Interactions Between Dissolved Oxygen, pH, and Temperature at Lake Merritt

Kua Ngilbus, Albino Guzman, Terra Mack, Anthony Majors, Dario Pratt
Jackson Liang, Don Pham, Andres Unigarro, Luciano Corazza, Kevin Cuff
Lawrence Hall of Science
University of California, Berkeley

Introduction

Lake Merritt is referred to poetically as the "Necklace of Lights" at nighttime. The water itself, however, is superficially described by local residents as having a foul odor, peculiar appearance, and being full of debris. Thus, we have researched many areas in and around Lake Merritt in the interest of testing these preconceived notions about Lake Merritt's water quality. If it is as low as commonly believed, we will make recommendations towards improving the water's health.

Methods

We took measurements of dissolved oxygen, pH, and temperature changes at twelve sites around the lake (Figure 1, 1-12) and six sites in the center of the lake (Figure 1, A-F). We use these three particular measures of quality because there are direct and important interactions between each of them. For example, dramatic temperature increases lowers the dissolved oxygen level. Also, if the pH is too low it decreases the ability of fish to effectively absorb dissolved oxygen. Appropriate pH levels also helps minimize the risk of lead being dissolved into the water. Dissolved oxygen levels and temperature changes were taken with PASCO Xplorer GLXs, and the pH levels were taken with Fisher Scientific electronic pH meters.

Each measure is scored on a 100 point scale, dependent on how close each is to the optimal level. The optimal level for dissolved oxygen is 9.1 mg/L, and for pH is roughly 7.4. The optimal temperature change is, naturally, 0. We then calculate a water quality index (WQI) for each site using the guidelines provided by the U.S. Geological Survey and the National Science Foundation. Because we focus on just three of the 12 standard measures, our water quality index is weighted differently from that of the U.S. Geological Survey. Our Index is weighted as follows: 0.5 for dissolved oxygen, 0.3 for pH, and 0.2 for temperature. The Index is on a 100 point scale and allows us to compare sites and determine the quality of water.

In order to determine the relative health of water for the entire lake, we then created contour maps of each measure of quality (Figures 2a-2c) -- as well as the overall WQIs (Figure 3) -- using the Surfer 7.0 software by Golden Software.

Figure 1. Sites sampled over a one month period from June to July.

Lake Merritt Perimeter
1 - Rotary Nature Center
2 - Boat Dock
3 - Beach
4 - City Runoff (Fountain)
5 - Cement Pipe
6 - Tidal Gates
10 - Main Fountain (Fountain)
11 - Eastern Shoreline
12 - Barrier by the Archway (Fountain)

On the Lake
A - Center of the Lake
B - Archway (Fountain)
C - Main Fountain (Fountain)
D - Tidal Gates
E - Boathouse Museum
F - City Runoff (Fountain)

Estuary to San Francisco Bay
7 - Peralta Park Lagoon
8 - Lake Merritt Channel Park
9 - Below Freeway 880

Predictions

The patterns of data we expect to see are based on the fact that the San Francisco Bay is a larger body of water -- and therefore a better heatsink. Thus, the water coming in from the Bay at site 6 would be cooler and better saturated with dissolved oxygen. In sum, sites 6, 9, and 10 will have higher relative qualities of dissolved oxygen because of their proximity to the Bay and to an aerating fountain.

Additionally, we expect sites that are close to motor emissions to be more drastically acidic. Therefore, sites 2, 9, and E will have lower qualities of pH due to their proximity to motor boats and vehicle traffic, respectively.

As mentioned previously, water from the Bay will be cooler and less susceptible to temperature changes. However, the estuary that connects the Bay and Lake Merritt is narrow, and therefore is actually a smaller body of water. As a result, sites 7 through 9 will show lower qualities of temperature change.

Overall, however, we expect the WQI of the water coming in from the San Francisco Bay to be higher because of the influx of more oxygen-saturated water at the tidal gates.

Figures 2a-2c. Contour maps for relative dissolved oxygen quality (left), pH quality (middle), and temperature change quality (right) respectively.

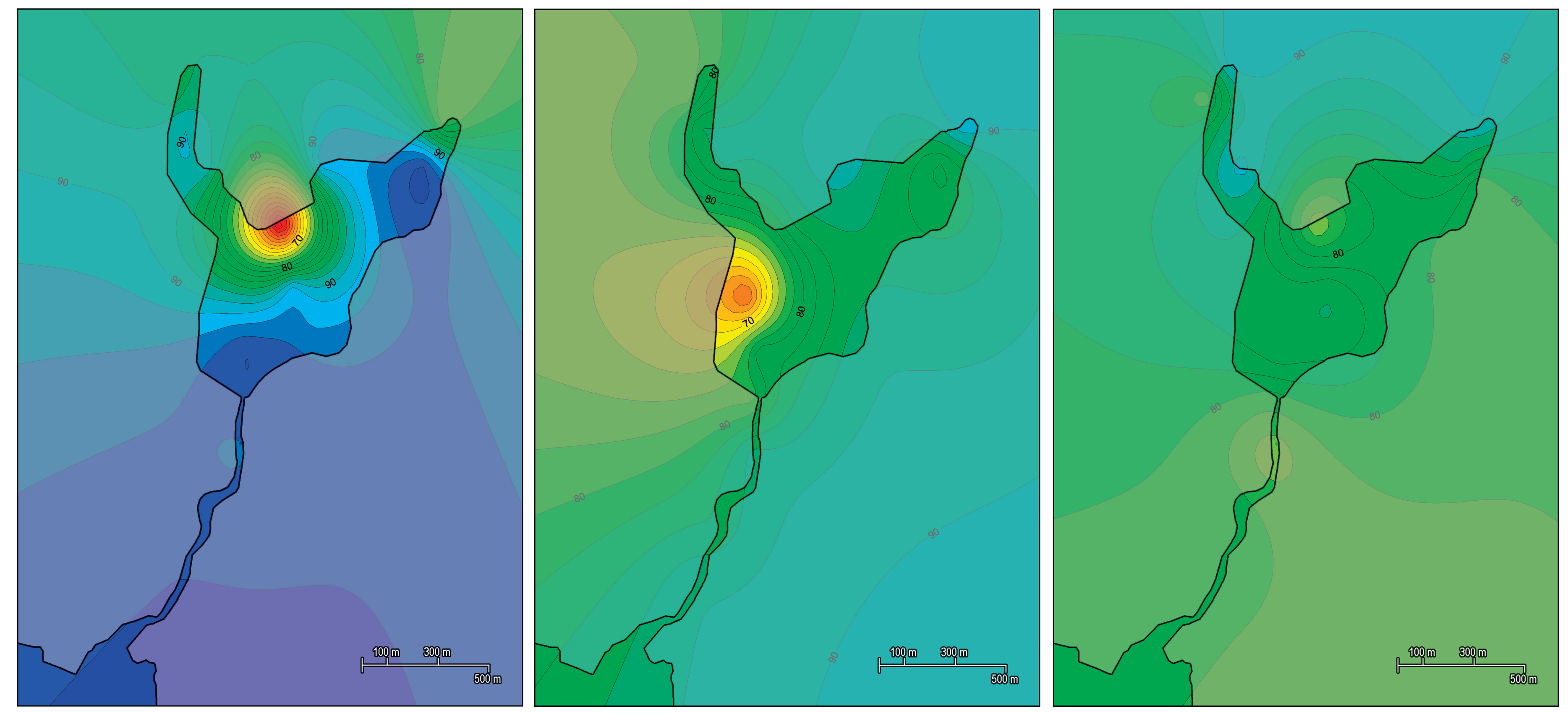
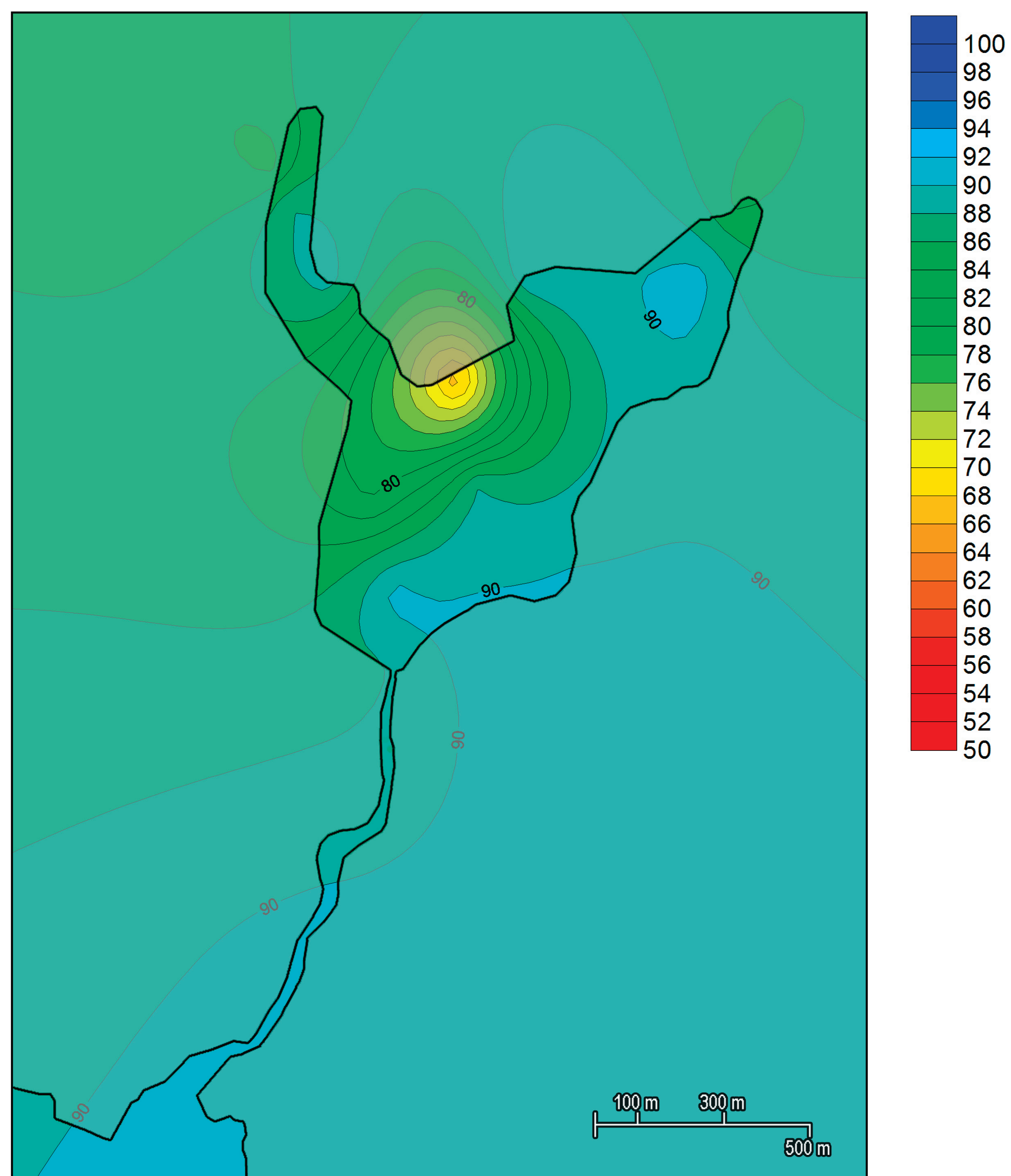


Figure 3. Weighted Water Quality Indices (WQIs) for Lake Merritt based on the three measures of quality exemplified by Figures 2a-2c.



Results

We discovered that dissolved oxygen content was optimal in the southern sites 6 and 9, which was what we expected to see (Figure 2a). Unexpectedly, the contour map also revealed a specific area of much lower dissolved oxygen quality: site 2. This was the Boat Dock, and what we observed may be due to the effects of relatively low pH at this site (Figure 2b). pH was of even lower quality at site E, which we also predicted. Lastly, temperature changes were indeed greater -- and therefore of lower quality -- in the estuary (Figure 2c), likely because it is a smaller body of water. Moreover, the quality of temperature change was also much lower in the Boat Dock and at the City Runoff, which we did not expect. In general, the difference in quality for pH and temperature were less drastic than that of dissolved oxygen, even before we weighted them for the water quality indices.

The contour map of our WQIs suggest that water quality tends to be higher near the tidal gates, where water from the San Francisco Bay influxes. This is in line with our predictions.

Conclusions

As we expected, the water quality is greater near the estuary where a constant supply of water from the Bay renews the Lake. Overall, the water quality of Lake Merritt is not as low as anecdotal evidence would suggest. However, there is cause to believe that the difference in quality between the northern and southern areas of the lake is great enough to warrant further examination. Our immediate recommendation is to discover ways to circulate water from south to north. Fountains that churn and therefore aerate the water already exist, and we can see that those areas have slightly higher WQIs. However, their effects are extremely localised, so either more fountains will need to be installed or a different method must be devised. One such method is to increase the number of machines that thresh and filter the water periodically throughout the lake.

Secondly, the biggest contributor to the patterns that we observe is the presence of the boating facility at site 2. We suspect that motor activity in that area is lowering the quality of water there. We realize that boating is a great source of funding for that boat club and contributes recreational value to Lake Merritt as a whole. However, we do recommend applying some of that money toward focused efforts at cleaning up that specific site. Ideally, trivial usage of motor boats will be limited during the summer seasons, so as to at least keep the quality of the water more consistent -- even though we expect boat activity to increase along with rising temperature. One could additionally replace gasoline motors with electric or solar-powered motors, in order to reduce emissions in the area. This would also apply to the threshing machines that already circle Lake Merritt.

Future Directions

In sum, our results raise the immediate concern that healthier water is not effectively being circulated around the entire lake, although further research is necessary to determine whether this truly caused the observed pattern. This will involve analysis on windspeed measurements taken over the course of one or two months. We expect to observe a correlation in lower windspeeds -- resulting in stagnant water -- with lower WQIs.

Additionally, we intend to perform a secondary analysis using image sampling to determine whether the physical appearance of the water can be correlated with water quality at each site. This may be a powerful, new technique for efficiently and cost-effectively obtaining an indication of health for the water.

Images show the coloration of water and therefore how much algae is in the water. For example: red algae reflects red but absorbs green and blue. The water itself reflects blue; essentially, only red and green light penetrate the surface of the water. Green algae in the upper layer absorbs the red portion of this light, and reflects the green portion. This green is a light green because a significant amount of light is being reflected, being near the top of the water. In the bottom or deep layer there is not much penetrating light left and is dominated by the red algae, which absorbs green light but reflects red and to some extent blue. The red algae, therefore, appears to be a dark purplish red.

Our samples for image analysis came largely from the upper layer. As a result, we would expect the water to have a higher trace of green algae in sites where the water is healthier. It would therefore show a higher component of green light in the image analysis, in comparison to water from less healthy sites and the distilled water control. However, the presence of red algae is not inconceivable, and would also indicate healthier water.

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