Processed CTD data from R/V Kilo Moana cruise KM1312 in the Eastern North Pacific Ocean from 2013-2013 (POWOW project)

Website: https://www.bco-dmo.org/dataset/518582
Data Type: Cruise Results
Version: 1
Version Date: 2014-07-11

Project
» Seasonal and decadal changes in temperature drive Prochlorococcus ecotype distribution patterns (POWOW)

Contributors	Affiliation	Role
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Abstract
Binned-profile CTD data from cruise KM1312 during July 2013. Data were processed with Sea-Bird SBE Data Processing Version 7.21K.

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Coverage

Spatial Extent: **N**:46.6888 **E**:-118.316 **S**:21.391 **W**:-158.2908
Temporal Extent: 2013-07-02 - 2013-07-27

Dataset Description

Binned-profile CTD data from cruise KM1312 during July 2013. Data were processed with Sea-Bird SBE Data Processing Version 7.21K using windows and filters as described below.

Methods & Sampling

Note: some cast numbers may be missing/skipped for a given station because of aborted casts.

Header information from Sea-Bird SBE 9 Data File:
Software Version Seasave V 7.21k
Temperature SN = 1489; Conductivity SN = 1176
Number of Bytes Per Scan = 41; Number of Voltage Words = 4

Number of Scans Averaged by the Deck Unit = 1
SBE 11plus V 5.2
number of scans to average = 1; pressure baud rate = 9600; NMEA baud rate = 4800
GPIB address = 1
advance primary conductivity 0.073 seconds
advance secondary conductivity 0.073 seconds
autorun on power up is disabled
units = specified
name 0 = scan: Scan Count
name 1 = prDM: Pressure, Digiquartz [db]
name 2 = t068C: Temperature [ITS-68, deg C]
name 3 = c0S/m: Conductivity [S/m]
name 4 = sbeox0Mm/Kg: Oxygen, SBE 43 [umol/Kg]
name 5 = flECO-AFL: Fluorescence, WET Labs ECO-AFL/FL [mg/m^3]
name 6 = CStarAt0: Beam Attenuation, WET Labs C-Star [1/m]
name 7 = nbf: Bottles Fired
name 8 = sal00: Salinity, Practical [PSU]
name 9 = sigma-é00: Density [sigma-theta, Kg/m^3]
name 10 = potemp090C: Potential Temperature [ITS-90, deg C]
name 11 = scan: Scan Count
name 12 = t168C: Temperature, 2 [ITS-68, deg C]
name 13 = c1S/m: Conductivity, 2 [S/m]
name 14 = sbeox1Mm/Kg: Oxygen, SBE 43, 2 [umol/Kg]
name 15 = flSP: Fluorescence, Seapoint
name 16 = sal11: Salinity, Practical, 2 [PSU]
name 17 = sigma-é11: Density, 2 [sigma-theta, Kg/m^3]
name 18 = potemp168C: Potential Temperature, 2 [ITS-68, deg C]
name 19 = par: PAR/Irradiance, Biospherical/Licor
name 20 = nbin: number of scans per bin
name 21 = flag: flag
span 0 =6985, 37235
span 1 =2.000, 800.000
span 2 =5.0419, 26.5629
span 3 =3.335783, 5.502325
span 4 =31.444, 198.040
span 5 =0.0100, 0.4971
span 6 =-0.0571, 0.0100
span 7 =0, 0
span 8 =34.0618, 35.3564
span 9 =23.0269, 27.2279
span 10 =4.9751, 26.5547
span 11 =6985, 37235
span 12 =5.0415, 26.5595
span 13 =3.335901, 5.501779
span 14 =30.989, 206.103
span 15 =5.1724e-02, 5.0659e-01
span 16 =34.1016, 35.3541
span 17 =23.0310, 27.2294
span 18 =4.9758, 26.5577
span 19 =9.5884e-02, 3.8336e+02
span 20 =1, 47
span 21 =0.0000e+00 0.0000e+00
interval = decibars: 1
bad_flag = -9.990e-29
Sensors count="13"
Sensor Channel 1: Frequency 0, Temperature; SensorID=55; Serial Number: 1489
Calibration Date: 01-Nov-12
UseG_J: 1
A: 0.00000000e+000; B: 0.00000000e+000; C: 0.00000000e+000; D: 0.00000000e+000; F0_Old: 0.000
G: 4.78324023e-003
H: 6.52533514e-004
I: 2.17843448e-005
J: 1.47229280e-006

F0: 1000.000
Slope: 1.00000000; Offset: 0.0000

Sensor Channel 2: Frequency1, Conductivity; Sensor ID=3; Serial Number: 1176
Calibration Date: 24-Oct-12
UseG_J: 1
<!-- Cell const and series R are applicable only for wide range sensors. -->
Series R: 0.0000
Cell Const: 2000.0000
Conductivity Type: 0
Coefficients equation=0
A: 0.00000000e+000; B: 0.00000000e+000; C: 0.00000000e+000; D: 0.00000000e+000; M: 0.0
CPcor: -9.57000000e-008
Coefficients equation=1
G: -4.05760658e+000; H: 5.58151895e-001; I: 1.19301041e-004; J: 2.48712115e-005
CPcor: -9.57000000e-008
CTcor: 3.2500e-006
<!-- WBOTC not applicable unless ConductivityType = 1. -->
WBOTC: 0.00000000e+000
Slope: 1.00000000; Offset: 0.00000

Sensor Channel 3: Frequency2, Pressure, Digiquartz with TC; Sensor ID=45; Serial Number: 0310
Calibration Date: 14-Aug-12
C1: -3.928393e+004; C2: 1.087860e+000; C3: 1.199240e-002
D1: 3.882500e-002; D2: 0.000000e+000
T1: 3.029977e+001; T2: 4.275780e-005; T3: 4.335010e-006; T4: 2.205920e-009
Slope: 0.99982291; Offset: -3.07238
T5: 0.000000e+000
AD590M: 1.151000e-002
AD590B: -8.749880e+000

Sensor Channel 4: Frequency3, Temperature, 2; Sensor ID=55; Serial Number: 1503
Calibration Date: 02-Apr-13
UseG_J: 1
A: 0.00000000e+000; B: 0.00000000e+000; C: 0.00000000e+000; D: 0.00000000e+000; F0_Old: 0.000
G: 4.35232305e-003
H: 6.46632031e-004
I: 2.24386514e-005
J: 1.95656353e-006
F0: 1000.000
Slope: 1.00000000; Offset: 0.0000

Sensor Channel 5: Frequency4, Conductivity, 2; Sensor ID=3; Serial Number: 3977
Calibration Date: 31-Jan-13
UseG_J: 1
<!-- Cell const and series R are applicable only for wide range sensors. -->
Series R: 0.0000
CellConst: 2000.0000
ConductivityType: 0
Coefficients equation=0
A: 0.00000000e+000; B: 0.00000000e+000; C: 0.00000000e+000; D: 0.00000000e+000; M: 0.0
CPcor: -9.57000000e-008
Coefficients equation=1
G: -9.93055578e+000
H: 1.32723802e+000
I: -1.01831158e-003
J: 1.37808089e-004
CPcor: -9.57000000e-008
CTcor: 3.2500e-006
<!-- WBOTC not applicable unless ConductivityType = 1. -->
WBOTC: 0.00000000e+000
Slope: 1.00000000; Offset: 0.00000

Sensor Channel 6: A/D voltage 0, Oxygen, SBE 43; Sensor ID=38; Serial Number: 2215
Calibration Date: 07-Aug-12
Use2007Equation: 1
CalibrationCoefficients equation=0
<!-- Coefficients for Owens-Millard equation. -->
Boc: 0.0000
Soc: 0.0000e+000
offset: 0.0000
Pcor: 0.00e+000
Tcor: 0.0000
Tau: 0.0
CalibrationCoefficients equation=1
<!-- Coefficients for Sea-Bird equation - SBE calibration in 2007 and later. -->
Soc: 5.1293e-001
offset: -0.4912
A: -2.3087e-003
B: 5.6369e-005
C: -1.0582e-006
D0: 2.5826e+000
D1: 1.92634e-004
D2: -4.64803e-002
E: 3.6000e-002
Tau20: 2.0000
H1: -3.3000e-002
H2: 5.0000e+003
H3: 1.4500e+003

Sensor Channel 7: A/D voltage 1, Oxygen, SBE 43, 2; Sensor ID=38; Serial Number: 2194
Calibration Date: 28-Aug-12
Use2007Equation: 1
CalibrationCoefficients equation=0
<!-- Coefficients for Owens-Millard equation. -->
Boc: 0.0000
Soc: 0.0000e+000
offset: 0.0000
Pcor: 0.00e+000
Tcor: 0.0000
Tau: 0.0
CalibrationCoefficients equation=1
<!-- Coefficients for Sea-Bird equation - SBE calibration in 2007 and later. -->
Soc: 5.4510e-001
offset: -0.5002
A: -2.0842e-003
B: 3.3140e-005
C: -3.9685e-007
D0: 2.5826e+000
D1: 1.92634e-004
D2: -4.64803e-002
E: 3.6000e-002
Tau20: 1.4500
H1: -3.3000e-002
H2: 5.0000e+003
H3: 1.4500e+003

Sensor Channel 8: A/D voltage 2, Fluorometer, Seapoint; Sensor ID=11; Serial Number: 2440
Calibration Date: 30-Apr-13
<!-- The following is an array index, not the actual gain setting. -->
GainSetting: 0; Offset: 0.000

Sensor Channel 9: A/D voltage 3, PAR/Irradiance, Biospherical/Licor; Sensor ID=42; Serial Number: 70307
Calibration Date: 04-Feb-13
M: 1.00000000
B: 0.00000000

Calibration Constant: 10718113612.00428000
Multiplier: 1.00000000
Offset: 0.00083970

Sensor Channel 10: A/D voltage 4, Fluorometer, WET Labs ECO-AFL/FL; Sensor ID=20; Serial Number: 1303
Calibration Date: 15-Mar-13
Scale Factor: 6.00000000e+000
<!-- Dark output -->
Vblank: 0.0580

Sensor Channel 11: A/D voltage 5, Turbidity Meter, WET Labs, ECO-NTU; Sensor ID=67; Serial Number: 1303
Calibration Date: 15-Mar-13
ScaleFactor: 2.000000
<!-- Dark output -->
DarkVoltage: 0.083000

Sensor Channel 12: A/D voltage 6, Transmissometer, WET Labs C-Star; Sensor ID=71; Serial Number: CST-1366DR
Calibration Date: 13-Mar-13
M: 21.5749
B: -0.0789
Path Length: 0.250

Sensor Channel13 : <!-- A/D voltage 7, Free -->

Data Processing Description

The processed data files submitted to BCO-DMO include 2 plots for each cast: plot 1 contains temperature, oxygen, PAR, and density vs. pressure; plot 2 contains fluorescence, salinity, beam attenuation, and density vs. pressure. Plots have been compiled into a single PDF file: POWOW3 CTD Plots (58.9 MB PDF)

BCO-DMO obtained the processed .cnv files (binned profiles) and replaced values of '-9.990e-29' with 'nd' to indicate 'no data'. Parameter names were modified to conform with BCO-DMO convention. month_utc, day_utc, year, time_start, lat_start, lon_start, and depth_w were taken from the .cnv file headers and the scanned CTD cast logs.

Processing description from Sea-Bird SBE 9 Data Files:
(from station 1, cast 1 data file)
datcnv_date = Jul 06 2013 20:27:05, 7.22.4 [datcnv_vars = 20]
datcnv_in = C:\Users\zij\Desktop\2013-POWOW3-HNL2SanDiego\data\CTD\km1312_s01_c01_ctd001.hex C:\Users\zij\Desktop\2013-POWOW3-HNL2SanDiego\data\CTD\km1312_s01_c01_ctd001.XMLCON
datcnv_skipover = 0
datcnv_ox_hysteresis_correction = yes
datcnv_ox_tau_correction = yes
wfilter_date = Jul 06 2013 20:27:27, 7.22.4
wfilter_in = C:\Users\zij\Desktop\2013-POWOW3-HNL2SanDiego\data\CTD\km1312_s01_c01_ctd001.cnv
wfilter_excl_bad_scans = yes
wfilter_action prDM = gaussian, 5, 1, 0
wfilter_action t068C = median, 21
wfilter_action c0S/m = median, 21
wfilter_action sbeox0Mm/Kg = gaussian, 5, 1, 0
wfilter_action flECO-AFL = gaussian, 21, 1, 0
wfilter_action CStarAt0 = gaussian, 5, 1, 0
wfilter_action sal00 = gaussian, 5, 1, 0
wfilter_action sigma-é00 = gaussian, 5, 1, 0
wfilter_action potemp090C = median, 21
wfilter_action t168C = median, 21
wfilter_action c1S/m = median, 21
wfilter_action sbeox1Mm/Kg = gaussian, 5, 1, 0

wfilter_action flSP = gaussian, 21, 1, 0
wfilter_action sal11 = gaussian, 5, 1, 0
wfilter_action sigma-é11 = gaussian, 5, 1, 0
wfilter_action potemp168C = median, 21
wfilter_action par = gaussian, 21, 1, 0
wildedit_date = Jul 06 2013 20:27:41, 7.22.4
wildedit_in = C:\Users\zij\Desktop\2013-POWOW3-HNL2SanDiego\data\CTD\km1312_s01_c01_ctd001.cnv
wildedit_pass1_nstd = 2.0
wildedit_pass2_nstd = 20.0
wildedit_pass2_mindelta = 0.000e+000
wildedit_npoint = 100
wildedit_vars = prDM t068C c0S/m sbeox0Mm/Kg flECO-AFL CStarAt0 sal00 sigma-é00 potemp090C t168C c1S/m sbeox1Mm/Kg flSP sal11 sigma-é11 potemp168C par
wildedit_excl_bad_scans = yes
loopedit_date = Jul 06 2013 20:27:53, 7.22.4
loopedit_in = C:\Users\zij\Desktop\2013-POWOW3-HNL2SanDiego\data\CTD\km1312_s01_c01_ctd001.cnv
loopedit_minVelocity = 0.250
loopedit_surfaceSoak: minDepth = 5.0, maxDepth = 40, useDeckPress = 1
loopedit_excl_bad_scans = yes
binavg_date = Jul 06 2013 20:28:10, 7.22.4
binavg_in = C:\Users\zij\Desktop\2013-POWOW3-HNL2SanDiego\data\CTD\km1312_s01_c01_ctd001.cnv
binavg_bintype = decibars
binavg_binsize = 1
binavg_excl_bad_scans = yes
binavg_skipover = 0
binavg_surface_bin = no, min = 0.000, max = 0.000, value = 0.000
file_type = ascii

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Data Files

File
CTD_KM1312.csv (Comma Separated Values (.csv), 9.06 MB) MD5:4b8d69d48e10b32e885f10828b3d7ffe Primary data file for dataset ID 518582

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Supplemental Files

File
POWOW3_CTD_plots.pdf (Portable Document Format (.pdf), 58.89 MB) MD5:51d2f56d6bfa777fc2edcd24333f50b7 Plots of CTD Casts from POWOW3 (KM1312) cruise

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Parameters

Parameter	Description	Units
CTD_num	CTD number (sequential for the cruise).	unitless

station	Station number (sequential based on location).	unitless
cast	Cast number (sequential; starts at 01 for each new location/station number). Some cast numbers may be missing/skipped for a given station because of aborted casts.	unitless
month_utc	2-digit month of year, UTC, at start of cast.	mm (01 to 12)
day_utc	2-digit day of month, UTC, at start of cast.	dd (01 to 31)
year	4-digit year at start of cast. in the format YYYY	unitless
time_start	Time (UTC) at start of CTD cast, 24-hour clock.	HHMM
lat_start	Latitude at start of CTD cast. Positive = North.	decimal degrees
lon_start	Longitude at start of CTD cast. Positive = East.	decimal degrees
depth_w	Depth of the water (bottom depth).	meters
ISO_DateTime_UTC	Date/Time (UTC) ISO8601 formatted. T indicates start of time string; Z indicates UTC.	YYYY-mm-ddTHH:MM:SS.ssZ
press	Pressure, Digiquartz.	decibars
temp	Temperature from primary sensor, ITS-68, measured in degrees Celsius.	degrees C
temp2	Temperature from secondary sensor, ITS-68, measured in degrees Celsius.	degrees C
cond	Conductivity from primary sensor measured in Siemens per meter.	S/m
cond2	Conductivity from secondary sensor measured in Siemens per meter.	S/m
O2_umol_kg	Oxygen measured by primary SBE 43 sensor in micromoles per kilogram.	umol/kg
O2_umol_kg2	Oxygen measured by secondary SBE 43 sensor in micromoles per kilogram.	umol/kg

fluor	Fluorescence measured by WET Labs ECO-AFL/FL in milligrams per cubic meter.	mg/m^3
fluor_spt	Fluorescence, Seapoint.	?
sal	Salinity from primary sensor in practical salinity units.	PSU
sal2	Salinity from secondary sensor in practical salinity units.	PSU
sigma_0	Sigma theta density from primary sensor in kilograms per cubic meter.	kg/m^3
sigma_0_2	Sigma theta density from secondary sensor in kilograms per cubic meter.	kg/m^3
potemp	Potential temperature from primary sensor, ITS-90, measured in degrees Celsius.	degrees C
potemp2	Potential temperature from secondary sensor, ITS-90, measured in degrees Celsius.	degrees C
beam_c	Beam attenuation measured by the WET Labs C-Star transmissometer.	1/m
par	PAR/Irradiance, Biospherical/Licor	?
nbin	Number of scans per bin.	unitless

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Instruments

Dataset-specific Instrument Name	CTD SBE 9
Generic Instrument Name	CTD Sea-Bird 9
Generic Instrument Description	The Sea-Bird SBE 9 is a type of CTD instrument package. The SBE 9 is the Underwater Unit and is most often combined with the SBE 11 Deck Unit (for real-time readout using conductive wire) when deployed from a research vessel. The combination of the SBE 9 and SBE 11 is called a SBE 911. The SBE 9 uses Sea-Bird's standard modular temperature and conductivity sensors (SBE 3 and SBE 4). The SBE 9 CTD can be configured with auxiliary sensors to measure other parameters including dissolved oxygen, pH, turbidity, fluorometer, altimeter, etc.). Note that in most cases, it is more accurate to specify SBE 911 than SBE 9 since it is likely a SBE 11 deck unit was used. more information from Sea-Bird Electronics

Dataset-specific Instrument Name	LI-COR Biospherical PAR
Generic Instrument Name	LI-COR Biospherical PAR Sensor
Generic Instrument Description	The LI-COR Biospherical PAR Sensor is used to measure Photosynthetically Available Radiation (PAR) in the water column. This instrument designation is used when specific make and model are not known.

Dataset-specific Instrument Name	SBE-43 DO
Generic Instrument Name	Sea-Bird SBE 43 Dissolved Oxygen Sensor
Generic Instrument Description	The Sea-Bird SBE 43 dissolved oxygen sensor is a redesign of the Clark polarographic membrane type of dissolved oxygen sensors. more information from Sea-Bird Electronics

Dataset-specific Instrument Name	ECO AFL/FL
Generic Instrument Name	Wet Labs ECO-AFL/FL Fluorometer
Generic Instrument Description	The Environmental Characterization Optics (ECO) series of single channel fluorometers delivers both high resolution and wide ranges across the entire line of parameters using 14 bit digital processing. The ECO series excels in biological monitoring and dye trace studies. The potted optics block results in long term stability of the instrument and the optional anti-biofouling technology delivers truly long term field measurements. more information from Wet Labs

Dataset-specific Instrument Name	WL CSTAR Trans
Generic Instrument Name	WET Labs {Sea-Bird WETLabs} C-Star transmissometer
Generic Instrument Description	The C-Star transmissometer has a novel monolithic housing with a highly intgrated opto-electronic design to provide a low cost, compact solution for underwater measurements of beam transmittance. The C-Star is capable of free space measurements or flow-through sampling when used with a pump and optical flow tubes. The sensor can be used in profiling, moored, or underway applications. Available with a 6000 m depth rating. More information on Sea-Bird website: https://www.seabird.com/c-star-transmissometer/product?id=60762467717

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Deployments

KM1312

Website	https://www.bco-dmo.org/deployment/515629
Platform	R/V Kilo Moana
Report	http://dmoserv3.whoi.edu/data_docs/POWOW/POWOW3-cruise_report.pdf
Start Date	2013-07-01
End Date	2013-07-28
Description	From the cruise report: The POWOW#3 cruise was the third in a series of cruises to study the influence of temperature and other environmental variables on Prochlorococcus, its viruses and other members of the microbial community in the Northern Pacific Ocean. The primary goal of this cruise was to measure the abundance, diversity and activity of Prochlorococcus and associated bacterial and viral communities across temperature (and other environmental) gradients to understand how climate change may impact ocean ecology and biogeochemistry. There are many additional scientific and broader impact goals including characterizing oxidative stress and investigating nitrogen uptake/utilization molecular diversity. The official title of the project is "Collaborative Research: Seasonal and decadal changes in temperature drive Prochlorococcus ecotype distribution patterns" and it is part of NSF #1031064 (Duke) and 1030518 (UTK). Cruise information and original data are available from the NSF R2R data catalog.

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Project Information

Seasonal and decadal changes in temperature drive Prochlorococcus ecotype distribution patterns (POWOW)

Website: http://oceanography.ml.duke.edu/johnson/research/powow/

Coverage: Eastern North Pacific Ocean

Project also known as '*Prochlorococcus* Of Warming Ocean Waters' (POWOW).

The two numerically-dominant ecotypes of the marine cyanobacterium *Prochlorococcus* partition the surface ocean niche latitudinally, with ecotype eMIT9312 dominant in the 30 degree N to 30 degree S region and eMED4 dominant at higher latitudes. These ecotypes may account for 25-50% of primary production in open ocean ecosystems, but this percentage is dependent on which ecotype dominates. The relative abundance of the two ecotypes follows a log-linear relationship with temperature, with the transition from eMIT9312 to eMED4 occurring at approx. 18 degrees C. From these descriptive data, it has been hypothesized that temperature is the primary driver of relative abundance. Their contribution to net primary production, however, appears to be independent of temperature, suggesting temperature regulates ecotype dominance through photosynthesis-independent mechanisms.

To test these hypotheses, the PIs are undertaking a series of field and lab studies to investigate the effect of temperature change on the distribution of these ecotypes. Two cruises in the North Pacific will trace the transitions from eMIT9312- to eMED4-dominated regions, with one cruise during the winter and the other during summer. They have hypothesized that the ratio of ecotype abundance will move latitudinally with the seasonal shift in temperature gradient: migration of the 18 degrees C isotherm northward in the summer will be matched by a similar migration of the 1:1 ecotype transition point. Multiple crossings of the 18 degrees C isotherm are proposed, and the summer cruise will also follow the isotherm to the Western US coast to gain insight on physical and geochemical influences. Environmental variables such as nutrient concentrations, light/mixing depths, and virus /grazing based mortality, which may impinge on the relationship between temperature and ecotype ratio, will be assessed through a series of multivariate analyses of the collected suite of physical, chemical and biological data. Seasonal comparisons will be complemented with on-deck incubations and lab competition assays (using existing and new isolates) that will establish, for the first time, how fitness coefficients of these ecotypes relate to temperature. As latitudinal shifts in temperature gradient and migration of ecotypes during seasonal warming likely share common features with high latitude warming as a consequence of climate change, the investigator's analyses will contribute important biological parameters (e.g., abundances, production rates, temperature change coefficients) for modeling biological and biogeochemical responses to climate change. This research will be integrated with that of committed collaborators, generating data sufficient for ecosystem-scale characterizations of the contributions of temperature (relative to other forcing factors) in constraining the range and seasonal migration of these numerically dominant marine phototrophs.

Publications produced as result of this research:

Rowe, J.M., DeBruyn, J.M., Poorvin, L., LeCleir, G.R., Johnson, Z.I., Zinser, E.R., and Wilhelm, S.W. 2012. Viral and bacterial abundance and production in the Western Pacific Ocean and the relation to other oceanic realms. FEMS Microbiology Ecology, 72, p. 359. DOI: 10.1111/j.1574-6941.2011.01223.x

Morris, J.J., Lenski, R.E. and E.R. Zinser. 2012. The Black Queen Hypothesis: Evolution of Dependencies through Adaptive Gene Loss. mBio, 3, p. e00036-12. DOI: 10.1128/mBio.00036-12

Morris, J.J., Johnson, Z.I., Szul, M.J., Keller, M., and Zinser, E.R. 2011. Dependence of the cyanobacterium *Prochlorococcus* on hydrogen peroxide scavenging microbes for growth at the ocean's surface. PLoS One, 6(2), p. 16805. DOI:10.1371/journal.pone.0016805

Ringuet, S., Sassano, L., and Johnson, Z.I. 2011. A suite of microplate reader-based colorimetric methods to quantify ammonium, nitrate, orthophosphate and silicate concentrations for aquatic nutrient monitoring. Journal of Environmental Monitoring. DOI:10.1039/C0EM00290A

Ritchie, A.E. and Johnson, Z.I. 2012. Abundance and genetic diversity of aerobic anoxygenic phototrophic bacteria of coastal regions of the Pacific Ocean. Applied and Environmental Microbiology, 78, p. 2858. DOI: 10.1128/AEM.06268-11

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-1031064
NSF Division of Ocean Sciences (NSF OCE)	OCE-1030518

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