Climate Change Modeling of Lake Mead: Extrapolating Model Results to Biological Change

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Modeling was carried out by Flow Science Inc.
A linked hydrodynamic, biological, and chemical numerical simulation model for Lake Mead has been developed over the past decade.

ELCOM: Estuary and Lake Computer Model
- 3D Hydrodynamic model

CAEDYM: Computational Aquatic Ecosystem Dynamics
- Aquatic Ecology model coupled to the ELCOM model

The performance of the model(s) has been evaluated and enhanced throughout its life.
Computation Grid for Whole Lake Model

Boulder Basin

Muddy River
Virgin River
Colorado River

Las Vegas Wash

Lake Mead

Hoover Dam

elevation (m)

240 260 280 300 320 340 360

= 300 x 300 x 2 m grid cell
Initial Model Runs: Average Temperature Increases

- 2050 median: +2.0 °C Air Temperature
- 2090 median: +3.2 °C Air Temperature
- 2090 90th percentile: +5.4 °C Air Temperature

CMIP3 projections

Based on initial model runs and literature review water temperatures were adjusted to 67% of these values in the surface and inflow and 40% of these values for the lower water column.
Temperature Profiles at Station CR346.4

Temperature Profiles at Station CR346.4

July 1

October 1

December 1

January 1

February 1

March 1

April 1

July 1

depth (m)

depth (m)

depth (m)

depth (m)

depth (m)

depth (m)

temperature (°C)

temperature (°C)

temperature (°C)

temperature (°C)

temperature (°C)

temperature (°C)
Chlorophyll a Concentrations

Temperature and Chlorophyll a at Station CR346.4

Surface Temperature

Top 5 m Average Chlorophyll a
Chlorophyll a impacts

Chlorophyll a Top 5 m Average at Station CR346.4

- Run 1, baseline, 2006-2007
- Run 2, moderate, median 2050s
- Run 3, high, median 2090s
- Run 4, extreme, 90th%-ile 2090s

Chlorophyll a (µg/L)

Metrics:
- annual 95th%-ile
- annual average
- GSA
- summer average
Chlorophyll, Temperature and Nutrients

With warmer temperatures there is a pronounced decrease in summer Chlorophyll a concentrations.

There is a second significant chlorophyll peak in the early autumn after temperatures fall back below 30 °C.

There was little difference in average concentrations.

Depending on how average is calculated.
A key part of this cycle is the accumulation of nutrients during the summer.

There is extensive data indicating that algae in Lake Mead is phosphorus limited.

The Las Vegas Wash contributes a large proportion of the available phosphorus to the lake.

During the summer months the majority of the Las Vegas Wash water enters the lake as an interflow, adding phosphorus to the surface/middle waters of the lake.

When temperatures are too high for the current algal community, phosphorus accumulates, allowing for the development of an Autumn chlorophyll peak.
Can we modify the community?

There is no reason to believe that the community present today would be the same following ~70 years of gradual warming.

- There are algal species that can thrive at > 30 °C.

Within the model this is accomplished by adding a second “generic” algal group with slightly higher thermal tolerance.

The pattern returned to “normal”.
Chlorophyll a Impacts: Modified Community

Chlorophyll a at Station CR346.4

Top 5 m Average

- Run 1, baseline, 2006-2007
- Run 3, high, median 2090s
- Run 4, extreme, 90th%-ile 2090s
- Run 9, high, median 2090s, two groups
- Run 10, extreme, 90th%-ile 2090s, two groups

Chlorophyll a (µg/L)

Date: Jan, Apr, Jul, Oct

Jan 2006-2007 to Jan 2090s
Accommodating Higher Temperatures

If we know that the model is limited by the current state of knowledge and...

We know that we can modify the model slightly and obtain believable results

- Slight modifications in the sense that they are biologically likely, but not explicitly quantitatively derived

So what can we predict, biologically, in light of these model changes

- i.e. what changes will we see in the algal community to meet the need to accommodate a 3 – 5 °C peak temperature increase
From the literature it has been demonstrated that higher temperatures typically lead to some fairly predictable changes:

- Smaller celled species tend to dominate over larger celled species.
- Cyanobacterial species tend to become more dominant.
Smaller Celled Species

In general terms smaller celled species have metabolic advantages during periods of stress.

- Generally explained as an advantage derived from changes in relative surface area to volume ratios.
- Smaller cells have a large surface area and smaller volume.
  - Facilitates capture of light for photosynthesis and nutrient acquisition.

The Lake Mead algal community is already dominated (numerically) by small celled species.

- Low nutrient concentrations
- Grazing losses
- Temperature
Cyanobacteria tend to outcompete other algal groups at higher temperatures

- 2 theories
  - Better physiological adaptation at higher temps
  - More capable of moving in the water column, preventing settling and maintaining favorable position

It doesn’t really matter why they are advantaged

Cyanobacteria pose 2 threats

- Bloom forming species
- Toxin producing species
Cyanobacterial Threats

Bloom forming species

Cyanobacteria frequently produce significant blooms as they are able to use available nutrients very efficiently.

As long as phosphorus remains the limiting nutrient, and loading is maintained at current levels these blooms should be infrequent.

Toxin producing species

As one strategy for competition with other algal species, some cyanobacteria produce toxins.

SNWA currently monitors for toxin producing species and some toxins.

Potentially toxin producing species are present.

Toxins have never been detected.
Slight increases in chlorophyll concentrations
Potential shifts in species composition
Not addressed, other ecosystem shifts
Food quality, changes in location of productivity
If the Worst Happens, How to Respond?

- Decreases in the size of the algal cells
  - Drinking Water: Maintenance of filtration capacity
  - Ecosystem: Changes in the availability of food to the rest of foodweb is unclear
  - Species shifts

- Increased possibility of blooms
  - The management of nutrient loading from the Las Vegas Valley has kept algal blooms in check for 13 years.

- Increased possibility of algal toxins
  - Drinking Water: Ozonation destroys toxins
  - Ecosystem: Potentially harmful
  - Recreation: Potential risk
Questions?

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