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The beginning

- *Microcystis* has usually (for the past several years at least) appeared during the late summer, peaked in the fall, and decreased during the winter.
  - This makes sense
  - Late summer, high temperatures and “low” wind favor cyanobacterial growth
  - *Microcystis* decreased during the winter as the water temperatures decreased and the water column began to mix.

- This year the *Microcystis* did not disappear, and was seen in “high” concentrations in both Lakes Mead and Mohave, in a variety of locations
  - Boulder Basin
  - Las Vegas Bay
  - Overton Arm
  - “Lower” Lake Mohave
What we were seeing in February

At that time, and for all dates since, it would be difficult to categorize conditions in Mead or Mohave as a “Bloom”.
What are we worried about?

- Lake Erie and the Toledo Water Supply

- Microcystis can produce microcystin
  - Microcystin is a hepatotoxin that can impact the liver
    - Can get sick from contact or ingestion
    - Can be fatal to pets and livestock drinking/ingesting the toxin
All indications were that the species we had was *Microcystis wesenbergii* which is not a toxin producer. *Microcystis aeruginosa* is the most common toxin producer. We had never detected microcystin in any sample we have analyzed. We were not experiencing a "bloom." Toxins are typically produced when the population is:

- At very high concentrations
- When it is under stress
  - Nutrient stress
  - Overpopulation
- (not really that predictable)
Lake Erie 2014
Lake Mead May 2001
Issues we face

- Identification of the species present each sampling
  - *M. wessenbergii*: Not a big deal, *M. aeruginosa*: A potential risk
  - We need to sample an active, abundant population to ensure correct identification of the species
    - Visual identification has proved difficult due to odd colony characteristics
  - Recent samples by USBR, analyzed by PCR/genetic screening, *may have confirmed M. aeruginosa*
    - Waiting on methodology, most of characterizations look for toxin producing genes
    - Some experts feel that identification of species/strains is not possible.

- *M. wessenbergii*  
- *M. aeruginosa*
Quantification of microcystin

- **ELISA**
  - Prior to March 2015 all results in the past had been negative
    - Some reluctance to continue in light of negative results
  - All results at drinking water intake locations continue to be negative
    - Toxin only detected at Las Vegas Boat Harbor Marina, Gregg Basin, and Lake Mohave
  - Results semi-quantitative
    - SNWA will be implementing a more quantitative method

- **Analytical chemistry**
  - Methods have been “developed” for SNWA R&D lab using LC/MS/MS
  - Low detection limits, “high” cost, intensive

- **Intracellular or Extracellular?**
  - SNWA will be switching to primarily analyzing total toxin; intra+extracellular
    - Extracellular: The risk you face today
    - Intracellular: The risk you may face in the future
What have we seen since February

- **March 10 2015**
  - City of Las Vegas observes an increase in *Microcystis* in Las Vegas Bay
  - LMNRA observes an increase in *Microcystis* in southern Lake Mohave

- **March 11 2015**
  - COLV and SNWA return to continue sampling Lake Mead and observe very high concentrations in the Las Vegas Boat Harbor Marina
  - We collect a sample from the marina for microcystin analysis
    - ELISA results show a concentration between 0.5 and 3 µg/L microcystin
    - Chlorophyll concentrations (very localized) were ~1000 µg/L
    - This is the first detection of toxin in Lake Mead EVER
  - Sampling was expanded in the marina
    - Inner, middle outer
  - Still not a bloom, wind driven aggregation
### March 12 2015

<table>
<thead>
<tr>
<th>Date Collected</th>
<th>Location</th>
<th>Sub Location</th>
<th>ALGAL TOXIN ppb</th>
<th>Average Chlorophyll µg/L</th>
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<td>3/12/2015 9:15</td>
<td>IPS-3</td>
<td>70M</td>
<td>&lt; 0.5</td>
<td>&lt; 1.0</td>
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<td>3/12/2015 9:00</td>
<td>IPS-3</td>
<td>SURFACE</td>
<td>&lt; 0.5</td>
<td>1.05</td>
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<td>3/12/2015 9:40</td>
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<td>3/12/2015 10:20</td>
<td>LVBH</td>
<td>MID MARINA</td>
<td>0.5 - 3.0</td>
<td>949</td>
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<tr>
<td>3/12/2015 10:40</td>
<td>LVBH</td>
<td>END OF DOCK</td>
<td>0.5 - 3.0</td>
<td>919.27</td>
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<tr>
<td>3/12/2015 10:50</td>
<td>LVBH</td>
<td>SHORELINE</td>
<td>0.5 - 3.0</td>
<td>1258.66</td>
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</tbody>
</table>

Microcystin could still be measured in Las Vegas Boat Harbor Days after algal death
March 12 2015 cont.

- CAP observes significant *Microcystis* in the forebay of their pumping plant in Lake Havasu and USGS and NPS report *Microcystis* at various locations in Lake Mead
March 13 2015

- SNWA and LMNRA public information staff coordinate to develop fact sheets (internal and external) and LMNRA issues an advisory on contact with the water
SNWA Water Treatment

- Is/Was this a significant threat to the drinking water supply
  - Not in the current and recent past formulation of the “bloom”
    - Toxins were NEVER detected near the current SNWA Intakes, the “new” SNWA Intake location or the intakes for the City of Henderson
      - Some of the LMNRA Intakes for campgrounds and staff housing may have been at slightly higher risk due to shallow pump depth
  - If this “bloom” had been an actual BLOOM would it have posed a risk of Microcystin reaching the intakes
    - Almost certainly not for the SNWA intakes, *Microcystis* tends to be a surface dweller
      - LM1+2 were >25 m below the surface of the lake
      - LM3 would be ~85 m below the surface of the lake
      - The risk to COH and LMNRA could be larger as their intakes are not as deep
  - If the microcystin had reached the depth of the SNWA Intakes would it have posed a risk to the drinking water supply
    - SNWA Research and Development, as well as other researchers, have demonstrated that microcystin is destroyed by both Chlorine and Ozone
    - SNWA already employs both Chlorine and Ozone for disinfection, benchtop experiments confirmed that treatment concentrations were capable of destroying microcystin in the lake water
March 16 2015

- Reports of *Microcystis* from the Colorado River downstream of Parker Dam as far as Yuma
March 20 2015

- Populations in Lake Mead appeared to be in decline

- Lake Mohave looked “healthier”
March 21 2015

- Photos from Lake Havasu
March 23 2015

- Samples from Lake Mead (SNWA Intakes) were evaluated through the water column for *Microcystis* abundance

<table>
<thead>
<tr>
<th>Depth</th>
<th><em>Microcystis</em> Cells/ml</th>
<th>Microcystin ppb</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>609 (very low)</td>
<td>&lt; 0.5</td>
</tr>
<tr>
<td>2</td>
<td>660 (very low)</td>
<td>&lt; 0.5</td>
</tr>
<tr>
<td>4</td>
<td>50</td>
<td>&lt; 0.5</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>&lt; 0.5</td>
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<tr>
<td>8</td>
<td>0</td>
<td>&lt; 0.5</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>&lt; 0.5</td>
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<tr>
<td>12</td>
<td>0</td>
<td>&lt; 0.5</td>
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<tr>
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<td>&lt; 0.5</td>
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<td>20</td>
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<td>24</td>
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<td>&lt; 0.5</td>
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<tr>
<td>26</td>
<td>0</td>
<td>&lt; 0.5</td>
</tr>
<tr>
<td>28</td>
<td>50</td>
<td>&lt; 0.5</td>
</tr>
</tbody>
</table>
Lake Havasu Sampling March 24 2015

- Samples were collected by USBR and Lake Havasu City during routine sampling

- 10 locations, all positive for Microcystin
  - 8 with concentrations <1.5 µg/L, 6 below 1 µg/L
  - 1 location with ~6 µg/L
  - 1 location with >20 µg/L
Cottonwood Cove March 25 2015
Late March

- Overall in Lakes Mead and Mohave conditions appear to have improved
  - Occasional aggregations were still being found in Lake Mead, less sampling on Mohave
    - Hopefully windy, colder days in March and April limited *Microcystis* growth
    - Other algal taxa became more dominant
    - Some *Microcystis* continues to be seen in most samples
      - May be a deeper population in Lake Mead
  - SNWA had not detected microcystin in more recent samples
    - Sampling on Lake Mohave is less frequent but there have been occasional reports
  - Additional sampling in Upper Lake Mead did not find *Microcystis* until late May
    - USBR detected very low concentrations near Hoover Dam (0.28 µg/L) and moderate concentrations near the confluence with the Colorado River (2.97 µg/L). Sample in Las Vegas Bay was below detection
  - There are no reports of *Microcystis* in Lake Powell but the data is lacking
Lake Havasu

- CAP continues reports occasionally abundant *Microcystis* near their forebay
- Lake Havasu continues to face (potential problems)
- Continued reports of algae (*Microcystis*?) around the lake
- USBR collected samples for microcystin from Lake Havasu in mid-May
  - Results Mixed
    - Most sites positive for microcystin by ELISA
      - > 1 µg/L at CR207.7 (2.81 µg/L), CR199.6 (4.76 µg/L) and CR192.3 (1.1 µg/L)
      - Not detected at inflow
    - HPLC (?) analysis suggests lower concentrations, but confirms presence
      - Suggests presence of other algal toxins at very low concentrations
        - Anabaenopeptin B, Euglenophycin, Anatoxin A
        - No detection for cylindrospermopsin, nodularin, or saxotoxin
  - Frequent reports of visible algae
“…saw dozens of dead ducks floating in mats of blue-green algae
May and June 2015

- *Microcystis* is present in Gregg Basin of Lake Mead from Temple Bar to the Colorado River Confluence
  - USBR: Samples collected to verify species composition
  - SNWA/COLV: Samples collected and dominant species was *Microcystis*
    - Microcystin and Anatoxin a were detected in total toxin analysis
  - Very low nutrient region of the lake
- *Microcystis* again observed in Las Vegas Boat Harbor in early June by SNWA/COLV
  - Free and Total toxins measured in June 9th sample
    - Higher toxin with higher algal biomass; ~10 µg/L free toxin, ~2000 µg/L total toxin
  - No toxin measured in June 11th sample from same location
- Samples collected from SNWA and COH intake locations June 10
  - All samples negative for toxins
- Samples collected from Gregg Basin June 10
  - All samples negative for toxins
- LMNRA continues to receive reports of *Microcystis* and illness from Lake Mohave visitors
  - NPS Epidemiologist has been contacted and is becoming involved
  - Visitor Fact Sheet has been updated with added cautions
June 2015

- *Microcystis* is present in Gregg Basin of Lake Mead from Temple Bar to the Colorado River Confluence
  - LMNRA sampled June 15-16 and detected toxin in the first ~5 miles of Lake Mead
  - SNWA and LMNRA returned to sample for toxins and nutrients between the Narrows and the confluence June 18
    - No toxins detected
    - Ortho-phosphorus remains near detection limits
Since June

- Water Quality Monitoring Staff, Regional Water Quality Staff, LMNRA Resource Staff, and USBR Boulder City have continued looking for *Microcystis* and measuring microcystin
  - Expanded sampling at intake location (SNWA and COH) plus early warning stations in Lake Mead
  - Monthly sampling plus visitor response sampling on Lake Mohave
  - Bi-Monthly sampling on Lake Havasu

- For the most part the “Blooms” have subsided

- Microcystis is making its usual Autumn return, in low numbers so far

- Microcystis and microcystin continue to be found in Lake Havasu samples
So why did this happen

- Theory 1
  - Many fall/winters Lake Mead sees a rise in the abundance of *Microcystis*.
  - Every year recently (6 years) the *Microcystis* disappeared over the winter months, before spring.
  - This winter the *Microcystis* persisted throughout the winter into the spring.
  - The main factor was a warmer winter
    - only ~1 week of near freezing temperatures
    - Average air temps ~4 F°/2 C° warmer
    - incomplete mixing of the water column
      - 14 C° surface water vs 10 – 12 C° surface water when mixed
  - Nutrients appear to be unchanged, TIN is typically 100’s of µg/L   TP is typically 10 – 20 µg/L at most.
  - The warmer winter allowed the *Microcystis* to survive
  - As temperature and light conditions improved during the spring the *Microcystis* was well positioned to “bloom”
  - The *Microcystis* offset some (most?) of the other algae that typically have high production in the spring
  - **The *Microcystis* used the available nutrients and died back**
Why did the “blooms” not bloom?

- There is strong evidence from past/present data, experiments, and the scientific literature that algae in Lake Mead are strongly limited in their growth potential by the supply of phosphorus
  - Rationale for enhanced phosphorus removal from LVV wastewater
  - This approach has helped keep productivity in Lake Mead low.
- *Microcystis* has the ability to incorporate phosphorus when it is available for later use
  - Luxury uptake
- It appears that this luxury uptake was sufficient to allow the *Microcystis* to grow rapidly in small areas, producing the observed “blooms”
- As soon as the stored phosphorus was depleted, the water column concentrations were insufficient to sustain growth and the “bloom” crashed
  - The distinguishing characteristic in Lake Mead for these crashes is the cycle time
    - Days versus weeks
What do we do next

- We should definitively identify the species we have
  - Genetic testing, more problematic than it should be
    - One consultant has confirmed *Microcystis aeruginosa* by genetic analysis
    - If “blooms” become more consistent but toxin production remains sporadic this might be worth investigating

- We need to keep looking for the presence of *Microcystis* in the lakes
  - Surface dwelling species easy to see
    - Can also live below the surface, which seems to be occurring in Lake Mead
  - There other toxin producing cyanobacteria that live in the water column that need to be looked for as well
    - *Cylindrospermopsis, Anabaena, Lyngbya, Aphanizomenon, Planktothrix*

- The presence of *Microcystis* does not necessarily indicate the presence of toxins
  - Unfortunately the opposite can also be true.
  - ELISA based testing (Abraxis, Greenwater Labs, Envirologix) provides high quality presence:absence data, quantitative values really require LC/MS/MS
Questions?

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