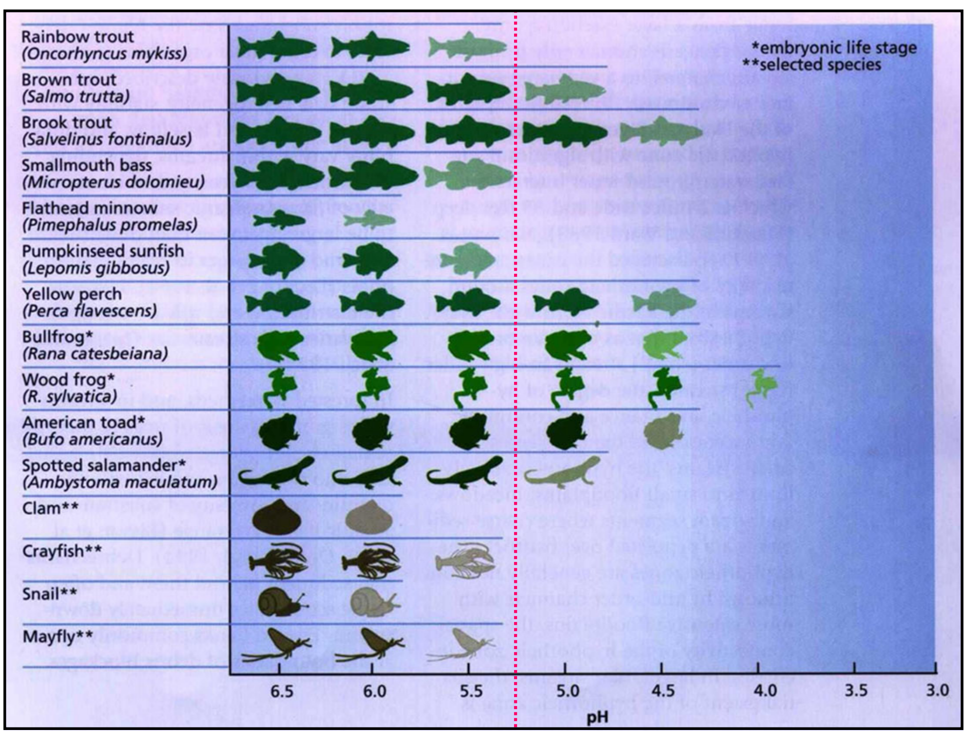
Experimental Lakes Area
Ontario, Canada

David Schindler

Eutrophication Experiments



Lake Acidification in Canada
Non-acidified
Adding sulfuric acid
Acidified
A starving lake trout captured in acidified Lake 223 when the pH was 5.1. Most of the trout's food supply had been killed off by the acid.

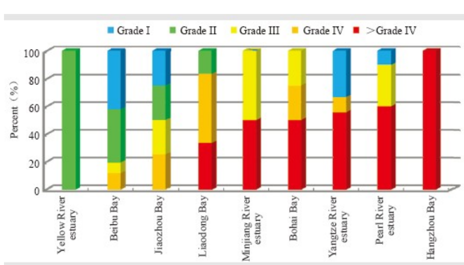


Rainbow trout (Oncorhyncus mykiss)
Brown trout (Salmo trutta)
Brook trout (Salvelinus fontinalus)
Smallmouth bass (Micropterus dolomieu)
Flathead minnow (Pimephalus promelas)
Pumpkinseed sunfish (Lepomis gibbosus)
Yellow perch (Perca flavescens)
Bullfrog* (Rana catesbeiana)
Wood frog* (R. sylvatica)
American toad* (Bufo americanus)
Spotted salamander* (Ambystoma maculatum)
Clam**
Crayfish**
Snail**
Mayfly**
*embryonic life stage
**selected species
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
pH

Adding lime to increase the pH of lakes in northern USA

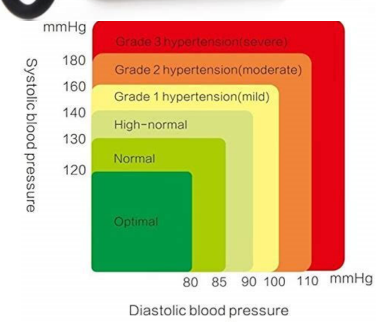
$CaCO_3$ (lime) + H_2O = Ca^{2+} + HCO_3^- + OH^- base

Water Quality Monitoring

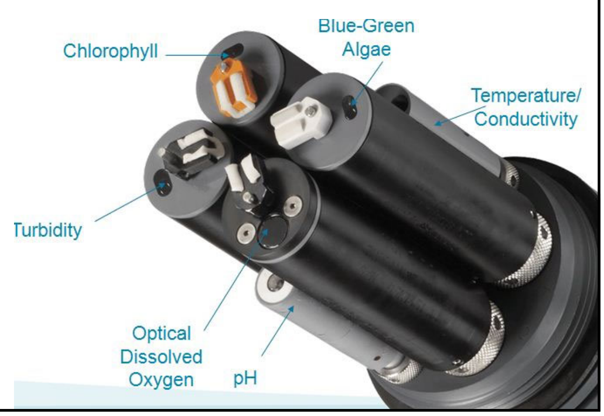


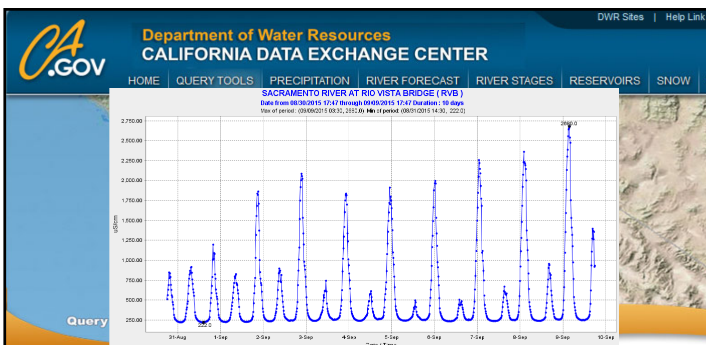
Water quality of important estuaries and bays in 2011

Blood Pressure Monitoring



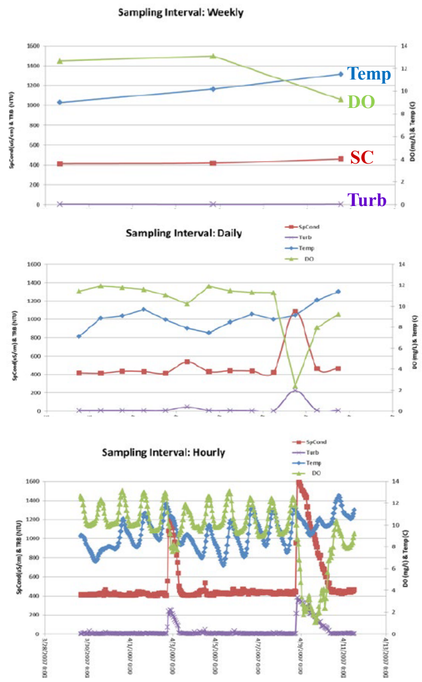
Water Quality Sondes





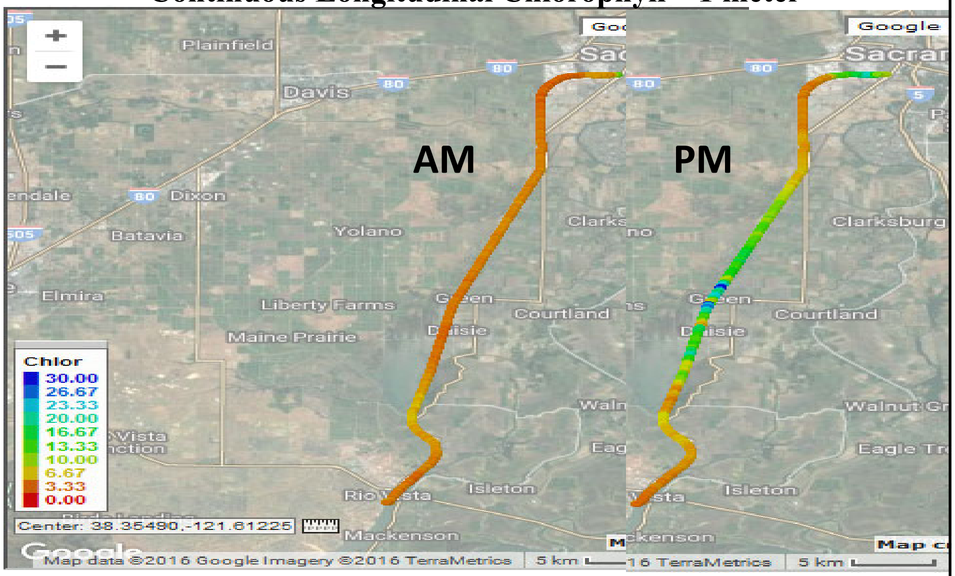
SACRAMENTO RIVER AT RIO VISTA BRIDGE *(RVB)*

Date / Time	RIV STG	TEMP	WIND SP	WIND DR	EL COND	CHLORPH	PH VAL	TEMP W	TURB W	DIS OXY	SOLAR R
(PST)	FEET	DEG F	MPH	DEG	uS/cm	ug/L	PH	DEG F	NTU	MG/L	W/M^2
03/10/2016 07:00	5.70	56	3	169	171	4.90	7.4	54.2	38.60	8.9	21.00
03/10/2016 08:00	5.11	56	4	151	143	4.90	7.3	53.2	46.50	9.1	77.10
03/10/2016 09:00	4.56	56	9	152	138	6.30	7.4	53.4	41.20	9.1	115.10
03/10/2016 10:00	4.08	58	4	107	140	5.80	7.4	53.5	39.20	8.9	111.80
03/10/2016 11:00	3.68	59	8	129	140	4.40	7.4	53.6	44.00	9.0	250.40
03/10/2016 12:00	3.71	60	5	163	149	4.60	7.5	53.9	41.80	9.1	148.20
03/10/2016 13:00	4.66	61	6	165	167	5.40	7.5	54.0	40.50	9.1	161.60
03/10/2016 14:00	5.57	61	4	179	168	5.30	7.5	54.1	39.30	9.2	131.20
03/10/2016 15:00	6.34	60	5	186	166	4.30	7.5	54.0	40.10	9.1	30.30
03/10/2016 16:00	6.79	59	4	182	163	5.10	7.5	53.9	40.30	9.2	40.40
03/10/2016 17:00	6.90	59	2	166	161	5.40	7.5	53.9	39.20	9.0	6.30
03/10/2016 18:00	6.45	57	4	182	160	4.70	7.5	53.9	38.60	9.0	1.00

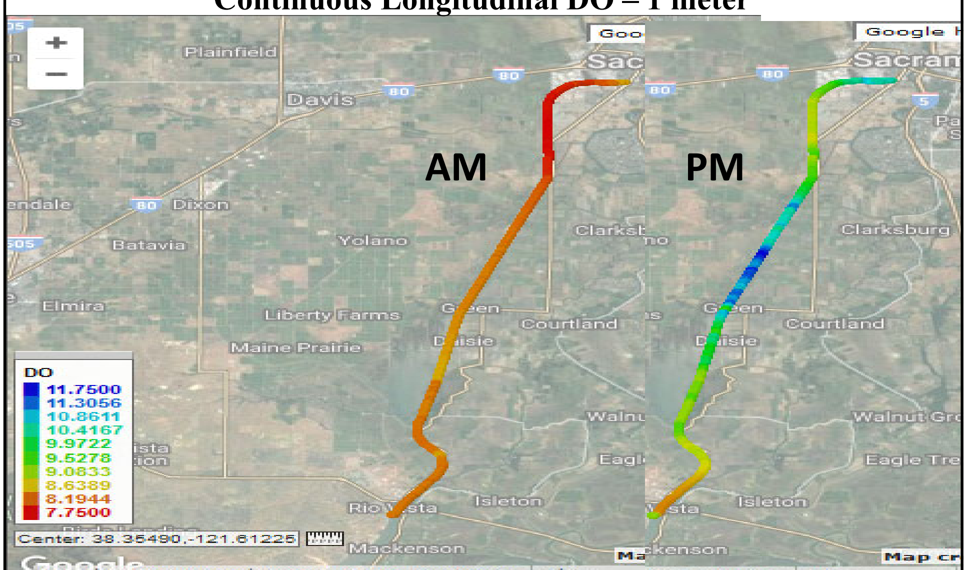


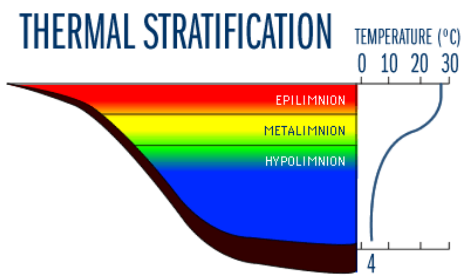
Resolution Evolution

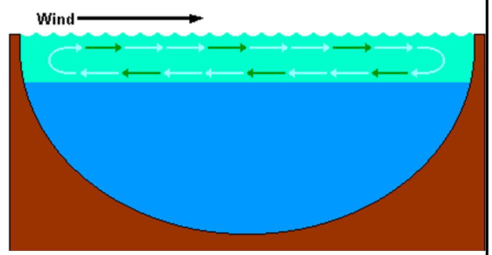
Continuous Longitudinal Chlorophyll – 1 meter

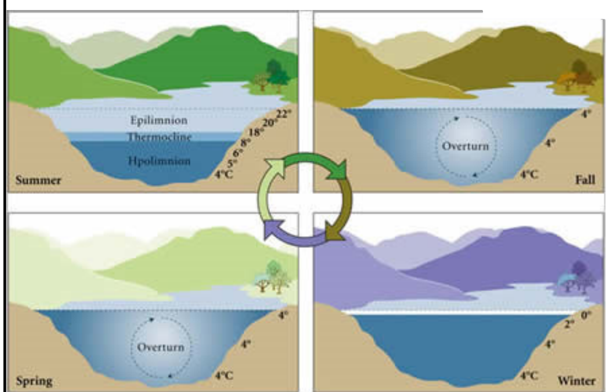


Continuous Longitudinal DO – 1 meter



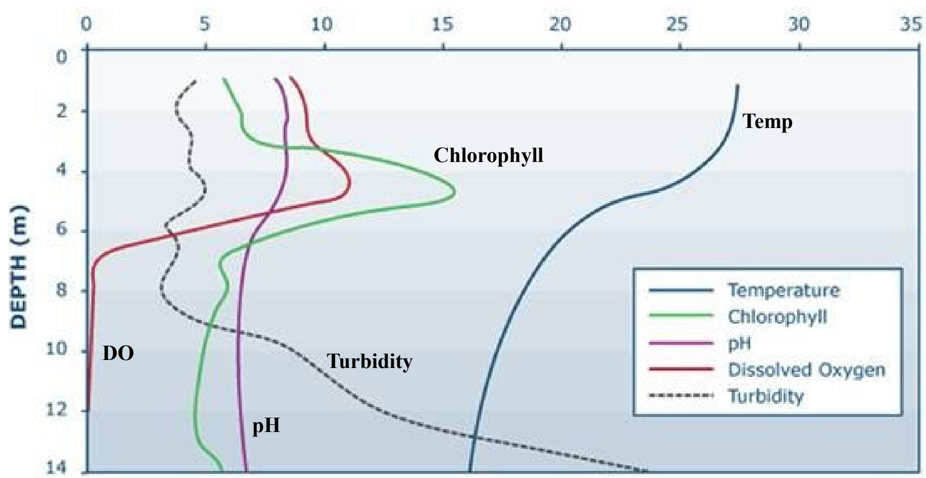






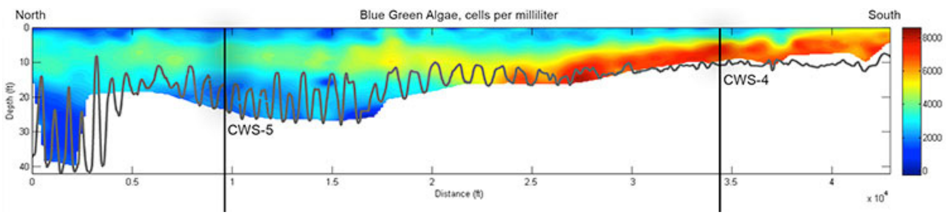
Lake/Reservoir Vertical Stratification

Water Quality Patterns with Depth During Stratification



Three-dimensional mapping of reservoirs using an AUV to identify location and conditions for elevated chlorophyll and blue-green algae concentrations

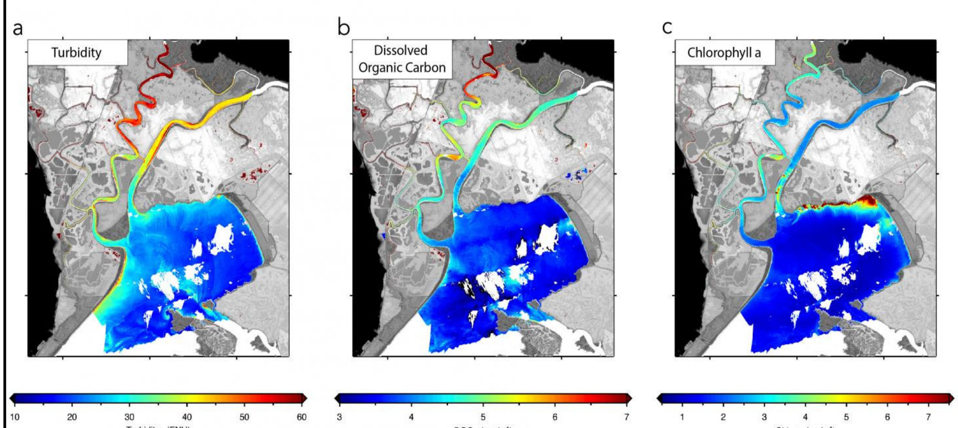
Downstream ← Upstream



Autonomous Underwater Vehicle (AUV)

http://sc.water.usgs.gov

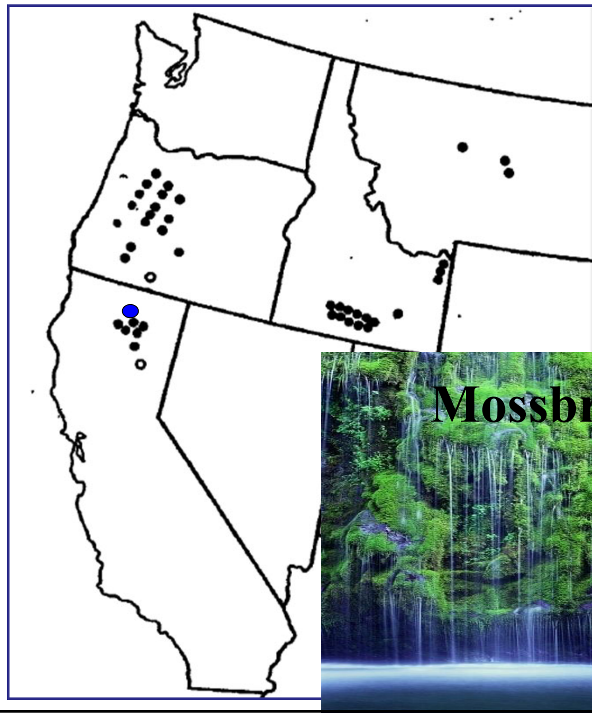
High-resolution Remote Sensing of water quality



From Subduction to Salmon: Geologic Subsidies Drive High Productivity of Volcanic Spring-Fed River

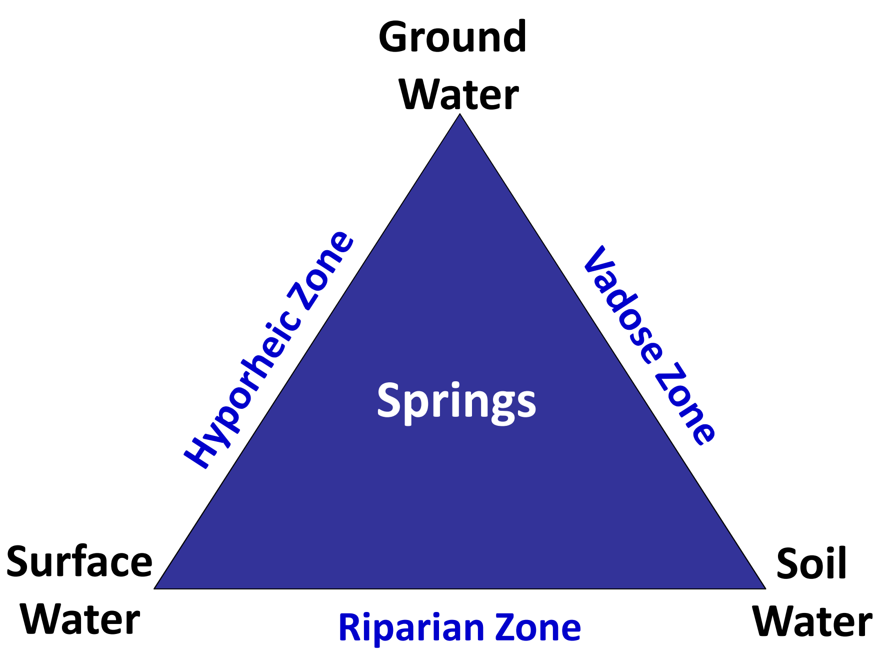
Randy Dahlgren
Land, Air and Water Resources
University of California - Davis

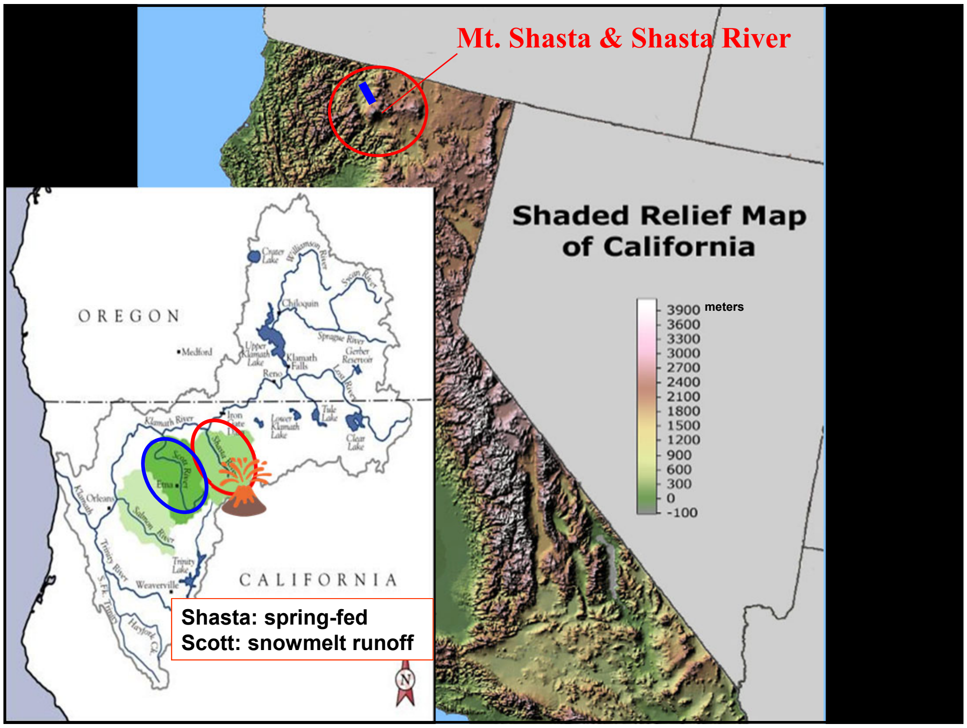
Carson Jeffres, Andrew Nichols, Rob Lusardi,
Mike Deas, Jeffery Mount & Peter Moyle



Large springs in the western USA (>100 cfs)

Meinzer, 1927

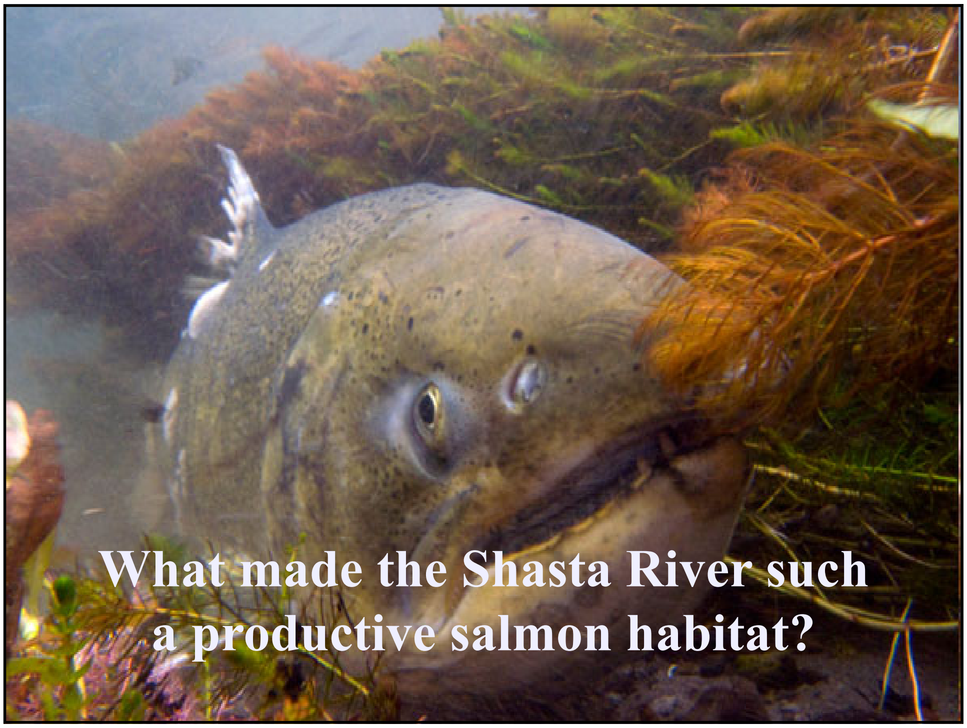




Historic Salmon Production

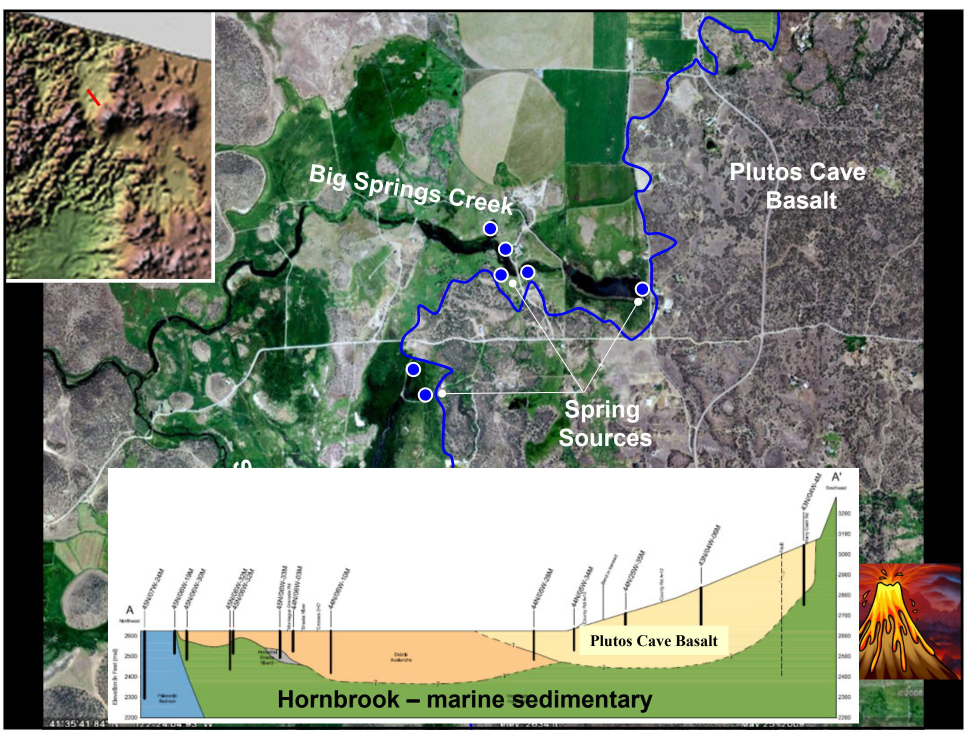
During the 1920-30’s, the Shasta River had 50% of the Chinook salmon in the entire Klamath Basin and produced <1% of the water.

Adult returns over 80,000 when first counted in 1930


What made the Shasta River such a productive salmon habitat?


Mt. Shasta Stratovolcano
Elevation 4317 m – 10 Glaciers
~133 million m^3 of water storage
amorahquanyin.com


Big Springs Complex
Shasta River
Springs contribute >70% of summer streamflow

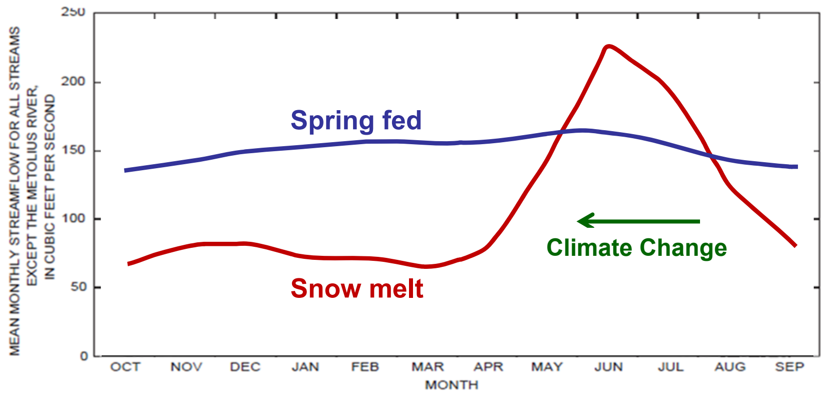

Big Springs Creek
Plutos Cave
Basalt
Spring
Sources
Plutos Cave Basalt
Hornbrook – marine sedimentary

Big Springs Water Characteristics

- Mean recharge elevation: ~ 2,880 m
  - elevation based on $H_2{}^{18}O$
  - outflow temperature: 11^o C
  - slightly thermal spring
- Mean water age: 30 years (range 25 - 44 yr)
  - tritium-helium dating
  - a deep, long, regional groundwater flowpath

Spring-fed vs Snow-melt Stream Hydrographs

(Spring-Fed Deschutes River)

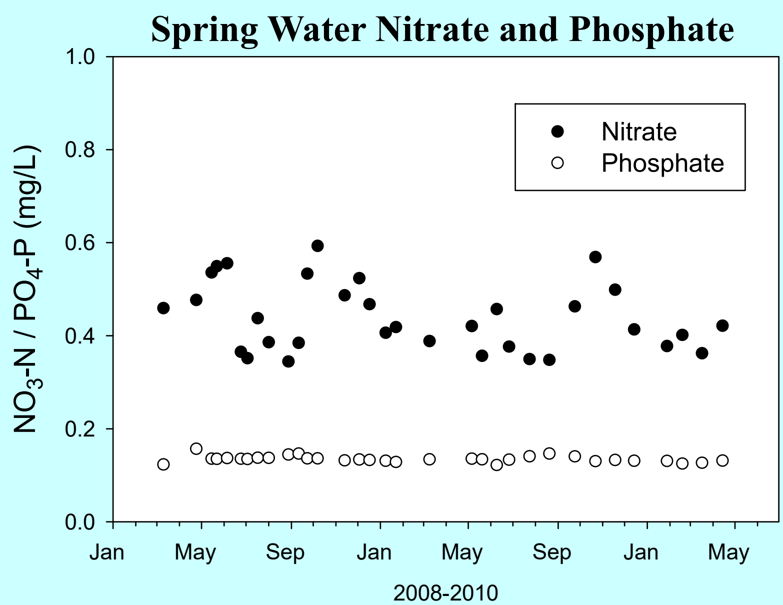


http://or.water.usgs.gov/projs_dir/deschutes_gw/

Big Springs Nutrients

- PO_4-P: ~0.15 mg/L
  - 16 kg P/d
- NO_3-N: ~0.48 mg/L
  - 51 kg N/d

(~N load of 100 returning Chinook salmon)



Equilibrium with Hydroxyapatite

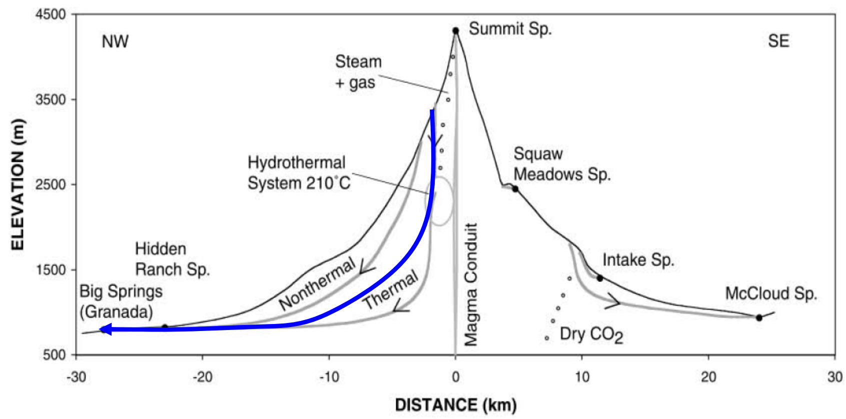
$$Ca_{10}(PO_4)_6(OH)_2 \rightleftharpoons 10Ca^{2+} + 6PO_4^{3-} + 2OH^-$$

$pK_3 = 12.3$: $PO_4^{3-} \rightleftharpoons HPO_4^{2-}$; $OH^- \rightleftharpoons 2H_2O$

$pK_2 = 7.2$: $HPO_4^{2-} \rightleftharpoons H_2PO_4^-$

$pK_1 = 2.1$: $H_2PO_4^- \rightleftharpoons H_3PO_4$

Mt. Shasta Hydrothermal System

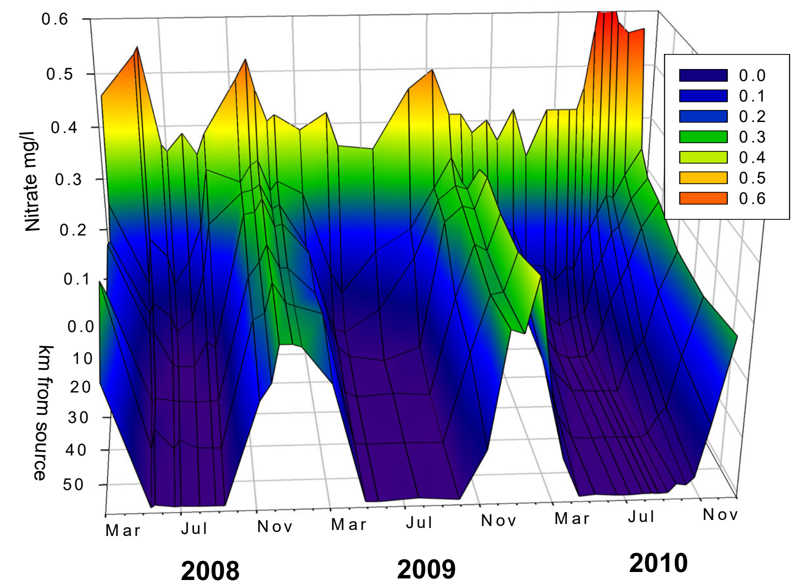


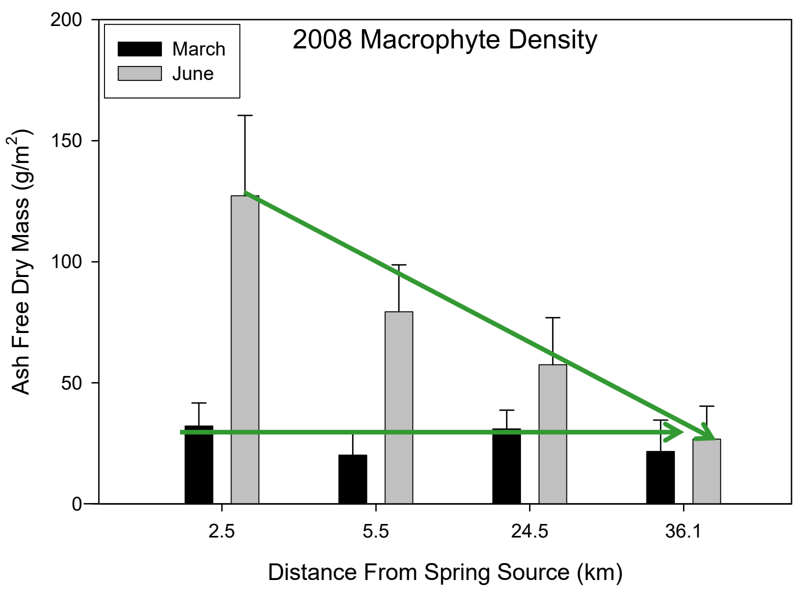
Thermal regime mobilizes sedimentary bound nitrogen

Nathenson et al. 2003
J Volcanology & Geothermal Res.

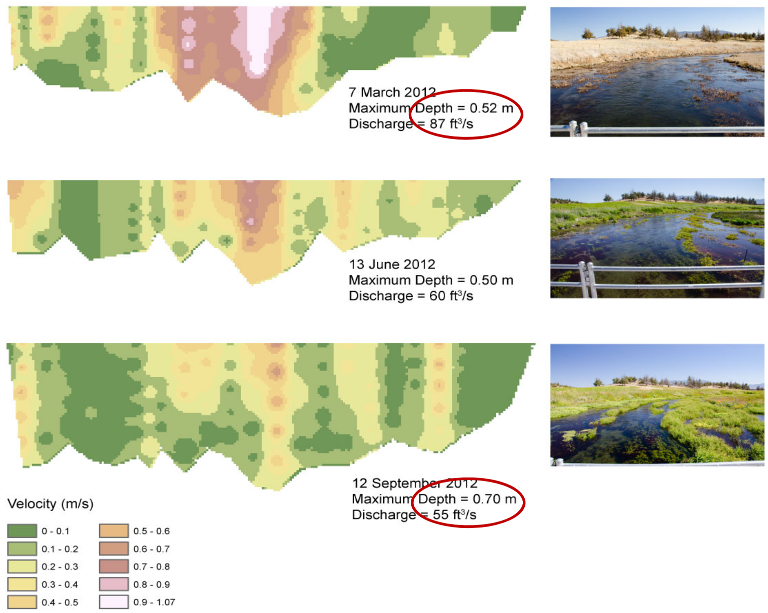
Habitat diversity
Velocity refuge
Increased stage
Shading of water column
Food web – 1º productivity

Nitrate Transport Downstream from Big Springs

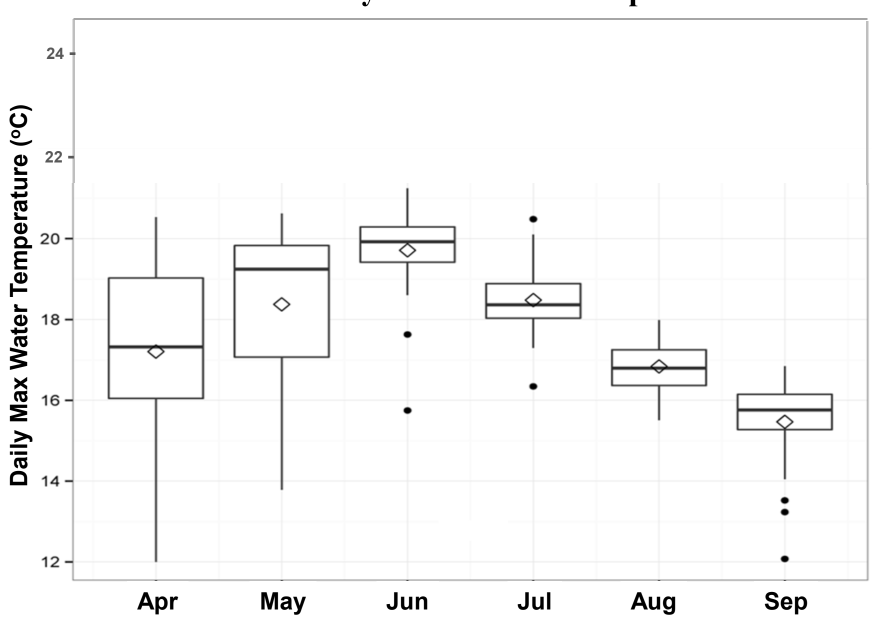




Stream Velocity in Cross-Section



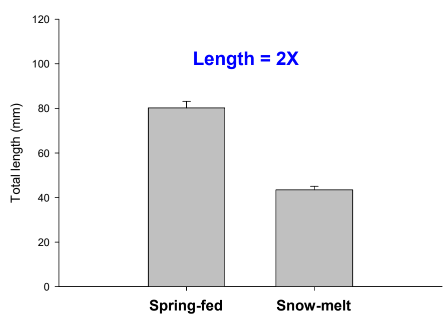
Maximum Daily Streamwater Temperatures

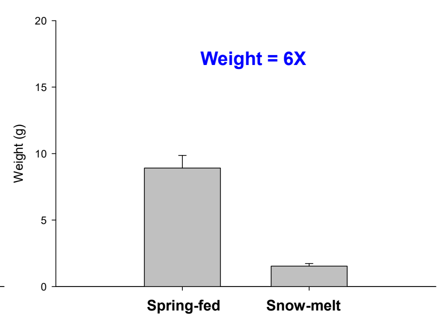


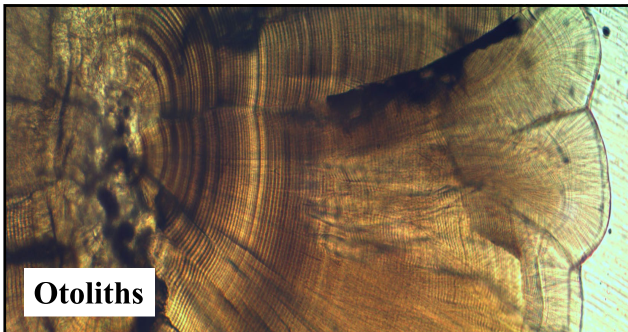
Primary Productivity

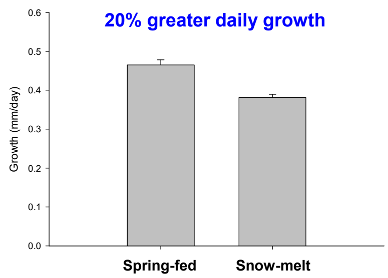
- Nutrients increase primary productivity
- Macro-invertebrate densities in excess of 100,000 individuals / m^2

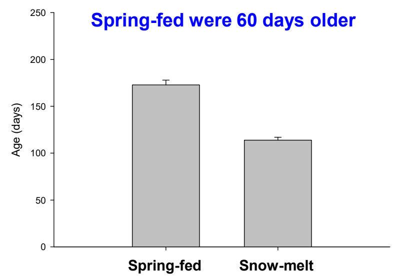
Steelhead collected in Shasta River (<u>spring-fed</u>) and Scott River (<u>snow-melt</u>) in September



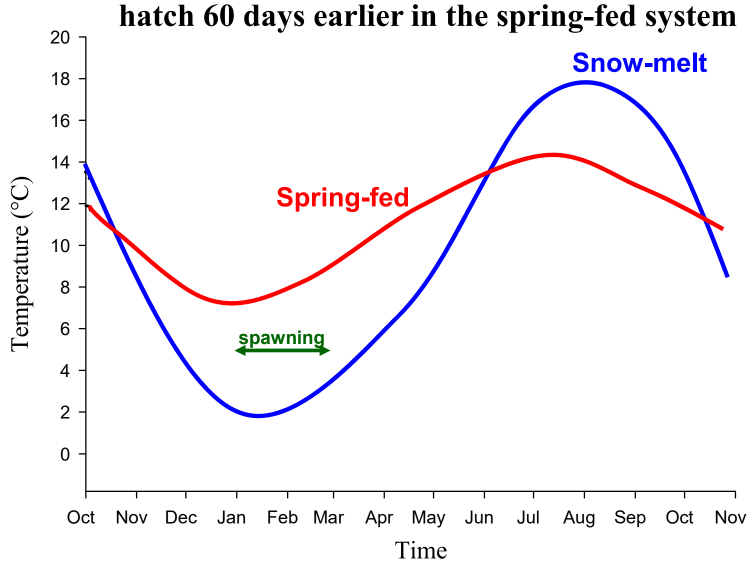




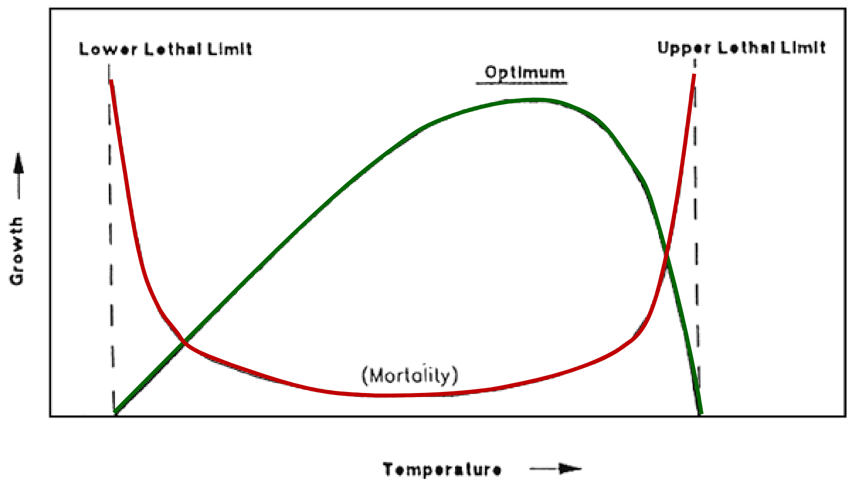




Warmer water temperatures allowed the eggs to hatch 60 days earlier in the spring-fed system



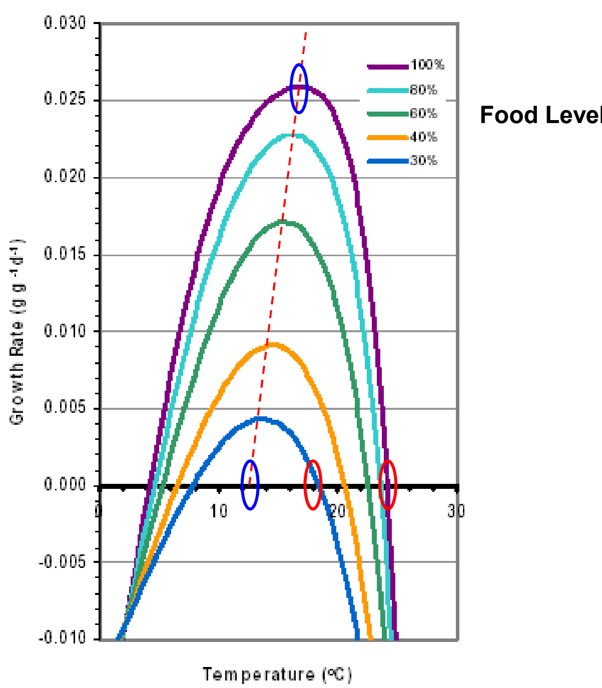
Temperature vs Growth vs Mortality



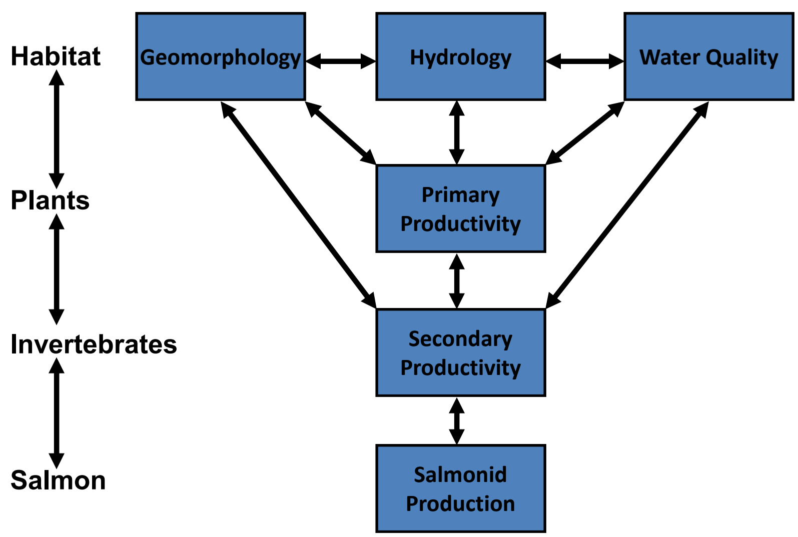
Optimum: 12 vs 16 °C

Lethal: 18 vs 24 °C

With more food, salmonids can survive higher water temperatures



What makes these volcanic spring-fed systems so productive?



Water Analysis Report

CRYSTAL GEYSER NATURAL ALPINE SPRING WATER — BOTTLED AT THE SOURCE

Spring Water
Finished Product
Weed / Shasta Source
Analysis Report 2010

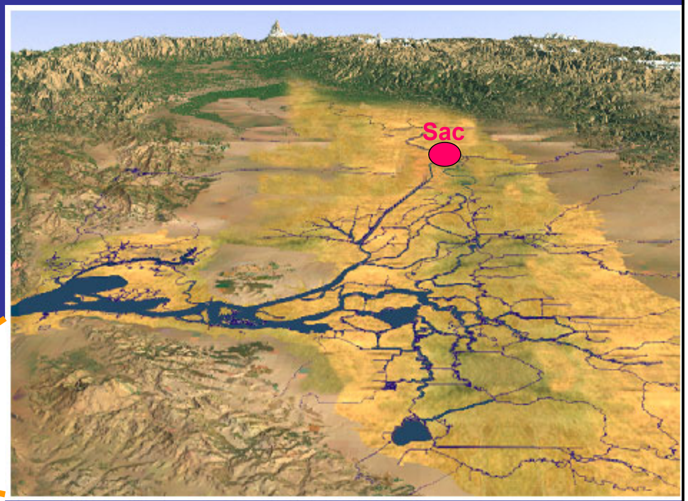
Bottled at the Source

WEED PLANT

ANALYSIS PERFORMED	MCL (mg/L)	RL (mg/L)	SPRING FINISHED PRODUCT (Produced from Shasta Spring Source)
Nitrate – N	10	0.05	0.15 – 0.64
Nitrite – N	1.0	0.05	ND
Ammonia – N	--	0.05	0.074 – 0.088
Orthophosphate	--	0.10	0.14 – 0.24

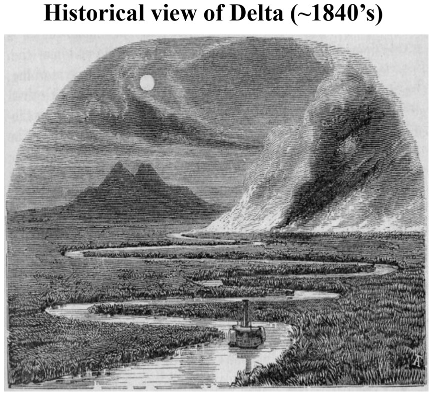
http://www.crystalgeyserasw.com/docs/Bottled_Water_Report_Shasta.pdf

Sacramento-San Joaquin Delta



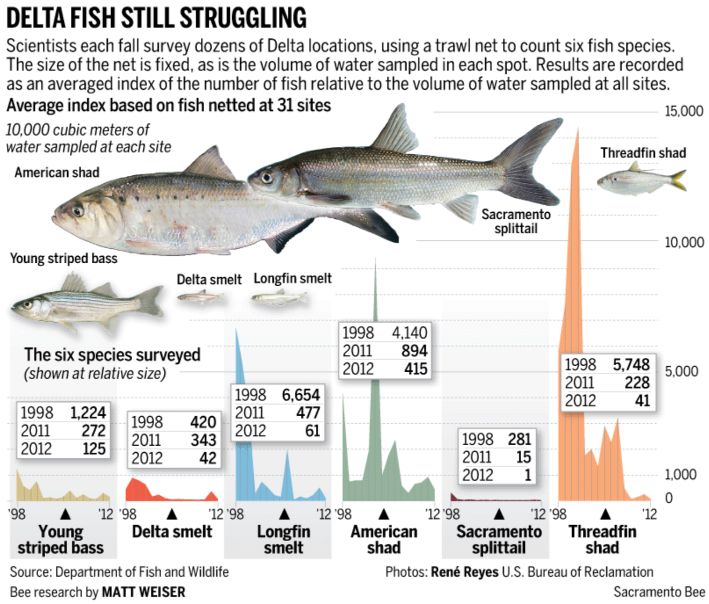
The Hub of California's Water Supply!

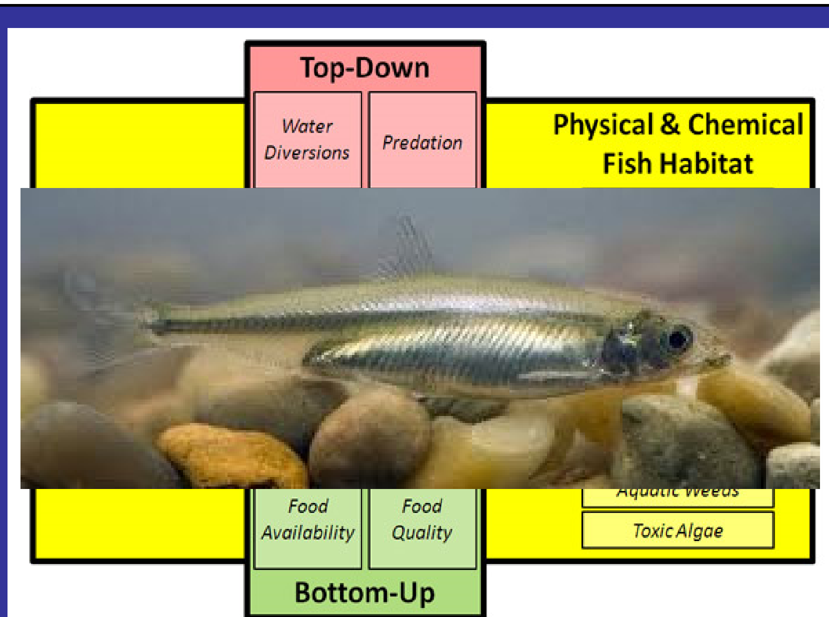
Historical view of Delta (~1840's)



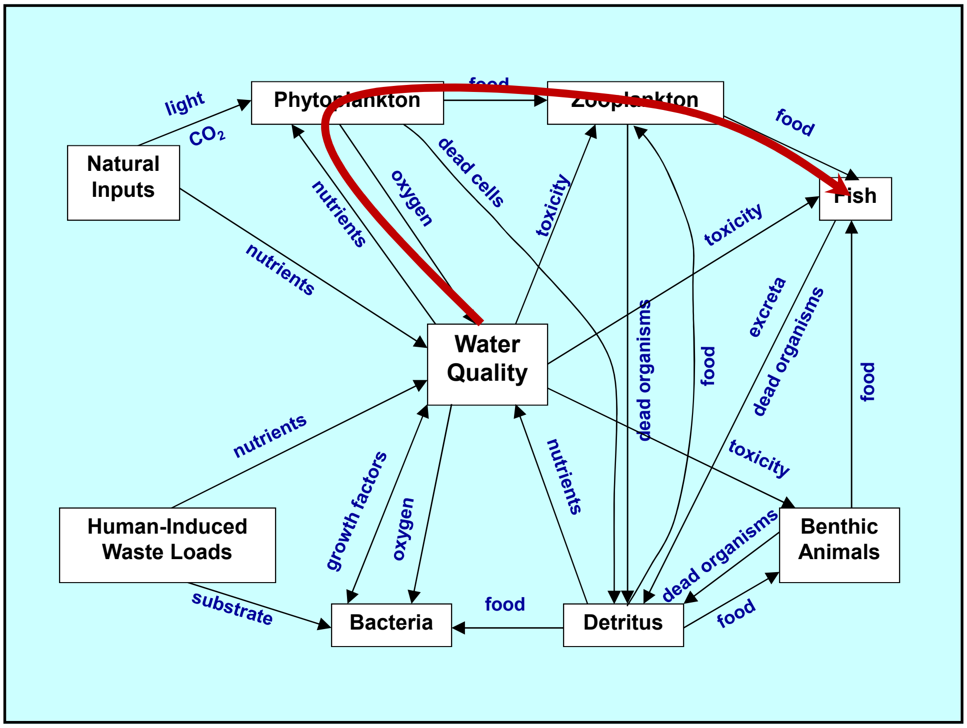
Delta today: Wetlands have been drained for agriculture and aquatic habitat has been lost

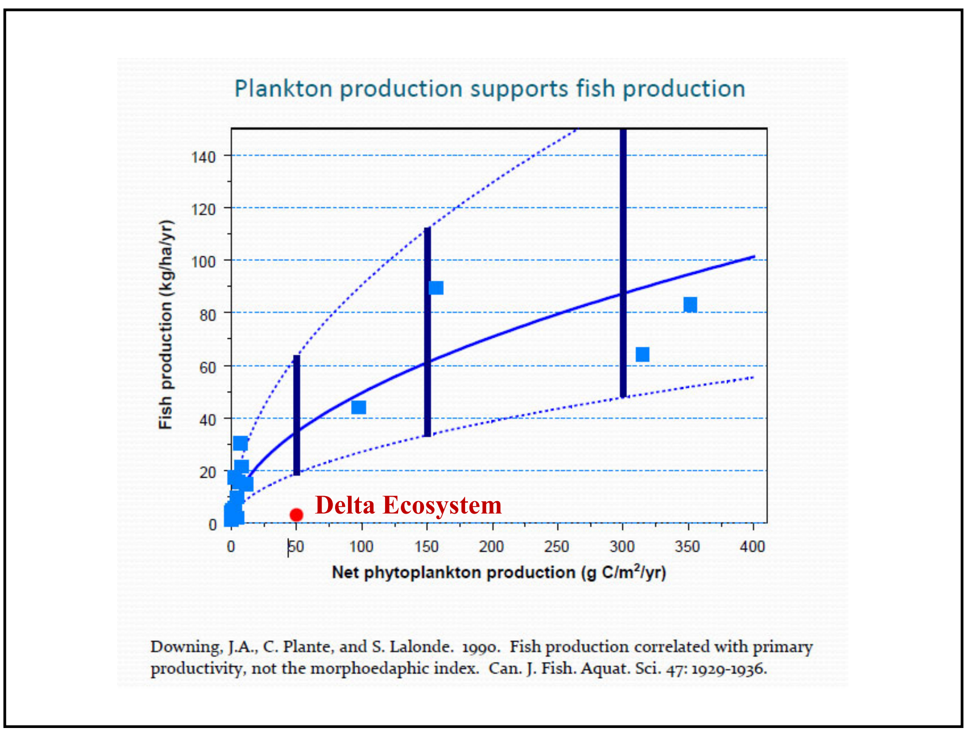
An Ecosystem in Crisis



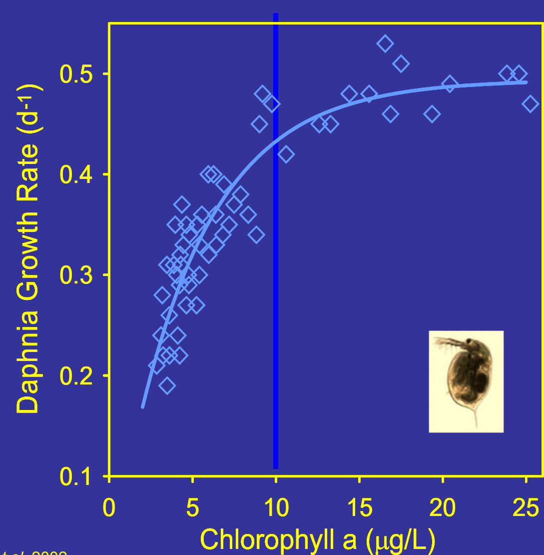


From: Sommer *et al.* 2007


Phytoplankton
Zooplankton
Natural Inputs
Fish
Water Quality
Human-Induced Waste Loads
Bacteria
Detritus
Benthic Animals
light
CO_2
food
nutrients
oxygen
dead cells
toxicity
dead organisms
excreta
growth factors
substrate


Plankton production supports fish production
Fish production (kg/ha/yr)
Net phytoplankton production (g C/m²/yr)
Delta Ecosystem
0
20
40
60
80
100
120
140
50
150
200
250
300
350
400
Downing, J.A., C. Plante, and S. Lalonde. 1990. Fish production correlated with primary productivity, not the morphoedaphic index. Can. J. Fish. Aquat. Sci. 47: 1929-1936.

Zooplankton growth vs. phytoplankton biomass



From: Mueller-Solger *et al.* 2002

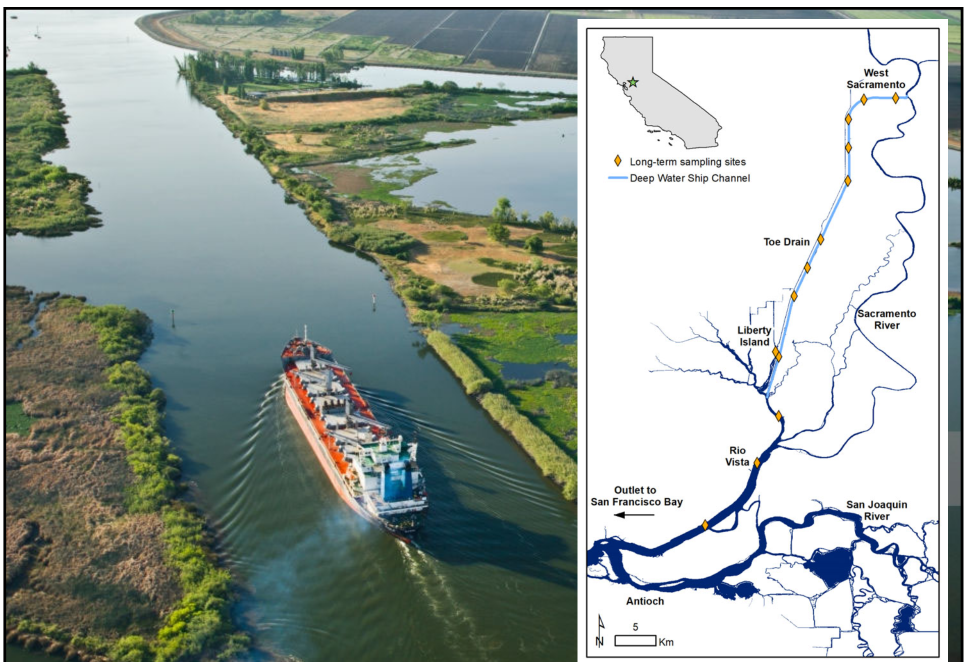
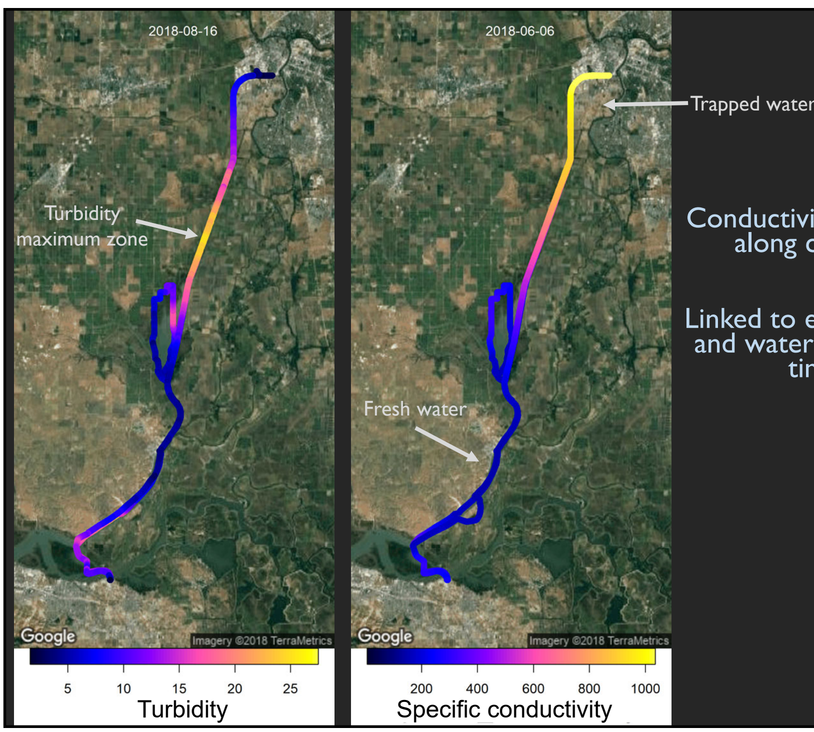


Image Credit: Bill and Brigitte Clough

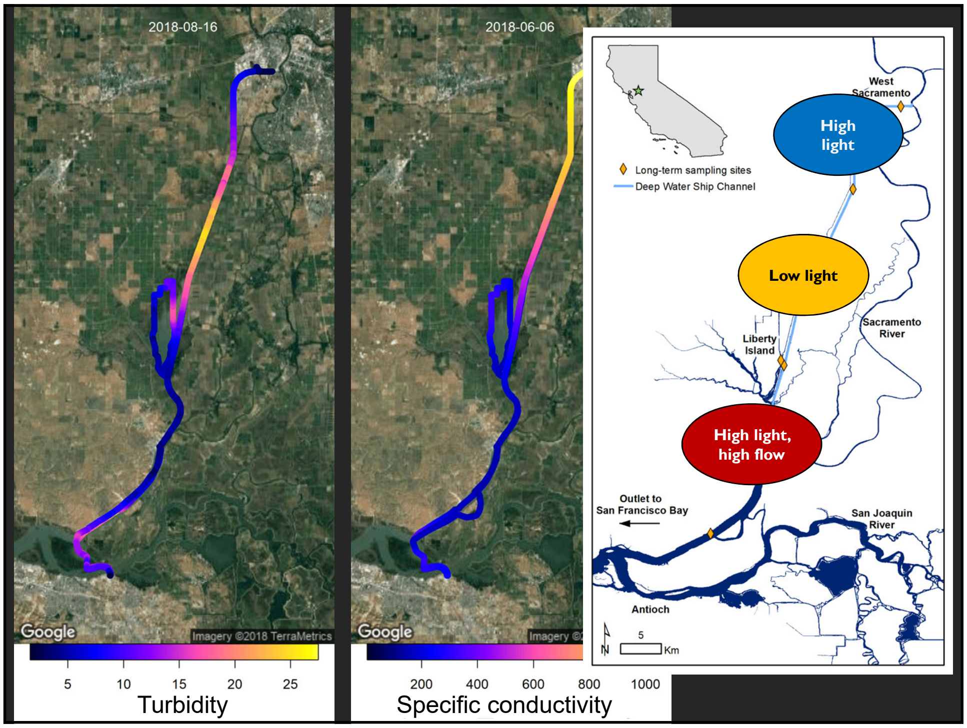
Ecosystem-Based Management of Ship Channel

Image credit: www.cityofwestsacramento.org, Jassby et al. 2002

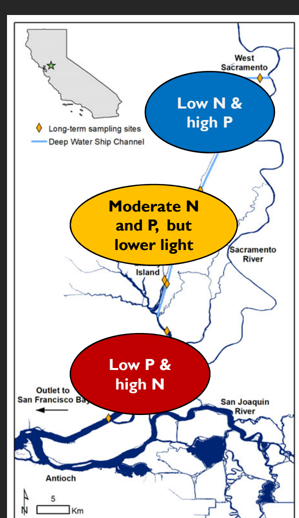


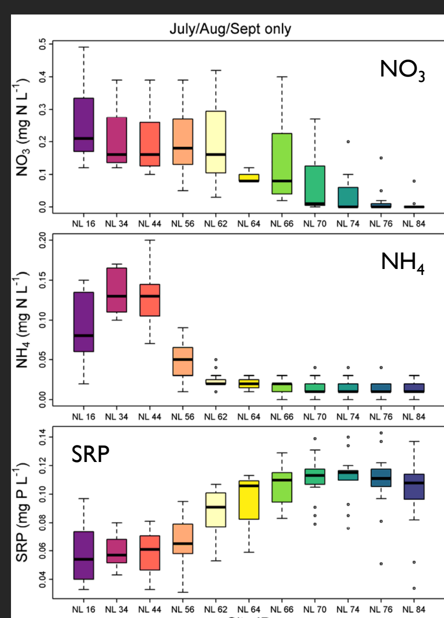
Conductivity gradient along channel

Linked to evaporation and water residence time



Summer conditions



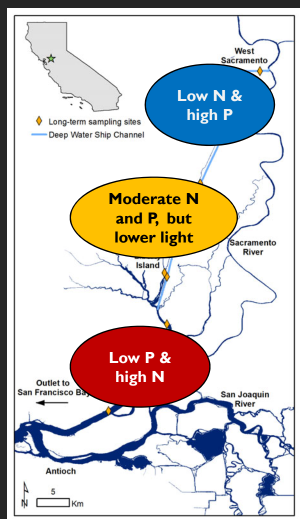


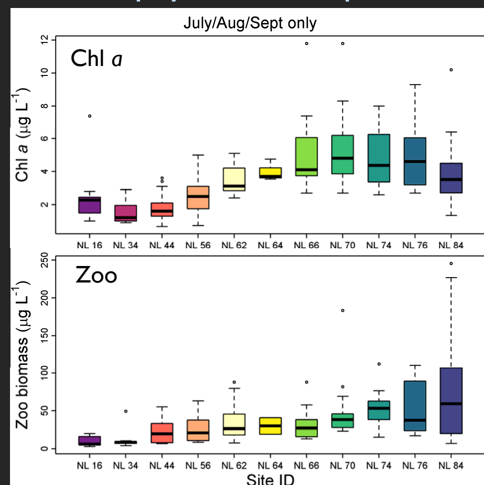
downstream

upstream

Summer conditions

Chlorophyll and Zooplankton

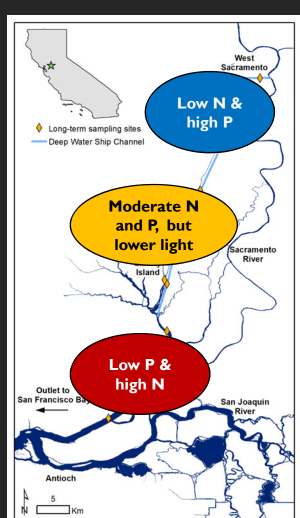




downstream

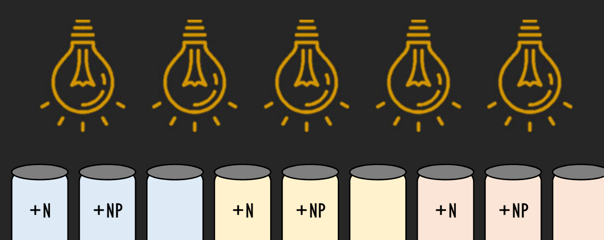
upstream

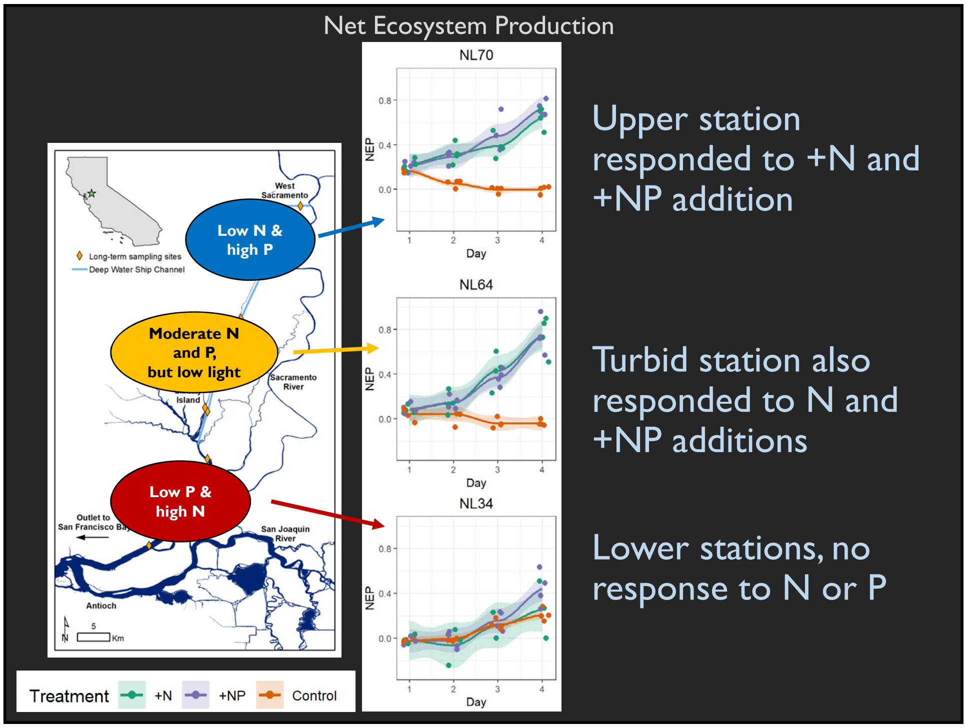
Test for limitation of primary production

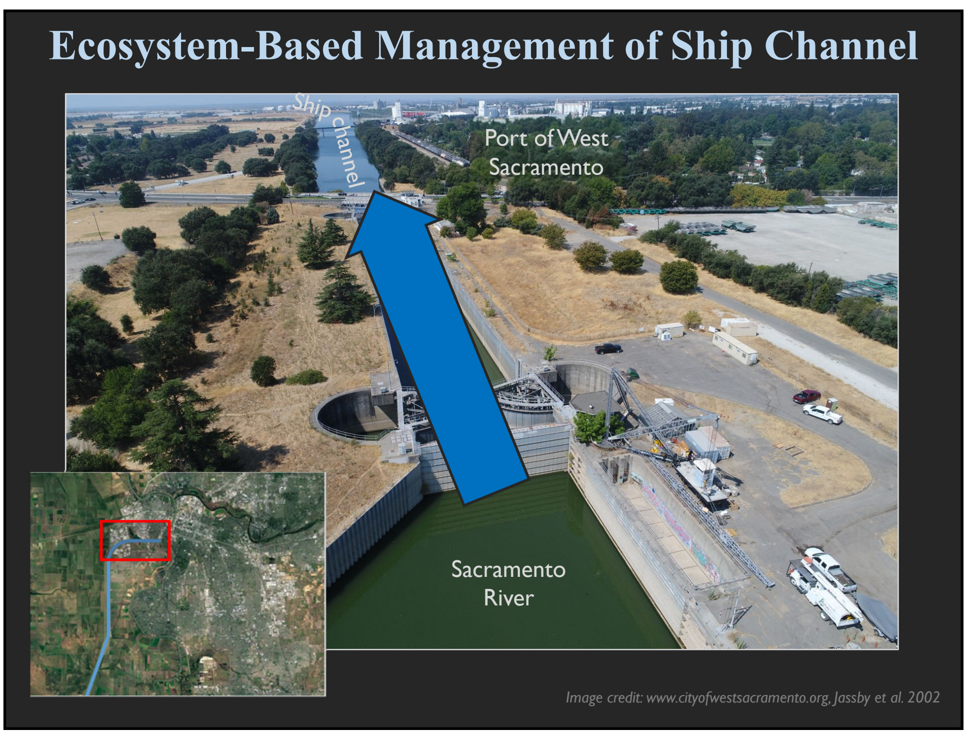


Incubate water from these zones with NO_3 and/or PO_4 additions.

Measure diel changes in dissolved oxygen and calculate metabolism

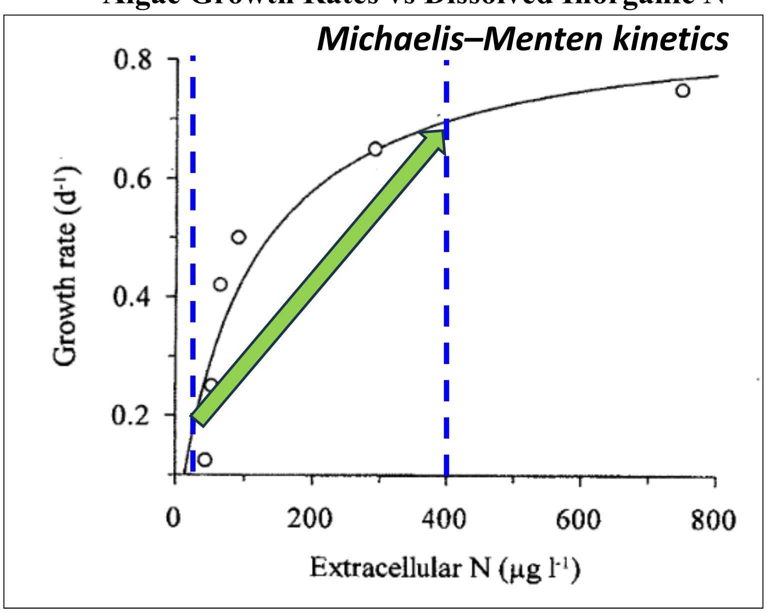



Net Ecosystem Production
NL70
NL64
NL34
NEP
Day
West Sacramento
Long-term sampling sites
Deep Water Ship Channel
Low N & high P
Moderate N and P, but low light
Sacramento River
Island
Low P & high N
Outlet to San Francisco Bay
San Joaquin River
Antioch
Km
Treatment +N +NP Control
Upper station responded to +N and +NP addition
Turbid station also responded to N and +NP additions
Lower stations, no response to N or P

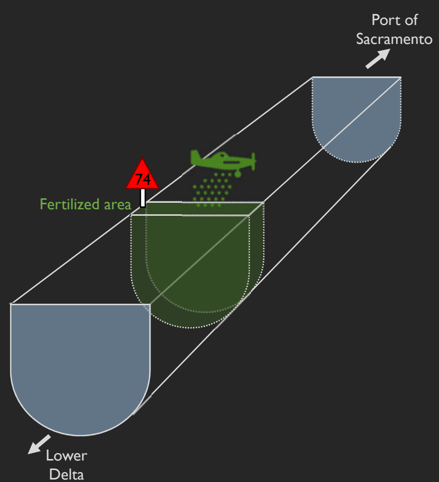

Ecosystem-Based Management of Ship Channel
Ship channel
Port of West Sacramento
Sacramento River
Image credit: www.cityofwestsacramento.org, Jassby et al. 2002

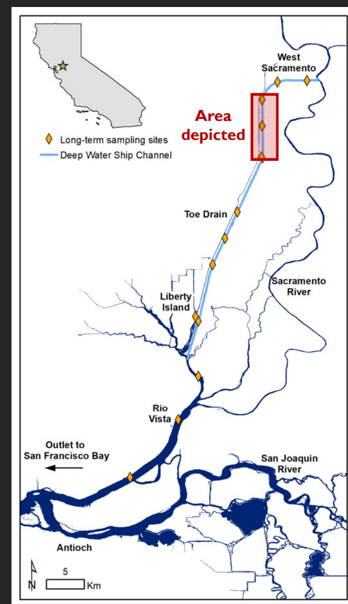
Aerial Application of $Ca(NO_3)_2$ to Ship Channel

Algae Growth Rates vs Dissolved Inorganic N

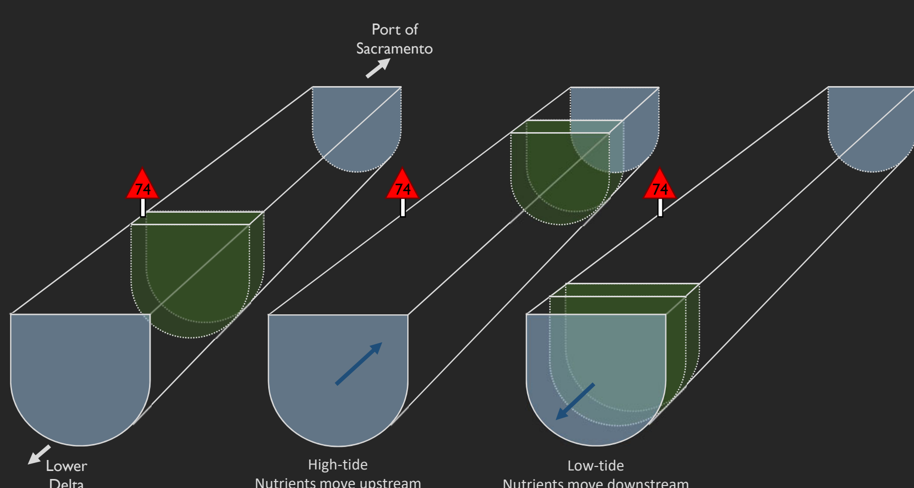


Fertilization Experiment

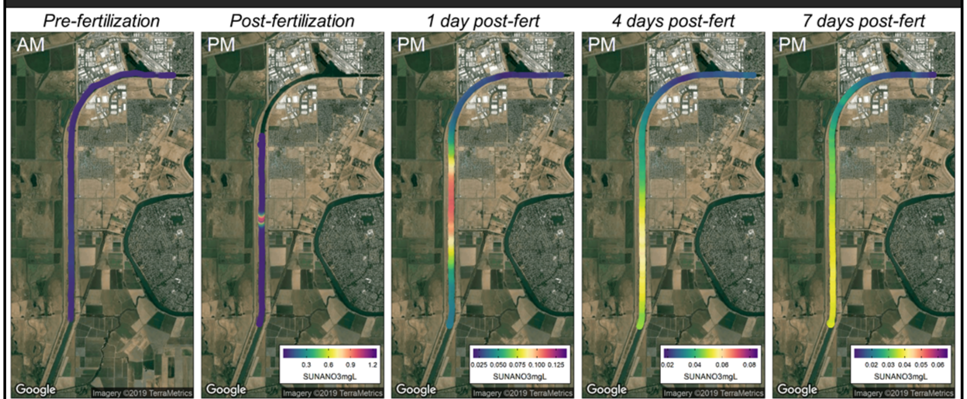




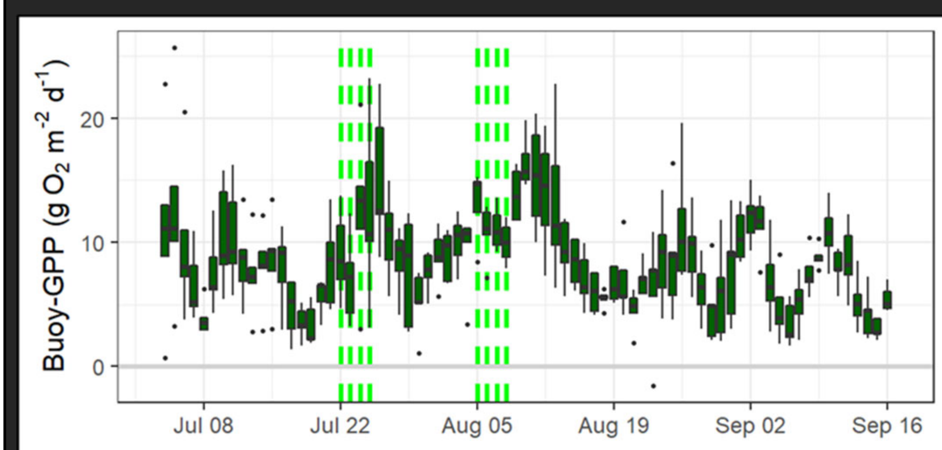
Hydrodynamics – Tidal Effects

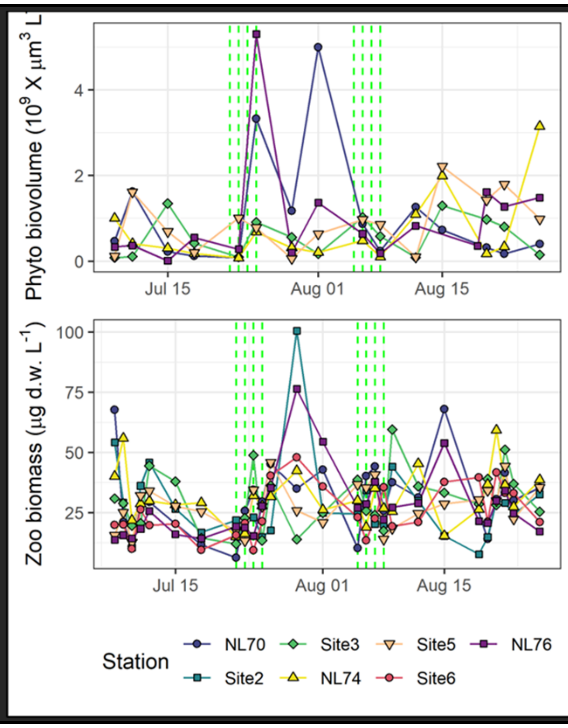


Longitudinal Monitoring of Nitrate Injection



Gross Primary Production Response to Nitrate





Response to Nitrate Application

Phytoplankton

Zooplankton

Tidal Wetlands as a Source of Food Resources?