Understanding Malheur Lake Turbidity and Potential Restoration Strategies

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1. Background

Malheur Lake is a large, shallow lake in southeastern Oregon within the Malheur National Wildlife Refuge. The basin is endorheic with no outflow from the lake, and surface-water inputs to the lake are the Silvies River from the north and the Donner und Blitzen River from the south (fig. 1).

When the refuge was established, Malheur Lake contained healthy communities of both emergent and submerged vegetation that supported populations of migratory water birds and other fauna.

Common carp (*Cyprinus carpio*) were introduced to the basin in the 1920s. Over the following decades, carp populations increased which negatively affected water quality and migratory bird food resources. The lake has shifted from a clear, vegetated state to a turbid state where few aquatic plants can survive.

The U.S. Geological Survey and U.S. Fish & Wildlife Service are studying the causes of the high turbidity in the lake and the effects of carp on water quality. Findings will help determine viable restoration strategies with the intent of returning the lake to a clear, vegetated system.

Figure 1. LandSat image of Malheur Lake taken on 04-26-2019 and continuous monitoring sites northeast (NE) and southeast (SE).

2. Turbidity and Light Extinction

- Data collected in 2018 in Malheur Lake revealed a sharp decline in photosynthetic light in the water column due to turbidity (figs. 2 & 3).
- Photosynthetic light, also referred to as photosynthetically active radiation (PAR), ranges from 400 to 700 nm and is the spectral range that plants use for photosynthesis.
- By approximately 20 cm from the surface, PAR is approaching zero. Photosynthetic light does not penetrate the water column and is not available to plants below ~20 cm.

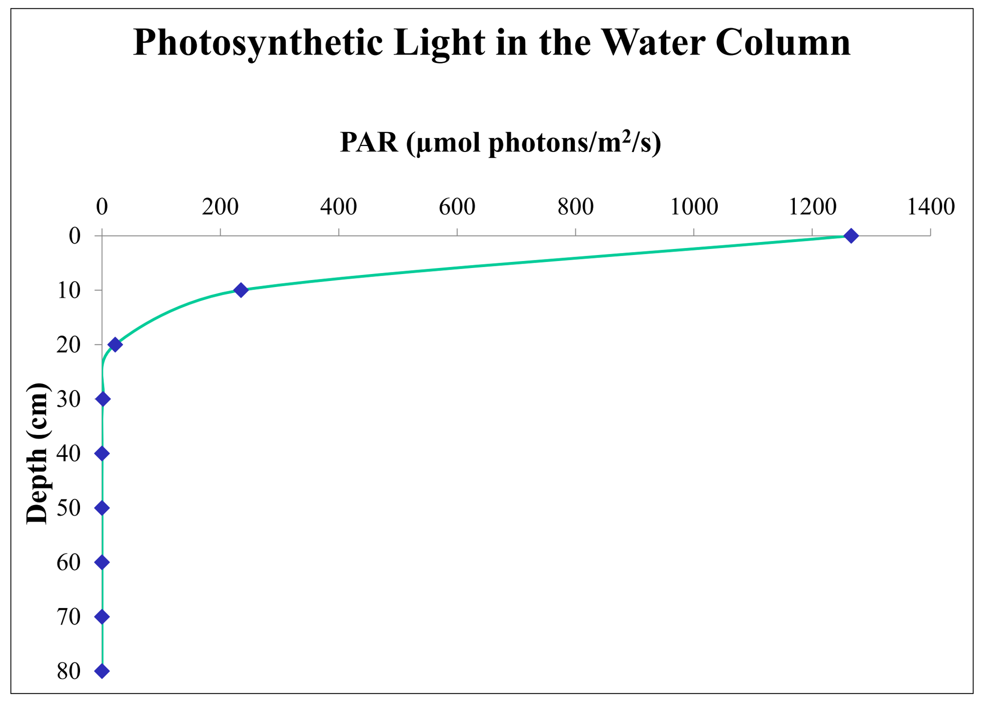

Figure 2. Photosynthetically active radiation measured in Malheur Lake along a depth gradient.

3. The Goal of Restoration

Restoration practices could aim to create more gradual light extinction with depth, which allows PAR to reach plants deeper in the water column (fig. 4).

Current Lake Status:

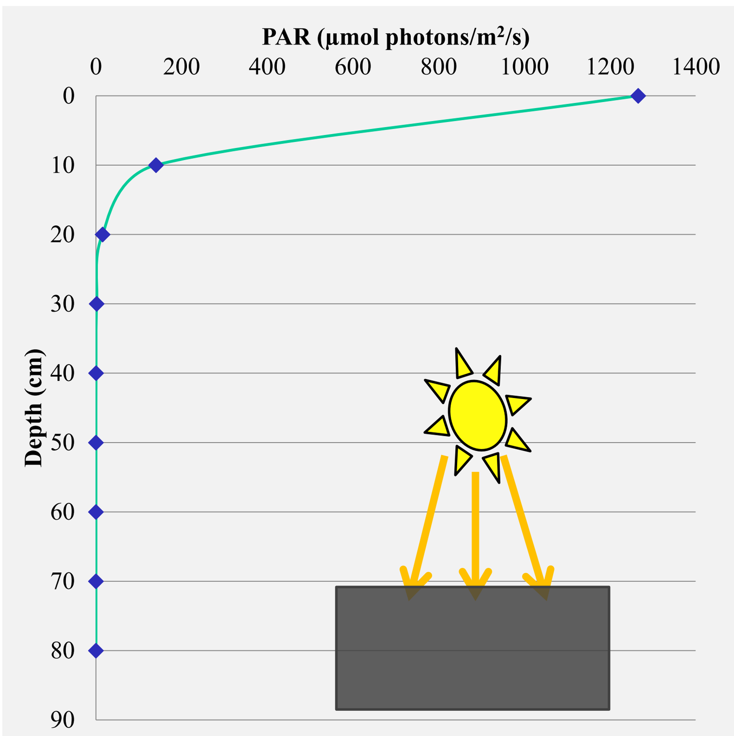

Figure 3. Photosynthetically active radiation measured in Malheur Lake along a depth gradient. Inset represents how light can only penetrate superficially in the turbid lake.

Restored Lake:

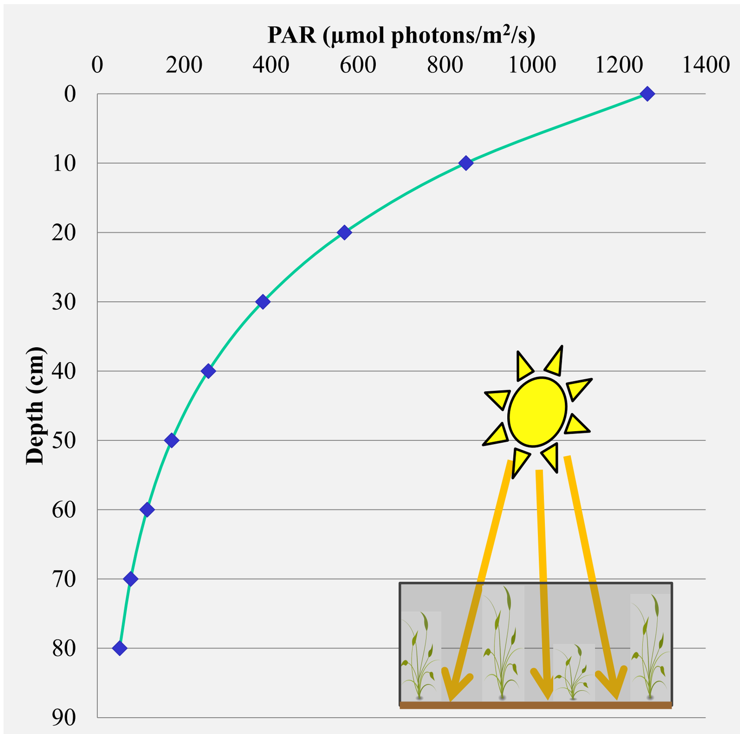

Figure 4. Photosynthetically active radiation along a depth gradient in a clear, vegetated, shallow lake. Inset represents how light can penetrate in the clear lake.

4. What causes the high turbidity?

Figure 5. Carp removal from Malheur Lake. Photo by U.S. Fish & Wildlife Service.

1. **Common carp** are benthic feeders with a suction-feeding technique.
   a. Suction-feeding and movement suspends sediment in the water column.
   b. Carp physically uproot aquatic vegetation leaving sediments exposed.
2. **Wind** is another driver of turbidity.
   a. Wind energy is transferred to the water, creating waves with circular orbits (fig. 6). The amount of erosion/suspension depends on wind strength, sediment characteristics, depth, and wind direction.
   b. Malheur Lake's large area of exposed water means long wind fetch, which increases wave action and erosion/suspension.
   c. Continuous datasondes deployed in the lake (NE and SE sites) and wind data collected at a nearby meteorological station revealed a strong relation between wind and turbidity on short time scales (up to a few days) associated with weather and diurnal wind patterns (fig. 7).

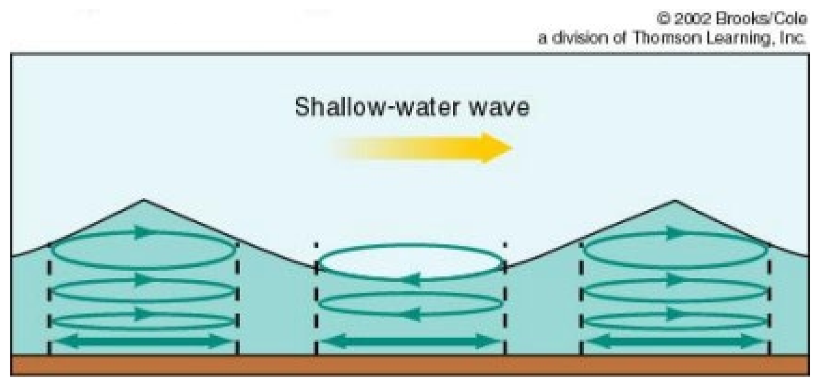

Figure 6. Shallow-water wave action. The back-and-forth movement associated with shallow waves creates shearing action at the lake bottom that lifts sediments into the water column.

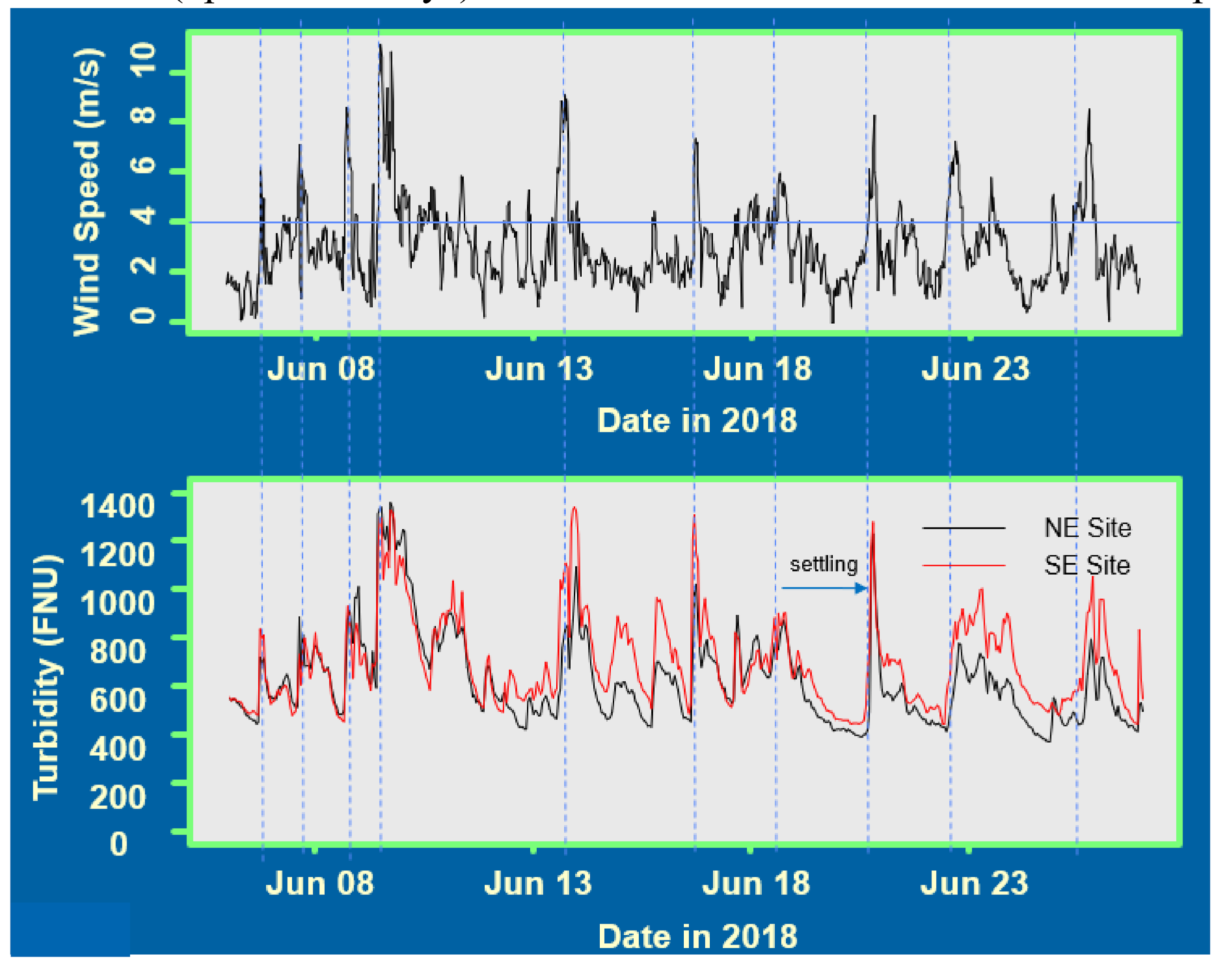

Figure 7. Continuous wind speed data and continuous turbidity data collected in Malheur Lake in 2018. Continuous turbidity data were collected at two sites within the lake (northeast [NE] and southeast [SE]). Vertical dashes align turbidity peaks with wind events.

3. Continuous chlorophyll-*a* data and discrete samples collected in 2018 indicate that turbidity in Malheur Lake is not only from suspended sediment. **Phytoplankton** are also a large component of the turbidity. Figure 8 shows an elevated baseline of chlorophyll-*a* (measured in relative fluorescence units [RFU]) that appears relatively consistent.
   a. Are nutrients in the lake supporting the phytoplankton communities? If so, can nutrients be managed to decrease the light-reducing phytoplankton?

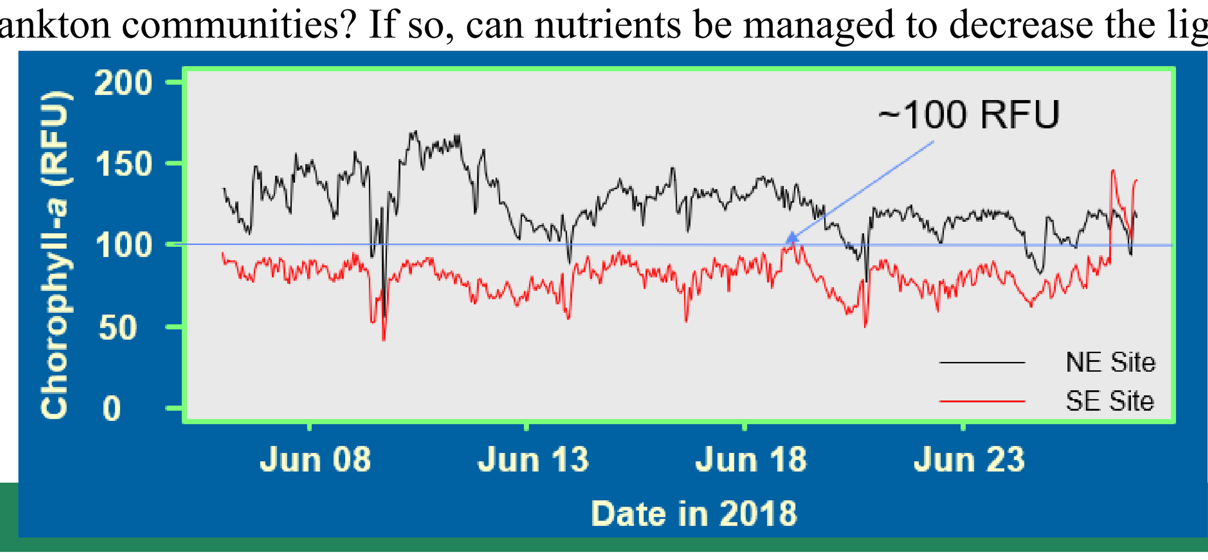

Figure 8. Continuous chlorophyll-*a* data (measured in relative fluorescence units) collected at two sites (northeast [NE] and southeast [SE]) in Malheur Lake in 2018.

5. Next Steps– 2019 & 2020 Field Seasons

- Quantify in-lake nutrient storage (nitrogen and phosphorus), capturing seasonal and inter-annual variability.
- Quantify external nutrient loads (inputs to the lake) through time.
- Determine organic, inorganic, and bioavailable fractions of nutrients.
- Quantify internal recycling (relation between resuspension and nutrient concentration).
- Determine role of nitrogen-fixing cyanobacteria in nitrogen balance.

6. Conclusions

- Malheur Lake has shifted from a clear, vegetated lake to a turbid, non-vegetated lake.
- Currently, the turbidity in the lake prevents PAR from penetrating the water column, where aquatic plants require it for survival.
- High turbidity in the lake is a result of carp behavior, resuspension of sediment due to wind, and the phytoplankton community.
- Nutrients within the lake may be supporting the phytoplankton community.
- Managing nutrients in the lake may be one way to reduce turbidity, allowing more aquatic vegetation to grow. Aquatic vegetation would also reduce wind fetch and erosion/suspension.