



AGU Advances

Supporting Information for

Extant mat world analog microbes synchronize migration to a diurnal tempo

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Introduction

Supplemental Information is provided in support of the findings reported in the manuscript in the form of a data table, figures, time-lapse movie and a cover image. These include 1. a table depicting non-linear growth model parameters describing the daily movements of microbial filaments during July 2018 (see plots in Figure S4), 2. a map of the Great Lakes basin showing the geological context and the study site, 3. a bathymetric map of NW Lake Huron showing the location of Middle Island Sinkhole where the present study was carried out, 4. a day and night sequence of photos of the microbial mat surface during the repeat study of June 2019, 5. results showing the data and model simulation of the data that help explain the non-linear pattern of diel filament movement, 6. a 93-frame half-hourly time-lapse movie of the changes that occurred over the microbial mat surface at Middle Island Sinkhole during July 10-12, 2018, and 7. a suggested journal cover photo of microbial mat – diver image of Middle Island Sinkhole, Lake Huron. Each of these is accompanied by a fully explanatory legend.

Supplemental Materials: Table, Figures, Movie, and Cover Image

Table S1. Non-linear growth model parameters: Equation parameters and 95% confidence intervals for said parameters of the models for progression of mat coverage by white sulfur oxidizing bacteria and purple cyanobacteria. For field data and modeled progression coverage curves, see Table 1 and Figure S4, respectively. Additional raw field data can be accessed through the Center for Open Science's - Open Science Framework, available at: <https://osf.io/seuq5>.

Parameter	White Model	White 95% CI	Purple Model	Purple 95% CI
01	89.86	86.87 – 93.11	103.52	94.20 – 115.39
02	-2.14	-2.48 – -1.86	-5.29	-9.07 – -3.37
03	0.42	0.36 – 0.49	0.77	0.48 – 1.32



Figure S1. The Great Lakes basin: Surface geology map of the North American Laurentian Great Lakes basin showing abundance of limestone/dolomite bedrock surrounding and underlying all of the lower Great lakes. Arrow indicates study site In Northwest Lake Huron. Figure from Biddanda et al. 2012, published in *Nature Education Knowledge*.

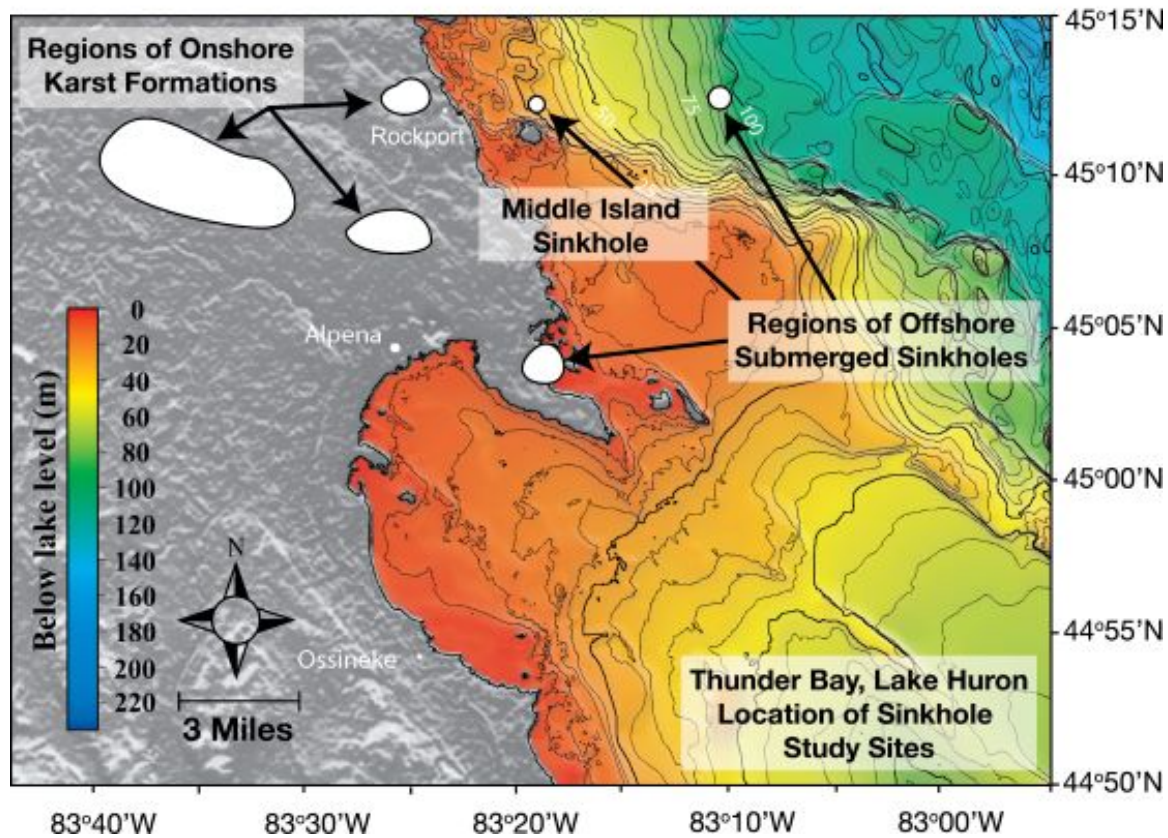


Figure S2. Lake Huron's submerged sinkholes: Known regions of on land karst formations in the northeast part of the lower peninsula of Michigan (USA), and underwater karst sinkholes in the Thunder Bay National Marine Sanctuary, Lake Huron (depth contours in 5m intervals). Site of the present study is the Middle Island Sinkhole. Figure from Biddanda et al. 2012, published in *Nature Education Knowledge*.

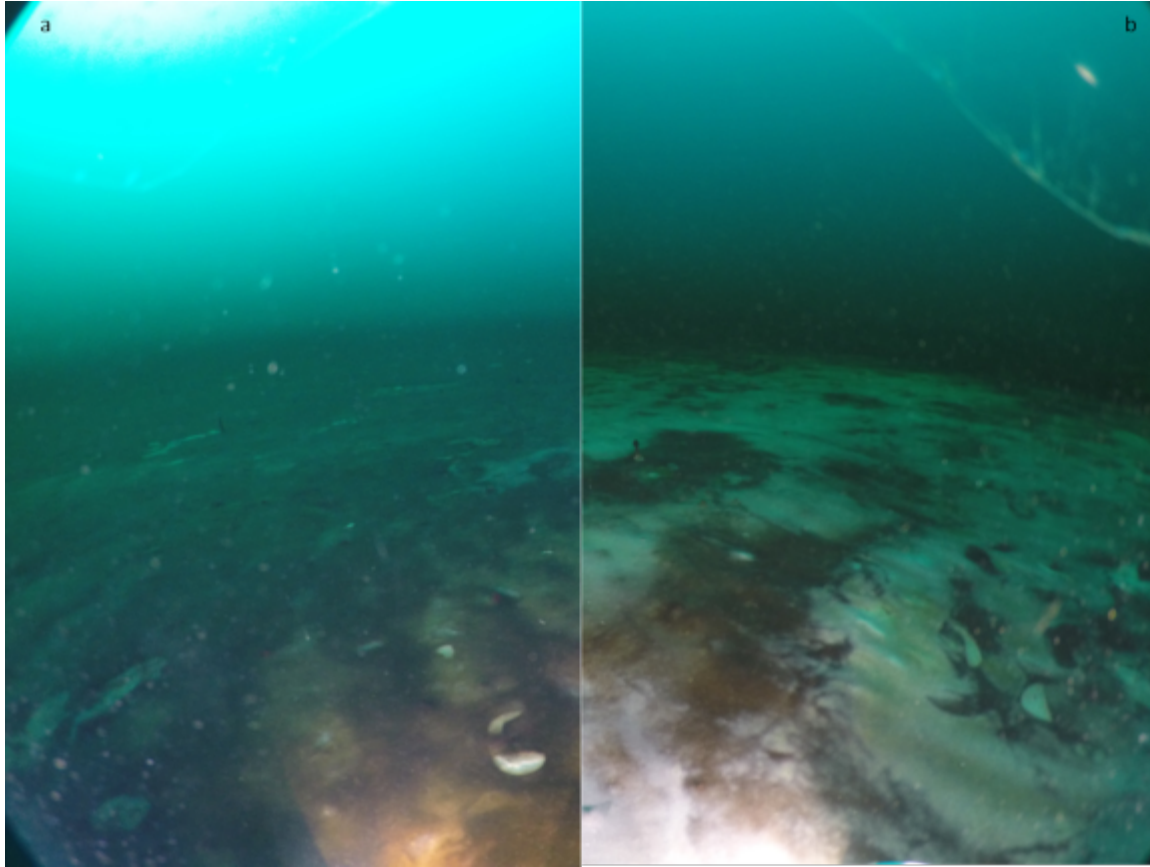


Figure S3. In-field re-validation of DVM in 2019: (a) Dusk - June 11 20:00 and (b) dawn - June 12 7:00 time-lapse photos from June 2019 in-field camera deployment in Middle Island Sinkhole show the same diurnal changes in mat color as seen in the July 2018 deployment (Figure 1 and Extended Data Movie 1). Note: These panels represent the left (a) and the right (b) halves of the entire viewing field of the camera, and do not represent the exact same fields of view – further confirmation that DVM is not site specific, but is universal in the mat world.

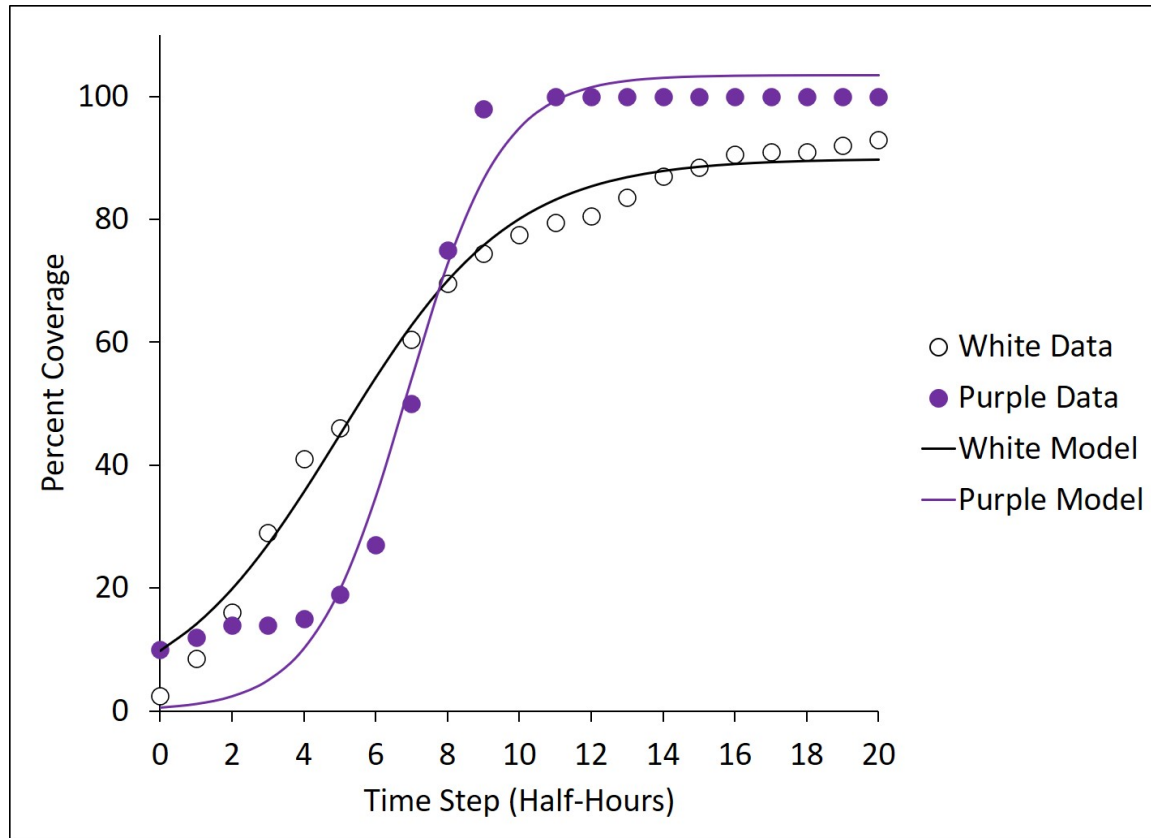
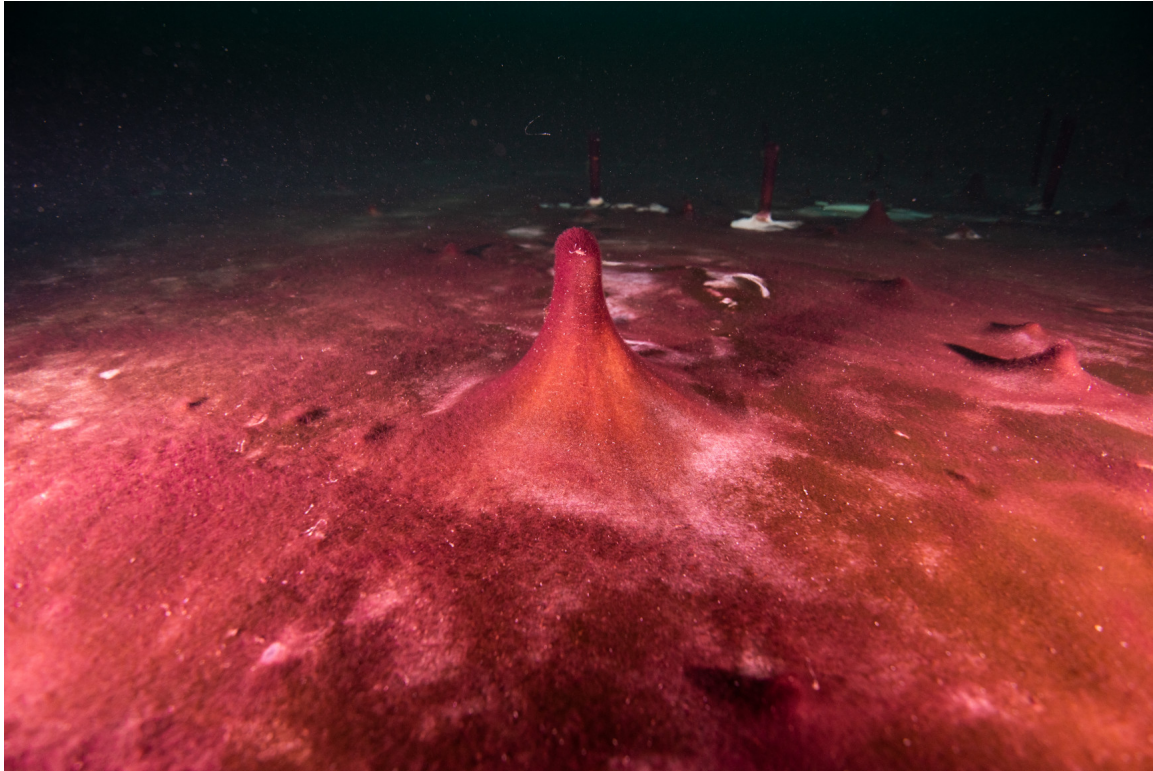


Figure S4. Percent Coverage Raw Data vs Modeled Data for DVM recorded in July 2018: Points represent grid counts or percent mat coverage starting from the first time point that coverage for whites 2-night average (black points) or purples 1 day (purple points) started to increase around sunset or sunrise respectively. Lines represent modeled coverage progression during the same time periods for whites (black line) and purples (purple line). The zero time step represents the first increase in coverage near dusk for whites (which started increasing during low light just before sunset) and dawn for purples. Data were modeled as described in Fox and Weisberg 2019.

Movie S1. Diurnal microbial tango:
2-day time-lapse movie tracking the DVM of alternating waves of purple photosynthetic
cyanobacteria and white chemosynthetic sulfur-oxidizing bacteria in the microbial mats of
Middle Island Sinkhole, Lake Huron. Time-lapse submersible camera started at 11:30 on July 10,
2018 and turned off 11:30 on July 12, 2018. There are, a total of 93 frames in this movie that
were used for cell counting. The vertical stick in the background is a tilt meter, which measures
flow velocity and direction, among other deployed instruments like metabolism chambers and a
water quality logger mounted on a PVC sled. You will notice the tilt meter tilting between time
lapse images in response to changing ground water flow over the mats. Cloudy image at 11:00
on July 11, 2018 was caused by sediment kicked up by divers during their mid-day operations
nearby. You will also notice the build-up of falling planktonic debris that have settled over the
top part of the camera housing's dome, more visible during the second night. Movie S1 is
available through the Center for Open Science's - Open Science Framework, available at:
<https://osf.io/seuq5> file name: BiddandaWeinke_M01.mp4, but may also be viewed through the
link <https://youtu.be/sAtIzTYkfZ8>



Journal Cover Image.

Mat world rising: Colorful microbial mats composed of photosynthetic cyanobacteria (purple layer) and chemosynthetic microbes (white patches) that resemble life in the early biosphere thrive in the cold, low-light, oxygen-poor, sulfur-rich waters of submerged sinkholes in Lake Huron. This underwater daytime photo shows predominantly purple cyanobacteria seeking sunlight available at the surface (23m depth) in the Middle Island Sinkhole. At night, the mat turns predominantly white as the cyanobacteria migrate below, and the chemosynthetic sulfur oxidizing bacteria migrate up along the moving oxygen/hydrogen sulfide interface – constituting diurnal vertical migration. The 10-30 cm high finger-like projections of the mats that we see in the photo represent hot-spots buoyed by excess hydrogen sulfide and methane gasses trapped beneath them that are produced in the organic carbon-rich sediments sequestered beneath the mats. Such projections often tear and float up to the surface where they may be dispersed by water or air. Mat worlds like these on the Precambrian seafloor may have laid the foundation for

134 the modern biosphere by optimizing photosynthesis and carbon burial. Diver photo credit: Phil
135 Hartmeyer, NOAA Thunder Bay National Marine Sanctuary.

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