

Blachman, S.A. and M.J. Brush. 2025. Pelagic primary production and respiration in Mobjack Bay, VA, 2023-2025.

Background and Study Site

Phytoplankton are the dominant primary producers (i.e., photosynthesizers) in most coastal and oceanic ecosystems, providing the organic carbon that fuels the marine food web (Brush et al. 2021). The rate of pelagic (i.e., water column) primary production by phytoplankton is thus a critical rate process in the study of these systems, yet sustained measurements of this process are rare, especially in shallow, nearshore waters around the perimeter of deeper systems like the Chesapeake Bay. Some portion of pelagic primary production is respired by the planktonic community (e.g., phytoplankton, zooplankton, and bacteria), so the balance between pelagic primary production and respiration provides an important index of the organic carbon remaining to support higher trophic levels including suspension-feeding bivalves.

Beyond the importance of phytoplankton primary production to our general understanding of marine ecosystems, it provides the major food source for cultured bivalves in coastal systems. The rapid expansion of shellfish aquaculture in Virginia has generated an important source of revenue and jobs, provided a local source of quality seafood, and supported the economy and culture of local communities (Hudson & White 2025). Virginia's aquaculture industry is dependent on an adequate food supply derived chiefly from primary production by phytoplankton. Limited food availability can reduce the growth and potential harvest of cultured bivalves at high planting densities, and the effect of food limitation can vary seasonally as a function of temperature, irradiance, and nutrient supply. The balance between phytoplankton primary production and respiration over time sets a critical control on growth and potential harvest of cultured bivalves.

Given the limited availability of primary production measurements in shallow, nearshore regions of Chesapeake Bay where bivalve aquaculture is concentrated, and to provide resource managers with information necessary to ensure the industry's ecological and economic sustainability, we measured rates of pelagic primary production and respiration in Mobjack Bay, a relatively shallow embayment in the lower Chesapeake Bay with growing aquaculture activity. Rates were measured in the main bay and each of its four tidal tributaries, the Severn River, the Ware River, the North River, and the East River.

Methods

Mobjack Bay and its tributary rivers were divided into coarse segments using major geographic constrictions (Fig. 1). A sampling station was selected at a central point along the channel in each box; within the Mobjack Bay box a second sampling station was selected along the eastern shoal (Table 1). Monthly surveys were conducted for a two-year period from March 2023 to March 2025.

At each station, a YSI EXO2 datasonde was used to measure sub-surface (0.5 m depth) water temperature, salinity, and turbidity (a proxy for suspended solids). At station 4 an irradiance profile was measured with a LI-COR LI-1400 datalogger with LI-190SA and LI-192SA air and underwater quantum sensors, respectively, at the surface (0 m) and at 0.25 m intervals through the water column to a depth of 1.75 m. When wave conditions at station 4 were too rough to profile, irradiance measurements were collected at station 1. The vertical attenuation coefficient (k_D measured) was computed on each date using least squares exponential regressions between the fraction of surface irradiance and depth. Station-specific vertical attenuation coefficients (k_D calculated) were also computed on each date using the following function developed for the lower York River from Lake & Brush (2015):

$$k_D \text{ (m}^{-1}\text{)} = 0.6853 + (0.0175 * Chl-a) + (-0.0001 * Sal) + (0.0945 * Turb)$$

where *Chl-a* is the active chlorophyll-*a* concentration in $\mu\text{g l}^{-1}$, *Sal* is salinity in ppt, and *Turb* is turbidity in Formazin Nephelometric Units (FNU).

Triplicate 500 ml surface water samples were collected in amber Nalgene bottles at each site and transported on ice for filtration in the lab. Active water column chlorophyll-*a* was determined by filtering 60 ml of sample water through 0.7 μm glass fiber filters. Filters were frozen for 2 – 4 weeks before samples were extracted for 24 hours in the dark using 8 ml of a 45:45:10 mixture of acetone : dimethyl sulfoxide : distilled water with 1% diethylamine (Shoaf & Lium 1976). Fluorescence of the extractant was analyzed before and after acidification using a Turner Designs 10 AU fluorometer and used to calculate active chlorophyll-*a* concentrations ($\mu\text{g l}^{-1}$) using the

Table 1. Latitude and longitude of sampling stations in degree minutes seconds.

Sampling station	Latitude	Longitude
Station 1 (North River)	37°24'26.09"N	76°24'23.01"W
Station 2 (East River)	37°23'58.90"N	76°20'43.50"W
Station 3 (Bay Shoal)	37°20'31.14"N	76°19'38.03"W
Station 4 (Bay Channel)	37°19'26.49"N	76°21'8.60"W
Station 5 (Severn River)	37°18'57.61"N	76°25'5.60"W
Station 6 (Ware River)	37°22'39.55"N	76°27'37.27"W

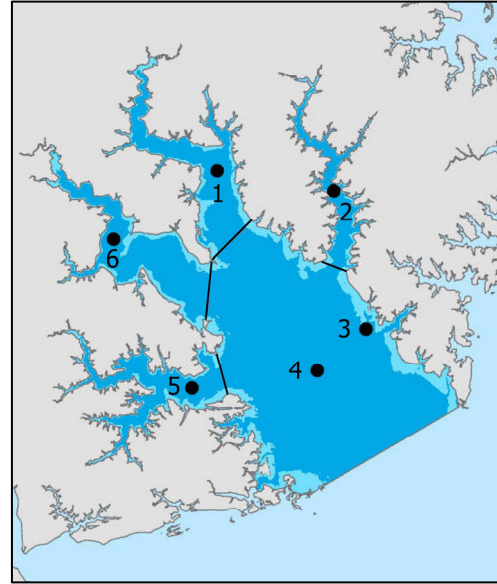


Fig. 1. Map of sampling stations and associated spatial segments in Mobjack Bay. Light blue shading in each segment denotes areas ≤ 1 m in depth.

equations from Arar & Collins (1997). Triplicate concentrations of chl-*a* were averaged to obtain a single value at each site in each month.

An additional 4 l of surface water was collected at each site in blackened Nalgene bottles and transported on ice to run site-

specific metabolic incubations in the lab. Metabolic rates were determined using the methods of Giordano et al. (2012) and Lake et al. (2013). For each site, initial dissolved oxygen (DO) measurements were taken using a Hach HQ 40d oxygen meter with luminescent DO sensors. Ten 60 ml clear biological oxygen demand (BOD) bottles were then filled with sample water and placed in a temperature-controlled, flow-through light gradient box set at *in situ* temperatures. The bottles were exposed to a gradient of photosynthetically active radiation (PAR) ranging from 40 to 2000 $\mu\text{E m}^{-2} \text{s}^{-1}$ for 2 – 5 hours. Four corresponding 60 ml dark BOD bottles were also filled with site water and kept at *in situ* temperatures in a separate temperature-controlled, flow-through dark chamber for approximately 24 hours. Final oxygen measurements were taken from each bottle immediately following the incubation period using the Hach meter.

Changes in DO in each bottle were divided by the incubation period in hours and normalized by site-specific chl-*a* biomass to determine biomass-specific rates of net community production (light bottles) and respiration (dark bottles). The Platt et al. (1980) photosynthesis-irradiance (P-I) curve including photoinhibition was fit to the incubation data from each site on each date using least squares regression:

$$P_B = P_{sB} \left(1 - e^{-\frac{\alpha_B I}{P_{sB}}} \right) e^{-\frac{\beta_B I}{P_{sB}}} + R_B$$

where P_B , P_{sB} , and R_B are the net photosynthetic rate, gross photosynthetic rate in the absence of photoinhibition, and respiration rate, respectively ($\text{mg O}_2 \text{ mg}^{-1} \text{ chl-}a \text{ h}^{-1}$), α_B and β_B are the initial slope of the P-I curve and negative slope characterizing photoinhibition, respectively ($\text{mg O}_2 \text{ mg}^{-1} \text{ chl-}a \text{ h}^{-1} (\mu\text{E m}^{-2} \text{s}^{-1})^{-1}$), and I is irradiance (PAR, $\mu\text{E m}^{-2} \text{s}^{-1}$). The subscript B denotes that all parameters are normalized to chl-*a* biomass.

P-I curves were combined with hourly PAR data, local bathymetry, measured chl-*a*, and calculated k_D to scale rates to daily values over the entire water column. PAR data from the Chesapeake Bay National Estuarine Research Reserve in Virginia (CBNERRVA) meteorological station at Taskinas Creek, VA were downloaded from the NERRS Centralized Data Management Office (NOAA n.d.) for the two-week period prior to and following each sampling date. Data were used to compute average hourly instantaneous PAR ($\mu\text{E m}^{-2} \text{s}^{-1}$) over the four-week period to be applied to each sampling date.

Bathymetric data from the USGS (2018) Topobathymetric Elevation Model of Chesapeake Bay (1 m^2 resolution) were downloaded for Mobjack Bay and the associated tributaries from the Coastal National Elevation Database (CoNED) Project Viewer. Depths were converted from NAVD88 to mean sea level (MSL) using tidal datums from the NOAA Yorktown USCG Training Center tidal station (ID 8637689). Data were used to compute the area and volume contained within 10 cm vertical intervals in each segment from MSL to the bottom.

Hourly instantaneous PAR on each sampling date and at each station was then computed in each 10 cm vertical interval using calculated k_D , and combined with P-I curves to compute net

community production and respiration in each vertical interval each hour. Values were summed over 24 hours, volume-weighted over the water column, and combined with measured chl-*a* to compute area-normalized, daily rates of gross primary production, net community production, and respiration in oxygen units. Values were converted to carbon units using a constant photosynthetic quotient of 1.4 mol O₂ : mol C (Harding et al. 2002) and a constant respiratory quotient of 0.8 mol C : mol O₂. Rates were volume-weighted both at the scale of the entire segment (i.e., a ‘whole-system’ calculation), and only within the portion of each segment with depths ≤ 1 m to correspond to the location where bivalve aquaculture is commonly found; associated areas within each segment are provided in Table 2. For purposes of estimating food availability for cultured bivalves, we suggest the latter calculation is more reflective of food the organisms have direct access to.

Table 2. Surface areas in m² applied to areal rates at each location for Area-Integrated Net Community Production calculations.

Segment	System-wide	≤ 1 m depth
North River (Station 1)	18,174,084	4,780,643
East River (Station 2)	13,956,295	5,185,547
Mobjack Bay (Stations 3 & 4)	86,867,873	10,987,540
Severn River (Station 5)	8,173,538	2,996,135
Ware River (Station 6)	16,387,072	4,835,558

Parameter names, descriptions, and units of the variables included in the dataset are provided in Table 3.

Acknowledgements

This work was supported with funding from the Virginia Institute of Marine Science (VIMS). We are grateful for the support of Dr. Mark Luckenbach, VIMS Associate Dean of Research and Advisory Services, and to Hunter Walker for providing vessels support and analyzing nutrient samples.

Table 3. Project metadata.

Parameter	Description	Units
Year	Year of sample collection	n/a
Month	Month of sample collection	n/a
Date	Date of sample collection	mm/dd/yyyy
Station	Station number	n/a
Location	Location of sample collection	n/a
Temp	Surface water temperature	°C
Salinity	Surface salinity	PPT
Turbidity	Surface turbidity	FNU
Chl- <i>a</i>	Surface chlorophyll- <i>a</i>	µg l ⁻¹
k _D measured	Attenuation coefficient for irradiance	m ⁻¹
k _D calculated	Attenuation coefficient for irradiance	m ⁻¹
GPP-O ₂	Daily Gross Primary Production (O ₂ units)	g O ₂ m ⁻² d ⁻¹
GPP-C	Daily Gross Primary Production (C units)	g C m ⁻² d ⁻¹
R-O ₂	Daily Respiration (O ₂ units)	g O ₂ m ⁻² d ⁻¹
R-C	Daily Respiration (C units)	g C m ⁻² d ⁻¹
NCP-O ₂	Daily Net Community Production (O ₂ units)	g O ₂ m ⁻² d ⁻¹
NCP-C	Daily Net Community Production (C units)	g C m ⁻² d ⁻¹
NCP _{int} -C	Area-Integrated Net Community Production (C units)	g C d ⁻¹
GPP _{1m} -O ₂	Daily Gross Primary Production ≤ 1m depth (O ₂ units)	g O ₂ m ⁻² d ⁻¹
GPP _{1m} -C	Daily Gross Primary Production ≤ 1m depth (C units)	g C m ⁻² d ⁻¹
R _{1m} -O ₂	Daily Respiration ≤ 1m depth (O ₂ units)	g O ₂ m ⁻² d ⁻¹
R _{1m} -C	Daily Respiration ≤ 1m depth (C units)	g C m ⁻² d ⁻¹
NCP _{1m} -O ₂	Daily Net Community Production ≤ 1m depth (O ₂ units)	g O ₂ m ⁻² d ⁻¹
NCP _{1m} -C	Daily Net Community Production ≤ 1m depth (C units)	g C m ⁻² d ⁻¹
NCP _{int1m} -C	Area-Integrated Net Community Production ≤ 1m depth (C units)	g C d ⁻¹

References

Arar, E.J., and G.B. Collins. 1997. Method 445.0: *In vitro* determination of chlorophyll *a* and pheophytin *a* in marine and freshwater algae by fluorescence. National Exposure Research Laboratory Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, OH.

Brush, M.J., P. Mozetič, J. Francé, F. Bernardi Aubry, T. Djakovac, J. Faganeli, L. Harris, and M. Niesen. 2021. Phytoplankton dynamics in a changing environment. Ch. 4 in: Malone, T.C., A. Malej, and J. Faganeli (eds.), *Coastal Ecosystems in Transition: A Comparative Analysis of the Northern Adriatic and Chesapeake Bay*, Geophysical Monograph 256. American Geophysical Union, John Wiley & Sons, Inc.

Giordano, J.C.P., M.J. Brush, and I.C. Anderson. 2012. Ecosystem metabolism in shallow coastal lagoons: patterns and partitioning of planktonic, benthic, and integrated community rates. *Marine Ecology Progress Series* 458: 21–38.

Harding, Jr., L.W., M.E. Mallonee, and E.S. Perry. 2002. Toward a predictive understanding of primary productivity in a temperate, partially stratified estuary. *Estuarine, Coastal and Shelf Science* 55(3): 437–463.

Hudson, K., and S.B. White 2025. Virginia Shellfish Aquaculture Situation and Outlook Report: Based on the results of the 2024 Virginia Shellfish Aquaculture Situation and Outlook Survey. VIMS Marine Resource Report No. 2025-5, Virginia Institute of Marine Science, Gloucester Point, VA. <https://doi.org/10.25773/dapk-yc40>.

Lake, S.J., and M.J. Brush. 2015. Contribution of nutrient and organic matter sources to the development of periodic hypoxia in a tributary estuary. *Estuaries and Coasts* 38: 2149–2171.

Lake, S.J., M.J. Brush, I.C. Anderson, and H.I. Kator. 2013. Internal versus external drivers of periodic hypoxia in a coastal plain tributary estuary: the York River, Virginia. *Marine Ecology Progress Series* 492: 21–39.

NOAA National Estuarine Research Reserve System (NERRS). System-wide Monitoring Program. Data accessed from the NOAA NERRS Centralized Data Management Office website: <http://www.nerrsdata.org>. doi:10.25921/vw8a-8031.

Platt, T., C.L. Gallegos, and W.G. Harrison. 1980. Photoinhibition of photosynthesis in natural assemblages of marine phytoplankton. *Journal of Marine Research* 38: 687–701.

Shoaf, W.T., and B.W. Lium. 1976. Improved extraction of chlorophyll *a* and *b* from algae using dimethylsulfoxide. *Limnology and Oceanography* 21: 926–928.

USGS (United States Geological Survey). 2018. Topobathymetric elevation model of Chesapeake Bay. Data accessed from the Coastal National Elevation Database (CoNED) Project Viewer: https://topotools.cr.usgs.gov/topobathy_viewer/.