

Appendix K: Algae Representation

This appendix is in connection with Section 4.3 in the main report – Calibration Parameters. It is compiled from DRBC staffs' presentations to its Model Expert Panel. The appendix is aiming at providing additional information on selecting and parameterizing three classes of algae.

Two primary sources of data were used to characterize and conceptualize algae in the Delaware River Estuary.

- Boat Run data from 2010-2019, comprised of monthly chlorophyll-a samples during the growing season at 22 center-channel locations;
- Algal composition analyses performed by the Academy of Natural Sciences at Drexel University under contract with the DRBC. These include live scans of Boat Run samples beginning in April 2019.

The Boat Run data and Dijkstra *et al.* (2019) were especially relied upon to characterize the locations and timing of algal blooms that recur throughout the Estuary. A number of insights and benchmarks were also gleaned from Pennock and Sharp (1986) regarding phytoplankton productivity in the Delaware Estuary, which does not appear to have changed substantially in recent decades.

- Productivity (1981–1985) averaged 307 g C m^{-2} with marked inter-annual variability
- 90% of production occurs in lower estuary (downstream of ETM¹)
- Mid-estuary ($2.6 \text{ g C m}^{-2} \text{ d}^{-1}$) during the spring diatom bloom
- Low-estuary ($4.2 \text{ g C m}^{-2} \text{ d}^{-1}$) during summer (low phytomass, 2-10 $\mu\text{g/L}$ Chl-a)
- Upper-estuary (max $1.1 \text{ g C m}^{-2} \text{ d}^{-1}$) in summer related to Chl-a concentrations
- ETM downstream of nutrient sources limits biomass accumulation below nuisance levels
- Light availability is the predominant regulator of production in the estuary
- “Although growth was light-limited, neither chlorophyll specific production nor the light intensity at which photosynthesis saturates was related to the mean light intensity in the mixed surface-layer. These results suggest that photoadaptive response times are slower than the vertical mixing rate and that photoadaptation is of minor significance to overall production in the system.”

One of the more common phytoplankton species in the Delaware River Estuary is *Skeletonema costatum* (*S. costatum*). The Delaware Bay is generally dominated by diatoms, and *S. costatum* is the dominant bloom-forming species. According to the University of British Columbia Phyto'pedia,² *S. costatum* exhibits the following characteristics.

- Diameter: 2 - 21 μm
- Optimal temperature of 25 °C and irradiance of $1.6 \times 10^{16} \text{ quanta/s} \cdot \text{cm}^2$

¹ ETM refers to the region of Estuary Turbidity Maximum, which in the Delaware River Estuary is centered around river mile 55.

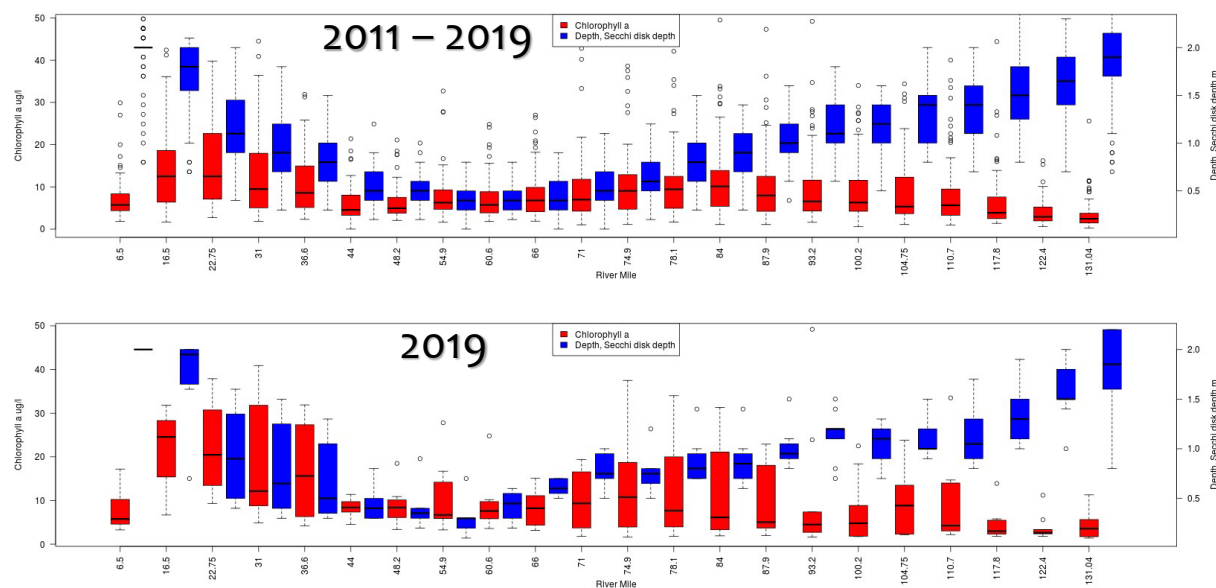
² <https://phytoplankton.eoas.ubc.ca/>

Water Quality Model for the Delaware Estuary

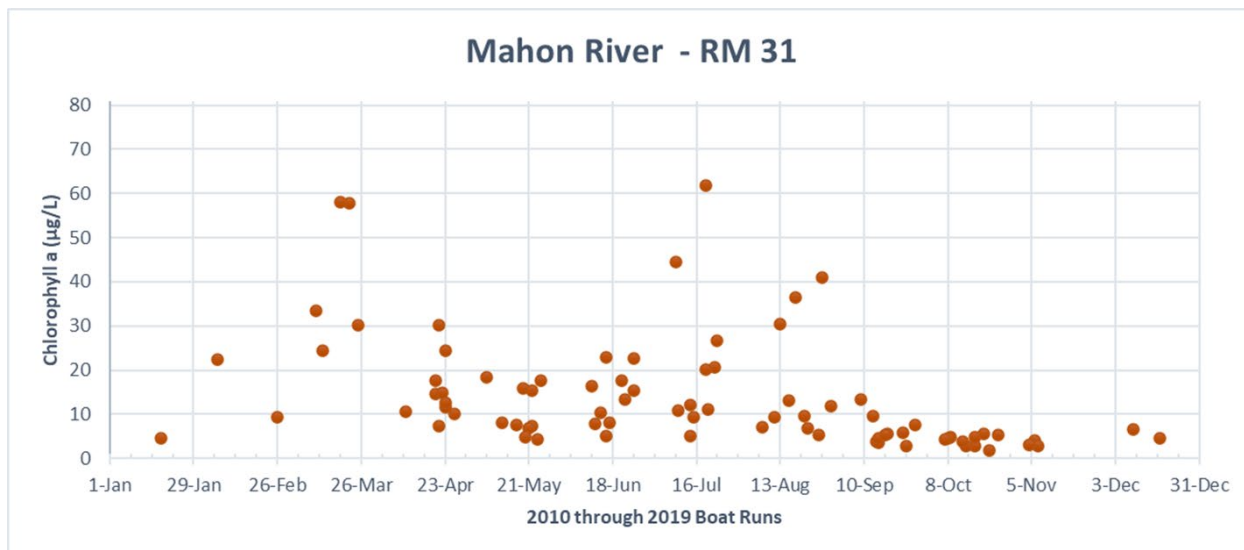
- Optimal salinity range of 18 - 25 ; capable of significant growth in salinity range of 5 – 40 ppt
- Often dominant in waters characterized by salinity fluctuations
- Dominant under non-limiting nutrient conditions
- Often forms dense blooms when silicate concentrations > 2 $\mu\text{mol/L}$
- Bimodal (winter-spring and summer blooms) bloom pattern with the winter-spring bloom greater

While many factors influence algal dynamics in the Delaware River Estuary (e.g., Sharp et al., 2009; Sun et al., 2007), light limitation is long known to be a dominant factor. The influence of light (Dijkstra et al., 2019; Harding et al., 1986; Pennock, 1985) can be seen by looking at Secchi depth measurements with chlorophyll-a analyses, and chlorophyll-a results at specific locations relative to the ETM.

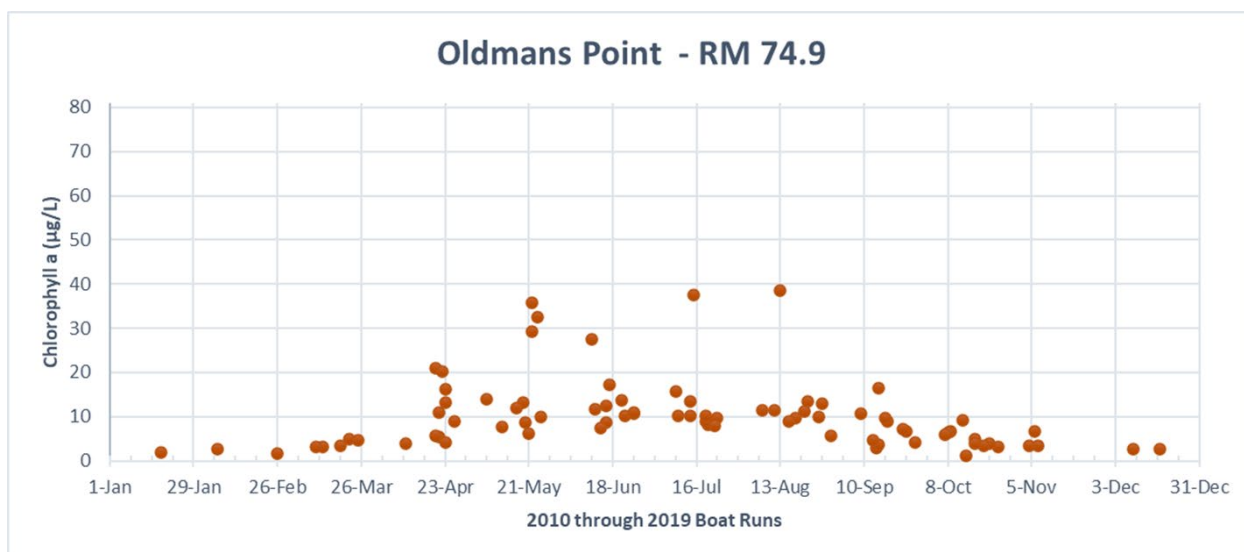
Secchi depth and chlorophyll-a distribution by river mile



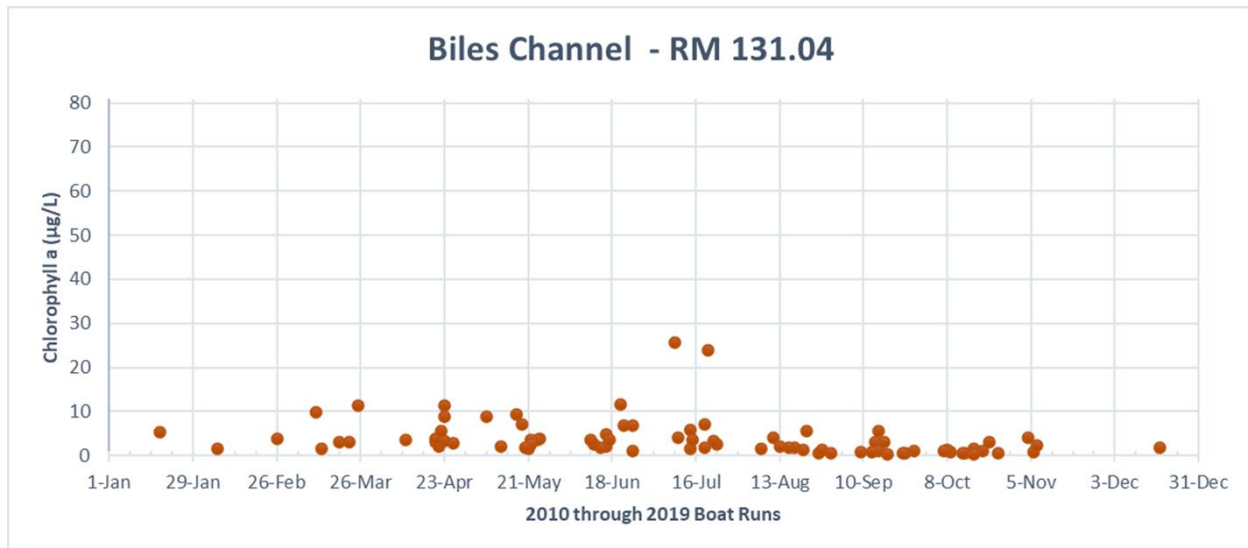
Boat Run Data 2010-2019 | Downstream ETM



Boat Run Data 2010-2019 | Upstream ETM



Boat Run Data 2010-2019 | Upstream ETM



Careful review of chlorophyll-a data at all Boat Run locations from 2010 to 2019 yields a few broad generalizations.

In the Bay, downstream of the ETM:

- Highest concentrations observed at Elbow of Crossledge Shoal (RM 22.75)
- Bimodal distribution
 - Early spring peak 3rd week of March
 - Trough ~6 weeks May through mid-June
 - Summer peak 2nd week of July

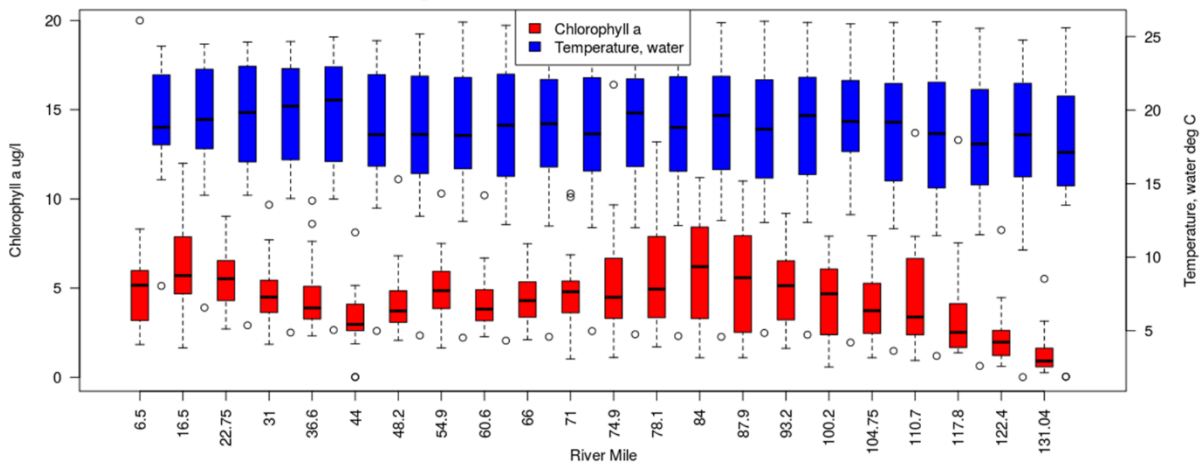
In the tidal river, upstream of the ETM:

- Phyto concentrations broadly distributed from Eddystone (RM 84) to Burlington Bristol Bridge (RM 117.8)
- Summer growth peaks extend from mid-June through mid-August
- Peaks occur earlier in Zones 3 and 4 than Zone 2

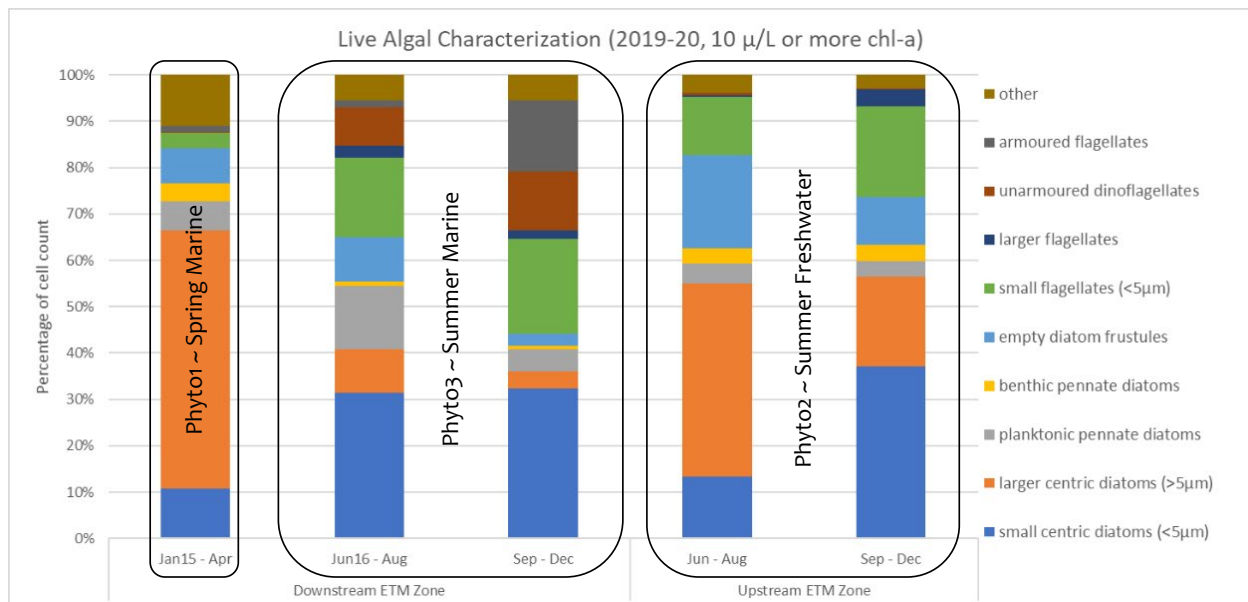
Phytoplankton levels are generally low in the Fall season, though a clear bimodal spatial distribution can be seen (below).

Water Quality Model for the Delaware Estuary

September – December



Initial live scan data (below) generally support the use of three phytoplankton groups, though a finer representation especially in the freshwater could also be justified.



Three phytoplankton groups described in the table below were used to characterize the diatom-dominated algal communities in the Delaware River Estuary. This model representation was based on the data available at the time the modeling framework was established. The DRBC has since obtained additional phytoplankton composition data and may revisit the phytoplankton representation in the model in accordance with its goals and resources.

Model SV	Phytoplankton Class ID	Description	Seasonal Peak	Geographic Peak
Phyto1	Spring Marine	Winter / Spring marine phyto community	Mid-Jan – mid-April	Elbow of Crossledge Shoal (RM 22.75)
Phyto2	Summer Freshwater	Summer freshwater phyto community	June – August	Eddystone (RM 84)
Phyto3	Summer Marine	Summer marine phyto community	Mid-June – August	Elbow of Crossledge Shoal (RM 22.75)

References

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