

Science Report for Week 1 of LTER 1701.

The LTER 1701 cruise departed Palmer Station on January 6, 2017, and proceeded to conduct a three-day process study in the sea floor canyon adjacent to the Palmer Station. The goal is to better understand the ecosystem dynamics in the canyon and how they shape the foraging strategies of the resident penguin colonies near Palmer Station. The process study consisted of along shore line along and across the canyon. The sampling consisted of full stations combined with day-night Mocness tows. A map of the station locations are provided in Figure 1. The stations mirrored stations in past years allowing for a comparison also between the years. Upon completion of the process station, the began its annual survey of the Peninsula running out initially along the 600-line on the LTER grid. By the end of the first week, the team has completed the 600, 500, 400 and 300 lines. This puts the team in a good position to put the birders ashore at Avian Island and layout the specifics for the next process study.

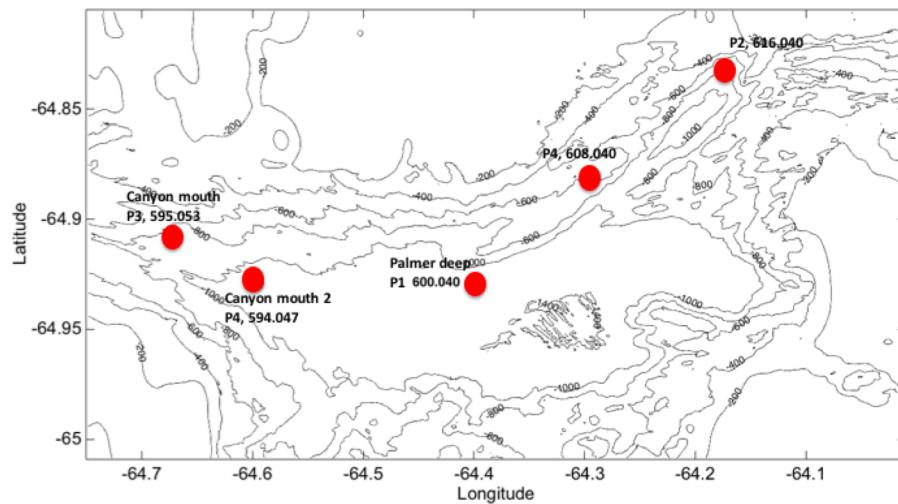


Figure 1. Map of location and the full stations sampled during Process Study 1 during LTER 1701.

B019: Phytoplankton and Primary Productivity Component (O. Schofield, Rutgers University; PI).

Field Team Members: Oscar Schofield, Paul Falkowski, Darren McKee, Schuyler Nardelli, Jonathan Sherman, Anjali Suman.

The objective of our component is to obtain a mechanistic understanding of the bio-physical controls that determine the overall primary productivity and phytoplankton community composition along the Western Antarctic Peninsula. Specific focus areas include improved understanding how the interactions between the physics, nutrient availability drive the overall carbon fixation in the upper ocean and how that is related

to the structure function of the higher trophic levels. Our routine measurements include discrete measurements of chlorophyll *a*, chemotaxonomic pigments via high performance liquid chromatography, fluorescence induction and relaxation kinetics to derive estimates of the optical cross section of photosystem II and the maximum quantum yield of electron transport, whole water carbon fixation rates. These discrete measurements are complemented with watercolumn bio-optical profiles of the absorption and attenuation properties at nine wavelengths, optical backscatter at a single wavelength, and chlorophyll and colored dissolved organic matter fluorescence. For this cruise we are also genomic samples (RNA and DNA) for Professor Adrian Marchetti at the University of North Carolina at Chapel Hill. Finally, joining on this cruise is Professor Paul Falkowski and his graduate student Jonathan Sherman (Rutgers University) that are providing a wide range of chlorophyll fluorescence instrumentation that will be used to assess the physiological status of the phytoplankton populations (see below).

During the first week of operations we have collected our full suite of water column profiles of discrete measurements at 14 Stations, 5 of which were collected during the first process study conducted in the Palmer Deep canyon. These measurements have been complemented with a series deckboard experiments. Samples, collected by the CTD, are being incubated with an addition of iron to assess micronutrient limitation of the phytoplankton populations.

A major focus for our science this year is on the photochemistry of the phytoplankton. In the 1930's a German scientist, Kautsky, noticed that when a blue light was shone on a leaf in the dark, the leaf glowed red. The phenomenon is due to the fluorescence of the green chlorophyll molecules in the leaf. But Kautsky also noted (with his naked eyes) that the intensity of the fluorescence changed over a period of a few seconds. The "Kautsky" effect, or the "induction" curve is only observable in live photosynthetic cells. In the 1970's, Warren Butler closely examined and modeled the initial rise in fluorescence and showed that the changes could be quantitatively related to how efficient any photosynthetic organism converts light to chemical bond energy. The logic is actually pretty simple - Light absorbed by a photosynthetic organism has three possible fates: it can move electrons (which is the basis of photosynthesis), be re-emitted as fluorescence, or dissipated as heat. The latter two processes are waste products. Butler reasoned that in the dark the potential for a photosynthetic organism to partition the energy of the sun into the three processes can be described simply as the sum of three rates:

$$\Phi_{\text{totalD}} = k_p + k_f + k_t \quad (1)$$

where Φ_{totalD} is the total *potential* fate of absorbed light (= 1.0; remember, the cells are in the dark), k_p is the rate constant for photochemistry, k_f is the rate constant for fluorescence, and k_t is the rate constant for thermal loss (heat). The three k's have values between 0 and 1.0. Let's imagine that we now expose the cell or organism to very high light, such that all the photosynthetic machines are working and they can't work any faster. In that condition, k_p will go to zero. In that situation

$$\Phi_{\text{totalL}} = k_f + k_t \quad (2)$$

Where Φ_{totalL} is the *actual* fate of absorbed light when k_p is nil. In this condition, fluorescence rises to its maximum value, F_m , because absorbed photons can not do any more work (i.e., they can't move electrons because all of the machines are already busy). The difference between Φ_{totalD} and Φ_{totalL} is k_p :

$$k_p = \Phi_{\text{totalD}} - \Phi_{\text{totalL}} \quad (3)$$

Empirically, $\Phi_{\text{totalD}} - \Phi_{\text{totalL}}$ is the initial change in fluorescence (originally observed by Kautsky), or the “variable” fluorescence, F_v . When F_v is normalized to (divided by) F_m the result is the quantum yield of photochemistry – that is the efficiency by which absorbed light can be used to move electrons (i.e., “work”). Over several decades we have designed and built very sensitive sea-going fluorometers that are capable of measuring F_v/F_m very precisely. The latest incarnation of this class of instruments is called FIREs (fluorescence induction and relaxation experiment) and can measure F_v/F_m underway every second using flow through cuvettes. We brought two of these instruments on the Gould – one is dedicated to the flow through measurements, the second is used for discrete measurements in the lab.

While the variable fluorescence measurements from the FIRE instruments tell us a lot about how phytoplankton photochemistry changes in response to the environment, we also wanted to “close” the energy budget for absorbed photons. To that end, we have a choice of measuring k_f or k_t . From a technical perspective, it is easier to measure k_f – but we needed to build another instrument – one that measures the lifetime of chlorophyll fluorescence in the picosecond (10^{-12} s) time domain.

The logic of that measurement is also relatively straightforward. The absorption spectrum of chlorophyll has two major bands – one in the blue (the “Soret” band) and one in the red (the “Q_v” band). The latter is the spectral manifestation of electrons in chlorophyll molecules that populate the lowest excited state orbitals. Now, imagine

that all those electrons returned to their ground state (there would be no absorption of light by the molecules under that condition), and the only fate of the change in energy from the lowest excited state to the ground state was fluorescence. This condition cannot be experimentally determined but can be calculated based on relatively simple statistical quantum mechanics. The result is that the population of electrons would

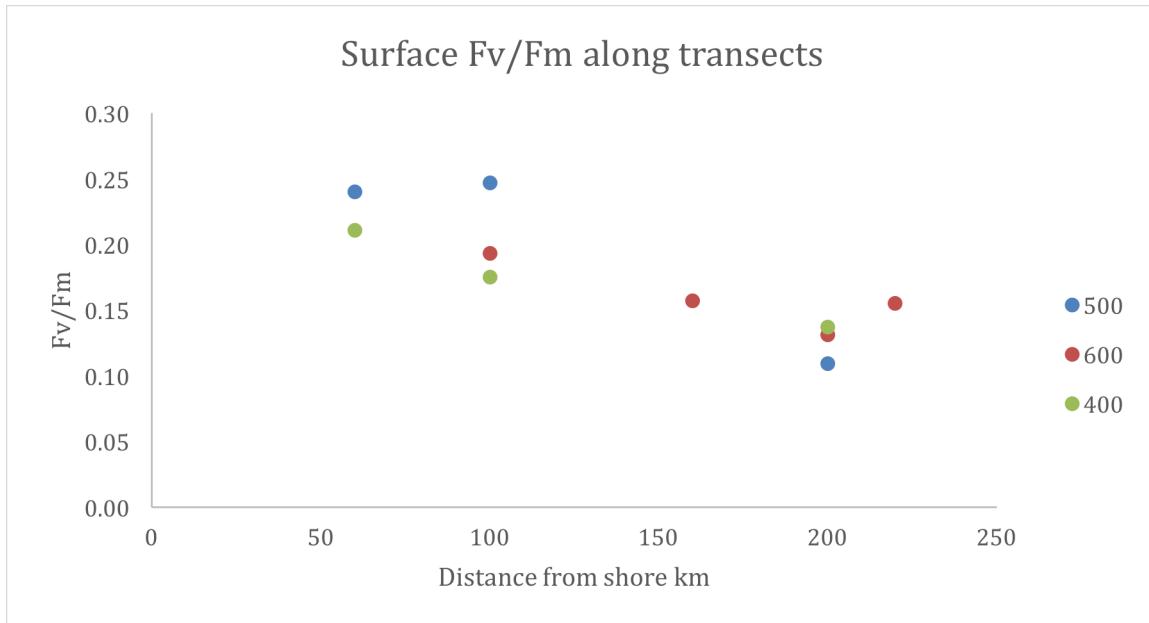


Figure 2. Changes in F_v/F_m plotted versus distance from the coast for three parallel transects separated by 100 km each. Note the decline in F_v/F_m as one moves seaward – that decline is consistent with nutrient limitation – most likely iron.

relax to the ground state in ~ 15 ns (10^{-9} s). That value is a constant for a specific molecule and is called the “natural” lifetime, τ_0 .

Now, let's consider the actual, measured fluorescence lifetime in a living cell, τ which has to be shorter than τ_0 , because there are two other potential fates for the electronic energy in the chlorophyll molecules – they can be used for photochemistry or generate heat. The ratio τ/τ_0 is the quantum yield of fluorescence, k_f in eq. 1. We built a fluorometer that measures fluorescence lifetimes in the picosecond time domain. The instrument is ultrasensitive and in the Gould, we plumbed it in series with the FIRE instrument so that measurements of both F_v/F_m and τ/τ_0 are made on the same samples at the same time. With measurement of both F_v/F_m and τ/τ_0 , we can solve for k_f . Our instruments show dramatic changes in photochemical energy conversion efficiency from close to the continental margin (where the efficiencies are high) to further offshore (where they are incredibly low). The data are consistent with iron limitation of photosynthesis seaward of the continental shelf/slope boundary.

The crew/RPSC support on the ship has been excellent. During the first week, the sea cable of the AC-9 optical instrument broke in heavy seas. The two ETs (Julian Race and Alec Chin) did excellent job identifying the problem and quickly devising a fix. The instrument is now being used routinely due to their fine efforts. Lindsey Loughry is doing excellent job coordinating between the large number effort occurring simultaneously.

C-045: Microbial Biogeochemistry Component (H. Ducklow, Lamont Doherty Earth Observatory; PI).

Field Team Members: Hugh Ducklow, Naomi Shelton, Mary McElroy, Israel Musan, Tyler Rohr, and Marie Zahn.

The objective of our component is to obtain a mechanistic understanding of the carbon cycle along the Western Antarctic Peninsula, and the roles of heterotrophic bacterioplankton and sinking particles in these geochemical transformations. We are also concerned with possible responses of the microbial foodweb and biogeochemical processes to climate warming. Our routine measurements include heterotrophic and autotrophic microbial abundance by flow cytometry conducted on-site, bacterial production by ^3H -leucine incorporation, as well as water column inventories of dissolved inorganic and organic carbon, particulate organic carbon and nitrogen and inorganic macronutrients. We are collecting samples for oxygen-18 analyses to determine glacial and meteoric inputs to seawater, in collaboration with LTER colleague Dr Mike Meredith (BAS-UK). We employ a new Equilibrator Inlet Mass Spectrometer (EIMS) to estimate Net Community Production while the ship is underway, continuing a time series of NCP estimates begun in 2008 in collaboration with Michael Bender and Kuan Huang (Princeton Univ) and Nicolas Cassar and Rachel Eveleth (Duke Univ). We deploy a time-series sediment trap to collect settling particles and determine the export flux from the upper ocean.

We continue to estimate particle export from the upper 200 meters using in situ measurements of the ^{238}U : ^{234}Th disequilibrium in the upper water column, research started by former postdoc Mike Stukel (now at Florida State). ^{234}Th measurements allow us to determine the export rate of ^{234}Th on particles that have sunk out of the water column during the roughly one month period of time prior to our occupation of a station. This measurement allows us to estimate carbon and nitrogen export, a key process contributing to atmospheric carbon storage in the deep sea. So far on this cruise Mary McElroy and Israel Musan (Team Thorium) have measured ^{238}U : ^{234}Th disequilibrium profiles at a total of 7 LTER stations.

Israela joins our group this year to sample the oxygen-17 of dissolved oxygen in seawater for her PhD at the Hebrew University of Jerusalem under the guidance of Professor Boaz Luz. From previous research, we know that atmospheric O₂ has lower ¹⁷O content than expected for O₂ of pure photosynthetic origin (bio-O₂). Bio-O₂ has an excess of ¹⁷O (¹⁷Δ) with respect to air O₂. Dissolved O₂ in seawater consists of two isotopic end members, one which is derived from gas exchange with air-O₂ and the other which is produced by photosynthesis in the ocean. Unlike O₂ concentration, ¹⁷Δ is not affected by respiration and preserves the ¹⁷Δ signature acquired in the upper water source regions of deep water masses. Thus, ¹⁷Δ is a unique conservative tracer in the deep sea and an archive of past productivity conditions at the source regions. In addition, because both photosynthesis and air-sea O₂ exchange depend on the physical properties of the water columns, including water stratification, the existence and thickness of sea ice, and light penetration, ¹⁷Δ records the timing and conditions in which the deep water formed. Preliminary measurements from the *Palmer LTER* shown that ¹⁷Δ is quite uniform and high at all depths in the Southern Ocean, providing a clear evidence that bio-O₂ is introduced from photosynthesis in the photic zone to the entire water column of the Antarctic Circumpolar Water (ACW).

On this year's cruise Israela will be sampling in the LTER grid to add to our data on ¹⁷Δ and what it can tell us about water mass origins and conditions in the shelf-slope region. The photo shows Israela in the LMG Baltic room sampling water from the CTD rosette with a specially-designed evacuated flask that preserves the dissolved oxygen signal of ¹⁷Δ. Samples will be returned to Hebrew University for analysis. Israela's research

further expands the PAL network of scientific collaboration on biogeochemical tracers in the WAP region.

During the first week of operations, we conducted most of the aforementioned measurements at LTER grid stations on the 600, 500 and 400 lines and at all five Process Study 1 Stations. Preliminary results from leucine incorporation experiments at 14 stations suggest bacterial abundance and activity show typical decreasing onshore to offshore gradients, consistent with



Figure 3. Israela sampling the CTD rosette during LTER 1701.

Primary productivity and Fv/Fm distributions, possibly in response to iron availability.

B-020. Zooplankton Component (D. Steinberg, VIMS; PI)

Field Team Members: Joe Cope, Patricia Thibodeau, Jack Conroy, Kharis Schrage, Katie Westmoreland.

The overall objective of our component in Palmer LTER is to understand the role that zooplankton community structure plays in biogeochemical cycling of carbon and nutrients, and the effects of climate change on zooplankton communities in the continental shelf sea of the west Antarctic Peninsula (WAP). This year, with three process study stations, we are examining the role that zooplankton play in the biological pump and in nutrient cycling (grazing, excretion, fecal pellet production, and diel vertical migration). We are focusing some of our sampling and experiments this year on the pteropod (pelagic snail), *Limacina helicina*, one of the most abundant zooplankton taxa in the WAP (**Fig.4**). Because of its calcium carbonate shell, this animal is susceptible to the effects of ocean acidification, thus there is much current interest in the status of this species in the WAP. Our aim is to identify environmental and physiologic mechanisms controlling pteropod biogeography as well as its influence on carbon cycling in the WAP food web.



Figure 4. The sea butterfly (pteropod) *Limacina helicina* with swimming wings extended from shell.



Figure 5. Ph.D. student Patricia Thibodeau conducting a pteropod respiration experiment.

In the first week, we concentrated our operations at the 3-day process study situated in the Palmer Deep canyon area and LTER grid point 600.040, as well as along the 600 and 500 grid lines. At each station we performed net tows for larger macrozooplankton (e.g., krill, salps) and smaller mesozooplankton (e.g., copepods). Animals from the macrozooplankton tows were identified and counted on board. We paired this with day and night sampling of zooplankton distribution at discrete depth intervals using the MOCNESS (Multiple Opening-Closing Net Environmental Sensing System) to investigate depth distribution and diel vertical migration of zooplankton. This year we saw a large salp bloom at the process study station, and along the 600 line. The water temperatures were high (up to 3 °C), a condition which favors salps. The MOCNESS tows indicated the salps were vertically migrating, with higher abundances during day at depth and at night in surface waters. We also found a high abundance of pteropods on the 600 line, especially at the shelf and slope stations. This was fortuitous and allowed us to collect enough live animals to start a pteropod metabolism experiment.

PhD student Tricia Thibodeau is conducting multi-stressor experiments to measure pteropod metabolism this year (**Fig. 5**). She is measuring the potential future effects of limited food availability (e.g., chlorophyll) and higher seawater temperature on pteropod metabolism (e.g., respiration and excretion) by conducting shipboard experiments exposing pteropods to elevated temperature and decreased phytoplankton (food), along with a present-day temperature and natural (higher) chlorophyll concentration control. She completed her first full experiment this week, with results currently being analyzed.

The crew/RPSC support on the ship has been excellent. The deployment of our net tows has been going smoothly with the expertise of the vessel pilots, marine technicians, and winch operators. The MOCNESS (Multiple Opening-Closing Net Environmental Sensing System), which in the past we regularly have some technical problems with, worked well on both casts. We appreciate all the help of the MTs and MST setting up incubators and other equipment for pteropod experiments

C-013: Seabird Component (W.R. Fraser Polar Associates, PI)

Field Team Members: Darren Roberts and Megan Roberts

The objective C-013's component of this year's cruise is to continue the long-term data

set of at-sea bird surveys to assess abundance and distribution across the LTER regional study grid. In addition, we plan to continue studies of Adélie penguin breeding and foraging ecology at Avian Island, which is located approximately 600 km south of Palmer Station. This southern study area located in Marguerite Bay provides a higher latitude comparison with seabird studies conducted at Palmer Station. Mainly focusing on Adelie Penguins (but also Southern Giant Petrels, Blue Eyed Shags, South Polar and Brown Skuas) we will assess how and if annual environmental variability (e.g. sea ice and snow conditions) affects population



Figure 6. A Wandering Albatross with a Cape Petrel for scale.

trends, foraging success and diet, growth rates, survival and recruitment, as well as seasonal dispersal. If ice conditions allow we also plan to conduct similar fieldwork at Charcot Island.

During the first week of bridge surveys we completed hourly surveys during Process Study 1 and transect and stationary surveys along the 600 and 500 lines of the LTER grid. Near shore we observed medium densities of Kelp Gulls, South Polar Skuas, and Southern Giant Petrels. Once off shore we came into high density groups of Cape Petrels which followed the ship for much of the 600 and 500 lines. We observed relatively high abundance of Southern Fulmars and Black Browed Albatross. In addition to the species

above we had some sightings of species that are relatively rare for the LTER. We observed three Wandering Albatross, three Grey-headed Albatross, and one Black-bellied Storm Petrel.

B-???. Whale Component (A. Friendlander, Oregon State University; PI)

Field Team Members: David Johnson, Julian Dale.

During the first week of the cruise the cetacean team (David Johnston and Julian Dale) conducted a series of visual

surveys, small boat operations

and Unoccupied Aircraft System

(UAS) flights. Visual surveys for

whales have generated 25

sightings of humpback whale

groups from the Palmer Deep

through the 500 line of the PAL

grid. Small boat operations are

conducted to collect individual

IDs of whales (through pictures of

their flukes and dorsals fins) as

well as biological samples

through a crossbow biopsy

system. Biopsy samples are used for population genetics studies, as well as to determine

sex, reproductive status and diet of individual whales. During the first week of the

cruise, the cetacean team collected 11 biopsy samples and 20 individual IDs through

photo-identification. An example of a fluke photo ID image is presented in figure 1.



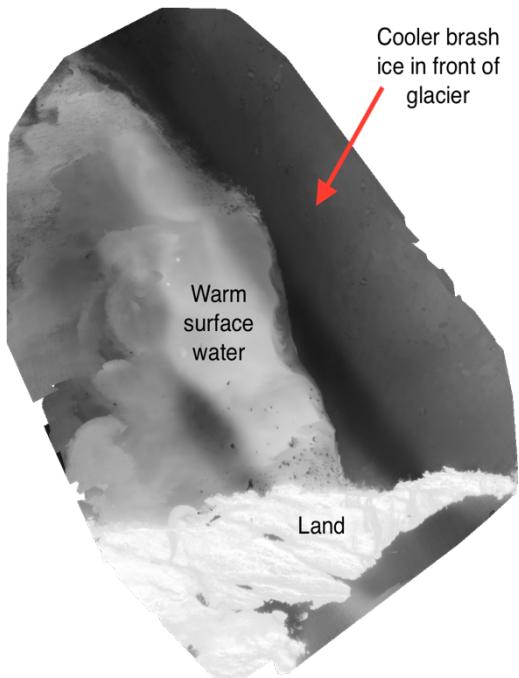
Figure 1. A photo-identification image of a humpback whale fluke collected in the Palmer Deep region



Figure 2. An orthomosaic image at 3cm ground sampling resolution of the bottom of Marr Glacier near Palmer Station.

The cetacean team also conducted the first official LTER UAS (aka drones) flights. Drone operations consisted of both fixed wing flights with a senseFly eBee and multirotor flights with a FreeFly Alta. Fixed wing flights will be used to support colony assessments for penguins and establish new approaches for water sampling. Initial operations consisted of test mapping missions behind Palmer Station with the standard RGB sensor (figure 2.) along with a test of the thermal mapping sensor over the water adjacent to the Marr glacier in

Arthur Harbor to look for fine scale sea surface temperature structure (figure 3).



The multirotor aircraft payload is designed to collect 4K video, thermal video and 24 megapixel still imagery of whales for photogrammetric assessments. Video data will be used to assess the feeding and social behavior of animals along with their thermal signature during these activities. Photogrammetric images will be used to measure the length and girth of individual whales, providing insight into their body condition. Multirotor flights were conducted on 2 days of the cruise so far, collecting approximately 100 minutes of whale behavior, thermal data, and over 80gb of still imagery of 7 individual humpback whales. These data will be integrated with biopsy and individual ID data mentioned above to provide a holistic assessment of each animal. A still image and ass

Figure 3. A thermal orthomosaic (14cm/pixel) of Arthur Harbor adjacent to the Marr glacier



Figure 4. Synoptic RGB and thermal video frame of a humpback whale surface adjacent to the Solas skiff in Arthur Harbor during LTER multirotor drone flight