

Protecting Two-Story Lakes: A Battle against Phosphorus and Climate Change

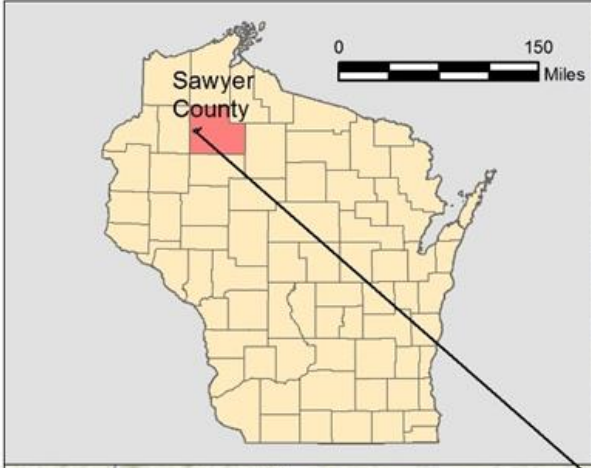
Hans Holmberg, LimnoTech
October 17, 2017

Minnesota Water Resources Conference

Acknowledgments

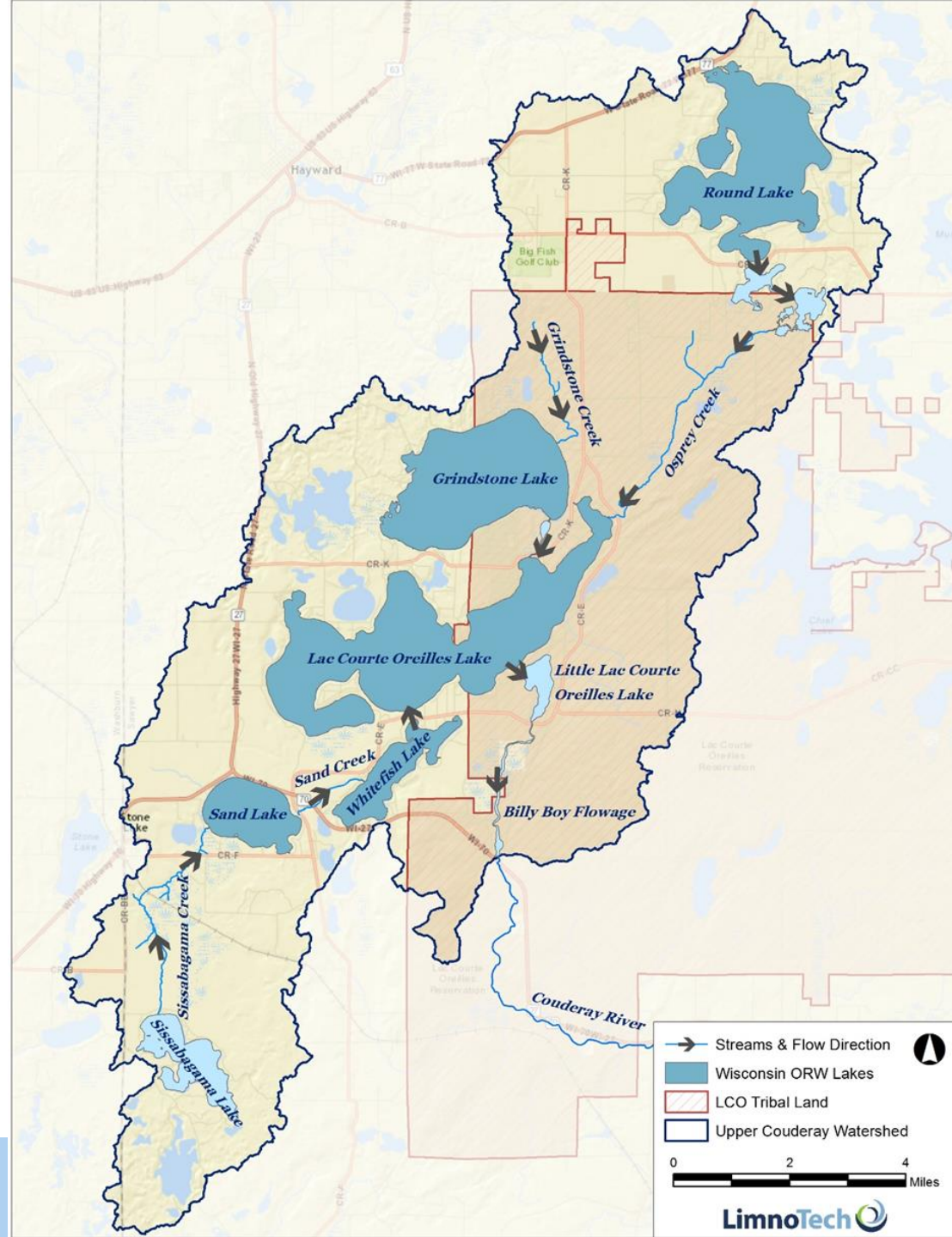
- Gary Pulford, Courte Oreilles Lake Association (COLA), www.cola-wi.org
- Dan Tyrolt, LCO Tribal Conservation Dept., www.lco-nsn.gov/
- Dendy Lofton, Ph.D. and Ben Crary, LimnoTech, www.limno.com



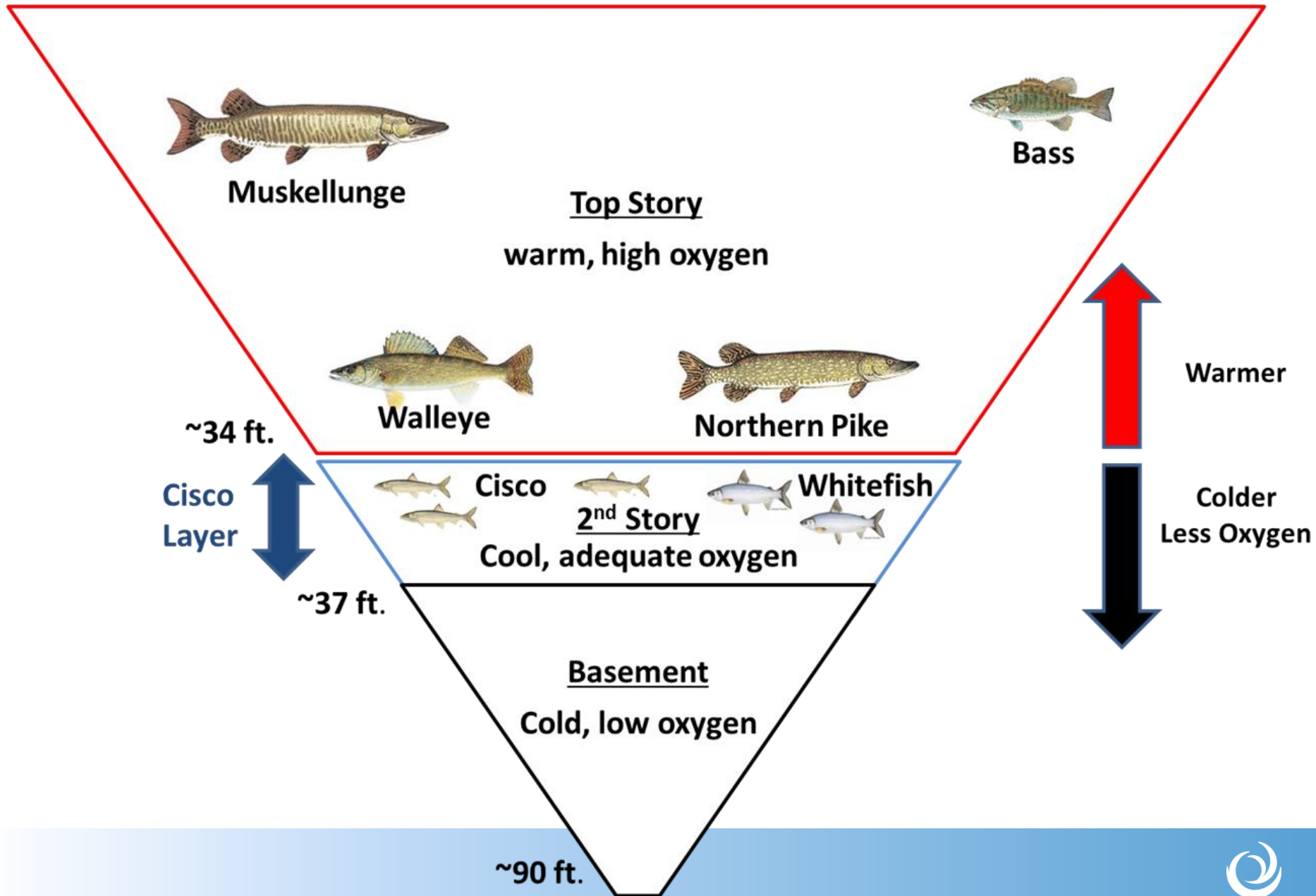


The LCO watershed

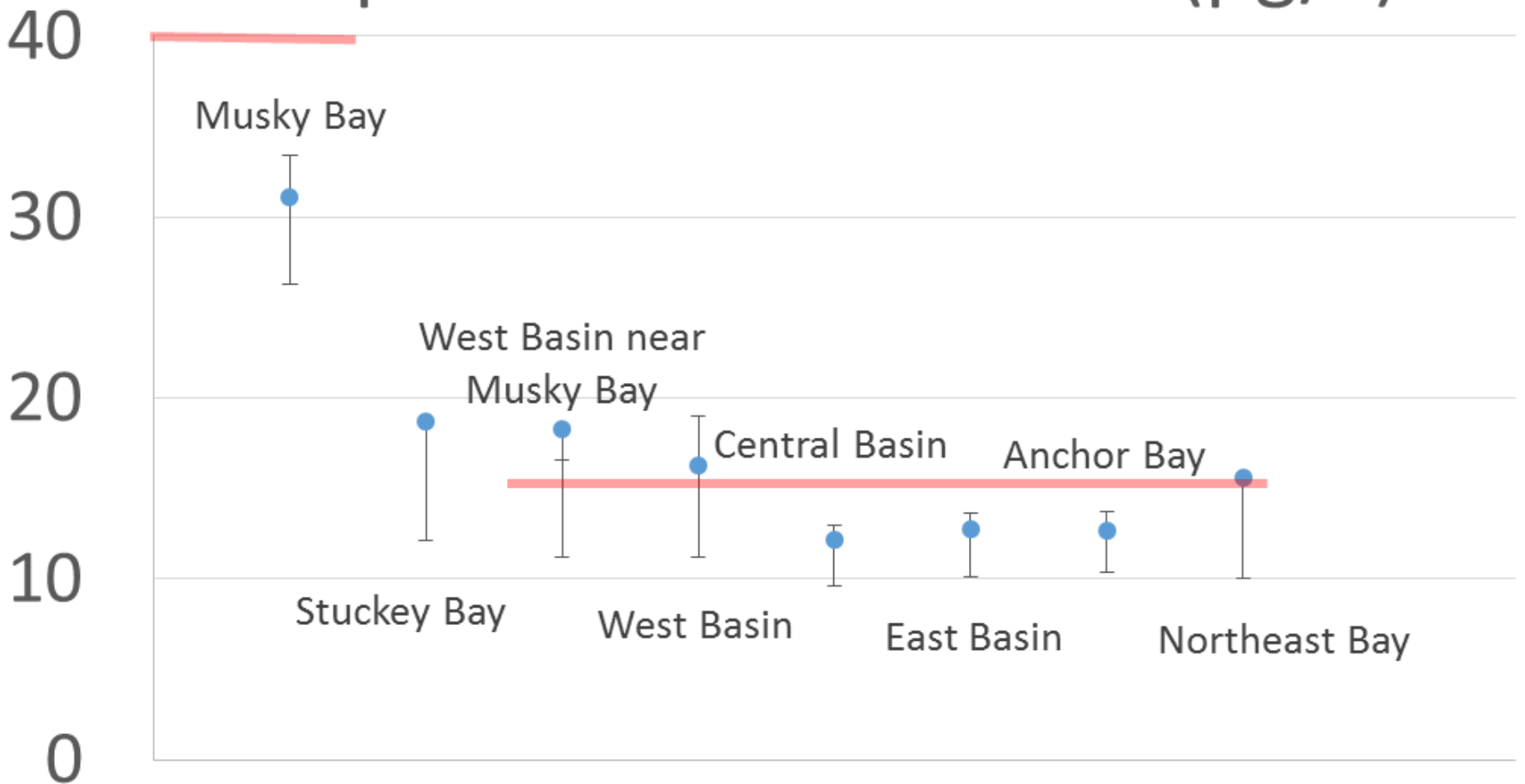
- Primarily forested and open water
- <10% agricultural and developed



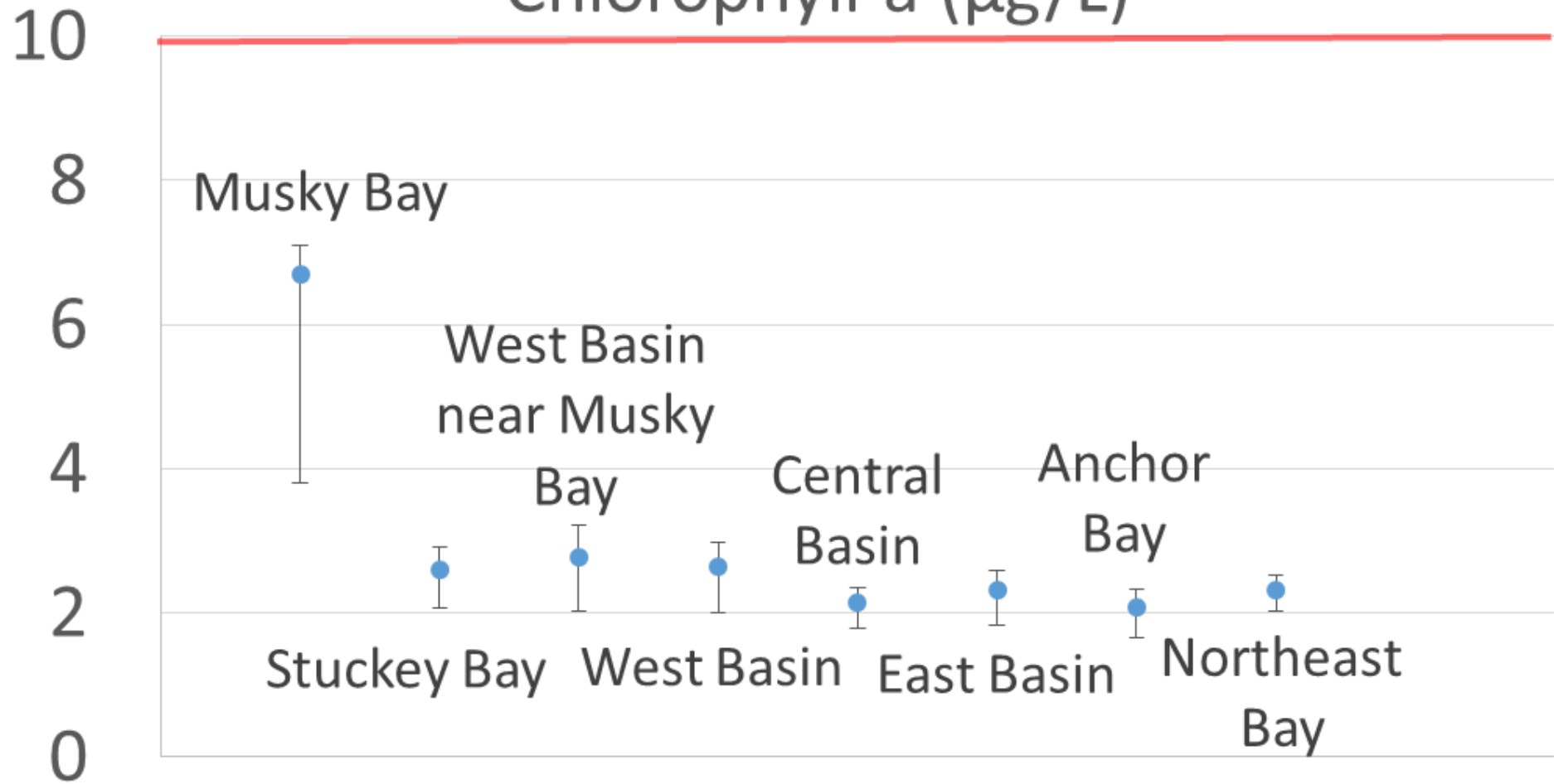
Two-Story Lakes



2012-2016 Growing Season Total Phosphorus Concentration ($\mu\text{g/L}$)



2012-2016 Average Growing Season Chlorophyll a ($\mu\text{g/L}$)



So, what's the matter?



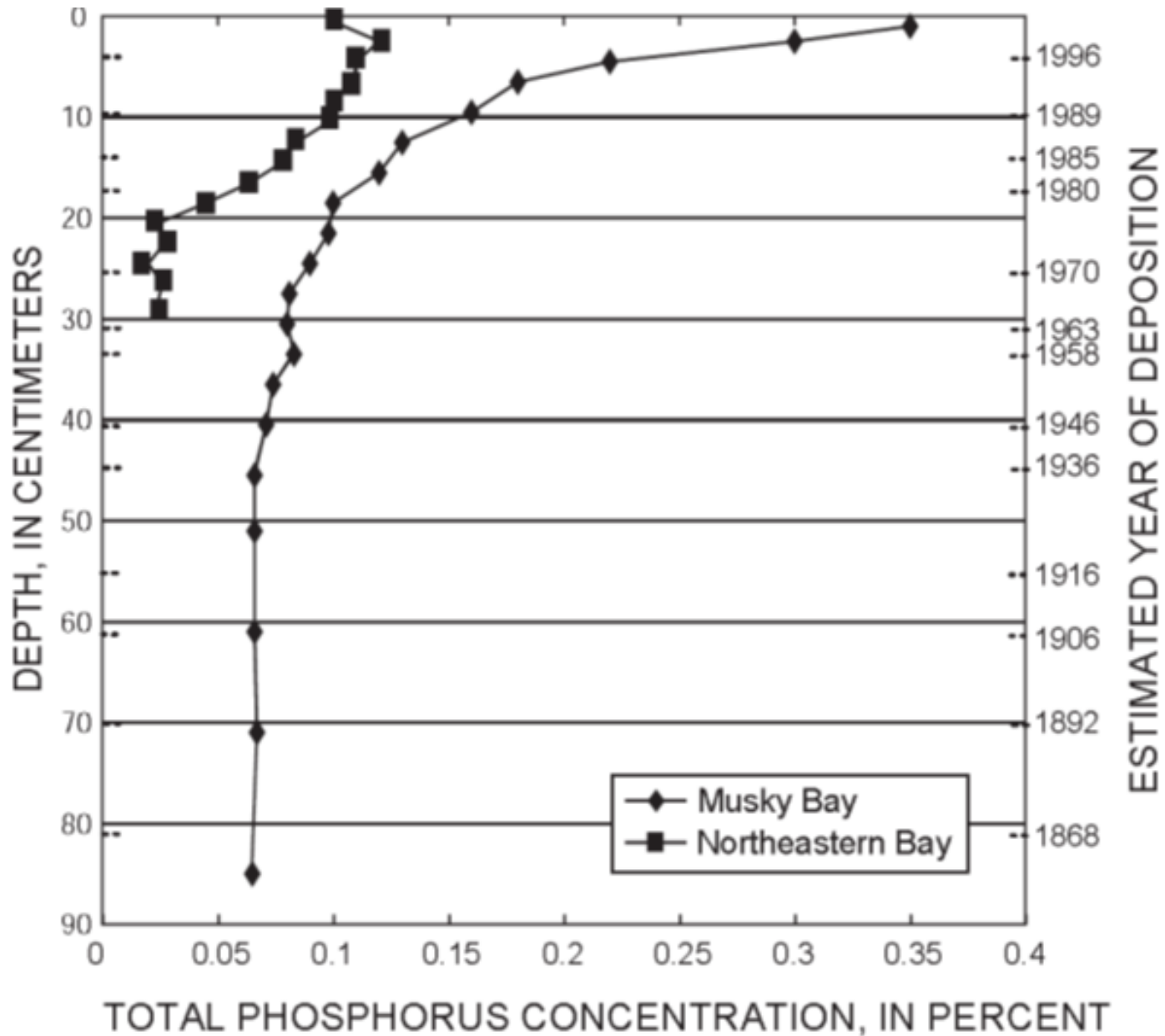
Coldwater habitat has been pinched too far resulting in fish kills



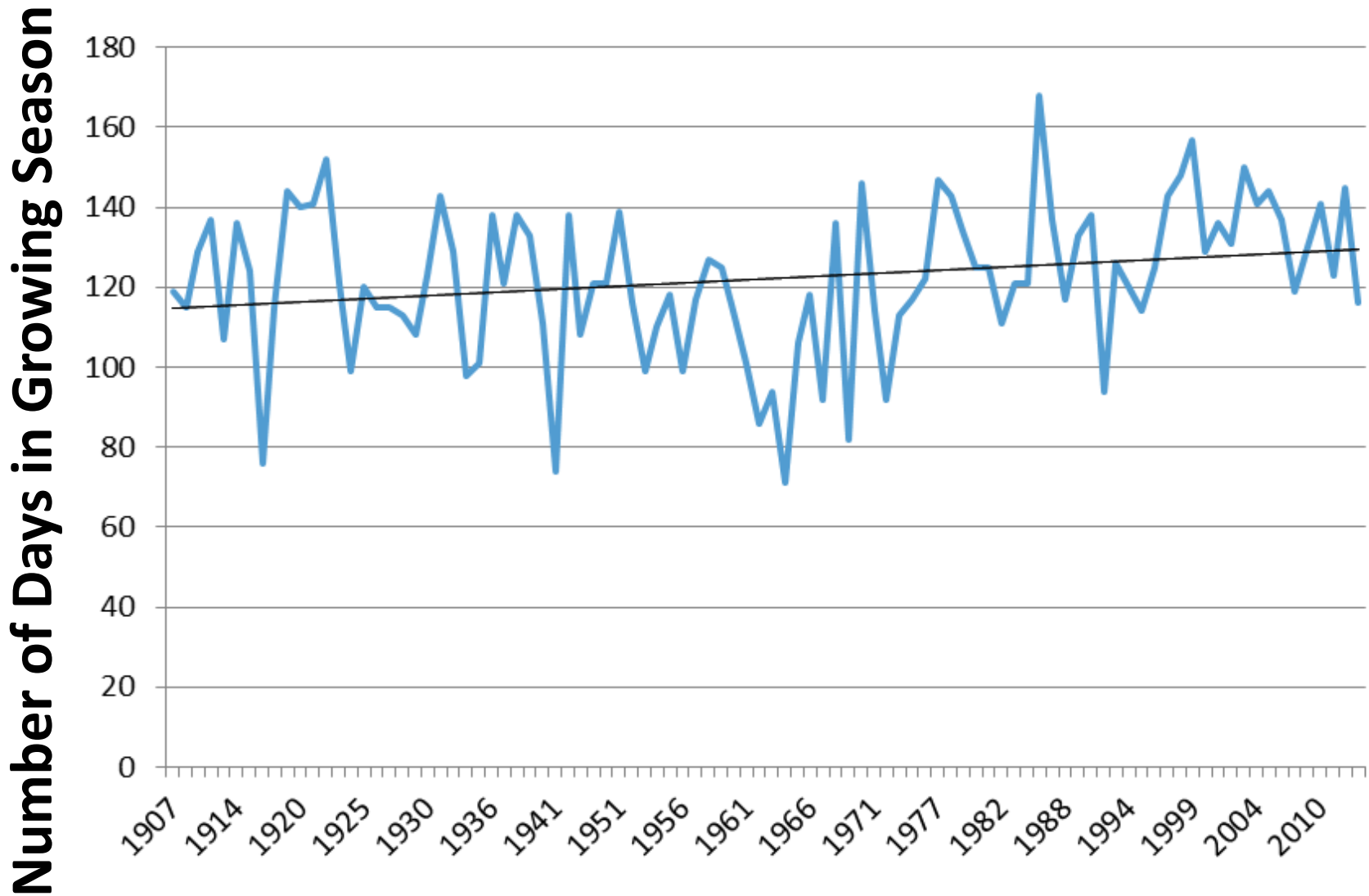
August 2016



Stressors: Increasing phosphorus



Stressors: Changing climate



Site-specific criteria needed to protect LCO coldwater fish

- How much oxygen?
- How cool of temps?
- How much space?
- For how long?
- What level of phosphorus to support?



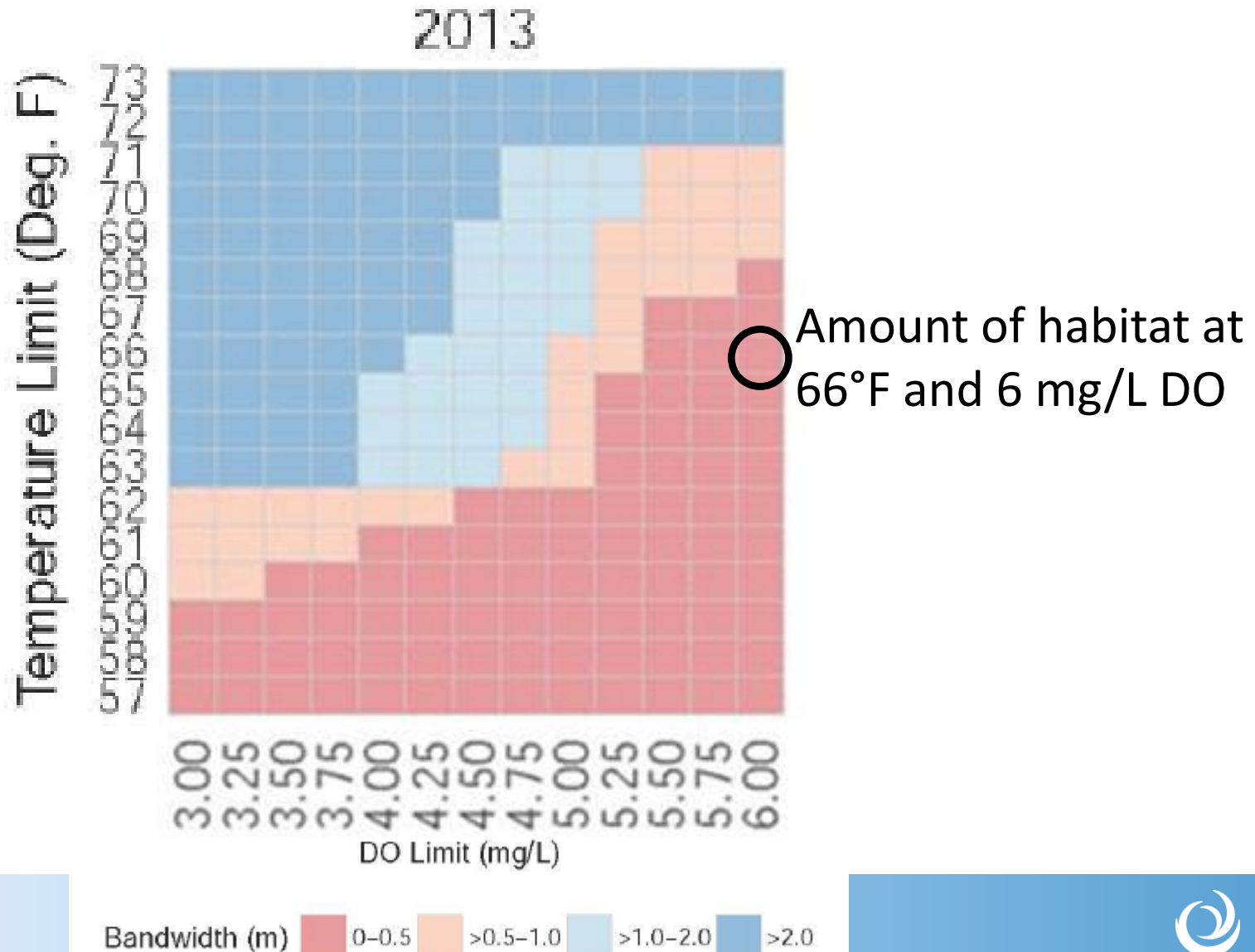
What do we know about these fishes?

- Cisco
 - Ideal temperatures 39-63°F, mortality around 73°F*
 - Can survive in dissolved oxygen of 3-5 mg/L, but suboptimal*
- Lake Whitefish like similar DO but cooler temps
 - Upper limit around 66°F*
- WDNR considering a habitat criterion as maintaining a band of water of at least 1 meter that is:
 - at or below the acceptable temperature; and
 - at or above the acceptable dissolved oxygen

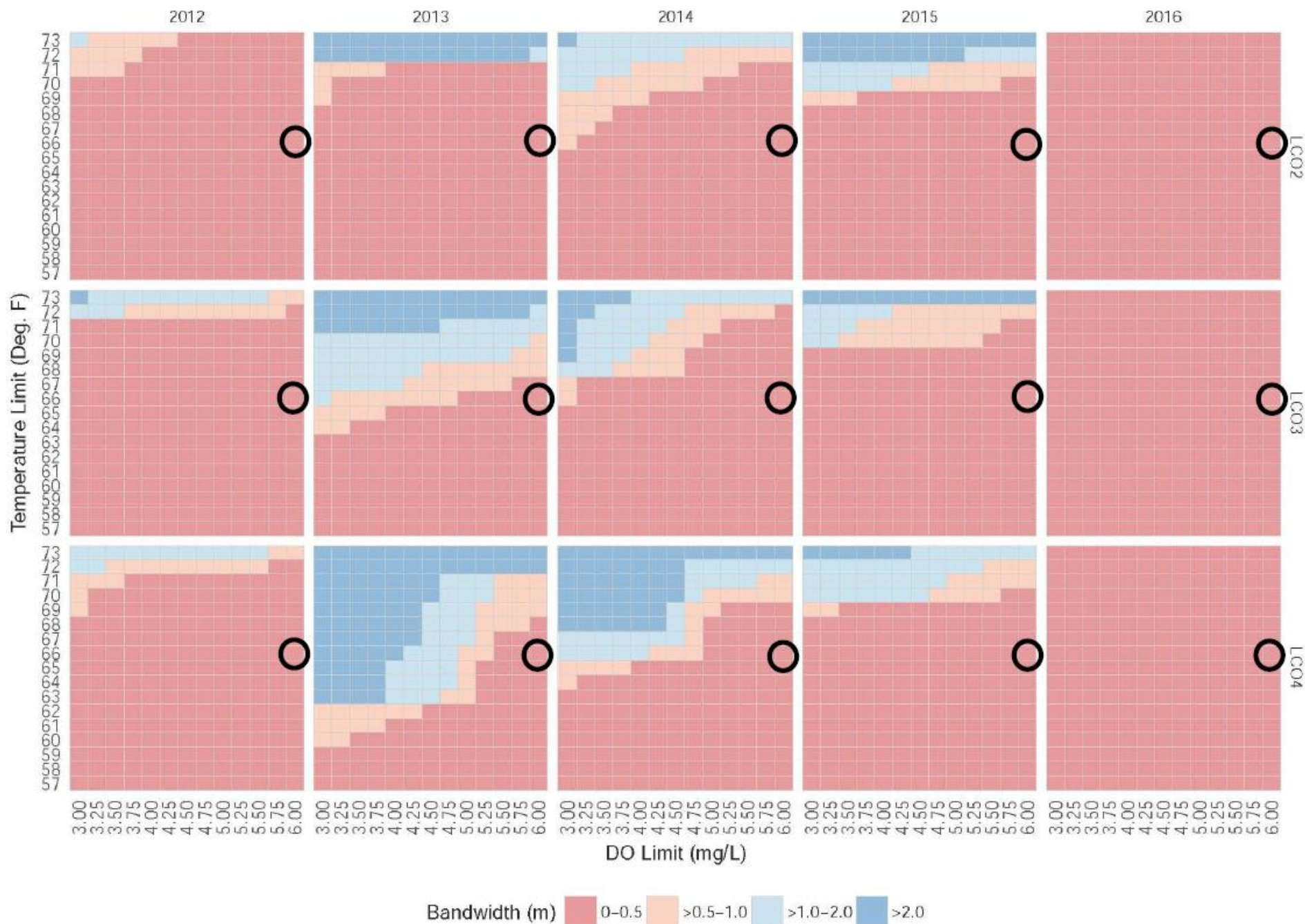
*Jacobson P.C., H.G. Stefan and D.L. Pereira. 2010. Coldwater Fish Oxythermal Habitat in Minnesota Lakes: Influences Of Total Phosphorus, July Air Temperature, and Relative Depth. *Canadian Journal of Fisheries and Aquatic Sciences* 67(12), 2003-2013.



Assessing habitat bands at different temperatures and DO



Minimum measured habitat bandwidth (2012–2016)



Is there a simple way to relate coldwater habitat conditions to phosphorus?

- Estimate future hypolimnetic oxygen demand (HOD) based on relative change in phosphorus

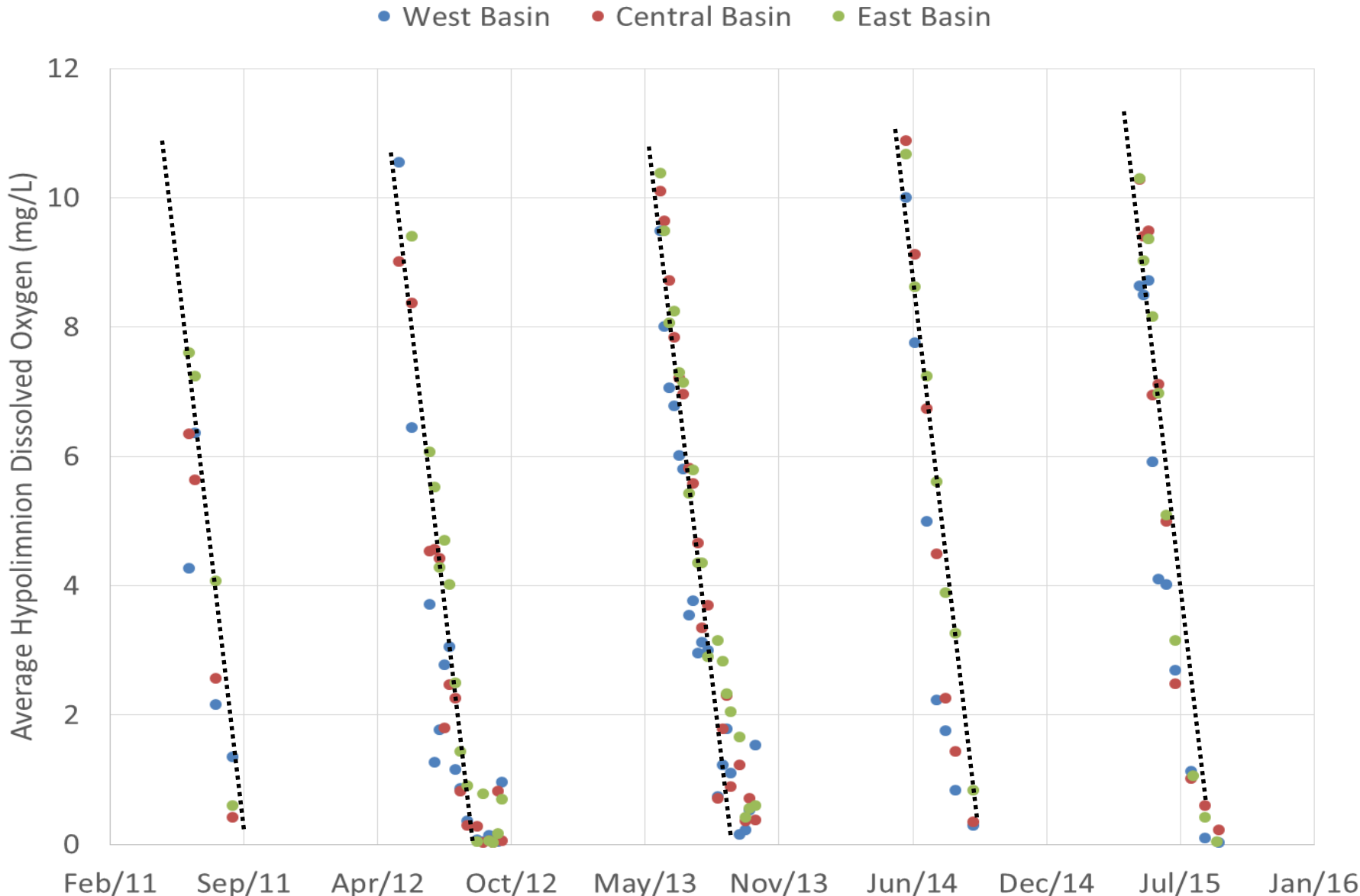
$$\text{HOD}_{\text{future}} / \text{HOD}_{\text{present}} = (\text{TP}_{\text{future}} / \text{TP}_{\text{present}})^{0.478*}$$

$$\text{HOD}_{\text{future}} = \text{HOD}_{\text{present}} \cdot (\text{TP}_{\text{future}} / \text{TP}_{\text{present}})^{0.478}$$

**Chapra. S.C. and R. P. Canale. 1991. Long-Term Phenomenological Model of Phosphorus and Oxygen For Stratified Lakes. Wat. Res. Vol. 25, No. 6, pp. 707-715.*



We can estimate HOD from dissolved oxygen trend in hypolimnion



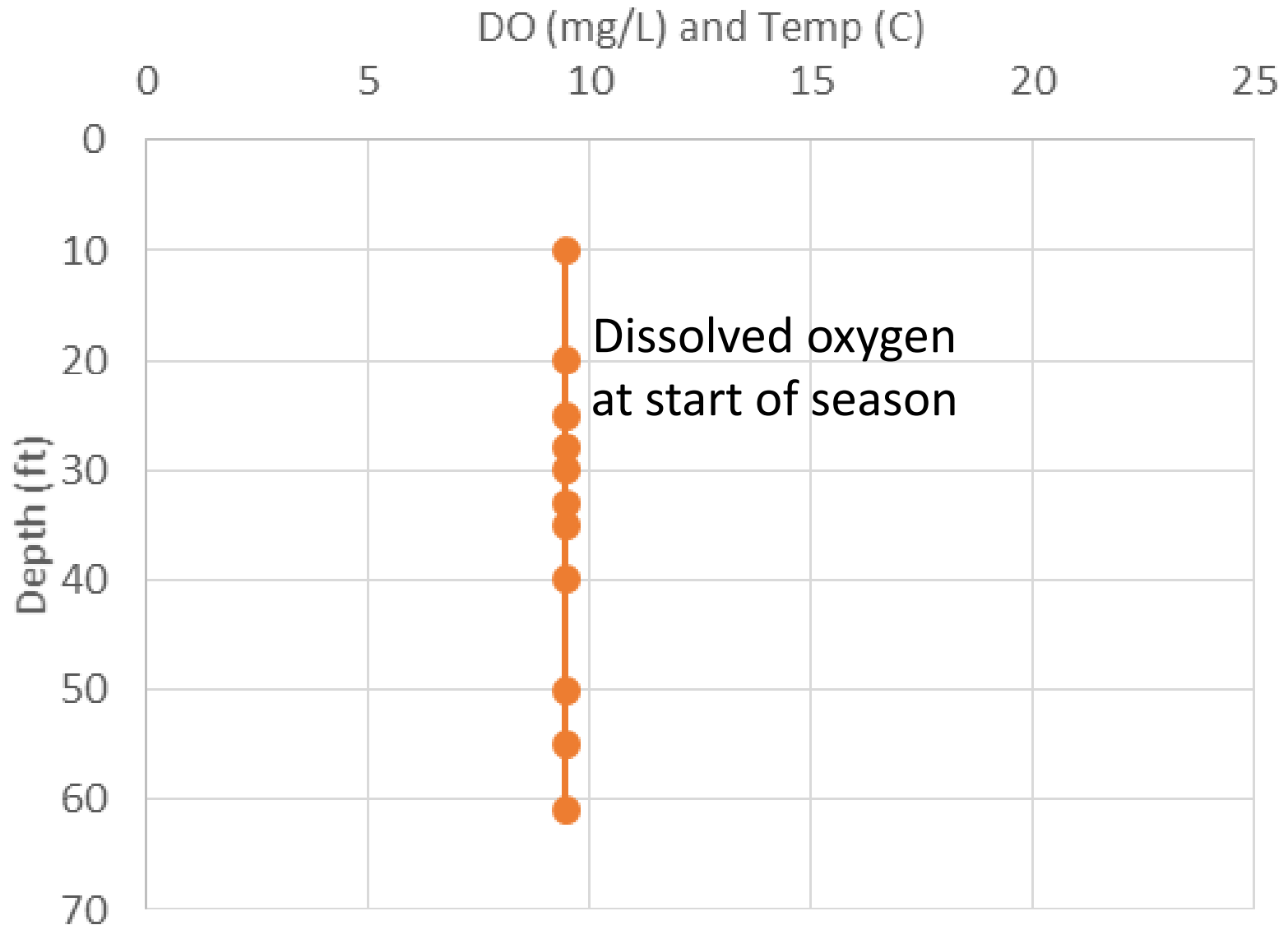
What is new dissolved oxygen profile at lower phosphorus?

- Adjust the dissolved oxygen deficit profile towards early season conditions relative to the predicted change in HOD

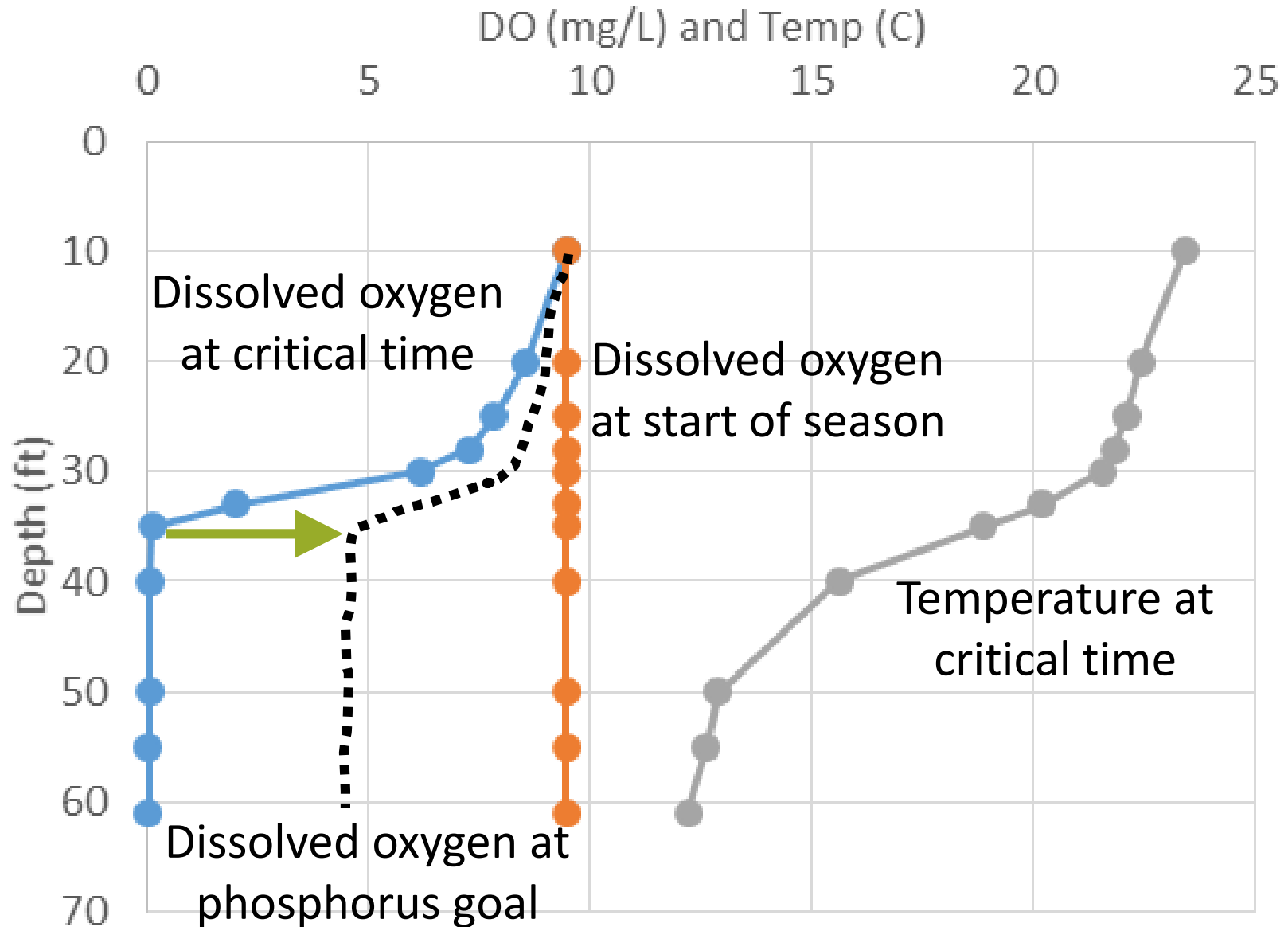
$$DO_{\text{deficit_future}} = HOD_{\text{future}} / HOD_{\text{present}} \cdot DO_{\text{deficit_present}}$$



Start with dissolved oxygen prior to stratification



Adjust critical time deficit



Lower TP leads to increased coldwater habitat

At 10 $\mu\text{g/L}$ TP...

West Basin gains 343 Olympic sized swimming pools (at $\sim 660,000$ gallons each) of suitable habitat at critical conditions, a 19% increase;

Central Basin gains 94 pools, a 7% increase; and

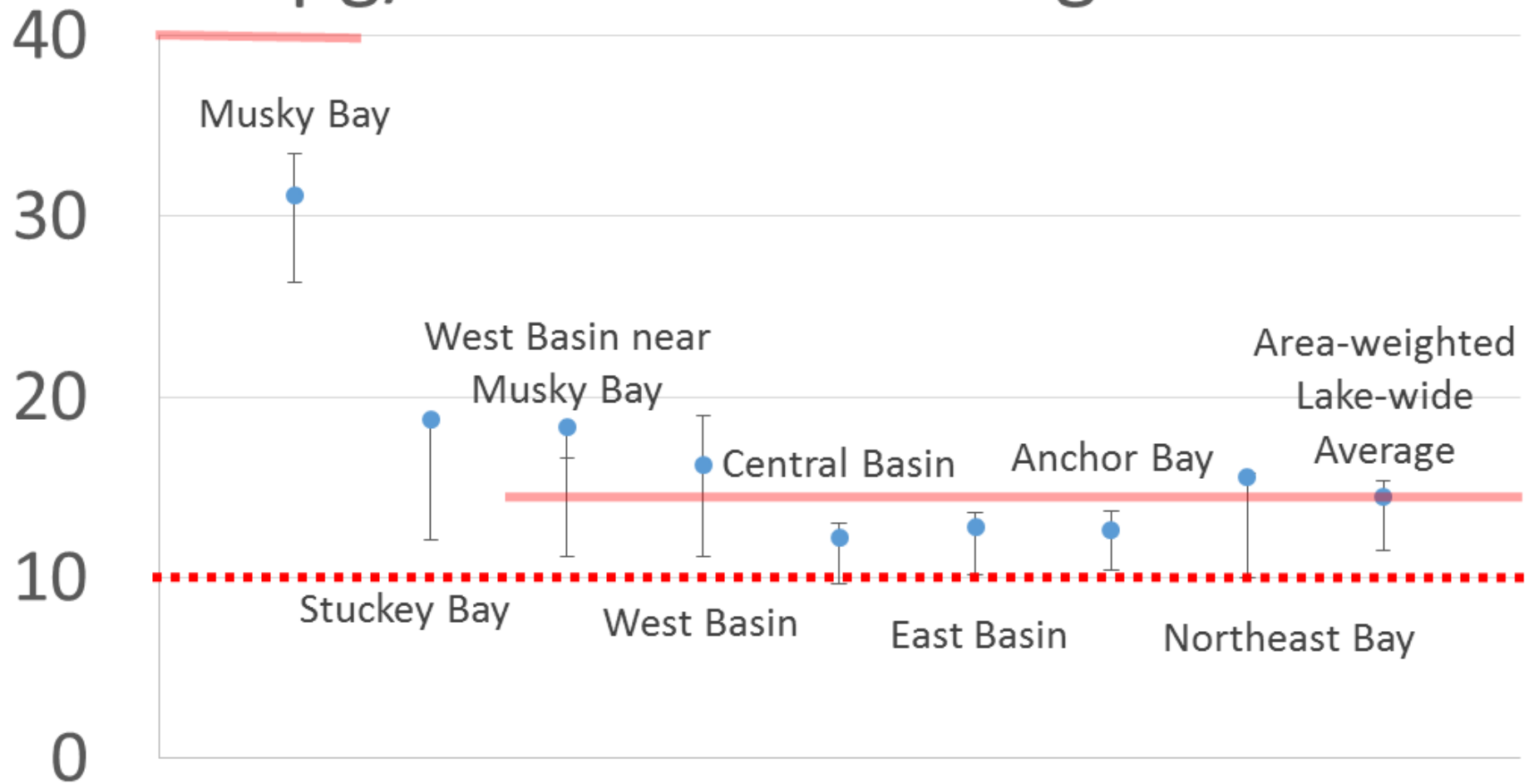
East Basin gains 1,720 pools, a 69% increase



Lower TP means more room for cisco and whitefish



Comparison to preliminary 10 $\mu\text{g}/\text{L}$ lake-wide average TP SSC



Lessons learned

- Can't beat having good data
 - Plan, fund, get the data, tell the story, repeat...
- Lakes are unique and complex
 - Look under the hood
- Regulatory changes are a hassle
 - Persevere
- Two-story lakes are a gem
 - *Let's not let them slip away!*



Questions?

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