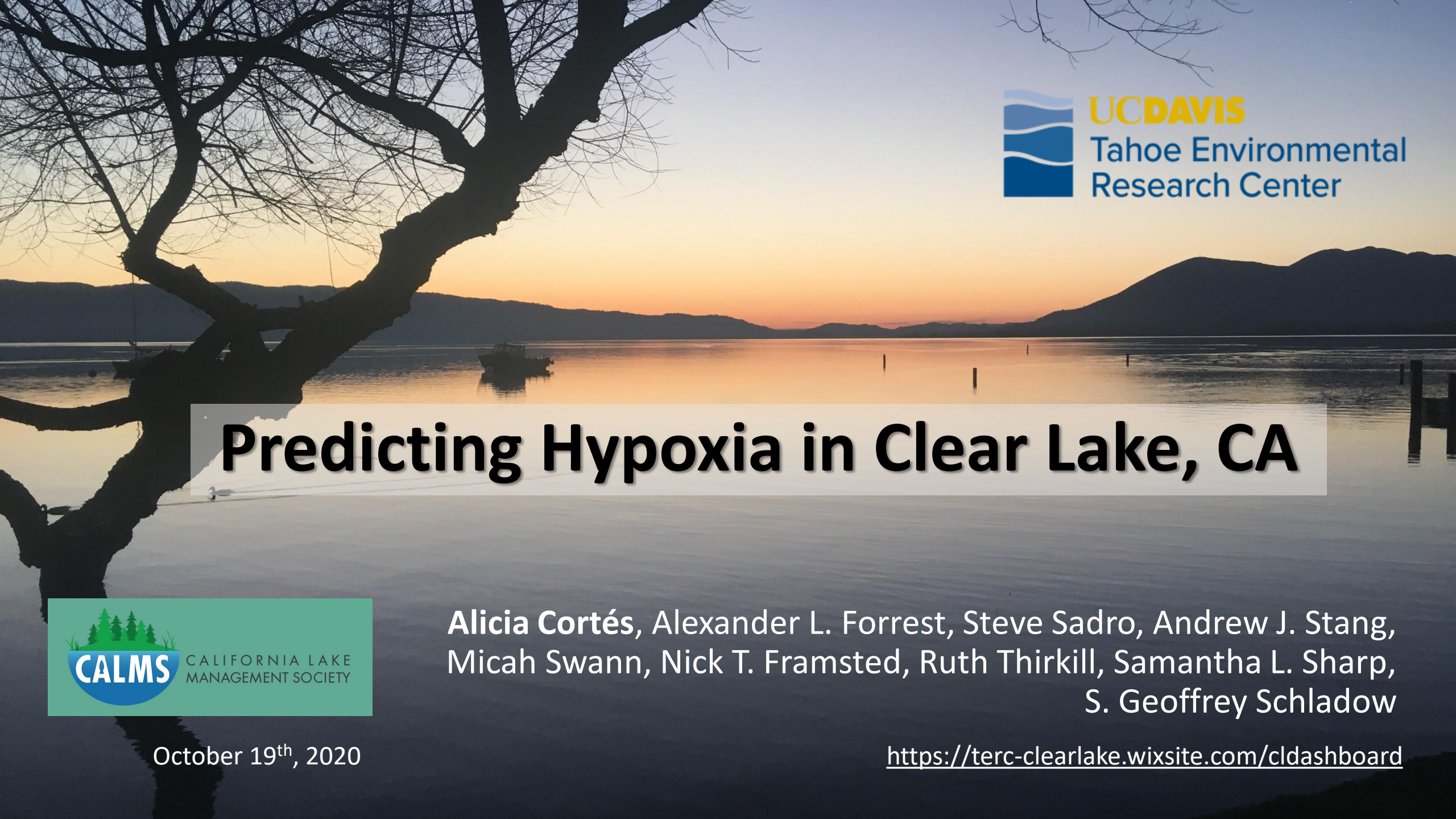


UCDAVIS Tahoe Environmental Research Center

Predicting Hypoxia in Clear Lake, CA

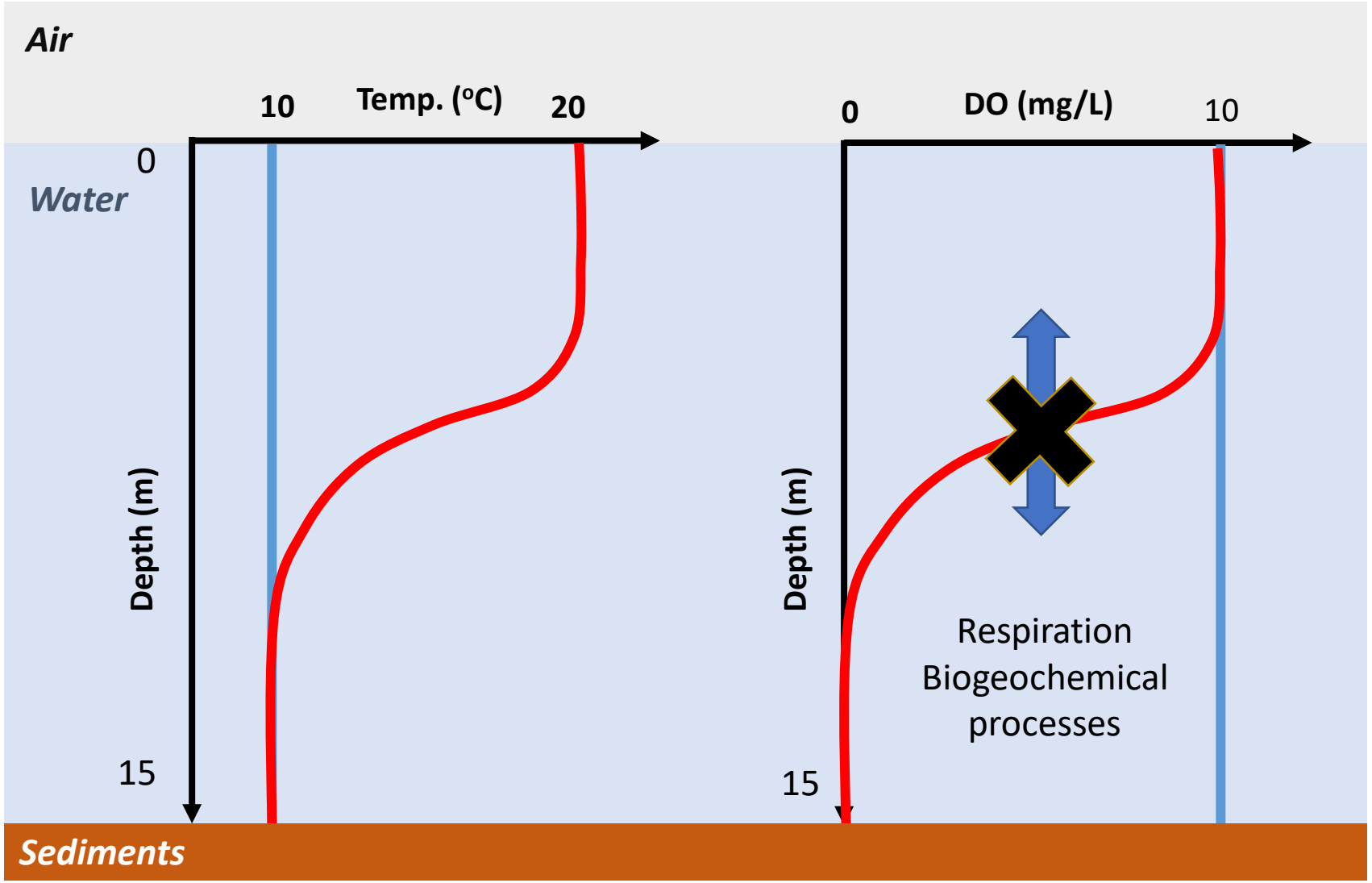
CALMS CALIFORNIA LAKE MANAGEMENT SOCIETY

Alicia Cortés, Alexander L. Forrest, Steve Sadro, Andrew J. Stang, Micah Swann, Nick T. Framsted, Ruth Thirkill, Samantha L. Sharp, S. Geoffrey Schladow

October 19th, 2020

https://terc-clearlake.wixsite.com/cldashboard

Dissolved Oxygen (DO), Temperature and Hypoxia



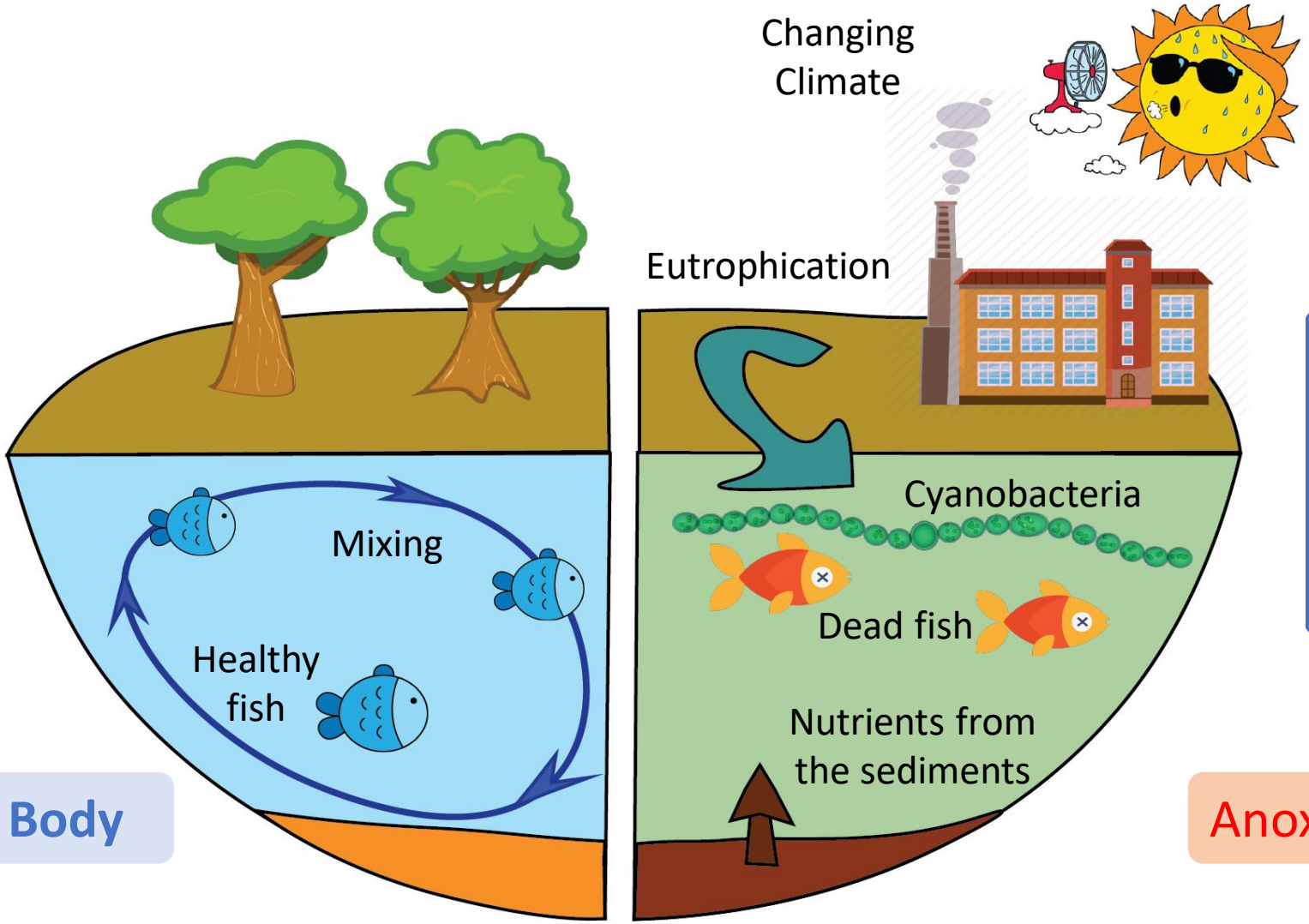
Winter (mixing)

Summer (stratification)

Problem in the past century

DO depletion in water bodies that leads to low levels of DO (hypoxia)

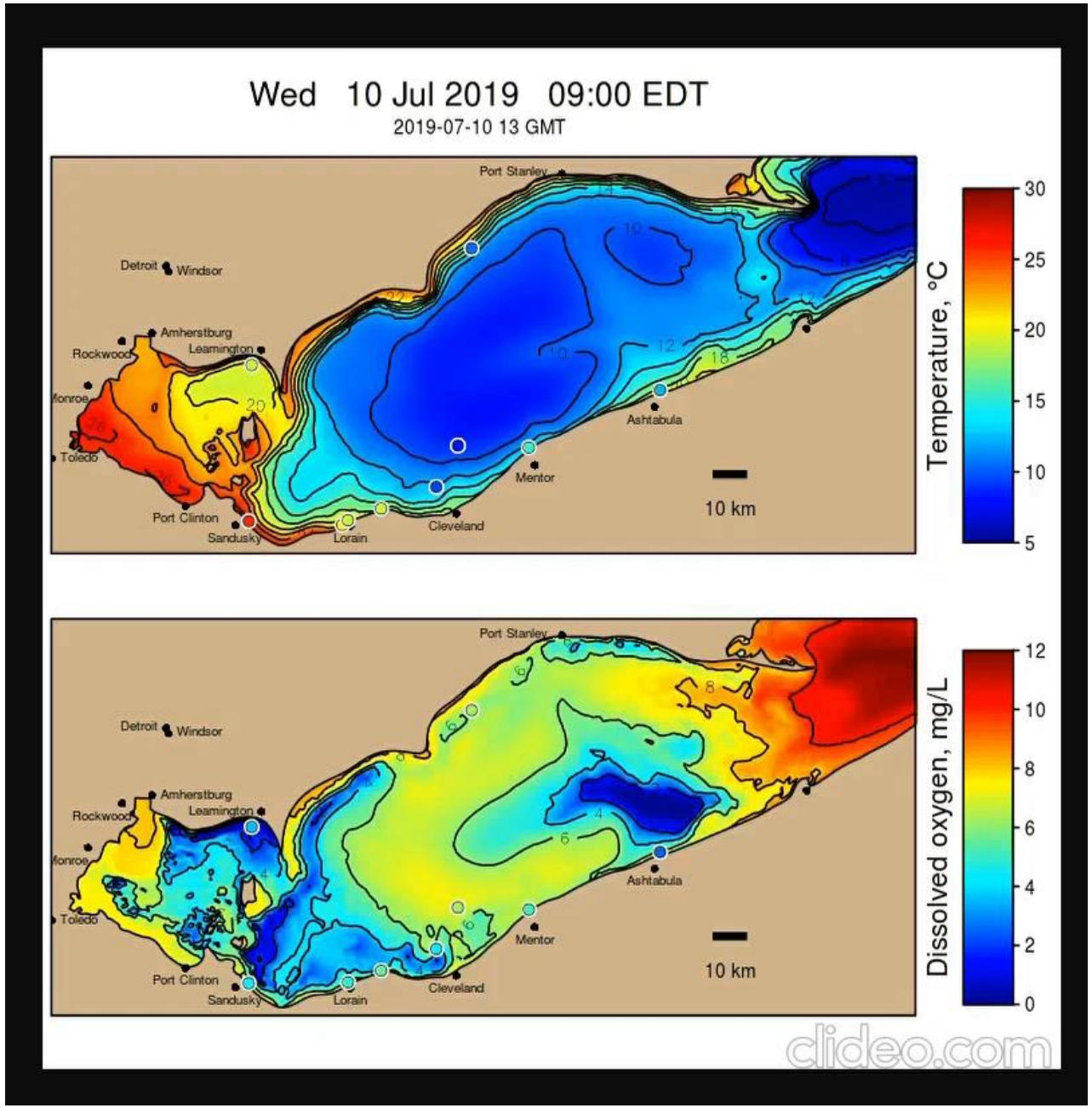
Causes and Effects of Hypoxia



Predicting the drawdown of DO in lakes and reservoirs

Oxic Water Body

Anoxic Water Body



Tools to Predict DO depletion: 3-D Models

NOAA - Great Lakes Environmental Research Laboratory

Lake Erie Hypoxia Forecast

https://www.glerl.noaa.gov/res/HABs_and_Hypoxia/hypoxiaWarningSystem.html

They need lots of data and calibration!

Main Goal

Predicting the drawdown of DO in lakes and reservoirs
BUT
Using simpler 1-D model that requires only a few input variables

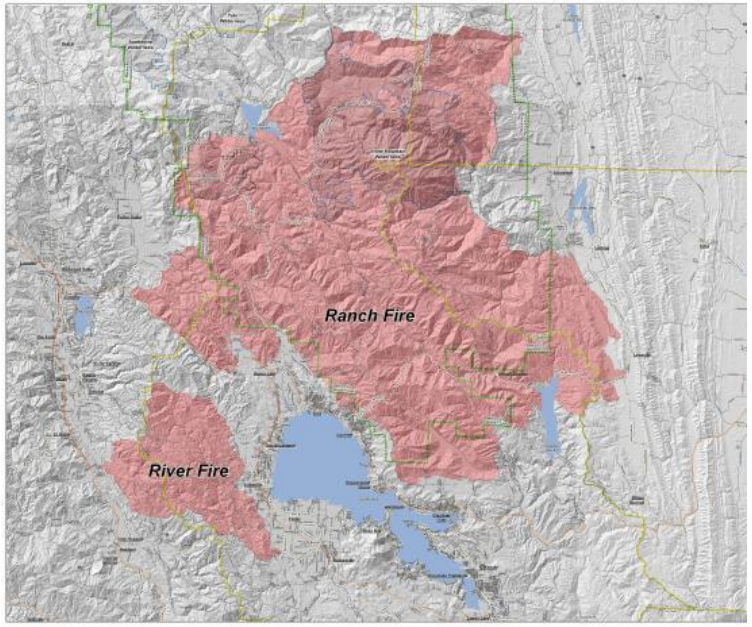
Clear Lake California

Clear Lake Singularities

- The **largest** natural lake in California (SA = 151 km^2)
- The **oldest** lake in North California (2.5 million years)
- Top contributor to the local **Lake County economy** (boating, bass fishing)
- Naturally **eutrophic** and biologically very **diverse**
- Essential for cultural activities and economies of **Native American Tribes**
  - *Big Valley Band of Pomo Indians*
  - *Scotts Valley Band of Pomo Indians*
  - *Habematolel Pomo of Upper Lake*
  - *Middletown Rancheria of Pomo Indians*
  - *Elem Indian Colony*
  - *Koi Nation of Northern California*

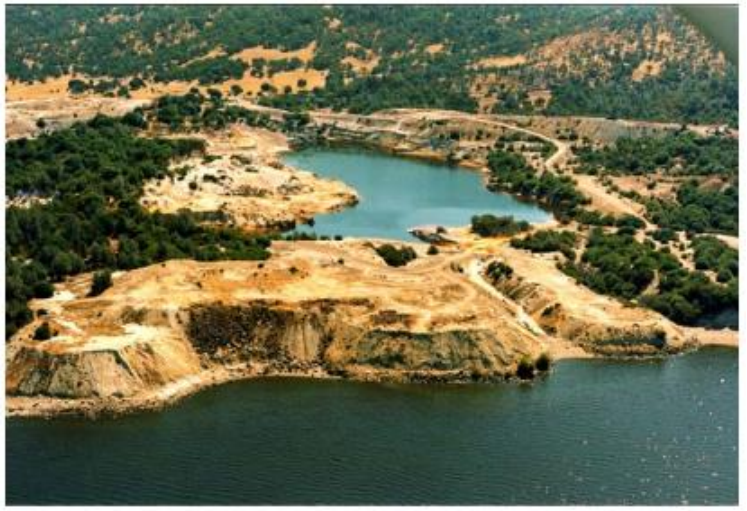
Clear Lake Environmental Challenges

- Eutrophication (agriculture)
- Cyanobacterial blooms
- Extreme wildfires
- Mercury contamination
- Pesticide overuse
- Fish kills



Impact of 2018 Mendocino Complex Fire

Cyanobacterial bloom, July 2016



Aerial view of the Sulphur Bank Mercury Mine

Blue Ribbon Committee for the Rehabilitation of Clear Lake



The 15-member ***Blue Ribbon Committee for the Rehabilitation of Clear Lake***, created by Assembly Bill 707 (Aguiar-Curry, Ch. 842, Statutes of 2017) includes representatives from:

- Tribes
- Lake County with expertise in agriculture, economics, environment and public water supplies
- UC Davis
- Central Valley Regional Water Quality Control Board

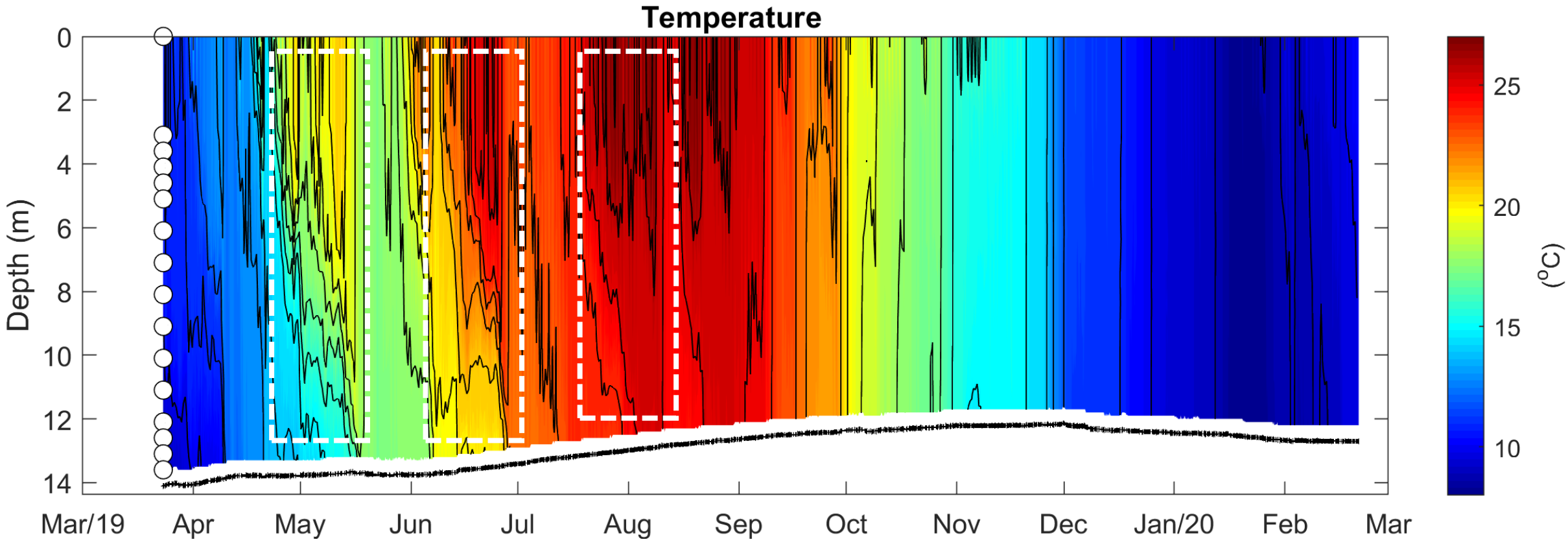
https://resources.ca.gov/Initiatives/Blue-Ribbon-Committee-for-the-Rehabilitation-of-Clear-Lake/

The Committee has been given the important charge of making recommendations for rehabilitating Clear Lake, which is critical to Lake County's economy, ecosystem, and heritage.

Clear Lake: A complex system

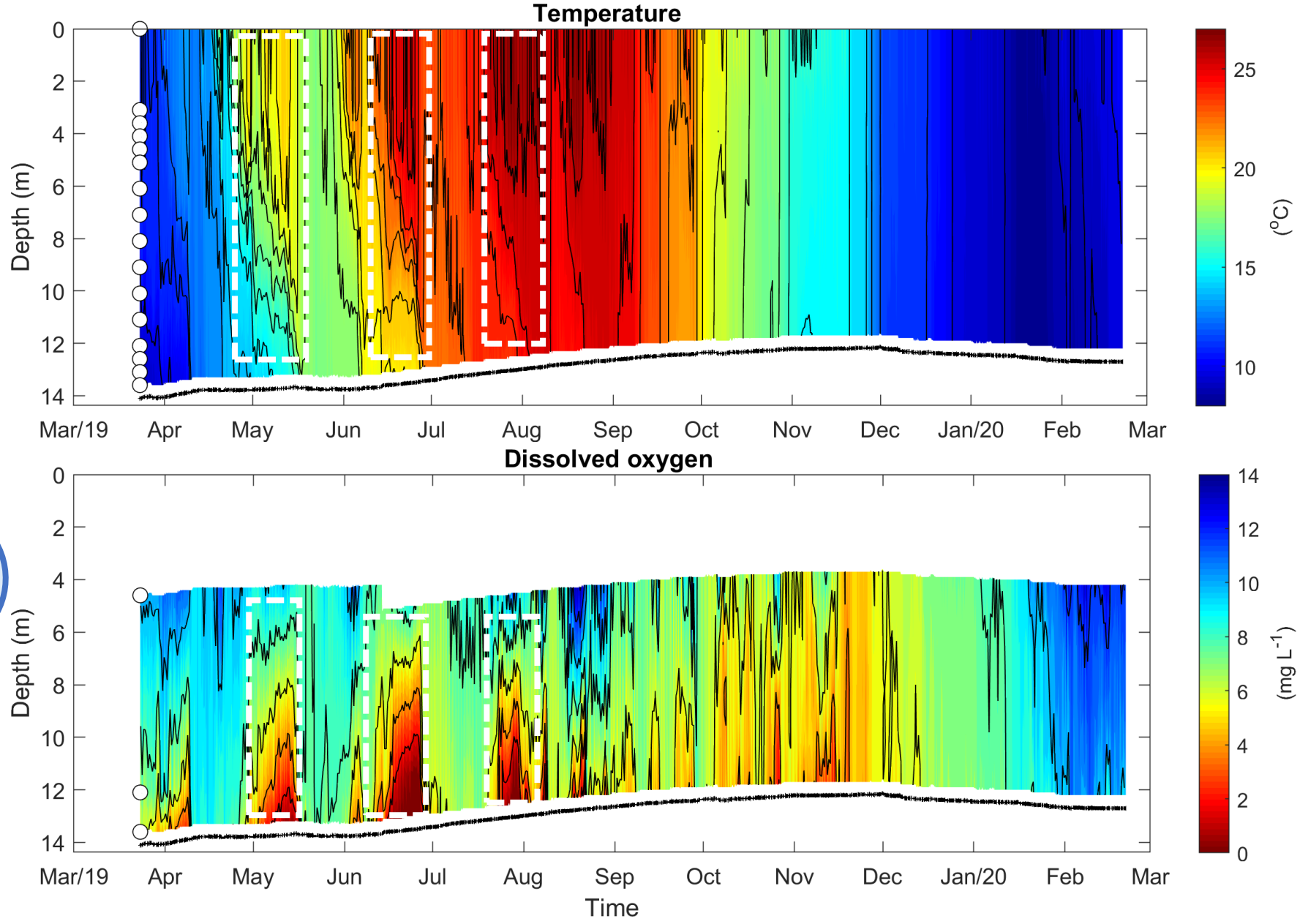
Large Lake (150 km^2) ➔ Different conditions in different basins
Shallow Lake (15 m) ➔ Large fraction of water exposed to the sediments
Polymictic Lake ➔ Multiple mixing events - Multiple cycles of oxygenation and anoxia

Lake Temperature Stratification

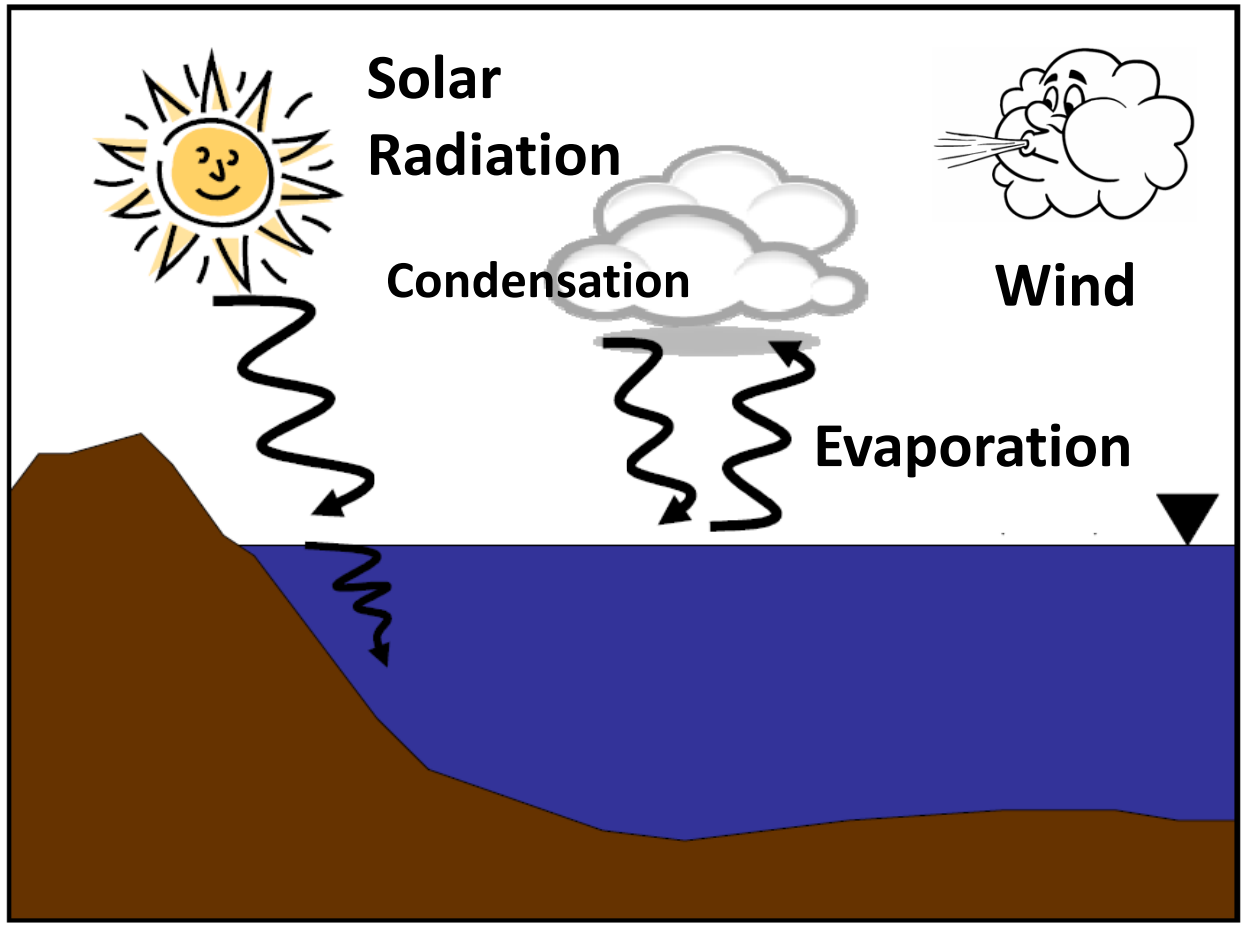


Lake Temperature Stratification and Hypoxia

How can we link Lake Temperature Stratification and Hypoxia?



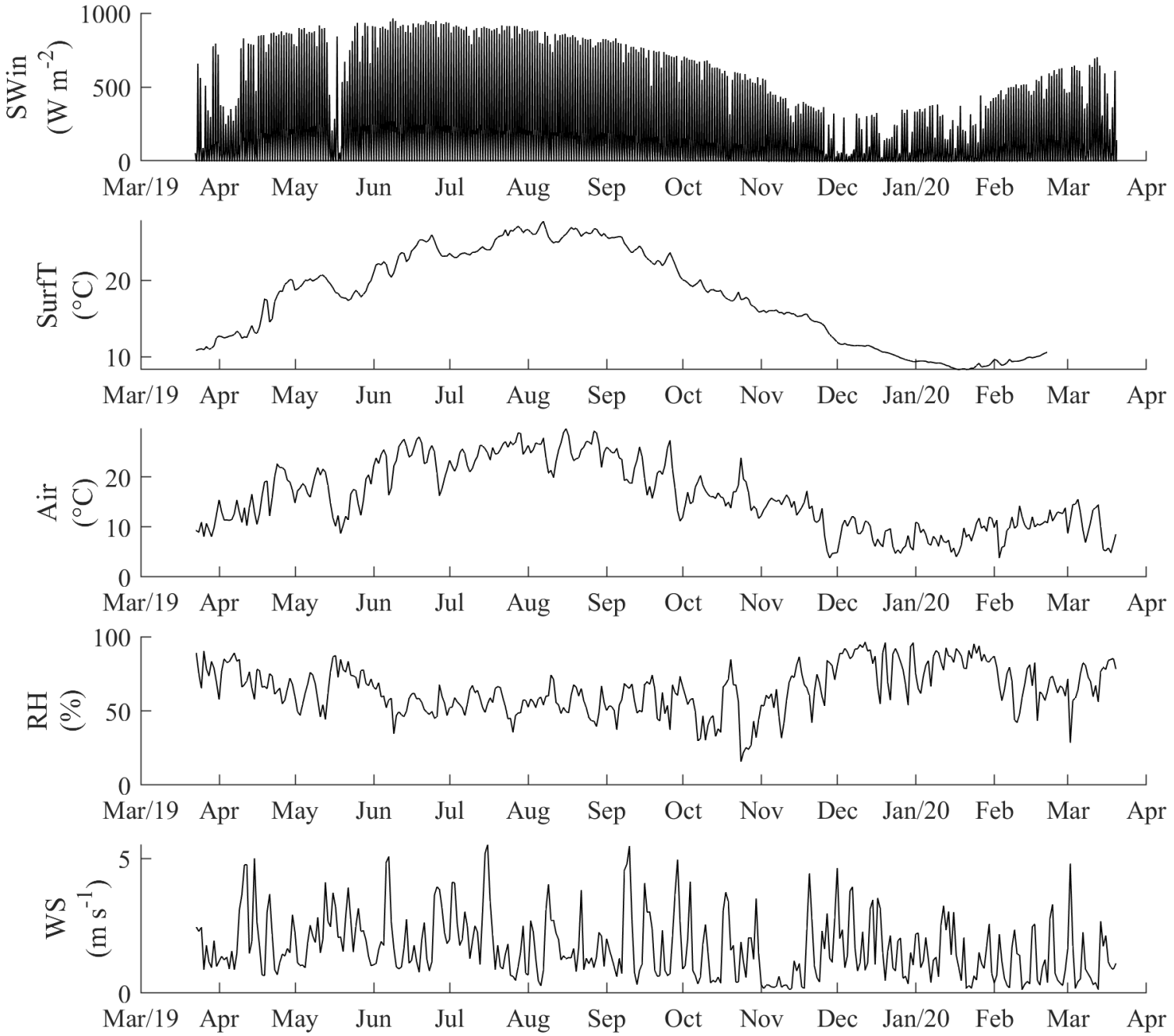
Meteorological Forcing



Predictive Tool of Anoxic Events based on How Much the Lake Heats and Cools

Meteorological Conditions

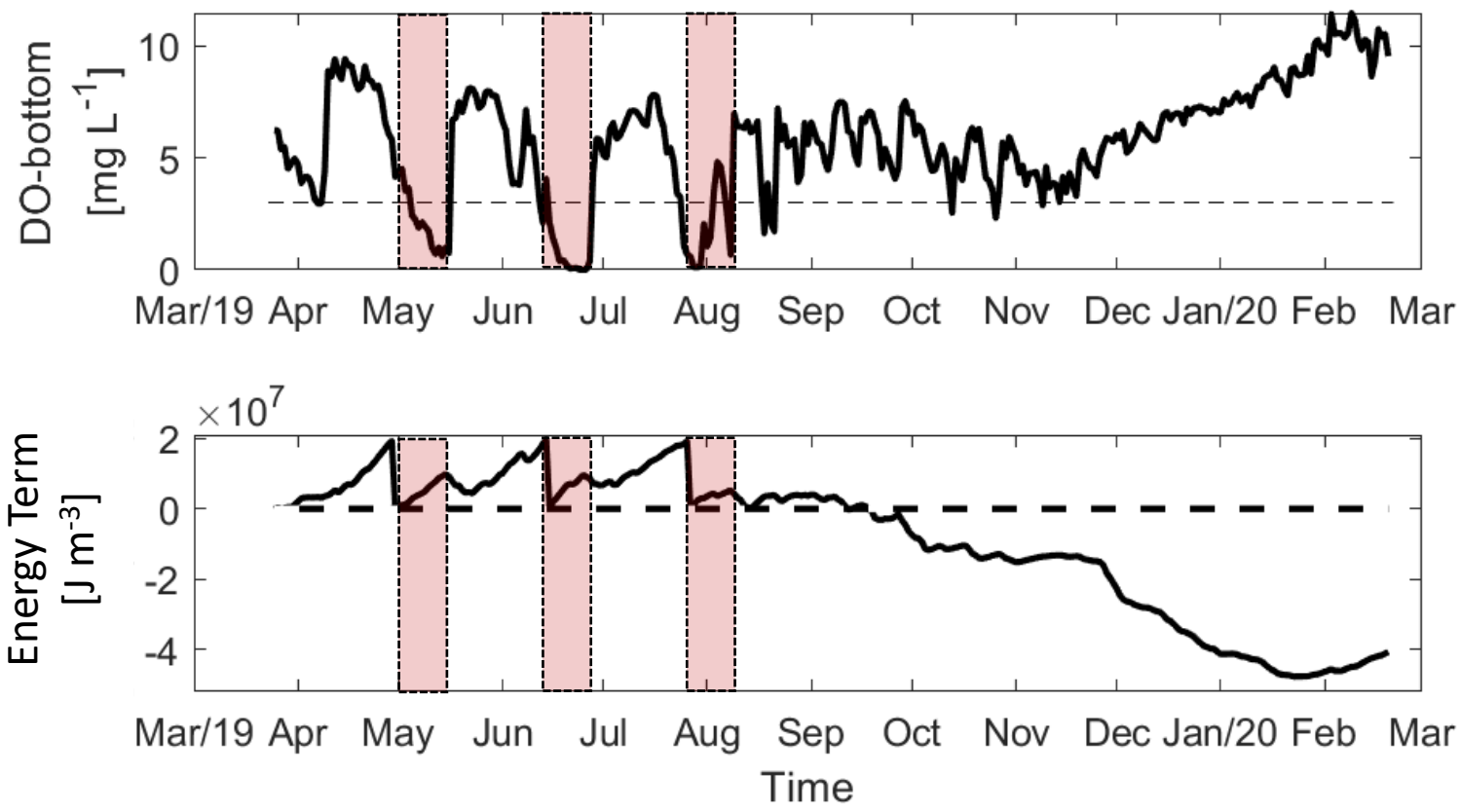
- Incoming Shortwave Radiation
- Air Temperature
- Relative Humidity
- Wind Speed
- Lake Surface Temperature



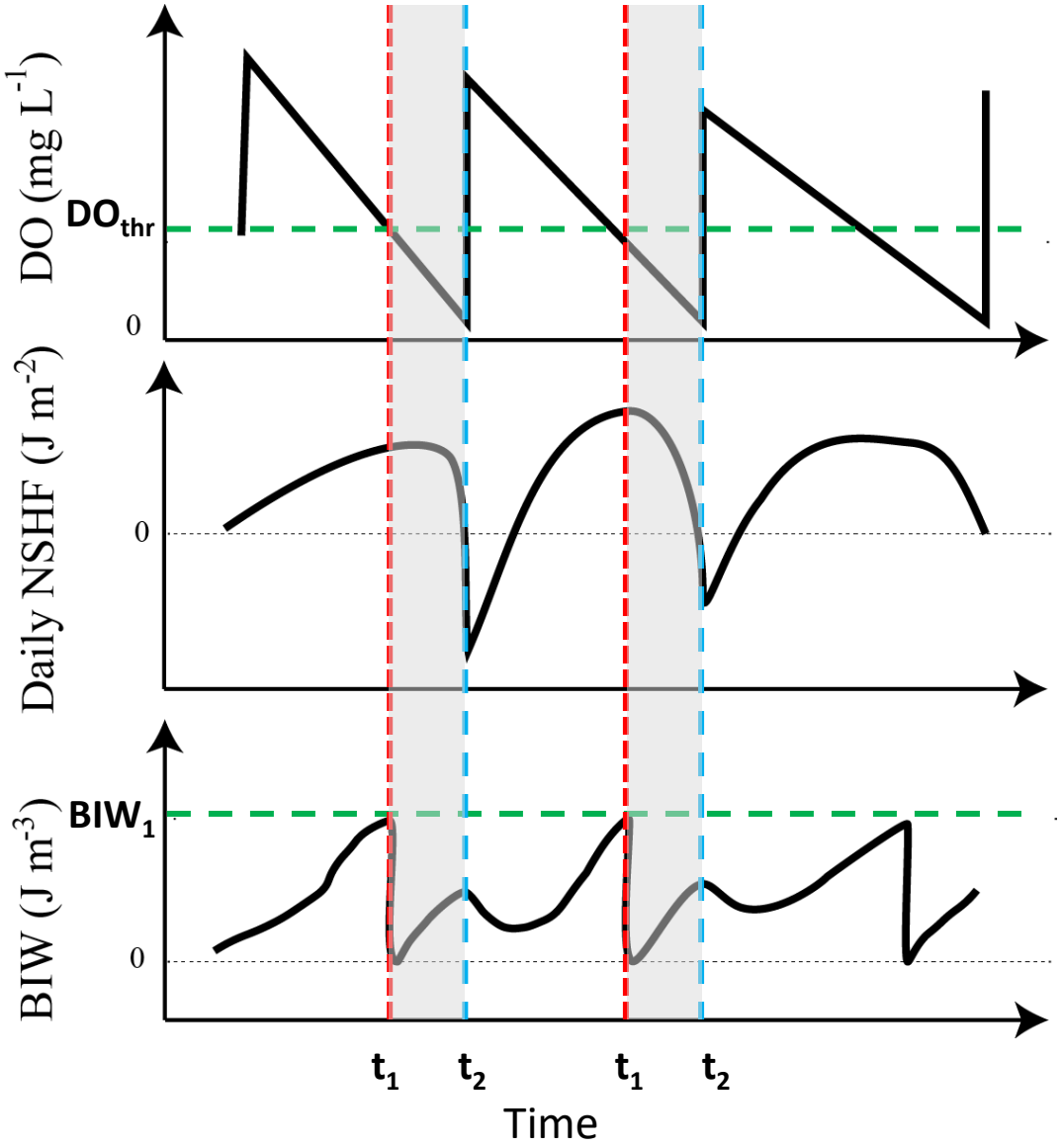
Prediction of Hypoxia from Meteorological Forcing

Lake Data

Prediction of Hypoxia
- **When does it start?**
- **How long does it last?**



Birge-Winkler Method to Predict Hypoxia



NSHF = *Net Surface Heat Flux* = Amount of heat that the lake gains or losses (met forcing)

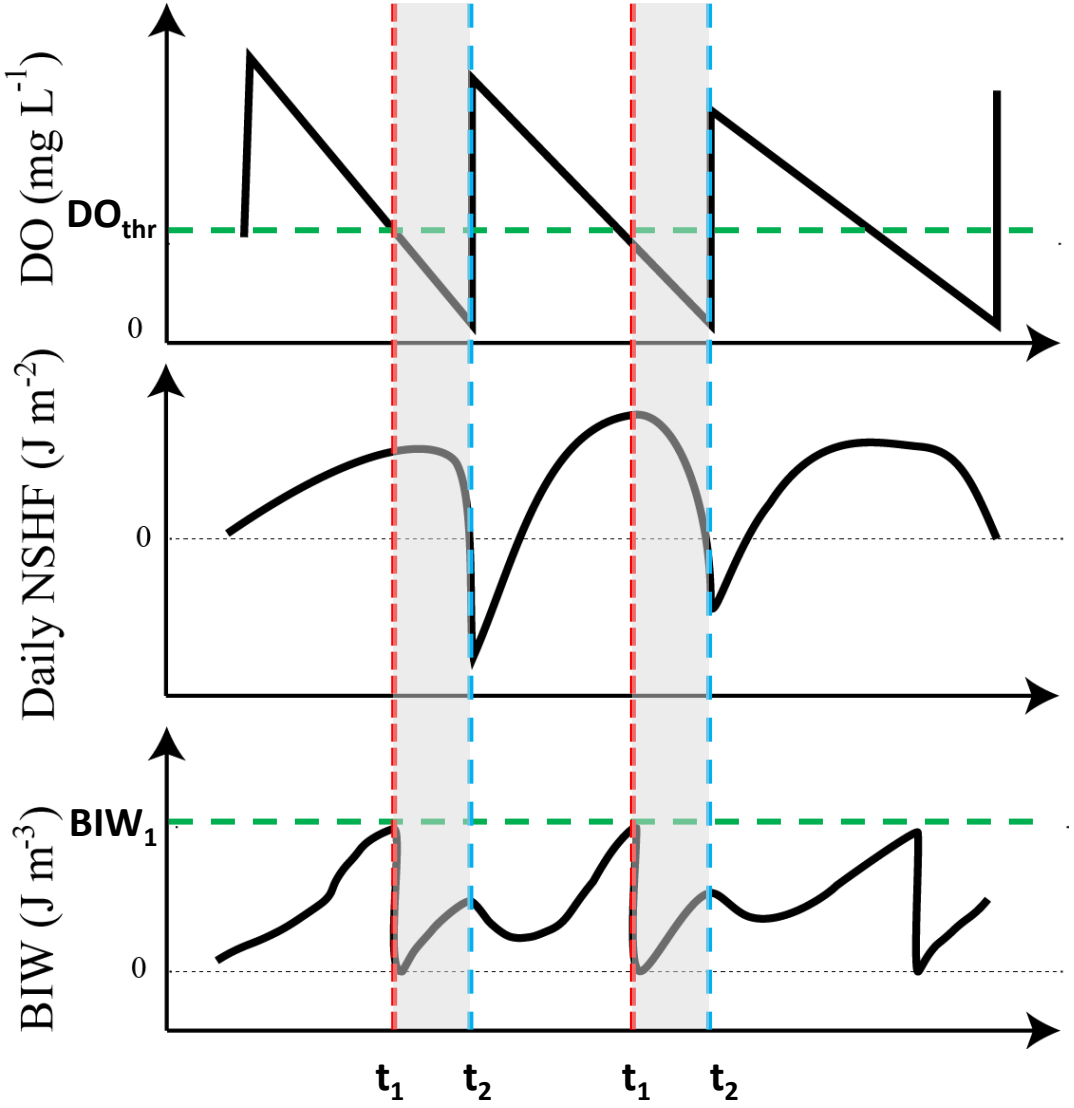
BIW = *Birge-Winkler Energy Term* = Cumulative NSHF between two consecutive hypoxic events

Model Calibration

1. Define a DO threshold of hypoxia ($\mathbf{DO_{thr}}$)
2. Define the first day of a hypoxic event ($\mathbf{t_1}$)
3. Compute the cumulative NSHF (BIW) and identify its value at the beginning of the hypoxic event ($\mathbf{BIW_1}$)
4. Reset to zero the BIW term until the next hypoxic event.
5. Identify the day when BIW experiences a sudden drop as the end of the hypoxic event ($\mathbf{t_2}$).
6. The length of the hypoxic event is:

$$t_{hypo} = t_2 - t_1$$

Birge-Winkler Method to Predict Hypoxia



NSHF = *Net Surface Heat Flux* = Amount of heat that the lake gains a losses (met forcing)
BIW = *Birge-Winkler Energy Term* = Cumulative NSHF between two consecutive hypoxic events

Once we identify the BIW value at the beginning of the hypoxic event (**BIW$_1$**) for a specific water body *we do not need time series of DO next to sediments*, and we can predict:

- When hypoxic events start
- How long hypoxic events last

Warning Tool for Water Purveyors, Cyanobacterial Sampling, Oxygenation Systems

Let’s try this tool in other CA lakes and reservoirs!

Parameters

- Lake latitude
- Lake elevation or atmospheric pressure
- Wind sensor height
- Maximum lake depth

Hourly time series

- Lake surface temperature
- Air temperature
- Relative humidity
- Incoming shortwave radiation
- Wind speed
- *DO next to the sediments (only for calibration)*

Lake Elsinore, Riverside County (1,200 ha, 13 m)

Lake Anza, Contra Costa County
(4 ha, <10 m)

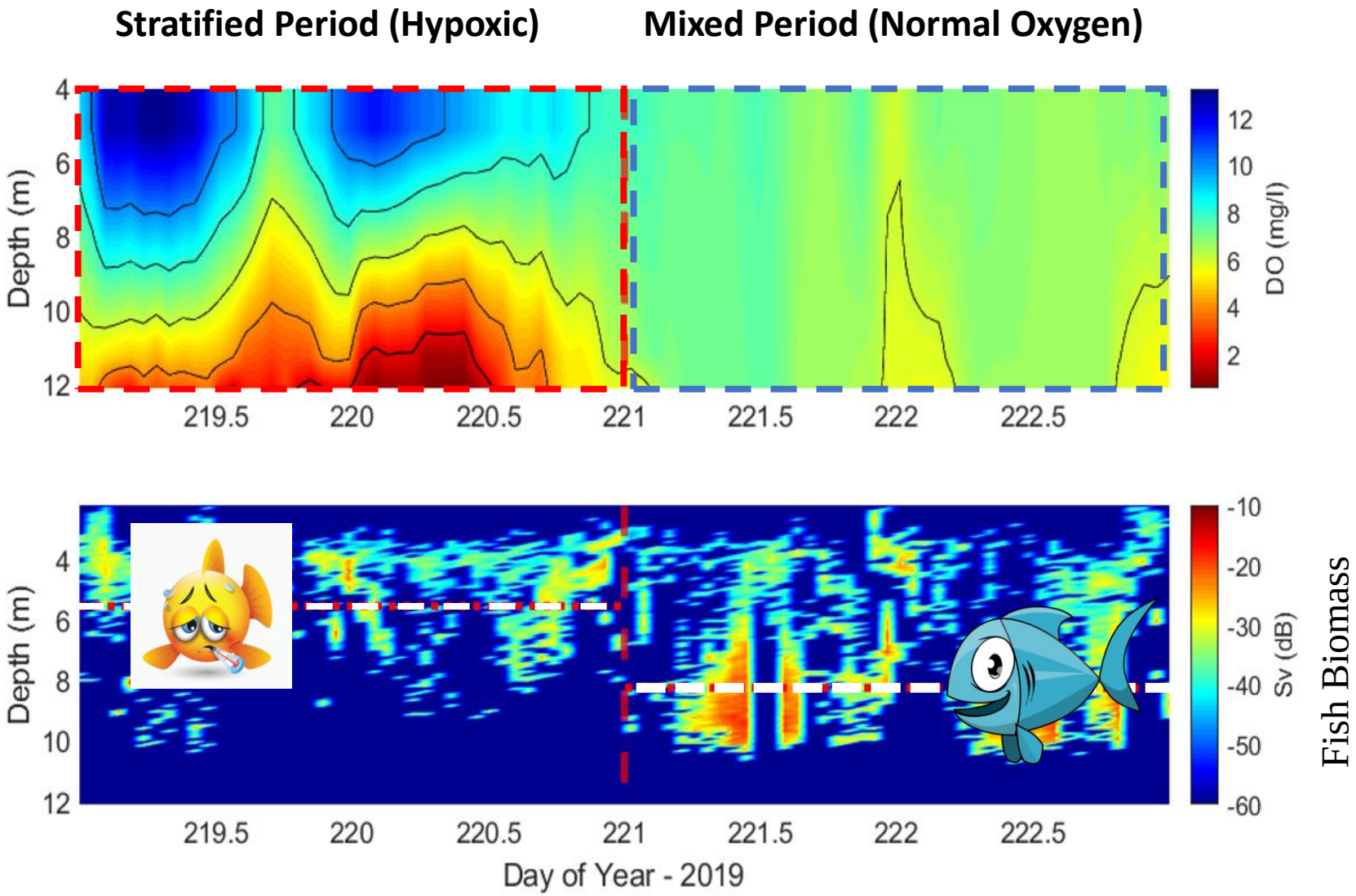
Contra Loma Reservoir,
Contra Costa County (280 ha, ~20 m)

How does it apply to deep lakes?

- **Fewer hypoxic events** than shallow lakes
  - ✓ Lower daily rates of *DO consumption* next to the sediments
- The system needs to **gain more energy** in order to experience a hypoxic event

Shasta Reservoir, November 2019

Fish Avoidance due to Hypoxia

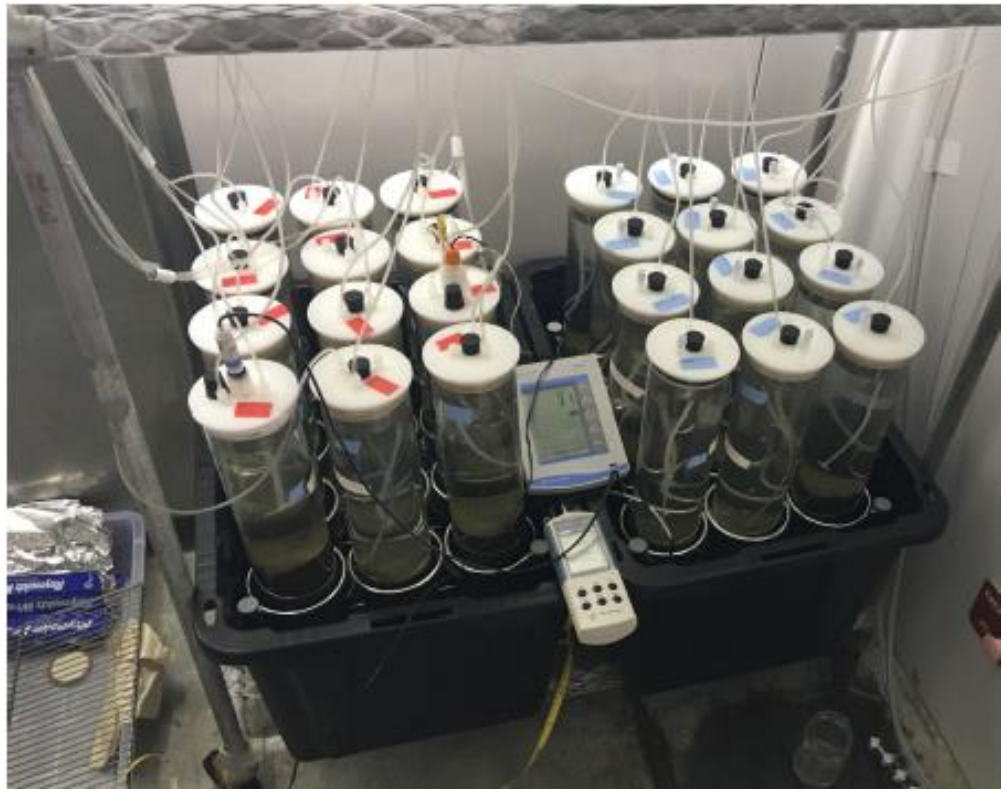


Fish Biomass

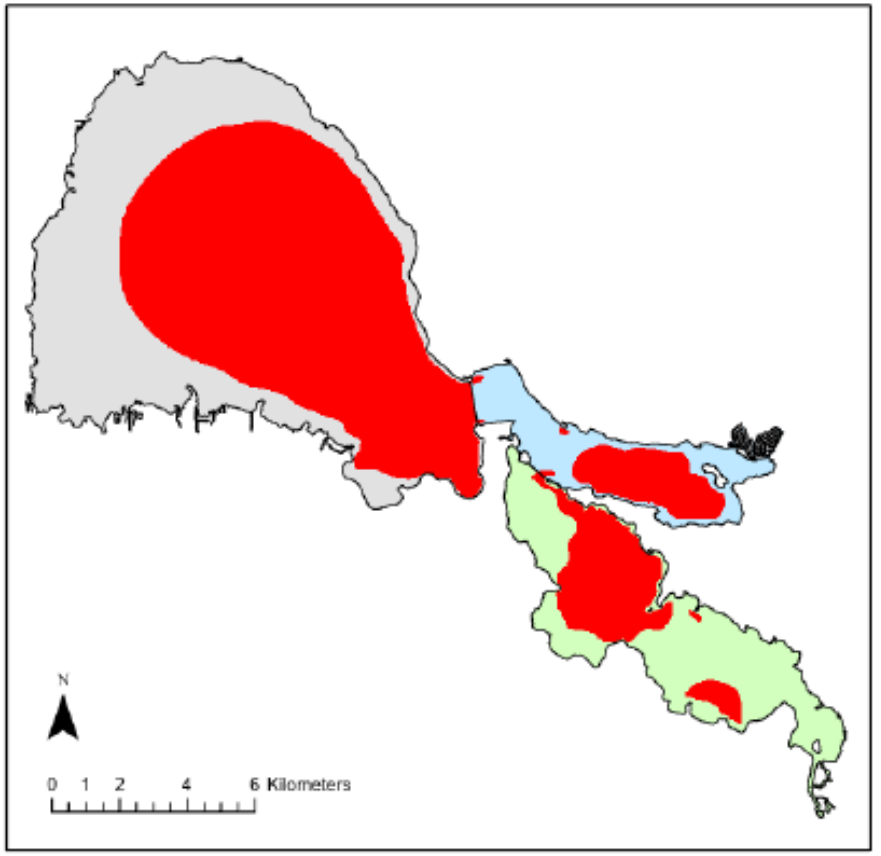
Under Hypoxic Conditions Fish are Changing Vertical Distribution

(Credit: Drew Stang, MS Student)

Estimating Phosphorus Load from the Sediments



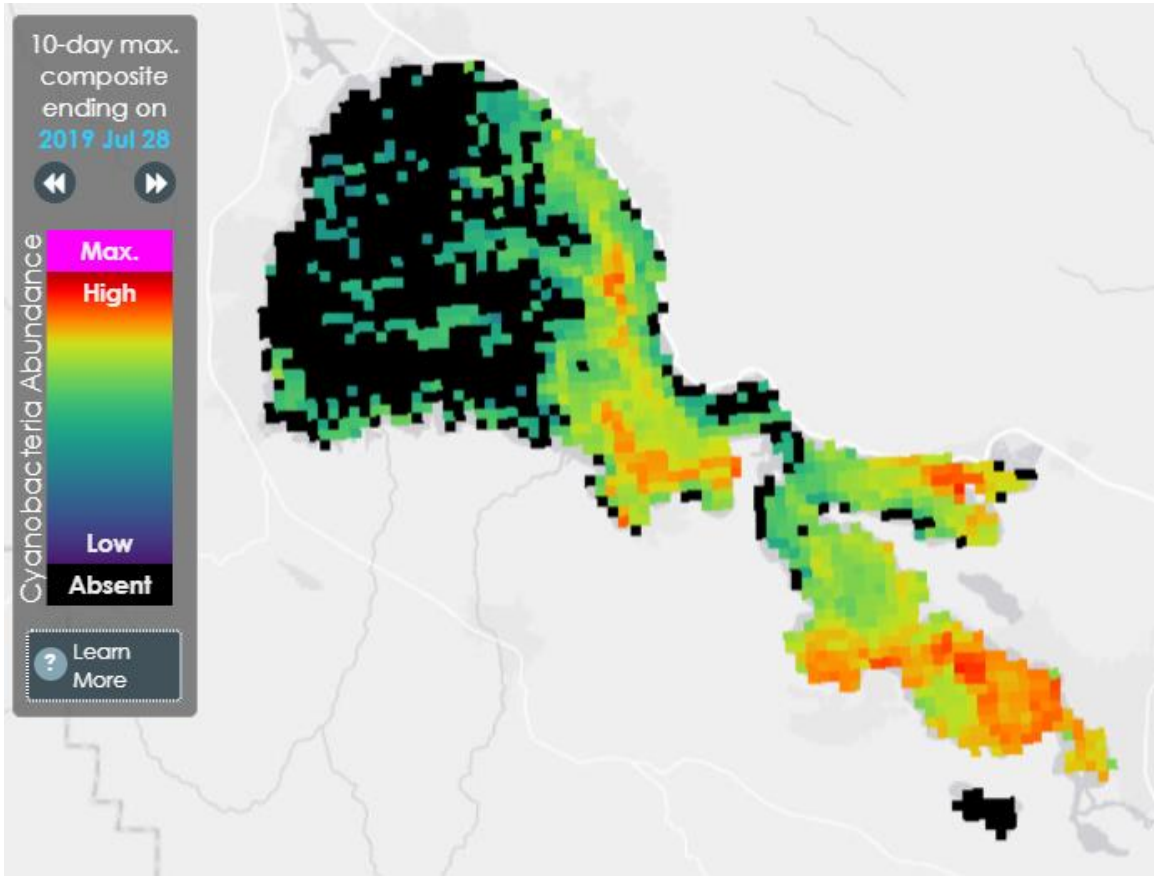
P-Loading Source	P-Species	Annual Load (MT yr^{-1})	% Annual SRP load
External	SRP	37.1 - 51.4[1]	59-67%
Internal	SRP	25.6	33-41%



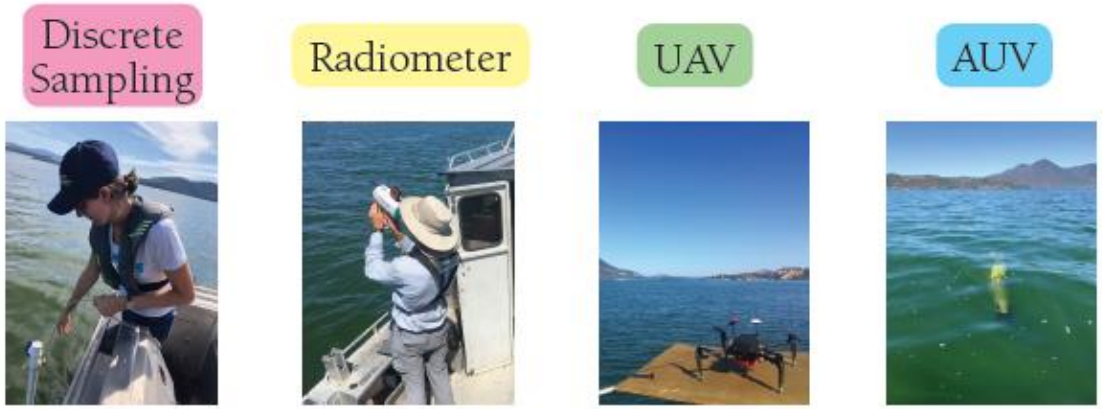
Red represents anoxia during the stratified period in 2019

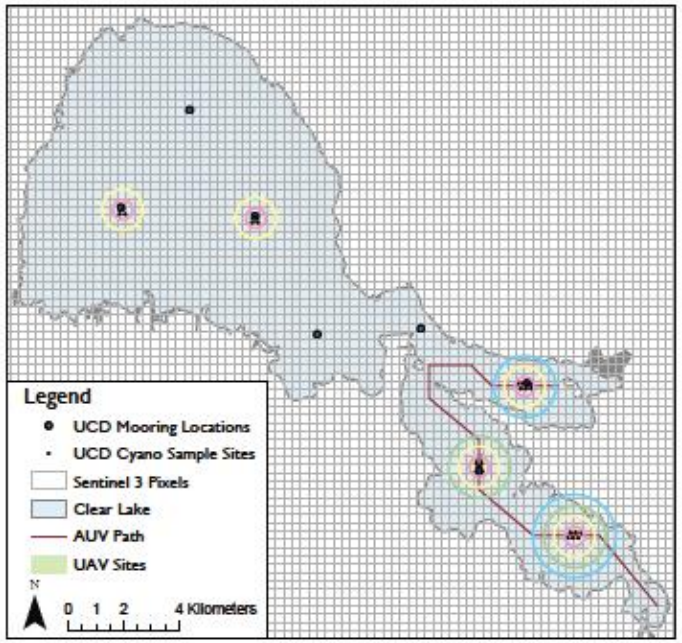
(Credit: Nick Framsted, MS Student)

Predicting Cyanobacteria Blooms (HABs)



SFEI/NOAA Harmful Algal Blooms Remote Sensing Tool (fhab.sfei.org)





(Credit: Samantha Sharp, MS Student)

How will Climate Change affect our 1-D model?

More energy gain → More hypoxic periods

Mixing less often → Longer hypoxic periods

Clear Lake, Cyanobacterial Bloom, July 2020

Clear Lake, Fish Kill, August 2017

Research Team

https://terc-clearlake.wixsite.com/cldashboard

Thank you!
Questions?

Name	Position
Geoff Schladow	Principal Investigator (PI)
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Steve Sadro	Co-PI
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Lidia Tanaka	Project Scientist (Phycologist)
Shohei Watanabe	Data manager & Project Scientist
Tina Hammell	Research Associate (Chemistry)
Anne Liston	Research Associate (Chemistry)
Steven Sesma	Research Associate (Chemistry)
Katie Senft	Research Associate (scuba & field)
Brandon Berry	Research Associate (scuba & field)
Drew Stang	Graduate Student
Micah Swann	Graduate Student
Nicholas Framsted	Graduate Student
Ruth Thirkill	Graduate Student
Samantha Sharp	Graduate Student
Carmen Woods	Project administration
Lindsay Vaughan	Technical Staff