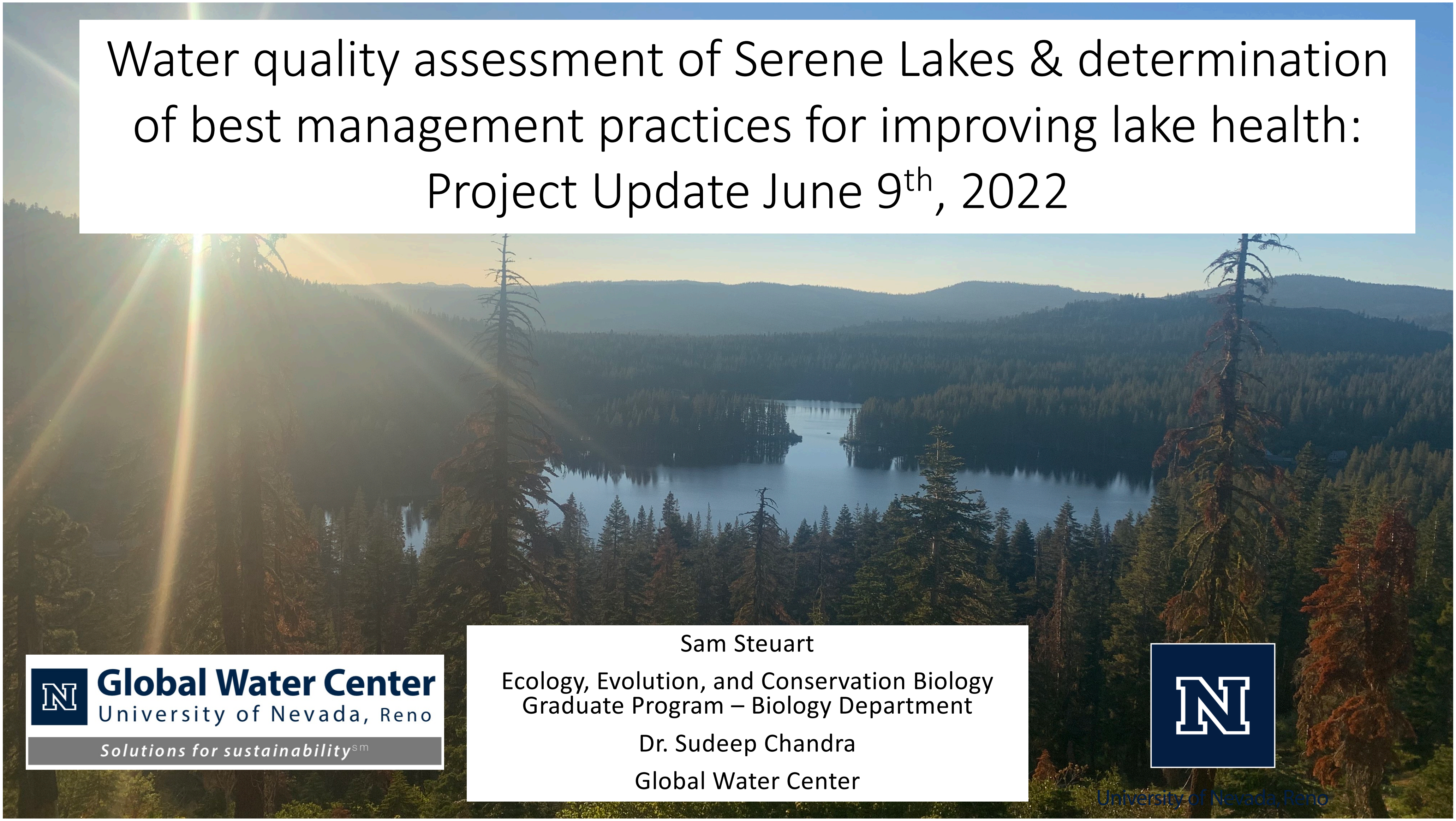
Water quality assessment of Serene Lakes & determination of best management practices for improving lake health: Project Update June 9th, 2022



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Global Water Center
University of Nevada, Reno
Solutions for sustainability[sm]

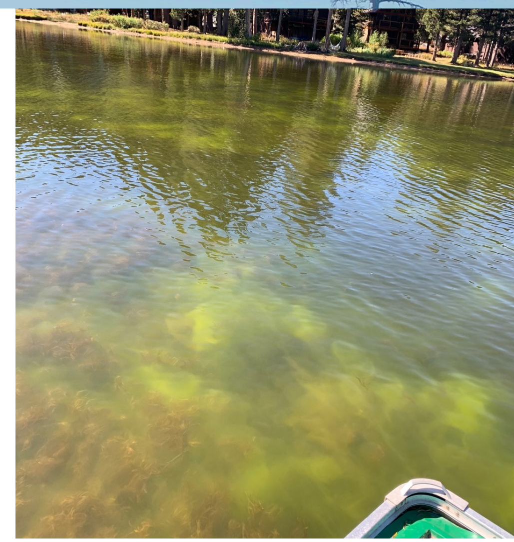
University of Nevada, Reno

Outline

- Issue: Eutrophication
- Water quality assessment
- Historical study by Vinyard
- Snow water equivalent (SWE)
- Water clarity
- Water temperature, chlorophyll a and dissolved oxygen (DO)
- Photosynthetically active radiation (PAR)
- PAR extinction coefficient
- Nutrient, pH, total dissolved solids (TDS) and electrical conductivity (EC) samples collected
- Wildfires and anoxic periods
- miniDOT sensor data
- Aquatic macrophytes
- Next steps

Issue: Eutrophication of Serene Lakes

- Mountain lake eutrophication is caused by complex and interactive drivers including changing environmental conditions, changes in lake hydrodynamics caused by climate change, nutrient pollution, and food web disturbances – Vadeboncoeur *et al.* (2021)
- The rates of warming of high elevation ecosystems are among the fastest globally – Sadro *et al.* (2018)
- The climate exerts control on hydrology, water temperature, solute concentrations and aquatic biota – Moser *et al.* (2019)
  - A warming climate generally leads to shortened ice cover duration, resulting in longer ice-free periods and warmer water temperatures thereby increasing the strength of the air/watershed connectivity to the lake – Moser *et al.* (2019)
- During high snowfall years, the total nutrient loads are higher, but flushing and dilution during snowmelt can lead to reduced in-lake nutrient concentrations at the start of the ice-free season. Alternatively, during years with lower snowpack, lakes ice-off earlier, warm more, and may have higher in-lake nutrient concentrations due to lower flushing rates – Sadro *et al.* (2018)
- Many mountain lakes were historically fishless with unique cold-water food webs whose keystone species were invertebrates, but in the western US most of all naturally fishless lakes have been stocked with nonnative trout species – Baron *et al.* (2020)
- Leads to cascading biological changes such as increased plant and algal growth, fish kills, changes in community structure



Large algal blooms at the shallow south end of Lake Dulzura photographed on 9/28/21

Contemporary Water Quality Assessment of Serene Lakes: Objectives

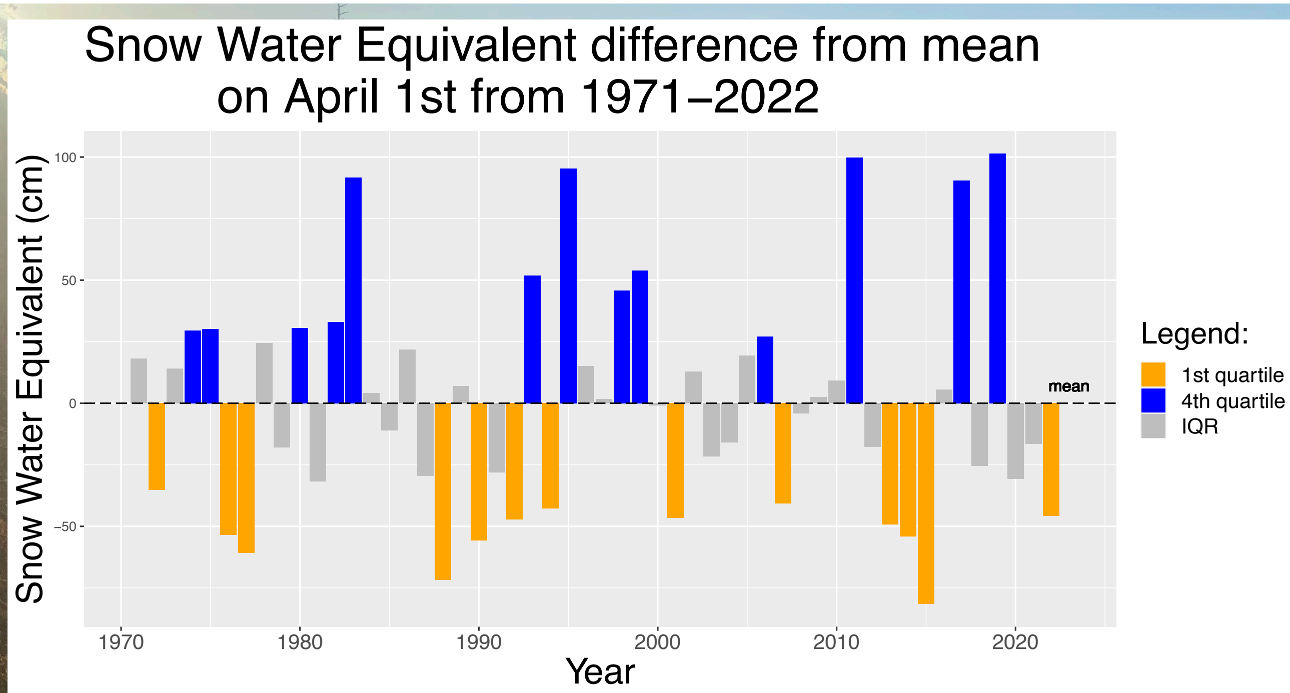
The last scientific report on the state of the Serene Lakes was the 1992 Limnology Report by Professor Gary Vinyard, University of Nevada

Objective: To determine the present status of Serene and Dulzura lakes and make informed suggestions for best management practices and potential restoration projects to maintain the health of the lakes.

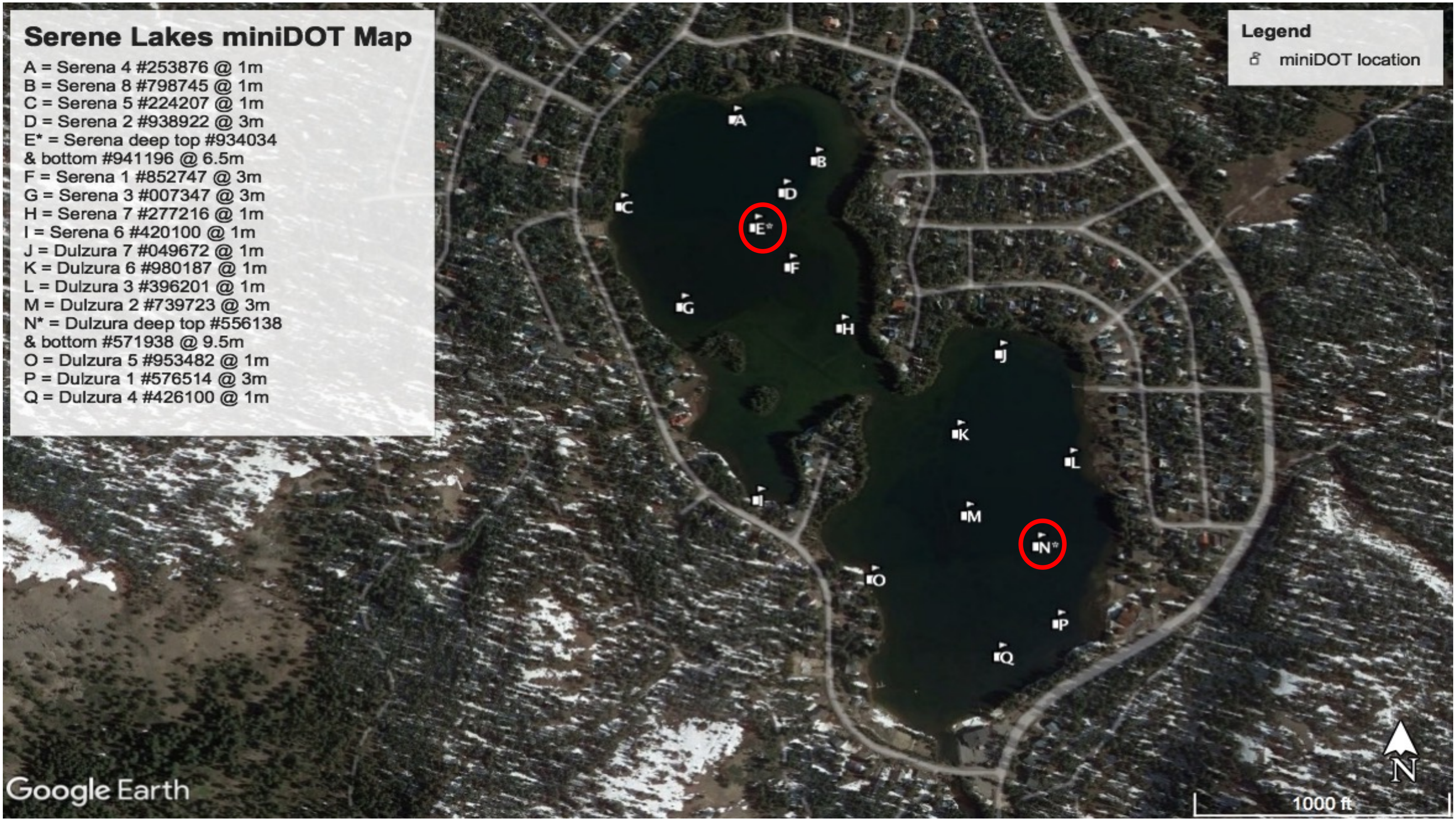
Historical study in 1992 by Vinyard evaluating the water quality in Serene Lakes

- Performed August 28, 1990 (snapshot)
- Classified Serene Lakes as mesotrophic or moderately productive
- Found high levels of nitrogen nutrient loading in Serene Creek, the inflowing creek
- Suggested a monitoring and control program to limit nutrient loading and sedimentation
  - Restoration projects such as constructing wetlands at the inflows
  - Sediment exclusion during times of high runoff
  - Plan to control vegetation growth and algal blooms due to shallow nature of the lakes – 50% of the lakes are less than 2m deep

The variation from the mean post-2010 is greater than it is pre-2010 ($p = 0.04$). This has important consequences as high April 1st SWE is correlated to late ice-off and nutrient flushing, while low April 1st SWE is correlated to early ice-off and high primary productivity (Sadro (2018))



“[P]hytoplankton biomass is increasing as a result of both interannual variability in precipitation and long-term warming trends” – Sadro (2018)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miniDOT location
A
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C
D
E*
F
G
H
I
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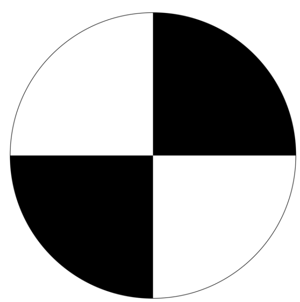
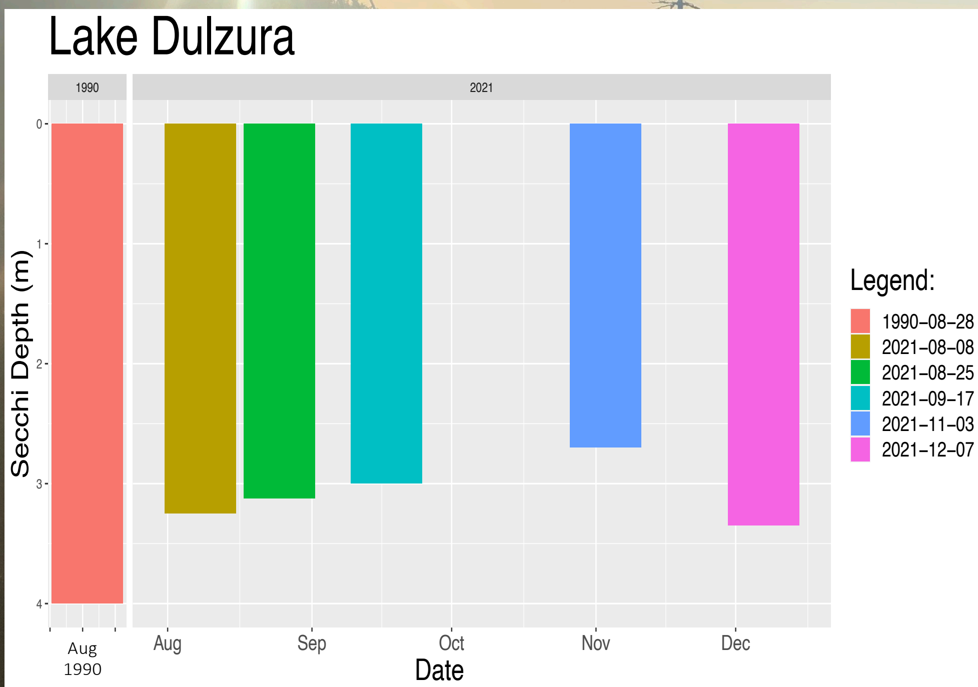
K
L
M
N*
O
P
Q
Google Earth
1000 ft
N

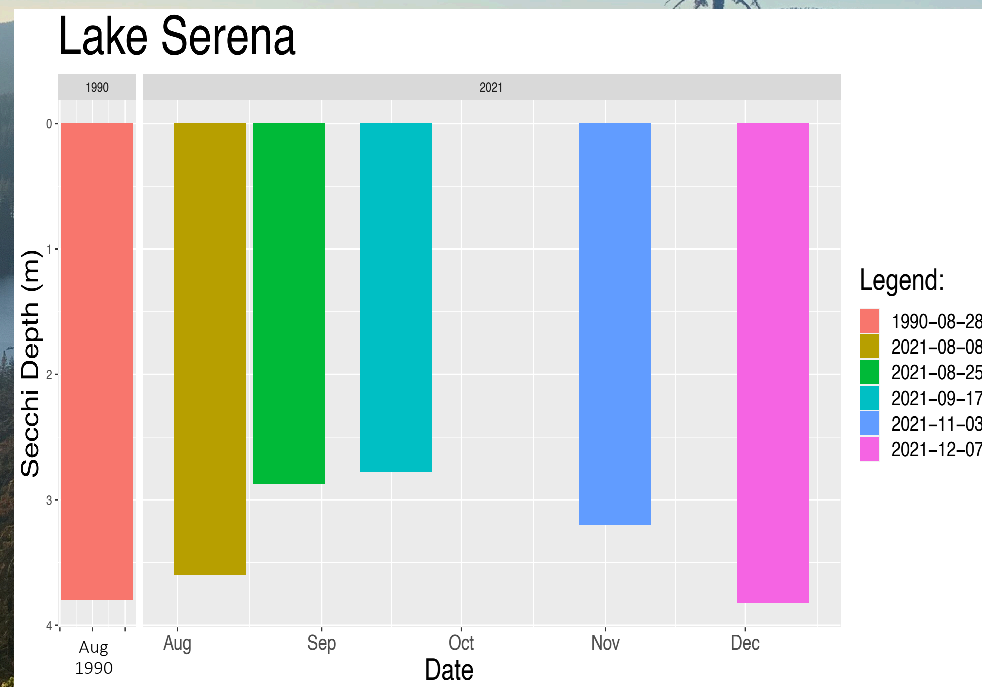
Water clarity measured with Secchi disk

- Secchi Depth is a simple measure of water clarity invented in 1865 by the Italian physicist Angelo Secchi which is still commonly used today
- A 30 cm disk on a rope or chain is lowered into the water until the point when one can no longer see it, then lowered further and raised until it becomes visible again
- The average of these two values is taken as a measure of the water clarity



Water clarity has decreased almost 1 meter as measured by Secchi depth

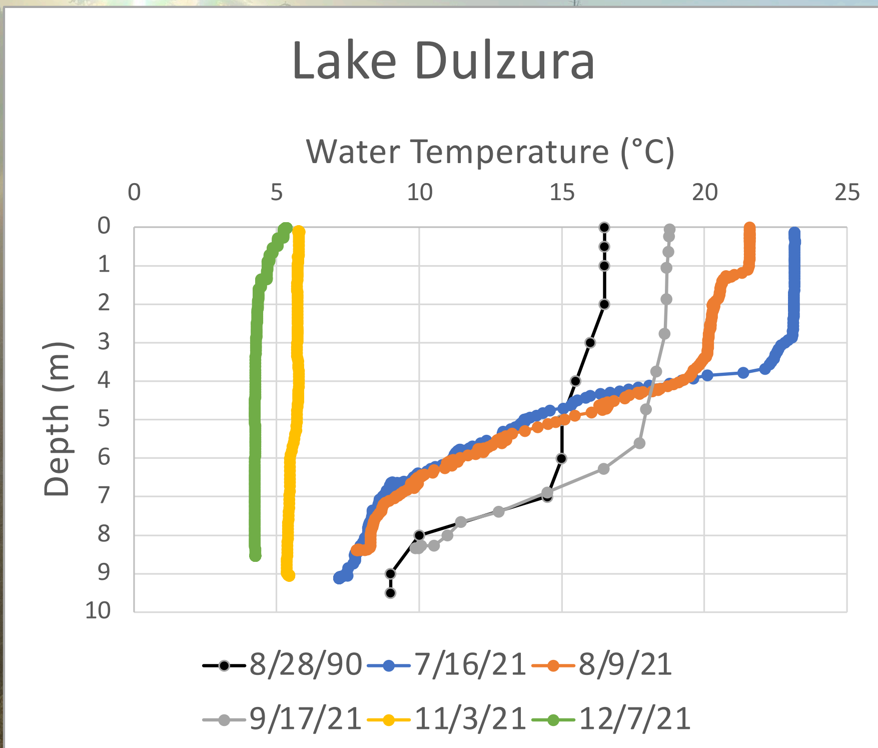


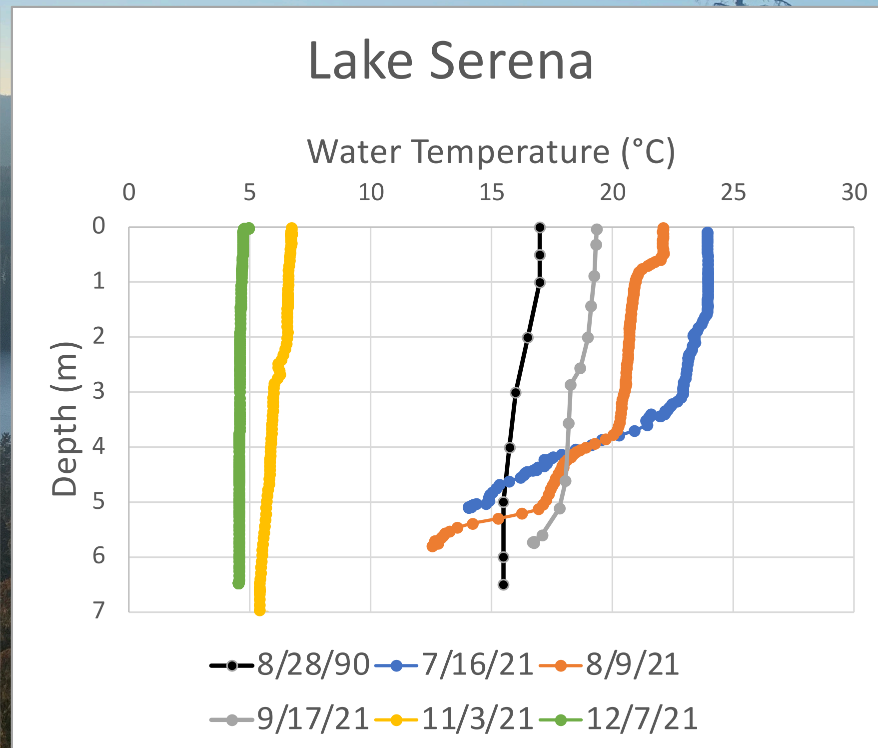


Water temperature, chlorophyll a, and dissolved oxygen profiles measured with RBR*maestro*^{3} multi-channel logger

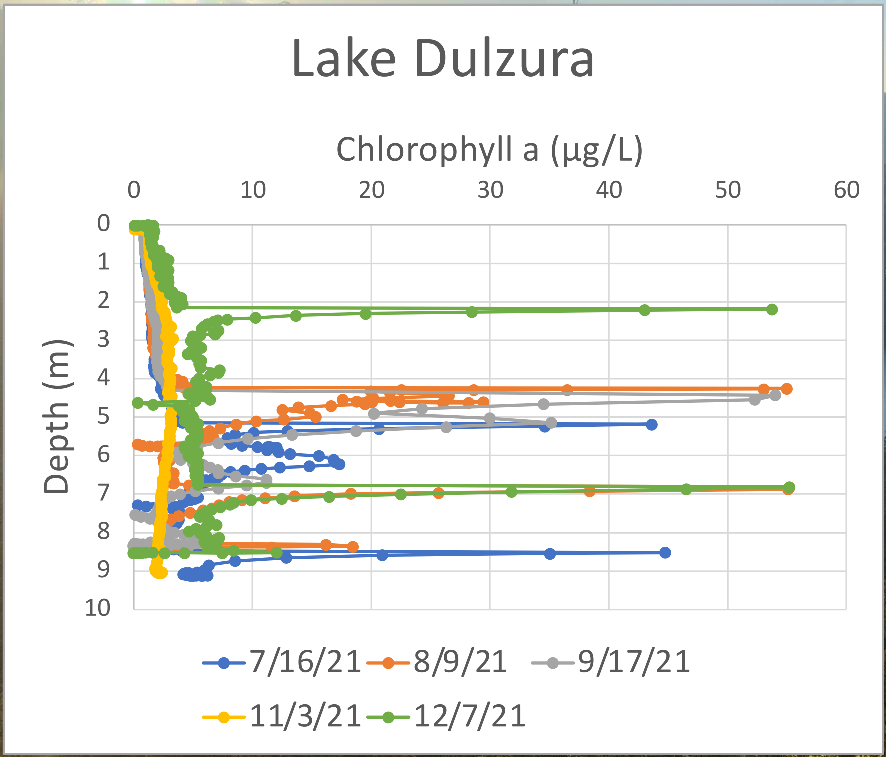
- The RBR*maestro*^{3} multi-channel logger is lowered from the boat to the bottom on the deepest part of the lake at each index station, taking 16 data points per second
- Allows for higher frequency data collection
  - For reference, the Vinyard study took 12 data points for Lake Dulzura profiles and 9 data points for Lake Serena profiles, the RBR*maestro*^{3} takes more than an order of magnitude more readings for similar profiles

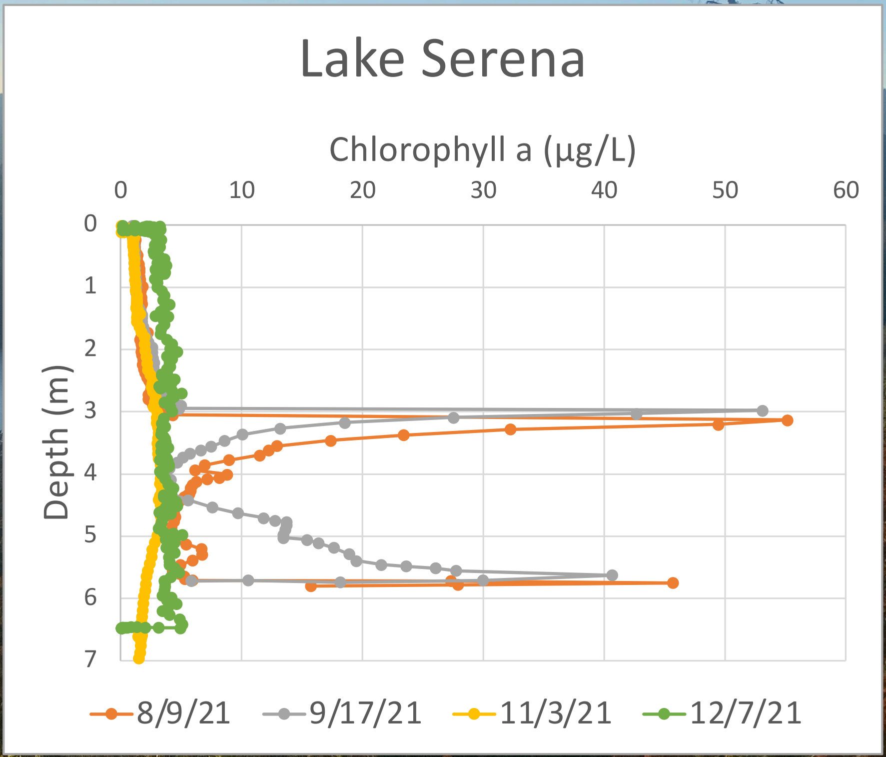
Water temperature indicates lake stratification and is higher than previous collection



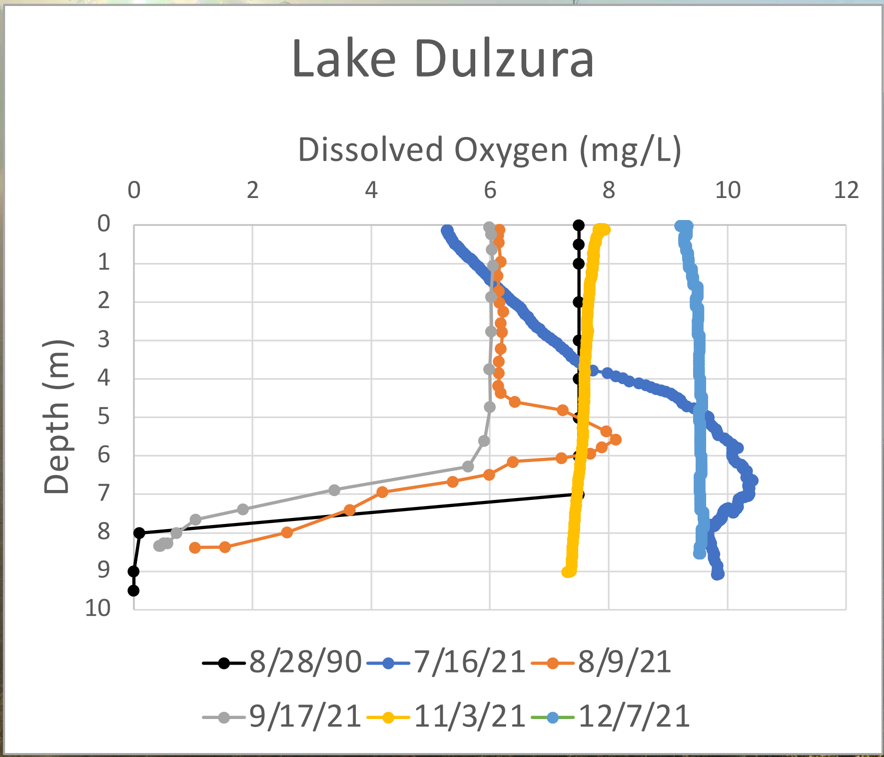


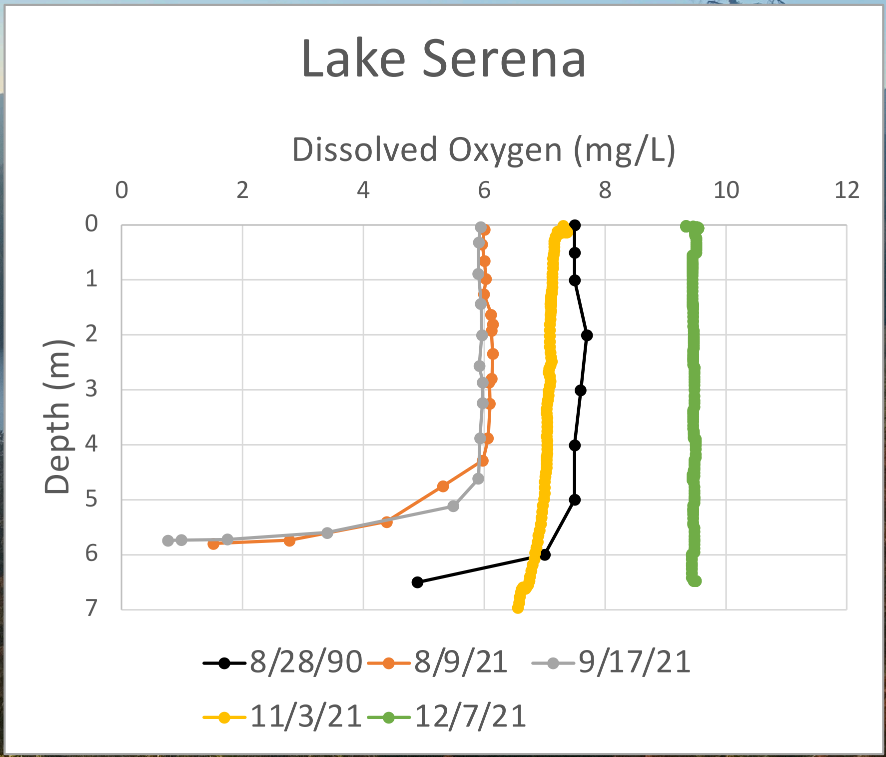
Chlorophyll levels indicate zones of high productivity which shift in depth over season





Dissolved oxygen shows anoxic hypolimnion during August and September and a deep chlorophyll maximum in Lake Dulzura during August

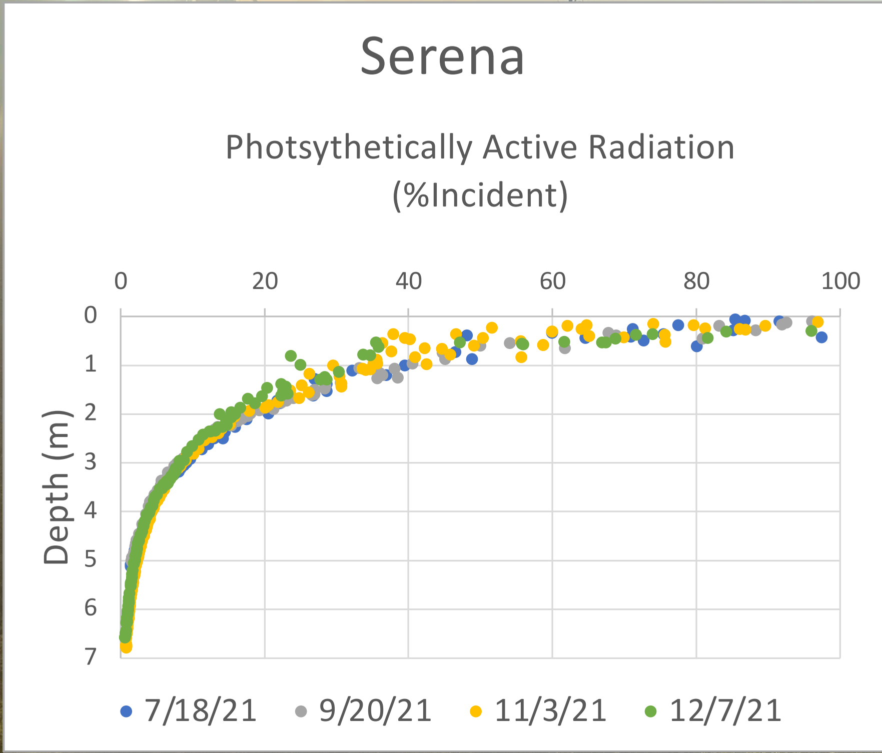


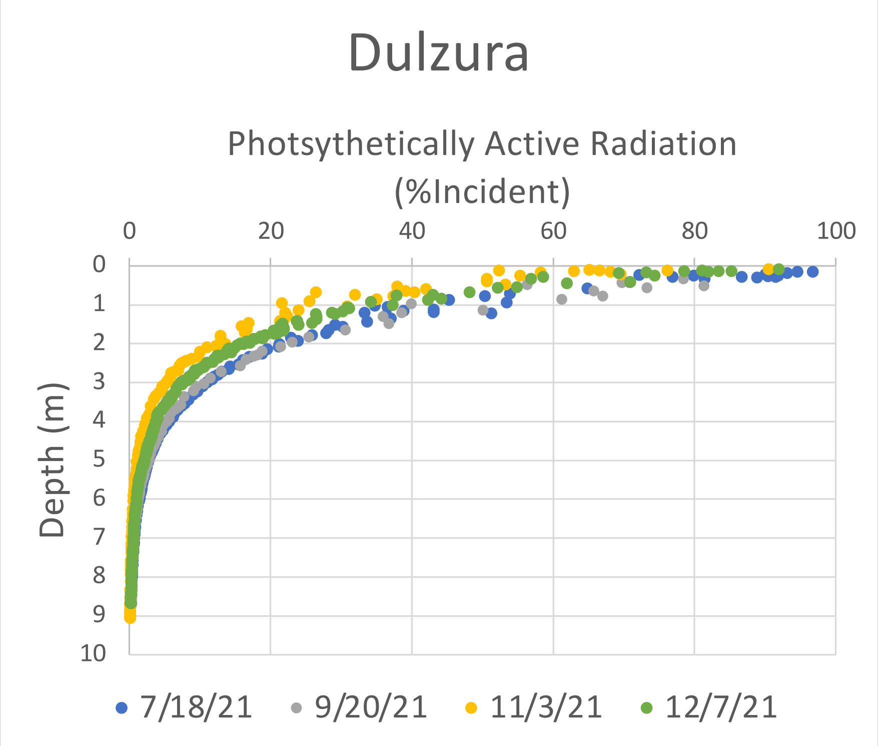


Light profiles with Biospherical Instruments UV radiometer

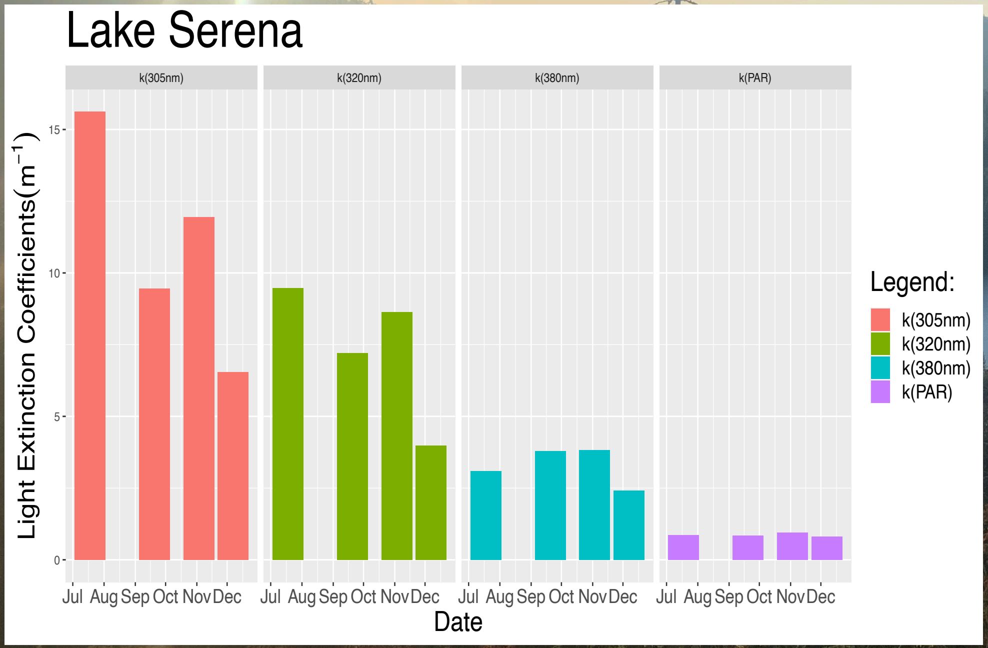
- The submersible multichannel radiometer logger is lowered from the boat to the bottom on the deepest part of the lake at each index station recording the intensity of radiation in the 305nm, 320nm, 380nm and PAR(400-700nm) spectra
- A deck cell remains on the boat recording the incident light of the same wavelengths

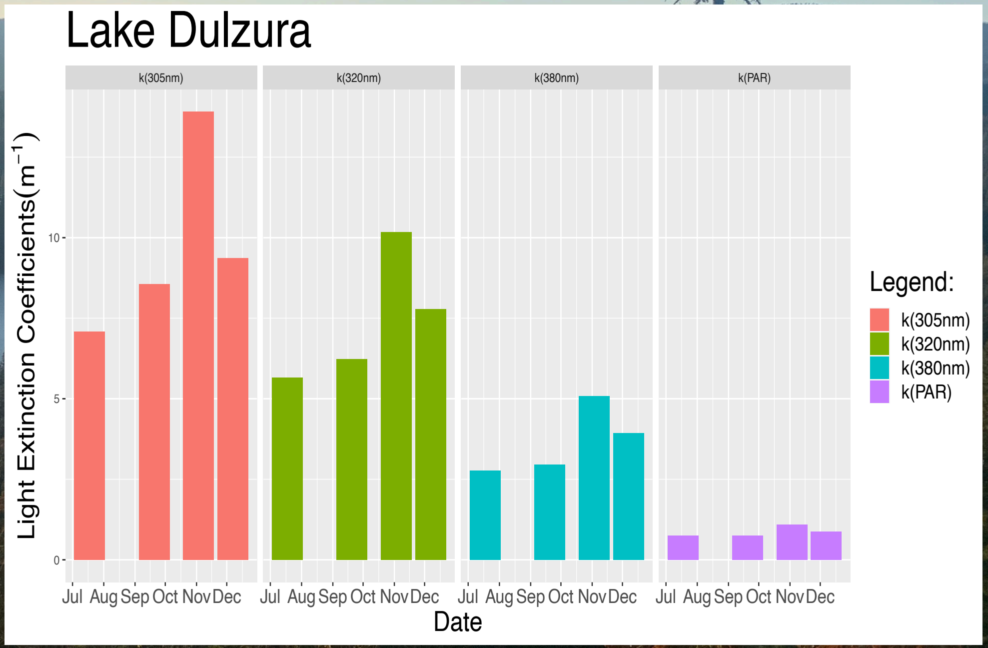
Visible light (PAR) transmission changes with depth and over season





Light attenuation varies by lake and light wavelength





Nutrient, pH, total dissolved solids and electrical conductivity samples collected

- Water samples collected with a Van Dorn depth sampler
  - Lake Dulzura: partially mixed layer sample consisting of 0, 1, and 3 m and a deep hypolimnion sample from 8 m
  - Lake Serena: partially mixed layer sample consisting of 0, 1, and 2 m and a deep hypolimnion sample from 5 m
- The Van Dorn is set up in the open position and lowered to the appropriate depth
- A metal “messenger” weight is sent down the line causing the end caps to retract thereby trapping a water sample from the desired depth in the device

Table of nutrient, pH, total dissolved solids and electrical conductivity samples collected

Legend:
Sites:
- SD = Lake Serena index site hypolimnion samples
- SPML = Lake Serena partially mixed layer epilimnion samples
- DD = Lake Dulzura index site hypolimnion samples
- DPML = Lake Dulzura partially mixed layer epilimnion samples
- SC = Serena Creek Inflow
- DC = Dulzura Creek Inflow

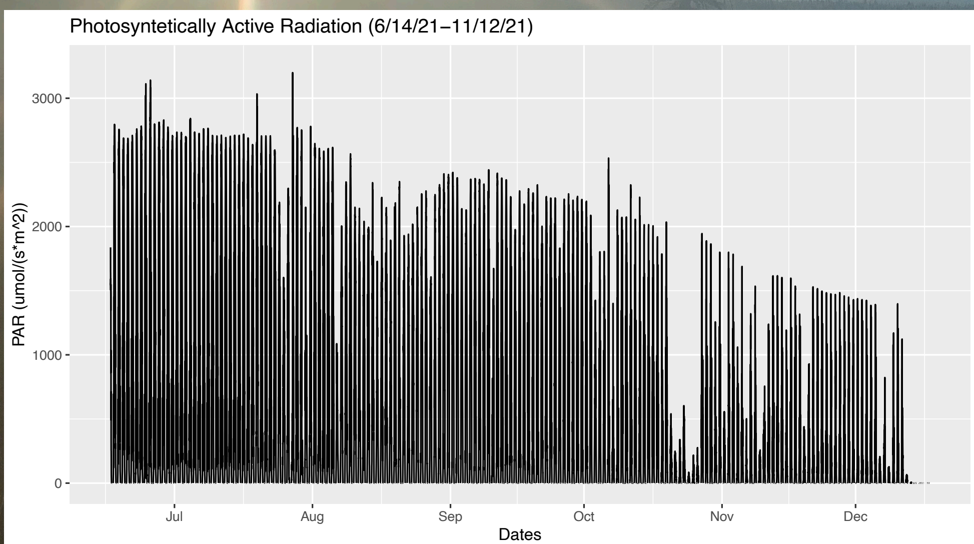
Nutrient Samples:
- C = collected

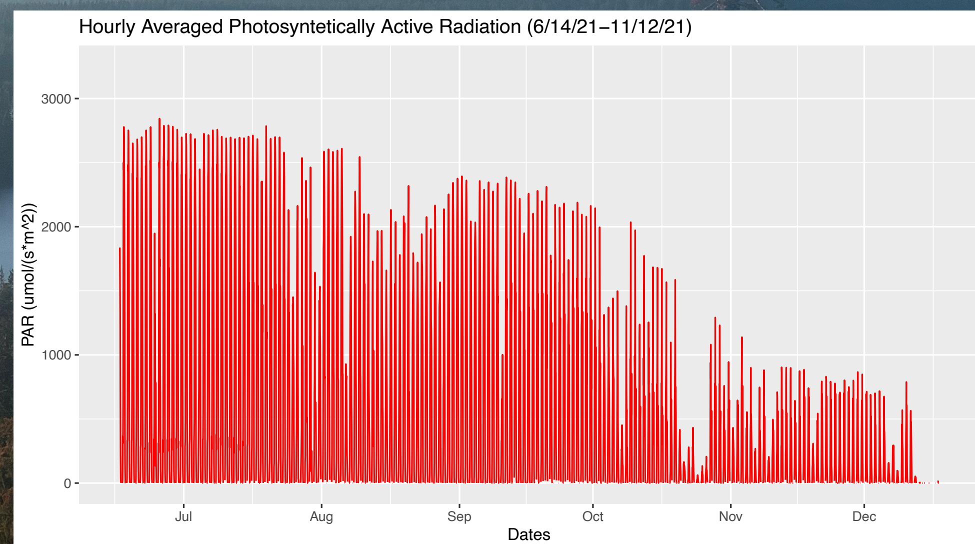
Date	Site	pH	TDS (ppm)	EC (µs/cm)	TN	TP	NO3/NH4	PO4	SO4
6/17/21	SD	7.58	28	58	C	C	C	C	C
6/17/21	SPML	7.32	46	23	C	C	C	C	C
6/17/21	DD	7.70	279	494	C	C	C	C	C
6/17/21	DPML	7.65	11	22	C	C	C	C	C
6/17/21	SC	7.38	45	94	C	C	C	C	C
6/17/21	DC	7.61	12	24	C	C	C	C	C
7/18/21	SD	6.73	32	64	C	C	C	C	C
7/18/21	SPML	6.90	22	44	C	C	C	C	C
7/18/21	DD	6.53	16	30	C	C	C	C	C
7/18/21	DPML	6.97	14	28	C	C	C	C	C
7/18/21	SC	6.14	17	34	C	C	C	C	C
8/9/21	SD	6.39	13	26	C	C	C	C	C
8/9/21	SPML	6.62	16	32	C	C	C	C	C
8/9/21	DD	5.90	9	18	C	C	C	C	C
8/9/21	DPML	6.58	13	26	C	C	C	C	C
8/9/21	SC	6.00	19	38	C	C	C	C	C
8/25/21	SD	6.86	14	28	C	C	C	C	C
8/25/21	SPML	6.91	18	36	C	C	C	C	C
8/25/21	DD	5.71	13	26	C	C	C	C	C
8/25/21	DPML	7.10	14	28	C	C	C	C	C
8/25/21	SC	6.41	17	34	C	C	C	C	C
9/17/21	SD	7.07	10	20	C	C	C	C	C
9/17/21	SPML	7.73	12	24	C	C	C	C	C
9/17/21	DD	5.87	10	20	C	C	C	C	C
9/17/21	DPML	7.88	14	28	C	C	C	C	C
9/17/21	SC	6.59	15	30	C	C	C	C	C
11/3/21	SD	7.65	11	22	C	C	C	C	C
11/3/21	SPML	7.84	18	36	C	C	C	C	C
11/3/21	DD	7.67	19	38	C	C	C	C	C
11/3/21	DPML	7.61	10	20	C	C	C	C	C
11/3/21	SC	6.62	17	34	C	C	C	C	C
12/7/21	SD	7.62	12	24	C	C	C	C	C
12/7/21	SPML	7.54	7	14	C	C	C	C	C
12/7/21	DD	6.93	7	14	C	C	C	C	C
12/7/21	DPML	6.83	6	12	C	C	C	C	C
12/7/21	SC	6.83	8	16	C	C	C	C	C

Observation: anoxic periods

- Daily cycle caused by lake metabolism: plant and algal photosynthesis and respiration
- Some anoxic periods associated with spikes in smoke from summer fires suppressing sunlight
  - Wildfire smoke suppresses UVR more than PAR, and can therefore have opposing effects on photosynthesis at different depths due to a release from photoinhibition from UVR in shallow water, while preventing PAR from reaching deeper habitat (Scordo *et al.* 2021)
- Other anoxic periods not associated with high smoke levels
- Possible explanations:
  - Bacterial respiration while decomposing plant and algal matter
  - Sediment resuspension from high winds
- DO below 2.5 mg/ L can result in catfish mortality

Visible light (PAR) at the surface of the lake was suppressed by wildfire smoke during study period from late June - September





"The development of high frequency, in-situ sensors have been used extensively in recent years to document temporal variability in, for example, temperature, dissolved oxygen, and nutrients, which are critical to understanding species biology and distribution" – Moser *et al.* (2019)

miniDOT sensors

- Deployed a total of 19 miniDOT throughout the two lakes
- Allows for vastly higher frequency and resolution data collection than was possible for the Vinyard study, as the sensors record DO and water temperature every ten minutes, and were strategically placed in different habitat zones; pelagic, littoral and profundal, with or without macrophytes present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Q = Dulzura 4 #426100 @ 1m
Legend
miniDOT location
A
B
C
D
E*
F
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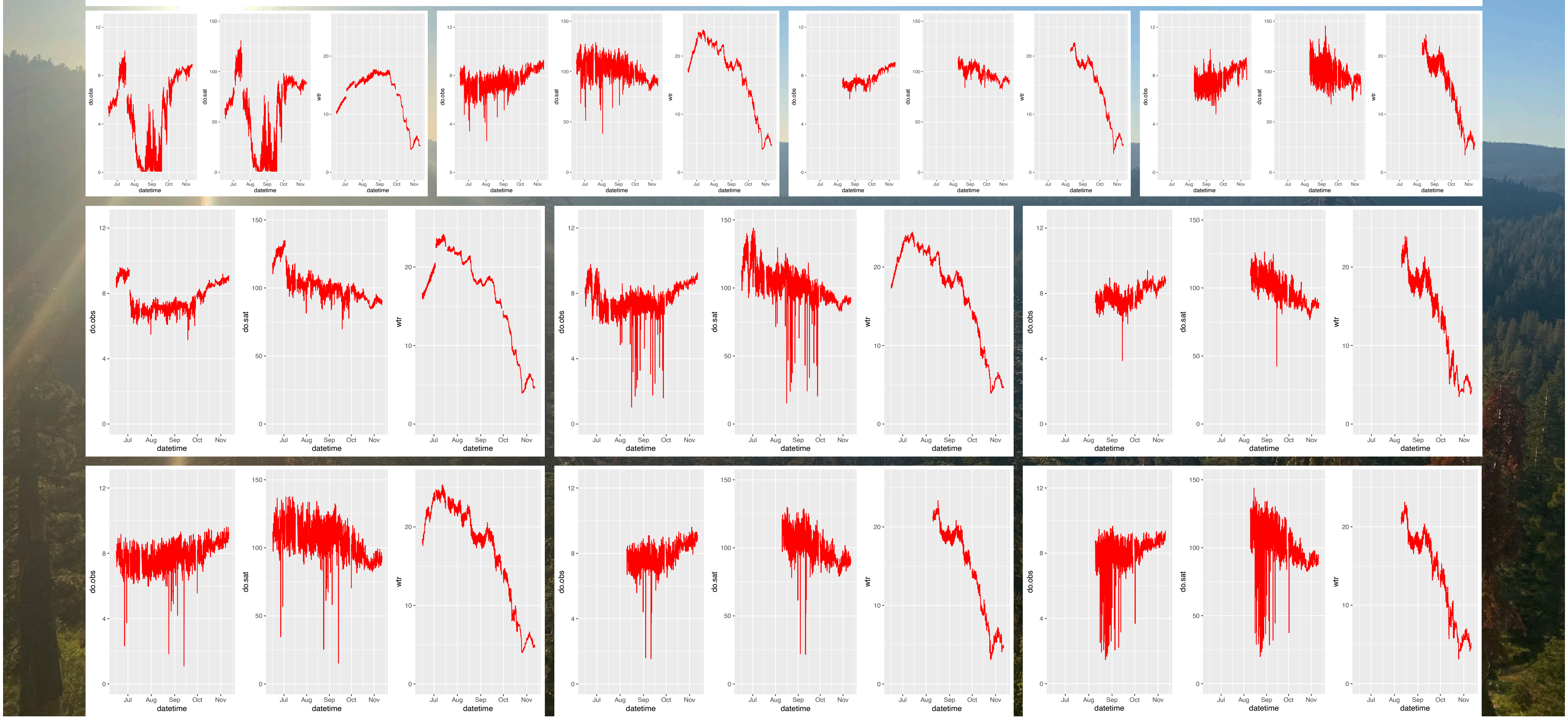
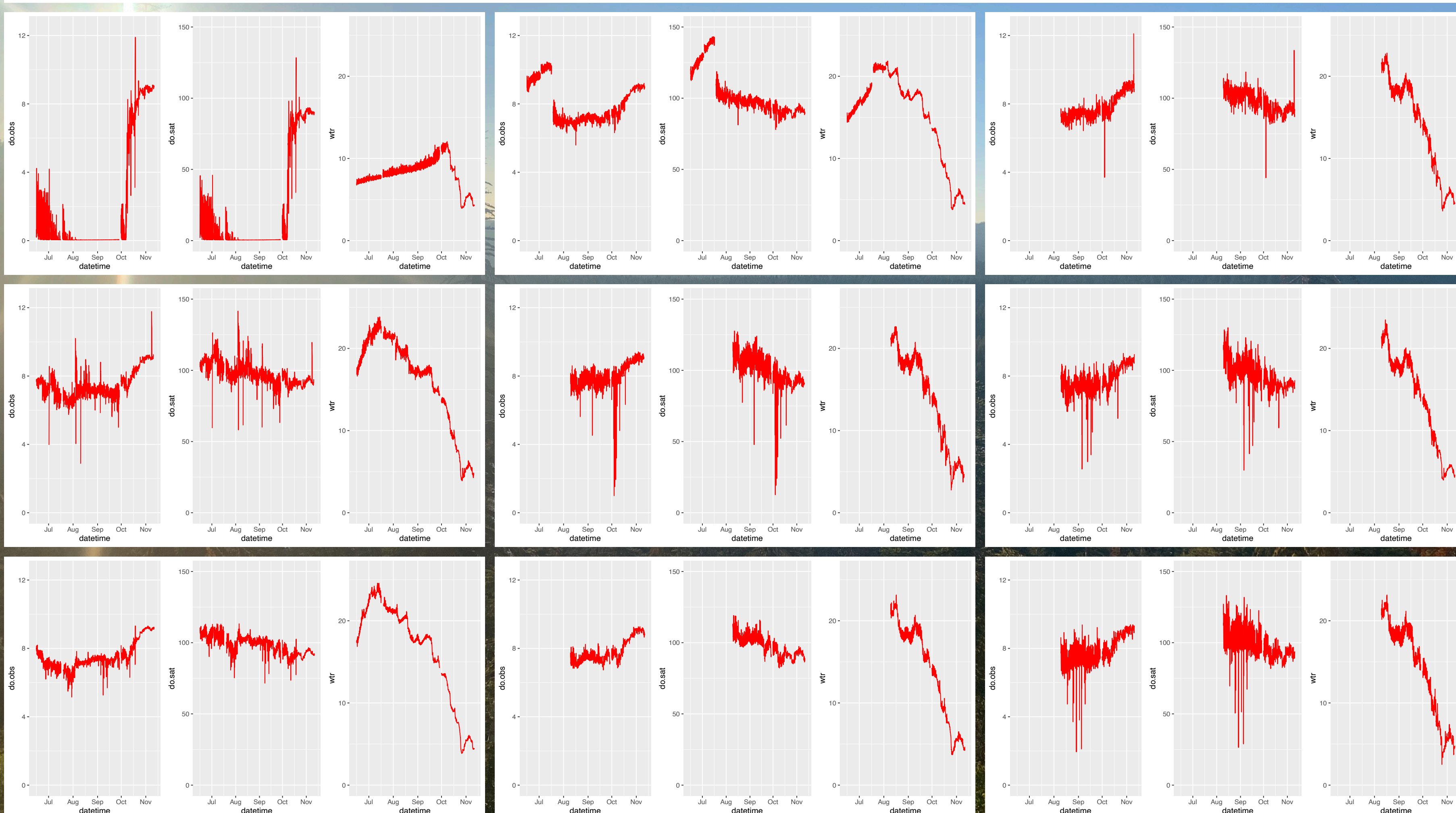
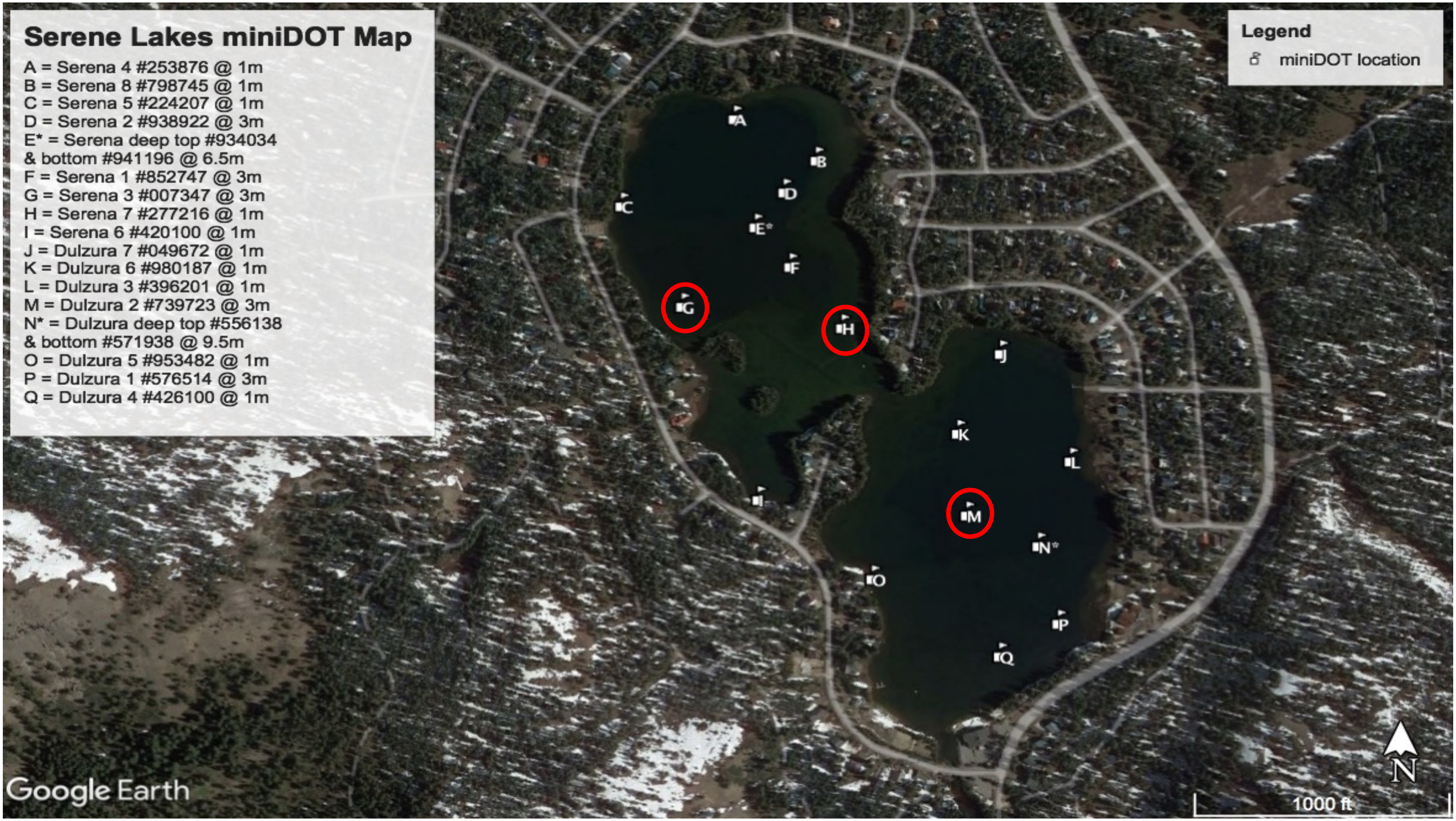
M
N*
O
P
Q
Google Earth
N
1000 ft

Lake Serena dissolved oxygen and temperature show highly variable patterns by site



Lake Dulzura miniDOT graphs also highly variable

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Google Earth
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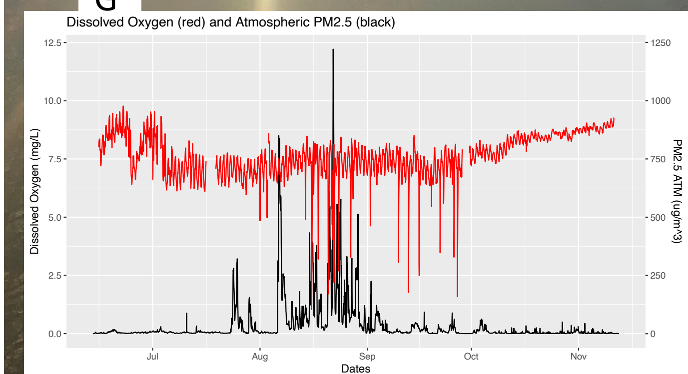
1000 ft

miniDOT Dissolved Oxygen and Smoke Graphs

G



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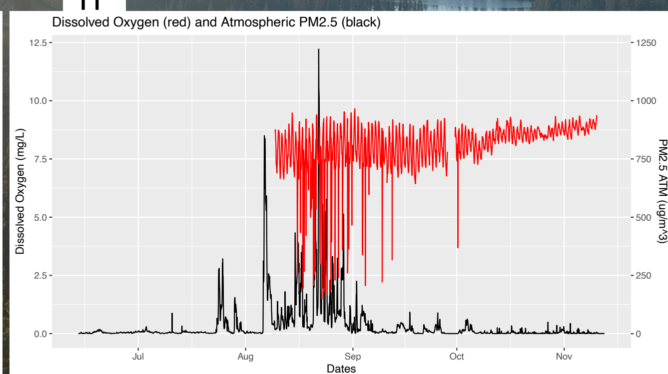

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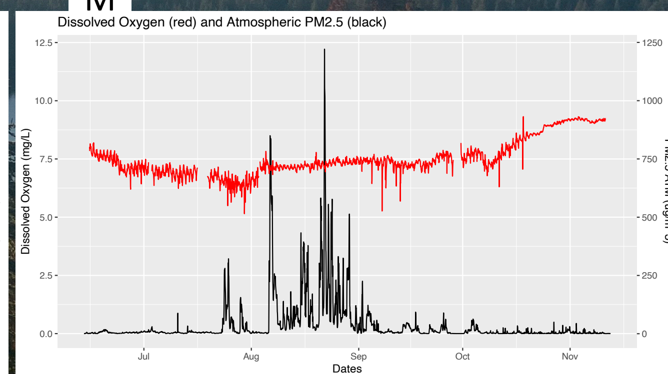
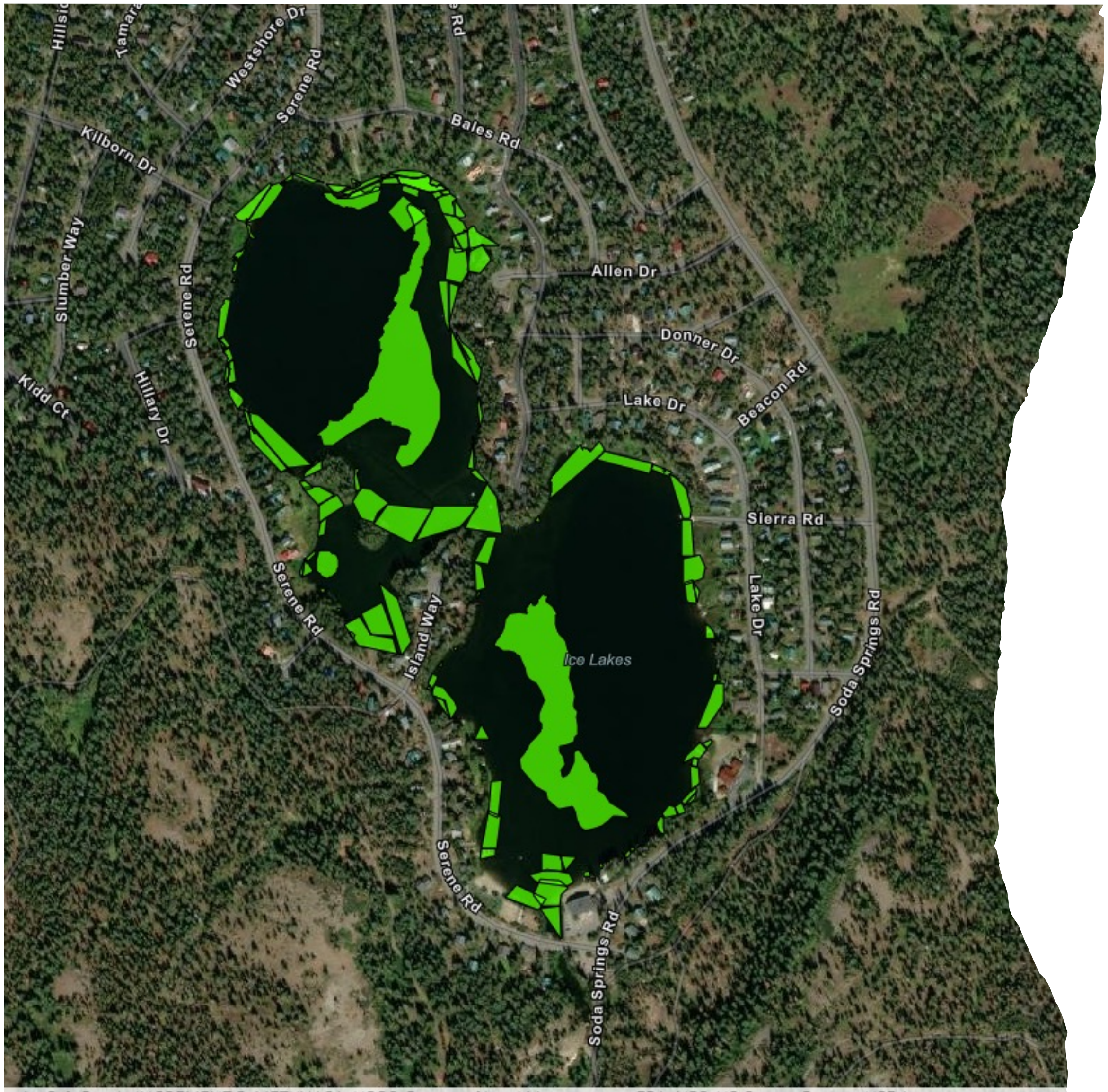
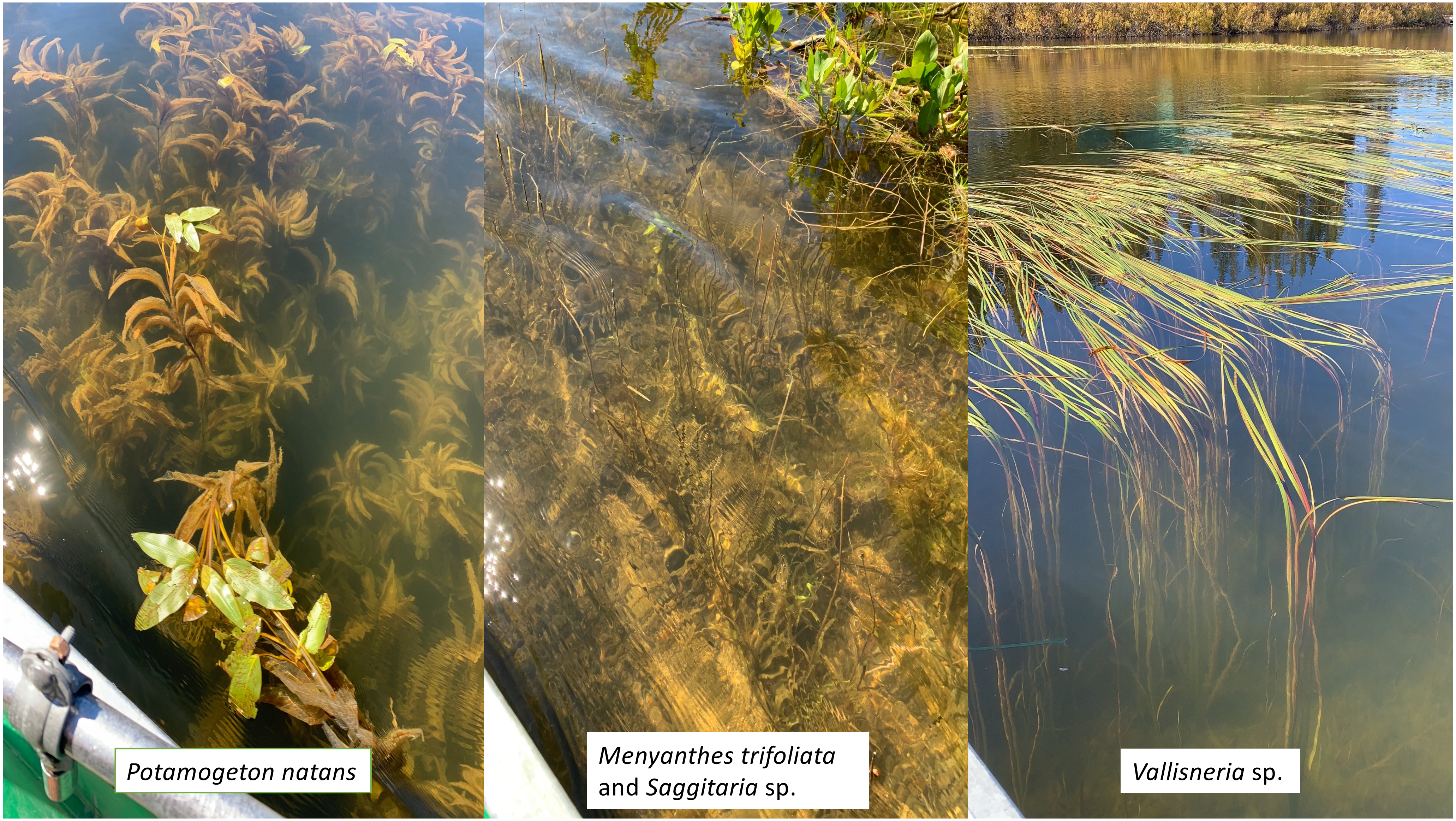




Aquatic Macrophyte Map

- Most of the patches around the perimeter of the lakes are bogbean (*Menyanthes*) and the two large patches in the middle of the two lakes are floating pondweed (*Potamogeton natans*)
- Interestingly, the shallow <2m depth zone identified by Vinyard was not the area of greatest plant density, rather it was about 1-3m for the pondweed


Potamogeton natans
Menyanthes trifoliata and Saggitaria sp.
Vallisneria sp.

Next Steps

- Refine analysis for oxygen/temperature plots, light profiles, integrating analysis with smoke and climate conditions (SWE, wind)
- Proceed with nutrient analysis on all collected samples and quality control of existing samples
- Process chlorophyll a samples from bioassay experiments
- Develop models and calibration to understanding metabolic growth
- Take bathymetry readings for a new bathymetric map
- Reach out to Dr. Heyvaert to develop our initial ideas for management practices and/or restoration projects

Summary

- Since the 1992 Vinyard Limnology Report, the water temperature of Serene Lakes has increased more than 3°C
- Water clarity has decreased by 0.9 m
- Dissolved oxygen was observed to be depleted to near 0 values at some locations in the lakes, which likely caused the catfish kills observed in June and July
- All three observations are hallmarks of eutrophication, further work will determine the nutrient loading and best management practices to control the issue


Thank you. Questions?

Citations

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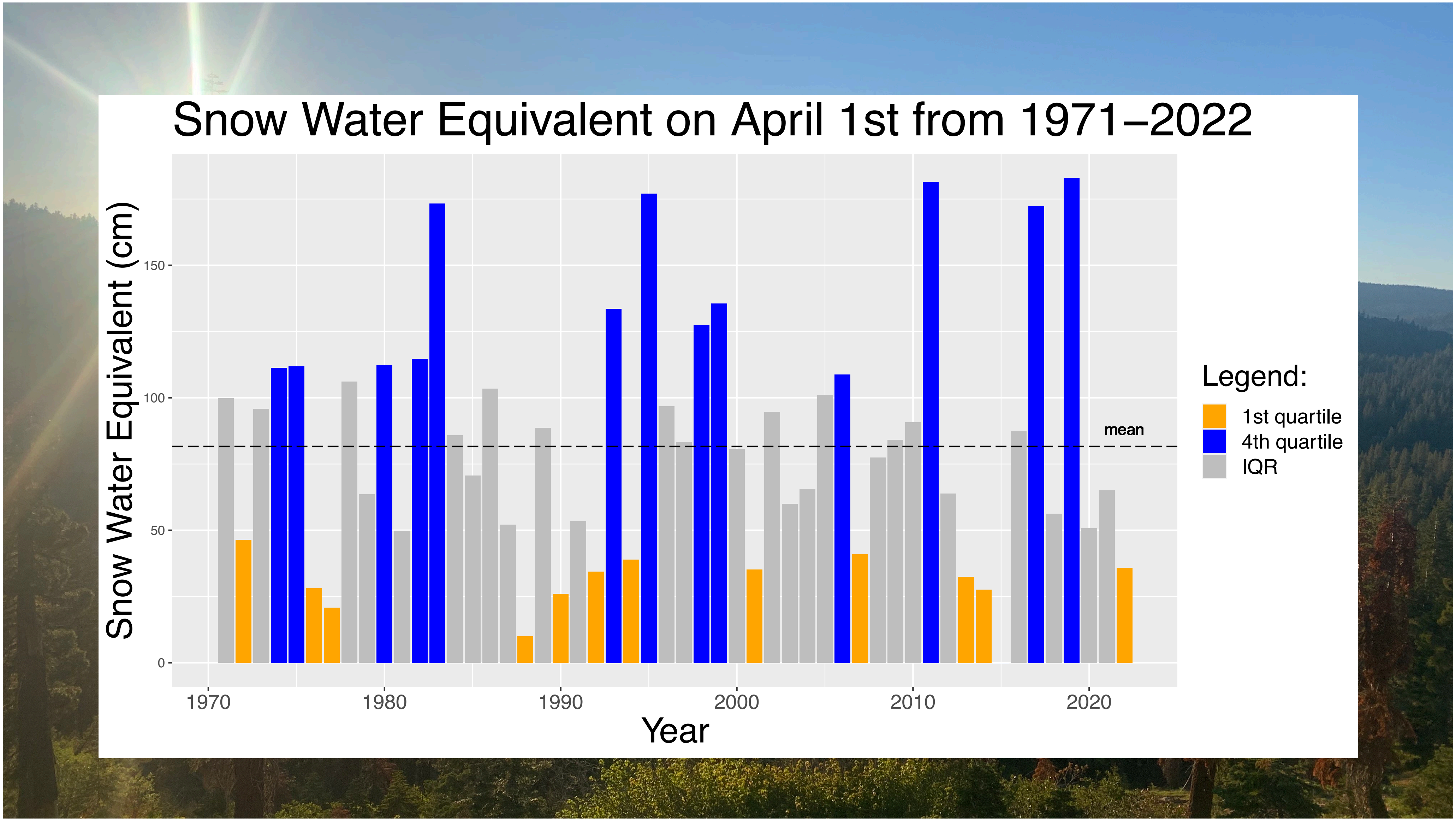

Snow Water Equivalent on April 1st from 1971–2022
Snow Water Equivalent (cm)
0
50
100
150
1970
1980
1990
2000
2010
2020
Year
mean
Legend:
1st quartile
4th quartile
IQR