A Hitchhikers Guide to Coeur d'Alene Lake Management

A Brief Look at 40 years of Progress in Coeur d'Alene Lake

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Our Gem Symposium

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Today's Talk

1. **Environmental Challenge in Coeur d'Alene Lake**
2. **"Limnology 101" and application to Coeur d'Alene Lake**
3. **How we use Limnologic Science to Help Manage the Lake**
4. **How the Lake is Doing**
5. **What Comes Next**

If you remember nothing else…

- Lake is a complex, dynamic, "lagged" system
- Metal contamination still an issue, starting to improve
- Nutrients increasing, beginning to impact lake health
- Everything revolves around oxygen (O_2)

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Environmental Challenge

1. **Historic mining contributed over 75 million metric tons of metal contaminated sediments into lake**
    - Arsenic, cadmium, lead, zinc
    - Have damaged lake health
    - Still entering lake today
2. **Beautiful and desirable lake sustains a vibrant community**
3. **Lake Management Plan alternative to EPA action under CERCLA**

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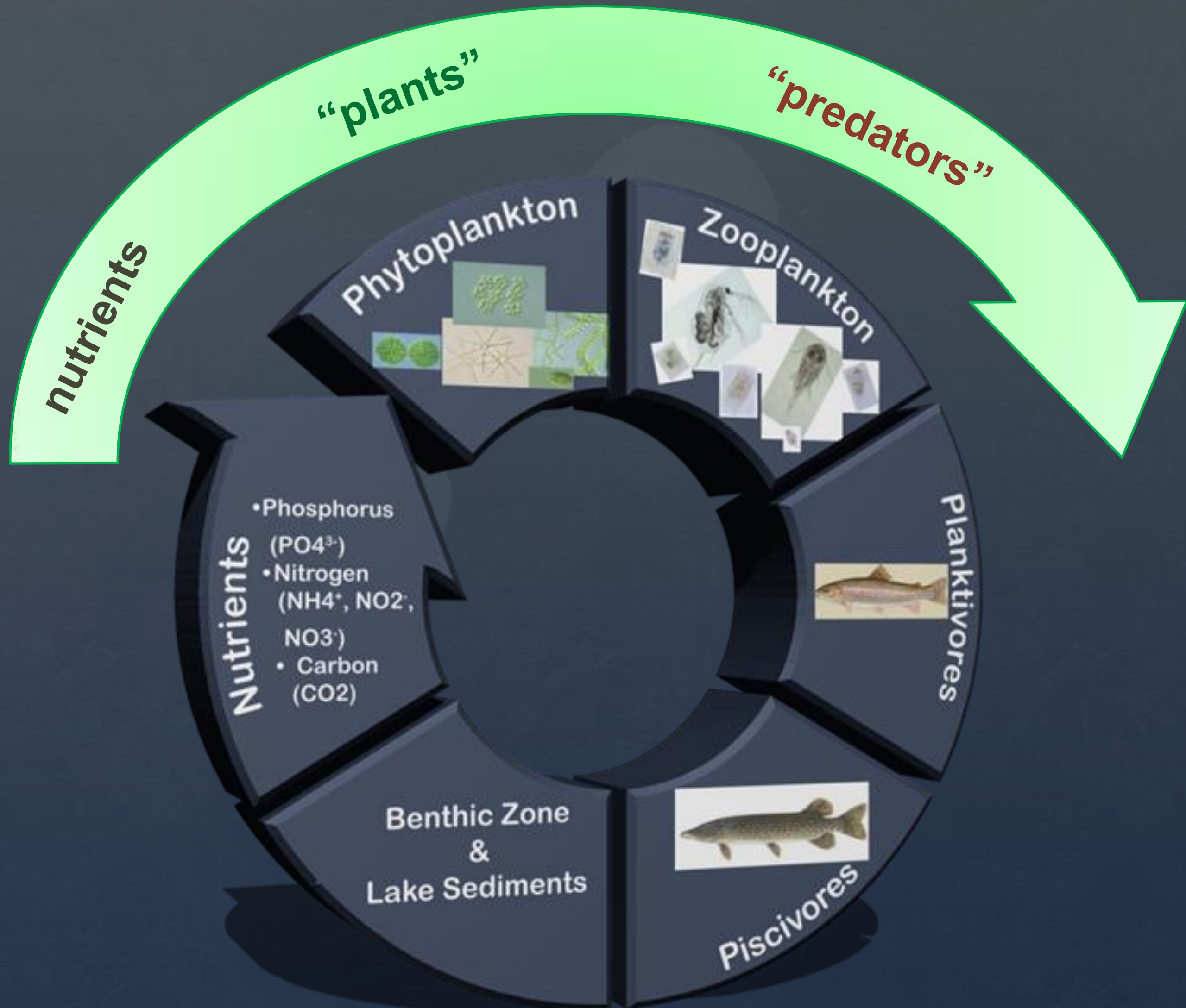
How Metals Impact the Food Web

Classic food chain

- Nutrients feed plants (phytoplankton)
- These feed 1st level predators (zooplankton)
- Zooplankton feed upper level predators (fish)
- Sediments, bacteria recycle nutrients within the lake.



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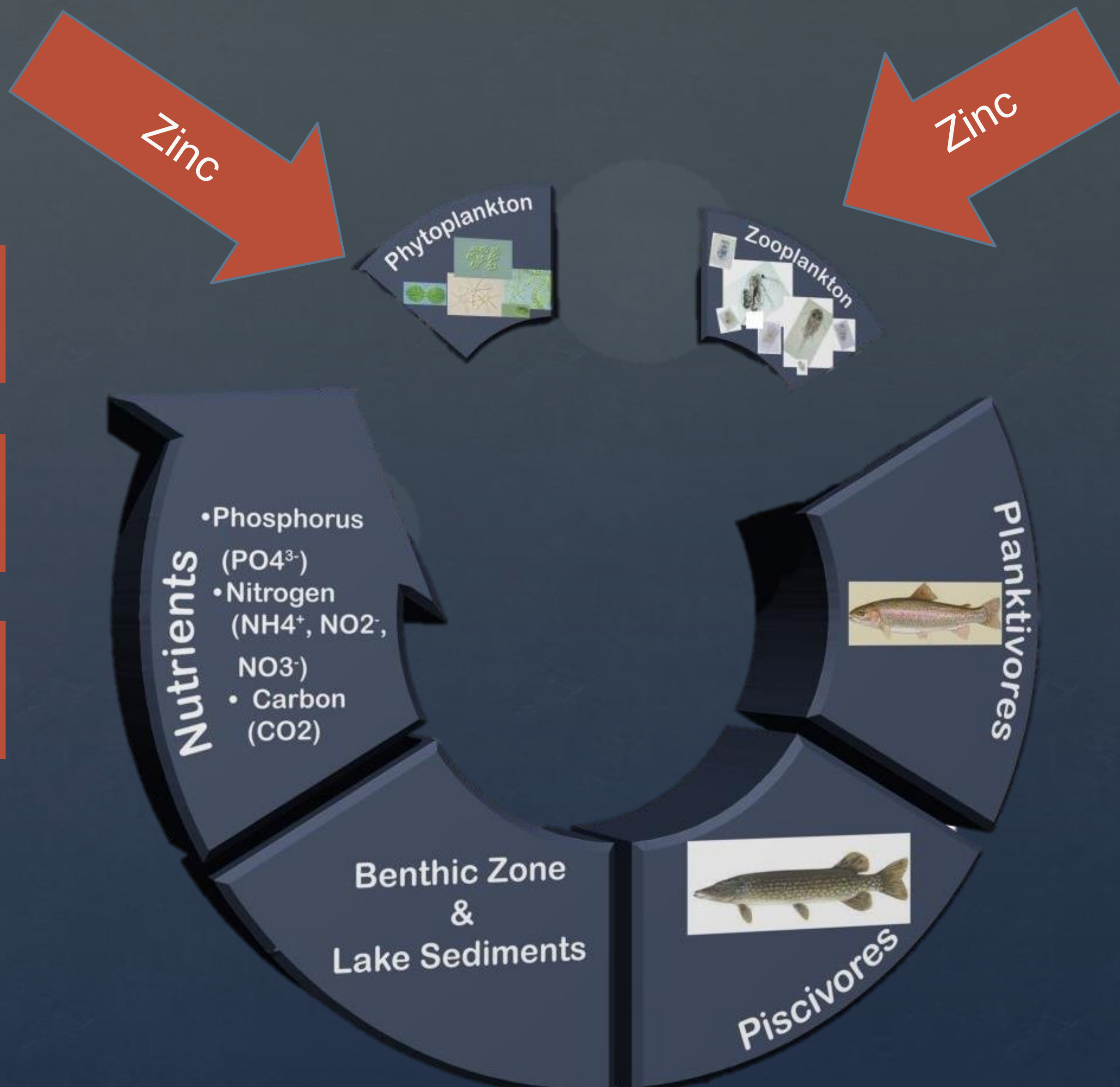
Metals Impact the Food Web

Metals can inhibit phytoplankton growth

Metals can also impact zooplankton

Can then inhibit the overall fishery



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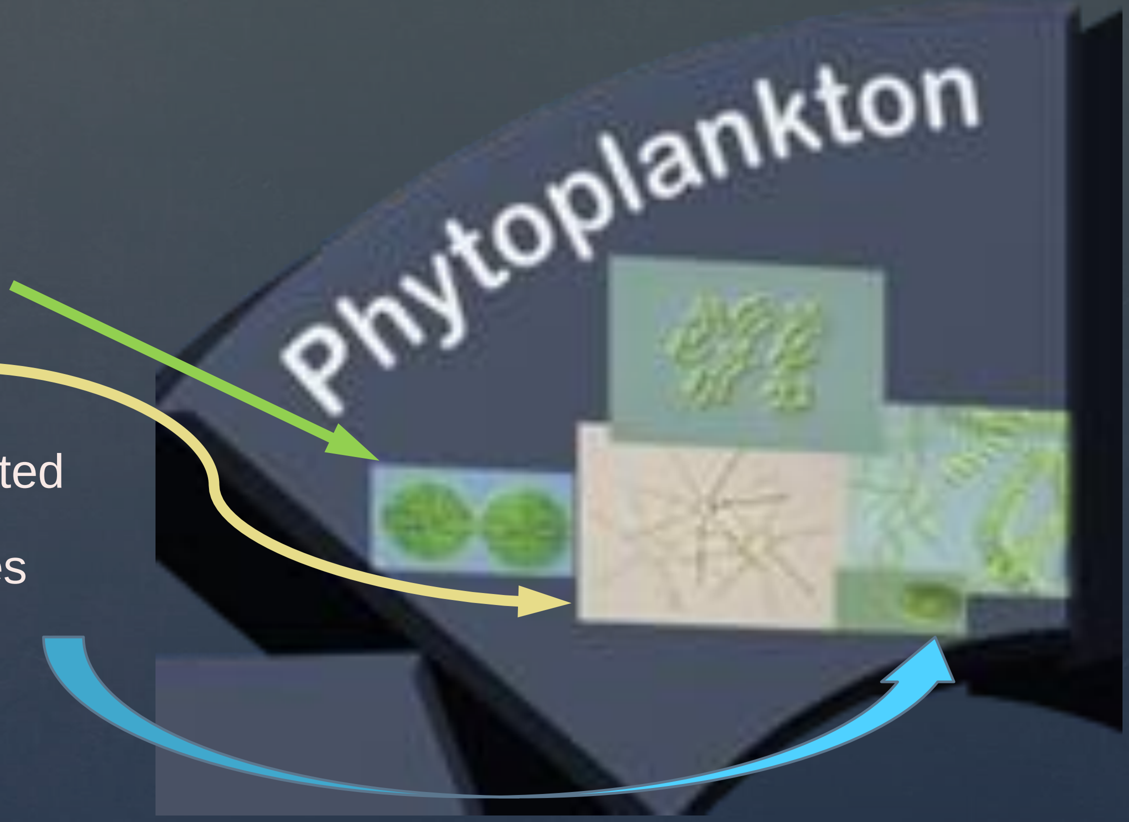
A Bit of Complexity

Metals Impact Different Plankton groups differently

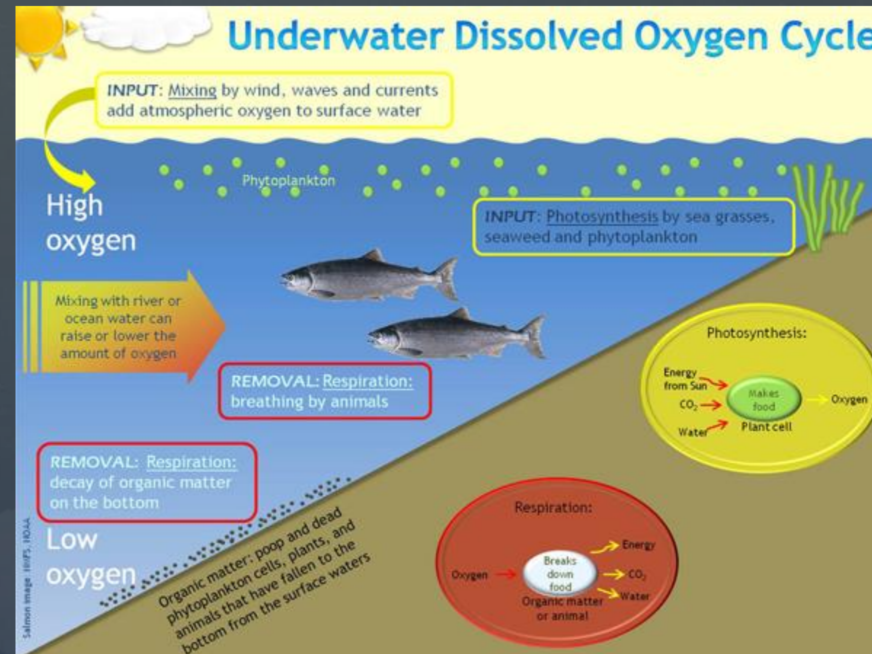
- "Greens" most impacted
- Diatoms less impacted
- "Blue-greens" least impacted
- Some "blue-green" species can cause noxious and/or toxic algae blooms

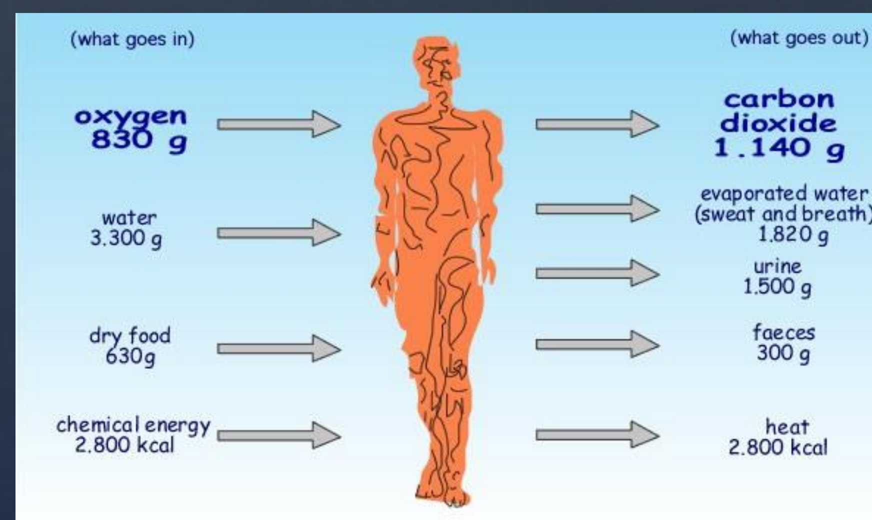


Zooplankton prefer "greens", which are most impacted by zinc

Food Web and Lake Metabolism

- Analogous to human metabolism.
- Does not look like a human body, but is functionally similar
- Lake circulation moves oxygen, just like our heart and bloodstream.
- Lakes need carbon, nutrients and oxygen, like human physiology.
- Lakes, “food” = plankton, make O_2
- Predators eat food, use O_2 & poop
- Bacteria eat “poop”, use more O_2





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Food Web and Lake Metabolism

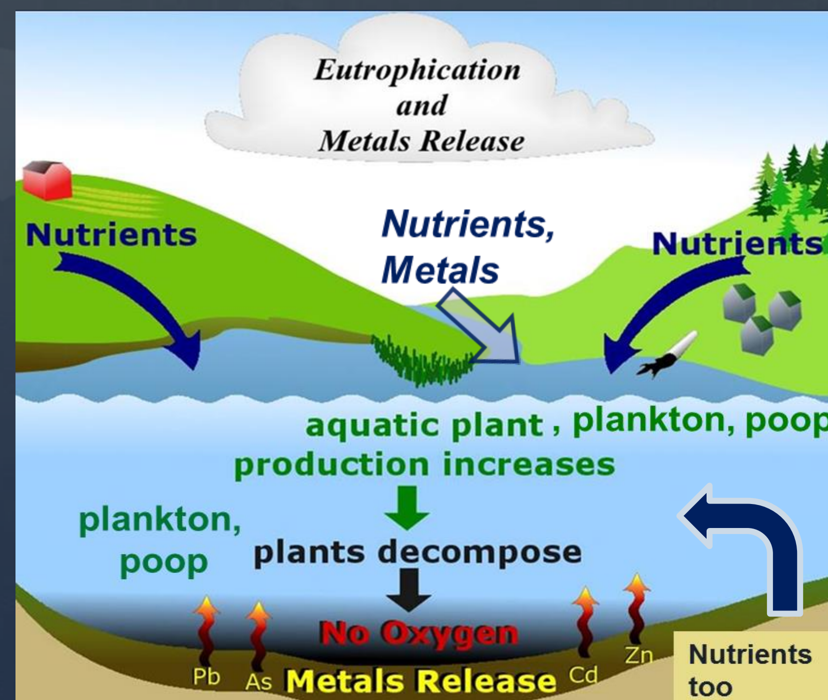
- What happens if a lake gets an unhealthy diet and "over-eats"
- This stimulates/accelerates a natural process known as eutrophication.
- Natural eutrophication takes centuries to millennia to occur.
- Human-accelerated takes years to decades
- Process is outlined in figure

More nutrients → more food produced

More food → more waste

More waste → less O2

Low O2 releases metals, nutrients



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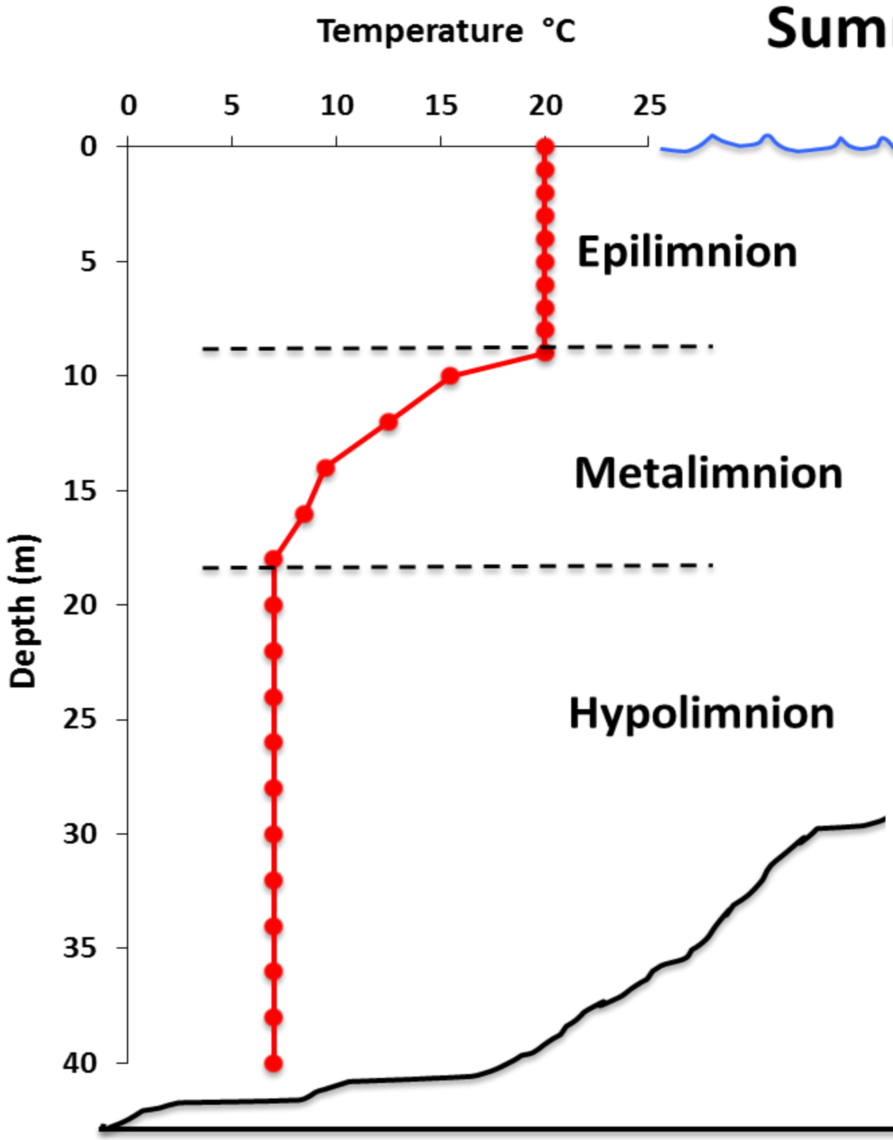
Lake Physics Governs O_2 Circulation

Summer Thermal Stratification

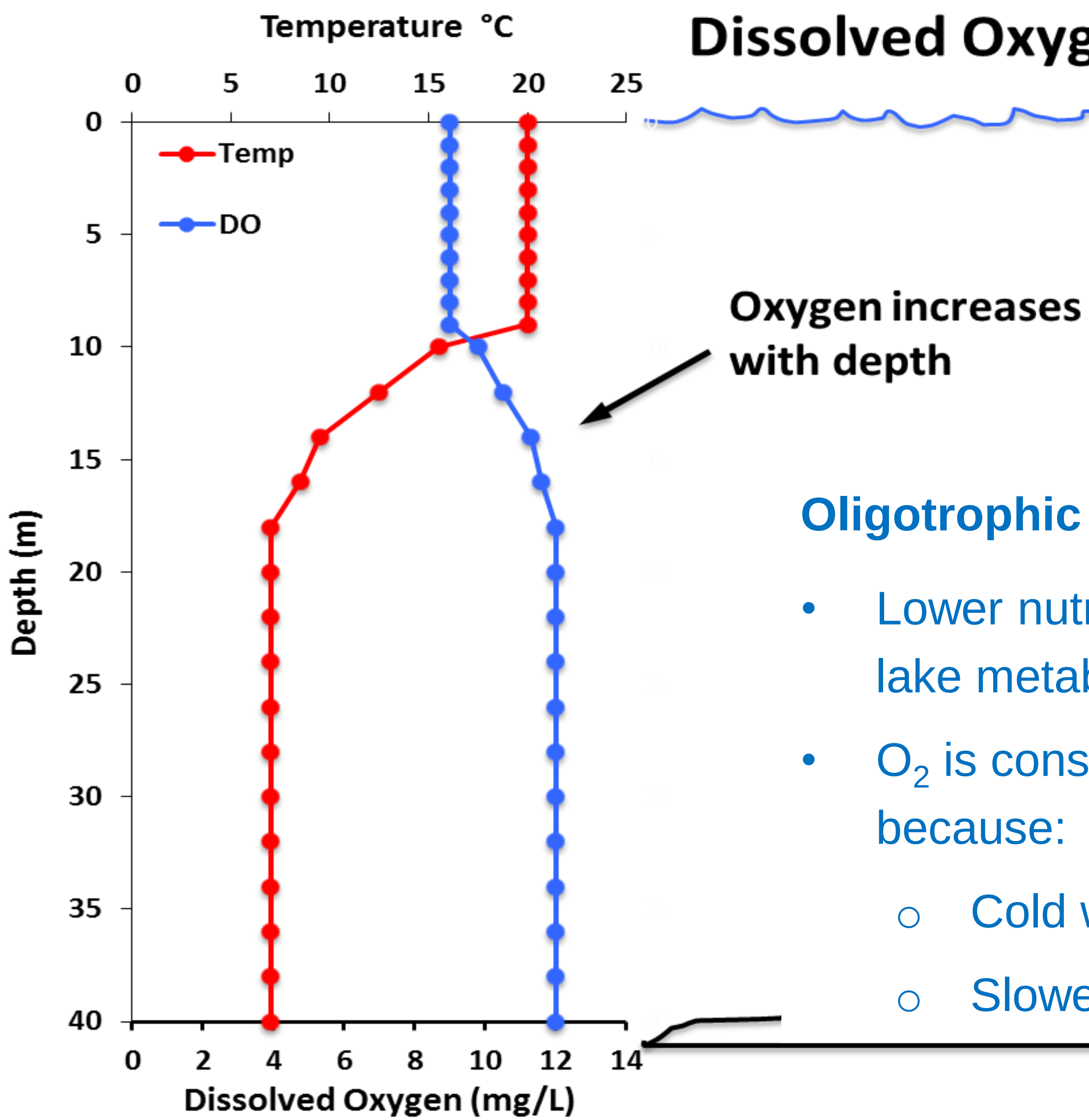


Lakes Stratify in Summer

- In winter, temperature is ~constant over the lake's depth
- In summer, heat warms the surface
- Makes surface water less dense
- Surface "floats" on top of colder, denser deeper water.
- Creates layers in lake that inhibit mixing, isolate bottom waters
- Lake circulation cannot replenish bottom water O_2 with "fresh air".

Lake Physics Impacts Oxygen

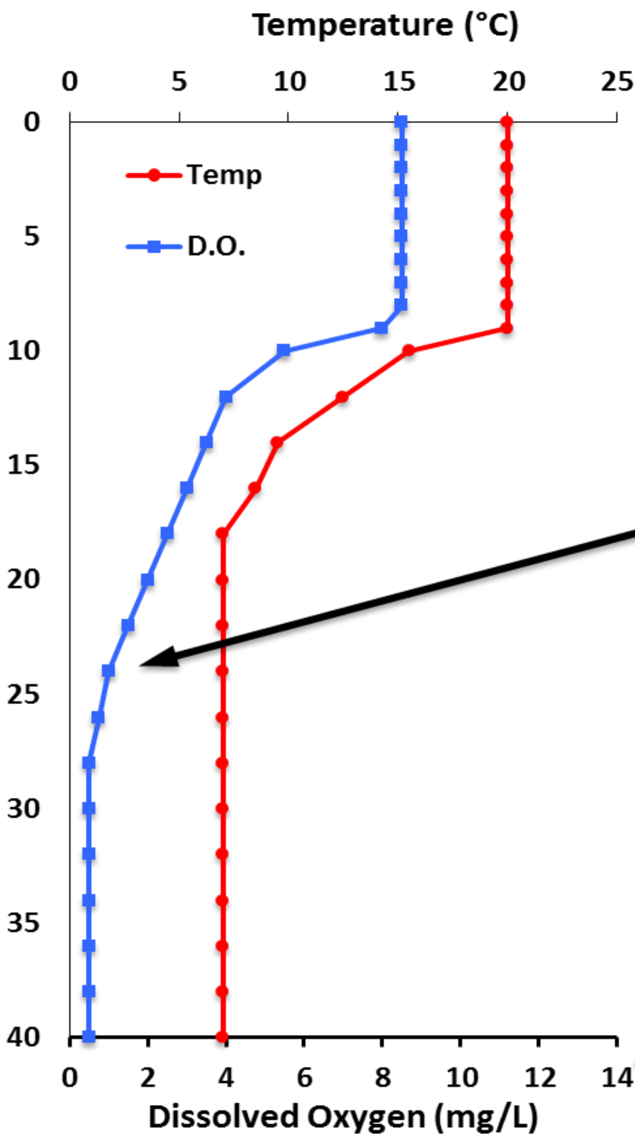
Dissolved Oxygen, Oligotrophic Lake



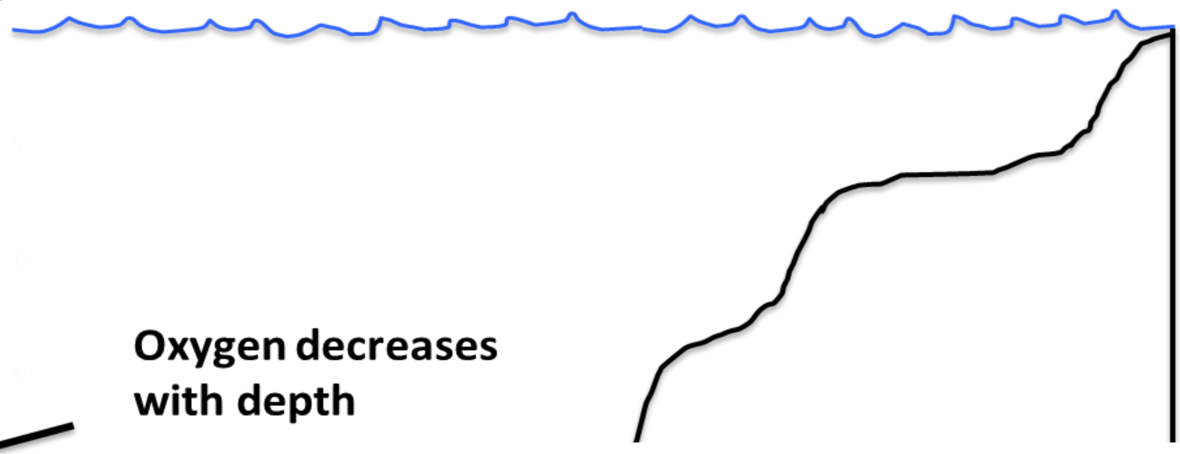
Oligotrophic Lake

- Lower nutrients, plankton production slows lake metabolism
- O_2 is constant or increases with depth because:
  - Cold water holds more O_2
  - Slower metabolism burns less O_2

Lake Physics Impacts Oxygen



Dissolved Oxygen, Eutrophic Lake



Oxygen decreases with depth

Eutrophic Lake

- Higher nutrients, plankton production speed up lake metabolism
- O_2 decreases with depth because:
  - Even though cold water holds more O_2
  - Faster metabolism burns more O_2 than can be supplied to the bottom water

Watershed Feeds Lake Metabolism

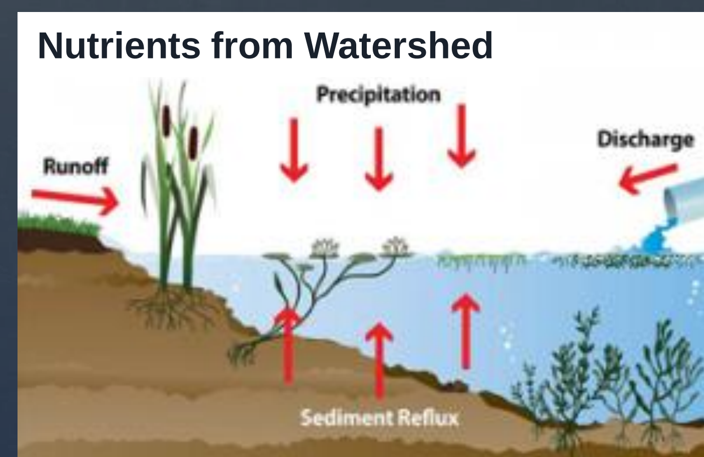
Oligotrophic

- Clear water
- Little to no Milfoil
- Balanced food web
- High bottom water O_2
- ***Fewer*** *metals released from sediments*

Low nutrient load

Eutrophic

- Cloudy green water
- Milfoil infestations
- Unbalanced food web
- Noxious algae
- Low bottom water O_2
- *Typically releases* ***more*** *metals from sediments*



High nutrient load

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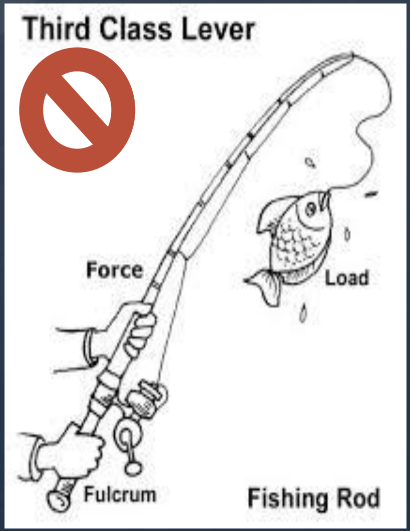
Manage Lakes According to “Tipping Points”

- Lakes and other environmental systems are complex buffered, lagged, noisy systems – hard to control
- No simple cause and effect
- Don’t follow “common sense” rules
- **Not** “mechanical”, like a dam or lever
- Can’t “flip a switch” and get an immediate response.
- More like the relationship(s) b/t metabolism and human health



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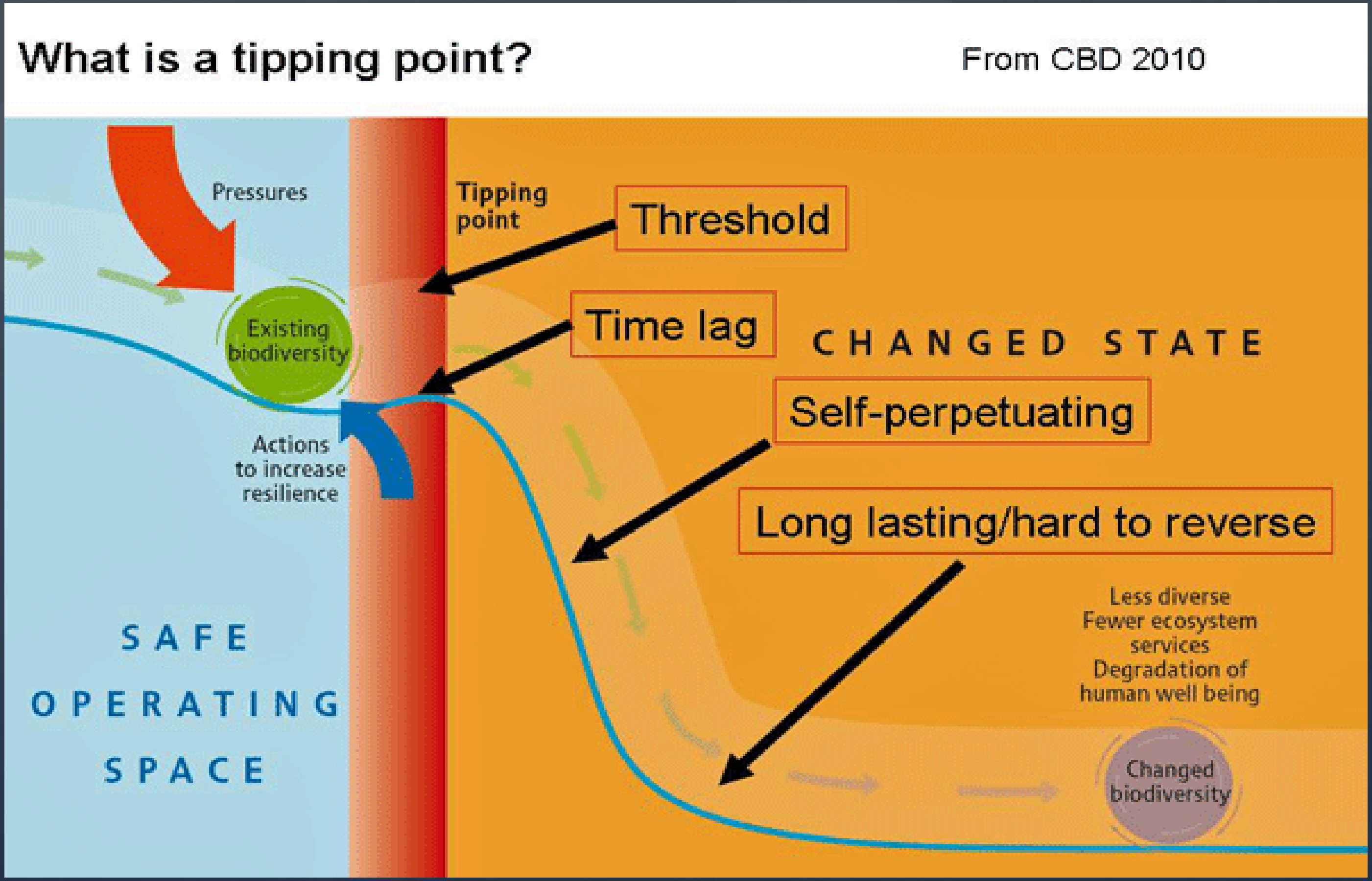
What is a “Tipping Point”

- Tipping points refer to the behavior of “buffered, lagged” systems
- Competing pressures hold a system in a “healthy space”, until….

- System is overwhelmed
- Becomes imbalanced
- “Tipped” into an unhealthy state



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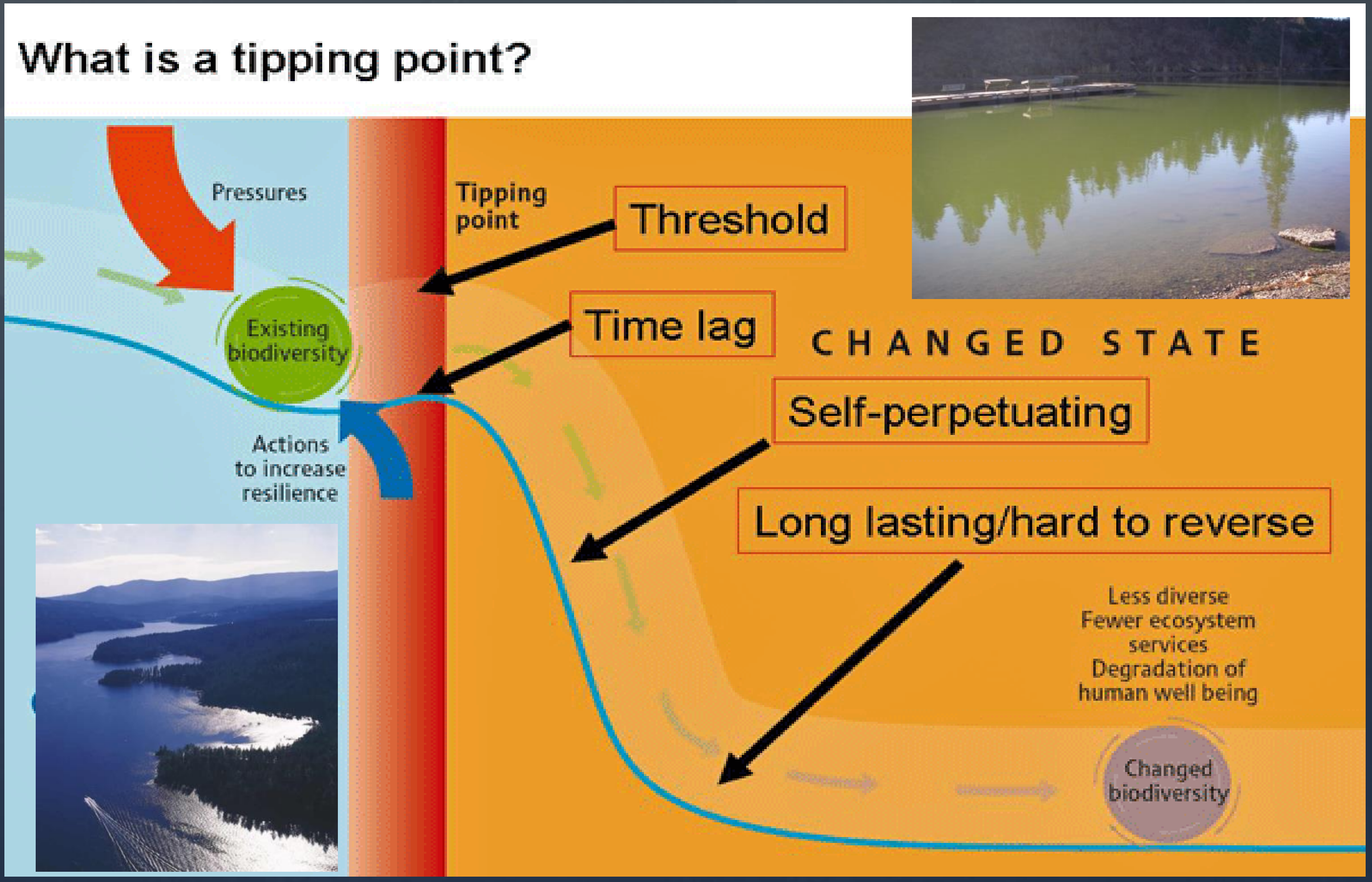
Lake Management and "Tipping Points"

- Many corollaries to human metabolism. Examples include…
- Smoking and lung cancer, poor diet and diabetes/heart disease
- LMP designed around this concept
- Deliberately looks for small changes
- Provides forewarning



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Metals, Nutrients, and the LMP

Primary Objective of the 2009 Lake Management Plan—

"To protect and improve lake water quality by limiting basin-wide nutrient inputs that impair lake water quality conditions, which in turn influence the solubility of mining-related metals contamination contained in lake sediments."

- **Put simply** — control nutrients to maintain high O_2 → *manage metals*
- **How we do it** — monitor, assess, communicate, advise, coordinate with management authorities, *help* advance nutrient reduction projects
- **Technical process** — Five general steps, some can be concurrent

1. Evaluate lake performance according to "triggers"
2. If exceeded, then "triggers" coordination & analysis
3. Analyze for cause and effect, communicate findings
4. Advise land/water management agencies, entities
5. *Help* accelerate consensus nutrient reduction work

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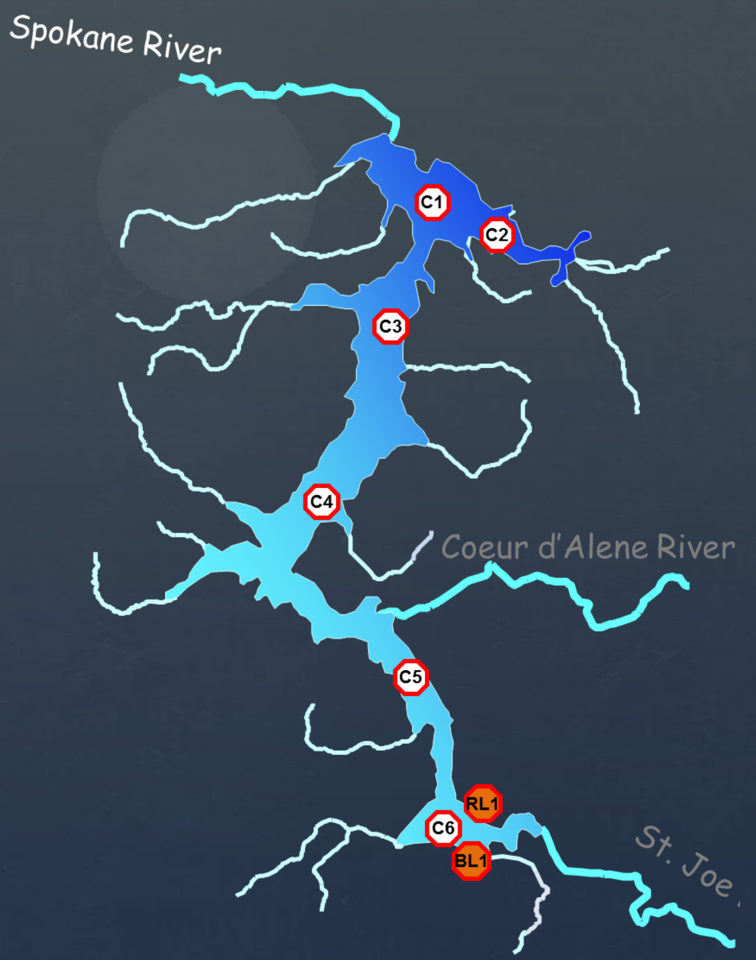
LMP Scientific Process

1. **Collect samples** — two types of locations
   - *Core monitoring* — lake assessment
   - *Lake Science* — help understand trends
2. **Evaluate** — are performance criteria met? Do we see trends? Potential causes?
3. **Analyze causes** — What factors drive change in the lake? *Computer modeling.*
   - *Large rivers* — easiest to measure
   - *Smaller watersheds* — harder to measure
   - *Internal lake* — very difficult to measure
4. **Provide options** — What are our choices?



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Help inform decision making processes

Evaluation and Communication

- **2009 LMP Established performance criteria —** *"triggers"*
  - Cover metals, oxygen, lake metabolism, biologic impacts
  - Metals triggers based on Idaho, Tribe water quality standards
  - Oxygen trigger supports metals objectives, fishery health
  - Lake metabolism triggers directly support oxygen needs
  - Biologic triggers reflect changes in lake metabolism
- **Generates lots of data —**
- **Communication Challenge —**
  - Distill 1000's of data points into a useful summary
  - Balance technical rigor with communication utility
  - Work in progress, and we value continued feedback

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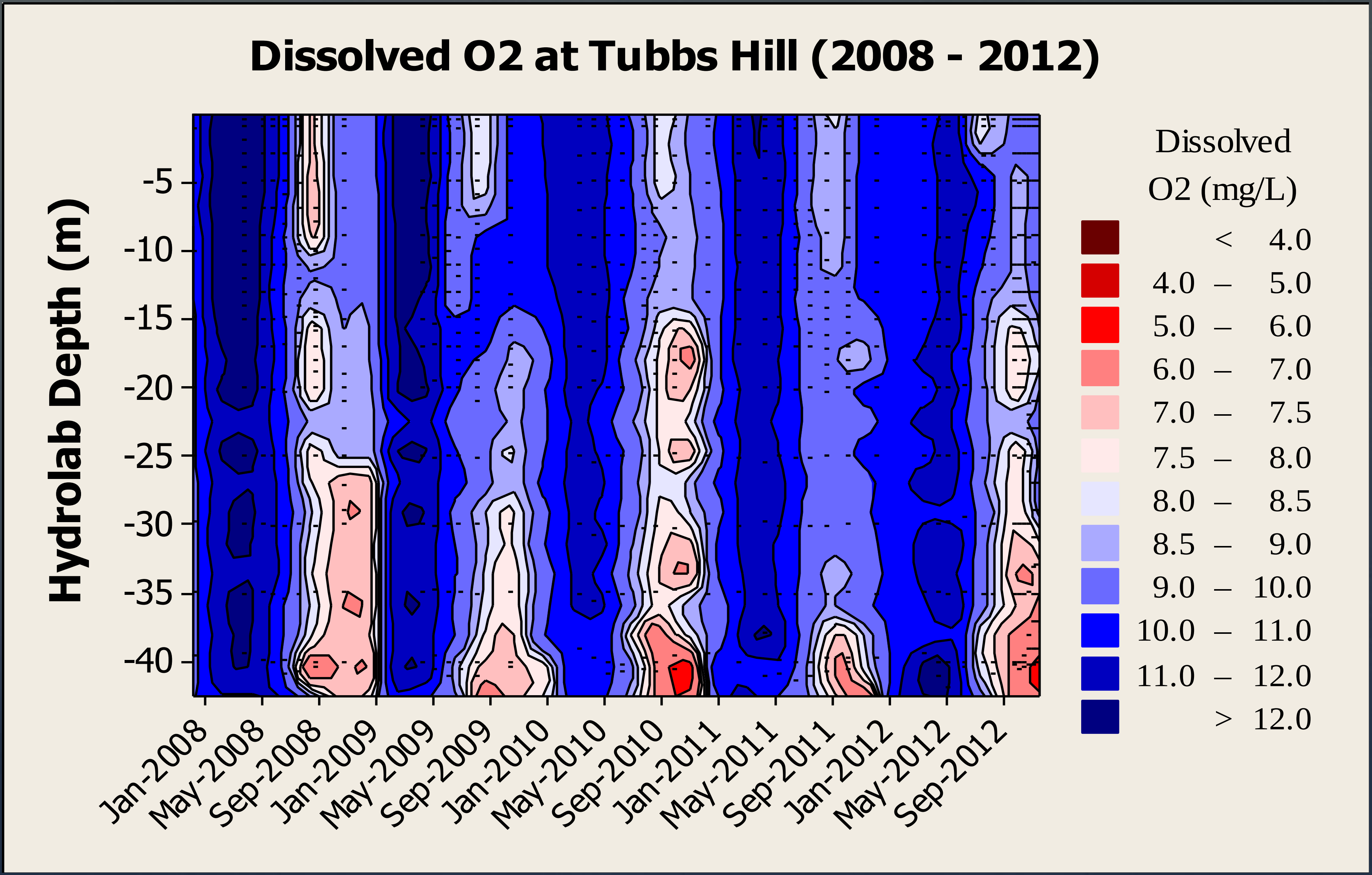
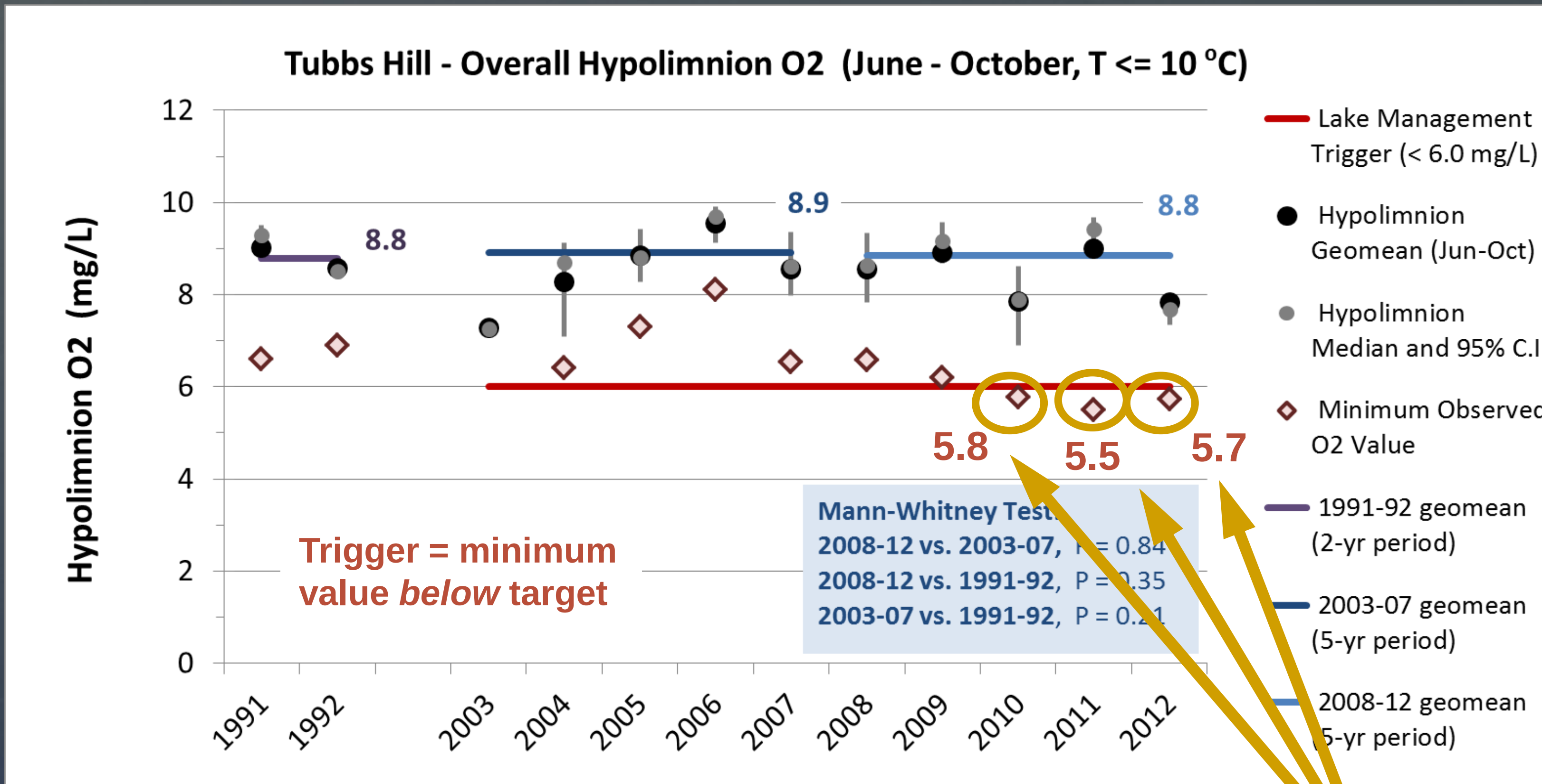
- **Today —** *Show examples of detailed data, two possible ways to "distill" it*

Start with Dissolved O_2



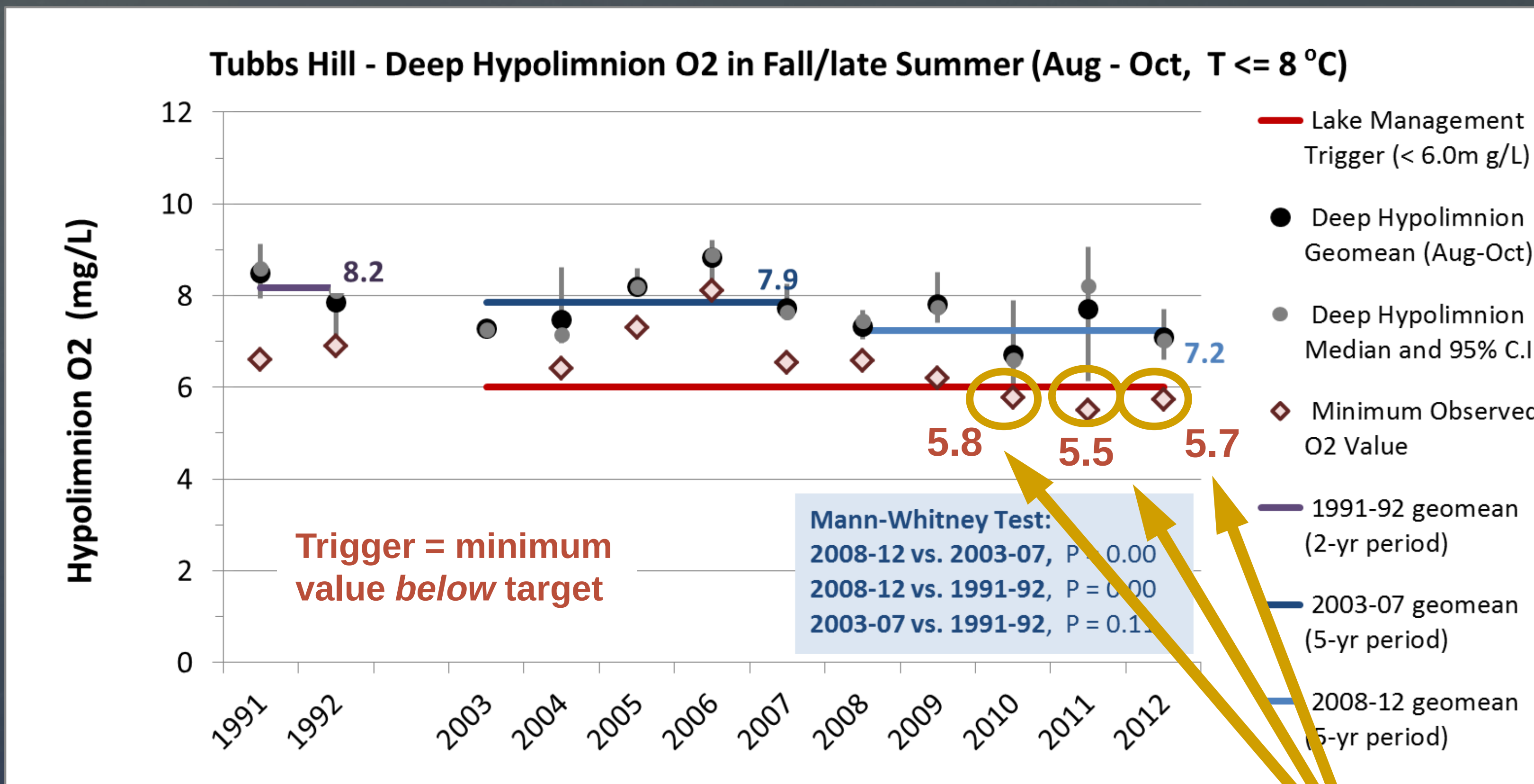
Another way of Looking at O_2



Triggers exceeded, but overall hypolimnion shows no trend

Trigger Exceedance

Method of Data Evaluation is Important



Trigger Exceedance

Closer examination of “deepest, oldest waters” may reveal a trend of declining oxygen in deepest, oldest hypolimnion waters

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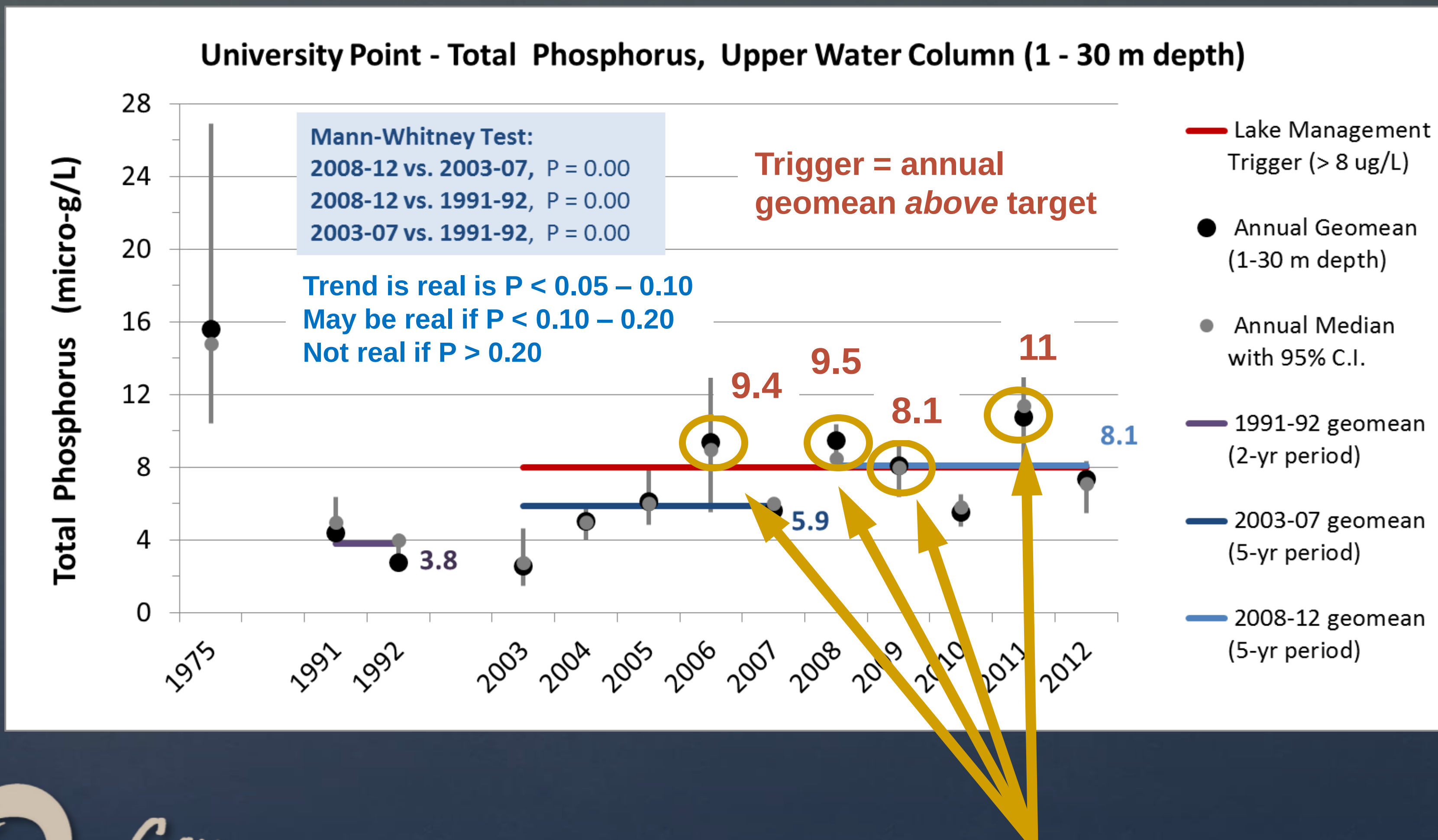
Data Example – Total Phosphorus



Trigger Exceedance

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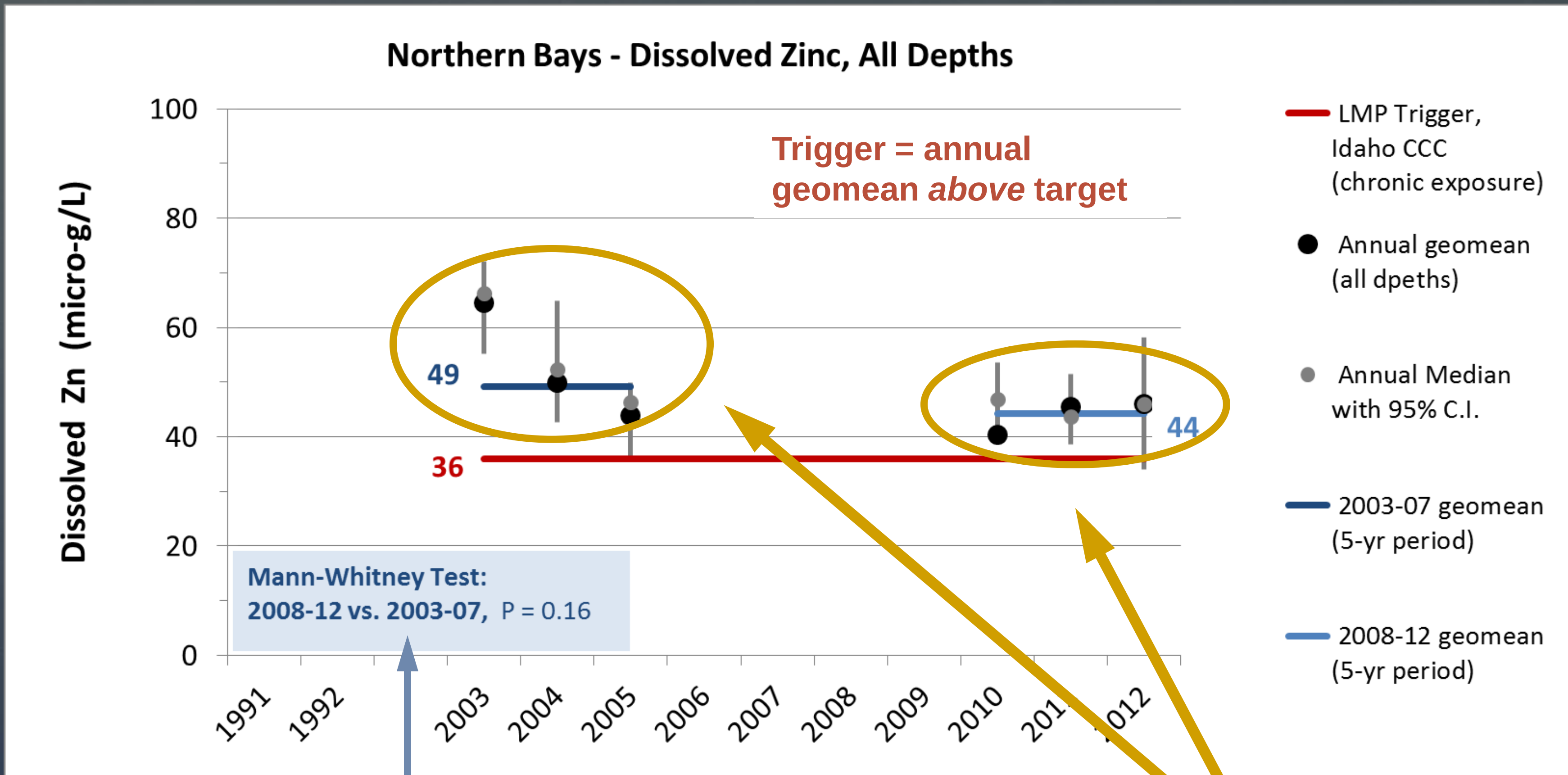
Data Example – Dissolved Zinc



Trend is real is P < 0.05 – 0.10
May be real if P < 0.10 – 0.20
Not real if P > 0.20

Trigger Exceedance

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Tubbs Hill (Northern Pool)

Variables	Desired Condition	Trigger Condition	CY91-92 Condition	WY 04-06 Condition	CY 2003-07 Condition	CY 2008-12 Condition	Trigger Ever Exceeded? CY 2008-12
Total phosphorus (1– 30 m depth)	no greater than WY04-06 condition	≥ 8.0 µg/L annual geomean	**2.7 µg/L** geomean[c]	5.0 µg/L 3-yr geomean	**4.7 µg/L** 5-yr geomean *2-26 µg/L range*	**6.0 µg/L** 5-yr geomean *3-24 µg/L range*	**Yes** (2011)
Dissolved oxygen (hypolimnion)	minimum > 6.0 mg/L	minimum < 6.0 mg/L	minimum > 6.0 mg/L	minimum > 6.0 mg/L	**minimum = 6.4** > 6.0 mg/L	**minimum = 5.5** < 6.0 mg/	**Yes** (2010-2012)
Maximum chlorophyll-a (photic zone)	no greater than WY04-06 condition	≥ 5.0 µg/L maximum	**1.3 – 1.7 µg/L** maximum	3.3 µg/L maximum	**3.3 µg/L** maximum	**8.4 µg/L** maximum	**Yes** (2008, 09)
Geomean chlorophyll-a (photic zone)	no greater than WY04-06 condition	≥ 3.0 µg/L annual geomean	**0.92 µg/L** geomean	1.57 µg/L 3-yr geomean	**1.5 µg/L** 5-yr geomean	**2.0 µg/L** 5-yr geomean	**Yes** (2008)
Blue-green algae (cyanobacteria) blooms	blue-greens minor component	blue-greens are dominant algal group with seasonal blooms	blue-greens **minor component**	not measured	CY-07 geomean for blue-greens bionumber was **28% of total**	Annual geomean **26-47% of total** bionumber, with seasonal blooms	**Increasing predominance** (2008-12)
Water clarity Secchi depth July – October	no less than CY91-92 condition	*Undefined* – clarity trigger may reflect chlorophyll a trigger	**8.3 m** seasonal geomean	9.4 m 3-yr seasonal geomean	**9.6 m** 5-yr seasonal geomean	**9.5 m** 5-yr seasonal geomean	**No, clarity meets desired condition**
Dissolved zinc all depths	meet Idaho WQS	Idaho WQS (CCC) > 36 µg/L	only total zinc measured	62 µg/L 3-yr geomean *33-91 range*	**61 µg/L** 5-yr geomean *33-91 range*	**56 µg/L** 5-yr geomean *35-79 range*	**Yes** (2008-12)
Dissolved lead all depths	meet Idaho WQS	Idaho WQS (CCC) > 0.54 µg/L	only total lead measured	0.12 µg/L 3-yr geomean *0.05-0.88 range*	**0.11 µg/L** 5-yr geomean *0.04-0.9 range*	**0.19 µg/L** 5-yr geomean *0.05-4.5 range*	**No**
Dissolved cadmium all depths	meet Idaho WQS	Idaho WQS (CCC) hardness-dependent (> 0.22 – 0.25 µg/L)	only total cadmium measured	0.23 µg/L 3-yr geomean *0.15-0.52 range*	**0.23 µg/L** 5-yr geomean *0.15-0.34 range*	**0.22 µg/L** 5-yr geomean *0.16-0.37 range*	**Yes** (2011-12)

Alternate Summary (N. Pool)

- Insufficient data
- Within trigger
- Within trigger, data uncertainty
- Exceeds trigger, data uncertainty
- Exceeds trigger

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Northern Pool *Tubbs Hill*	**1970's (1 yr)**	**1991-92 (2-yr)**	**2003-07 (5-yr)**	**2008-12 (5-yr)**	**Current Trend**
Dissolved Metals					
Dissolved Cd (µg/L) *geomean > ~0.22 – 0.25 ug/L*	no data	totals only	0.23	0.22	no trend
Dissolved Pb (µg/L) *annual geomean > 0.54 ug/L*	no data	totals only	0.11	0.19	**Away** *from target*
Dissolved Zn (µg/L) *annual geomean > 36 ug/L*	no data	totals only	61	56	**Towards** *target*
Trophic State					
Dissolved O_2 (mg/L) *Minimum < 6.0 mg/L*	no data	6.6	6.4	5.5	**Away** *from target*
Maximum Chl-a (µg/L) *Maximum > 5 ug/L*	17	1.7	2.7	8.4	**Away** *from target*
Geomean Chl-a (µg/L) *annual geomean > 3 ug/L*	8.3	1.0	1.5	2.0	**Away** *from target*
Tot. Phosphorus (µg/L) *annual geomean > 8 ug/L*	13	< 3	4.7	6.0	**Away** *from. target*
Water Clarity (m) *summer/fall geomean*	3.9 m	8.3 m	9.6 m	9.5 m	no trend
Bioindicators					
Eurasian Milfoil *presence/absence in bays*	no data	not present	not present	not present	no trend
Total cyanobacteria *dominant algae group data show geomean (range)*	~10% (5 to > 50%)	~5% (0% – 10%)	~28% (19% – 49%)	~37% (11% – 62%)	**Away** *from target*
Toxin-capable algae *Equivalent to CY 1991-92 data show geomean (range)*	~8% (3 to ~40%)	< ~5% (0% – 10%)	~13% (10% – 19%)	~4% (0% – 47%)	**Uncertain**

Alternate Summary – Metals

Northern Pool *Tubbs Hill*	**1970's (1 yr)**	**1991-92 (2-yr)**	**2003-07 (5-yr)**	**2008-12 (5-yr)**	**Current Trend**
Dissolved Metals					
Dissolved Cd (µg/L) *geomean > ~0.22 – 0.25 ug/L*	no data	totals only	0.23	0.22	no trend
Dissolved Pb (µg/L) *annual geomean > 0.54 ug/L*	no data	totals only	0.11	0.19	**Away** *from target*
Dissolved Zn (µg/L) *annual geomean > 36 ug/L*	no data	totals only	61	56	**Towards** *target*

- Cd occasionally exceeds trigger, generally stable
- Lead does not exceed trigger, but increasing
- Zinc continually exceeds trigger, but decreasing

Alternate Summary – Trophic State

Northern Pool *Tubbs Hill*	**1970's (1 yr)**	**1991-92 (2-yr)**	**2003-07 (5-yr)**	**2008-12 (5-yr)**	**Current Trend**
Trophic State					
Dissolved O_2 (mg/L) *Minimum < 6.0 mg/L*	no data	6.6	6.4	5.5	**Away** *from target*
Maximum Chl-a (µg/L) *Maximum > 5 ug/L*	17	1.7	2.7	8.4	**Away** *from target*
Geomean Chl-a (µg/L) *annual geomean > 3 ug/L*	8.3	1.0	1.5	2.0	**Away** *from target*
Tot. Phosphorus (µg/L) *annual geomean > 8 ug/L*	13	< 3	4.7	6.0	**Away** *from. target*
Water Clarity (m) *summer/fall geomean*	3.9 m	8.3 m	9.6 m	9.5 m	no trend

- Oxygen occasionally exceeds trigger, decreasing
- Max Chl-a occasionally exceeds trigger, increasing
- Mean Chl-a occasionally exceeds trigger, increasing
- Total P occasionally exceeds trigger, increasing
- Water clarity stable, but more variable

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Alternate Summary – BioIndicators

Northern Pool *Tubbs Hill*	**1970's (1 yr)**	**1991-92 (2-yr)**	**2003-07 (5-yr)**	**2008-12 (5-yr)**	**Current Trend**
Bioindicators					
Eurasian Milfoil *presence/absence in bays*	**no data**	**not present**	**not present**	**not present**	**no trend**
Total cyanobacteria *dominant algae group* *data show geomean (range)*	**~10%** (5 to > 50%)	**~5%** (0% – 10%)	**~28%** (19% – 49%)	**~37%** (11% – 62%)	**Away** *from target*
Toxin-capable algae *Equivalent to CY 1991-92* *data show geomean (range)*	**~8%** (3 to ~40%)	**< ~5%** (0% – 10%)	**~13%** (10% – 19%)	**~4%** (0% – 47%)	**Uncertain**

- Milfoil not observed adjacent to northern pool
- Total cyanobacteria becoming more dominant
- Seasonal blooms exceed trigger, but not annual mean
- Have seasonal blooms of toxin-capable cyanobacteria

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University Point (Central Pool)

Variables	Desired Condition	Trigger Condition	CY91-92 Condition	WY 04-06 Condition	CY 2003-07 Condition	CY 2008-12 Condition	Trigger Ever Exceeded? CY 2008-12
Total phosphorus (1– 30 m depth)	no greater than WY04-06 condition	≥ 8.0 µg/L annual geomean	**3.8 µg/L** geomean[c]	6.2 µg/L 3-yr geomean	**5.9 µg/L** 5-yr geomean *2-23 µg/L range*	**8.1 µg/L** 5-yr geomean *3-41 µg/L range*	**Yes** (2008-09, 2011)
Dissolved oxygen (hypolimnion)	minimum > 6.0 mg/L	minimum < 6.0 mg/L	minimum > 6.0 mg/L	minimum > 6.0 mg/L	**minimum = 5.9** < 6.0 mg/L	**minimum = 5.8** < 6.0 mg/	**Yes** (2012)
Maximum chlorophyll-a (photic zone)	no greater than WY04-06 condition	≥ 5.0 µg/L maximum	**1.5 – 1.8 µg/L** maximum	3.1 µg/L maximum	**3.1 µg/L** maximum	**5.3 µg/L** maximum	**Yes** (2009)
Geomean chlorophyll-a (photic zone)	no greater than WY04-06 condition	≥ 3.0 µg/L annual geomean	**0.94 µg/L** geomean	1.55 µg/L 3-yr geomean	**1.5 µg/L** 5-yr geomean	**1.8 µg/L** 5-yr geomean	**No**
Blue-green algae (cyanobacteria) blooms	blue-greens minor component	blue-greens are dominant algal group with seasonal blooms	blue-greens **minor component**	not measured	CY-07 geomean for blue-greens bionumber was **18% of total**	Annual geomean **31-53% of total** bionumber, with seasonal blooms	**Increasing predominance** (2008-12)
Water clarity Secchi depth July – October	no less than CY91-92 condition	*Undefined* – clarity trigger may reflect chlorophyll a trigger	**7.7 m** seasonal geomean	8.6 m 3-yr seasonal geomean	**8.8 m** 5-yr seasonal geomean	**8.5 m** 5-yr seasonal geomean	**No, clarity meets desired condition**
Dissolved zinc all depths	meet Idaho WQS	Idaho WQS (CCC) > 36 µg/L	only total zinc measured	68 µg/L 3-yr geomean *36-104 range*	**66 µg/L** 5-yr geomean *36-94 range*	**62 µg/L** 5-yr geomean *34-97 range*	**Yes** (2008-12)
Dissolved lead all depths	meet Idaho WQS	Idaho WQS (CCC) > 0.54 µg/L	only total lead measured	0.27 µg/L 3-yr geomean *0.05-2.76 range*	**0.24 µg/L** 5-yr geomean *0.05-2.8 range*	**0.4 µg/L** 5-yr geomean *0.05-5.5 range*	**Yes** (2008, 2011)
Dissolved cadmium all depths	meet Idaho WQS	Idaho WQS (CCC) hardness-dependent (> 0.22 – 0.25 µg/L)	only total cadmium measured	0.26 µg/L 3-yr geomean *0.16-0.43 range*	**0.25 µg/L** 5-yr geomean *0.16-0.43 range*	**0.26 µg/L** 5-yr geomean *0.11-0.40 range*	**Yes** (2008-2009, 2011-12)

Central Pool

- Insufficient data
- Within trigger
- Within trigger, data uncertainty
- Exceeds trigger, data uncertainty
- Exceeds trigger

Central Pool *University Point*	1970's (1 yr)	1991-92 (2-yr)	2003-07 (5-yr)	2008-12 (5-yr)	Current Trend
Dissolved Metals					
Dissolved Cd (µg/L) *geomean > ~0.22 – 0.25 ug/L*	no data	totals only	0.25	0.26	no trend
Dissolved Pb (µg/L) *annual geomean > 0.54 ug/L*	no data	totals only	0.24	0.40	Away *from target*
Dissolved Zn (µg/L) *annual geomean > 36 ug/L*	no data	totals only	66	62	Towards *target*
Trophic State					
Dissolved O_2 (mg/L) *Minimum < 6.0 mg/L*	no data	7.0	5.9	5.8	Uncertain
Maximum Chl-a (µg/L) *Maximum > 5 ug/L*	26	1.9	3.1	5.3	Away *from target*
Geomean Chl-a (µg/L) *annual geomean > 3 ug/L*	11	1.0	1.5	1.8	Away *from target*
Tot. Phosphorus (µg/L) *annual geomean > 8 ug/L*	16	3.8	5.9	8.1	Away *from. target*
Water Clarity (m) *summer/fall geomean*	2.8 m	7.7 m	8.8 m	8.5 m	no trend
Bioindicators					
Eurasian Milfoil *presence/absence in bays*	no data	not present	not present	present	*found, 2011* Uncertain
Total cyanobacteria *dominant algae group* *data show geomean (range)*	~10% (5 to > 50%)	~5% (0% – 10%)	~18% (10% – 35%)	~40% (10% – 69%)	Away *from target*
Toxin-capable algae *Equivalent to CY 1991-92* *data show geomean (range)*	~8% (3 to ~40%)	< ~5% (0% – 10%)	~8% (2% – 17%)	~2% (0% – 53%)	Uncertain

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Metals Comparison – Northern, Central Pools

Northern Pool *Tubbs Hill*	**1970's (1 yr)**	**1991-92 (2-yr)**	**2003-07 (5-yr)**	**2008-12 (5-yr)**	**Current Trend**
Dissolved Metals					
Dissolved Cd (µg/L) *geomean > ~0.22 – 0.25 ug/L*	**no data**	**totals only**	**0.23**	**0.22**	**no trend**
Dissolved Pb (µg/L) *annual geomean > 0.54 ug/L*	**no data**	**totals only**	**0.11**	**0.19**	**Away** *from target*
Dissolved Zn (µg/L) *annual geomean > 36 ug/L*	**no data**	**totals only**	**61**	**56**	**Towards** *target*

Central Pool *University Point*	**1970's (1 yr)**	**1991-92 (2-yr)**	**2003-07 (5-yr)**	**2008-12 (5-yr)**	**Current Trend**
Dissolved Metals					
Dissolved Cd (µg/L) *geomean > ~0.22 – 0.25 ug/L*	**no data**	**totals only**	**0.25**	**0.26**	**no trend**
Dissolved Pb (µg/L) *annual geomean > 0.54 ug/L*	**no data**	**totals only**	**0.24**	**0.40**	**Away** *from target*
Dissolved Zn (µg/L) *annual geomean > 36 ug/L*	**no data**	**totals only**	**66**	**62**	**Towards** *target*

Shallow Bays of the Northern Lake

Variables	Desired Condition	Trigger Condition	Summer 1991-92, 1995-2002	WY 04-06 Condition	CY 2003-07 Condition	CY 2008-12 Condition	Trigger Ever Exceeded? CY 2008-12
Eurasian milfoil	not present	present	not present	not present	not present	present in 2011	**Yes**
Total phosphorus (all depths)	no greater than WY04-06 condition	≥ 9.0 µg/L annual geomean	**5.7 µg/L** geomean[c]	5.8 µg/L 3-yr geomean	**5.7 µg/L** 5-yr geomean *3-23 µg/L range*	**8.5 µg/L** 5-yr geomean *3-48 µg/L range*	**Yes** (2011)
Dissolved oxygen (all depths)	minimum > 6.0 mg/L	minimum < 6.0 mg/L	minimum > 6.0 mg/L	not reported	not reported	**minimum = 7.2** > 6.0 mg/	**No**
Max. chlorophyll-a (photic zone)	no greater than WY04-06	≥ 5.0 µg/L maximum	**1.7 – 2.0 µg/L** maximum	3.5 µg/L maximum	**3.5 µg/L** maximum	**10.8 µg/L** maximum	**Yes** (2010 – 2012)
Geomean chlorophyll-a (photic zone)	no greater than WY04-06 condition	≥ 3.0 µg/L annual geomean	**0.90 µg/L** geomean	1.2 µg/L 3-yr geomean	**1.2 µg/L** 5-yr geomean	**1.4 µg/L** 5-yr geomean	**No**
Blue-green algae (cyanobacteria) blooms	blue-greens minor component	blue-greens are dominant algal group with seasonal blooms	not measured	not measured	not measured	Annual geomean **27-50% of total** bionumber, with seasonal blooms	**Increasing predominance** (2010-12)
Water clarity Secchi depth July – October	no less than current condition	*Undefined* – clarity trigger may reflect chlorophyll a trigger	**8.1 m** seasonal geomean	not measured	not measured **e**	deeper than lake bottom in bays	**No, clarity meets desired condition**
Dissolved zinc all depths	meet Idaho WQS	Idaho WQS (CCC) > 36 µg/L	**58 µg/L** 3-yr geomean *28-272 range*	49 µg/L 3-yr geomean *25-98 range*	**49 µg/L** 5-yr geomean *25-98 range*	**44 µg/L** 5-yr geomean *5-80 range*	**Yes** (2010-12)
Dissolved lead all depths	meet Idaho WQS	Idaho WQS (CCC) > 0.54 µg/L	**Below detection** (< 3 µg/L)	0.17 µg/L 3-yr geomean *0.05-1.24 range*	**0.17 µg/L** 5-yr geomean *0.05-1.24 range*	**0.36 µg/L** 5-yr geomean *0.05-7.6 range*	**Some Bays** Powderhorn, 2011 Windy, Carlin, 2012
Dissolved cadmium all depths	meet Idaho WQS	Idaho WQS (CCC) hardness-dependent (> 0.22 – 0.25 µg/L)	**Below detection** (< 0.5 µg/L)	0.19 µg/L 3-yr geomean *0.10-0.35 range*	**0.19 µg/L** 5-yr geomean *0.10-0.35 range*	**0.20 µg/L** 5-yr geomean *0.10-0.41 range*	**Yes** (2012)

Northern Bays

- Insufficient data
- Within trigger
- Within trigger, data uncertainty
- Exceeds trigger, data uncertainty
- Exceeds trigger

Northern Bays	1970's (1 yr)	1991-92 (2-yr)	2003-07 (5-yr)	2008-12 (5-yr)	Current Trend
Dissolved Metals					
Dissolved Cd (µg/L) *geomean > ~0.22 – 0.25 ug/L*	no data	no data	0.19	0.20	no trend
Dissolved Pb (µg/L) *annual geomean > 0.54 ug/L*	no data	no data	0.17	0.36	**Away** *from target*
Dissolved Zn (µg/L) *annual geomean > 36 ug/L*	no data	no data	49	44	**Towards** *target*
Trophic State					
Dissolved O_2 (mg/L) *Minimum < 6.0 mg/L*	no data	> 6.0	no data	7.2	no trend
Maximum Chl-a (µg/L) *Maximum > 5 ug/L*	no data	no data	3.5	11	**Away** *from target*
Geomean Chl-a (µg/L) *annual geomean > 3 ug/L*	no data	no data	1.2	1.4	no trend
Tot. Phosphorus (µg/L) *annual geomean > 9 ug/L*	no data	no data	5.7	8.5	**Away** *from. target*
Water Clarity (m) *summer/fall geomean*	no data	> 8 m	no data	8.5 m	no trend
Bioindicators					
Eurasian Milfoil *presence/absence in bays*	no data	not present	not present	present	*found, 2011* **Uncertain**
Total cyanobacteria *dominant algae group* *data show geomean (range)*	no data	no data	no data	~38% (4% – 77%)	*~main lake* **Uncertain**
Toxin-capable algae *Equivalent to CY 1991-92* *data show geomean (range)*	no data	no data	no data	~1% (0% – 25%)	*ptnl HAB, 2010* **Uncertain**

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Trophic Comparison

- Similar trends
- Change in bays larger than in the main lake
- Phosphorus is now highest in the bays
- Bays used to be equivalent to central pool

Northern Bays	1970's (1 yr)	1991-92 (2-yr)	2003-07 (5-yr)	2008-12 (5-yr)	Current Trend
Trophic State					
Dissolved O_2 (mg/L) *Minimum < 6.0 mg/L*	no data	> 6.0	no data	7.2	no trend
Maximum Chl-a (µg/L) *Maximum > 5 ug/L*	no data	no data	3.5	11	Away *from target*
Geomean Chl-a (µg/L) *annual geomean > 3 ug/L*	no data	no data	1.2	1.4	no trend
Tot. Phosphorus (µg/L) *annual geomean > 9 ug/L*	no data	no data	5.7	8.5	Away *from. target*
Water Clarity (m) *summer/fall geomean*	no data	> 8 m	no data	8.5 m	no trend

Central Pool *University Point*	1970's (1 yr)	1991-92 (2-yr)	2003-07 (5-yr)	2008-12 (5-yr)	Current Trend
Trophic State					
Dissolved O_2 (mg/L) *Minimum < 6.0 mg/L*	no data	7.0	5.9	5.8	Uncertain
Maximum Chl-a (µg/L) *Maximum > 5 ug/L*	26	1.9	3.1	5.3	Away *from target*
Geomean Chl-a (µg/L) *annual geomean > 3 ug/L*	11	1.0	1.5	1.8	Away *from target*
Tot. Phosphorus (µg/L) *annual geomean > 8 ug/L*	16	3.8	5.9	8.1	Away *from. target*
Water Clarity (m) *summer/fall geomean*	2.8 m	7.7 m	8.8 m	8.5 m	no trend

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Summary Status of Northern Lake

- **Overall —** several overlapping trends, consistent across N. Lake
  - Some metals (Zinc) are beginning to decline
  - Lake metabolism triggers show increased eutrophication pressure
  - Biologic triggers reinforce trends from lake metabolism
- **Metals —** Zinc declining, cadmium stable, lead variable
- **Trophic State —** Metabolism trending away from oligotrophic status
  - Increasing nutrients and chlorophyll
  - Signs of declining oxygen
  - Bays may be facing more eutrophication pressure than main lake
- **Bioindicators —** Reinforce observed trends in metabolic indicators
  - Phytoplankton community structure shifting towards cyanobacteria predominance
  - Increased frequency of blue-green algae blooms
  - Detection of Eurasian watermilfoil in northern bays

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What Does This All Mean?

- **Don't Panic**
  - Yes, lake is changing
  - Yes, apparent trends in trophic state are not what we desire
  - But – metals situation is steadily improving for zinc
  - And – lake community is actively working to reduce nutrient loading
- **We have work to do**
  - LMP staff need to evaluate causes, provide options
  - Regional stakeholders need to be apprised of lake status
  - What additional response(s) make sense?
  - Community collaboration to formulate action plan, then implement
- **"Clear Water" does not equate to a "Clean Lake"**
  - Lake is beautiful and desirable
  - But – contains "hidden processes" that are not healthy
  - Pro-active response reduces risk of an "unhealthy" lake

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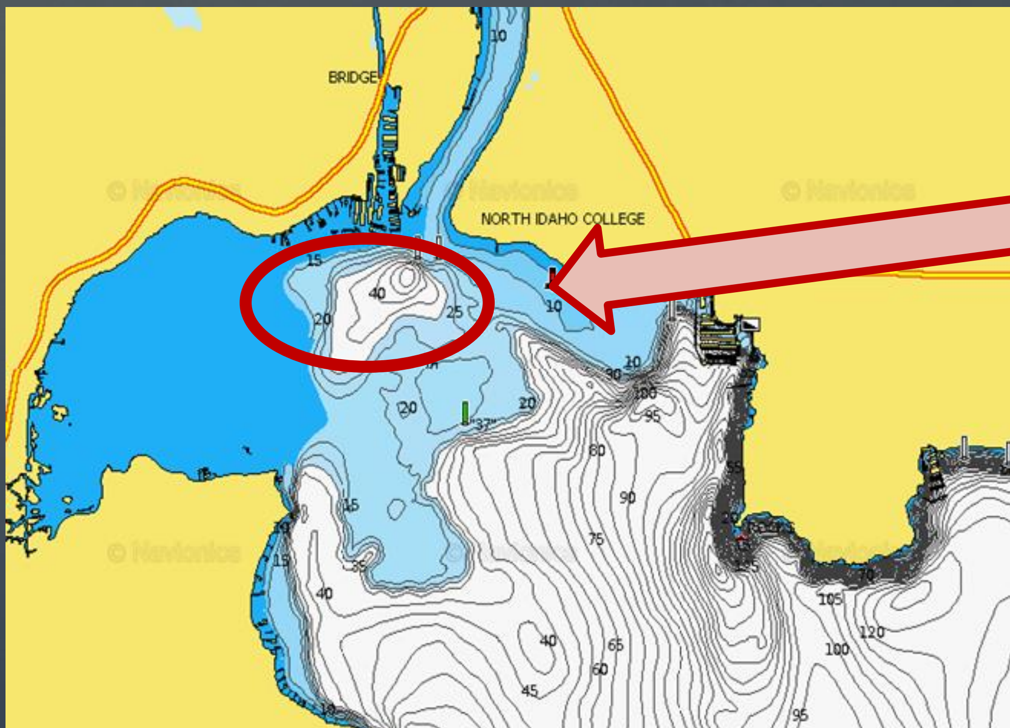
New Site: Shallows of NW Lake, Near Outlet



- New monitoring site (2013 – 2014)
- Cougar-2 or “Cougar Deeps”
- Shallower, potential for anoxia behind sill

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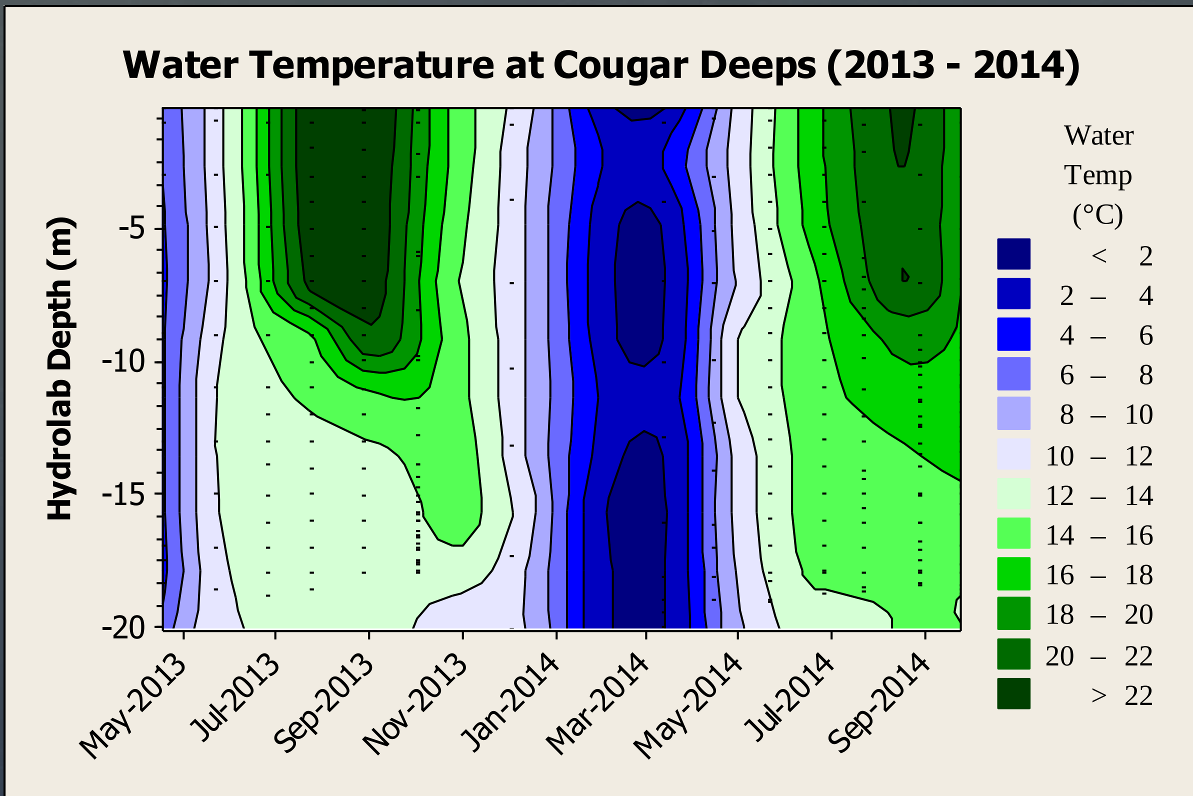
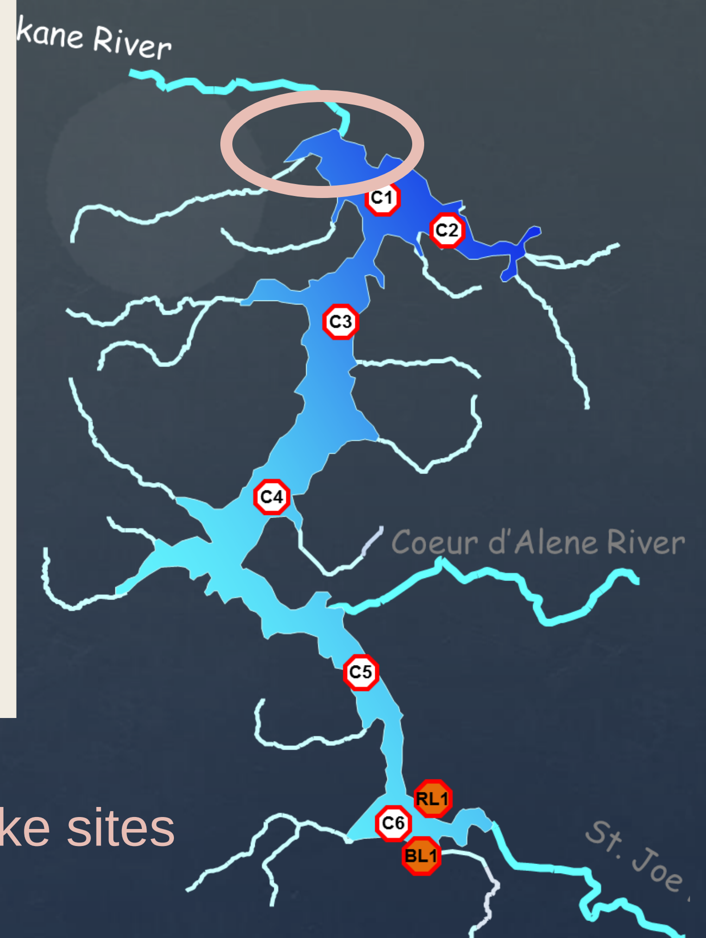
New Data: Stratification, Warmer Water





- Water warmer than main lake sites
- Stratifies in summer
- Stratifies depth ~10-12 m (~30 – 36 ft)

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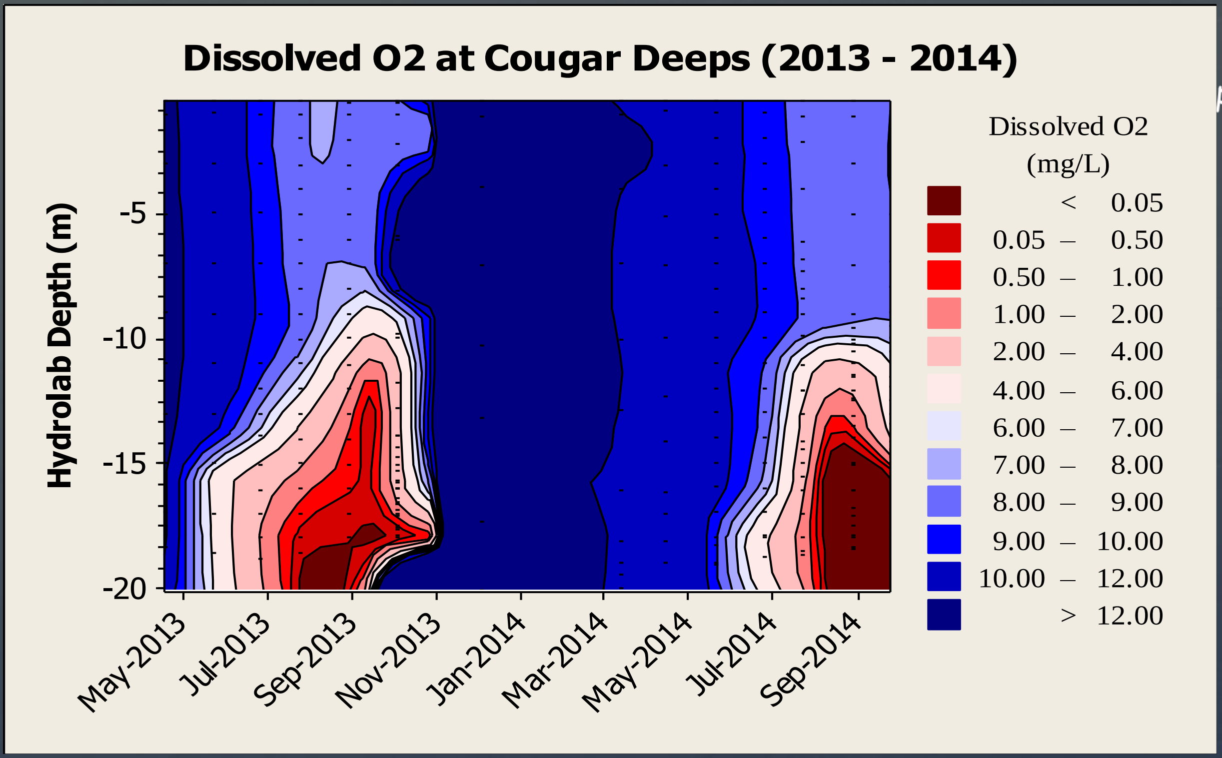
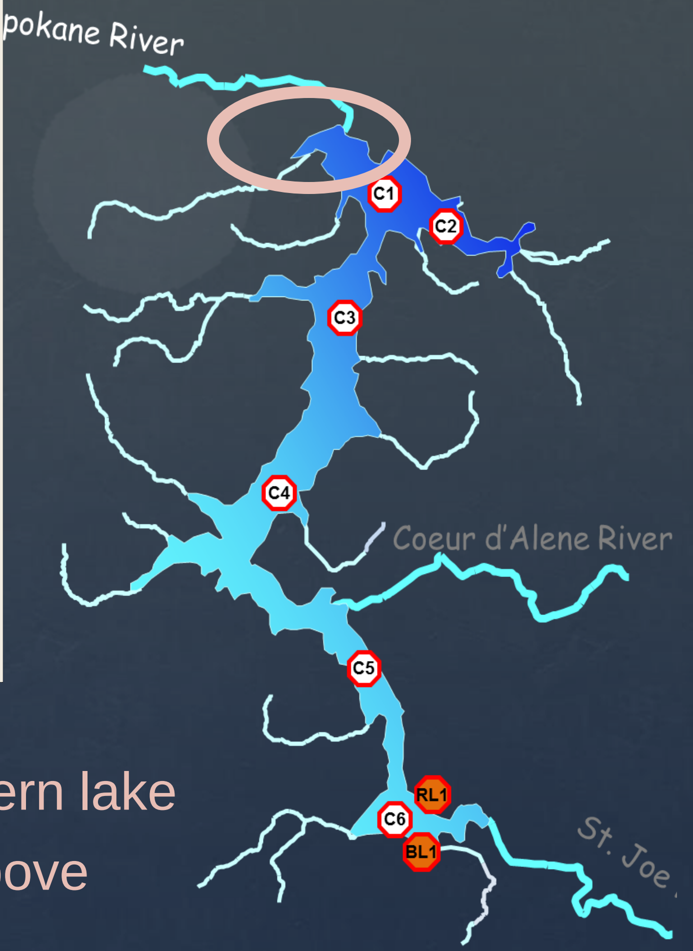
New Data: Seasonal Anoxia in NW Lake





- See anoxia (no O_2) in northern lake
- Hypoxia (low O_2) extends above thermocline.
- Metals, nutrient changes being studied

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