Annual Report for Period: 09/2011 - 08/2012
Submitted on: 07/10/2012
Principal Investigator: Ducklow, Hugh W.
Award ID: 0823101
Organization: Marine Biological Lab
Submitted By:
Ducklow, Hugh - Principal Investigator
Title:
Palmer, Antarctica Long Term Ecological Research Project

Project Participants

Senior Personnel

Name: Ducklow, Hugh
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Fraser, William
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Martinson, Douglas
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Baker, Karen
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Simmons, Beth
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Schofield, Oscar
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Steinberg, Debbie
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Stammerjohn, Sharon
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Doney, Scott
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Friedlaender, Ari
Worked for more than 160 Hours: Yes
Contribution to Project:

Guest cruise participant

Name: McKee, Darren
Worked for more than 160 Hours: Yes
Contribution to Project:
physical oceanography data analysis and interpretation

Post-doc

Name: Montes-Hugo, Martin
Worked for more than 160 Hours: Yes
Contribution to Project:
Postdoc with M Vernet & O Schofield

Name: Kahl, Alex
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Saba, Grace
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Sailley, Sevrine
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Lunau, Mirko
Worked for more than 160 Hours: Yes
Contribution to Project:
Visiting Postdoc from Alfred-Wegener Institute, Germany; member of Ducklow field team 2011-12 (microbial biogeochemistry)

Name: Saenz, Ben
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Seguret, Marie
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Stukel, Michael
Worked for more than 160 Hours: Yes
Contribution to Project:
member of Ducklow field team 2011-12 (microbial biogeochemistry)

Graduate Student

Name: Fragoso, Glaucia
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Rukke, Kate
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Price, Lori
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Gorman, Kristen
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Guo, Jige
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Moeller, Heidi
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Gaas, Brian
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Randall-Goodwin, Evan
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Mankoff, Ken
Worked for more than 160 Hours: No
Contribution to Project:

Name: Donovan, Joan
Worked for more than 160 Hours: No
Contribution to Project:

Name: Stamieszkin, Karen
Worked for more than 160 Hours: Yes
Contribution to Project:
Cruise volunteer

Name: Luria, Catherine
Worked for more than 160 Hours: Yes
Contribution to Project:
Cruise participant and Palmer Station field team; working on PhD thesis

Undergraduate Student

Name: Gleiber, Miram
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Garzio, Michael
Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Cermino, Meghan
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Savard, Steven
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Wiley, Sean
Worked for more than 160 Hours: No
Contribution to Project:

Name: Peterson, Robert
Worked for more than 160 Hours: No
Contribution to Project:

Name: Gates, Lara
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Coleman, Kaycee
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Smoot, Caitlin
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Funkey, Carolina
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Armstrong, Frances
Worked for more than 160 Hours: Yes
Contribution to Project:
Cruise volunteer

Name: Paxton, Dominique
Worked for more than 160 Hours: Yes
Contribution to Project:
Cruise volunteer

Name: Moriarty, Pamela
Worked for more than 160 Hours: Yes
Contribution to Project:
member of Ducklow field team 2011-12 (microbial biogeochemistry)

Name: Snow, Amelia
Worked for more than 160 Hours: Yes
Contribution to Project:

member of Schofield field team (phytoplankton ecology)

Technician, Programmer

Name: Erickson, Matthew
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Waldron, Maggie
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Iannuzzi, Richard
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Cope, Joseph
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Patterson, Donna
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Blum, Jennifer
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Yeager, Kirstie
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Kerfoot, John
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Leonardis, Elizabeth
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Connors, James
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Wanetick, Jerome
Worked for more than 160 Hours: No
Contribution to Project:

Name: Yarmey, Lynn
Worked for more than 160 Hours: No

Contribution to Project:

Name: Kortz, Mason
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Lima, Ivan
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Haskins, Tina
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Ryan, Sean
Worked for more than 160 Hours: No
Contribution to Project:

Name: Couto, Nicole
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Travers, Mark
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Ducklow, Kelsey
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Mannas, Jennifer
Worked for more than 160 Hours: Yes
Contribution to Project:
Field assistant at Palmer Station and on LM GOULD

Name: Gordon, Jesse
Worked for more than 160 Hours: Yes
Contribution to Project:
Programmer in IM component

Other Participant

Name: Morgan, Tawna
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Smaniotto, Rick
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Rasmussen, Mark

Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Whiteley, Daniel
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Jones, Bethan
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Laber, Christian
Worked for more than 160 Hours: Yes
Contribution to Project:
Cruise lab assistant

Name: Snow, Amelia
Worked for more than 160 Hours: Yes
Contribution to Project:
Cruise lab assistant

Name: Irwin, Andrew
Worked for more than 160 Hours: Yes
Contribution to Project:
Cruise guest from Mt Allison Univ, Canada

Name: McKay, Luke
Worked for more than 160 Hours: Yes
Contribution to Project:
member of Ducklow field team 2011-12 (microbial biogeochemistry)

Name: Murgai, Nikhil
Worked for more than 160 Hours: Yes
Contribution to Project:
member of Ducklow field team 2011-12 (microbial biogeochemistry)

Research Experience for Undergraduates

Name: Cardman, Zena
Worked for more than 160 Hours: Yes
Contribution to Project:

Years of schooling completed: Junior
Home Institution: Other than Research Site
Home Institution if Other: University of North Carolina
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2009
REU Funding: REU supplement

Name: Jiang, Grant
Worked for more than 160 Hours: Yes
Contribution to Project:
Worked in Doney lab at WHOI on data synthesis and modeling

Organizational Partners

Old Dominion University

Woods Hole Oceanographic Institution

Simon Fraser University

University of South Florida

University of Wisconsin-Madison

COSEE

University of California-San Diego Scripps Inst of Oceanography

Fredericksburg Christian School

Point Reyes Bird Observatory

Smithsonian Institution

Santa Clara University

University of Quebec

University of Michigan

University of Delaware College of Marine Studies

California Polytechnic State University

University of Minnesota-Twin Cities

British Antarctic Survey

Antarctic Climate and Ecosystems Coopera

Catholic University of Louvain

Lamont-Doherty Earth Observatory of Columbia University

Boston Museum of Science
Education/outreach outlet for presentations and public outreach

Harvard University Harvard Forest

University of New Mexico

Centre National de la Recherche Scientif
Centre National de la Recherche Scientifique, Montpellier, France

Friedrich Schiller University
Jena, Germany

Alfred Wegener Institute Foundation for Polar a. Marine Research

H. T. Harvey & Associates
scientific collaboration with Drs Fraser & Stammerjohn

Institute of Arctic and Alpine Research

Jet Propulsion Laboratory

The Last Ocean Project
www.lastocean-project.org

NASA / Goddard Space Flight Center

National Center For Atmospheric Research

National Snow and Ice Data Center

Ohio University

University of Southampton

University of Texas at San Antonio

Other Collaborators or Contacts

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Bettina Meyer, Alfred Wegener Institut
Bill Sydemann Farallon Institute Advanced Ecosystem Research
Bjorn Alfthan IPY Oslo conference collaboration
Camille Aragon (Educator/Peace Corps Vol.) Chateaubelair Methodist Primary School, St. Vincent
Carolyn Whitehouse Ocean Night Rob Machado Foundation
Cassandra Brooks (The Last Ocean Project)
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Cheryl Peach Birch Aquarium at Scripps (BAS)
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Cyndy Chandler, WHOI
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David Schneider (NCAR)
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Florence Millerand, University of Michigan
Geoffrey Bowker, Santa Clara University
Hans Ulrich-Peter, Friedrich Schiller University, JENA, Germany
Hariett Linskey (director) Hands Across the Sea
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Ian Allison (ACE CRC, Australia)
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James T Hollibaugh, Univ of Georgia
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Janelle Schroeder (Reporter, Medill News Service, Chicago)
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Joan Emner
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Katherine Leitzel (Science Writer, NSIDC)
Katherine Leonard, LDEO
Katie Snider NOAA Ocean Today Kiosk Executive Producer
Ken Buesseler, WHOI
Kristin Evans Southwest Marine Educators Association/ National Marine Educators Association
Laurie Guest Mare Island Technology Academy (MARE)
Lisa Lawrence VIMS
Margaret Brumsted, Science Teacher, Dartmouth High School, MA.
Margi Dashevsky Schoolyard LTER book series
Mario Lebrato, Alfred Wegener Institut
Mark Moline, California Polytechnic State University, San Luis Obispo, California, USA
Martin Vancoppenolle, Universite Catholique de Louvain, Belgium
Mathew Oliver, University of Delaware, Lewes, Delaware, USA
Matthias Kopp, Friedrich Schiller University, JENA, Germany
Melissa Pitkin Point Reyes Bird Observatory
Naomi Oreskes, Dept of History, UCSD
Nell Hermann, Learning Enrichment/Gifted Support Specialist State College, PA.
Nicole Lovenduski (INSTAAR, CU Boulder)
Patricia Yager, UGA
Patti Hauck Fredericksburg Christian Elementary School
Paul Morin, University of Minnesota, Minneapolis, Minnesota, USA
Petra Heil, Australian ACE CRC
Rob Massom, Australian ACE CRC
Ron Kwok (JPL)

Ryan Fogt (Ohio University)
Sarah Barbrow & Steve Jackson (Outreach, University of Michigan/Cornell)
Sarah Dahl Fredericksburg Christian Middle School
Sharon McDonald (principal) Piaye Combined School, St. Lucia
Stan Jacobs, LDEO
Steve Ackley, UTSA
Steven McGee Co-chair Schoolyard LTER
Ted Maksym (WHOI)
Terry Forshaw, Amber Books, London
Thomas Scott Snider
Tom Hart, Institute of Zoology, London, UK.
Tony Williams, Simon Fraser University, BC, Canada
Tony Worby, Australian ACE CRC
Tsvetan Bachvaroff, Smithsonian Research Inst
Walker Smith (VIMS)
Wright Fredericksburg Christian School, Stafford Virginia
Xelu Moran, Spanish Institute of Oceanography, Xixon
Xiaojun Yuan, LDEO

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)
see attached PDF file, narrative of 2011-12 project activities

Findings: (See PDF version submitted by PI at the end of the report)
see attached file, narrative of 2011-12 project findings

Training and Development:
Palmer LTER provides access for undergraduate, graduate and postdoctoral students to Antarctica and the research infrastructure provided by the US Antarctic Program. PAL-LTER also provides mentoring opportunities for our students. We rely significantly on undergraduate volunteers and REUs to conduct our research; thus college undergrads are exposed to, and participate in real scientific research in the field as well as in the lab. Volunteer opportunities are also extended to teachers and non-scientist colleagues in order to broaden exposure to real-life scientific research and the USAP.

Outreach Activities:
All LTER Sites are mandated to maintain a high level of outreach in their programs. We employ a half-time Education & Outreach Coordinator (Beth Simmons). From our website:

Our Education and Outreach program teams scientists with local scientific and educational facilities engaging the 'K through gray' community in both the process and the understanding gained from this research. We train undergraduates, graduate students, and postdoctoral scholars across disciplinary boundaries. Through collaborations with formal and informal science education organizations, we reach many schoolchildren each year, including local low-income and minority students.

Journal Publications

Ducklow, H.;, "Microbial services: challenges for microbial ecologists in a changing world", Aquatic Microbial Ecology, p. 13-19, vol. 53, (2008). Published,

Ducklow, Hugh W.;, "Long-term studies of the marine ecosystem along the west Antarctic Peninsula", Deep Sea Research II, p. 1945-1948, vol. 55, (2008). Published,

Ducklow, Hugh W.;Doney, Scott C.;Steinberg, Deborah K.;, "Contributions of Long-Term Research and Time-Series Observations to Marine Ecology and Biogeochemistry", Annual Review of Marine Science, p. 279-302, vol. 1, (2009). Published,

Ducklow, Hugh W.;Erickson, Matthew;Kelly, Joann;Montes-Hugo, Martin;Ribic, Christine A.;Smith, Raymond C.;Stammerjohn, Sharon E.;Karl, David M.;, "Particle export from the upper ocean over the continental shelf of the west Antarctic Peninsula: A long-term record, 1992-2007", Deep Sea Research II, p. 2118-2131, vol. 55, (2008). Published,

F. Millerand, GC Bowker, "Metadata Standard: Trajectories and Enactment in the Life of an Ontology", Formalizing Practices: Reckoning with Standards, Numbers and Models in Science and Everyday Life, p. , vol. , (2009). Published,

Friedlaender, A. S.;Fraser, W. R.;Patterson-Fraser, D. L.;Qian, S. S.;Halpin, P. N.;, "The effects of prey demography on humpback whale (Megaptera novaeangliae) abundance around Anvers Island, Antarctica", Polar Biology, p. 1217-1224, vol. 31, (2008). Published,

Gasol, JM;Pinhassi, J;Alonso-Saez, L;Ducklow, H;Herndl, GJ;Koblizek, M;Labrenz, M;Luo, Y;Moran, XAG;Reinthaler, T;Simon, M;, "Towards a better understanding of microbial carbon flux in the sea", Aquatic Microbial Ecology, p. 21, vol. 53, (2008). Published,

Geisz, Heidi N.;Dickhut, Rebecca M.;Cochran, Michele A.;Fraser, William R.;Ducklow, Hugh W.;, "Melting Glaciers: A Probable Source of DDT to the Antarctic Marine Ecosystem", Environ. Sci. Technol., p. 3958, vol. 42, (2008). Published,

Kirchman, David L.;Moran, Xose Anxelu G.;Ducklow, Hugh;, "Role of temperature and potential impact of climate change", Nature Reviews - Microbiology, p. 451-459, vol. 7, (2009). Published,

Montes-Hugo, MA;Ducklow, H;Schofield, OM;, "Contribution by different marine bacterial communities to particulate beam attenuation", Aquatic Microbial Ecology, p. 13-22, vol. 379, (2009). Published,

Montes-Hugo, Martin;Doney, Scott C.;Ducklow, Hugh W.;Fraser, William;Martinson, Douglas;Stammerjohn, Sharon E.;Schofield, Oscar;, "Recent Changes in Phytoplankton Communities Associated with Rapid Regional Climate Change Along the Western Antarctic Peninsula", Science, p. 1470-1473, vol. 323, (2009). Published,

Patterson, D. L.;Woehler, E. J.;Croxall, J. P.;Cooper, J.;Poncet, S.;Peter, H. -U.;Hunter, S.;Fraser, W. R.;, "Giant Petrel Macronectes halli and the Southern Giant Petrel M. giganteus", Marine Ornithology, p. 115-124, vol. 36, (2008). Published,

Ribic, C. A.;E. W. Chapman;W. R. Fraser;G. L. Lawson;P. H. Wiebe;, "Top predators in relation to bathymetry, ice, and krill during austral winter in Marguerite Bay, Antarctica", Deep Sea Research II, p. 485-99, vol. 55, (2008). Published,

Rind, D.;J. Jonas;S. Stammerjohn;P. Lonergan;, "The Antarctic ozone hole and the Northern Annular Mode: a stratospheric interhemispheric connection", Geophysical Research Letters, p. doi: 10.1, vol. 36, (2009). Published,

Shearn-Bochsler, V. D.;Green, E.;Converse, K. A.;Docherty, D. E.;Thiel, T.;Geisz, H. N.;Fraser, W. R.;Patterson-Fraser, D. L.;, "Cutaneous and diphtheritic avian poxvirus infection in a nestling Southern Giant Petrel (Macronectes giganteus) from Antarctica", Polar Biology, p. 569-73, vol. 31, (2008). Published,

Siniff, D. B.;Garrott, R. A.;Rotella, J. J.;Fraser, W. R.;Ainley, D. G.;, "Projecting the Effects of Environmental Change on Antarctic Seals", Antarctic Science, p. 425-35, vol. 20, (2008). Published,

Stammerjohn, S. E.;D. G. Martinson;R. C. Smith;X. Yuan;D. Rind;, "Trends in Antarctic Annual Sea Ice Retreat and Advance and their Relation to ENSO and Southern Annular Mode Variability", Journal of Geophysical Research, p. doi: 10.1, vol. 113, (2008). Published,

Stammerjohn, Sharon E.;, Douglas G.;Smith, Raymond C.;Iannuzzi, Richard A.;, "Sea ice in the western Antarctic Peninsula region: Spatio-temporal variability from ecological and climate change perspectives", Deep Sea Research II, p. 2041-2058, vol. 55, (2008). Published,

Straza, Tiffany R. A.;Cottrell, Matthew T.;Ducklow, Hugh W.;Kirchman, David L.;, "Geographic and phylogenetic variation in bacterial biovolume using protein and nucleic acid staining", Appl. Environ. Microbiol., p. 4028, vol. 75, (2009). Published,

Baker, Karen S.;Chandler, Cynthia L.;, "Enabling long-term oceanographic research: Changing data practices, information management strategies and informatics", Deep Sea Research Part II: Topical Studies in Oceanography, p. 2132-2142, vol. 55, (2008). Published,

Clarke, Andrew;Meredith, Michael P.;Wallace, Margaret I.;Brandon, Mark A.;Thomas, David N.;, "Seasonal and interannual variability in temperature, chlorophyll and macronutrients in northern Marguerite Bay, Antarctica", Deep Sea Research Part II: Topical Studies in Oceanography, p. 1988-2006, vol. 55, (2008). Published,

Martinson, Douglas G.;Stammerjohn, Sharon E.;Iannuzzi, Richard A.;Smith, Raymond C.;Vernet, Maria;, "Western Antarctic Peninsula physical oceanography and spatio-temporal variability", Deep Sea Research II, p. 1964-1987, vol. 55, (2008). Published,

McClintock, J.;H. W. Ducklow;W. Fraser;, "Ecological responses to climate change on the Antarctic Peninsula", American Scientist, p. 414-422, vol. 96, (2008). Published,

Meredith, Michael P.;Murphy, Eugene J.;Hawker, Elizabeth J.;King, John C.;Wallace, Margaret I., "On the interannual variability of ocean temperatures around South Georgia, Southern Ocean: Forcing byEl Nino-Southern Oscillation and the Southern Annular Mode", Deep Sea Research II, p. 2007, vol. 55, (2008). Published,

Montes-Hugo, M. A.;Vernet, M.;Martinson, D.;Smith, R.;Iannuzzi, R.;, "Variability on phytoplankton size structure in the western Antarctic Peninsula (1997-2006)", Deep Sea Research Part II: Topical Studies in Oceanography, p. 2106-2117, vol. 55, (2008). Published,

Ross, Robin M.;Quetin, Langdon B.;Martinson, Douglas G.;Iannuzzi, Rich A.;Stammerjohn, Sharon E.;Smith, Raymond C.;, "Palmer LTER: Patterns of distribution of five dominant zooplankton species in the epipelagic zone west of the Antarctic Peninsula, 1993-2004", Deep Sea Research II, p. 2086-2105, vol. 55, (2008). Published,

Smith, Raymond C.;Martinson, Douglas G.;Stammerjohn, Sharon E.;Iannuzzi, Richard A.;Ireson, Kirk;, "Bellingshausen and western Antarctic Peninsula region: Pigment biomass and sea-ice spatial/temporal distributions and interannual variabilty", Deep Sea Research II, p. 1949-1963, vol. 55, (2008). Published,

Vernet, Maria;Martinson, Douglas;Iannuzzi, Richard;Stammerjohn, Sharon;Kozlowski, Wendy;Sines, Karie;Smith, Ray;Garibotti, Irene;, "Primary production within the sea-ice zone west of the Antarctic Peninsula: I--Sea ice, summer mixed layer, and irradiance.", Deep Sea Research II, p. 2068-2085, vol. 55, (2008). Published,

Wallace, Margaret I.;Meredith, Michael P.;Brandon, Mark A.;Sherwin, Toby J.;Dale, Andrew;Clarke, Andrew;, "On the characteristics of internal tides and coastal upwelling behaviour in Marguerite Bay, west Antarctic Peninsula", Deep Sea Research Part II: Topical Studies in Oceanography, p. 2023-2040, vol. 55, (2008). Published,

Ainley, David;Russell, Joellen;Jenouvrier, Stephanie;Woehler, Eric;Lyver, Philip O, "Antarctic penguin response to habitat change as Earth", Ecological Monographs, p. 49-66, vol. 80, (2010). Published,

Amaral-Zettler, L. A.;.;Ducklow, H. W.;Huse, S. M.;, "A Method for Studying Protistan Diversity Using Massively Parallel Sequencing of V9 Hypervariable Regions of Small-Subunit Ribosomal RNA Genes", PLoS ONE, p. doi:10.13, vol. 4, (2009). Published,

Aronova, E.;K. Baker;N. Oreskes;, "From the International Geophysical Year to the International Biological Program: Big Science and Big Data in Biology, 1957-present", Historical Studies in the Natural Sciences, p. 183-224, vol. 40, (2010). Published,

Chapman, Erik W.;Hofmann, Eileen E.;Patterson, Donna L.;Fraser, William R.;, "The effects of variability in Antarctic krill (Euphausia superba) spawning behavior and sex/maturity stage distribution on Ad????lie penguin (Pygoscelis adeliae) chick growth: A modeling study", Deep Sea Research II, p. 543, vol. 57, (2010). Published,

Montes-Hugo, M.;C. Sweeney;S. C. Doney;H. W. Ducklow;R. Frouin;D. G. Martinson;S. Stammerjohn;O. Schofield;, "Seasonal forcing of summer dissolved inorganic carbon and chlorophyll a on the Western Shelf of the Antarctic Peninsula", Journal of Geophysical Research-Oceans, p. doi:10.10, vol. 115, (2010). Published,

O. Schofield;H.W. Ducklow;D.G. Martinson;M.P. Meredith;M.A. Moline;W.R. Fraser;, "How Do Polar Marine Ecosystems Respond to Rapid Climate Change?", Science, p. 1520-1523, vol. 328, (2010). Published, Ainley, D.;Russell, J.;Jenouvrier, S.;Woehler, E.J.;Lyver, P.O???B.;Fraser, W.R.;Kooyman, G.L.;, "The derivation of a model ensemble useful to predict changes in penguin habitat", Ecological Archives, p. , vol. M080-00, (2010). Published,

Ainley, DG.;Jongsomjit, D.;Ballard, G.;Thiele, D.;Fraser, WR;Tynan, C.;, "Modeling the relationship of Antarctic minke whales to major ocean boundaries", Polar Biology, p. , vol. , (2011). Accepted,

Baker, Karen S.;Yarmey, Lynn;, "Data Stewardship: Environmental Data Curation and a Web-of-Repositories", International Journal of Digital Curation, p. , vol. 4, (2009). Published,

Bowker, Geoffrey C.;Baker, Karen;Millerand, Florence;Ribes, David;, "Toward Information Infrastructure Studies: Ways of Knowing in a Networked Environment", International Handbook of Internet Research, p. 97-117, vol. , (2010). Published,

Boyd, P. W.;Doney, S. C.;Strzepek, R.;Dusenberry, J.;Lindsay, K.;Fung, I.;, "Climate-mediated changes to mixed-layer properties in the Southern Ocean: assessing the phytoplankton response", Biogeosciences, p. 847-864, vol. 5, (2008). Published,

Boyd, P.W.;C.S. Law;S.C. Doney;, "Boyd, P.W., C.S. Law, and S.C. Doney, A climate change atlas for the ocean, Oceanography, in press (June 2011 issue).", Oceanography, p. 13-16, vol. 24, (2011). Published,

Buesseler, K. O.;McDonnell, A. Mp;Schofield, Oscar M. E.;Steinberg, Deborah K.;Ducklow, Hugh W.;, "High particle export over the continental shelf of the west Antarctic Peninsula", Geophysical Research Letters, p. 1-5, vol. 37, (2010). Published,

Chance, Rosie;Weston, Keith;Baker, Alex R.;Hughes, Claire;Malin, Gill;Carpenter, Lucy;Meredith, Michael P.;Clarke, Andrew;Jickells, Timothy D.;Mann, Paul;Rossetti, Helen;, "Seasonal and interannual variation of dissolved iodine speciation at a coastal Antarctic site", Marine Chemistry, p. 171-181, vol. 118, (2010). Published,

Chapman, E.W.;Hofmann, EE;Patterson, DL;Ribic, CA;Fraser, WR;, "Marine and Terrestrial Factors Affecting Adelie Penguin (Pygoscelis adeliae) Chick Growth and Recruitment off the Western 2 Antarctic Peninsula", Marine Ecology Progress Series, p. , vol. , (2011). Accepted,

Clarke, Andrew;Brierley, Andrew S.;Harris, Colin M.;Lubin, Dan;Smith, Raymond C.;, "Polar and ice-edge marine systems", Aquatic Ecosystems: Trends and Global Prospects, p. 319-333, vol. , (2008). Published,

Clarke, Andrew;Griffiths, Huw J.;Barnes, David K. A.;Meredith, Michael P.;Grant, Susie M.;, "Spatial variation in seabed temperatures in the Southern Ocean: Implications for benthic ecology and biogeography", Journal of Geophysical Research, p. , vol. 114, (2009). Published,

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Web/Internet Site

URL(s):
http://pal.lternet.edu/
Description:
Project Website, contains Palmer LTER data archives at:
http://oceaninformatics.ucsd.edu/datazoo/data/pallter/datasets

Other Specific Products

Product Type:

Data or databases

Product Description:
All oceanographic data collected in Palmer LTER since 1990:
http://oceaninformatics.ucsd.edu/datazoo/data/pallter/datasets
Sharing Information:
Open-access via Internet. Data fully documented with associated metadata

Product Type:

Teaching aids

Product Description:

K12 Lesson Plans for teachers. All found: http://pal.lternet.edu/outreach/educators/instructional_materials_resources/
* Carlson K & Simmons B (2011) Ecosystem Illustrations
* Carlson K. & Simmons B. (2011) Animal identification cards
* Simmons & Soder (2011) Students explore how organisms in an ecosystem depend on one another.
* Simmons & Soder (2011) Students compare the temperature and salinities of the World?s Ocean
* Simmons & Deal (2011) Animal Classification: How animals of the same genus survive in two different ecosystems.
* Simmons & Deal (2011) How are populations of organisms in marine food webs affected by changes in the physical and biological properties of that ecosystem?

Sharing Information:

work with individual teachers on lesson planning and development

Product Type:

Teaching aids

Product Description:

Simmons (2011) Evidence of Change, NOAA Ocean Today kiosk project http://oceantoday.noaa.gov/

Sharing Information:

Public website

Contributions

Contributions within Discipline:

Oceanography: Palmer LTER is an oceanographic research program, contributing inter- and multidisciplinary research, understanding and data on the marginal sea ice zone of the West Antarctic Peninsula, on rapid climate change and ecosystem responses.

Long-term ecological research: Palmer LTER recently passed the 20 year milestone for continuing observations along the Antarctic Peninsula, one of the most rapidly-warming and changing ecosystems on the planet. By enhancing and refining observation technologies, our program is a leader in the field of long term ecological studies, providing unique case studies of ecosystem change and transformation.

Contributions to Other Disciplines:

Science: As PAL LTER has expanded and diversified its observational capabilities in the past 5 years, we have become regarded as a model observing program for documenting and studying ocean climate change and ecosystem transformation. This has been shown recently by numerous presentation at national and international meetings, and through participation by PAL coPIs in many panels and boards (eg, NSF OPP Blue Ribbon Panel)

Information Management: PAL contributed to the fields of science and technology studies, communication studies, and infrastructure studies as well as information sciences and history of science (http://interoperability.ucsd.edu).

Contributions to Human Resource Development:

We train undergraduate, graduate and postdoctoral students in oceanography and marine ecology in the field (Antarctica) and laboratory at a number of Universities and Non-profit research institutions.

Our field program has traditionally attracted technicians and students interested in further training and experience in a variety of areas, including field project planning and logistics, protocol development and implementation, and data management and analysis. Many of these individuals remain with our program for 2-4 years, and eventually seek positions with state and federal governments or pursue graduate degrees. Two of our former technicians, Tawna Morgan and Rick Smaniotto, moved into positions with the Prince William Sound Science Center, Cordova, Alaska, and Montana Fish Wildlife and Parks, Bozeman, Montana, respectively.

Contributions to Resources for Research and Education:

PAL-LTER participates in the LTER Schoolyard LTER Program to provide introductions to scientific research and opportunities to contribute to our research effort by K-12 students. See: http://schoolyard.lternet.edu/

Other educational contributions:

Training and collaboration with Scott Snider in the use of Final Cut Express is ongoing to facilitate the development of additional educational video podcasts for the Ocean Today kiosk projects.

The Power of Stories with two-time Grammy award winning artists Bill Harley ideas on how to use stories in your interactions with children. (April, 2011)

Collaboration with Dr. Herrid at the National Center for Case Study Teaching in science writing and development of instructional case studies for teaching.

Partnerships with Boston Aquarium to set up video kiosks featuring our research.

Analysis of mooring data (detecting signal from noise) used as example in Martinson's course on Quantitative Methods of Data Analysis training graduate students.

Contributions Beyond Science and Engineering:

Conference Proceedings

Special Requirements

Special reporting requirements: None
Change in Objectives or Scope: None
Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:

Contributions: To Any Beyond Science and Engineering
Any Conference

RESEARCH FINDINGS: Palmer LTER 2011-12.

This brief Report highlights some recent results from field and lab-based research and data analyses, especially highlights from recent publications or recently submitted manuscripts. Publications are listed at the end of the text, to avoid duplication in each section, and entered into the Fastlane publication database.

Sea Ice and Climate (Sharon Stammerjohn).

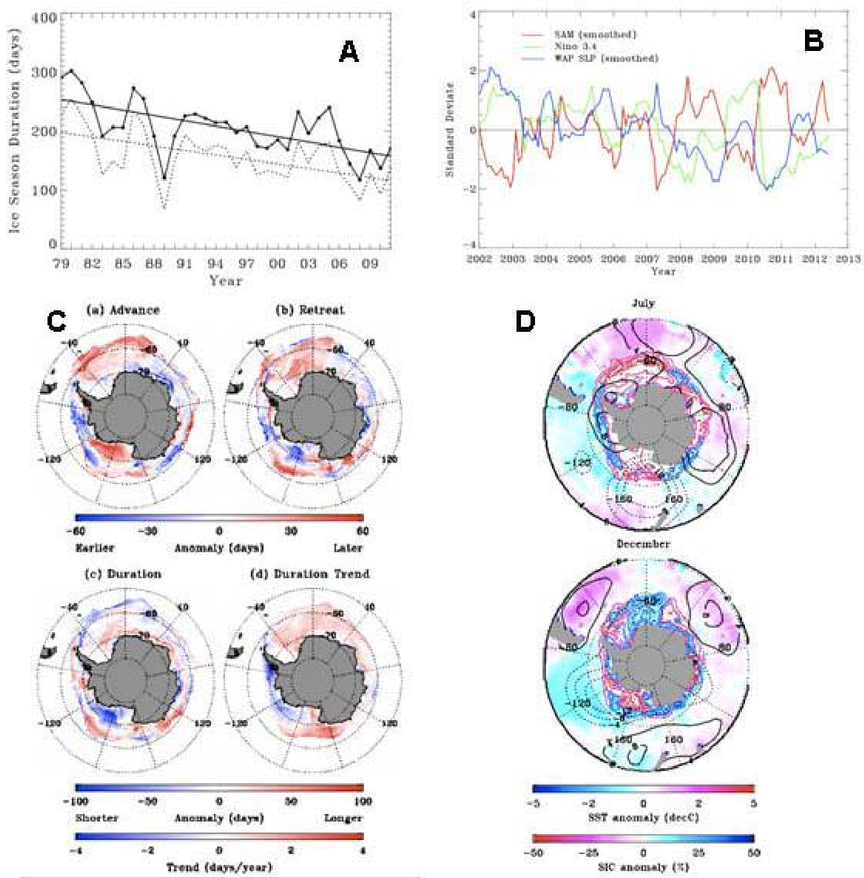


Figure 1: Clockwise from top left: (A) Ice season duration for PAL (solid line: -200 to 600 lines; dotted lines: 000 to 600 lines); (B) climate indices for ENSO (the Nino3.4 index) and SAM (Marshall, 2003) against WAP sea-level pressure (SLP); (C) 2011-12 anomalies for sea ice advance, retreat and duration against the 1979/80-2011/12 duration trend; and (D) July and December 2011 anomalies for SST (color shading), SLP (black contours) and sea ice concentration (color contours).

(1) Recalling that last year's sea ice season (2010-11) was the shortest on PAL record (1992-2010) for the area averaged over the original PAL study area (000 to 900 lines), this sea ice season (2011-12) was the longest compared to the last 5 years (**Fig 1A**). (Note, here we show the time series averaged over the -200 to 600 lines, solid curve, compared to the 000 to 600 lines, dotted curve.) Unlike last year (2010-11), which was characterized by a strong +SAM at high latitudes, La Nina conditions at low latitudes, and low sea-level pressure conditions west of PAL (**Fig 1B**), this sea ice season (2011-12) was characterized by a weakening La Nina in the tropical Pacific, a transition to –SAM conditions at higher latitudes and positive sea level pressure anomalies west of PAL during winter-spring. These quiescent conditions prevailed until December-January when there was an abrupt but short term shift to strong +SAM conditions

(+3.43, highest on record for December, and +3.08, 3rd highest for January; not explicitly shown in **Fig 1B** due to smoothing). The quiescent conditions favored an averaged to earlier autumn sea ice advance along the WAP and an averaged to later spring sea ice retreat in the northern PAL area (**Fig 1C**), which then transitioned to a slightly earlier sea ice retreat mid-peninsula during December and January in response to the increased northerly winds associated with the abrupt shift to +SAM conditions. Similar to the slight sea ice recovery observed in 2009-10, year 2011-12 stands in stark contrast to the 33-year trend (1979/80 to 2011/12), which otherwise shows strong decreases in ice season duration in the PAL and greater Bellingshausen Sea region (**Fig 1C**). The –SAM condition in 2011-12 is illustrated by the circumpolar sea level pressure anomaly pattern for July, showing strong positive pressure anomalies at high latitudes (**Fig 1D**). This is contrasted against the abrupt shift to +SAM conditions in December, showing strong negative pressure anomalies at high latitudes, particularly in the Amundsen Sea at 120W (concurrently, a zonal wavenumber 3 pattern is evident at mid latitudes). Year 2011-12 was also characterized by relatively strong negative sea surface temperature anomalies in the greater southeast Pacific region (**Fig 1D**) and cool conditions along the peninsula for most of the 2011 calendar year. This was in contrast to high surface air temperature anomalies in winter-spring exceeding +3°C over much of the Antarctic continent (not shown), more than 2 standard deviations above the long-term mean (Fogt et al., submitted).

The generally longer sea ice duration and later retreat were reflected in the extensive summer sea ice we encountered in southern Marguerite Bay on the 2012 cruise (see Activities report).

In summary, **Fig 1** illustrates our continued investigations of regional/circumpolar ice-climate assessments for PAL and also illustrates the types of derived ice-climate data we maintain (in DataZoo) in support of continued investigations of ecosystem response to climate variability and change.

(2) We continue to analyze the PAL underway ship data (temperature, salinity, pCO_2 and O_2), an effort initiated and maintained by my former research assistant, Nicole Couto, who is now Oscar Schofield's graduate student. We presented some of these analyses in a poster for the PAL site review in December 2011 (Couto et al., 2011); we hope to finalize this analysis for a manuscript this year. As described below, the 1-D modeling tool developed by my postdoc Ben Saenz in collaboration with Scott Doney, may aid our interpretation of the on/offshore relationships we reported last year. For example, offshore of the mid-peninsula (300-600 lines), a later sea ice retreat typically corresponds to cooler than normal SST, higher than normal pCO_2, and lower than normal primary production. The MLD is also shallower than normal, which is consistent with a later sea ice retreat (i.e., less time for wind-induced mixing). The question for the 1-D model is whether the high pCO_2 is due to recently exposed winter water (high in pCO_2) and/or the lack of a significant biological drawdown due to possible micronutrient limitation. Moving inshore, when there is a later sea ice retreat, there is also lower than normal SST and a shallower than normal MLD. But in contrast to offshore conditions, here there is lower than normal pCO_2 and higher than normal primary production. Is it the availability of coastal-derived (or sediment re-suspended) micronutrients that fuels the higher biological activity and greater pCO_2 drawdown inshore versus offshore? Perhaps the timing of sea ice retreat and lower winds inshore (inshore versus offshore) present more favorable conditions for larger or more sustained blooms. These are questions we can investigate by comparing contrasting years, against which we can also explore mechanisms using modeling approaches as described below.

(3) Using our greatly improved and refined 1-D ocean-ice-ecosystem model (Saenz et al., 2011), we are now examining in greater detail the yearly variability in ocean mixed layer dynamics in relation to surface forcing variability (sea ice, winds) and the corresponding biological response (**Fig 2**). Leading this effort is my postdoc Ben Saenz, with assistance from LTER Co-PI Scott Doney. Ben has successfully integrated the 1-D KPP ocean model with a 1-D version of the CESM biology/biogeochemical model, while also greatly improving the sea ice/snow model components based on his

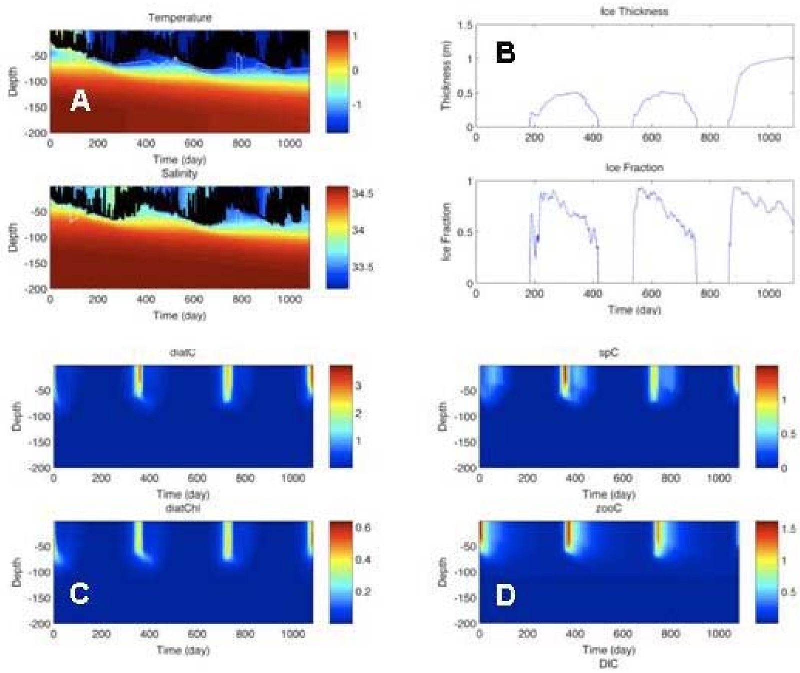


Figure 2: Example output of a 3-year simulation of the PAL mid-peninsula area from the 1-D ocean-ice-ecosystem model, clockwise from top left: (a) seasonal evolution of the upper ocean in temperature and salinity; (b) simulated sea ice thickness and ice fraction; (c) simulated seasonal blooms of diatoms in terms of carbon and chl-a; and (d) simulated seasonal blooms of small phytoplankton and zooplankton abundances in terms of carbon (not shown e.g., the seasonal evolution in macro/micro-nutrients). These initial runs indicated the need to improve surface/lateral forcing when compared to satellite observed sea ice coverage/drift & mooring observed mixed layer variability

purpose-built sea ice physics model (Saenz, 2011; Ph.D. thesis). We are now working with LTER Co-PI Doug Martinson to investigate the effect of seasonal mixed layer dynamics on sea ice mass balance by first improving and constraining surface and lateral forcing of the 1-D model so that it closely simulates the observed upper ocean variability at Doug's mooring sites. Once we characterize the surface forcing and seasonal evolution in mixed layer dynamics that favor high or low phytoplankton biomass (e.g., with respect to wind forcing, timing of sea ice retreat, proximity to the coast, latitudinal gradients in day length), we can then relate those scenarios to zooplankton grazers and grazing dynamics to arrive at predictions of export production based on the specified bottom-up controls. Ben will also run his sea ice algal model (Saenz, 2011; Saenz et al., 2012) in parallel to test various aspects of the rectification hypothesis, in particular how a later autumn sea ice advance and earlier spring retreat (as observed through time) ultimately affect air-sea gas exchange via potential seasonal mis-matches in the biological response. Ben is also beginning to work with Scott Doney's postdoc, Sevrine Sailley. Sevrine has been conducting investigations of foodweb dynamics in the PAL area using an inverse foodweb model (see Modeling section below). The work with Ben will involve running the inverse foodweb and the 1-D ocean-ice-eco models in parallel to investigate seasonally evolving environmental constraints on foodweb dynamics.

(**4**) Collaborative studies in the Bellingshausen/Amundsen and Ross Sea regions continue and involve analysis of ocean-ice-ecosystem interactions (Planquette et al., submitted; Smith et al., 2011; Yager et al., submitted; Yuan et al., submitted) and water mass modification by sea ice and meltwater inputs (Randall-Goodwin, 2012). These collaborations help place PAL/WAP observations into a broader circumpolar context, with particular focus on the West Antarctic continental shelf regions, areas that show the strongest influence of warm Circumpolar Deep Water (CDW) (Martinson, 2011), increased coastal meltwater inputs (Meredith et al., submitted; Randall-Goodwin et al., 2011; 2012) and largest sea ice decreases (Stammerjohn et al., 2012). My graduate student, Evan Randall-Goodwin, who recently completed his Master's Thesis (April 2012), was involved in a comparative study in the Amundsen Sea: the Amundsen Sea Polynya International Research Expedition (ASPIRE, Yager Lead PI). Evan and I are currently finalizing several ASPIRE findings for publication. For example, Evan has calculated freshwater contributions to the surface ocean using oxygen isotope data from seawater samples collected during ASPIRE. The approach involves calculating the fractional freshwater contributions from sea ice production/melt and from surface meteoric sources (precipitation or glacial meltwater run-off). Our analyses to date indicate a relatively smaller contribution of surface meteoric inputs (relative to the WAP), perhaps owing to the study's location higher latitude, but a greater presence of meltwater at depth. The meltwater at depth is likely from basal melting of the floating ice shelves in the Amundsen Sea embayment area. Once these analyses are complete, we hope to work with Mike Meredith and Rob Sherrell to do a comparative study of freshwater inputs to the PAL and ASPIRE regions to highlight and explore these interesting and informative regional contrasts.

Physical Oceanography (Doug Martinson BP-021).

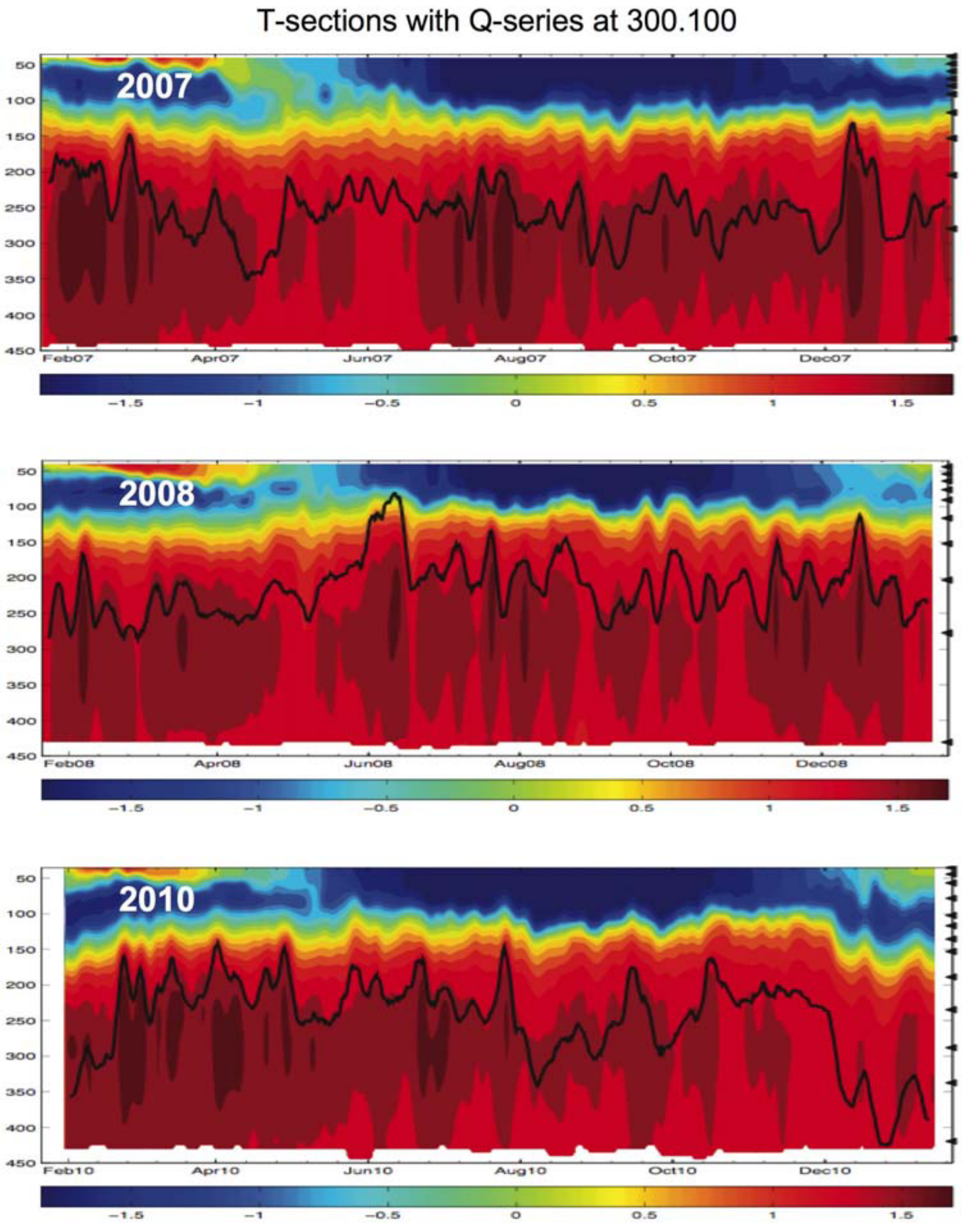


Figure 3: For the mooring at 300.100, temperature (*T*) as a function of depth and time, with ocean heat content (*Q*) overlain (black line) to show the relationship between *T* and *Q*-events. *Q*-events clearly coincide with warm (red) deep anticyclonic boluses (eddies). Arrows on right ordinate show depths of *T* sensors. Color bar shows temperature scale (degrees C).

(**1**) Data from 4 years of successful mooring deployments have allowed us to definitively answer the question of how the warm, nutrient-laden Upper Circumpolar Deep Water (UCDW) is delivered to the PAL LTER sampling area from the Antarctic Circumpolar Current (ACC) flowing over the adjacent continental slope (**Figure 3**). In particular, it is clearly shown that of several potential mechanisms, eddies (containing pure UCDW) embedded within advective intrusions are the active mechanism for getting heat and nutrients onto the continental shelf (at depths above the canyons cutting across the shelf, which channel the water to the base of the ice shelves along the coast and in coastal bays). The advective intrusions track bathymetry, allowing us to project flow direction past our moorings and estimate entry point of intrusions at slope-shelf break (Martinson 2011).

(**2**) Given an updated version of the global deep water warming (*Levitus et al.,* 2012) we have shown (**Figure 4**) that the warming of the UCDW mirrors that of the global *deep* waters (from which the UCDW originates). This has consequences far different than those for which the warming mirrors the global surface waters (which we showed last, in the absence of a revised global deep water warming curve). The latter may simply reflect that west Antarctica serves as a conduit by which the warmed surface waters are moved to the deep storage reservoir (though the region of this study, is one of the rare sites around Antarctica where deep water is *not* produced). Mirroring the warmed *deep* waters suggests that the glaciers are being melted by waters that effectively have a *limitless* amount of heat to melt the glacial ice!

Before proclaiming UCDW reflects global deep or surface water warming, a subtle detail must be examined and considered. In the final decade of comparison, the UCDW is a bit cooler than the global deep water signal (but agrees with the surface warming curves). We must determine if this is a distinguishing difference.

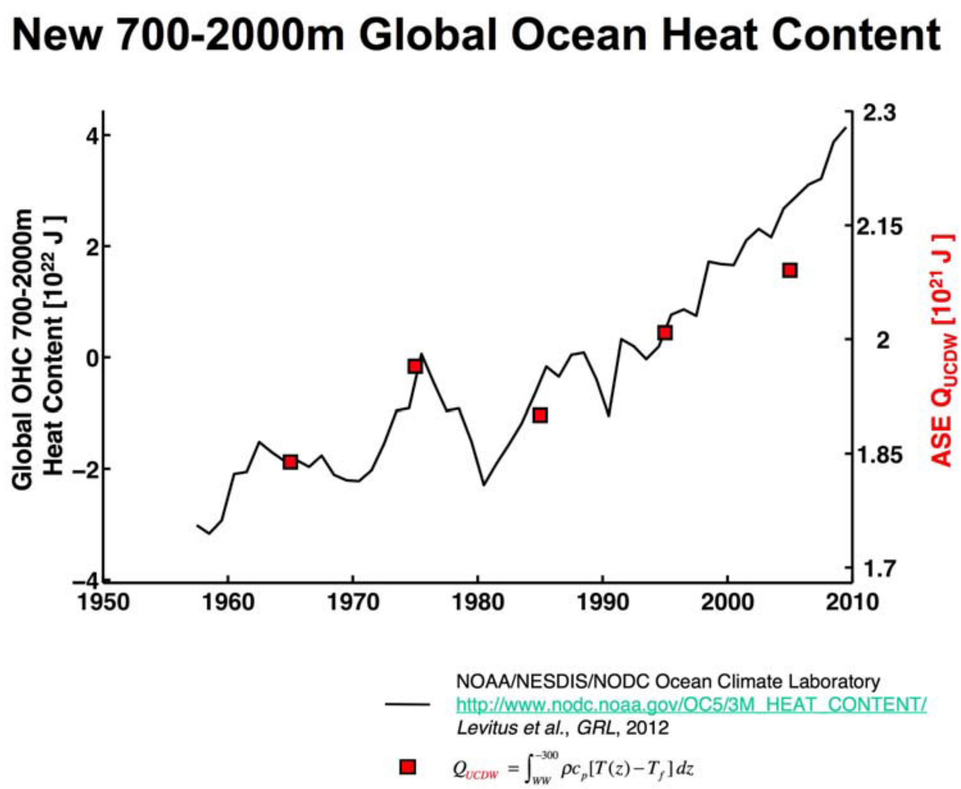


Figure 4: *Levitus et al.* 2012 latest results for deep global ocean heat content (solid black) with heat content (red squares showing decadal average values) of UCDW as delivered by the Antarctic Circumpolar Current to the west Antarctic Peninsula and Amundsen Sea Embayment (ASE) where the major ice streams draining the West Antarctic Ice Sheet enter the sea and are melted by this warm water. Note that the 2000-2010 decade UCDW heat content is less than the deep water.

Phytoplankton and trace metals (Oscar Schofield, Rob Sherrell, Rutgers; B-019).

Results from the cruise showed moderate phytoplankton productivity rates across the WAP grid with the overall productivity near the climatological mean observed over the 20 year LTER database. Generally 14C-uptake rates declined by 3-5 fold in offshore compared to nearshore waters. Overall productivity rates were highest in the coastal zones of Process study 1 and 2 during the cruise. Preliminary analysis indicates abundance and taxonomic gradients both cross-shelf and along the peninsula. Cryptophytes and other small flagellates were most abundant towards the coastal stations and Palmer station while small and medium diatoms became more abundant off shore and south of Adelaide Island. Samples taken from sea ice were particularly diverse in diatoms. *Corethron* was the most commonly observed large diatom and a *Phaeocystis*-like colonial species was observed at both Process station 1 and 2 (Palmer Station and Adelaide Island, respectively). The major phytoplankton groups exhibited clear biogeographic patterns in their relative abundances. Cryptophytes contributed over 80% of the community in the southern coastal region and were often associated with the highest chlorophyll biomass. Diatom relative abundance exceeded 70% in the northern offshore stations, where chlorophyll concentrations were still low. Dinoflagellates were predominantly found offshore in the southern stations, contributing up to 20% of the numerical abundance. Our current thought is that the abundance of small flagellates reflect the ice melt associated with the big ice year encountered during the 2011-2012 field season. These results are anchoring two manuscripts, which are currently in preparation and are expected to be submitted in July.

Glider operations from the LMG were successful with the navigation of the RU26D glider past Avian Island through an ice field to Rothera Station where it was recovered. Additionally a second glider (RU05) was deployed from the LMG and was left to sample Avian Island waters while the ship transected south to finish the sampling grid and conduct Process Station 3 at the ice edge. The glider flight locations at Avian were driven by historical penguin foraging tracks, determined via radio-tags, and efforts focused on collecting data inside and outside of penguin "hot-spots". The glider, after 4 days of sampling, was directed to fly offshore and rendezvous with the LMG at LTER grid station 200:050 as the ship was returning north to deploy the physical oceanography moorings. The glider data encountered two distinct water masses near Avian Island. The upper 200 m were dominated by either 1) a warm (>0.5 degrees C) and low salinity ($\geq$33.25 salinity units) water masses consistent with offshore waters or 2) colder waters with values ranging from -1.4 to -0.7 and even lower salinity values (<33.5) waters. The chlorophyll fluorescence and scattering were 3-4x fold higher in colder water which appeared to associated with the retreating ice edge. Data analysis efforts will next combine the available glider, ship and satellite data to provide a coherent picture of the factors driving the variability in the phytoplankton distributions.

While many different efforts are being conducted, we highlight a new effort. A major focus on the glider data analysis this year was to develop a means to estimate depth resolved circulation using glider data, as requested by our site review. This combined with glider measurements of water column heat can be used to calculate the heat budget and transport across the shelf. Assuming that the pressure and Coriolis forces are the dominant forces affecting water movement in the coastal ocean on the shelf of the western Antarctic Peninsula, the geostrophic balance between these forces can be used to calculate currents. A horizontal pressure difference between points at equal depths will cause a geostrophic flow perpendicular to the direction of the pressure gradient. Pressure is a function of density and thus, geostrophic currents can be calculated from measured density differences. Integrating this equation gives geostrophic current relative to the current at a reference level. Often, oceanographers assume a level of no motion at 2000 m depth. This assumption cannot be made on the western Antarctic Peninsula where depths are shallower and currents extend to the bottom. Instead, the known surface currents were used as the reference. Once the currents at all depths are known, the heat transport can be calculated simply be multiplying by the heat content (**Figure 5**). These measurements look promising and we hope to implement these calculations as a real-time web product in the coming year.

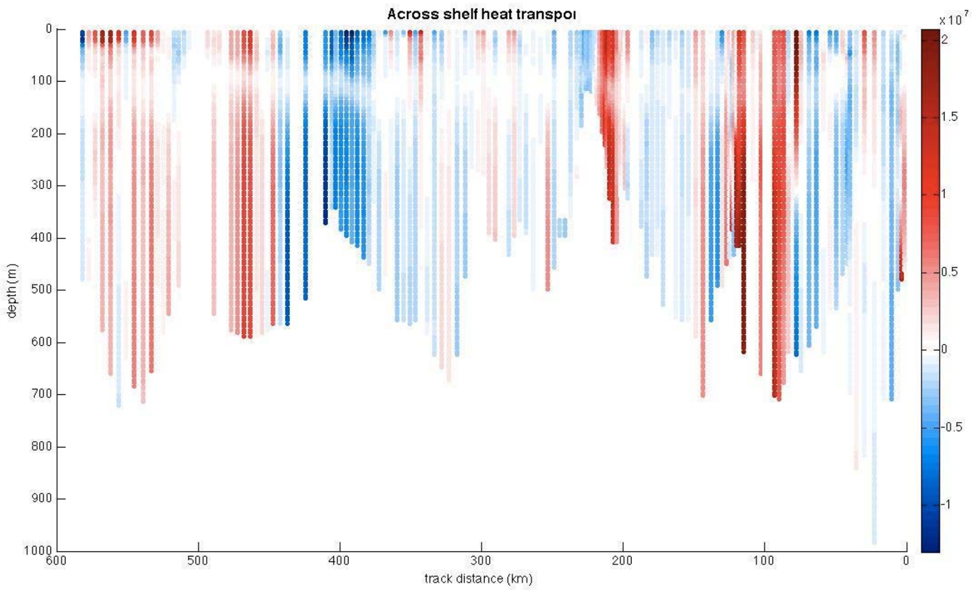


Figure 5. Combined geostrophic estimates of the depth resolved cross-shore circulation and water column heat content. This provides an estimate of the shelf heat transport. The red colors represent the onshore transport of heat. This approach will be applied to the large library of glider data we have amassed over the last four years.

Zooplankton and micronekton (Debbie Steinberg B-020).

Zooplankton and biogeochemical cycling

In our last report we described how long-term changes in distribution and relative abundance of krill and salps may lead to changes in biogeochemical cycling and carbon export from surface waters. In a recent publication (Gleiber et al., accepted) we present results from analyses of the PAL LTER sediment trap to further address this. Fecal pellets collected at 170 m depth in the PAL LTER moored sediment trap from Jan. 2004 - Jan. 2009 were analyzed. Fecal pellet shape and size (i.e. carbon content) were quantified to assess flux of pellets from different zooplankton taxa, and compared between seasons and years. Fecal pellet POC constituted the dominant proportion of total POC flux (**Fig. 6**), with summer (Nov. – Apr.) pellet POC flux (67%) significantly higher than winter (May – Oct.; 34%), and phytodetritus or fecal 'fluff' constituting the remainder. Cylindrical euphausiid pellets contributed to a monthly mean of 72% of total fecal pellet flux; ovoid copepod and tabular salp pellets contributed significantly less (22% and 6%, respectively). Cylindrical and ovoid pellet export was significantly higher in summer samples, while 48% of tabular pellet flux occurred in the winter. Tabular pellets had the highest carbon content (median = 1.0 µgC pellet^{-1}, largest 134.9 µgC pellet^{-1}), followed by cylindrical (0.2 µgC pellet^{-1}), and ovoid (0.04 µgC pellet^{-1}) pellets. As krill fecal pellets are the dominant component of particle export in the WAP, we predict a decrease in krill and increase in salps in the region could alter export of POC to the deep sea.

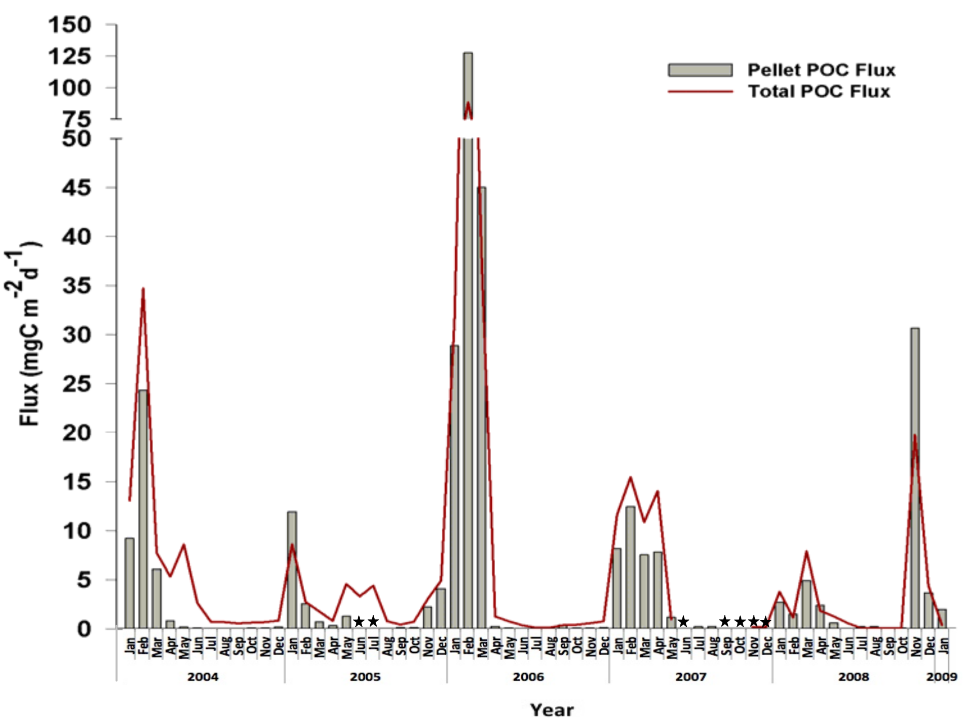


Figure 6. Fecal pellet POC flux for each month from Jan. 2004 – Jan. 2009. Pellet flux in summer months is a weighted average of samples within that month (n=2-5). Red line is total POC flux for each month. Stars indicate samples not analyzed for pellets due to small amount of material in trap samples.

Krill distribution in near-shore penguin foraging areas-

A ten year dataset obtained from satellite tags placed on Adélie penguins suggests that they forage within 6 km of their breeding sites on Humble Island during diurnal tides and move further offshore towards the head of the Palmer Deep canyon (up to 10 km away) during semi-diurnal tides (see Seabird Findings below). Since the foraging behavior of these penguins likely reflects the availability of the prey source, we thus tested the hypothesis that krill biomass in the near shore off Palmer Station is significantly greater during diurnal tides than semi-diurnal tides (Bernard et al., in prep.). An acoustic survey grid (using a 120 kHz Biosonics DT-X echo sounder) was sampled within the 6 km penguin foraging zone off Palmer Station every 2nd or 3rd day for a period of 3 months. Krill biomass was significantly higher during diurnal tides than during semi-diurnal tides ($p<0.05$, **Figure 7**). Krill aggregations were patchy during semi-diurnal tides, but during diurnal tides (particularly towards the mid-season) krill formed layers within the top 20 m of the water column, covering extensive areas of the near shore. Overall, krill biomass appeared to increase through the season, with greatest densities observed during the last two diurnal tidal series. Events such as wind storms (northerlies) and eddies may counter the affect of the tide, representing an additional element of complexity in the system. During the early season a 2-day gale force northerly wind was followed by a near complete absence of krill in the survey area. During the mid-season, glider data indicated that an eddy passed through the area, this was followed by a significant drop in krill densities. These results clearly indicate that diurnal tides affect near shore krill densities. However, it is yet uncertain whether these tides directly influence krill by actively advecting them into the near shore, or indirectly by setting up conditions that prompt the krill to move into the near shore to feed.

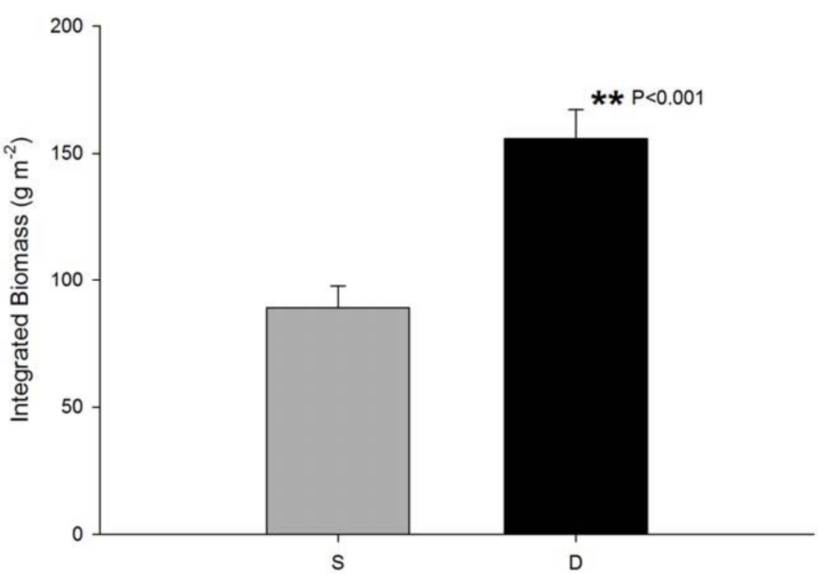


Figure 7. Integrated krill biomass (g m^{-2}), measured acoustically, during diurnal (D) and semi-diurnal (S) tidal phases in the near shore off Palmer Station.

Microzooplankton community structure and grazing-

Lori Price has just defended her M.S. thesis on the microzooplankton community of the WAP. Distributions of major microzooplankton taxa in January 2010 and 2011 were examined within the top 100 m of the water column, along both north-south and coastal-offshore gradients of the WAP, using microscopy. Microzooplankton are potentially responding to climate forcing along with other trophic levels, as there was generally higher microzooplankton biomass in the south compared to the north. Biomass was higher in surface waters compared to 100 m depth, and variability in microzooplankton biomass between years and with distance from shore was most likely influenced by sea ice dynamics. Microzooplankton biomass was also positively correlated with chlorophyll-*a* and particulate organic carbon (POC), and biomass of several microzooplankton taxonomic groups peaked near Marguerite Bay, historically a productivity "hot spot" (**Fig. 8**). Phytoplankton and bacterial growth and grazing mortality rates were derived using the dilution method at select stations along the WAP in January 2009 – 2011 and in the near shore waters near Palmer Station in February – March 2011. Microzooplankton exerted higher grazing pressure on bacteria compared to phytoplankton in this productive season along the WAP. Microzooplankton exhibited selective grazing on smaller phytoplankton (picoautotrophs and nanophytoplankton) (**Fig. 9**), and on the more actively growing bacterial cells, thus shaping phytoplankton and bacterial assemblages and effectively cropping production. There was a significant positive correlation between temperature vs. phytoplankton grazing mortality. This study contributes key information to studies modeling the flow of carbon through the WAP food web (e.g., Sailley et al., in prep., see below) and provides a baseline for studying how future changes will affect microzooplankton community structure and food web dynamics in this region.

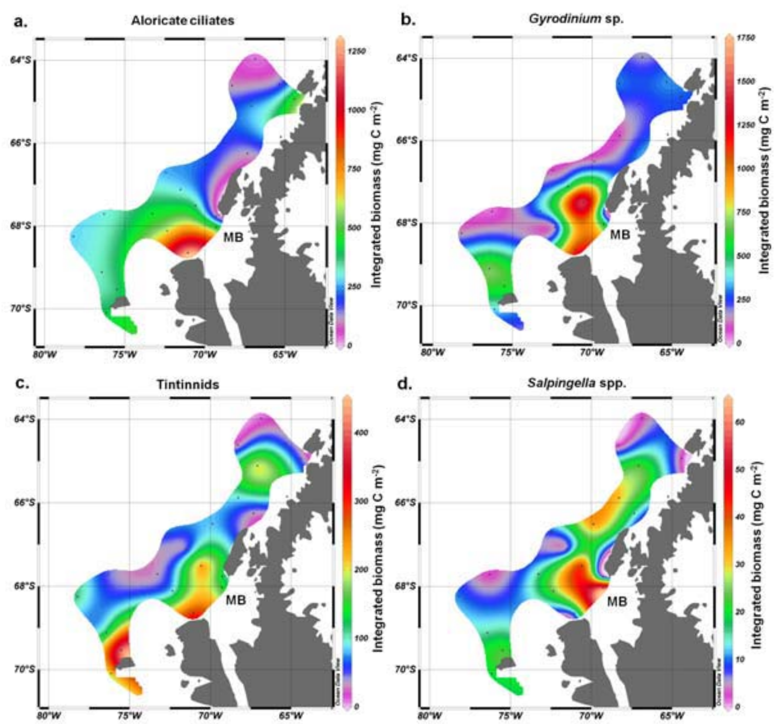


Figure 8. Integrated biomass (0-100m) in 2011 for four microzooplankton taxa, (a) total ciliates, (b) dinoflagellate *Gyrodinium* sp., (c) total tintinnids, and (d) tintinnids *Salpingella* spp. MB: Marguerite Bay.

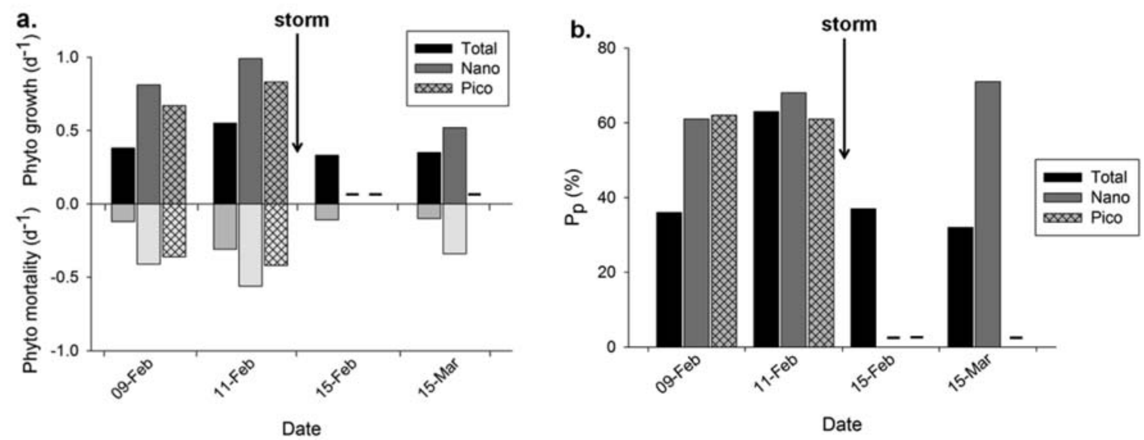


Figure 9. (a) Phytoplankton growth and grazing mortality rates, and (b) the percent of primary production removed in dilution experiments conducted at Palmer Station in February – March 2011. Size fractions: Total = as measured by chl-*a* extraction (filtration on GF/F filters, nominal pore size 0.7 µm); Nano = Nanophytoplankton (approx. 2 – 20 µm) and Pico = Picoeukaryotes (approx. 0.5 – 2 µm) size fractions were determined using flow cytometry. One experiment per date. Experiments with no grazing/mortality rates on any phytoplankton size fraction significantly different than zero were omitted. A dash (–) indicates there were no grazing/mortality rates significantly different than zero on a specific phytoplankton size fraction. Arrow indicates occurrence of a strong storm with wind gusts up to 60 knots that seems to have altered phytoplankton growth and microzooplankton grazing.

Krill lipid dynamics

We hypothesized that warming trends in the northern part of the WAP, that have altered perennial sea-ice dynamics and the magnitude and community structure of the summer phytoplankton blooms, have potential implications for prey quality. We compared lipid content and nutrient (C:N) ratios of macrozooplankton collected from the north and south of the WAP to assess whether regional warming is affecting zooplankton prey quality. Lipid content (both neutral and polar lipids) of juvenile, mature male and mature female *Euphausia superba* were elevated in the southern part of the WAP where sea ice still persists, compared to the north (**Figure 10**). Krill nutrient ratios showed no distinct trends. These results have implications for studies modeling trophic interactions and affects of climate change on prey quality along the WAP.

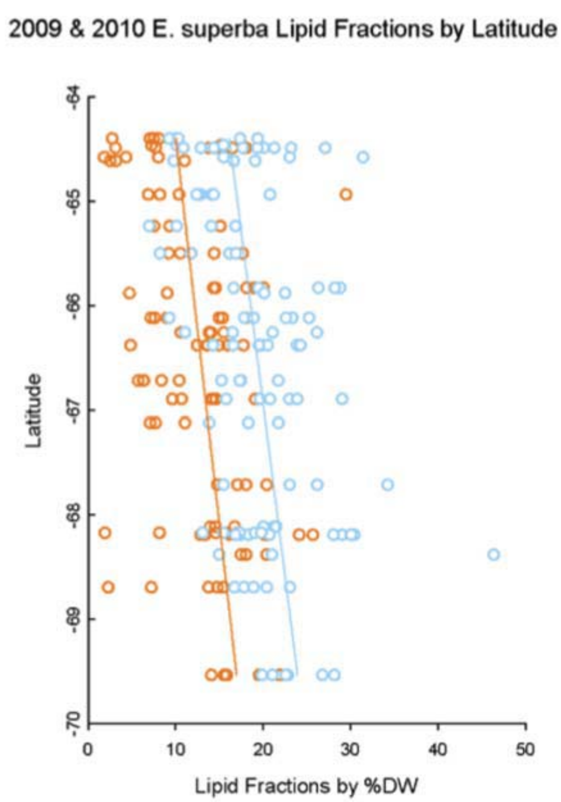
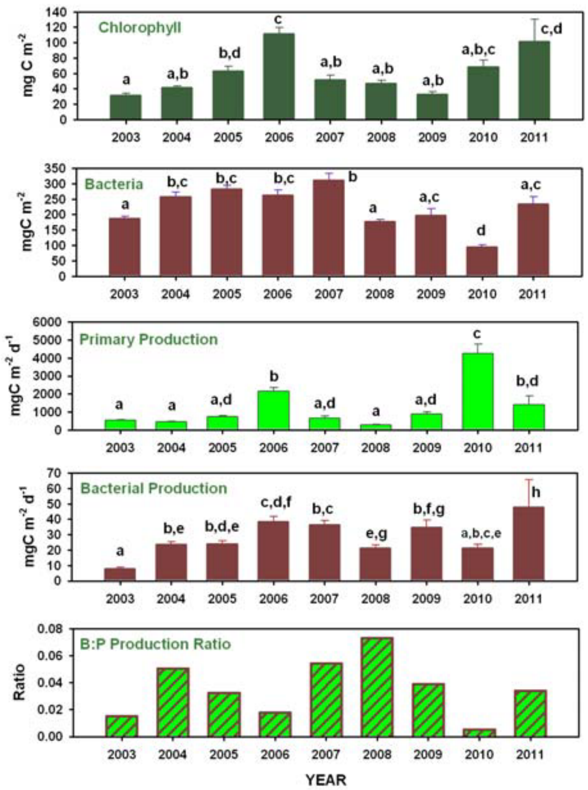


Figure 10. Lipid Fractions of Antarctic krill (*Euphausia superba*) along the Western Antarctic Peninsula. Both neutral (orange) and polar (blue) fractions in Antarctic krill increase slightly going from north to south. Regressions: neutral lipid fractions $r^2 = 0.1429$, $p < 0.0001$; Polar lipid fractions $r^2 = 0.1480$, $p < 0.0001$.

Microbes and Biogeochemistry (Hugh Ducklow BP-045).

1. Ducklow, H. W., O. Schofield, M. Vernet, S. Stammerjohn, and M. Erickson. 2012. Multiscale control of bacterial production by phytoplankton dynamics and sea ice along the western Antarctic Peninsula: A regional and decadal investigation. Journal of Marine Systems **98-99**:26-39.



In 2002-03, we initiated a new program within PAL to study the distributions and dynamics of heterotrophic bacterioplankton along the WAP. This year, we published results from an extensive (2003-11) analysis of phytoplankton and bacterial production and related hydrographic properties collected on nine annual summer cruises. Previous work showed that primary production and zooplankton in the region are strongly influenced by interannual variations in the duration and extent of sea ice cover. We hypothesized that the effects of sea ice on bacteria are modulated through their trophodynamic linkage with phytoplankton. The summer bacterial assemblage is the product of seasonal warming and freshening of the upper water column following spring sea ice retreat and the subsequent plankton succession occurring in that evolving water mass. Bacterial production rates averaged 20 mgC m^{-2} d^{-1} and were a low (5%) fraction of the primary production (PP, **Fig 11**).

Figure 11. Annual average phytoplankton and bacterial properties in the shelf region of the PAL study area. Bars with different letters differ at $p<0.05$.

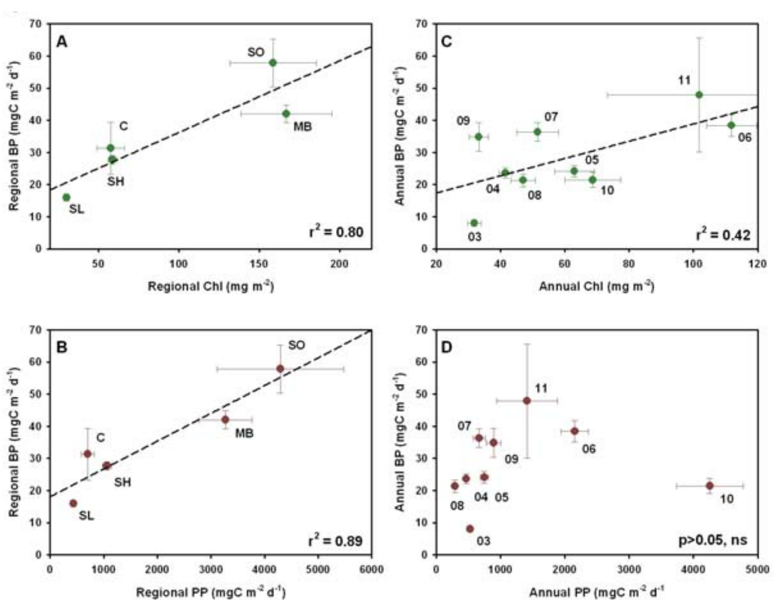


Figure 12. Regional and annual relationships between chlorophyll, primary production and bacterial production indicating persistent coupling between bacteria and phytoplankton in the WAP region.

There was significant variation in BP between regions and years (**Figs. 11,12**), reflecting the variability in sea ice, chlorophyll and PP. Leucine incorporation was significantly correlated (r^2 ranging 0.2-0.7, $p<0.001$) with both chlorophyll and PP across depths, regions and years (**Fig. 12**) indicating strong phyto-plankton-bacteria coupling. Relationships with temperature were variable, including positive, negative and non-significant relationships. Water temperature does not exert a consistent influence over bacterial production rates (**Figure 13**). In some cases the highest rates are observed in the coldest water.

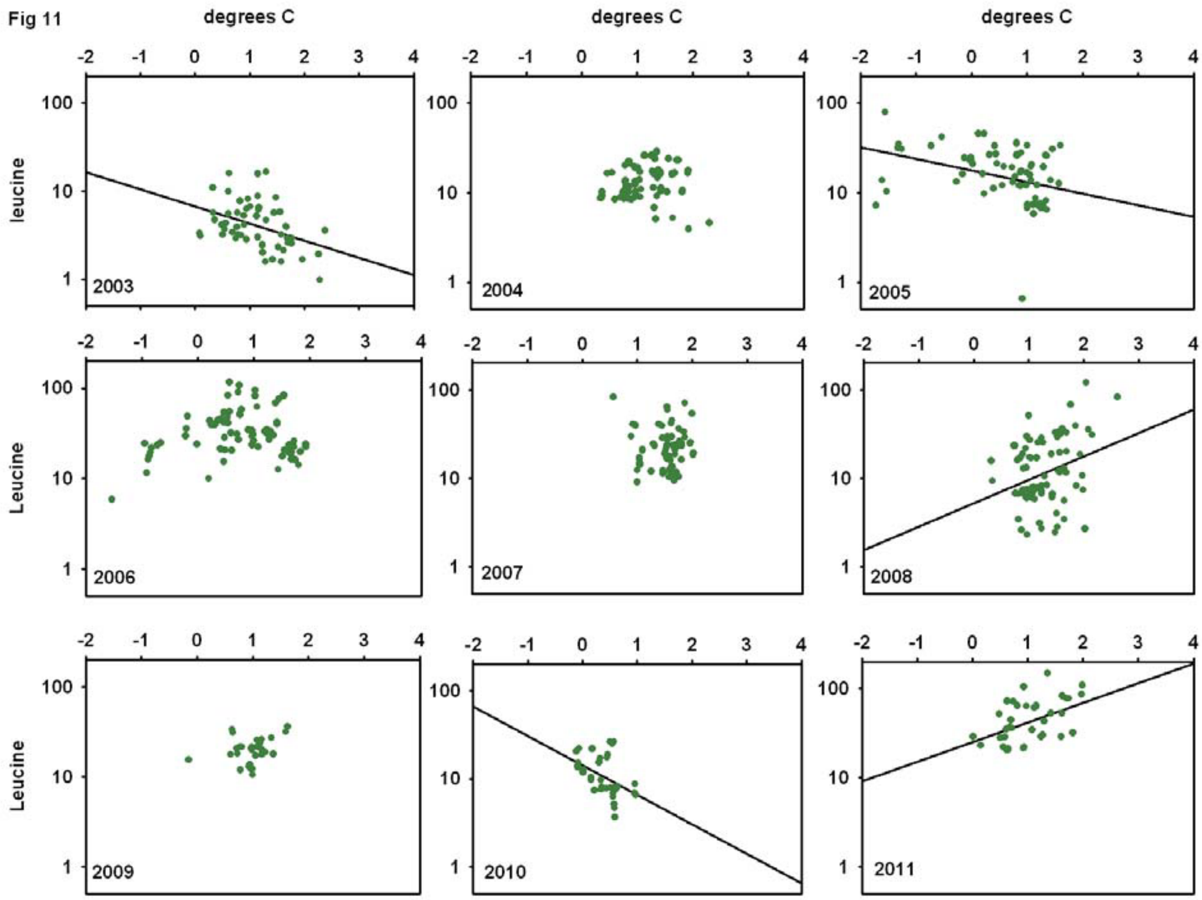


Figure 13. Relationships between leucine incorporation (bacterial production) and temperature. Plots without lines are not significant.

Bacterial production is regulated indirectly by variations in sea ice cover within regions and over years, setting the levels of phytoplankton biomass accumulation and PP rates; these in turn fuel BP, to which PP is coupled via direct release from phytoplankton or other less direct pathways. These other pathways include organic matter flux from zooplankton. We plan to investigate this linkage in the upcoming season.

2. Huang, K., H. Ducklow, M. Vernet, N. Cassar, and M. L. Bender. 2012. Export production and its regulating factors in the West Antarctica Peninsula region of the Southern Ocean. Global Biogeochemical Cycles **26**:doi:10.1029/2010GB004028

We have been collecting surface samples for determination of the triple isotopic composition of dissolved oxygen (Oxygen 16, 17,18) and dissolved oxygen/Argon ratio on the LTER grid for K. Huang (PhD student) and M Bender at Princeton since 2008. With these data and certain assumptions about mixed layer dynamics and air-sea exchange, it is possible to estimate the rates of gross primary production (GPP) and net community production (NCP) over timescales of about ten days, and the corresponding advective space scale in the region. Although the methodology is different, GPP and NCP have the same ecological meaning as in terrestrial systems. Positive NCP is available to support fishery yields and export to depth. Negative NCP implies excess respiration and subsidies of organic matter from another region. Kuan joined our cruise in 2011, and this year published a paper on the 2008 data set. These are the first GPP and NCP estimates for our region and they add a significant new level of understanding about the ecology of the local system.

Our measurements give NCP ranging from -2 to 52 mmol O2 m^2 d^{-1} (-15 to 450 mg C m^2 d^{-1}), and GPP from 30 to 170 mmol O_2 m^2 d^{-1} (130 to 710 mmol C m^2 d^{-1}). The O_2 NCP/GPP ratios range from -0.03 to 0.38, and are highest in the northern coastal area, decreasing to lower values toward the southern coastal area and toward the open ocean. The inshore-offshore gradient appears to be regulated primarily by iron availability in the region, as supported by the positive correlation between NCP and Fv/Fm ratios. Highest NCP are found in fresher, warmer surface water lenses in the northern coastal area which probably formed from melted coastal glaciers. Mixed layer depth (MLD) determined from the CTD profiles is inversely correlated with NCP and NCP/GPP. These results suggest that export production increases where water stratification is intensified by input of fresh meltwater, and the strength of mixed layer stratification is the major factor regulating NCP in the inner-shelf and coastal regions. Along-shelf variability of phytoplankton community composition is highly correlated with the variation of NCP, i.e., NCP increases when the diatom-dominated community in the south transitions to the cryptophyte-dominated one in the north (**Figure 14**). A high correlation is also observed between NCP and the logarithm of the surface chlorophyll concentration, which makes it possible to estimate carbon export as a function of Chl a concentration in this region.

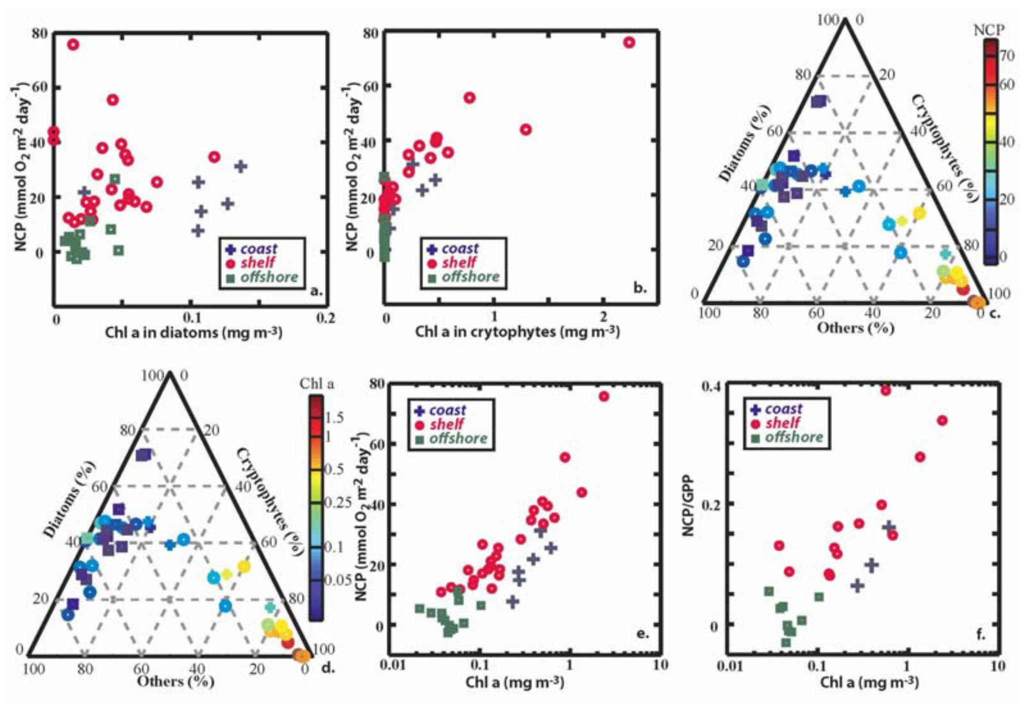


Figure 14. Relationships among NCP, NCP/GPP ratios and phytoplankton in the WAP region, January 2008.

Seabirds (Bill Fraser, B-013).

1. Since the inception of LTER field studies, Adélie penguin research has focused on five island colonies (**Fig. 15**). In 1991 these colonies held 13,052 breeding pairs; at the end of the 2011/2012 field season they held 2,511 breeding pairs, a decrease of 81%. As shown in Fig. 15, however, these changes have not been symmetrical, but instead encompass an island-specific component. Thus, although the Litchfield Island (LIT) colony went extinct in 2007, four other colonies have persisted. We have long hypothesized that one of the factors determining these island-specific asymmetries, is the loss of large penguin breeding groups, or groups that number in excess of 50 breeding pairs (Fraser and Patterson 1997), but we had insufficient data to test this idea. Analyses conducted this season show that the Cormorant (COR) and Christine (CHR) Island colonies crossed this threshold (where small breeding groups outnumber large breeding groups) in 2006 and 2008, respectively, and their populations are continuing to decline (Fig. 15). In contrast, large breeding groups still dominate the demographics of Humble (HUM) and Torgersen (TOR) Islands, and their populations have remained stable since 2007 (Fig. 15). We suspect that increasing vulnerability of smaller breeding groups to predation by skuas is driving these dynamics, suggesting a source of colony extinction that is independent of -- but works in tandem with -- other undesirable effects on demography induced by marine variability. Given similar trends observed on LIT nearly a decade ago, we are predicting that the CHR and COR colonies will be extinct within 3-5 years.

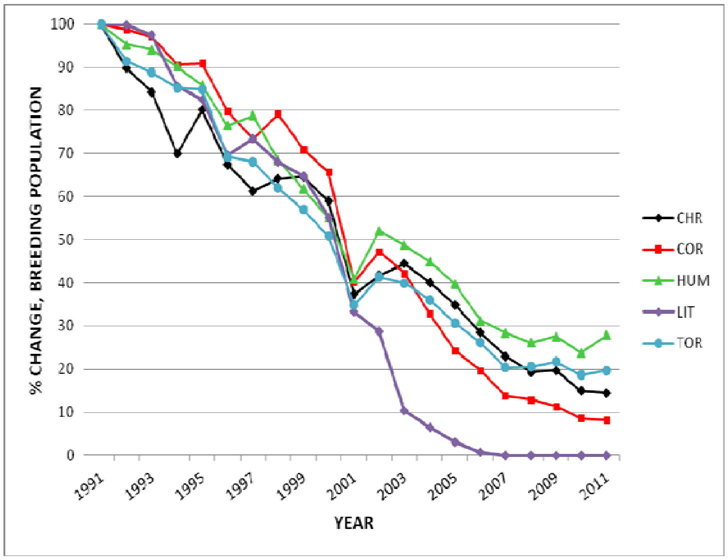


Figure 15. Percent change in Adélie penguin breeding population numbers on five island colonies since 1991, Christine (CHR), Cormorant (COR), Humble (HUM), Litchfield (LIT) and Torgersen (TOR).

2. Our collaborative work with the University of Delaware revealed that Adélie penguin summer foraging locations are strongly governed by tidal forcing. Thus, while there was a general tendency for this species to preferentially forage over the deep bathymetry associated with the Palmer Deep, Adélie penguins (and other top predators such as whales and seals) foraged inshore during diurnal tides and offshore during semi-diurnal tides (**Fig. 16**). Importantly, small boat surveys of krill distributions showed a similar response to tidal phase, with inshore biomass increasing during diurnal tides and decreasing during semi-diurnal tides (**Fig. 17**), thus directly linking predator foraging behavior to tidally-forced changes in the distributions of their prey. Although we have known for some time that submarine canyons play an important role in structuring WAP predator distributions ((Fraser and Trivelpiece 1996), the unique combination of animal-borne sensors, AUVs and small boat surveys for sampling the local marine environment have provided the first mechanistic understanding of some of the processes involved.

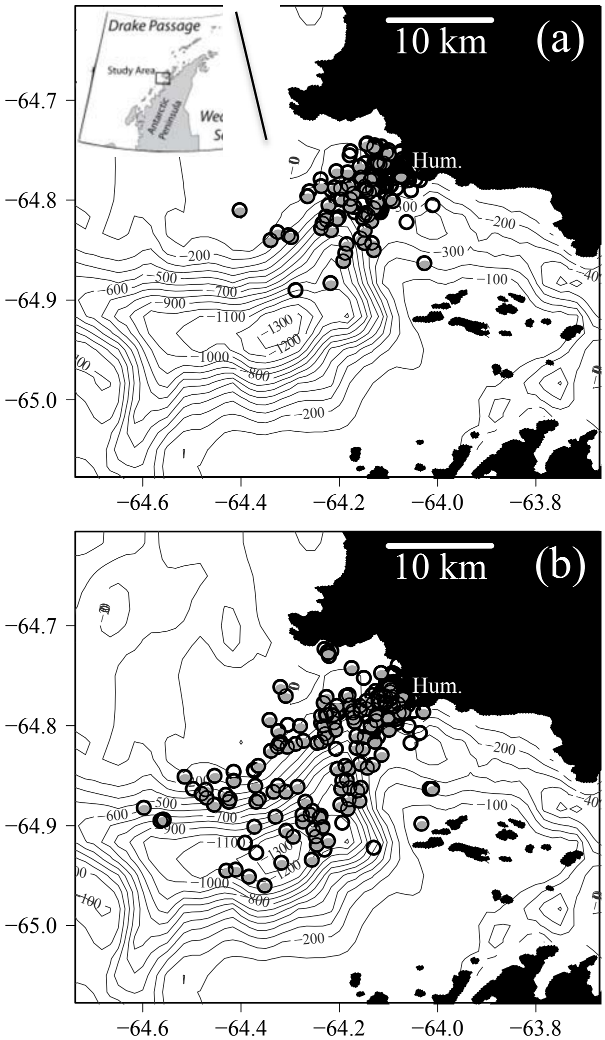


Figure 16. Penguin foraging locations (circles) over Palmer Deep near the Humble Island (HUM) colony during diurnal (a) and semi-diurnal (b) tidal regimes.

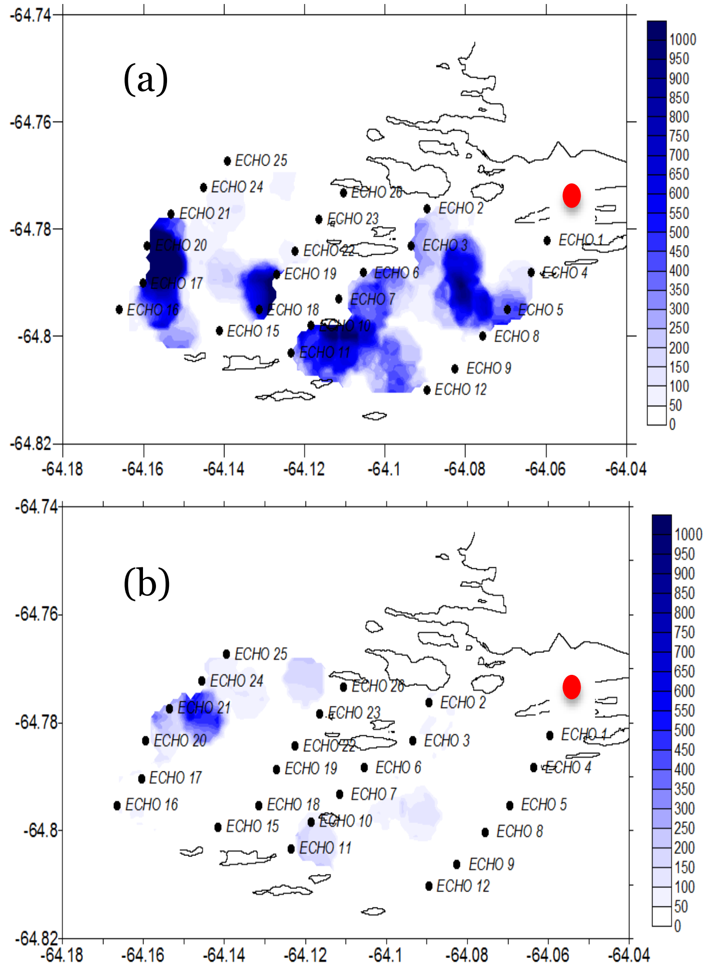


Figure 17. Integrated biomass of krill (g/m^2) sampled during a diurnal (a) and a semi-diurnal (b) tidal regime. The red circle denotes Palmer Station

Numerical Ecosystem Modeling (Scott Doney, WHOI):

***End-to-end Food web Modeling*:**

Initial results from an inverse modeling study were presented as a short section in a synthesis book chapter on PAL-LTER (Ducklow et al., 2012). A more detailed and extensive analysis has been completed and is being drafted into a manuscript (Sailley et al., in prep.) Using Palmer LTER data from annual summer sampling cruises, a food-web inverse model for the WAP pelagic food web was constrained, and model solutions were generated for two regions with Adélie penguin colonies presenting different population trends (a northern and a southern colony) for a 12 year period (1995-2006). Comparing carbon flow through bacteria, microzooplankton and krill showed that the diatom - krill - apex predator food chain is not the dominant pathway. The food web is more complex, including a food chain through microzooplankton and the microbial loop. Using both inverse model results and network indices, it appears that in North WAP the food web is dominated by the microzooplankton and the microbial loop, with a temporal trend toward increasing importance of the microbial loop (**Figure 18**). The model results on microzooplankton appear consistent with recent data collected on the zooplankton community as part of the Palmer cruises. The dominant pathway for the South WAP food web varies from year to year with no detectable temporal trend toward dominance of one group of organisms or process over the rest of the food web. In addition, sensitivity analysis indicates that the north colony of Adélie penguins, whose population size has been declining in the past 35 years, appears to have enough krill during summer to sustain its basic metabolic needs and rear chicks, suggesting the importance of other processes in regulating the decline.

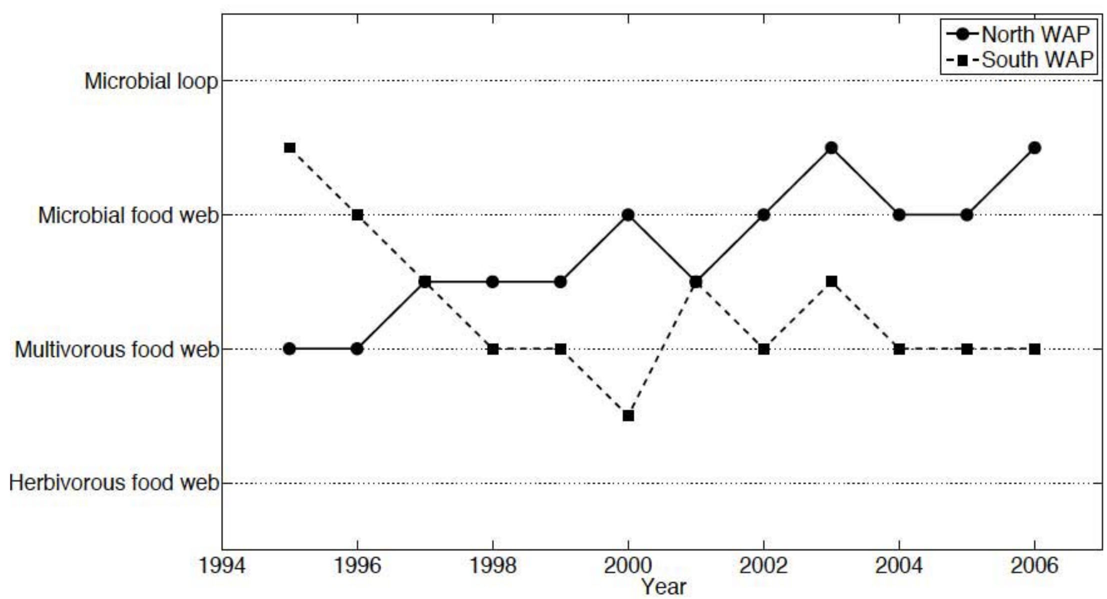


Figure 18: Annual dominant food-web pathway as indicated by network indices for North (solid line) and South (dashed line) WAP sites. Note the trend at the North site towards a more microbial food web.

***Regional and Global Ocean Physical-Ecological-Biogeochemical Simulations*:**

Murphy et al. (Prog. Oceanogr., in press) consider the main ecological and modeling challenges in predicting the responses of Southern Ocean ecosystems to change, and propose three interlinked focus areas that will advance the development of integrated models for Southern Ocean ecosystems. The first focus area is development of fundamental understanding of the factors that determine the structure and function of the food webs at multiple scales. Ecological research in the Southern Ocean is often centered on key species or localized systems, a tendency which is reflected in existing food web and ecosystem models. To build on this, a systematic analysis of regional food web structure and function is required. The second focus area is development of a range of mechanistic models that vary in their resolution of ecological processes, and consider links across physical scales, biogeochemical cycles and feedbacks, and the central role of zooplankton. These two focus areas underlie the third, which is development of methodologies for scenario testing across a range of trophic levels of the effects of past and future changes, which will facilitate consideration of the underlying complexity of interactions and the associated uncertainty. The complex nature of interactions determining Southern Ocean ecosystem structure and function will require new approaches, which we propose should be developed within a scale-based framework that emphasizes both physical and ecological aspects.

Dynamic Green Ocean Models (DGOMs) include different sets of Plankton Functional Types (PFTs) and equations, thus different interactions and food webs. Using four DGOMs (CCSM-BEC, PISCES, PlankTOM5 and NEMURO) we are exploring how the predator prey interactions influence food web dynamics. Using each model’s equations and biomass output, interaction strengths were calculated and the role of zooplankton in modeled food webs examined. In CCSM-BEC the single size-class, adaptive zooplankton component preys on phytoplankton according to prey availability and food preferences, as parameterized. In PISCES the micro- and meso- zooplankton groups compete for food resources; in addition to the available phytoplankton, mesozooplankton graze microzooplankton equally to diatoms. In NEMURO macrozooplankton controls the biomass of other zooplankton PFTs, and defines the structure of the food web. In PlankTOM5, competition and predation between micro- and mesozooplankton along with strong preferences for one phytoplankton (nanophytoplankton and diatoms, respectively) leads to their mutual exclusion. This stresses the importance of equation and parameter choice as they define interactions between PFTs. Additionally, the simulated food web obtained after running each model can be substantially different from the intended one, and also result in different dynamics (competition, bottom-up or top-down effects) for the food webs (**Figure 19**).

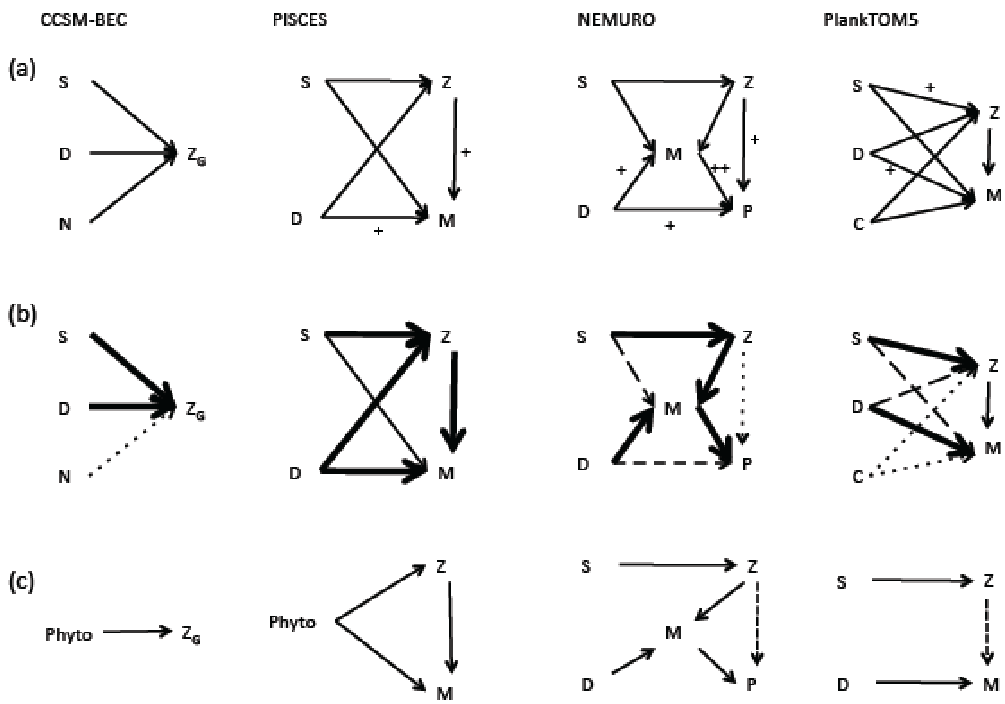


Figure 19: Schematic of (a) intended food webs in global marine ecosystem models. Preferred prey, as designated by model equations and parameters, are identified by a '+', (b) strong predator-prey interaction strengths are represented by thicker lines, dotted lines are for weak interaction strengths due to low biomass (CCSM-BEC and PlankTOM5) and dashed lines represent weak interaction strength due to a lack of co-existence of the two zooplankton groups (PlankTOM5) or food preferences (NEMURO); and (c) obtained food webs with dashed arrows representing existing, but weak, interaction between prey and predators. S: nanophytoplankton, D: diatom, C: coccolithophore, N: diazotroph, ZG: generic zooplankton in CCSMBEC, Z: microzooplankton, M: mesozooplankton and P: macrozooplankton

Climate Change and Ocean Acidification Impacts on Marine Ecosystems

The review article by Doney et al. (*Ann. Rev. Mar. Sci., 2012*) examines the impact on marine ecosystems of rising atmospheric CO_2 and climate change, which are associated with concurrent shifts in temperature, circulation, stratification, sea-ice cover, nutrient input, oxygen content, and ocean acidification, with potentially wide-ranging biological effects. Population-level shifts are occurring due to physiological intolerance to new environments, altered dispersal patterns, and changes in species interactions. Together with local climate-driven invasion and extinction, these processes result in altered community structure and diversity, including possible emergence of novel ecosystems. Impacts are particularly striking for the poles and the tropics, because of the sensitivity of polar ecosystems to sea-ice retreat and poleward species migrations and the sensitivity of coral-algal symbiosis to minor increases in temperature. Mid-latitude upwelling systems, like the California Current, exhibit strong linkages between climate and species distributions, phenology, and demography. Aggregated effects may modify energy and material flows and biogeochemical cycles, eventually impacting the overall ecosystem functioning and services upon which people and societies depend.

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RESEARCH ACTIVITIES: Palmer LTER 2011-2012.

This is the fourth annual report for the fourth grant period of Palmer LTER (2008-2014, OPP 0823101). This report focuses on the activities undertaken by PAL since October, 2011.

Principal Personnel and Scientific Research Components (coPIs, grad students and postdocs)

- Hugh Ducklow, Lead PI (MBL, microbes and biogeochemistry.
    - Catherine Luria, Brown-MBL PhD student
    - Jennifer Brum, polar postdoc, co-advised with Matt Sullivan, U-Arizona
- James Conners (Scripps, Information Management)
- Scott Doney (WHOI, ocean modeling)
    - Sevrine Sailley, postdoc
- Doug Martinson (LDEO, physical oceanography)
- Mike Meredith (BAS-UK, physical oceanography)
- Bill Fraser (Polar Oceans Research Group, seabirds)
    - Kristen Gorman, PhD student (Simon Fraser Univ)
- Oscar Schofield (Rutgers Univ., primary production and optics)
    - Grace Saba, postdoc (PhD, VIMS 2010)
    - Mike Garzio, MSc student
    - Travis Miles, PhD student
- Rob Sherrell (Rutgers Univ., trace metals)
    - Marie Seguret, postdoc (PhD, Plymouth, UK 2009)
- Beth Simmons (Ocean Ingenuity, education and outreach)
- Sharon Stammerjohn (Univ Colorado, sea ice and climate)
    - Evan Randall-Goodwin, UCSC MSc student
    - Ben Saenz Post-doc
- Debbie Steinberg (VIMS, zooplankton)
    - Kim Bernard, postdoc (PhD, Rhodes Univ, S. Africa, 2007)
    - Miram Gleiber, PhD student
    - Kate Ruck, MSc student
    - Lori Price, MSc student

Field Season. In April, 2012 we completed the fourth field season of the current award, and the 21st in the Palmer LTER program that commenced in 1991-92. The annual summer cruise (LMG 12-01, H. Ducklow, Chief Scientist) and summer season at Palmer Station were both successful. Field operations commenced at Palmer Station in mid-October and continued until the end of March. Unlike the previous year, we got off to a slow start due to weather and lingering sea and brash ice that hampered small boating operations until mid-November. The early season was highlighted by our Site Review in December.

Details of individual Palmer- and LMG-based activities are provided below. The summer LMG cruise was entirely successful with no equipment losses or significant time loss due to weather or breakdown. We recovered and redeployed 3 physical oceanography moorings with conductivity and temperature sensors and current meters and our sediment trap mooring that was deployed in January 2011. During the cruise we conducted three longer (~3-days each) process study stations near the Palmer Deep, the Avian Island penguin foraging region and a sea ice edge near 69

South. These are described further below. We also had our annual visit at the BAS Rothera Base to carry out joint scientific operations and visit with our BAS colleagues.

We hosted two related, collaborating projects on LMG 1201: O-405: "Physiological and Ecosystem Structure Forcings on Carbon Fluxes in the Southern Ocean Mixed Layer," (Nicolas Cassar, Duke Univ., PI) and an LTER guest project, "Distribution, abundance, and movement patterns of baleen whales within the Palmer LTER study area," (Ari Friedlaender, Duke Univ., PI). Cassar's project involved installation of an underway, continuous flow, equilibrator-inlet mass spectrometer to measure the isotopic composition of dissolved gases in seawater. Friedlaender's project (closely coordinated with Fraser, B-013 seabird ecology), included placing satellite transmitters on whales to track their movements, and obtaining tissue biopsy samples for genetic marker analyses. Both projects will be back for LMG 1301.

As always, Palmer LTER provided opportunities for students and postdocs to participate in our field research program. In addition to postdocs and graduate students (see above), XX undergraduate interns worked with us at Palmer Station and aboard the LMG cruise. Besides these field- and lab-based opportunities, our Education and Outreach component sponsored major educational contributions through other outlets such as working directly with teachers and with aquariums and museums (see below).

Publications are listed in the **Findings** document.

Major Meetings, Boards and Workshops. We held our annual meeting in Woods Hole in September 2011. In addition to the coPIs, our Planner from RPSC, Eric Pohlman, attended the meeting to plan logistics support for the upcoming season. **Ducklow** was a member of the National Academy Committee for *Future Science Opportunities in the Antarctic and Southern Ocean*, whose Report of that name was released in summer, 2011. **Ducklow** was appointed to the NSF Blue Ribbon Panel charged by White House Science Advisor John Holdren and NSF Director Subra Suresh to "…review the U.S. Antarctic Program with regard to the breadth and future landscape of changing U.S. scientific endeavors n Antarctica and their logistical support and infrastructure needs." The Panel Report, "More and Better Science through Increased Logistical Effectiveness" will be released in June, 2012. The Panel visited Palmer Station in March 2012 and met and talked with PAL field personnel. We sponsored colleague **Doug Nowacek** (Duke Univ) to represent PAL at the CCAMLR Workshop on Marine Critical Areas in Valparaiso, Chile in May 2012. **Stammerjohn** and **Meredith** attended the international IMCoast Workshop in Buenos Aires in April. This was a followup meeting to the workshop we organized in Cambridge, UK (with NSF Supplement Support) in July 2011. Through these activities, we're trying to build a coordinated international research program with German and Argentine colleagues on the Antarctic Peninsula.

Individual Component Reports.

Information Management (James Conners, SIO-UCSD).

Information Management at PAL LTER continues to be engaged in network activities through participation in a number of information management working groups as well as NIS Tiger Teams. Involvement and contribution for 2011 and 2012 includes the Unit Dictionary Working Group, Web Services Working Group, IM Website Working Group and Governance Working Group as well as NISAC membership and Tiger Team participation (Metadata

Quality).

Regular network database contributions (ClimDB) continue and are up to date. In addition, we're continuing to improve the quality and availability of site data and metadata through the network catalog. Improvements to metadata are currently underway that address better compliance with network best practices as well and ease of updating by site personnel. Efforts are also being made to stay in step with network trends, which include direct access to site data through a centralized network portal (NIS). Our local data system infrastructure has been made ready to begin adding data content to our metadata submissions and will begin shortly.

Local access to data by researchers and site personnel is being improved using feedback obtained during data-system review sessions. Comments and discussions produced valuable input for updates aimed at improved usability and ease-of-access to site data. Continued use of community review groups is planned.

Work will begin shortly on the transition of our current site website into the Drupal content management system framework. In addition to improvements that this provide for site research documentation and outreach efforts, plans to utilize the functionality of this new framework for improving our data management workflow have been established. In order to better facilitate the flow of site data to the network, we will begin utilizing this new website framework for the documenting protocols, publishing dataset processing and availability status and facilitating intra-site communication related to the management of site data.

Education and Outreach (Beth Simmons, VIMS & Ocean Ingenuity).

The Palmer Long Term Ecological Research (LTER) Education and Outreach program is creating broad partnerships with international organizations, as well as local and regional educational professionals. We strive to promote ocean literacy, improve public awareness and encourage a greater understanding of climate change along the western Antarctic Peninsula. Recent completed projects include multimedia productions such as the, 'Evidence of Change' video, which discusses the challenges the Adélie penguin face along the western Antarctic Peninsula (see **http://pal.lternet.edu/outreach/multimedia/** for all videos and podcast files). An audio podcast and four video stories were published in collaboration with Boston's Museum of Science as a result of footage obtained from the 2011 field season. This video and podcast discuss the environmental pressures the peninsula is facing and highlights the technology scientists who investigate these long-term changes. Several of these videos are currently a part of our effort to contribute to a nationwide effort with aquariums and museums nationwide belonging to the Coastal Ecosystem Learning Center network. Several of our other videos are supporting efforts in informal science museum exhibits like the *Poles in Peril* Exhibit at the Long Beach Aquarium, California. We continue to share our children's book Sea Secrets at events including the Antarctic Days held at the Henry T. Wing Elementary School in East Sandwich, Massachusetts for 100 fourth graders and also reached out to both the Heard Elementary School and the Tanque Verde Elementary schools in Arizona where B-045 postdoctoral fellow Jenn Brum shared the book with over 180 first through fourth graders.

Other education activities:

Donated Sea Secrets children's books and educational materials with Sylvia and Lanny Miller, Palmer station visitors with Abercrombie/Kent travel. They presented at the Chandler Elementary School in Pasadena Ca.

Contributed Palmer LTER Antarctica wildlife photographs from our multimedia gallery by editor Terry Forshaw with Amber Books in London for a children's encyclopedia of animals publication.

Supplied educational materials for 108 first graders, 77 fifth graders, and public presentation for 6^{th} graders by Jennifer Brum, graduate student at University of Arizona.

Publications

Simmons, Beth (2012) Telling Stories – Case Studies as an Inquiry Method, NSF LTER Schoolyard Children's Book Series Workshop CD collection.

Invited seminars and workshops

Simmons, Beth (2012) Telling Stories – Case Studies as an Inquiry Method, NSF LTER Schoolyard Children's Book Series Workshop CD collection.

Simmons, Beth (2012) Climate Literacy and Energy Awareness Network (CLEAN) webinar – Climate Change will have consequences for the Earth system and human lives. http://www.cleanet.org/clean/community/webinars/IW7.html

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Sea Ice, Climate and Modeling (Sharon Stammerjohn, University of Colorado).

This year's main research activities involved (a) ongoing investigations of regional and circumpolar sea ice and climate assessments for PAL; (b) continued analyses of PAL underway data (by LTER graduate student Nicole Couto); (c) continued refinement and testing of a 1-D ice-ocean-ecosystem model (by postdoc Ben Saenz) for assessing bottom-up controls on ice-ecosystem interactions; initial focus is on sensitivity of mixed layer dynamics to physical forcing; (d) continued comparisons of water masses in the WAP/PAL region against the 'ASPIRE' (Amundsen Sea Polynya International Research Expedition) study area, including seasonal modification of the mixed layer by different sea ice and meltwater inputs; and (e) submitting/revising PAL publications and presenting PAL findings at several invited conferences and workshops (as well as participating in several interviews about PAL as detailed below). Results from these activities are described in the next section.

Education & Outreach

This past year involved several interactions with reporters and science writers. For example, Janelle Schroeder, wildlife reporter for Medill News Service, interviewed me about Antarctic ice-climate changes (April, 2011). Janelle wrote an article on whales and krill in Antarctica (http://news.medill.northwestern.edu/chicago/news.aspx?id=185508) that appeared last April 29, 2011. Katherine Leitzell, science writer for National Snow and Ice Data Center (NSIDC) in Boulder, CO, interviewed me about Antarctic sea ice (January, 2012); her article, 'Sea ice down under: Antarctic ice and climate', appeared in the January 2012 issue of NSIDC's Icelights (http://nsidc.org/icelights/2012/01/). Jane Qui, freelance reporter, interviewed me (March, 2012) about ice-climate interactions and changes in the west Antarctic region; Jane is currently finalizing her article on ecosystem and climate changes in west Antarctica for *Science* Magazine.

Sarah Barbrow (Univ. of Michigan) interviewed me recently (June, 2012) about my role and interactions as an ice-climate scientist for PAL. Sarah is working with Prof. Steve Jackson (now at Cornell University), who received an NSF Career award to explore information technology use, collaboration patterns, and governance in the ecological sciences. Sarah and Steve are specifically focusing on the LTER and NEON. As part of that work, they are (and have been) conducting interviews with a range of researchers, information managers, support staff and other personnel at various LTER sites. Sarah and Steve plan to publish initial findings at the upcoming LTER All Scientists Meeting, September 2012.

I also was invited to submit an article (August, 2011) on Sea Ice Processes and Change for Nature Magazine's online *Nature Education Knowledge* Project (http://www.nature.com/scitable/knowledge/earth-systems-40378443). This article will be included in a new series on Oceanography, due to appear later in 2012. (See also *Published Abstracts* and *Invited Seminars and Workshops*). Lastly, I also was invited to submit highlights from Stammerjohn et al (2012) to the IPCC AR5 Working Group 1 (WG1) Chapter 4 on Polar Regions (Comiso et al., submitted).

Student, Postdoc and Technician Presentations

Couto, N., S. Stammerjohn, C. Sweeney, H. Ducklow, Surface ocean variability from PAL underway data, Poster presented at the PAL Site Review, ARSV Gould and Palmer Station, Antarctica, December 9-13, 2011.

Randall-Goodwin, E., S. Stammerjohn, R. Sherrell, P. Yager, and K. Mankoff, Mixing at mid-depths in the vicinity of an iceberg in the Amundsen Sea polynya, Poster presented at the Gordon Research Conference on Polar Marine Science, Ventura, CA, March 20-25, 2011.

Randall-Goodwin, E. M., S. Stammerjohn, and R. Sherrell, Detecting meltwater-modified CDW in the Amundsen Sea polynya, Poster presented at the Ocean Sciences Meeting 2012 (Session 115), Salt Lake City, UT, February 20-24, 2012.

Saenz, B. L., Sea algal modeling results and future needs. Multimedia presentation at the OASIS (Ocean-Atmopshere-Sea Ice-Snowpack) workshop, Telluride, CO, June 19-25, 2011.

Saenz, B., K. Arrigo, and S. Stammerjohn, Modeling the spatial and temporal dynamics of Antarctic sea ice, Poster presentation at the NASA Carbon Cycle Conference, Alexandria, VA, October 2-5, 2011.

Saenz, B., K. Arrigo, S. Stammerjohn, Consideration of void space in ridged sea ice affects estimates of ice thickness and algal production, Talk presented at the Ocean Sciences Meeting 2012 (Session 115), Salt Lake City, UT, February 20-24, 2012.

Invited Seminars and Workshops

Stammerjohn, S., Sea ice and climate, variability and trends along the western Antarctic Peninsula, Invited talk, Peninsula Workshop at Magdalene College, Cambridge, UK, July 26-28, 2011.

Stammerjohn, S., R. Massom, D. Rind and D. Martinson, Regions of rapid sea ice decline, a polar comparison of ocean-atmosphere interactions, Invited talk, ATOC Oceanography Seminar (6020), University of Colorado, Boulder, CO, October 17, 2011.

Stammerjohn, S., et al., Sea ice and ecology in the western Antarctic Peninsula, Highlights from the Palmer Long-Term Ecological Research (LTER) program, Invited talk, CLIVAR/CliC/SCAR Southern Ocean Region Implementation Panel 7th Meeting, Boulder, CO, October 19-21, 2011.

Stammerjohn, S. et al., Highlights of recent studies of ocean-ice-ecosystem interactions and changes in the Western Antarctic Ocean, Invited overview talk for Session 115: Western Antarctic ocean ecosystems: chemical, physical and biological connections, Ocean Sciences Meeting 2012, Salt Lake City, UT, February 20-24, 2012.

Stammerjohn, S., R. Massom, D. Rind and D. Martinson, Regions of rapid sea ice change: an inter-hemispheric seasonal comparison, Invited talk, National Center for Atmospheric Research (NCAR) Climate and Global Dynamics (CGD) seminar, Boulder, CO, March 23, 2012

Stammerjohn, S. Ice-climate variability in the Ross Sea on seasonal to interannual time scales, Invited talk, Workshop to identify significant uncertainties concerning the effects of climate change and the Antarctic toothfish fishery on the Ross Sea Marine Ecosystem, La Jolla, CA, March 27-30, 2012.

Stammerjohn, S., et al., Spatial and temporal variability in ocean-atmosphere-ice interactions along the western Antarctic Peninsula region and connections to ecosystem change, Invited talk, IMCOAST workshop (IMpact of Climate induced glacial melting on marine COASTal systems in the WAP region), Buenos Aires, AR, April 16-20, 2012.

Physical Oceanography (Doug Martinson, LDEO; B-021).

We have processed all Palmer Station hydrographic data (much of it archived without processing), processed all shipboard CTD data through 2010, and are well into 2011. Given another successful recovery of our thermistor mooring array, recovered with help from the scientific party and support personnel (including RPSC and ship crew) and introduction of Darren McKee to our analysis team, we completed analysis of another year of mooring data.

Leveraged with NOAA funding, this year we expanded the data set from which our estimates of Upper Circumpolar Deep Water (**UCDW**) heat content were computed applying a more careful and thorough quality control (inspection of individual profiles within the grid chosen to sample UCDW as delivered by the Antarctic Circumpolar Current (**ACC**).

Published abstracts from meetings.

Martinson, D.G and L. Webb April 2012. Deep waters melting West Antarctic Ice Sheet fringe mirror global ocean exponential warming, 10th International Conference on Southern Hemisphere Meteorology and Oceanography, Noumea, New Caledonia.

Invited seminars and workshops.

Martinson and Webb, June 2011. Warming of global deep waters melting West Antarctic Ice Sheet, FRISP workshop Scripps Institution of Oceanography.

Phytoplankton and trace metals (Oscar Schofield, Rob Sherrell, Rutgers; B-019).

The 2011-2012 LTER field season was extremely successful with an expanded sampling effort conducted at Palmer Station and over the entire grid sampled by the RV Gould. The objective of this component is to understand how the ocean physics regulates overall phytoplankton productivity and community composition and how these dynamics affect the higher trophic levels of the food web. The team is focused on collecting an extensive set of measurements during the cruise. Bio-optical properties were characterized at 44 stations with measurements of the inherent (absorption, attenuation, backscatter) and apparent (spectral irradiance, radiance) optical properties. The inherent optical properties are measured with WetLabs absorption/attenuation meter (AC-9) and WetLabs EcoPucks. The visible and ultraviolet spectral radiometry is measured with Bio-Spherical Profiling Reflectance Radiometer (PRR) and Profiling UltraViolet sensor (PUV). These profiling measurements were complemented with 370 measurements of chlorophyll a, HPLC, CHN, phytoplankton productivity ascertained via 14C-radioisotope, and photosystem II quantum yield (Fv/Fm).

The measurements are augmented with samples collected for dissolved and particulate trace metal concentrations. This year, these micronutrient samples are augmented with measurements of particulate barium and RNA. Additionally 4 incubations carried out for the response to micronutrient additions (manipulations carried out on the 600 line, at 600.040 and 600.160 stations) using natural iron and zinc isotopes and two were carried out on the -100 line at the process study PS-3. Both incubations involved the enriched isotopes, the PS-3.3 (outside the ice edge) was spiked with Fe57 and Zn68, while the Process Station 3.4 (inside the ice edge) was spiked with Fe57. B-019 also collected 42 samples of particulate iodide that will be given to Dr. Tim Jickell's at the University of East Anglia. Measurements of particle size distribution and microbial community composition were made at each station using Beckman Coulter Multisizer 3 and Fluid Imaging Inc. FlowCAM unit respectively. Over the 2012 field season, 43 surface samples and 22,735 particles were identified. At the Process Stations the phytoplankton team conducted three dual-labeled stable isotope nitrogen and carbon uptake measurements to determine general cycling of nitrogen, uptake rates of various nitrogen sources (NO3-, NH4+, and urea), and preferential selection of nitrogen types by different phytoplankton communities along the WAP.

During the 2011-2012 work year, the B-019 team provided 8 invited seminars, 7 contributed presentations, were coauthors on 6 papers that used LTER data. Another 2 papers are currently in press. One Master student (Michael Garzio) will graduate in August and the LTER is currently central to the work being conducted by 3 graduate students and one post-doctoral researcher.

Zooplankton and micronekton (Debbie Steinberg B-020).

This season the zooplankton group again emphasized the role that zooplankton play in the biological pump (grazing, fecal pellet production, and diel vertical migration), long-term changes in zooplankton community structure, and characterizing the zooplankton prey field in penguin foraging regions. At each station on the annual cruise we performed a pair of net tows for larger macrozooplankton (e.g., krill, salps; sorted onboard) and mesozooplankton (e.g. copepods). We also took samples at selected stations for macro/mesozooplankton lipid and gut fluorescence analyses. At the process study stations we performed depth-stratified zooplankton sampling using the MOCNESS (Multiple Opening-Closing Net Environmental Sensing System) to investigate depth distribution of the abundant taxa over a diel cycle. We performed dilution experiments to measure microzooplankton grazing, allowing us to quantify removal of primary producers by the zooplankton community. We performed additional fecal pellet production experiments with krill and salps to determine their role in export of organic carbon. Using an acoustic towfish we surveyed deep-canyon penguin feeding grounds to investigate penguin prey fields (part of post-doc Dr. Bernard's project). As in past years, we collected a significant number of samples for collaborators on the cruise and at Palmer Station this year.

Resident at Palmer Station this past season were post-doc Kim Bernard, and undergraduate student volunteer Dominque Paxton. Activities there included characterization of local krill distribution as related to tidal cycle using acoustics.

Sample analysis at VIMS continued for vertical flux of zooplankton fecal pellets from archived PAL time-series sediment trap samples, zooplankton lipids, and gut fluorescence. Quantification of microzooplankton samples across the LTER grid is complete for both 2010 and 2011 seasons, and Lori Price successfully defended her M.S. thesis on microzooplankton community structure and grazing on June 14, 2012. We also devoted a large amount of time to revising the historical PAL archive of zooplankton data. The macrozooplankton on-line data are now up to date through 2011 on the PAL DataZoo website.

Published abstracts/ scientific meetings with PAL LTER results presented–

Steinberg D.K. "Long-term changes in the role of zooplankton in ocean biogeochemical processes" Sverdrup Award Lecture, TOS/AGU/ASLO Ocean Sciences Meeting, Salt Lake City, UT, Feb., 2012. (invited)

Price, L. M., **Steinberg, D. K., Ducklow, H. W.** "Microzooplankton community structure and grazing impact along the Western Antarctic Peninsula". TOS/AGU/ASLO Ocean Sciences Meeting, Salt Lake City, UT, Feb., 2012.

Gleiber, M. R., **Steinberg, D. K., Ducklow, H. W**. "Time series of vertical flux of zooplankton fecal pellets on the continental shelf of the Western Antarctic Peninsula". TOS/AGU/ASLO Ocean Sciences Meeting, Salt Lake City, UT, Feb., 2012.

Bernard, K. S., **Steinberg, D. K., Fraser, W. R**. "Krill distribution and Adelie penguin diet at Anvers and Avian islands, Western Antarctic Peninsula". TOS/AGU/ASLO Ocean Sciences Meeting, Salt Lake City, UT, Feb., 2012.

Ruck, K. E., **Steinberg, D. K.,** Canuel, E. A. "Krill lipid dynamics along the Western Antarctic Peninsula". TOS/AGU/ASLO Ocean Sciences Meeting, Salt Lake City, UT, Feb., 2012.

Invited seminars (no abstract)

Steinberg D.K. "Zooplankton and biogeochemical cycling in the changing ecosystem of the West Antarctic Peninsula" Georgia Institute of Technology, Atlanta, GA, Mar., 2012.

Ducklow, H. W. and Steinberg D.K. "Carbon export and zooplankton dynamics in the Palmer LTER". Alfred Wegner Institute for Polar and Marine Research, Bremerhaven, Germany, Aug., 2011.

Steinberg D.K. "Zooplankton and biogeochemical cycling west of the Antarctic Peninsula".

Joint BAS-AWI-PAL Workshop, Cambridge, UK, July, 2011.

Microbes and Biogeochemistry (Hugh Ducklow BP-045).

The microbial biogeochemistry group conducted semi-weekly time series sampling operations at Palmer Station in close conjunction with the B-019 phytoplankton group. Our routine measurements include bacterioplankton and nanoplankton abundance and bacterial production rates, dissolved inorganic nutrients (nitrate, phosphate, silicate) and dissolved organic carbon We also performed weekly incubation experiments to quantify the net growth rates (production minus removal) of bacteria and phytoplankton. During the second half of the season, new Brown-MBL PhD student Cat Luria performed several large-volume incubation experiments to investigate the factors structuring bacterial community composition. Illumina equencing of community DNA from these experiments is pending.

On the annual cruise we performed routine sampling for dissolved inorganic carbon, alkalinity, nutrients, dissolved organic carbon, particulate carbon and nitrogen, bacterial and nanoplankton abundance and bacterial production rates. In addition, we collected samples for Mr. Kuan Huang, who has been studying net community production in our study region for his PhD thesis at Princeton (M. Bender, advisor). Kuan's ecosystem-level estimates of NCP based on the isotopic oxygen composition, may significantly change our views of the primary production system in the peninsular region (see Findings).

Invited seminars

2011 H. Ducklow. Rapid climate change and microbial responses at Palmer, Antarctica. Cary Institute for Ecosystem Studies, Millbrook, NY. October.

2011 H. Ducklow. Rapid climate warming forces abrupt ecosystem shifts on the western Antarctic Peninsula. Ohio State University, Dept. of Earth Science. October.

2012 H. Ducklow, Ecosystem transformation in response to rapid climate change on the Antarctic Peninsula. Portland State University, May 2012.

2012 H. Ducklow. Palmer Antarctica: Rapid climate change and microbial responses. University of Connecticut Department of Marine Science, April

2012 H. Ducklow. Ecosystem transformation in response to rapid climate change on the Antarctic Peninsula. University of Michigan School of Natural Resources and Environment. March.

Published abstracts/ scientific meetings with PAL LTER results presented *(others listing Ducklow as a coauthor are included in other component sections)*

Brum, J. R.; **Ducklow, H. W**.; Sullivan, M. B.: MARINE VIRAL SURVIVAL SKILLS: HOW OCEANIC MICROBIAL VIRUSES SUCCEED IN THE SOUTHERN OCEAN. 2012 Ocean Sciences Meeting. Salt Lake City, Utah (The Oceanography Society, American Society of Limnology and Oceanography and American Geophysical Union).

Huang, K.; **Ducklow, H**.; Bender, M. L.: SPATIAL AND INTER-ANNUAL VARIABILITY OF NCP AND GPP IN THE WESTERN ANTARCTIC PENINSULA REGION, 2008-2011. 2012 Ocean Sciences Meeting. Salt Lake City, Utah (The Oceanography Society, American Society of Limnology and Oceanography and American Geophysical Union).

Education activities:

We have several undergrad colleague students working in our lab in the summer, analyzing PAL samples from previous seasons. Kenyon College graduate ('11) Pam Moriarty participated on our cruise and UNC '12 student Zena Cardman was on the Palmer Station field team. ***Graduate Students:*** We continued sampling for Princeton PhD student Kuan Huang (supervisor M. Bender). Kuan published a paper in Global Biogeochemical Cycles on his work (See Findings). A new Brown-MBL PhD student, Catherine (Cat) Luria participated on our cruise and joined our field team at Palmer Station, conducting several experiments for her thesis research. UNC PhD student Luke McKay was a member of our Palmer team (with Zena).

Seabirds (Bill Fraser, Polar Oceans Research Group, B-013).

The seabird research group operated in the Palmer Station region from November 2011 to April 2012, sampling daily as weather permitted, and focusing its core activities on the demography, foraging ecology and breeding biology of Adélie penguins. However, in response to the impending local extinction of this species on an additional two islands (Figure 1), we established semi-permanent field camps on Biscoe Point and Dream Island to capitalize on the availability of gentoo and chinstrap penguins, respectively. These species are increasing and replacing Adélie penguins regionally, signaling a need for more thorough studies of their ecology in the context of climate change. In January, two group members participated in the annual LTER cruise (LMG 12-01), continuing surveys of seabirds and marine mammals within the LTER grid. This cruise included a 5-day field camp on Avian Island, Marguerite Bay, to continue a time series on aspects of Adélie penguin ecology that provides metrics to compare with populations at Palmer Station. Unfortunately, and attempt to reach Charcot Island further south for similar reasons was unsuccessful due to heavy summer sea ice. The 11/12 field season also observed a continuing collaboration with Dr. Matt Oliver (University of Delaware) to test long-established hypotheses regarding the role of cross-shelf canyons in enhancing prey availability to top predators. This effort employs small boat surveys of krill distributions and AUVs programmed with waypoints based on Adélie penguin satellite telemetry to explore in real time the physical and biological properties of the nearshore marine environment that constitutes the 3-dimensional foraging space of these and other predators.

Education/Outreach:

A long-term collaboration with the BBC concluded with the production of On Thin Ice, which is episode 7 of the series, Frozen Planet. A new collaboration with producer Jon Bowermaster is in progress, and the film, "Wild Antarctica 3D", should be in selected museums, science institutes and theaters by spring of 2013.

Published abstracts from meetings.

Gorman, KB, Ruck, KE, Williams, TD, **Fraser, WR**. 2012. Trophic interactions and variation in reproductive performance within a community of Antarctic penguins (genus Pygoscelis). SCAR Conference, Portland, Oregon, USA.

Gorman, KB, Williams, TD, **Fraser, WR**. 2012. Stress hormone modulation of reproductive performance within a community of Antarctic penguins (genus Pygoscelis). SCAR Conference, Portland, Oregon, USA.

Osama, M, Body, A, **Fraser, W,** Hetel, F, Kopp, M, Lyver, P, Metzig, R, Peter, H-S, Pfeifer, C, Weimerskirch, H. 2012. Towards an Antarctic-wide and multinational system of monitoring penguin colonies by using satellite based remote sensing. SCAR Conference, Portland, Oregon, USA.

Invited seminars and workshops.

Fraser, WR. 2011. Looking back in time through marine ecosystem space: Top predator perspectives on climate and change in the Western Antarctic Peninsula. March, Duke University Marine Lab, Beaufort, North Carolina, USA.

Fraser, WR. 2011. Detecting and managing abrupt transitions in ecological systems. Workshop participant, May, Harvard Forest LTER, Petersham, MA, USA.

Numerical Ecosystem Modeling (Scott Doney, WHOI).

End-to-end Food Web Modeling: We are using inverse analysis techniques to synthesize Palmer LTER measurements into an end-to-end food web model for the West Antarctic Peninsula. The inverse analysis approach uses an input biomass compartment structure and a set of specified biological rules to solve for the multiple fluxes within a food web using limited data inputs. The steady-state model solutions are internally consistent and mass conserving. S. Doney also contributed to an international synthesis on the current status and future directions of Southern Ocean ecosystem modeling; the effort grew out of an Integrating Climate and Ecosystem Dynamics in the Southern Ocean (ICED) Workshop.

Regional and Global Ocean Physical-Ecological-Biogeochemical Simulations: As part of the new Marine Ecosystem Model Intercomparison Project (MAREMIP), we are working with international collaborators on a comprehensive scheme for comparing global marine ecosystem models and evaluating their skill relative to observations. With Palmer LTER support, we have focused on assessing model simulated zooplankton dynamics, a known weakness in this class of models and a bottleneck for translating our end-to-end foodweb results into larger-scale models.

Climate Change and Ocean Acidification Impacts on Marine Ecosystems: S. Doney completed a review article for *Annual Reviews of Marine Science* on climate change and ocean acidification impacts on marine ecosystems using Polar ecosystems as one of the case studies.

Presentations on Palmer LTER & Climate and Ocean Acidification Impacts:

American Fisheries Society 141st Annual Meeting, Invited Keynote Talk, "*Ocean Acidification and Living Marine Resources*", Seattle, WA, Sept. 2011

Lindsay, K., M.C. Long, and **S.C. Doney**, 2012: The impact of climate change on the Southern Ocean carbon cycle in CESM1-(BGC) CMIP5 experiments, AGU/ASLO/TOS Ocean Sciences Meeting 2012, Salt Lake City, UT, Abstract 12855.

Sailley, S.F., **H. Ducklow, S.C. Doney**, and H. Moeller, 2012: Carbon fluxes and pelagic ecosystem dynamics around two western Antarctic Peninsula Adelie penguin colony: an inverse model approach, AGU/ASLO/TOS Ocean Sciences Meeting 2012, Salt Lake City, UT, Abstract 11791.

Jonsson, B.F., **S.C. Doney**, J. Dunne, and M.L Bender, 2012: Evaluation of Southern Ocean O_2/Ar-based NCP measurements in a model framework, AGU/ASLO/TOS Ocean Sciences Meeting 2012, Salt Lake City, UT, Abstract 11270.

Boyd, P.W., C.S. Law, and **S.C. Doney**, 2012: A climate change atlas for the ocean, AGU/ASLO/TOS Ocean Sciences Meeting 2012, Salt Lake City, UT, Abstract 9775.

Williams College Oceans Symposium Lecture Series, Invited Talk, *Rising Atmospheric* CO_2 *& Ocean Acidification*, Williamstown, MA, March 2012

International SOLAS Open Science Conference (Surface Ocean-Lower Atmosphere Study), Invited Plenary Talk, *Rising Atmospheric* CO_2 *& Ocean Acidification*, Cle Elum, WA, May 2012.

Outreach, LTER Network Participation

Partnership in Education Program (summer undergraduate student diversity program) and Sea Education Association, Invited Talk, "*Climate Change and the Future of Oceans in the 21st Century*", Woods Hole, MA, June 2011

Semester in Environmental Science (SES) Distinguished Scientist Seminar, Marine Biological Laboratory, Invited Talk, "*Rising Atmospheric* CO_2 *& Ocean Acidification*", Woods Hole, MA, Sept. 2011

National Network for Oceans and Climate Change Interpretation (NNOCCI) (joint effort among WHOI, New England Aquarium and the Frameworks Institute), Invited, "*Climate Change: Observations & Model Projections*", Woods Hole, MA, Nov. 2011

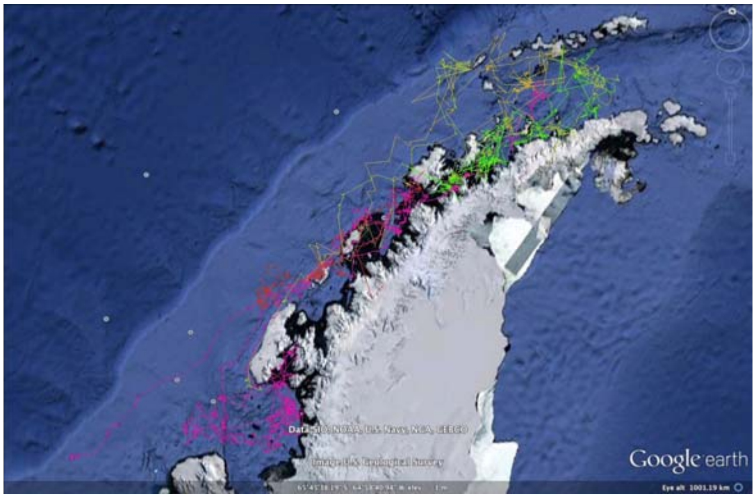
AAAS Science and Technology Policy Fellows Workshop, Invited Talk, "*Communicating Science for Policy: Lessons Learned from Ocean Acidification*", Washington DC, Jan. 2012

2012 Ocean Sciences Meeting Workshop, *Communicating Your Science: Challenges and Opportunities with Ocean Acidification*, Panel Presentation and Discussion, Salt Lake City, UT, Feb. 2012

Advancing Oceans at Rio+20, Side Event at the Rio+20 3rd Intersessional Meeting, Invited Talk, *Ocean Acidification in the Rio+20 Zero Draft*, hosted by Global Ocean Forum & Intergovernmental Oceanographic Commission (IOC-UNESCO), United Nations, New York, NY, March 2012 (web-link http://globaloceanforum.org/2012/04/02/global-ocean-forum-ioc-unesco-and-the-permanent-un-missions-of-seychelles-and-fiji-organize-high-level-ocean-side-event-at-rio20-negotiations/)

AGU Science Policy Conference, Invited Talk and Panel Discussion, *A Research Agenda for Ocean Acidification to Support Decision Makers*, Washington, DC, May 2012

Baleen whales (Guest Project, Ari Friedlaender, Duke Marine Lab).



During LMG 1201, dedicated whale survey, biopsy, and tagging activities took place for the first time integrated with the LTER research program. The work was initiated as a proof-of-concept to determine the feasibility of conducting similar science as part of the LTER in the future. Visual surveys were conducted from the bridge of the LMG during daylight hours when the vessel was in transit. Data were collected on the position, species, and number of animals sighted.

Figure 1. Satellite-linked tracks of humpback whales tagged during LMG 1201.

Survey data were collected using a customized data acquisition system on an Apple IPad using Bento software and Bad Elf GPS. A total of 147 sightings were made comprising 282 humpback whales, 10 minke whales, and 20 killer whales.

Skin and blubber biopsy samples were collected from 30 humpback whales. These tissue samples will be used to determine the sex of the whale, the stable isotope and fatty acid composition, and stock structure from genetic markers.

Seven satellite-linked tags were deployed on humpback whales. The average tag duration is > 60 days and a single tag is still active, having been transmitting for > 120 days. This activity represents a significant milestone both logistically and scientifically. The research activities conducted on LMG 1201 are among very few to deploy tags on whales in this region and the overwhelming success of the tags will allow for greater and more sophisticated hypotheses to be testing regarding the distribution, movement patterns, and ecology of humpback whales within the LTER scientific framework. We are hopeful that this research activity, along with visual surveys and biopsy sampling, can become an ongoing feature of the LTER research program.

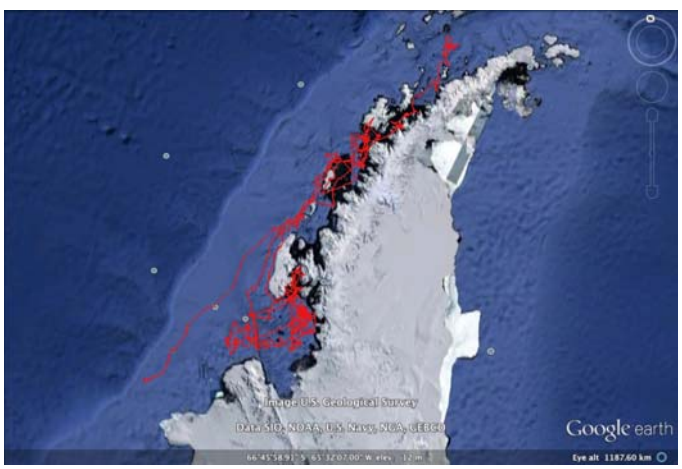
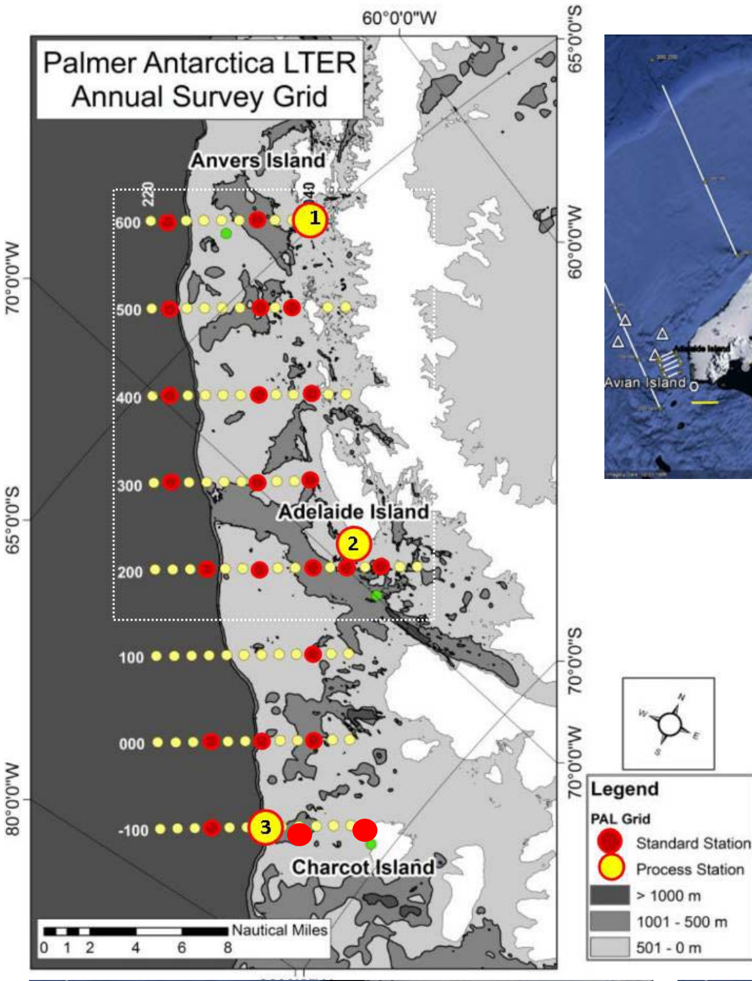


Figure 2. Track of satellite-linked tag deployed on a humpback whale. The tag is still active and the whale remains in the Bransfield Strait in close proximity to the sea ice edge.

APPENDIX: Process Studies conducted during the 2009-12 LMG cruises.

From 1993 until 2008, Palmer LTER occupied about 50 hydrographic stations annually during the summer cruise along the western Antarctic Peninsula (**Figure 4**, next page). Beginning in 2009 this coverage was changed in response to LTER Site Review recommendations to devote more effort to process-oriented hypothesis testing; and our own decision to investigate the region farther south, enlarging the study area by about 70%. In 2009, we reduced the survey resolution by occupying fewer grid stations (but over a larger area) and devoting about 10-12 days of each annual 28-day cruise to process studies conducted in three regions along the Peninsula (**Fig 4**). The purpose of the process studies is to concentrate on ecological and physical processes in a particular region, allowing us to make more measurements, and measure more processes over an extended 3-4 day period than is feasible during routine grid survey operations (ca 3 hours per station). Most of our emphasis has been on oceanographic processes in submarine canyon regions that are the focus of Adélie penguin foraging activity. These sites are located near the Palmer Deep and Marguerite Trough canyons and at Charcot Island farther south (**Figs 4-6**). In 2009 and 2010, we conducted studies of particle export and sedimentation processes near our moored sediment trap. We relocated operations nearer to Palmer Station and the Palmer Deep in 2011-12. We have conducted processes studies near the penguin colony at Avian Island (**Fig 3**) each year since 2009. We also conducted process studies near the penguin colony at Charcot Island in 2009-11.

Figure 3. Adélie penguin colony on Avian Island (Figure 5), harboring ~65,000 breeding pairs. **Inset**: small (50 nests) Adélie colony on Charcot Island, discovered by Palmer LTER January 28, 2009.



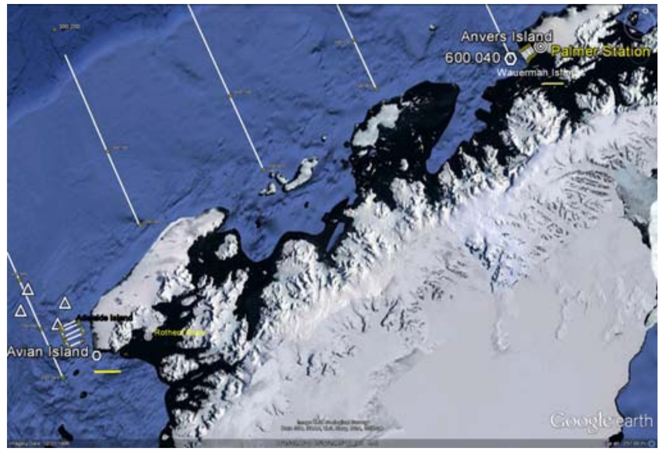
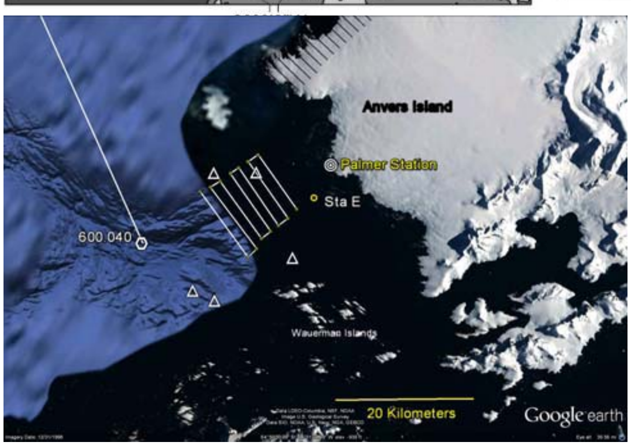


Figure 4. Left: LTER survey grid along the west Antarctic Peninsula showing standard grid stations (yellow) and stations occupied on reduced resolution grid (red). Large yellow dots are 2012 process study stations. The area within the dotted lines was the grid before 2009, when 3 new survey lines were added. Above right: Process studies 1 (Palmer Station region, upper right) and 2 (Avian Island region, lower left) showing acoustic survey tracks and CTD stations. Maps of Process 1 and 2 areas are shown in detail below. Each acoustic track leg is 10 km and the two areas are 370 km apart.



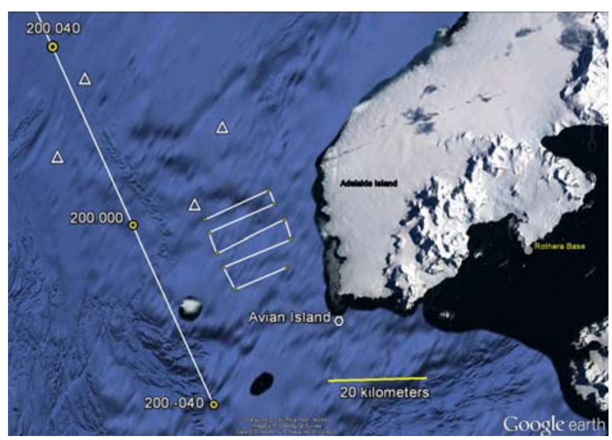


Figure 5. Left: Process 1 study area near Anvers Island and Palmer Station. The small grid is the acoustic zooplankton survey track. Triangles are CTD stations. The regular LTER 600 survey line is to the left with station 600.040 over the Palmer Deep canyon. **Right**: Process 2 study area off Avian Island. Tracks and stations as in Process 1 figure, with LTER 200 line to left, over Marguerite Trough canyon. Survey tracks were designed using penguin foraging returns.

In 2012, we conducted acoustic surveys in the Palmer and Avian Island regions (**Figure 5**), in order to map distributions of Antarctic krill in relation to physical properties characterized by Webb-Slocum glider surveys (see Phytoplankton and Zooplankton sections above), and to relate the krill and physical distributions to data on penguin foraging locations from satellite transmitters attached to the birds (See Seabird section above, and in Findings document).

In 2011-12 heavy sea ice persisted into midsummer in southern Marguerite Bay and the region farther South (**Figure 6**), preventing us from accessing Charcot Island. Instead, we carried out a detailed study of biological processes and distributions in relation to the retreating ice edge near our -100.000 station. Sea ice imagery provided by the Polar Geospatial Center, University of Minnesota, was invaluable for planning our study. Over four days, we occupied eight stations, four on either side of the ice edge (**left**, yellow dots; in and out of the ice), performing CTD casts and zooplankton net tows and deploying a glider to transit along the ice edge. We regard sea ice cover that persists into summer as a hallmark feature of polar marine ecosystems. Although summer sea ice existed in the Palmer Station region into the 1970s, summer sea ice is now rare throughout the LTER study region, having been seen on just two of our annual cruises since 2003 in the Marguerite Bay area. We made the decision to extend our survey and experimental activities farther south, in order to increase our chances of encountering summer sea ice. We are currently analyzing samples collected during the 2012 process studies, and synthesizing data from the 2009-11 observations, with several manuscripts in preparation.

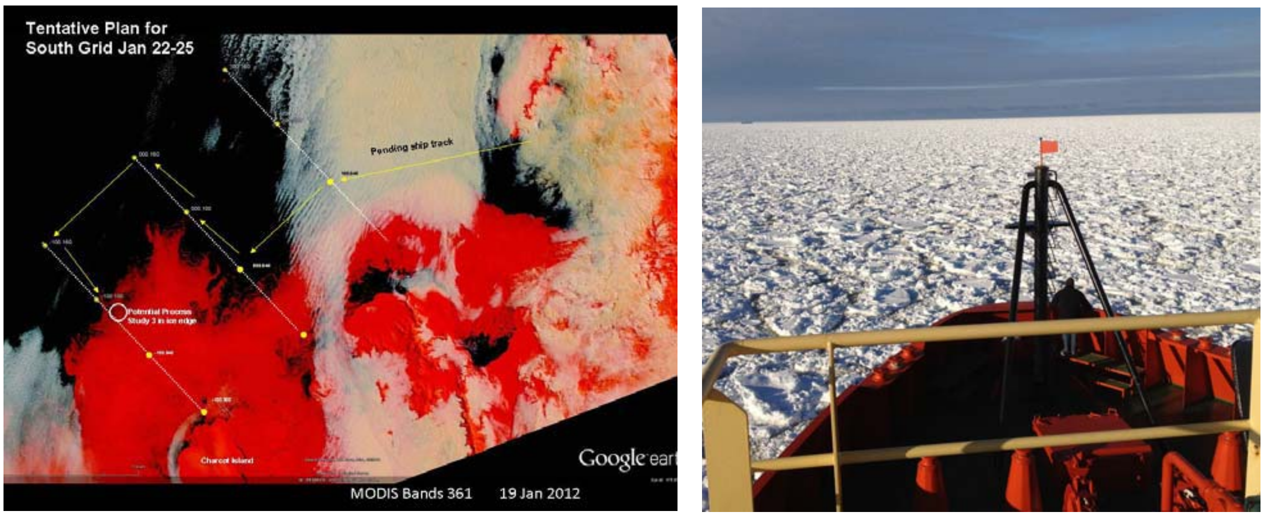


Figure 6. Left: Image showing sea ice (red) and LTER 100, 000 and -100 hydrographic grid lines in relation to ice cover, and area of ice edge study (white circle). Image courtesy Paul Morin, Polar Geospatial Center. Right: Sea ice edge in study area near LTER grid station -100.000, 25 Jan. 2012.