Results from feeding assays conducted as part of seasonal global change experiments examining the effects of seasonal variation in light availability and nutrients on the response of three high-latitude kelp species

Website: https://www.bco-dmo.org/dataset/906416
Data Type: experimental
Version: 1
Version Date: 2023-08-17

Project
» CAREER: Energy fluxes and community stability in a dynamic, high-latitude kelp ecosystem (High latitude kelp dynamics)

Contributors	Affiliation	Role
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Abstract
These data are from feeding assays determined during two, month-long global change laboratory experiments conducted in Sitka, Alaska from February 12 to March 18, 2020 ("winter" experiment) and August 15 to September 16, 2020 ("summer" experiment). These experiments were used to tease apart the effects of seasonal variation in light availability and nutrients on the response of three high-latitude kelp species (Macrocystis pyrifera, Hedophyllum nigripes, and Neoagarum fimbriatum) to pH and temperature. Experimental controls were designed to approximate current environmental conditions in Sitka Sound, and treatments were based on projected end-of-century scenarios of ocean acidification (OA) and warming (OW) for this region. At the end of the experiments, the investigators assessed the seasonal impact of OW and OA on kelp growth rates, thallus nitrogen content, and carbon acquisition strategy based on thallus δ13C values. Finally, to test whether kelp palatability was impacted by future warming and acidification, tissue of H. nigripes and N. fimbriatum grown during the experiments was used to perform feeding assays with a common kelp forest consumer. These experiments were performed to improve our understanding of how global change will alter marine primary producer resources by integrating natural variation in environmental drivers. This project was overseen by Dr. Kristy Kroeker and her Ph.D. student Lauren Bell, both at the University of California Santa Cruz. Experiments took place in the basement laboratory at the Sitka Sound Science Center in Sitka, AK. This work was supported by the National Science Foundation (OCE-1752600), the David and Lucile Packard Foundation, the North Pacific Research Board's Graduate Student Research Award (1748-02), the UCSC Physical and Biological Sciences 2019 Future Leaders in Coastal Science Award, the Seymour Marine Discovery Center's Student Research and Education Award, and the California State University Monterey Bay Undergraduate Research Opportunities Center.

Table of Contents

Coverage

Spatial Extent: **Lat**:57.073 **Lon**:-135.414
Temporal Extent: 2021-04-17 - 2021-05-08

Methods & Sampling

To tease apart the effects of seasonal variation in light availability and nutrients on the response of high-latitude kelp species to pH and temperature, the investigators conducted two separate studies: a "winter" experiment from February 12 to March 18, 2020 (35 days), and a "summer" experiment from August 15 to September 16, 2020 (32 days). In the experimental design, analysis, and reporting, the investigators endeavored to follow best practices for OA research with macroalgae (Cornwall et al., 2012; Cornwall & Hurd, 2016). Both experiments took place at the Sitka Sound Science Center in a flow-through seawater system drawing source water from 20 meters (m) depth (MLLW) in Sitka Sound, Alaska. Incoming seawater was filtered to 20 micrometers (µm) and routed through a UV filter (Smart UV®, Pentair) before diverging into two temperature-controlled (TITAN® heat pump and Optima compact heaters, AquaLogic) recirculating tanks representing treatments for "current" or control temperatures (7° Celsius (C) in winter; 14°C in summer) and "future" ocean warming (OW) projections (11°C in winter; 18°C in summer) (IPCC, 2018) by season. From here, temperature-regulated seawater was pumped into eight header tanks where pH was maintained at setpoint levels for control conditions (pHT 7.6 in winter; pHT 7.9 in summer) and "future" ocean acidification (OA) projections (pHT 7.2 in winter; pHT 7.5 in summer) (Mathis et al., 2015) through a relay system (N = 2 header tanks per pH/temperature treatment). In both seasonal experiments, achievable pHT setpoints for control treatments were constrained by the ambient pH of incoming seawater and were, therefore, lower than the typical seasonal *in situ* pHTminima observed on local rocky reefs by ~0.1 - 0.2 pH units (Kroeker et al., 2021). That said, the lower-than-average pH values of the control treatments did still fall within the observed pHs captured across all years of in situ environmental data. The investigators chose to maintain the projected end-of-century pH offset for this region (~0.4 pH units) to define the OA treatment setpoints relative to achievable control pH levels. A DuraFET sensor (Honeywell) in each header tank communicated real-time pH measurements to a controller (UDA 2152, Honeywell) that regulated injection of pre-equilibrated low pH seawater through solenoid valves into the headers to maintain pH at treatment set points. The low pH (~6) seawater was produced by bubbling pure CO2 gas into two tanks of seawater flowing from each temperature-controlled tank. Once in each header tank, the CO2 and temperature-equilibrated seawater was continuously mixed before delivery to 24 experimental aquaria (N = 3 aquaria per header) at an average flow-through rate of 2-2.5 liters per minute per aquaria (L min-1 aquaria-1). The "Header pH and Temperature" Supplemental File (2020_kelpGCexps_headerdata.csv) contains a summary of the calibrated pH and temperature data recorded by the Durafet sensors in each header during the experiments.

Seawater nutrient concentrations were not manipulated and thus reflected what was delivered through source water inflow to the system during each experiment. Terrestrial outflow from heavy precipitation over Southeast Alaska's temperate rainforests and wind stress dynamics in the Gulf of Alaska control nutrient supply onto the Northeast Pacific shelves (Hermann et al., 2009; Hood & Scott, 2008; Ladd & Cheng, 2016; Stabeno et al., 2016). The complexities of how climate change may impact these drivers in tandem with altered phytoplankton productivity (Ji et al., 2010) means that there is little consensus on how seasonal nutrient supply into Sitka Sound may change. Therefore, the investigators chose to assume that nutrient availability, like seasonal light availability, would not differ significantly in this region in the future. All aquaria were fitted with a full-spectrum light (Aqua Illumination) that provided seasonally relevant regimes of photosynthetically active radiation spectra and photoperiod within the aquaria based on observations during overcast days in Sitka Sound (Bell et al., 2022). The entire experimental system was shielded from external light sources, and aquaria positions were randomized by treatment and location in the laboratory to minimize spatial variation among the random factors *aquaria* and *header*. The "Nutrient Concentrations with Experimental Aquaria" Supplemental File (2020_kelpGCexps_nutrients.csv) contains the data on nutrient concentrations within experimental aquaria.

At the beginning, middle, and end of each experiment, discrete water samples were collected for the determination of pHT, TA, and nutrient concentrations in each aquarium and header tank. Water samples were collected without aeration and poisoned with saturated HgCl2 (0.025%) in glass bottles within 20 minutes. Airtight samples were transported to the University of California Santa Cruz (UCSC) for analysis within 9 months of collection. pH was measured spectrophotometrically (Shimadzu, UV-1800) using m-cresol purple following best practices (Dickson et al., 2007). Total alkalinity (TA) was measured using open cell titration (Metrohm, 905 Titrandro) and corrected against certified reference materials of CO2 in seawater (Dickson laboratory, Scripps Institute of Oceanography). Water chemistry samples from each tank had a mean standard error of 0.0013 pH units and 0.87 micromoles per kilogram seawater (µmol kg-1 SW-1) among sample triplicates. To calculate in situ pH on the total hydrogen ion concentration scale (pHT; mol kg-1 SW-1)

(Dickson, 1993), the investigators used their laboratory measurements of spectrophotometric pH and TA, measurements of temperature and salinity recorded with a handheld meter (YSI) concurrently with discrete water sample collection, and stoichiometric dissociation constants (Dickson & Millero, 1987; Mehrbach et al., 1973) as inputs to the program CO2SYS (Lewis & Wallace, 1998; Pierrot et al., 2006). Corrections were applied to the continuous time series of pH values recorded by durafets in each header during each experiment by calculating an average offset from pHT values calculated from discrete samples.

Kelp used in both winter and summer experiments came from 4.5-7.5 m depth at Talon Island (57.073 N, 135.414 W), Sitka Sound. These experimental "individuals" were collected as whole thalli (*Neoagarum fimbriatum* and *Hedophyllum nigripes*), or as single blades with their attached pneumatocysts that were cut from young sporophytes at approximately 1 m above their holdfasts (*Macrocystis pyrifera*). During transport to the laboratory and prior to the start of the experiments (less than 2 days), all algae was held continuously in ambient flow-through seawater (winter experiment: ~6°C, pHT 7.8; summer experiment: ~13.5°C, pHT 8.0). Individuals were removed briefly only to clean off epiphytes and to record initial morphometrics (maximum blade length, total wet mass) after trimming all blades to 10 centimeters (cm) total length. The investigators took pictures of each trimmed blade to estimate total surface area using ImageJ (NIH v1.8.0).

In both the winter and summer experiments, 3 individuals of each kelp species were randomly assigned to each experimental aquaria (N = 18 individuals per species per treatment). The investigators affixed individuals upright in aquaria by placing their stipes or pneumatocysts through three-strand line suspended over the open ends of 5 cm tall PVC stands. After all seaweeds were processed for initial morphometrics, pH and temperature were gradually changed in treatment tanks stepwise over the course of 3 days to reach final setpoints. During the experiment, kelps were visually checked daily for necrosis and were lightly brushed biweekly during aquaria cleaning to remove diatoms.

At the end of each experiment, individuals were measured and photographed for final morphometrics. Due to the difficulty in capturing three-dimensional tissue growth and the error inherent in wet mass measurements, kelp growth rates were estimated using three different metrics: wet mass in grams (g), maximum blade length in centimeters (cm), and total blade surface area in square centimeters (cm^2). The initial (Ginitial) and final (Gfinal) measurements of each metric were used to calculate three relative growth rates (RGR; percent per day (% d-1)) for each individual using Equation 1 (see the attached Supplemental File), where Δt (days (d)) represents the total number of days elapsed between the beginning and end of the experiment. Relative growth rates were used for subsequent statistical analyses of experimental results. Absolute blade length extension rates were used to compare experimental growth to *in situ* kelp growth measurements (Bell & Kroeker, 2022).

From each individual, the investigators excised new blade tissue grown during the experiment adjacent to the intercalary meristem and pooled this tissue for all species replicates in each aquarium. A portion of this tissue was frozen at -20°C for use in feeding assays. The other portion of this tissue was dried at 60°C for >24 hours and analyzed for nitrogen (N) content (% dry mass) and δ13C values by the UCSC Stable Isotope Laboratory using a CE Instruments NC2500 elemental analyzer coupled to a Thermo Scientific DELTAplus XP isotope ratio mass spectrometer via a Thermo-Scientific Conflo III (routine measurement error ≤ 1.0 %C and ≤ 0.2 %N). The investigators also analyzed blade tissue from non-experimental kelp individuals collected at Talon Islands in each season ("field controls"; N=6 species-1 season-1) for elemental and isotopic analysis.

To compare *in situ* nutrient and light data with aquaria conditions during the experiment, environmental data was collected at the Talon Island experimental collection site. Benthic seawater was collected for the determination of nutrient concentrations in February and August 2020 (N=3 samples-1 season-1). Seawater for nutrient samples was immediately filtered through a 0.2 µm filter and frozen until analysis for dissolved inorganic nitrogen content as NOx (NO3 + NO2) and ammonium (NH4+) on a Lachat QuikChem 8000 Flow Injection Analyzer at the University of California Santa Cruz Marine Analytical Laboratory (detection limits: < 0.28 µM NOx, < 2.40 µM NH4; average run measurement error < 0.1 µM NOx < 0.8 µM NH4). A Diving-PAM-II (Heinz Wlz GmbH) MINI-SPEC was used to haphazardly record the photosynthetic photon flux density (PPFD; micromoles per square meter per second (µmol m-2 s-1) reaching the benthos at more than 10 locations along the ~5 m depth contour on two clear days in winter (February 28) and summer (September 19).

Tissue from *H. nigripes* and *N. fimbriatum* individuals grown in the laboratory was used to investigate whether future ocean conditions affect the palatability of these understory kelp species in either season. In April 2021, methods used by Hay et al. (1994) were modified to create "gels" of homogenized kelp tissue suspended in agar and enmeshed in squares of window screen. Each 30 cm^2 gel was formed from 0.1547 ± 0.0004 g (mean ± SE) of freeze-dried (FreeZone, Labconco) *H. nigripes* or *N. fimbriatum* tissue growth in either the control treatment or the combination OW and OA treatment from each seasonal experiment. The total number of gels used for the feeding assays was limited by the available kelp tissue grown during each experiment, and was consequently lower for gels made from tissue grown in the winter experiment (*H. nigripes*: N = 11 gels

per treatment, *N. fimbriatum*: N = 12 gels per treatment) versus the summer experiment (*H. nigripes*: N = 24 gels per treatment, *N. fimbriatum*: N = 23 gels per treatment). Palatability assays were run by feeding these seaweed gels to the common kelp forest grazer, *Strongylocentrotus droebachiensis* (green urchin). Urchins with a test diameter of 24 ± 3 millimeters (mm) were collected from the intertidal, starved for 48 hours, and then placed in a flow-through chamber with a single gel in ambient seawater conditions (~7 °C, ~8.0 pH) for 48 hours. Photographs were taken of each gel before and after the assay and the relative consumption of seaweeds grown under different treatments was determined using Image J (NIH v1.8.0).

Data Processing Description

To calculate *in situ* pH of water samples taken from laboratory aquaria on the total hydrogen ion concentration scale (pHT; moles per kilogram seawater (mol kg-1 SW-1)) (Dickson, 1993), the investigators used their laboratory measurements of spectrophotometric pH and TA, measurements of temperature and salinity recorded with a handheld meter (YSI) concurrently with discrete water sample collection, and stoichiometric dissociation constants (Dickson & Millero, 1987; Mehrbach et al., 1973) as inputs to the program CO2SYS (Lewis & Wallace, 1998; Pierrot et al., 2006). They corrected the continuous timeseries of pH values recorded by durafets in each header during each experiment by calculating an average offset from pHT values calculated from discrete samples. R (R Core Team) was used for data processing of durafet sensor data recorded within experiment header tanks.

The image processing software ImageJ (NIH v1.8.0) was used for morphometric analysis of experimental kelp blades at the beginning and end of manipulative experiments, as well as to calculate the urchins' consumption of seaweed gels over the course of feeding assays.

Quality flags are used to indicate instances where experimental individuals degraded during the experiment, potentially compromising physiological data.

BCO-DMO Processing Description

- Imported original file named "2020_kelpGCexps_feedingassaydata.csv" into the BCO-DMO system.
- Converted all date columns to the format YYYY-MM-DD
- Created date-time fields in ISO 8601 format.
- Renamed fields to comply with BCO-DMO naming conventions.
- Saved the final file as "906416_v1_feeding_assays.csv".

[table of contents | back to top]

Data Files

File	
906416_v1_feeding_assays.csv	(Comma Separated Values (.csv), 19.58 KB) MD5:4a8518cfa00ddbccd326cc25375cd796
Primary data file for dataset ID 906416, version 1.	

[table of contents | back to top]

Supplemental Files

File

Equation 1

filename: Equation1.png

(Portable Network Graphics (.png), 55.04 KB)
MD5:6bf092d2fe25f1dfbf00f67a387e67e8

Depicts the equation used to determine relative growth rates. The initial (Ginitial) and final (Gfinal) measurements of each metric were used to calculate three relative growth rates (RGR; percent per day (% d-1)) for each individual using Equation 1, where Δt (days (d)) represents the total number of days elapsed between the beginning and end of the experiment. Relative growth rates were used for subsequent statistical analyses of experimental results.

Header pH and Temperature

filename: 2020_kelpGCexps_headerdata.csv

(Comma Separated Values (.csv), 694 bytes)
MD5:2b1b19ed930410851c1336319ffefcad

Summary of calibrated pH and temperature data recorded by Durafet sensors in each header during experiments.

Column names, descriptions, and units:

Season = Seasonal experiment ID from which algal tissue was sourced (Winter = experiment in Feb-March 2020, Summer = experiment in Aug-Sept 2020)".

Hdr = ID number (1-8) of header tank leading to experimental aquaria.

Treatment = Experimental treatment used in all aquaria downstream of this header (Control = control temperature and pH conditions; OA = OA pH conditions, control temperature conditions; OW = control pH conditions, OW temperature conditions; OA & OW = OA pH conditions, OW temperature conditions).

pH_mean = Average pH value recorded in this header during the entire experiment. Precision to 0.01 pH units.

pH_sd = Standard deviation of all pH values recorded in this header during the entire experiment. Precision to 0.01 pH units.

T_mean = Average temperature recorded in this header during the entire experiment. Precision to 0.1 degrees C.

T_sd = Standard deviation of all temperatures recorded in this header during the entire experiment. Precision to 0.1 degrees C.

N_10minavg = Sample size of data points used for calculations of mean and standard deviation values. Header conditions were initially recorded every 3 seconds. After calibration, these measurements were averaged in 10 min increments.

Nutrient Concentrations with Experimental Aquaria

filename: 2020_kelpGCexps_nutrients.csv

(Comma Separated Values (.csv), 2.31 KB)
MD5:f731ab4f3ddee46343b275bea843c006

Nutrient concentrations within experimental aquaria.

Column names, descriptions, and units:

Processing_date = Collection and processing date, format mm/dd/yy.

Season = Seasonal experiment ID (Winter = experiment in Feb-March 2020, Summer = experiment in Aug-Sept 2020).

Hdr = ID number (1-8) of header tank leading to experimental aquaria where nutrient sample was taken.

TankRep = Replicate identifier (A, B, or C) of experimental aquaria nested within header.

Temp = Temperature treatment factor (control = experimental control temp, OW = experimental OW treatment).

pH = pH treatment factor (control = experimental control temp, OA = experimental OA treatment).

NOx_uM = Total nitrate and nitrite concentration in nutrient sample. Precision to 0.001 uM; units = uM.

PO4_uM = Total phosphate concentration in nutrient sample. Precision to 0.001 uM; units = uM.

NH4_uM = Total ammonium concentration in nutrient sample. Precision to 0.001 uM; units = uM.

NO2_uM = Total nitrite concentration in nutrient sample. Precision to 0.001 uM; units = uM.

qualityflag_PO4NH4 = code for quality flag (y = phosphate and ammonium data was compromised during analysis, should not be used; n = phosphate and ammonium data is OK).

[table of contents | back to top]

Related Publications

Bell, L. E., & Kroeker, K. J. (2022). Standing Crop, Turnover, and Production Dynamics of Macrocystis pyrifera and Understory Species Hedophyllum nigripes and Neoagarum fimbriatum in High Latitude Giant Kelp Forests. Journal of Phycology, 58(6), 773–788. Portico. https://doi.org/10.1111/jpy.13291
Methods

Bell, L., Gómez, J., Donham, E., Steller, D., Gabrielson, P., & Kroeker, K. (2022). High-latitude calcified coralline algae exhibit seasonal vulnerability to acidification despite physical proximity to a non-calcified alga. Climate Change Ecology, 3, 100049. https://doi.org/10.1016/j.ecochg.2022.100049
Methods

Bell, LE, Westphal, L, O'Brien, E, Toy, JA, Damron, H., and Kroeker, KJ. (in review, 2023). Season influences interspecific responses of three canopy-forming kelps to future warming and acidification at high latitude.
Results

Cornwall, C. E., & Hurd, C. L. (2015). Experimental design in ocean acidification research: problems and solutions. ICES Journal of Marine Science, 73(3), 572–581. https://doi.org/10.1093/icesjms/fsv118
Methods

Cornwall, C. E., Hepburn, C. D., Pritchard, D., Currie, K. I., McGraw, C. M., Hunter, K. A., & Hurd, C. L. (2011). Carbon-use strategies in macroalgae: Differential responses to lowered pH and implications for ocean acidification. Journal of Phycology, 48(1), 137–144. https://doi.org/10.1111/j.1529-8817.2011.01085.x
Methods

Dickson, A. G. (1993). pH buffers for sea water media based on the total hydrogen ion concentration scale. Deep Sea Research Part I: Oceanographic Research Papers, 40(1), 107–118. https://doi.org/10.1016/0967-0637(93)90055-8
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
Methods

Dickson, A.G.; Sabine, C.L. and Christian, J.R. (eds) (2007) Guide to best practices for ocean CO2 measurement. Sidney, British Columbia, North Pacific Marine Science Organization, 191pp. (PICES Special Publication 3; IOCCP Report 8). DOI: https://doi.org/10.25607/OBP-1342
Methods

Hay, M. E., Kappel, Q. E., & Fenical, W. (1994). Synergisms in Plant Defenses against Herbivores: Interactions of Chemistry, Calcification, and Plant Quality. Ecology, 75(6), 1714–1726. Portico. https://doi.org/10.2307/1939631
Methods

Hermann, A. J., Hinckley, S., Dobbins, E. L., Haidvogel, D. B., Bond, N. A., Mordy, C., Kachel, N., & Stabeno, P. J. (2009). Quantifying cross-shelf and vertical nutrient flux in the Coastal Gulf of Alaska with a spatially nested, coupled biophysical model. Deep Sea Research Part II: Topical Studies in Oceanography, 56(24), 2474–2486. https://doi.org/10.1016/j.dsr2.2009.02.008
Methods

Hood, E., & Scott, D. (2008). Riverine organic matter and nutrients in southeast Alaska affected by glacial coverage. Nature Geoscience, 1(9), 583–587. https://doi.org/10.1038/ngeo280
Methods

IPCC. (2018). Summary for Policymakers. In. V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, & T. Waterfield (Eds.), Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty. Geneva, Switzerland, Intergovernmental Panel on Climate Change, 32 pp.
Methods

Ji, R., Edwards, M., Mackas, D. L., Runge, J. A., & Thomas, A. C. (2010). Marine plankton phenology and life history in a changing climate: current research and future directions. Journal of Plankton Research, 32(10), 1355–1368. https://doi.org/10.1093/plankt/fbq062
Methods

Kroeker, K. J., Powell, C., & Donham, E. M. (2020). Windows of vulnerability: Seasonal mismatches in exposure and resource identity determine ocean acidification's effect on a primary consumer at high latitude. Global Change Biology, 27(5), 1042–1051. doi:10.1111/gcb.15449
Methods

Ladd, C., & Cheng, W. (2016). Gap winds and their effects on regional oceanography Part I: Cross Sound, Alaska. Deep Sea Research Part II: Topical Studies in Oceanography, 132, 41–53.

https://doi.org/10.1016/j.dsr2.2015.08.006
Methods

Lewis, E. R., & Wallace, D. W. R. (1998). Program Developed for CO2 System Calculations. Environmental System Science Data Infrastructure for a Virtual Ecosystem. https://doi.org/10.15485/1464255
Methods

Mathis, J. T., Cooley, S. R., Lucey, N., Colt, S., Ekstrom, J., Hurst, T., Hauri, C., Evans, W., Cross, J. N., & Feely, R. A. (2015). Ocean acidification risk assessment for Alaska's fishery sector. Progress in Oceanography, 136, 71–91. https://doi.org/10.1016/j.pocean.2014.07.001
Methods

Mehrbach, C., Culberson, C. H., Hawley, J. E., & Pytkowicx, R. M. (1973). Measurement of the apparent dissociation constants of carbonic acid in seawater at atmospheric pressure. Limnology and Oceanography, 18(6), 897–907. doi:10.4319/lo.1973.18.6.0897
Methods

Pierrot, D., Lewis, E., & Wallace, D. 2006. MS Excel program developed for CO2 system calculations. ORNL/CDIAC-105a Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, US Department of Energy, Oak Ridge, Tennessee, Book https://cdiac.ess-dive.lbl.gov/ftp/co2sys/CO2SYS_calc_XLS_v2.1/
Methods

R Core Team (2022). R: A language and environment for statistical computing. R v4.2.1 (June 2022). R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/
Software

Stabeno, P. J., Bond, N. A., Kachel, N. B., Ladd, C., Mordy, C. W., & Strom, S. L. (2016). Southeast Alaskan shelf from southern tip of Baranof Island to Kayak Island: Currents, mixing and chlorophyll-a. Deep Sea Research Part II: Topical Studies in Oceanography, 132, 6–23. https://doi.org/10.1016/j.dsr2.2015.06.018
Methods

[table of contents | back to top]

Related Datasets

IsRelatedTo

Bell, L. E., Kroeker, K. J. (2023) **Carbon and nitrogen data from kelp determined during seasonal global change experiments examining the effects of seasonal variation in light availability and nutrients on the response of three high-latitude kelp species.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2023-08-18 doi:10.26008/1912/bco-dmo.906469.1 [view at BCO-DMO]

Bell, L. E., Kroeker, K. J. (2023) **Kelp growth data from seasonal global change experiments examining the effects of seasonal variation in light availability and nutrients on the response of three high-latitude kelp species.** Biological and Chemical Oceanography Data Management Office (BCO-DMO). (Version 1) Version Date 2023-08-16 doi:10.26008/1912/bco-dmo.906317.1 [view at BCO-DMO]

[table of contents | back to top]

Parameters

Parameter	Description	Units
Urchin_ID	Unique alphanumeric ID for each green urchin used in feeding assay	unitless
Urchin_D	Diameter of urchin test (excluding spines) at beginning of feeding assay. Precision to 1 mm	millimeters (mm)

Urchin_WW	wet weight of urchin at beginning of feeding assay. Precision to 0.0001 g	grams (g)
Season	Seasonal experiment ID from which algal tissue was sourced (Winter = experiment in Feb-March 2020, Summer = experiment in Aug-Sept 2020)	unitless
Sp	Kelp species used in feeding assay (NFIM = Neoagarum fimbriatum, HNIG = Hedophyllum nigripes)	unitless
Treatment	Experimental treatment under which algal tissue used in feeding assay was grown (Control = control temperature and pH conditions; OW & OA = OA pH treatment and OW temperature treatment)	unitless
date_start	date of feeding assay start; recorded in local time zone (AKST)	unitless
time_start	time of feeding assay start (24hr format); recorded in local time zone (AKST)	unitless
date_end	date of feeding assay end; recorded in local time zone (AKST)	unitless
time_end	time of feeding assay end (24hr format); recorded in local time zone (AKST)	unitless
missingsquares_start	Total number of mesh squares on gel grid that were not covered by algal gel at feeding assay start. Precision to 1 mesh square	mesh square
totalsquares_start	Total number of mesh squares within grid to start (both covered and uncovered by algal gel). Precision to 1 mesh square	mesh square
missingsquares_end	Total number of mesh squares on gel grid that were not covered by algal gel at feeding assay end. Precision to 1 mesh square	mesh square
poop_DW	Dry weight of urchin feces collected after feeding assay complete. Precision to 0.0001 g	grams (g)
area_start	Total area of grid covered by algal gel at feeding assay start, calcualted using ImageJ software. Precision to 0.001 cm2	square centimeters (cm^2)
area_end	Total area of grid covered by algal gel at feeding assay start, calcualted using ImageJ software. Precision to 0.001 cm2	square centimeters (cm^2)
galgae_pergel	Estimated mass of algal tissue used in gel. Precision to 0.0001 g	grams (g)

ISO_DateTime_Start	Date and time at the start of the feeding assay in ISO 8601 format; recorded in local time zone (AKST)	unitless
ISO_DateTime_End	Date and time at the end of the feeding assay in ISO 8601 format; recorded in local time zone (AKST)	unitless

[table of contents | back to top]

Instruments

Dataset-specific Instrument Name	
Generic Instrument Name	Aquarium
Generic Instrument Description	Aquarium - a vivarium consisting of at least one transparent side in which water-dwelling plants or animals are kept

Dataset-specific Instrument Name	
Generic Instrument Name	Camera
Generic Instrument Description	All types of photographic equipment including stills, video, film and digital systems.

Dataset-specific Instrument Name	Thermo-Scientific Conflo III
Generic Instrument Name	Continuous Flow Interface for Mass Spectrometers
Dataset-specific Description	Dried tissue was analyzed for nitrogen content and δ13C values by the UCSC Stable Isotope Laboratory using a CE Instruments NC2500 elemental analyzer coupled to a Thermo Scientific DELTAplus XP isotope ratio mass spectrometer via a Thermo-Scientific Conflo III.
Generic Instrument Description	A Continuous Flow Interface connects solid and liquid sample preparation devices to instruments that measure isotopic composition. It allows the introduction of the sample and also reference and carrier gases. Examples: Finnigan MATConFlo II, ThermoScientific ConFlo IV, and Picarro Caddy. Note: This is NOT an analyzer

Dataset-specific Instrument Name	CE Instruments NC2500
Generic Instrument Name	Elemental Analyzer
Dataset-specific Description	Dried tissue was analyzed for nitrogen content and δ13C values by the UCSC Stable Isotope Laboratory using a CE Instruments NC2500 elemental analyzer coupled to a Thermo Scientific DELTAplus XP isotope ratio mass spectrometer via a Thermo-Scientific Conflo III.
Generic Instrument Description	Instruments that quantify carbon, nitrogen and sometimes other elements by combusting the sample at very high temperature and assaying the resulting gaseous oxides. Usually used for samples including organic material.

Dataset-specific Instrument Name	TITAN heat pump and Optima compact heaters, AquaLogic
Generic Instrument Name	Immersion heater
Generic Instrument Description	Submersible heating element for water tanks and aquaria.

Dataset-specific Instrument Name	Thermo Scientific DELTAplus XP isotope ratio mass spectrometer
Generic Instrument Name	Isotope-ratio Mass Spectrometer
Dataset-specific Description	Dried tissue was analyzed for nitrogen content and δ13C values by the UCSC Stable Isotope Laboratory using a CE Instruments NC2500 elemental analyzer coupled to a Thermo Scientific DELTAplus XP isotope ratio mass spectrometer via a Thermo-Scientific Conflo III.
Generic Instrument Description	The Isotope-ratio Mass Spectrometer is a particular type of mass spectrometer used to measure the relative abundance of isotopes in a given sample (e.g. VG Prism II Isotope Ratio Mass-Spectrometer).

Dataset-specific Instrument Name	Lachat QuikChem 8000 Flow Injection Analyzer
Generic Instrument Name	Lachat QuikChem 8000 flow injection analyzer and Ion Chromatography (IC) system
Dataset-specific Description	Analysis for dissolved inorganic nitrogen content as NOx (NO3 + NO2) and ammonium (NH4+) was done on a Lachat QuikChem 8000 Flow Injection Analyzer at the University of California Santa Cruz Marine Analytical Laboratory.
Generic Instrument Description	The Lachat QuikChem 8000 can operate flow injection analysis and ion chromatography simultaneously and independently on the same instrument platform. Instrument includes sampler, dilutor, sampling pump, electronics unit, and data station. Analysis takes 20-60 seconds, with a sample throughput of 60-120 samples per hour. Measurements are in the range of parts per trillion to parts per hundred.

Dataset-specific Instrument Name	FreeZone freeze drier, Labconco
Generic Instrument Name	Lyophilizer
Generic Instrument Description	A lyophilizer, also known as freeze dryer or liofilizador, is a device that is used to freeze-dry material.

Dataset-specific Instrument Name	Metrohm 905 Titrando
Generic Instrument Name	Metrohm 905 Titrando potentiometric titrator
Dataset-specific Description	total alkalinity (TA) was measured using open cell titration (Metrohm, 905 Titrandro)
Generic Instrument Description	The Metrohm 905 Titrando potentiometric titrator is a modular potentiometric titrator for dynamic, monotonic, and set endpoint titrations. The device includes magnetic stirrers, rod stirrers, and a titration stand. It can be connected to various dosing units which include a buret and are attached to the reagent. Operation is carried out by means of a touch-sensitive display or with high-performance PC software. Temperature is measured by a Pt1000 or NTC. Ranges of the outputs are -13 to 20 pH, -1200 to 1200 mV, and -150 to 250 deg. C (Pt1000) or -5 ro 250 deg. C (NTC). Resolutions of the outputs are 0.001 for pH, 0.1 for mV, 0.1 deg. C for temperature. The measuring interval is of 100 ms. Works in conditions from 5 to 45 deg. C and at a maximum of 80 % relative humidity.

Dataset-specific Instrument Name	DuraFET
Generic Instrument Name	pH Sensor
Dataset-specific Description	A DuraFET sensor (Honeywell) in each header tank communicated real-time pH measurements to a controller.
Generic Instrument Description	An instrument that measures the hydrogen ion activity in solutions. The overall concentration of hydrogen ions is inversely related to its pH. The pH scale ranges from 0 to 14 and indicates whether acidic (more H+) or basic (less H+).

Dataset-specific Instrument Name	Diving-PAM-II (Heinz Wlz GmbH) MINI-SPEC
Generic Instrument Name	Photosynthetically Available Radiation Sensor
Dataset-specific Description	A Diving-PAM-II (Heinz Wlz GmbH) MINI-SPEC was used to haphazardly record the photosynthetic photon flux density.
Generic Instrument Description	A PAR sensor measures photosynthetically available (or active) radiation. The sensor measures photon flux density (photons per second per square meter) within the visible wavelength range (typically 400 to 700 nanometers). PAR gives an indication of the total energy available to plants for photosynthesis. This instrument name is used when specific type, make and model are not known.

Dataset-specific Instrument Name	Shimadzu UV-1800
Generic Instrument Name	UV Spectrophotometer-Shimadzu
Dataset-specific Description	pH was measured spectrophotometrically (Shimadzu, UV-1800)
Generic Instrument Description	The Shimadzu UV Spectrophotometer is manufactured by Shimadzu Scientific Instruments (ssi.shimadzu.com). Shimadzu manufacturers several models of spectrophotometer; refer to dataset for make/model information.

Dataset-specific Instrument Name	handheld meter (YSI)
Generic Instrument Name	Water Quality Multiprobe
Dataset-specific Description	measurements of temperature and salinity recorded with a handheld meter (YSI)
Generic Instrument Description	An instrument which measures multiple water quality parameters based on the sensor configuration.

[table of contents | back to top]

Project Information

CAREER: Energy fluxes and community stability in a dynamic, high-latitude kelp ecosystem (High latitude kelp dynamics)

Coverage: SE Alaskan coastal waters

NSF Award Abstract:
High latitude kelp forests support a wealth of ecologically and economically important species, buffer coastlines from high-energy storms, and play a critical role in the marine carbon cycle by sequestering and storing large amounts of carbon. Understanding how energy fluxes and consumer-resource interactions vary in these kelp communities is critical for defining robust management strategies that help maintain these valuable ecosystem services. In this integrated research and education program, the project team will investigate how consumer populations respond to variability in temperature, carbonate chemistry and resource quality to influence the food webs and ecosystem stability of kelp forests. A comprehensive suite of studies conducted at the northern range limit for giant kelp (Macrocystis pyrifera) in SE Alaska will examine how kelp communities respond to variable environmental conditions arising from seasonal variability and changing ocean temperature and acidification conditions. As part of this project, undergraduate and high school students will receive comprehensive training through (1) an immersive field-based class in Sitka Sound, Alaska, (2) intensive, mentored research internships, and (3) experiential training in science communication and public outreach that will include a variety of opportunities to disseminate research findings through podcasts, public lectures and radio broadcasts.

Consumer-resource interactions structure food webs and govern ecosystem stability, yet our understanding of how these important interactions may change under future climatic conditions is hampered by the complexity of direct and indirect effects of multiple stressors within and between trophic levels. For example, environmentally mediated changes in nutritional quality and chemical deterrence of primary producers have the potential to alter herbivory rates and energy fluxes between primary producers and consumers, with implications for ecosystem stability. Moreover, the effects of global change on primary producers are likely to depend on other limiting resources, such as light and nutrients, which vary seasonally in dynamic, temperate and high latitude ecosystems. In marine ecosystems at high latitude, climate models predict that ocean acidification will be most pronounced during the winter months, when primary production is limited by light.

This project is built around the hypothesis that there could be a mismatch in the energetic demands of primary consumers caused by warming and ocean acidification and resource availability and quality during winter months, with cascading effects on trophic structure and ecosystem stability in the future. Through complementary lab and field experiments, the project team will determine 1) how temperature and carbonate chemistry combine to affect primary consumer bioenergetics across a diversity of species and 2) the indirect effects of ocean acidification and warming on primary consumers via environmentally mediated changes in the availability, nutritional quality and palatability of primary producers across seasons. Using the data from the laboratory and field experiments, the project team will 3) construct a model of the emergent effects of warming and ocean acidification on trophic structure and ecosystem stability in seasonally dynamic, high latitude environments.

This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

[table of contents | back to top]

Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1752600
David and Lucile Packard Foundation (Packard)	Packard - Kelp Ecosystem Dynamics
North Pacific Research Board (NPBR)	Graduate Student Research Award 1748-02

[table of contents | back to top]