

Series 4A: Multiple stressor experiments on *Synechococcus elongatus* (CCMP1629) – pH measurements

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Project

» [Collaborative Research: Effects of multiple stressors on Marine Phytoplankton](#) (Stressors on Marine Phytoplankton)

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Abstract

The experiments were designed to test the combined effects of two CO₂ concentrations, four temperatures, and three light intensities on growth and photophysiology of the cyanobacteria *Synechococcus elongatus* CCMP1629 in a multifactorial design. This dataset contains measurements of pH made over the course of the experiments.

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Coverage

Temporal Extent: 2019-07 - 2019-08

Dataset Description

The experiments in Series 4A were designed to test the combined effects of two CO₂ concentrations, four temperatures, and three light intensities on growth and photophysiology of the cyanobacteria *Synechococcus elongatus* CCMP1629 in a multifactorial design. This dataset reports the pH levels measured during the experiments.

Acquisition Description

The experiments were designed to test the combined effects of two CO₂ concentrations, four temperatures, and three light intensities on growth and photophysiology of the cyanobacterium

Synechococcus elongatus CCMP1629 in a multifactorial design. Two CO₂ concentrations were tested: 410 ppm, and 1000 ppm. For each CO₂ concentration, four temperatures were tested: 20°C, 28°C, 36°C, and 44°C. Within each temperature, three light levels were tested: sub-optimum irradiance (SOI) intensity of 50 $\mu\text{mol photons} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$, optimum irradiance (OI) intensity of 230 $\mu\text{mol photons} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$ and extreme Irradiance (EI) intensity of 600 $\mu\text{mol photons} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$. All lights were set at a 12 h day: 12 h dark cycle. For logistical reasons, experiments were partially conducted in series, with all light treatments at all four temperatures running simultaneously. This was repeated for each CO₂ concentration.

Experiments were conducted in Multicultivator MC-1000 OD units (Photon Systems Instruments, Drasov, Czech Republic). Each unit consists of eight 85 ml test-tubes immersed in a thermostated water bath, each independently illuminated by an array of cool white LEDs set at specific intensity and timing. A 0.2 μm filtered CO₂-air mix (Praxair Distribution Inc.) was bubbled through sterile artificial seawater, and the humidified gas mix was supplied to each tube via gentle sparging through a 2 μm stainless steel diffuser. Flow rates were gradually increased over the course of the incubation to compensate for the DIC uptake of actively growing cells, and ranged from <0.04 Liters per minute (LPM) at the start of the incubations to 0.08 LPM in each tube after 2 days. For each CO₂ and temperature level, replication was achieved by incubating three tubes at sub-optimum light intensities, two tubes at optimum light intensity, and three tubes at extreme light intensities. Each experiment was split into two phases: An acclimation phase spanning 3 days, was used to acclimate cultures to their new environment. Pre-acclimated, exponentially-growing cultures were then inoculated into fresh media and incubated through a 3-day experimental phase during which assessments of growth, photophysiology, and nutrient cycling were carried out daily. All sampling started 5 hours into the daily light cycle to minimize effects of diurnal cycles.

Experiments were conducted with artificial seawater (ASW) prepared using previously described methods (Kester et al. 1967), and enriched with nitrate (NO₃), and phosphate (PO₄), at levels ensuring that the cultures would remain nutrient-replete over the course of the experiment. Trace metals and vitamins were added as in *f/2* (Guillard 1975). The expected DIC concentration, and pH of the growth media was determined for the different pCO₂ and temperatures using the CO2SYS calculator (Pierrot et al. 2006), with constants from Mehrbach et al. (1973, refit by Dickson & Millero 1987), and inputs of temperature, salinity, total alkalinity (2376.5 $\mu\text{mol} \cdot \text{kg}^{-1}$), pCO₂, phosphate, and silicic acid. DIC levels in ASW at the start of each phase of the experiments were manipulated by the addition of NaHCO₃, and was then maintained by bubbling a CO₂-Air mix through the cultures over the course of the experiments. The pH of the growth media was measured spectrophotometrically using the m-cresol purple method (Dickson 1993), and adjusted using 0.1N HCl or 0.1M NaOH. The media was distributed into 75 ml aliquots and each aliquot was inoculated with the *S. elongatus* CCMP 1629 (SE1629) stock culture at the start of the experiments.

pH measurements:

During the experiments, pH measurements were made at in-situ temperatures by immersing a three-point calibrated potentiometric glass reference electrode (Aquatrode plus Pt1000; Metrohm, Switzerland) directly into the culture tubes. For comparisons across treatments, the corresponding pH values expected at 25C were calculated using the CO2SYS calculator (Pierrot et al. 2006), with constants from (Mehrbach et al. 1973, Dickson and Millero 1987).

Processing Description

BCO-DMO Processing Notes:

- added conventional header with dataset name, PI name, version date
- modified parameter names to conform with BCO-DMO naming conventions

Related Publications

Dickson, A. G. (1993). The measurement of sea water pH. *Marine Chemistry*, 44(2-4), 131–142. doi:10.1016/0304-4203(93)90198-w [https://doi.org/10.1016/0304-4203\(93\)90198-w](https://doi.org/10.1016/0304-4203(93)90198-w)
Methods

Dickson, A. G., & Millero, F. J. (1987). A comparison of the equilibrium constants for the dissociation of carbonic acid in seawater media. *Deep Sea Research Part A. Oceanographic Research Papers*, 34(10), 1733–1743. doi:[10.1016/0198-0149\(87\)90021-5](https://doi.org/10.1016/0198-0149(87)90021-5)
Methods

Dickson, A.G., Sabine, C.L. and Christian, J.R. (Eds.) 2007. Guide to best practices for ocean CO₂ measurements. PICES Special Publication 3, 191 pp. ISBN: 1-897176-07-4. URL: https://www.nodc.noaa.gov/ocads/oceans/Handbook_2007.html <https://hdl.handle.net/11329/249>
Methods

Guillard, R. R. L. (1975). Culture of Phytoplankton for Feeding Marine Invertebrates. *Culture of Marine Invertebrate Animals*, 29–60. doi:[10.1007/978-1-4615-8714-9_3](https://doi.org/10.1007/978-1-4615-8714-9_3)
Methods

KESTER, D. R., DUEDALL, I. W., CONNORS, D. N., & PYTKOWICZ, R. M. (1967). PREPARATION OF ARTIFICIAL SEAWATER¹. *Limnology and Oceanography*, 12(1), 176–179. doi:[10.4319/lo.1967.12.1.0176](https://doi.org/10.4319/lo.1967.12.1.0176)
Methods

Mehrbach, C., Culberson, C. H., Hawley, J. E., & Pytkowicz, R. M. (1973). MEASUREMENT OF THE APPARENT DISSOCIATION CONSTANTS OF CARBONIC ACID IN SEAWATER AT ATMOSPHERIC PRESSURE¹. *Limnology and Oceanography*, 18(6), 897–907. doi:[10.4319/lo.1973.18.6.0897](https://doi.org/10.4319/lo.1973.18.6.0897)
Methods

Pierrot, D. E. Lewis, and D. W. R. Wallace. 2006. MS Excel Program Developed for CO₂ System Calculations. ORNL/CDIAC-105a. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee. doi: [10.3334/CDIAC/otg.CO2SYS_XLS_CDIAC105a](https://doi.org/10.3334/CDIAC/otg.CO2SYS_XLS_CDIAC105a).
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Parameters

Parameter	Description	Units
CO2	Indicates the concentration of CO2 in the CO2-Air mix that was bubbled through the samples over the course of the experiment	parts per million (ppm)
Temperature	Indicates the temperature at which the samples were incubated.	degrees Celsius
Irradiance	Indicates the irradiance at which the samples were incubated: SOI = sub-optimum irradiance intensity of 50 $\mu\text{mol photons} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$; OI = optimum irradiance intensity of 230 $\mu\text{mol photons} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$; and EI = extreme irradiance intensity of 600 $\mu\text{mol photons} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$.	micromol photons/meter ² /second
Tube	Indicates the tube number in the multicultivator. The tube numbers indicate replication within a treatment: T1-T3 = suboptimum irradiance; T4-T5 = optimum irradiance; T6-T8 = extreme irradiance	unitless
Phase	Indicates whether the sample was collected during the acclimation phase or the experiment phase of the experiment.	unitless
Day	Indicates the timepoint (day) of sampling. 0 = day 0; 1 = day 1; etc.	day
Salinity	Indicates the salinity of the sample	Practical Salinity Units
Measured_Temp	Measured temperature: Indicates the temperature of the sample as measured by the pH probe while making pH measurements.	degrees Celsius
Measured_pH	pH measurements in each tube at the measured temperature	pH units

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Instruments

Dataset-specific Instrument Name	Aquatrode plus Pt1000; Metrohm, Switzerland
Generic Instrument Name	Benchtop pH Meter
Dataset-specific Description	Used for daily pH measurements.
Generic Instrument Description	An instrument consisting of an electronic voltmeter and pH-responsive electrode that gives a direct conversion of voltage differences to differences of pH at the measurement temperature. (McGraw-Hill Dictionary of Scientific and Technical Terms) This instrument does not map to the NERC instrument vocabulary term for 'pH Sensor' which measures values in the water column. Benchtop models are typically employed for stationary lab applications.

Dataset-specific Instrument Name	Genesys 10SVIS spectrophotometer
Generic Instrument Name	Spectrophotometer
Dataset-specific Description	Used to measure sample pH.
Generic Instrument Description	An instrument used to measure the relative absorption of electromagnetic radiation of different wavelengths in the near infra-red, visible and ultraviolet wavebands by samples.

Dataset-specific Instrument Name	Multicultivator MC-1000 OD (Photon Systems Instruments, Drasov, Czech Republic)
Generic Instrument Name	Cell Cultivator
Dataset-specific Description	Used for incubation of TP1014 cultures.
Generic Instrument Description	An instrument used for the purpose of culturing small cells such as algae or bacteria. May provide temperature and light control and bubbled gas introduction.

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Project Information

Collaborative Research: Effects of multiple stressors on Marine Phytoplankton (Stressors on Marine Phytoplankton)

The overarching goal of this project is to develop a framework for understanding the response of phytoplankton to multiple environmental stresses. Marine phytoplankton, which are tiny algae, produce as much oxygen as terrestrial plants and provide food, directly or indirectly, to all marine animals. Their productivity is thus important both for global elemental cycles of oxygen and carbon, as well as for the productivity of the ocean. Globally the productivity of marine phytoplankton appears to be changing, but while we have some understanding of the response of phytoplankton to shifts in one environmental parameter at a time, like temperature, there is very little knowledge of their response to simultaneous changes in several parameters. Increased atmospheric carbon dioxide concentrations result in both ocean acidification and increased surface water temperatures. The latter in turn leads to greater ocean stratification and associated changes in light exposure and nutrient availability for the plankton. Recently it has become apparent that the response of phytoplankton to simultaneous changes in these growth parameters is not additive. For example, the effect of ocean acidification may be severe at one temperature-light combination and negligible at another. The researchers of this project will carry out experiments that will provide a theoretical understanding of the relevant interactions so that the impact of climate change on marine phytoplankton can be predicted in an informed way. This project will engage high schools students through training of a teacher and the development of a teaching unit. Undergraduate and graduate students will work directly on the research. A cartoon journalist will create a cartoon story on the research results to translate the findings to a broader general public audience. Each phytoplankton species has the capability to acclimatize to changes in temperature, light, pCO₂, and nutrient availability - at least within a finite range. However, the response of phytoplankton to multiple simultaneous stressors is frequently complex, because the effects on physiological responses are interactive. To date, no datasets exist for even a single species that could fully test the assumptions and

implications of existing models of phytoplankton acclimation to multiple environmental stressors. The investigators will combine modeling analysis with laboratory experiments to investigate the combined influences of changes in pCO₂, temperature, light, and nitrate availability on phytoplankton growth using cultures of open ocean and coastal diatom strains (*Thalassiosira pseudonana*) and an open ocean cyanobacteria species (*Synechococcus* sp.). The planned experiments represent ideal case studies of the complex and interactive effects of environmental conditions on organisms, and results will provide the basis for predictive modeling of the response of phytoplankton taxa to multiple environmental stresses.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1538602

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