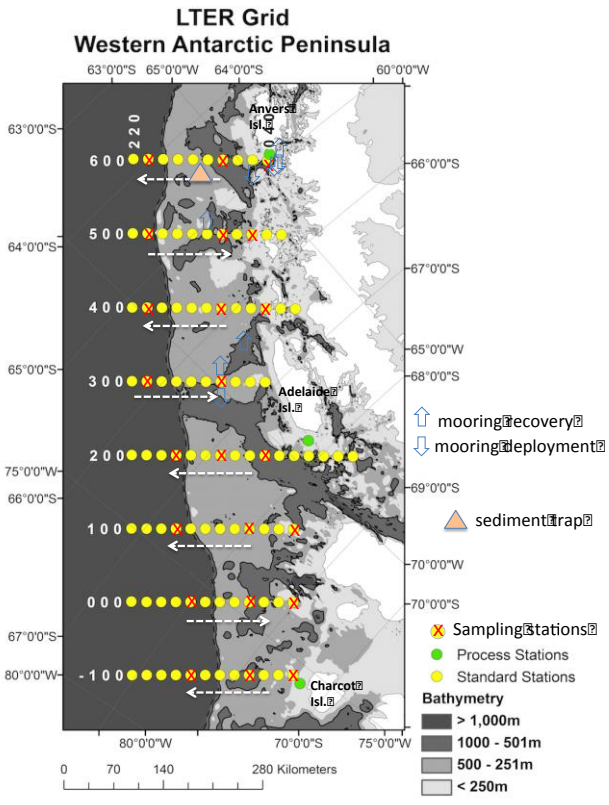
LMG 15-01: 29 Dec. 2014 – 09 February 2015, PAL LTER Cruise 23
Weekly Science Report I

LTER: Land-Shelf-Ocean Connectivity, Ecosystem Resilience and Transformation in a Sea-Ice Influenced Pelagic Ecosystem on the Western Antarctic Peninsula
&
Natural iron fertilization and bioactive metal dynamics on the Western Antarctic Peninsula shelf

Cruise Overview (Deborah Steinberg, Chief Scientist):

The overall long term objective of Palmer LTER is to understand the mechanistic linkages by which climate, physical oceanographic forcing and sea ice extent and duration control ocean productivity, food web processes, krill and penguin recruitment and carbon biogeochemistry in the marginal sea ice zone of the western Antarctic Peninsula (WAP) region. The WAP is one of the most rapidly-warming regions on the planet, and we have documented responses throughout the foodweb from phytoplankton to penguins. The annual oceanographic cruise (now in our 23rd year) provides a large scale regional view of physical-trophic-biogeochemical processes in the region, and contributes to a time series of ecosystem transformation in response to regional warming and sea ice loss. This year we also have Dr. Rob Sherrell's group (B-203-L) investigating iron and other trace metal distributions and dynamics in the region.



This cruise is about equally divided between 1) occupying standard LTER stations along the regional grid extending from Palmer Station to Charcot Island and from the inshore coastal region to deep (>3000 m) water off the continental shelf break in the Antarctic Circumpolar Current (**Fig. 1**), and 2) conducting three, 3-4 day mechanistic process studies along the Peninsula. This year's process studies are focused on the relationships among bathymetry (submarine canyons), physical oceanographic forcing, trace metal and nutrient distributions, phytoplankton and zooplankton community structure, and penguin and whale foraging. During the first week of the cruise, we completed Process Study I in the vicinity of Palmer Station in the Palmer deep submarine canyon (**Fig. 2**). We also adapted our sampling of a few stations to match potential upwelling and downwelling favorable regions (**Fig. 3**).

Figure 1. Map of LTER Study region along the Western Antarctic Peninsula, showing standard annual cruise grid stations. Sampling stations to be occupied on this cruise are shown with red X's; other activities are as indicated in legend. White arrows indicate direction of ship track, beginning at Palmer station on the north.

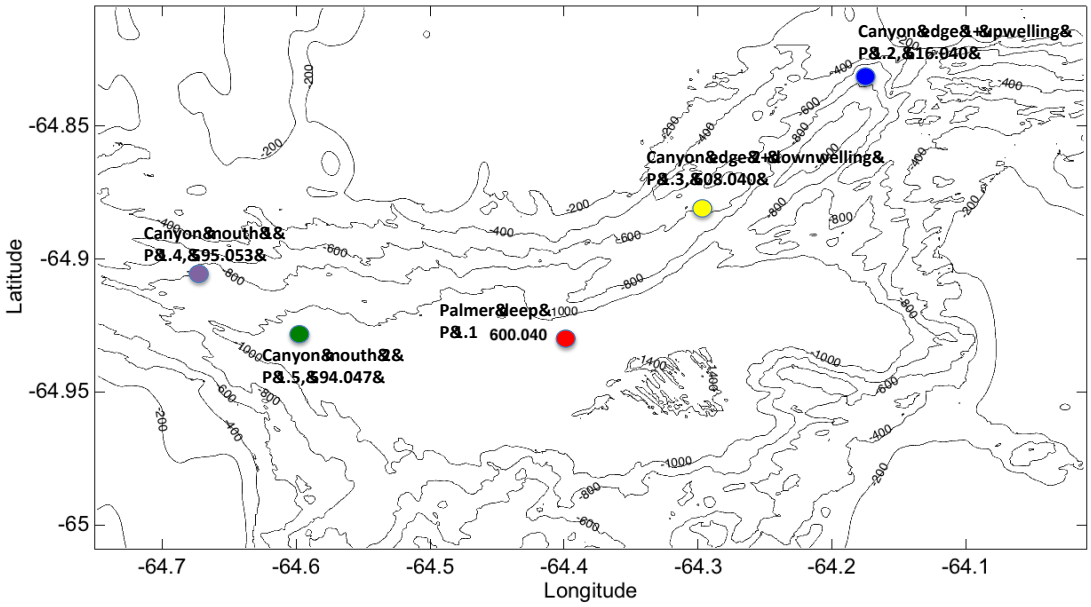


Figure 2. Map of stations occupied during LTER cruise Process Study 1, in and along the Palmer Deep submarine canyon. Bathymetery is in meters. LTER grid station 600.040 (Palmer Deep) is shown in red.

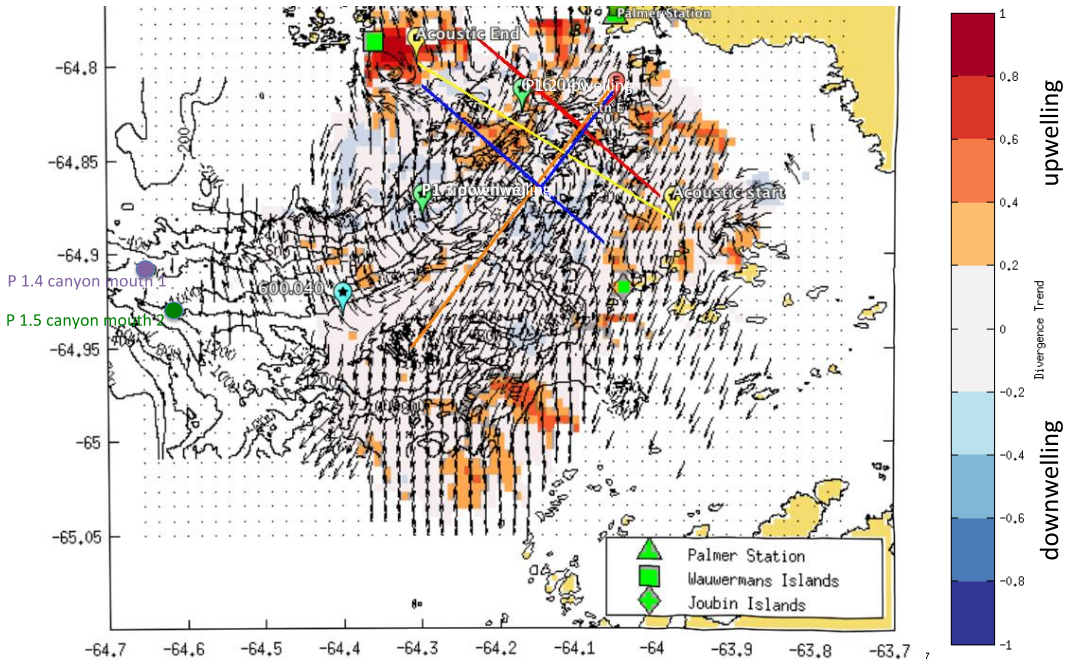


Figure 3. Map of stations occupied during LTER cruise Process Study 1, overlaid on 3-day composite of CODAR (surface current direction) from Josh Kohut and colleague's concurrent sampling project at Palmer Station. Also shown is an acoustic transect for krill distribution (yellow), and planned glider tracks. Note P 1.2 and P 1.3 are upwelling and downwelling favorable regions, respectively (CODAR data courtesy of J. Kohut).

As always, we received outstanding help from the ASC, Edison Chouest and Damco staff in Punta Arenas, at Palmer Station, and aboard the ship. The annual LTER cruise is a large and complex operation and we benefit greatly from the accumulated expertise and corporate memory of many dedicated colleagues and friends.

Individual component reports:

C- 021: Physical Oceanography Component (Doug Martinson, Lamont Doherty Earth Observatory; PI)

Field Team Member: Naomi Shelton

The physical oceanography component continues to have moorings deployed at four points of interest throughout the LTER grid. The moorings contain sensors throughout the vertical water column that monitor temperature, current, and pressure, which allow us to track movement of water masses throughout the year. So far this cruise we have successfully recovered the moorings located near Station E (Palmer Station), 500.120 (**Fig. 4**), and 347.088, with one remaining mooring to collect. We will be deploying 4 new moorings this year, three of which will be concentrated around the canyon near Palmer station.

Figure 4. Grappling the mooring line in preparation for recovery of mooring at 500.120, and all hands on deck pulling mooring on board.

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

Field Team Members: Naomi Shelton, Hyewon Kim, Kimberley Miner, Chelsea Petrenko, Leigh West.

The objective of this component is to obtain a mechanistic understanding of the carbon cycle along the Western Antarctic Peninsula, and the roles of heterotrophic bacterioplankton in these geochemical transformations. We are also concerned with possible responses of the microbial foodweb and biogeochemical transformations to climate warming. Our routine measurements include heterotrophic and autotrophic microbial abundance by flow cytometry conducted on-site, bacterial production by 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 sea ice and meteoric inputs to seawater, in collaboration with LTER colleague Dr. Mike Meredith (BAS-UK). We deploy a time-series sediment trap to collect settling particles and determine the export flux from the upper ocean. We are also studying new production and particle export by

measuring the 238U:234Th disequilibrium. 234Th measurements allow us to determine the export rate of 234Th 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. Finally, as part of an ongoing collaboration with Nicolas Cassar (Duke Univ.), we are using equilibrator inlet mass spectrometry (EIMS) to measure net community production (NCP) with high resolution. The instrument is continuously measuring gases dissolved in seawater from the ship's underway system. Measurements of O2/Ar supersaturation of surface waters will be used to constrain net community production (NCP) in the mixed layer. At steady-state, NCP is equal to new production and carbon export from the mixed-layer. We are interested in assessing the biogeochemical forcings on NCP and carbon export fluxes.

Our first port call at Palmer Station was very productive and the support staff at Palmer Station were monumentally helpfully in providing assistance with equipment needs and ensuring all supplies were on board. During the first week of operations, we conducted most of the aforementioned measurements at LTER grid stations on the 600 lines and at three Process Study 1 Stations in the Palmer Deep canyon. Bacterial production rates were similar across the process study stations. We were able to sort out instrumentation issues during the first week and ensure team members were aware of protocols and all samples were collected correctly. This season we have Hyewon Kim, who is a PhD student with Hugh Ducklow studying the interactions between physical and biological processes within seasonal dynamics in dissolved inorganic nutrients at Palmer Station. This is her first experience on an LTER cruise and she is very excited to gain a better understanding of the LTER fieldwork and all the aspects of the annual cruise.

C-019: Phytoplankton Component (Oscar Schofield, Rutgers; PI)

Field Team Members: Ana Filipa Carvalho, Mansha Seth-Pasricha, Philip Sontag, Cheryl Zurbrik

The objective of this component of the Palmer LTER is to understand the physiological ecology and the spatial/temporal distribution of phytoplankton along the WAP. Field efforts are focused on three areas. The first is to maintain the core time series of the Palmer LTER. Core time series of the phytoplankton time series are chlorophyll *a*, HPLC to provide phytoplankton accessory pigments, chlorophyll *a* fluorescence induction measurements of photosynthetic quantum yields, and daily 14C-radioisotope uptake experiments. This year we are adding species identification to the time series through selected SEM slides and preserved samples that will be counted microscopically. We additionally characterize the bio-optical properties of the water column to provide optical baseline measurements for remote sensing approaches. During the cruise we collect profiles of absorption/attenuation/backscatter at each LTER station. At selected stations (based on the time of the day), profiles of the spectral downwelling irradiance and upwelling radiance are collected. We use radiative transfer equations (e.g. HydroLight) to link the measurements of the apparent and inherent optical properties. Additionally during the cruise we conduct manipulation experiments to assess factor driving the overall community composition within the LTER grid during process stations. Finally, we support other efforts that rely on the LTER data. This year we are supporting collection of samples for meta-genomics (Beach, Stanford University), trace metals (Sherrell, Rutgers University), photosynthetic protein profiles (Bidle, Rutgers University), and genomically estimated growth rates (Kustka, Rutgers

University). The majority of the glider operations will be coordinated this year by the NSF sponsored Converge program being conducted at Palmer Station.

The first week of sampling during the first Process experiments was successful. Measurements (chlorophyll fluorescence) and 14C measurements indicated a moderate sized bloom spread out over the Palmer Deep canyon (**Fig. 5**). Daily water column integrated carbon fixation rates ranged 3-fold over the Palmer deep region, from 1894 to 5752 mgC fixed m^{-2} day^{-1}. These productivity rates are in the middle of historical rate measurements in the Palmer deep vicinity. Fluorescence induction measurements confirmed healthy populations with quantum yields ranging from 0.55 to 0.63. Lowest productivity rates were observed at the nearshore canyon head near Palmer Station. Offshore waters had higher productivity rates and there were indications that the productivity was increasing as we completed process station suggesting that Palmer Deep phytoplankton were blooming. The fleet of gliders deployed by the NSF LTER and Converge program will monitor the bloom dynamics after the RV Gould has left for its annual survey of the WAP as a whole.

During the process station we collected water for our first incubation experiment. A longstanding question for the Palmer LTER is to what degree the overall ecosystem productivity is shaped by deep seafloor canyons that potentially funnel warm circumpolar water towards the coast. Past glider deployments suggest enhanced phytoplankton productivity at the canyon flanks. This enhanced productivity may be driven by enhanced nutrient delivery of modified circumpolar water (mCDW) to the surface and/or the canyon provides an optimal light environment to promote phytoplankton growth. To study this we have initiated 5-day experiment to assess the factors leading to enhanced phytoplankton biomass by comparing the relative importance of A) light, B) enhanced iron delivered by the mCDW, and C) micrograzer grazing. This experiment will be sampled as the ship surveys the LTER grid this coming week.

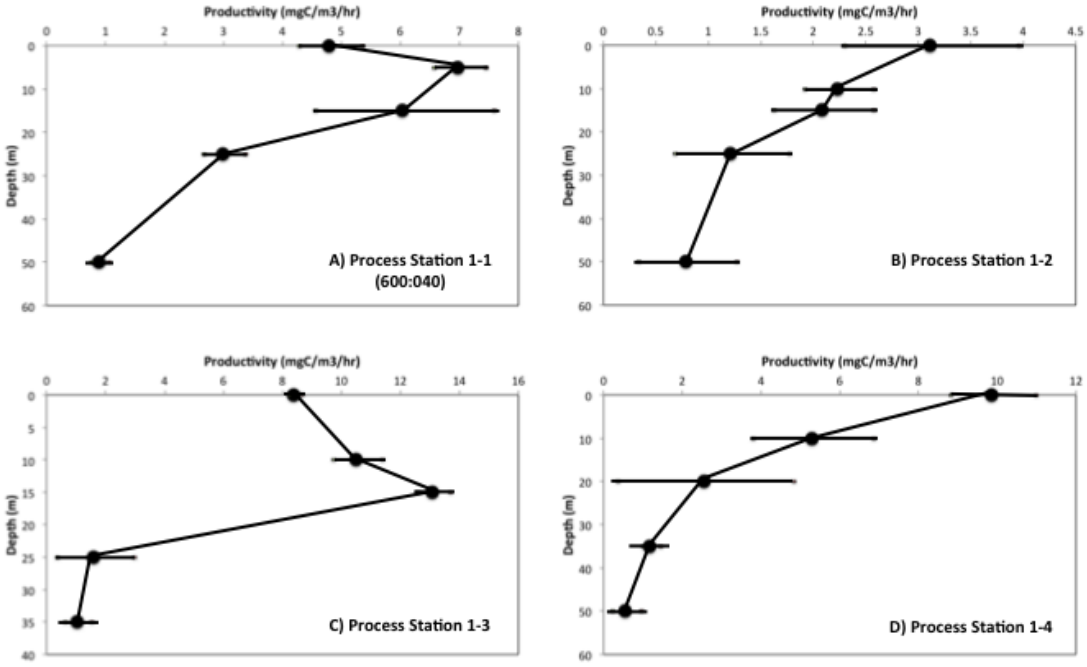


Figure 5. ^{14}C-derived productivity profiles collected during Process Station 1. The deep stations (Process Station 1-1 and 1-3) show peaks at depth associated with subsurface chlorophyll maximums.

Finally, intrusions of the mCDW represent the source of heat associated with the observed warming and associated changes in this ecosystem. These intrusions are ephemeral and short-lived making sampling difficult using ship-based sampling strategies. To that end we have initiated a glider effort to better understand these intrusions. On Christmas Day 2014, a deep-water glider was deployed and sent to survey the shelf and offshore canyon linked to Palmer Deep. The glider has encountered many intrusions of mCDW (**Fig. 6**). We will attempt to apply thermal wind equations to estimate of the transport of the water identified as mCDW. We conducted two ship-based ADCP surveys at the head of the nearshore and offshore entrance (**Fig. 7**). Ship data will be combined with glider data to provide more robust estimates of the heat inputs onto the WAP.

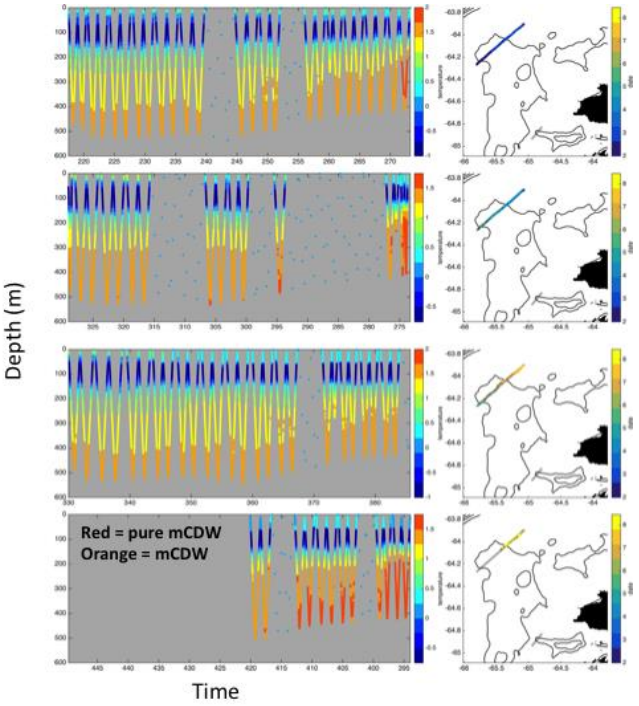


Figure 6. Deep water temperature surveys at the offshore mouth of the canyon that presumably feeds mCDW into the Palmer Deep.

Figure 7. Survey lines for Gould ADCP transects to complement ongoing glider efforts. Shorter line is positioned at the entrance to Palmer Deep submarine canyon, longer line at the shelf edge gateway.

C-020. Zooplankton Component (Debbie Steinberg, VIMS; PI)

Field Team Members: Deborah Steinberg, Joe Cope, Joshua Stone, Patricia Thibodeau, and Jack Conroy.

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. This year, with three process study stations, we are examining the role that zooplankton play in the biological pump and in nutrient cycling (grazing, dissolved organic matter excretion, particle or fecal pellet production, and diel vertical migration).

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 a pair of 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, while the presence/absence of taxonomic groups was noted in the mesozooplankton samples (and will be quantified at our home institution). We also take samples at selected stations for zooplankton gut fluorescence (a measure of grazing).

As in several past years, during the first Process Study we conducted a bio-acoustic survey as part of a collaboration with Dr. Kim Bernard, who is concurrently conducting similar surveys near Palmer Station. The purpose was to map out aggregations of krill in the Palmer Deep canyon over a diel cycle in order to explore relationships with whale distribution and penguin foraging locations. We pair 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 is the first cruise in 4 years that we have seen sizeable salp blooms, thus we have taken full advantage of this opportunity to sample and conduct experiments with salps. We had an unusual opportunity at the outer slope/ deep water station on the 600 line (600.200) to hand-collect salps for experiments. A large salp bloom, with salps clearly visible in surface waters, coupled with calm seas enabled us to gently dip net them from the ship, keeping these gelatinous animals in excellent shape for use in experiments. We also were able to quantitatively sample individual chains of salps and the large solitary stage, which were riddled with hyperiid amphipod (crustacean) parasites that we quantified (**Fig. 8**).

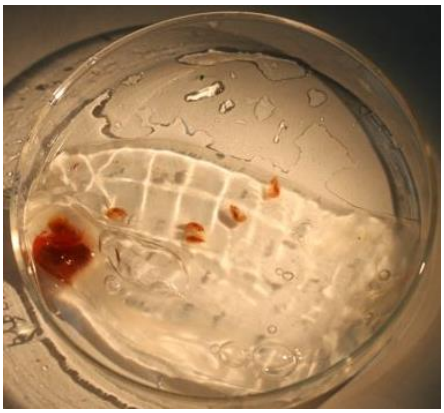


Figure 8. Large solitary stage salp with amphipod parasites (small orange crustaceans; large orange sphere to left is salp gut).

Figure 9. Ph.D. student Joshua Stone conducting salp carcass and fecal pellet sinking rate experiments.

We conducted two experiments measuring rates of dissolved organic matter (DOM) excretion by salps (*Salpa thompsoni*). These and other excretion experiments we are conducting this cruise will wrap up a set of experiments in collaboration with Hugh Ducklow's group measuring organic excretion by zooplankton, and uptake by bacteria of DOM excreted by different zooplankton taxa. We also completed 2 fecal pellet production rate experiments (on *Euphausia superba* and *Salpa thompsoni*) to continue our time series of the role that different zooplankton taxa play in particle export in the WAP, and salp carcass and fecal pellet sinking rate experiments (**Fig. 9**) to quantify the role of salps in particle export.

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.

C-013: Seabird Component (William Fraser, PI)

Field Team Members: Carrie McAtee and Ben Cook

The at-sea objective of the B-013 LTER component is to survey sea birds and marine mammals along the LTER regional study grid to continue the longstanding data set of abundance and distribution. Once on land at Avian, Charcot, and/or other island chains south of the Palmer Station Region we aim to study how the trends in diet and populations of more southern seabirds compare with those found near the Palmer Region. Mainly focusing on Adelie Penguins (but also Southern Giant Petrels, Blue Eyed Cormorants, South Polar and Brown Skuas) we will assess how and if annual environmental variability (e.g. sea ice and snow conditions) affects population trends, foraging success and diet, growth rates, survival and recruitment, as well as seasonal dispersal.

While in the Palmer Deep, we witnessed Chinstrap Penguins foraging for krill very near the surface and as expected numerous Southern Giant Petrels, Brown and South Polar Skuas (**Fig. 10**). Having just recently hit the traditional grid survey area, we've had the usual suspects following the ship; Cape Petrels (**Fig. 11**) and Southern Fulmars. Also observed thus far on the cruise are Black Browed Albatross, Wilson's and Black Bellied Storm Petrels, Grey-headed Albatross, Sooty-Shearwaters and a White Chinned Petrel. We also recorded Adelie and Gentoo Penguins (Gentoo noted only north of 600 grid line in the Palmer Region).

We're excited to be headed to Avian Island in the coming week, the land of close to 100,000 Adelie Penguins. Thanks to everyone who was involved in the logistics of prepping, loading and stowing all of our gear on the ship.

Figure 10. Seabirds in Palmer Deep and northern (600) grid line. Left: South Polar Skua flies by the bridge, Right: Cape Petrel pulls up just before a water landing.

C-024: Cetacean Biology & Ecology (Ari Friedlaender, Oregon State University, PI).

LMG 15-01: 29 Dec. 2014 – 09 February 2015, PAL LTER Cruise 23
Weekly Science Report I

Field Team Members: David Johnston (Co-PI). At Palmer Station: Andrew Read (Co-PI) & Zach Swaim.

The objective of this component of the Palmer LTER is to collect information on the distribution, movement patterns, behavior, and life history of whales around the Antarctic Peninsula to test ecological hypotheses regarding these top predators. We are interested in the most basic sense in understanding the demography and population structure of the whales that utilize this area as a feeding ground. To this end, we will be collecting skin and blubber biopsy samples as well as photographs of individual whale flukes. These data will be used to determine the sex ratio, pregnancy rates, breeding population identity and diet composition of humpback whales. We are also interested in the foraging behavior and movement ecology of these whales in relation to both physical and biological features of the seascape. In order to determine this, we will be deploying a number of location-gathering satellite-telemetry tags. The data from these instruments will allow us to determine location, movement patterns and broad scale behavior (e.g. feeding, traveling) of whales over long periods of time (months). By then linking the locations of foraging to oceanographic data collected under way and at stations we can begin to understand what features of the environment promote the necessary conditions for whales to feed. Likewise, we will also compare the amount of spatio-temporal overlap in foraging areas with other krill predators (e.g. Adelie penguins) to try and understand the interspecific interactions between these sympatric and krill-dependent animals.

During the first week of operations, we collected over 20 skin and blubber biopsy samples, deployed 5 satellite tags (**Fig. 12**) that are currently transmitting location information, and photographed over 20 individually identifiable whales (**Fig. 13**). We encountered roughly 130 whales over the course of the three-day process station period. The animals were generally found around the edge of the Palmer Deep Canyon as well as inshore in the vicinity of the Jouban Islands. Inshore surveys within the standard and extended boating area around Palmer Station found whales to the south of Janus Island and in Biscoe Bay to the east. Generally, the whales were found to be traveling or presumably deep feeding (based on dive times) during day time hours, and switched to bubble net and surface feeding in the evening hours. This cooperative feeding behavior is well known in humpback whale populations around the world but has never been quantitatively described from Antarctic waters (**Fig. 14**). Small boat operations have been flawless, and the MTs and ship's crew have maneuvered the boats on and off the water among the rest of the deck gear (and between the myriad other scientific requirements) with precision and aptitude. Both of the MTs that have driven for our operations have been excellent and have made the opportunities we have had as successful as possible.

Figure 12. Humpback whale with satellite tag visible below the dorsal fin.

Figure 13. Humpback whale flukes showing unique markings that allow individual animal identification.

Figure 14. Bubble net feeding humpback whales breaking the surface while feeding on krill near the surface in the Palmer Deep Canyon.

B-023: Trace Metals (Rob Sherrell, Rutgers U., PI).

Field Team Members: Rob Sherrell & Jessica Fitsimmons

The trace metals program has been going extremely well. Thanks to heroic efforts by the ASC ET's, the replacement trace metal CTD/rosette was assembled from parts sourced from the Gould and Palmer inventories, new purchases, and a very generous loan of the rosette frame from Dr. Kathy Barbeau (Scripps). Much work during the brief port call at Punta Arenas and during the relatively gentle Drake crossing yielded a working system before we arrived at Palmer Station. Teething pains on the first real deployment were tracked down to a bad connector, which was quickly re-fabricated by our excellent ASC team.

The trace metal team of PI Sherrell and Rutgers postdoc Jessica Fitzsimmons (**Fig. 15**) has been extremely busy sampling full profiles at each regular station for dissolved and particulate trace metals. In addition we are processing samples using ultrafiltration to distinguish truly soluble Fe from the very small colloidal particulate Fe that passes through conventional filters. We are also collecting samples for Fe isotopes and Nd isotopes, which will tell us about sources of Fe and transport paths from those sources into the WAP system. All of this work involves carrying the full Niskin bottles into our temporary clean room "bubble" built in the forward section of the Hydro Lab – this racking system working very well even though the space is tight.

The team has also been collecting surface water samples in high spatial resolution using the trace metal towfish. This system has supplied water for incubation experiments carried out at each station to determine the spatial distribution of Fe stress in the phytoplankton assemblage. An additional large incubation experiment has also been initiated, to test the relative bioavailability of soluble, colloidal and particulate Fe sourced from the deep waters of the Palmer Canyon, when mixed in various ratios with Fe-limited cells from off the shelf break between grid points 600.200 and 500.200.

We are very grateful for the support of our LTER colleagues and the incredibly capable ASC support staff.

Figure 15. PI Rob Sherrell (left), Rutgers Postdoc Jessica Fitsimmons (right), with MIT postdoc Cheryl Zurbrick of the Schofield team (middle) in front of the plastic clean room bubble in the Hydro Lab of the LM Gould.