

**Annual Report for Period:**09/2009 - 08/2010

**Submitted on:** 07/09/2010

**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:**

#### Post-doc

**Name:** Montes-Hugo, Martin

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

**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:**

#### Graduate Student

**Name:** Fragoso, Glaucia

**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:**

**Undergraduate Student****Name:** Gleiber, Miriam**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:****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:** No

**Contribution to Project:**

#### Other Participant

**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:** 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:**

#### 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

#### 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 South Florida St. Petersburg**

**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**

**Other Collaborators or Contacts**

Alison Cawood Graduate Students CCE LTER  
Alison Murray, Desert Research Institute  
Andrew Fountain, Portland State University  
Ann Artz The Preuss School University California San Diego  
Beth Deal Florida Christian School  
Bill Sydeman Farallon Institute Advanced Ecosystem Research  
Bjorn Alfthan IPY Oslo conference collaboration  
Catherine Fyfe Birch Aquarium at Scripps (BAS)  
Cheryl Peach Birch Aquarium at Scripps (BAS)  
Chris Fritsen, DRI

Colm Sweeney, NOAA/UC  
 Cyndy Chandler, WHOI  
 David Bailey, University of Glasgow, Glasgow, UK  
 David Kirchman, Univ of Delaware  
 David Ribes, Information School, UMichigan  
 David Rind, NASA GISS  
 Eileen Hofmann, Old Dominion University, Norfolk, Virginia, USA  
 Florence Millerand, University of Michigan  
 Geoffrey Bowker, Santa Clara University  
 Hamilton Fredericksburg Christian School, Stafford Virginia  
 Heather Wright Fredericksburg Christian Elementary  
 Helena Karasti, Oulu University, Finland  
 James Connors Technician/Programmer  
 James T Hollibaugh, Univ of Georgia  
 Jamie Hollingsworth Bonanza Creek LTER site manager/LTER maps  
 Jessie Soder Gustavus School, Alaska  
 Jill Johnson SANT Ocean Hall Exhibitor developer  
 Joan Emner  
 Jose Torres, University of South Florida,  
 Katherine Leonard, LDEO  
 Katie Snider NOAA Ocean Today Kiosk Executive Producer  
 Ken Buesseler, WHOI  
 Kristin Evans Southwest Marine Educators Association/ National Marine Educators Association  
 Langdon Quetin, UCSB  
 Laurie Guest Mare Island Technology Academy (MARE)  
 Lisa Lawrence VIMS  
 Maria Vernet, UCSD  
 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  
 Melissa Pitkin Point Reyes Bird Observatory  
 Naomi Oreskes, Dept of History, UCSD  
 Patti Hauck Fredericksburg Christian Elementary School  
 Paul Morin, University of Minnesota, Minneapolis, Minnesota, USA  
 Petra Heil, Australian ACE CRC  
 Rob Massom, Australian ACE CRC  
 Rob Massom, Australian ACE CRC  
 Robin Ross, UCSB  
 Sarah Dahl Fredericksburg Christian Middle School  
 Stan Jacobs, LDEO  
 Steve Ackley, UTSA  
 Ted Maksym, British Antarctic Survey  
 Thomas Scott Snider  
 Tom Hart, Institute of Zoology, London, UK.  
 Tony Williams, Simon Fraser University, BC, Canada  
 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 file

**Findings:** (See PDF version submitted by PI at the end of the report)

see attached file

### **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.

### **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**

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,

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-S???ez, L;Ducklow, H;Herndl, GJ;Kobl????zek, M;Labrenz, M;Luo, Y;Mor????n, XAG;Reinthal, T;Simon, M;,"Towards a better understanding of microbial carbon flux in the sea", *Aquatic Microbial Ecology*, p. 21-38, 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. , vol. , (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,

Mark A. Moline;Nina J. Karnovsky;Zachary Brown;George J. Divoky;Thomas R. Frazer;Charles A. Jacoby;Joseph J. Torres;William R. Fraser;,"High Latitude Changes in Ice Dynamics and Their Impact on Polar Marine Ecosystems", *Annals of the New York Academy of Sciences*, p. 267-319, vol. 1134, (2008). 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. AEM.00183, vol. , (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 by El Niño-Southern Oscillation and the Southern Annular Mode", *Deep Sea Research Part II: Topical Studies in Oceanography*, p. 2007-2022, 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 Part II: Topical Studies in Oceanography*, 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 variability", *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 Adelie penguin (*Pygoscelis adeliae*) chick growth: A modeling study", *Deep Sea Research Part II: Topical Studies in Oceanography*, p. 543-558, vol. 57, (2010). Published,
- Gorman, K.;Erdmann, E.;Pickering, B.;Horne, P.;Blum, J.;Lucas, H.;Patterson-Fraser, D.;Fraser, W.;, "A new high-latitude record for the macaroni penguin (*Eudyptes chrysolophus*) at Avian Island, Antarctica", *Polar Biology*, p. , vol. , (2010). Published,
- Hugh Ducklow;Andrew Clarke;Rebecca Dickhut;Scott C. Doney;Heidi Geisz;Kuan Huang;Douglas G. Martinson;Michael P. Meredith;Holly V. Moeller;Martin Montes-Hugo;Oscar Schofield;Sharon E. Stammerjohn;Debbie Steinberg;William Fraser;, "The Marine Ecosystem of the West Antarctic Peninsula", *Antarctica: An Extreme Environment in a Changing World*, p. , vol. (in pre, (2010). Published,
- McClintock, J. B.;Silva-Rodriguez, P.;Fraser, W. R.;, "Southerly breeding in gentoo penguins for the eastern Antarctic Peninsula: further evidence for unprecedented climate-change", *Antarctic Science*, p. , vol. Doi:10., (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,
- Fogt, R. L.;S. Barreira;D.H. Bromwich;S. Colwell;K. C. Jezek;B. Johnson;L. M. Keller;M. A. Lazzara;H. Liu;C.S. Long;R. A. Massom;E. R. Nash;P. A. Newman;M. C. Pitts;P. Reid;M. L. Santee;S. Stammerjohn;L. Wang;S-H Wang;, "State of the Climate 2009, Antarctica", *ogical Society*, p. , vol. Special, (2010). Published,
- Massom, R.A.;S.E. Stammerjohn;, "Antarctic sea ice change and variability ??? physical and ecological implications", *Polar Science*, p. , vol. (in pre, (2010). Published,
- Meredith, M. P.;M. I. Wallace;S. E. Stammerjohn;I. A. Renfrew;A. Clarke;H. J. Venables;D. R. Shoosmith;T. Souster;M. J. Leng;, "Changes in

the freshwater composition of the upper ocean west of the Antarctic Peninsula during the first decade of the 21st century", Progress in Oceanography, p. , vol. (accept, (2010). Published,

Stammerjohn, S.;T. Maksym;P. Heil;R. A. Massom;M. Vancoppenolle;K. C. Leonard;, "The influence of winds, sea surface temperature and precipitation anomalies on Antarctic Regional sea ice conditions during IPY 2007", Deep Sea Research II, p. , vol. (accept, (2010). Published,

### Books or Other One-time Publications

Simmons B, Cerullo MM, "Sea Secrets: Tiny Clues to a Big Mystery", (2008). Book, Published  
Collection: LTER Children's Book Series  
Bibliography: ISBN 10:0-9779603-9-0

Simmons, Beth, "Sea Secrets Website", (2008). Internet site, Published  
Bibliography: <http://cce.lternet.edu/outreach/seasecrets/>

Simmons, Beth, "Polar Books Website", (2009). Internet site, Published  
Bibliography: <http://www.unep.org/Publications/polarbooks/books/1015.aspx>

Karasti H, Baker KS, "Community Design: Growing One's Own Information Infrastructure", (2008). Book, Published  
Bibliography: Participatory Design Conference, Bloomington, IN

### 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

### Contributions

**Contributions within Discipline:**

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

Information Management: Three sessions on informatics were co-chaired at the American Geophysical Union meeting in December as a cross-institutional effort involving Scripps Institution of Oceanography (Karen Baker), Woods Hole Oceanographic Institution (Cyndy Chandler), and Monterey Bay Aquarium Research Institute (John Greybeale, Marine Metadata Interoperability/Initiative). The sessions brought together informatics projects across oceanography, highlighting infrastructural aspects of this work by envisioning future and past data networks in talks by Susan Avery, director of Woods Hole, Steve Jackson, science studies researcher at the Information School of University of

Michigan, and Peter Wiebe, zooplankton researcher at WHOI. LTER community efforts have included contribution of datasets to a network information system effort called Ecotrends, cochair of an information management governance working group, cochair of a unit dictionary working group, and editorship of the information management newsletter Databits.

### **Contributions to Other Disciplines:**

**Science:** As PAL LTER has expanded and diversified its observational capabilities in the past 3 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 Ducklow's invited talk at the Southern Ocean Observing System session at the AGU Ocean science meeting and the recently published paper in Science by Schofield et al.

**Information Management:** We are contributing to the social sciences fields of science and technology studies, communication studies, and infrastructure studies as well as information sciences and history of science through partnerships that continue a unique longitudinal ethnography for LTER and Ocean Informatics (<http://interoperability.ucsd.edu>). A presentation at the annual meeting of the Society for Social Studies of Science in Rotterdam resulted in an invitation to contribute to a book on Collaboration in the Life Sciences. Visits were hosted for Florence Millerand (Dept of Communication; UQuebec) to work on an ethnographic monograph on Ocean Informatics and for Helena Karasti (Dept of Information Systems, UOulu) to join in a working group on infrastructure held at the Computer Supported Cooperative Work Conference in San Diego.

### **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.

#### **B-013 (Fraser):**

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. Most of these individuals remain with our program for 3-4 years, and eventually seek positions with state and federal governments or pursue graduate degrees. This season two of our former technicians, Tawna Morgan and Rick Smaniotta, moved into positions with the Prince William Sound Science Center, Cordova, Alaska, and Montana Fish Wildlife and Parks, Bozeman, Montana, respectively.

In other developments, aspects of our public, posted long-term PAL seabird data were used, or are in use by other individuals as follows:

Nicole Casper, M.Sc. student, Western Washington University, using our decadal krill size-frequency data based on Ad??lie penguin diets for thesis development.

Jefferson Hinke, Ph.D. student, SCRIPPS/US AMLR Program, using our decadal Ad??lie penguin demographic data for dissertation development.

Lynch HJ, Fagan WF, Naveen R, Trivelpiece SG, Trivelpiece WZ. 2009. Timing of clutch initiation in Pygoscelis penguins on the Antarctic Peninsula: towards an improved understanding of off-peak census correction factors. CCAMLR Sci 16:149??'165.

### **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/>

### **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 ACTIVITIES: Palmer LTER 2009-2010.**

**Overview.** This is the second 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, 2009. In the past year, the newly-restructured PAL matured and we continued to solidify our identity as the go-to interdisciplinary program study climate change and ecosystem transformation in Antarctica.

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

- Hugh Ducklow, Lead PI (MBL, microbes and biogeochemistry)
  - Heidi Geisz, PhD student (VIMS, late 2010 graduation)
- Karen Baker (Scripps, Information Management)
- Scott Doney (WHOI, ocean modeling)
  - Sevrine Saille, postdoc (PhD, Universitat Bremen, 2009)
  - Holly Moeller, PhD student
- 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)
  - Alex Kahl, postdoc (finished in 2010)
  - Grace Saba, postdoc (PhD, VIMS 2010)
  - Mike Garzio, PhD student
- Rob Sherrell (Rutgers Univ., trace metals)
  - Marie Seguret, postdoc (PhD, Plymouth, UK 2009)
- Beth Simmons (Ocean Ingenuity, education and outreach)
- Sharon Stammerjohn (UCSC, sea ice and climate)
  - Evan Randall-Goodwin, UCSC PhD student
- Debbie Steinberg (VIMS, zooplankton)
  - Kim Bernard, postdoc (PhD, Rhodes Univ, S. Africa, 2007)
  - Kate Ruck, MSc student
  - Lori Price, MSc student
  - Miram Gleiber, undergraduate student (Senior Honors thesis)
  - Sarah Giltz, undergraduate student

**Field Season.** In April, 2010 we completed the second field season of the current award, and the 19th in the Palmer LTER program that commenced in 1991-92. The annual summer cruise (LMG 10-01, 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 with almost no interruptions. Details of the Palmer-based activities are provided below. The summer LMG cruise plagued by equipment losses but was successful overall. During the cruise we visited Rothera Station to carry out joint scientific operations and visit with our BAS colleagues. We recovered and redeployed 3 SASSI physical oceanography moorings with conductivity and temperature sensors and current meters, but lost 2 moorings. We failed to recover the sediment trap mooring that had been deployed and recovered without a break since 1993. Reasons for these failures are not known. We again hosted WHOI geochemist

Ken Buesseler's project on this cruise. They conducted multiple diverse studies of sinking particles. A paper reporting this research has been submitted to GRL (see listings in Results section). During the cruise we conducted three longer (~3-days each) process study stations near the sediment trap, and the Avian and Charcot Island penguin colonies. These are described in more detail below.



PAL-LTER cruise members arriving ashore at Rothera Station, 23 January, 2010 via man-basket. Rothera personnel came aboard for our annual instrument cross-calibration cruise in Ryder Bay. Photo by Mike Coons, RPSC.

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

**Meetings and training workshops.** All PAL personnel (coPIs, current students and postdocs) participated in the LTER All-Scientists Meeting in Estes Park, CO. We followed up that meeting with our own annual science and planning meeting in Boulder. Many RPSC personnel joined us in Boulder to help plan and organize the field season and cruise. Ducklow, Steinberg, Schofield and Sherrell attended the ASLO-AGU Ocean Sciences Meeting in Portland in February. Ducklow, attended the NSF-OPP organized workshop on Palmer Station logistics alternatives in Arlington, VA. Steinberg attended the annual meeting of the Society for Integrative and Comparative Biology in Seattle in January. Ducklow joined the LTER Network Executive Board in May 2009, completing his first year of membership recently. MSc student Lori Price, and Post-doc Kim Bernard, attended a two-day training workshop on microzooplankton identification with Dr. Wayne Coats of the Smithsonian Environmental Research Center in June. PhD student Mike Garzio, and post-docs Grace Saba and Kim Bernard, attended a three-day training workshop on glider operations and deployment at Rutgers University in June.



## Individual Component Reports.

### Information Management (Karen Baker, SIO-UCSD).

Updates were made to the PAL website, to dataset delivery and to the information system. Plot performance was improved by replacement of the plot library and options for contour and bubble plots were added. Redesign of the study-project schema for our local information system DataZoo added flexibility in response to display needs identified in practice. An updated approach to databases as generic resource streams was developed to address issues relating to the increasing size of datasets. Improvements were made to dataset documentation as datasets were submitted for publication in EcoTrends, a community effort. This work resulted in update of dataset metadata and publication of datasets to Metacat and to ClimDB. New approaches were developed for delivery of derived or value-added datasets and their identification using accession numbers important to data provenance. Our local team is leading a network-level LTER unit registry and unit best practices effort that received support from a LTER post All Scientist Meeting proposal award. This work has informed redesign of DataZoo architecture to a web-services orientation. The new unit registry replaces a static, isolated unit dictionary thus enacting one type of data comparability. Preparations were begun for replacing an aging collaboration server with a new one that supports virtual machines.

### Education and Outreach (Beth Simmons, VIMS).

Beth Simmons participated in the 2010 Palmer summer research cruise aboard the Laurence M. Gould. This has led to the design, development and publishing of supplemental activities that integrate the field research into inquiry-based investigations for students at the high school level. Concurrently throughout the months of June – August, we are investing considerable time into the reorganization of Palmer LTER Outreach web page. These changes are meant to meet the needs of the public and make our materials more widely visible and accessible. Our video for the [NOAA Ocean Today](#) Kiosk will be released in July and will also be featured on Palmer LTER's website as well. The busy summer months also lend themselves to our actively working with teachers in our RET professional development program. We continue to strengthen our LTER cross-site involvement by the inclusion of CCE LTER in our RET program and Bonanza Creek LTER on the design of the LTER maps project.

### Sea Ice, Climate and Modeling (Sharon Stammerjohn).

This year's research activities involved (a) the investigation of wind-driven versus ocean-forced ice-edge changes and the consequent accumulation and fate of snow on sea ice (using satellite-derived SST, ice drift, snow depth and numerical analyses of precipitation); (b) regional and circumpolar sea ice and climate assessments for several collaborative manuscripts; (c) continued PAL LTER collaborations in the southern Bellingshausen and Amundsen seas; and (d) the formation of a sea ice and climate research group at UCSC. Both (a) and (b) resulted in several submitted and published manuscripts and are further described under **Research Findings**, while activities associated with (c) and (d) are further described here.

Collaborative studies in the southern Bellingshausen and Amundsen Sea involve analysis of sea ice and ocean data collected on recent (and upcoming) cruises to investigate regional ocean-atmosphere-ice interactions (in collaboration with Stan Jacobs and Xiaojun Yuan) and seasonal ice mass balance changes (in collaboration with Ted Maksym and Steve Ackley). These collaborations help place PAL LTER/WAP observations into a broader circumpolar context, with particular focus on those regions in the Southern Ocean which show the largest sea ice decreases. Collaboration with Ted Maksym in particular brings new expertise to the PAL LTER



regarding sea ice processes. Here we are focusing on processes that control snow and sea ice thickness distributions, how summer sea ice responds to climate change, and the role of melt-induced porous gap layers in structuring sea ice ecosystems. Our objective is to combine snow and sea ice data collected on past cruises in the PAL LTER region with snow and sea ice data collected in the southern Bellingshausen and Amundsen to investigate regional differences in ocean-atmosphere forcing of sea ice and the contribution of snow-ice to ice mass balance.

Research activities this past year were also devoted to the formation of my research lab here at UCSC, which involved the addition two graduate students in Fall 2009 (Ken Mankoff and Evan Randall-Goodwin) and a research assistant (Nicole Couto). Ken Mankoff is focusing on ocean-ice shelf interactions in the Amundsen Sea, but he will be involved in processing and analyzing satellite-derived high-resolution sea ice drift and deformation for both the Bellingshausen and Amundsen Sea regions. Evan Randall-Goodwin is focusing on ice-ocean interactions, using both satellite-derived and model-derived assessments. He is initially investigating the fate of increased solar ocean warming caused by increased ice-free conditions in summer in the WAP-Bellingshausen-Amundsen Sea regions. Nicole Couto is a very new addition to my lab (March 2010) and is getting acquainted with PAL LTER data and the large-scale grid analysis. Our intention is to follow-up on results presented in the DSRII 2008 papers, e.g., a closer examination of the relationship between ice season duration and freshwater content in the seasonal mixed layer.

#### **Physical Oceanography (Doug Martinson, LDEO; BP-021).**

This component deals with physical oceanography. It carries the requirement of supplying core physical data. We have satisfied this requirement through the consistent collection of the grid CTD data set, its overall qa/qc, distribution to all participants (directly) and others through upload to LTER-public & NODC data bases, and general analysis. Other ship-based activities include recovery, service and redeployment of moorings and reporting of this activity from ship to grade school. Unfortunately, two of the 5 moorings could not be recovered during the 2010 cruise, due to no response from the mooring releases. We hope to drag for the most important of these at 300.100 in the 2010-2011 season; with 2.5 year battery life, the sensors will have recorded continuously over this last year; the mooring near Charcot Island may have been lost from heavy iceberg traffic noted in the region during the recovery).

#### **Phytoplankton (Oscar Schofield, Rutgers; B-019).**

The seasonal Palmer Station efforts continued successfully in 2009/2010. Efforts at Palmer Station included the bi-weekly time series at stations B and E. Zodiac operations maintained the time series collecting phytoplankton pigment, 14C productivity and bio-optical information, as well as deploying a Slocum glider to survey the Palmer Deep canyon offshore, which is a hot spot for penguin foraging. The bio-optical measurements were a significant addition. This year we added fast repetition rate fluorometry to the suite of glider measurements. The new additions included hyperspectral downwelling irradiance as well as upwelling radiance and spectral inherent optical properties (absorption, attenuation and backscatter). These optical properties will be used to conduct a series of optical closure analyses. Finally, the phytoplankton began a series of laboratory experiments at Palmer focused on the photo-acclimation dynamics of the existing cultures at the station. These light acclimation experiments have continued at Rutgers using polar cultures purchased from the Bigelow culture collection.

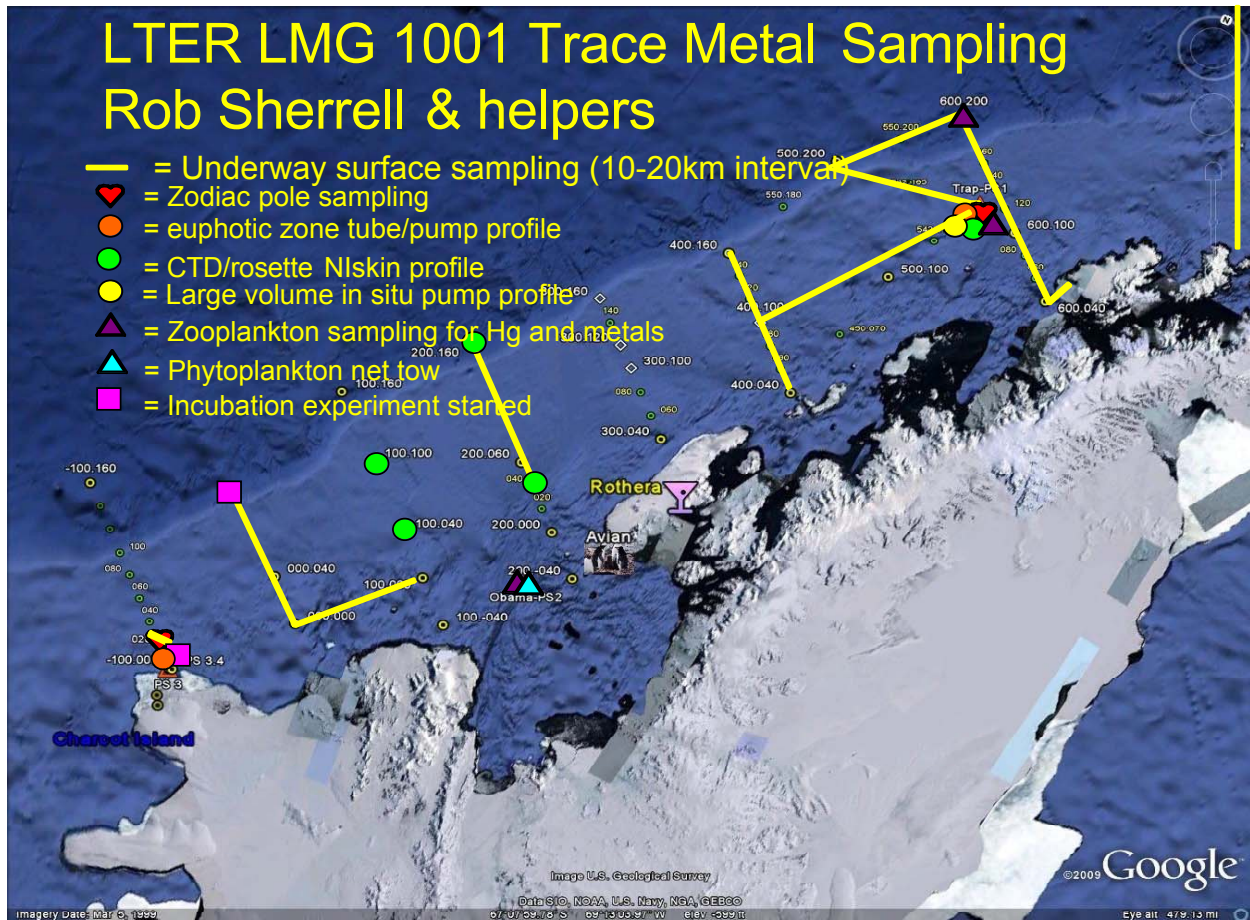
During the 2009/2010 we completed 3 glider deployments at Palmer and we completed three deployments during the survey cruise aboard the RV Gould. These deployments collected 1555 vertical profiles of data. Gliders were deployed at all three process stations including the station at Charcot Island. The gliders were deployed to support Lagrangian tracking of deployed sediment trap drifters, and a hydrographic survey of a region frequented by radio-tagged penguins. This effort will expand in the coming year with funding provided by the Gordon & Betty Moore Foundation and a recently awarded NASA Biodiversity proposal. The glider-based measurements to be added in the coming year include acoustic measurements from an ADCP. The new ADCP science bay has been constructed and will be test-flown prior to the deployment during a joint effort with the VIMS and the WHOI Bioacoustics group in June/July 2010.

The 2010 LTER survey cruise was very successful. A full bio-optics program was continued (spectral absorption, attenuation, backscatter and hyperspectral radiometry). These data are being combined with the other Palmer data to assist in algorithm development. These data will greatly assist in the interpretation of the discrete depth phytoplankton data as well as accelerate improvement of a new suite of satellite algorithms for these waters. Kinetic fluorometry was collected to complement the measured variability in the phytoplankton radio-labeled productivity measurements. These fluorometry measurements were made both on discrete depth as well as in surface mapping mode using the seawater intake line provided by the ship. In all this greatly expands the range of measurements collected by the phytoplankton component of the LTER and by utilizing proven technologies ushers in a new era of mapping capabilities to complement the traditional phytoplankton measurements.

**Outreach and education:** Outreach activity is coordinated and served via COSEE <http://coseenow.net/antarctica/>.

#### **Trace Metals (Rob Sherrell, Rutgers: B-019)**

The 2010 LTER survey cruise was the first major sampling effort ever for dissolved iron and other bioactive trace metals off the western Antarctic Peninsula, and it was highly successful. Rob Sherrell, with help from the Schofield phytoplankton team, collected ~120 filtered seawater samples and a comparable quantity of suspended particulate matter samples over the course of the cruise. The primary sampling effort was focused on spatial surface water distributions using a towed “fish” system to collect water from outside the halo of contamination generated by the ship’s hull. Additional sampling involved: profiling the fish to pump clean water to the lab from various depths in the upper 100m, using the “pole” method from zodiacs, the ship’s conventional CTD/rosette system, large volume *in situ* pumping, deploying metal-free phytoplankton net, and the zooplankton nets of PI D. Steinberg. In addition, in collaboration with Mirko Lunau of the Ducklow group, we carried out two metal-clean incubation experiments to explore light and Fe dependence of the phytoplankton community in an inshore and offshore station. A summary of the sample types and spatial distribution for the trace metal effort is shown below.



### Zooplankton and micronekton (Debbie Steinberg B-020).

Similar to last year's cruise, this season the zooplankton group emphasized the role that zooplankton play in the biological pump (grazing, particle or fecal pellet production, and diel vertical migration). At each station 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, and microzooplankton (e.g., ciliates, flagellates) abundance and community structure. 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. We also collected samples on the cruise this year for John Reinfelder (Rutgers) for analysis of Hg isotopes in zooplankton, and for Rebecca Dickhut (VIMS) for analysis of persistent organic pollutants in the food web (phyto- and zooplankton, and fish). Over the course of the year vertical flux of zooplankton fecal pellets was analyzed from archived PAL time-series sediment trap samples for the period Jan. 2005-Jan. 2009. We have completed set up the lipid analysis laboratory at VIMS and are beginning to run zooplankton samples from the 2009 and 2010 Jan. cruises. Analysis of gut fluorescence samples for meso/macrozooplankton grazing are also nearly complete from these two cruises.



Finally, this year two new MSc students and a Post-doc joined Steinberg's laboratory, and a William and Mary undergraduate completed her Senior Honors thesis (see Personnel), concentrating on the various activities described above (Post-doc funded by Gordon & Betty Moore Foundation).

### **Microbes and Biogeochemistry (Hugh Ducklow BP-045).**

The microbial biogeochemistry group participated in the annual cruise and also had personnel stationed at Palmer Station for the entire season (mid-October to mid-March). Cruise operations were generally similar to previous years (bacterial abundance and production rates, dissolved oxygen, dissolved organic and inorganic carbon, inorganic nutrients, moored sediment trap). We again hosted WHOI geochemist Ken Buesseler's independently-funded project on particle dynamics. They conducted a variety of studies on sedimentation rates and carbon fluxes, using neutrally-buoyant drifting sediment traps and gel columns to trap particles, a video profiling system and Thorium-234 measurements. We failed to recover our moored sediment trap and thereby lost the preceding year's 21 samples, breaking the time series for the second time in 19 years of deployments (the trap was recovered in 2001 but it had failed to rotate and collect samples). We also hosted a visiting researcher, Dr. Mirko Lunau, Alfred-Wegener Institut, Germany, as a member of our cruise team. Mirko has a Marie Curie Fellowship from the EC to conduct studies of nitrogen cycling during a 16-month visit to MBL. He conducted 3 large incubation experiments during our 3 process study stations.



**Figure 3.** The Accuri flow cytometer at Palmer Station. From left: Palmer the Orca, Dan Whiteley, Accuri, Matthew Erickson.

A highlight of our work on the cruise was near-real time analysis of plankton samples with our new Accuri Flow Cytometer which is portable and worked reliably aboard the vessel even in rough weather (Figure 3 and see Findings section). At Palmer Station, we completed 17 weeklong dilution experiments designed to examine bacterial growth dynamics. The final experiments completed after the cruise benefitted from the detailed analytical capabilities of the new flow cytometer.

(We shipped the Accuri in November but it was temporarily lost in Logan Airport by American Airlines and missed its flight).

**Data submission:** All PAL data through March-2008 have been submitted to the PAL data system. 2009 data are in the final QA-QC process.

**Education activities:** Our annual cruise provided field research opportunities for a recently-graduated undergraduate student from Brown University and a grad student from UCSD. Ohio State junior Kathleen Woods and Providence College junior Sarah Lapierre are working in our lab in Woods Hole this summer. **Graduate Students:** Current VIMS PhD student Heidi Geisz plans to graduate later this summer. Her thesis is titled, “Current Levels and Long-Term Trends of Persistent Organic Pollutants (POPs) in Antarctic Seabirds and Fur Seals.” We have also been conducting sampling for a PhD student at Princeton (K. Huang, under the supervision of M. Bender).

### **Seabirds (Bill Fraser BP-013).**

The seabird research group operated in the Palmer Station region from October 2009 to March 2010, sampling daily as weather permitted, and focusing its core activities on the demography, foraging ecology and breeding biology of Adélie penguins. As in past seasons, basic ecological data on other seabirds and marine mammals in the Palmer area were opportunistically obtained to ensure the continuity of species-specific databases that originated in the early 1970s. In January, two group members participated in the annual LTER cruise (LMG 10-01), continuing surveys of seabirds and marine mammals to investigate their abundance and distribution relative to bathymetry and annual variability in regional oceanography. This cruise included a 5-day field camp on Avian Island, Marguerite Bay, and a second landing and brief exploration of Charcot Island south of Marguerite Bay in continuation of a unique time series that compares the foraging ecology of Adélie penguins (diets and at-sea foraging locations/dive-depth profiles based on ARGOS-linked transmitters) with similar data from Palmer Station. The 09/10 field season also observed the conclusion of field research by Kristen Gorman, a Ph.D. student developing her dissertation through a collaboration with Simon Fraser University. This work (Title: Climate-induced divergence in population dynamics among *Pygoscelis* penguins: nutritional-physiological mechanisms and evolutionary consequences) focuses on the mechanistic processes linking climate change to changing WAP food webs, and its consequences to the population dynamics of the three breeding penguins species in the LTER grid.

### **Education and Outreach:**

- a. A long-term collaboration with Fen Montaigne, freelance writer, produced an article in *The New Yorker*, *The Ice Retreat* (December 2009), and a soon-to-be-published book, *Fraser’s Penguins, a Journey to the Future in Antarctica* (Henry Holt, November 2010),
- b. A new collaboration with Juanita Constible and Richard Lee (Miami University, Springboro, Ohio) and Luke Sandro (Springboro High School, Springboro, Ohio) produced a high school lesson plan and teacher’s guide, *A Collaborative Classroom Investigation of Climate Change on the Antarctic Peninsula*.
- c. A new collaboration with The Alder School, a K-6, one-room schoolhouse in remote, rural Montana resulted in an online “chat” and interactive session with students and teachers from Palmer Station, followed by an on-site visit and presentation. The school used for its Antarctic lesson plan the PAL children’s book *Sea Secrets*, a copy of which was provided gratis by PAL to the student body, 24 students.

- d. A new collaboration with Ari Shapiro, Center for Ocean Sciences Education Excellence (COSEE) produced “Antarctica Melting: A Story in Four Acts”, a multimedia presentation for the general public. The presentation can be accessed at <http://coseenow.net/antarctica/>.

### **Numerical Ecosystem Modeling (Scott Doney, WHOI).**

The primary focus of WHOI modeling group over the last year has been on three tasks: synthesis PAL-LTER data into a simplified end-to-end food web using inverse modeling techniques; data analysis of historical interannual variability in chlorophyll and dissolved inorganic carbon; development of improved approaches for evaluating regional and global ecosystem model skill.

#### ***End-to-end Food Web Modeling:***

H. Moeller, a MIT/WHOI graduate student, completed a two-semester long modeling research project with S. Doney and H. Ducklow. In the project, we used inverse analysis techniques to synthesize Palmer LTER measurements into an end-to-end food web model for the West Antarctic Peninsula. Our inverse analysis approach used singular value decomposition (SVD), 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. The research built on earlier modeling work by B. Daniels and H. Ducklow but included revisions to the model structure and observational constraints to reflect current understanding of the system. Specifically, we subdivided zooplankton consumption into krill, salp, and microzooplankton compartments and included *Pleuragramma* (Antarctic silverfish, which feed on krill and are in turn consumed by penguins) into the analysis. We also updated literature values to constrain better krill production, salp grazing and egestion, zooplankton respiration, and system export. Research on the inverse modeling was continued over the winter and spring by S. Saille, a new post-doc to our group. In particular, she is expanding the analysis to more data years to assess interannual variability and trends. In addition the EcoNetwrk software suite (Ulanowicz and Kay, 1991) for food web analysis is used to analyze model results for additional information on WAP pelagic food-web changes in the last years in South and North.

#### ***Data Analysis and Synthesis of Historical PAL-LTER Observations:***

S. Doney contributed to the revision and completion of an analysis paper on historical PAL-LTER data in collaboration with the bulk of the project team (Montes-Hugo et al., 2010). The Southern Ocean is a climatically sensitive region that plays an important role in the regional and global modulation of atmospheric CO<sub>2</sub>. In the paper we examined the relationship between physical climate driving factors (winds, ice, currents) and interannual variability in biological productivity and surface dissolved inorganic carbon concentrations. Specifically, the analysis focused on satellite-derived sea ice data, wind and cloudiness estimates from numerical models (National Centers for Environmental Prediction - National Center for Atmospheric Research reanalysis), and in situ measurements of surface (0–20 m depth) chlorophyll a and dissolved inorganic carbon concentration from PAL-LTER dataset.

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

Regional and global ocean simulations provide context for interpreting the interannual variability and trends in the PAL-LTER data and forecasting future climate change. Our main modeling tool is the ocean component of the Community Climate System Model (CCSM). As part of the new

Marine Ecosystem Model Intercomparison Project (MAREMIP), we are working with international collaborators to develop a comprehensive scheme for comparing global marine ecosystem models and evaluating their skill relative to observations.

**RESEARCH FINDINGS: Palmer LTER 2009-2010.**

*This brief Report highlights some recent results from recent field and lab-based research and data analyses, and also points out a few highlights from recent publications. Publications are listed at the end of the text, to avoid duplication in each section.*

**Information Management (Karen Baker, SIO-UCSD).**

An interdisciplinary investigation into work with data over time spanning from the International Geophysical Year to the International Biological Program to the LTER Program provides insight into ‘Big Data’ efforts and provides an opportunity for comparative study of the LTER network model (Aronova, Baker and Oreskes, 2010). We continued the study of infrastructure development empirically not only in terms of spatial issues but also, and equally importantly, temporal ones (Karasti et al, in press). This paper addresses the collaborative development of information infrastructure for supporting data-rich scientific collaboration. Further collaborative work within the LTER Network includes development of the LTER unit registry (Kortz, 2009) and visits with other LTER sites (Kaplan and Baker, 2009). Ocean Informatics milestones were summarized (Baker and Wanetick, 2010) while progress on technical developments (Conners, 2009) as well as educational opportunities (LYarmey, 2009) were reported in the LTER Information Manager Databits Newsletter. Finally, an introduction to informatics and an ethnographic monograph of LTER Information Management, written earlier as non-refereed internal reports and drawn upon for publications, continue to be useful so were published as SIO Technical Reports via the California Digital Library (Baker, 2005; Baker and Karasti, 2004).

**Education and Outreach (Beth Simmons):**

From June 2009 – present PAL LTER has furthered its Education and Outreach (E/O) program’s mission to educate the public about long-term ecological research and the Earth’s ecosystems. Throughout the year we have found that investing in educating our own outreach correspondents assists us in maintaining our involvement in a variety of wide-ranging outreach venues. For example, illustrator Kirsten Carlson was our liaison at the National Marine Educators Association (NMEA) conference last July in Monterey, California sharing our *Sea Secrets* field journal and children’s book with other marine science educators. High school teacher Christy Millsap connected her classroom LIVE with our Outreach program both prior to and in the field at Palmer station this past season. This summer, educators Beth Deal (Florida) and Jessie Soder (Alaska) will both participate in PAL LTER RET summer professional development program and team up with two other RET candidates from CCE LTER. In this role they will connect across the country and provide valuable insight into taking our site science to their classroom curriculums, helping to expand our program’s instructional materials to reach the middle and elementary grade levels. The goal of our educators is the design of materials that compare the Pacific and Atlantic oceans food webs to the Southern ocean food webs, exposing students to marine ecosystems dynamics around the world. Our current collaboration with Jamie Hollingsworth at Bonanza Creek LTER will tailor the use of the [LTER maps](#) to these teacher’s resources, adding a unique interactive feature to the resources. Feedback from this summer’s experience will contribute to and influence our participation next year during the first-ever LTER *RETS Summer Forum* at Andrews Experimental Forest LTER, gathering together RET candidates from the entire LTER network.

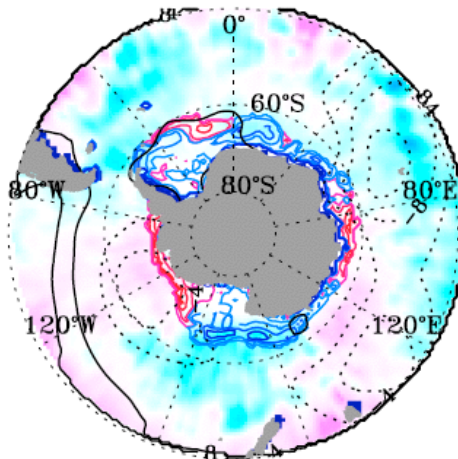


We continue to find that these correspondents aid our Outreach program in reaching broader audiences. Author Mary Cerullo continues to share and request copies of our [Sea Secrets](#) children's books for various professional development workshops, public speaking engagements and book signings throughout the Northeast. Recently, we donated several copies of Sea Secrets to an upcoming [International Polar Year Conference in Oslo](#), in Norway which was a result of our association and commitment to the [International Polar Books project](#). We also donated a classroom set of our books to the Freie Waldorfschule Oldenburg School in Germany.

Finally, my involvement in the last Palmer LTER research cruise afforded the E/O coordinator eight weeks of insight and contribution to the field research aboard the Laurence M. Gould. This led to five months of dedicated design and development of multiple cross-site outreach instructional materials and the production of a short video to be displayed at the [Ocean Today kiosk](#) at the Smithsonian Natural History Museum in Washington D.C.. Several of these instructional materials have been tested in elementary and middle school classrooms upon return from the cruise and are in their final state of revisions. The lessons are expected to be released this September, 2010 on our new [Palmer LTER Education and Outreach website](#). At the Network level, Beth Simmons is co-chair of the Schoolyard Education Committee and will continue her involvement in the Schoolyard education program and collaboration on the SLTER Children's Book Series committee. Through local presentations, LTER network activities and national endeavors, PAL LTER E/O continues to maintain an active program dedicated to the increase of ocean science literacy both in the classroom and the community as a whole.

### **Sea Ice and Climate (Sharon Stammerjohn).**

**(a) Stammerjohn et al (accepted, *DSRII*):** The 2007 International Polar Year (IPY) in the Antarctic was distinguished by strong regional and seasonal ice-atmosphere-ocean anomalies associated with an overall weakening of the prevailing westerly circulation. We assessed the ice-atmosphere-ocean conditions leading up to and during IPY 2007 using satellite-derived and numerically-analyzed surface and atmospheric variables of (i) winds and sea ice concentration and drift, (ii) sea surface temperature and ice-edge anomalies, and (iii) precipitation and snow accumulation. Maps of sea surface temperature (SST) and sea ice concentration (SIC) anomalies revealed distinct regional patterns, showing warm SST/low SIC in the WAP/Bellingshausen (60-100W), eastern Amundsen (100-120W) and western West Pacific (90-120E) regions, versus cool SST/high SIC in the Weddell, Ross and eastern West Pacific (120-130E) regions (**Figure XX**). In the former, warm northerly winds in May (overlying the warm SSTs) brought anomalously high precipitation to those regions, but due to the regional delays in sea ice advance (by up to 2 months), most fell on open ocean, which in turn contributed to negative and near zero September snow depth anomalies. During all of autumn (March to May), the areas of warm SSTs extended from mid-to-high latitudes, resulting from meridional advection of heat associated with a wave-3 atmospheric circulation pattern. In the Bellingshausen and western West Pacific region, the late sea ice advance followed unusually long ice-free summer periods, which suggests that solar ocean warming was relatively high in those regions. The warm ocean conditions may help to explain why the ice edge remained well south of its mean position despite instances during winter of cold southerly winds and northward sea ice drift. We plan to extend the analysis of SST/SIC/SLP to include all years between 1979-2010 in our ongoing investigation of the ocean's role in forcing ice-edge changes, particularly the delayed sea ice advance in the WAP/Bellingshausen Sea region.



**Figure 1.** May 2007 circumpolar anomalies (based on 1979-2007) of Reynolds sea surface temperature (color shading), SMMR-SMM/I sea ice concentration (color contours) and NCEP-NCAR Reanalysis sea-level pressure (black contours, dotted negative, solid positive).

**(b) Meredith et al (accepted, *Progress in Oceanography*):** This is a very nice contribution from our BAS collaborator, Mike Meredith, who investigated upper ocean changes in freshwater composition (meteoric versus sea ice derived) in the Marguerite Bay area. Hydrographic and stable oxygen isotope measurements from the Rothera Oceanographic and Biological Time Series (RaTS) show that meteoric water dominates the freshwater budget (with summer water column inventories of order 4-6m), while contributions from summer sea ice melt were generally lower (ranging from -1 to 0.5m, where a negative value indicates net sea ice formation from this water). Changes in mixed layer depth, which determined the near-surface freshwater percentages, were most notable in the winters of 2003, 2007 and 2008, when northerly winds associated with El Niño / Southern Oscillation and the Southern Annular Mode led to deep mixed layers. Key factors in controlling mixed layer depth were northerly winds, which greatly reduced sea ice cover in northern Marguerite Bay, allowing persistent air-sea heat fluxes and stronger rates of sea ice production. Interestingly, deep winter mixed-layers were then followed by weaker re-stratification the following spring/summer (less sea ice melting in situ). These results have some very interesting implications for the broader PAL LTER study area, given that Montes-Hugo et al (2009; 2010) suggest increased water column stratification with decreased sea ice in the southern WAP region. Differences are likely related to geography (coastal versus offshore), but ongoing studies will continue to track and compare upper ocean changes in response to climate-driven changes in winds and sea ice extent and production.

**(c) Massom and Stammerjohn (in press, *Polar Science*):** This is yet another very nice contribution from our long-time collaborator, Rob Massom, who crafted an amazing assessment of Antarctic sea ice change and variability and the known and complex physical and ecological implications. In this review, biologically significant aspects of Antarctic sea ice change are highlighted, which emphasizes the importance of space/time scales and thermodynamics versus dynamics processes. The direct and indirect effects of changing sea ice on ecosystem structure and function are reviewed, particularly those in the West Antarctic Peninsula region. Included are both the positive and negative impacts on primary production, Antarctic krill, fish, marine mammals and birds. The discussion also includes a review of the physical and ecological significance of those coastal areas influenced by polynyas, fast ice and icebergs, and the overall significance of extreme events, which produce paradoxical physical and ecological impacts. Finally, possible future scenarios are discussed in light of the predicted decline in sea ice by year 2100, e.g., increased storminess/waviness, numbers of icebergs and snowfall. This review nicely places the PAL LTER findings within a broad circumpolar context and distinctly highlights the

immense importance of a well-integrated and highly coordinated multidisciplinary program (such as the PAL LTER) in furthering our understanding of ecosystem response to sea ice changes, of distinguishing long-term trends from natural variability, and of being able to more accurately predict future impacts.

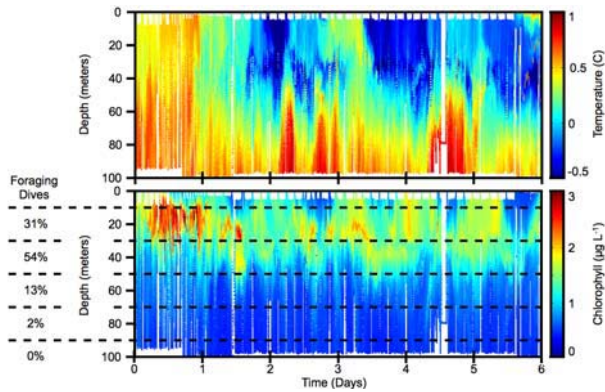
**(d) Fogt et al (accepted, *BAMS*):** In this (third) assessment of the ‘State of Antarctic Climate’, year 2009 was reviewed in context of decadal variability and change, assessments that are useful for placing WAP climate changes in a broader circumpolar context. Climatologically speaking, year 2009 was relatively calm for much of Antarctica, especially compared to the past two years, which included ice shelf collapses juxtaposed with all-time records in sea ice extent. However, the total ice sheet melt during austral summer 2008/2009 was the lowest of the 30-yr satellite record with no melt detected on the Ronne-Filchner and Ross Ice shelves, among other regions. In 2009, the polar atmosphere temperatures were persistently above average in the mid to lower troposphere during winter, while the latter half of the year was marked with short-lived anomalies lasting about one month. Nonetheless, the tropical El Niño event in late 2009 did influence Antarctica, particularly through ridging in the South Pacific. In turn, this created anomalous meridional temperature advection patterns that subsequently led to regional sea ice extent and concentration anomalies and decreased precipitation to the west of the Antarctic Peninsula. Decadal highlights include the following: (1) continued rapid warming of the WAP, particularly in winter; (2) recent evidence that the rest of West Antarctica also significantly warmed; (3) interior and coastal East Antarctica remained relatively stable; (4) significant continental ice loss along the AP and West Antarctica; (5) continued decreases in Bellingshausen sea ice extent juxtaposed against record-high circumpolar sea ice extent in austral summer-autumn of 2007-08; (6) lowest Antarctic-wide summer snowmelt in 2008-09; (7) a continuation of a positive-phased Southern Annular Mode; and (8) a record high Antarctic ozone hole extent on September 24, 2006, which otherwise has shown large interannual variability with no clear signs of recovery (yet).

**(e) Montes-Hugo et al (2010):** This paper nicely follows the Montes-Hugo et al (2009) paper, which showed a wind- and ice-driven poleward shift in primary productivity along the WAP region over 1998-2006 as compared to 1978-1986. In this more recent study, the poleward shift of enhanced primary productivity is shown to be associated with enhanced seasonal drawdown in inorganic carbon, as analyzed over 1992-2006 in the PAL LTER region. (For more exciting details, see Doney’s component summary.)

**(f) Ducklow et al (in press):** This was an invited contribution to *Antarctica: An Extreme Environment in a Changing World*, which consists of a wonderful PAL LTER grand synthesis led and orchestrated by Hugh Ducklow. A short section on ice-climate variability and trends was provided. (For more wonderful details, see Ducklow’s component summary.)

### **Physical Oceanography (Doug Martinson BP-021).**

We now have 5 moorings (4 original IPY moorings, but with the completion of IPY project, those 4 moorings have been transferred to the LTER project). For this past year, our mooring data has allowed us to answer our primary question regarding the manner in which the warm UCDW from the ACC over the continental slope is moved onto the continental shelf where it can be ventilated for atmospheric warming and make contact with the glacial ice melting it. The mooring results show that the water is transferred via eddies containing almost pure UCDW core water from the slope on the central portion of our LTER grid. The examination of the



**Figure 2.** A glider cross-section collected offshore Palmer Station. **A)** The variability in the temperature, with warm water intrusions to the surface representing upwelling. **B)** The chlorophyll fluorescence during the same time with daytime solar quenching being clearly evident. Using radio-tagged Adelie penguin tags, the foraging locations are binned on the fluorescence transect.

temperature of the eddy core as a function of time/distance from the slope break allows estimation of the heat flux, and comparison of that with the OMD analysis of fraction pure UCDW and heat distribution across the grid as published in Martinson et al., 2008 (DSR special PAL LTER issue). That comparison (which we are currently working on) will reveal what fraction of the observed heat distribution the eddies can likely satisfy, or if other mechanisms are required. Lagged correlations suggest that the eddies drift at a rate comparable with the mean ocean current speed, bathymetrically guided along the northern wall of the Marguerite trough. Further and more detailed analysis of these findings will be a priority in the upcoming year.

### Phytoplankton (Oscar Schofield, B-019).

Palmer glider surveys showed that enhanced phytoplankton stocks co-occurred with the biological “hot-spot” offshore of Palmer Station. Data suggested there was upwelling with the enhanced phytoplankton biomass in the canyon (**Figure 2**) and initial analyses suggest the quantum yields within the canyon appear to be enhanced relative to outside the canyon. This confirms that phytoplankton appear to be in best health within the canyon upwelling. Penguins were foraging 85% time within the chlorophyll maximum.

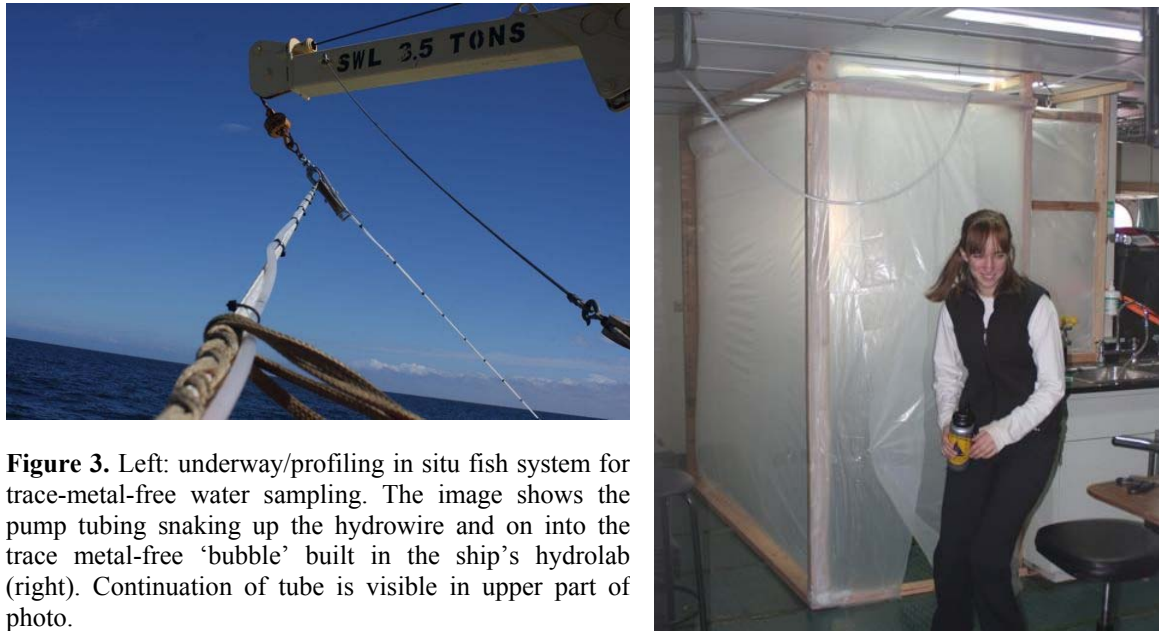
**Data analysis and synthesis.** Several publications were produced this year. Using decadal time series we assessed the seasonal dynamics in the carbon biogeochemistry on the WAP. We contributed to the LTER review prepared by Ducklow. We have a review and observational strategy for the Southern ocean in press at Science for an upcoming issue of the “Changing Oceans” which will be published June 18, 2010. Finally an analysis of glider capabilities combined with radiotagged penguins was the focus for a manuscript submitted to a special issue of Integrative and Comparative Biology. That manuscript is under review.

### Trace Metals (Rob Sherrell, Rutgers: B-019)

The initial goal of our research is to determine distributions of dissolved Fe in the euphotic zone off the WAP and to investigate relationships between the spatial concentration gradients and the distribution of primary production. We designed and deployed an underway “fish” system (photo below left) to bring metal-clean surface seawater into a plastic “bubble” cleanroom constructed on the LM Gould (photo below right). To achieve our analytical goals we are developing a new online ICP-MS method for determination of multiple trace elements in seawater. The method is 90% complete, and will use isotope dilution to quantify a suite of metals automatically using just 5mL of seawater at ~8min/sample. Our goal is to load the autosampler in the afternoon and come back in the morning to a set of high-quality raw data for up to 80 samples in one run. Very preliminary results show concentrations in surface waters

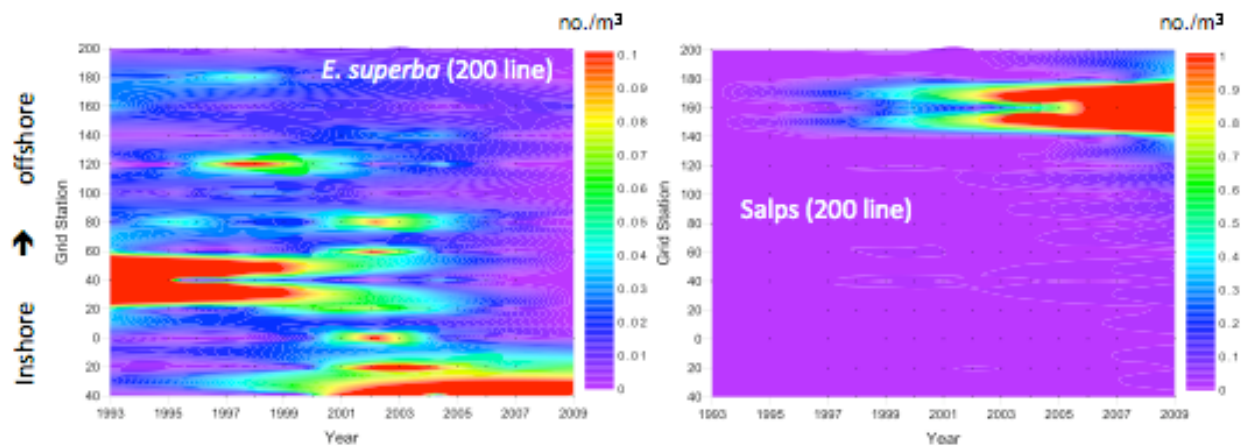


along the “600” line on the LTER grid are all below 1.0 nanomolar, and decrease generally with distance offshore. We are very pleased with this early result, which suggests that dissolved Fe is fairly low over the WAP shelf, and may decrease to potentially limiting concentrations near the shelf-slope break. Our sample collection system shows every indication of being very clean. A full set of seawater iron concentrations will be presented at the Palmer LTER annual workshop in Sept. 2010.



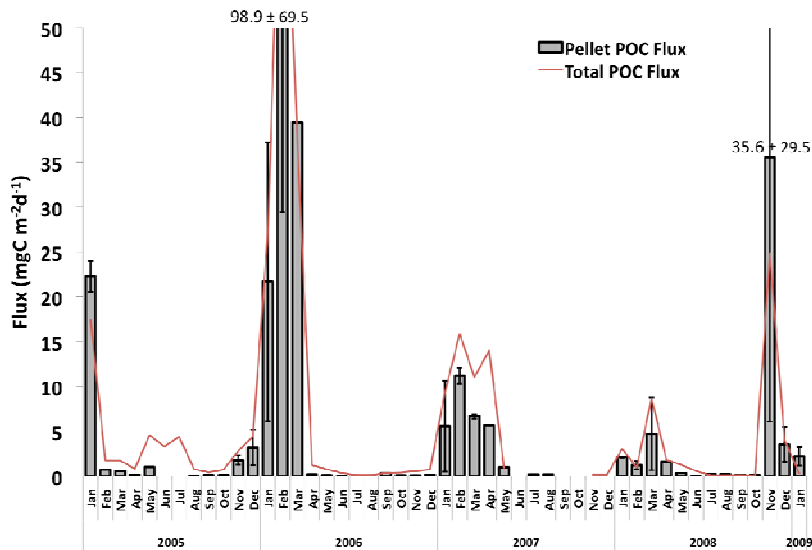
**Figure 3.** Left: underway/profiling in situ fish system for trace-metal-free water sampling. The image shows the pump tubing snaking up the hydrowire and on into the trace metal-free ‘bubble’ built in the ship’s hydrolab (right). Continuation of tube is visible in upper part of photo.

### Zooplankton and micronekton (Debbie Steinberg B-020).



**Figure 4.** Changes across the shelf (inshore to offshore) and over time in Antarctic krill (*Euphausia superba*) and salps (mostly *Salpa thompsoni*) along the northern-most sampling grid line (line 200).

Now that we have nearly completed transfer and overhaul of the main portion of the macrozooplankton database from years past into Datzoo we have been able to start identifying some long-term trends. There are changes in distribution and relative abundance of krill and salps, with a decrease in krill and an associated shift closer to shore, and an increase in salps, with a possible expansion over the shelf (Figure 4). We predict this will lead to changes in biogeochemical cycling and carbon and nutrient export from surface waters.

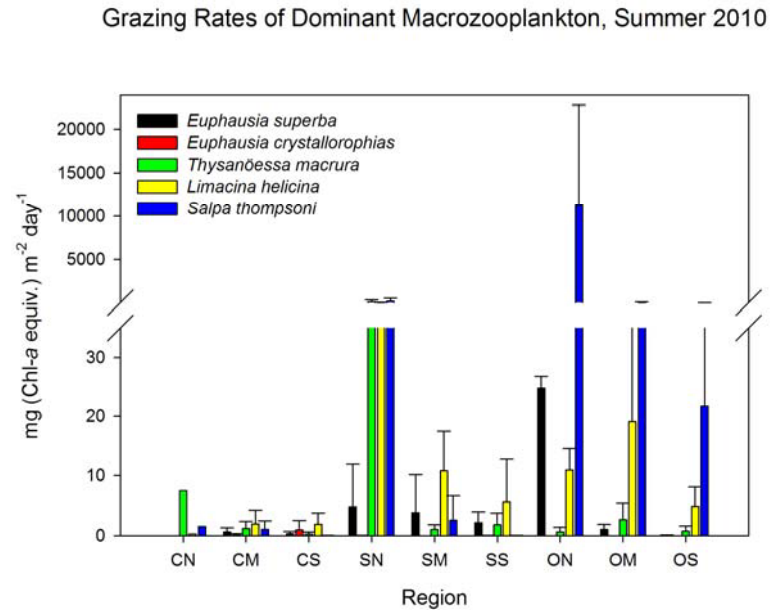


**Figure 5.** Monthly zooplankton fecal pellet POC flux (bars) compared to total POC flux (red line) from moored sediment trap in northern part of the grid over the shelf. Error bars are 1 standard error. Absence of bars indicates sample was not analyzed for pellet flux.

We thus have also been analyzing the contribution of zooplankton fecal pellets from different taxa to particulate organic carbon (POC) flux in the WAP to predict the effect of changes in the zooplankton community on export of fecal pellets, using the archived moored sediment trap samples. Fecal pellet POC flux constituted a significant proportion of total POC flux (Fig. 4), with summer pellet C flux (68% of total) significantly higher than in winter (36%) ( $n = 11,270$ ). Cylindrical pellets, produced by krill, dominated the flux contributing to a monthly mean of 79% of fecal pellet flux, with copepod and salp pellets contributing less (15% and 6%, respectively, of total fecal pellet flux).

This year we have also begun analyzing grazing rates. In January 2010, salps were responsible for the majority of macrozooplankton grazing in offshore waters (nearly 100% in the northern offshore region) (Fig. 6). The pteropod *L. helicina* was an important grazer of phytoplankton in the shelf and offshore waters. The Antarctic krill *E. superba* was an important grazer over the shelf, while the ice krill *E. crystallophias* contributed to over 25 % of total grazing in the southern coastal waters. The euphausiid *Thysanoessa macrura* was important in the northern shelf region, and offshore. Estimates of daily rations suggest that krill were consuming a predominantly heterotrophic food source, while salps were able to consume up to 82 % of their body carbon per day in phytoplankton, and in some instances even more. Next we will be

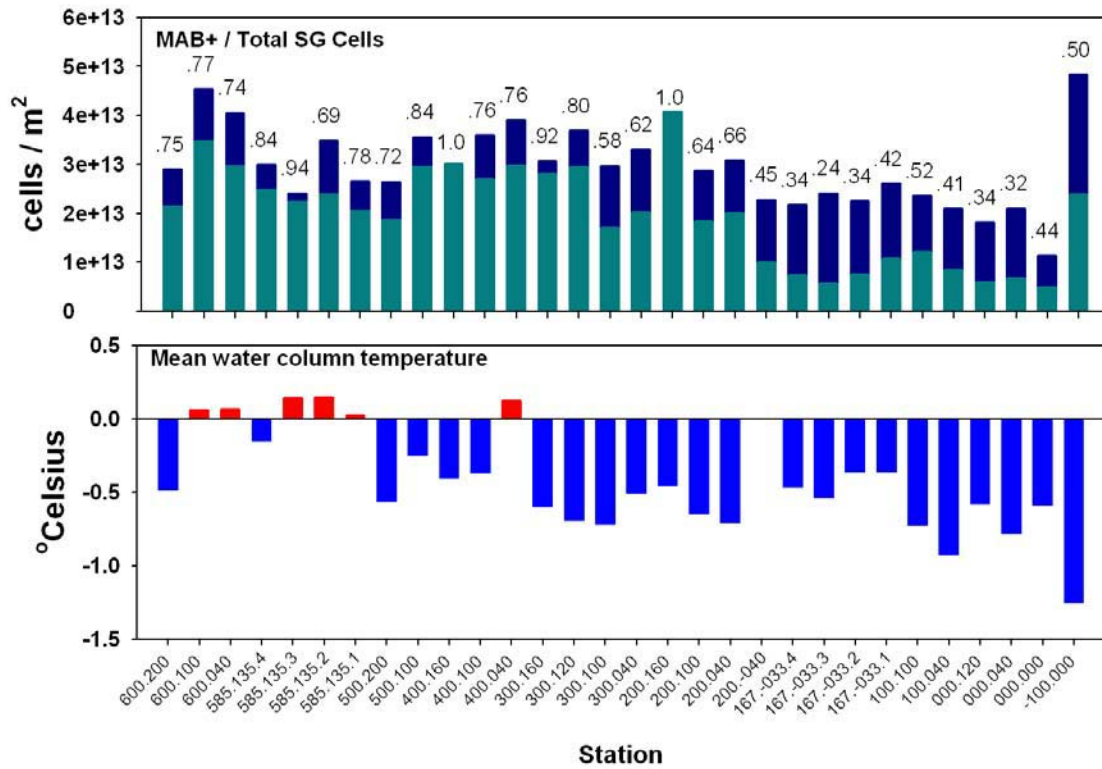
comparing these grazing rates to primary production (PP) to calculate removal rates, and also to microzooplankton grazing rates to determine the relative importance of macro- vs. microzooplankton in removal of PP.



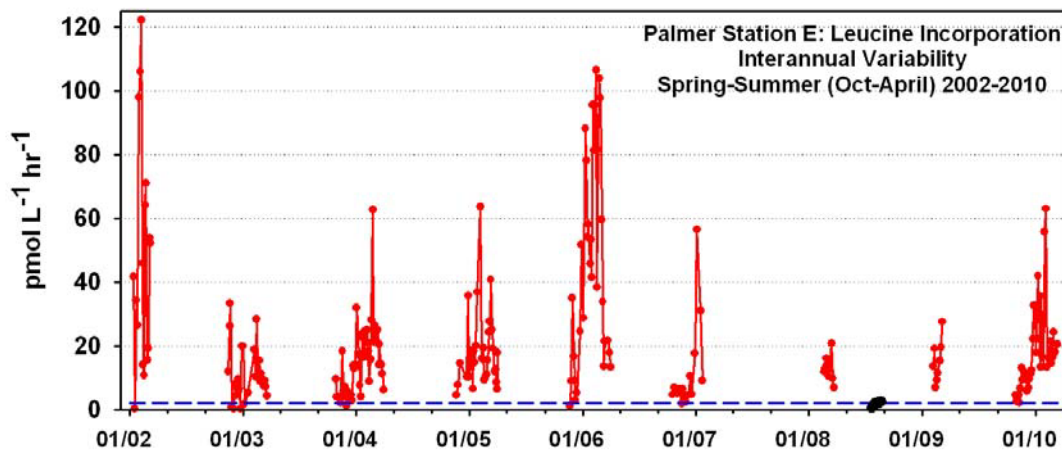
**Figure 6.** Grazing rates of dominant macrozooplankton in the WAP from the Jan. 2010 cruise as determined by the gut fluorescence method. Rates are integrated to 120 m. Region key: CN = coastal northern; CM = coastal middle; CS = coastal southern; SN = shelf northern; SM = shelf middle; SS = shelf southern; ON = offshore northern; OM = offshore middle; OS = offshore southern.

### Microbes and Biogeochemistry (Hugh Ducklow BP-045).

We had a very productive season, obtaining several novel preliminary (i.e., not published yet) data sets with the new Accuri Flow Cytometer (FC). By using the DNA stain Sybr Green, which stains all cells containing DNA, and the membrane-integrity stain DiOC6 (both from Molecular Probes, Eugene, OR) we can estimate the proportion of living, healthy and membrane-active bacterial cells (MAB+ cells; not all cells observed under the microscope or detected by FC are believed to be “active” as defined by various probes and tracers). **Figure 7** below shows the integrated (0-50 m) bacterial abundance, the fraction of MAB+ cells and the mean water column temperature. All stations north of the LTER 200 transect line had >50% activity. Most stations south had <50% with the exception of -100.000 (Charcot Island), which was undergoing an intense phytoplankton bloom at the time of our visit. Note that there was no clear relationship between temperature and % activity. The Accuri cytometer enables us to analyze live samples immediately after collection, avoiding potential artifacts from preservation and storage. Indeed, comparison of live vs stored, preserved samples has already suggested loss of cells during storage.



**Figure 7.** Standing stocks (cells m<sup>-2</sup> in the upper 50 meters) of bacteria + archaea determined by shipboard flow cytometry on live samples. The lighter-colored, lower part of each bar is the active fraction of the cell assemblage, as determined by the vital membrane probe DiOC6. The lower panel is the depth-averaged water column temperature. Numbers above the bars are the fraction of active cells (active/total).



**Figure 8.** Bacterial production rates (presented as picomoles of leucine incorporated per liter per hour) at Palmer Station E, January 2002 – March 2010. The back dots are activities measured in winter 2008 in a separate IPY project. The blue dashed line extrapolates those measurements as a mean winter activity level.



Our first complete field season at Palmer Station with regular sampling from October through March since 2006 has caused us to refine our concept of a ‘typical seasonal cycle’ in these waters (**Figure 8**). High bacterial production episodes (>60 pmol/l/hr) are sporadic and usually short-lived. Of the 6 years when we have reasonably complete seasonal time series, only one has sustained high BP (2005-06). With our new FC capability we can look more closely at this phenomenon by using various activity probes to examine relationships between the production rates and activity of individual cells in the population.

### **Seabirds (Bill Fraser BP-013).**

A key, long-term objective of our research has been to identify and mechanistically understand the processes that regulate the contrasting demographic responses of Adélie, Gentoo and Chistrap penguins. As noted in these reports during the last two years, one aspect of this effort focused on exploring the role that Antarctic Silverfish (*Pleuragramma antarcticum*) may play in these dynamics (e.g., Chapman et al. 2009, 2010) through collaborations with Simon Fraser University and the University of South Florida-St. Petersburg. This season, as a result of these related and continuing collaborations, we observed what we would regard as a landmark finding for our program and its objectives. More specifically, an autumn fishing cruise with J. Torres (USF) confirmed that silverfish may be regionally extinct in the northern half of the PAL LTER grid, a pattern first evident in seabird diets, but until this year lacking validation via targeted, exploratory fishing. Given the known importance of silverfish to the food web, the significance of these findings cannot be overstated. Indeed, within the scope of the key objective introducing this paragraph, this finding fundamentally enhances our understanding of the causal role that physiological diversity plays in species-specific demographic responses to a changing climate. Further development of this work is the topic of Ph.D. student Kristen Gorman’s dissertation via the collaboration with Simon Fraser University.

### **Numerical Ecosystem Modeling (Scott Doney, WHOI):**

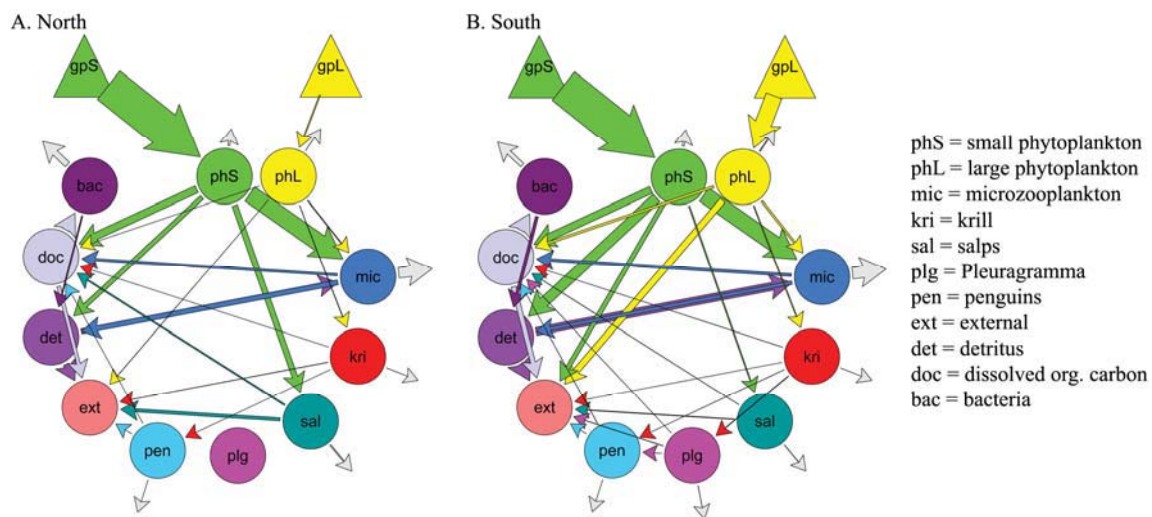
The primary focus of WHOI modeling group over the last year has been on three tasks: synthesis PAL-LTER data into a simplified end-to-end food web using inverse modeling techniques; data analysis of historical interannual variability in chlorophyll and dissolved inorganic carbon; development of improved approaches for evaluating regional and global ecosystem model skill.

**End-to-end Food web Modeling:** Results from H. Moeller’s inverse modeling study were presented as a short section in a synthesis book chapter on PAL-LTER (Ducklow et al., in press). S. Sailley attended the CAMEO E2E (End-to-End) workshop in spring 2010 and presenting preliminary results from her analysis in a poster (Sailley et al., 2010). For the solutions presented in Ducklow et al., (in press), we used measurements for summer (Jan.-Feb.) from stations on the 600 line (North, near Palmer Station Adélie colonies) and 200 line (South, near Avian Island Adélie colonies) and literature values to constrain the model. Specifically, we used measured primary production, chlorophyll-*a* levels, and bacterial production to set three model fluxes. By assuming that primary production is proportional to chlorophyll-*a* amounts, we divided primary production into large (>20  $\mu\text{m}$ ) and small (0.4-20  $\mu\text{m}$ ) phytoplankton pools. We used krill and salp biomass, penguin populations, and the sediment trap record to constrain trophic and export fluxes. Measurements were converted to carbon fluxes per square meter, and averaged over the feeding radius of the Adélie penguin colonies. In the North, where *Pleuragramma* do not comprise a significant portion of the food web, that pool is excluded from the analysis.

Flow rates and pathways through the model food web are driven by both the magnitude and size distribution of observed primary production, which is input as a driving factor. The results of our inverse solutions suggest a role for both the “traditional” Antarctic food chain linking diatoms, krill, and penguins, and the microbial loop of small phytoplankton, microzooplankton and bacteria. Specific findings from the modeling work include:

- Bacteria have a very variable biomass from year to year, but bacterial production never exceeds 10% of the primary production. It is unclear whether there is insufficient DOM present for them to use or a strong grazing pressure.
- Despite four-fold variations in measured krill and salp biomass, most of the primary production in the model is grazed by microzooplankton, more than previously estimated. Microzooplankton has the potential to regulate phytoplankton biomass (growth rate close to that of phytoplankton), while krill is a link from primary producer to higher trophic level (fish and penguins).
- Salps are increasing in abundance with time in WAP waters and are distinct from krill because they can prey on the smaller size fraction of phytoplankton and present high growth rate through asexual reproduction. Salps have no known predators and they efficiently repackage their prey into heavy fecal pellets with a high sinking rate. As such they can be considered to be a “dead-end” for carbon flow.
- Adelie penguin populations are an order of magnitude larger in the South, driving a twenty fold variation in the fraction of primary production consumed by penguins (0.01% in the North on a krill diet and 0.2% in the South, where they feed on both krill and *Pleuragramma*)
- The model results suggest that a substantial fraction of primary production (35-50%) is exported as detritus or DOC. By contrast, sediment trap measurements suggest exports of less than 5% of primary production, confirming concerns about trap underestimation.

Understanding the role of each group of organisms is therefore crucial to the development of a realistic picture of the food-web.



**Figure 9.** Inverse model reconstruction for fluxes (arrows) and their importance (arrow thickness) through the food web at (A) Palmer Station (North) and (B) Avian Island (South). The thickness of an arrow is proportional to the flux value. Note the greater relative abundance of large phytoplankton (phL) in the south, but overall dominance by smaller cells in both regions, leading to larger inputs of primary production into microzooplankton (mic) than krill (kri). Nonetheless the model satisfies metabolic needs for observed krill stock in both regions. In these diagrams, some trophic exchanges are permitted by the model, but did not appear as nonzero flows in the model solution (e.g. microzooplankton consumption by krill and salp). Note also further flows through salp in the north, where greater sea-ice declines may be stimulating salp blooms.

Results from interannual variability and trends analyses include:

- Primary production in the North, years 1999 to 2005, is highly variable both in its importance, from 111 to 15 mmol C m<sup>-2</sup> d<sup>-1</sup>, and its composition, from 80 to 1.6 % of primary production due to the large fraction of phytoplankton. However, the distribution of primary production to the different food web compartment does not show a response to this variation except for the year 2004 when the proportion of large phytoplankton was of 1.6%, too low to support the needs of krill, who thus preyed on microzooplankton.
- Primary production in the South, years 1999 to 2005, shows little variation compare to the north, its magnitude being between 32 and 43 mmol C m<sup>-2</sup> d<sup>-1</sup> except in 1999 when it was 8 mmol C m<sup>-2</sup> d<sup>-1</sup>, 68 to 22% of it is due to large fraction of phytoplankton. Flow of carbon through krill are decreasing from year to year (from 3 to 1% of primary production flowing through krill), while other flows are increasing.
- The food web present more links in the South (22) than in the North (15).
- Food web in South is changing slowly with an increase in detritivory (from 4.8 to 13.5 mmol C m<sup>-2</sup> d<sup>-1</sup>, EcoNetwrk result), ascendancy (50.8 to 222.1 mmol C m<sup>-2</sup> d<sup>-1</sup>, measure of ecosystem organization and size, reflect pathways efficiency) and total system throughput (30.2 to 137.5 mmol C m<sup>-2</sup> d<sup>-1</sup>, measure of system size and growth). The high value are in the range of value for the North food web from year to year (detritivory: 6.6 to 18.2; ascendancy: 123 to 309 mmol C m<sup>-2</sup> d<sup>-1</sup>; total system throughput: 76.2 to 184.4 mmol C m<sup>-2</sup> d<sup>-1</sup>). Indicating that the food web in the south of WAP is slowly becoming the same as in the north.

Expanding the study to previous year (before 1999 and after 2005) is therefore of importance to see the changes in WAP pelagic ecosystem due to global warming along with the change trend and consequences on the food-web.

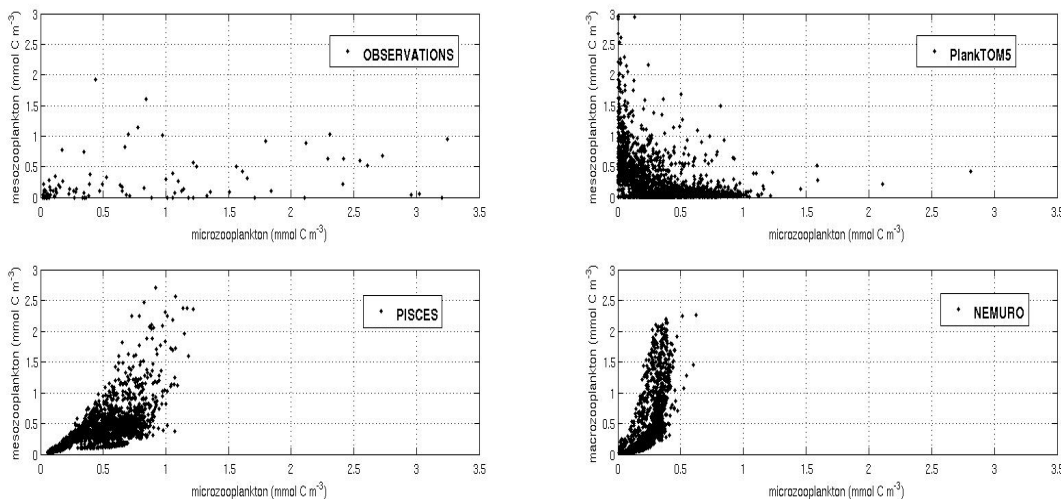
**Data Analysis and Synthesis of Historical PAL-LTER Observations:** In Montes et al. (2010), we demonstrate that strong northerly winds during spring are associated with enhanced summer biological productivity and dissolved inorganic carbon (DIC) drawdown. Specifically we show sea ice concentration from June to November and spring wind patterns between 1979 and 2006 had a significant influence on midsummer (January) primary productivity and carbonate chemistry for the WAP. In general, strong (>3.5 m s<sup>-1</sup>) and persistent (>2 months) northerly winds during the previous spring were associated with relatively high (monthly mean > 2 mg m<sup>-3</sup>) surface chlorophyll and low (monthly mean < 2 mmol kg<sup>-1</sup>) salinity<sub>corrected</sub>, surface DIC during midsummer. The greater surface chlorophyll accumulation and DIC depletion was attributed to an earlier growing season characterized by decreased spring sea ice cover or nearshore accumulation of phytoplankton in association with sea ice. The impact of these wind-driven mechanisms on chlorophyll and DIC depended on the extent of sea ice area during winter. Winter sea ice are affected phytoplankton blooms by changing the upper mixed layer depth during the subsequent spring and summer (December–January–February). Midsummer surface

DIC was not related to DIC concentration during the previous summer, suggesting an annual replenishment of surface DIC during fall/winter and a relatively stable pool of deep (>200 m depth) “winter-like” DIC on the WAP.

**Regional and Global Ocean Physical-Ecological-Biogeochemical Simulations:** The MAREMIP Program “kick-off” meeting was held in Cambridge, UK in fall 2009 (co-chaired by C. Le Quere and S. Doney) attended by representatives from 11 different international groups (<http://lgmacweb.env.uea.ac.uk/maremip/index.shtml>). A work plan was developed for MAREMIP Phase-1:

- compiling field, laboratory and remote sensing data for different phytoplankton and zooplankton functional groups for model evaluation and parameterization development;
- creating standardized univariate and multivariate model-data skill metrics;
- integrating a suite of common model simulations (historical reconstructions);
- comparing simulated ecosystem dynamics between models and against observation.

A pilot MAREMIP Phase-0 is also underway for a subset of 4 models (CCSM-BEC, NEMURO, PISCES, and PlankTOM5). Preliminary results from MAREMIP Phase-0 analysis for phytoplankton were presented at the 2010 Ocean Sciences Meeting (Vogt et al., 2010; Hashioka et al., 2010). Sevrine Sailleu also began a project with the Phase-0 models to intercompare simulated zooplankton distributions and dynamics.



**Figure 10.** Variation in the concentration of microzooplankton and mesozooplankton (both in  $\text{mmol C m}^{-3}$ ) when co-occurring. For the observation (upper left) and three ecosystem model coupled to a GBCM: PlankTOM5 (upper right); PISCES (lower left) and NEMURO (lower right). Note how the variation of microzooplankton and mesozooplankton concentration is different in PlankTOM5, indicating a different relation (very strong competition and exclusion) than in PISCES and NEMURO. Also maximal concentrations of microzooplankton are lower for NEMURO ( $\sim 0.5 \text{ mmol C m}^{-3}$ ) and PISCES ( $\sim 1 \text{ mmol C m}^{-3}$ ) than for PlankTOM5 ( $\sim 2 \text{ mmol C m}^{-3}$ ) and observations ( $\sim 3 \text{ mmol C m}^{-3}$ ) indicating limitation of microzooplankton by either grazing by mesozooplankton or abundance in phytoplankton.

**Publications (students and postdocs underlined; coPIs in bold)**

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- Ducklow, H.**, A. Clarke, R. Dickhut, **S.C. Doney**, H. Geisz, K. Huang, **D.G. Martinson**, **M.P. Meredith**, H.V. Moeller, M. Montes-Hugo, **O. Schofield**, **S.E. Stammerjohn**, **D. Steinberg**, and **W. Fraser**, Marine pelagic ecosystems: the West Antarctic Peninsula, in *Antarctica: An Extreme Environment in a Changing World*, ed. A.D. Rogers, Wiley, *in press*.
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#### **Presentations at Conferences and Workshops:**

- Bernard, K.S., **Steinberg, D. K.** & **Schofield, O.M.E.** 2010. Summer grazing impact of the dominant macrozooplankton in the Western Antarctic Peninsula. Scientific Committee on Antarctic Research 4<sup>th</sup> Open Science Conference, August 2010, Buenos Aires, Argentina.
- Chapman, E., Hofmann, EH, Ribic, CA, **Fraser, WR**. 2009. Factors affecting Adélie penguin foraging and chick growth off the Western Antarctic Peninsula: A modeling study. September, LTER ASM, Estes Park, Colorado, USA.
- Ducklow, H**, **Baker, K**, **Doney, S**, **Fraser, W**, **Martinson, D**, **Schofield, O**, **Simmons, B**, **Stammerjohn, S**, **Steinberg, D**. 2009. Palmer, Antarctica Long Term Ecological Research: Looking back in time through marine ecosystem space. September, LTER ASM, Estes Park, Colorado, USA.
- Ducklow, H.**, **B Fraser**, **D Martinson**, **O Schofield**, **S E Stammerjohn**. 2010 Long-term observations of climate change and ecosystem response along the western Antarctic Peninsula, 1975-2009. (*Invited*): Ocean Sciences Meeting, 2010, Portland OR

- Fraser, WR, Gorman, K, Smaniotta, R, Martinson, D, Ducklow, H, Patterson-Fraser, D, Steinberg, D, Schofield, O.** 2009. Back to the cold, a discovery cruise to Charcot Island, Western Antarctic Peninsula. September, LTER ASM, Estes Park, Colorado, USA.
- Fraser, WR.** A landscape effect on Adélie penguin demography. 2010. August, ESA Annual Meeting, Pittsburgh, Pennsylvania, USA.
- Geisz, HN, Dickhut, RM, Cochran, MA, **Fraser, WR.** 2009. Tracing persistent organic pollutants into Antarctic seabird eggs. September, LTER ASM, Estes Park, Colorado, USA.
- Geisz, HN, Dickhut, RM, Cochran, MA, **Fraser, WR, Patterson-Fraser, DL, Ducklow, HW.** 2010. Persistent organic pollutants as tracers of Antarctic seabird ecology. September, First World Seabird Conference, Vancouver, British Columbia, Canada.
- Hashioka, T., Y. Yamanaka, M.N. Aita, M. Vogt, C. Le Quere, S. Alvain, L. Bopp, E.T. Buitenhuis, **S.C. Doney**, and I. Lima, 2010: Spatio-temporal differences in plankton compositions among models from the first results of MARine Ecosystem Model Inter-comparison Project (MAREMIP), AGU/ASLO/TOS Ocean Sciences Meeting 2010, BO25H-03.
- Huang, K, H Ducklow, M Vernet, M R Hiscock, N Cassar, M L Bender. 2010 Export production and its regulating factors in the Western Antarctic Peninsula region of the Southern Ocean: Ocean Sciences Meeting, 2010, Portland OR
- Kahl, A, Ducklow, H, Fraser, W, Martinson, D, Schofield, O. 2009. Autonomous robotic surveys of Adélie penguin foraging “hot spots” offshore of Palmer Station, Antarctica. September, LTER ASM, Estes Park, Colorado, USA.
- Lunau, M; Erickson, M; Waldron, M; Ducklow, H W: 2010SHIPBOARD, NEAR-REAL-TIME ENUMERATION OF LIVING PHYTOPLANKTON AND BACTERIA ALONG THE WEST ANTARCTIC PENINSULA. ASLO Summer Meeting, Santa Fe, NM. (Poster).
- Montes-Hugo M.A., Gould R.W., Arnone R.A., Ducklow H., Steinberg D., Schofield O. 2010. Day-night patterns of particle dynamics of Antarctic waters based on glider-derived observation. Ocean Optics Meeting, Anchorage, AL, Sept.
- Oliver, M., **Fraser, W.,** Irwin, A., **Schofield, O.,** Kohut, J. 2010. Satellite Driven Analysis of Climate Mediated Changes in Antarctic Food-Webs. Ocean Sciences Meeting (Portland, Oregon).
- Oliver, M, **Fraser, WR,** Irwin, A, **Schofield, O,** Kohut, J. 2010. Satellite-driven analysis of climate mediated changes in Antarctic food webs. May, NASA Ocean Color Science Meeting, New York, New York, USA.
- Ribic, CA, Ainley, DG, Ford, RG, **Fraser, WR,** Tynan, CT, Woehler, EJ. 2010. Water masses, ocean fronts, and the structure of Antarctic seabird communities: putting the eastern Bellingshausen Sea in perspective. September, First World Seabird Conference, Vancouver, British Columbia, Canada.
- Sailley, S., H. Ducklow, S. Doney, H. Moeller, 2010: Western Antarctic Peninsula: Modeling and understanding the pelagic food-web within the global warming context, Poster at CAMEO E2E Workshop (Building the Foundation: Marine Trophic Webs from End-to-End), Marine Biological Laboratory, Woods Hole MA.
- Schofield, O, Kahl, A, Ducklow, H, Fraser, W, Martinson, D, Jones, C. 2009. Using Webb gliders to study the physical regulation of ecosystem dynamics at Palmer Station Antarctica. LTER ASM, Estes Park, Colorado, USA.

- Schofield, O., H Ducklow, M Arrott, A Kahl, D Martinson, DK Steinberg, B Fraser, K Gorman.** 2010. Bathymetric structuring of biological hotspots in the West Antarctic Peninsula (*Invited*): Ocean Sciences Meeting, 2010, Portland OR
- Stammerjohn, S.,** Spatio-Temporal Mapping of Southern Ocean Sea Ice Advance and Retreat (with regional contrasts between PAL LTER and Ross Sea regions), Talk presented at the New Zealand Ministry of Fisheries in partnership with the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), an Expert Workshop on Ross Sea Marine Spatial Protection and Management (June 2009, Wellington, NZ).
- Stammerjohn, S., H. Ducklow, D. Martinson, R. Massom, D. Rind,** The Fastest Changing Sea Ice Habitats, Poster presented at the LTER All Scientists Meeting, 'Integrating Science and Society in a World of Constant Change', followed by a talk given in the ASM Workshop, 'Disappearing Cryosphere: Processes, Causes and Implications', organized and lead by Hugh Ducklow (14-16 September 2009, Estes Park, CO)
- Steinberg, D K SE Wilson, MR Gleiber, H Ducklow, K Buesseler.** 2010 (*Invited*): Cross-system comparison of zooplankton effects on transport of organic matter to the deep sea. Ocean Sciences Meeting, 2010, Portland OR
- Steinberg D.K., O.M. E. Schofield, W. R. Fraser, S. E. Stammerjohn, D. G. Martinson, S. C. Doney, M. Montes-Hugo, and H. W. Ducklow.** 2010 (*Invited*): The changing ecosystem of the West Antarctic Peninsula. Society for Integrative and Comparative Biology Meeting, Seattle, WA, Jan. 2010.
- Steinberg, D.K., K. E. Ruck, L. M. Price, M. R. Gleiber, J. S. Cope, H. W. Ducklow.** 2009. Zooplankton Export of Organic Matter in the West Antarctic Peninsula. Long-Term Ecological Research (LTER) All Scientists Meeting, Estes Park, CO, Sept. 2009.
- Straza, T R, H Ducklow, AE Murray, D Kirchman.** 2010 *POSTER* Abundance and single-cell activity of bacterial groups in Antarctic waters: Ocean Sciences Meeting, 2010, Portland OR
- Vogt, M., C. LeQuere, S. Alvain, L. Bopp, E.T. Buitenhuis, **S.C. Doney**, T. Hashioka, I. Lima; M.N. Aita, and Y. Yamanaka, 2010: First results from the MARine Ecosystem Model Inter-comparison Project (MAREMIP) (*Invited*), AGU/ASLO/TOS Ocean Sciences Meeting 2010, BO13A-01.

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### Internet/Websites

- K Baker (2010) Palmer Data Portal <http://pal.lternet.edu/data/dataportal/>
- B Simmons (2010) Palmer LTER Cruise blog <http://cce.lternet.edu/outreach/blogs/cruise/>
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- Ocean Today kiosk project <http://oceantoday.noaa.gov/>

### Newsletter

- N Kaplan and K Baker, 2009. Experiences from an Information Management Cross-Site Visit. LTER Databits Newsletter, Fall 2009.
- M. Kortz, 2009. LTER Unit Registry: Products and Process. LTER Databits Newsletter, Fall 2009.
- L Yarmey, 2009. Continuing Education Options for Information Managers. LTER Databits Newsletter, Fall 2009.



J Conners, 2009. Matplotlib: An Open Source Python 2-D Plotting Library. LTER Databits Newsletter, Fall 2009.

K Baker and J Wanetick, 2010. SIO Ocean Informatics Update: Growing Infrastructure in Support of Scientific Research. LTER Databits Newsletter, Spring 2010.

### **Invited Seminars**

Ducklow, HW. 2010. "Long-term observations of climate change and ecosystem response along the western Antarctic Peninsula, 1975-2009." WHOI Department of Biology. Invited Seminar.

Ducklow, HW. 2010. "Long-term observations of climate change and ecosystem response along the western Antarctic Peninsula, 1975-2009." Invited guest lecturer, Rutgers University Marine Sciences graduate students (one per year).

Ducklow, HW. 2010. "Long-term observations of climate change and ecosystem response along the western Antarctic Peninsula, 1975-2009." Invited guest lecturer, University of Georgia Marine Sciences graduate students (one per semester).

Fraser, WR. 2009. Top-down vs. bottom-up: Top predator perspectives on climate and ecosystem change in the Western Antarctic Peninsula region. October, SCRIPPS Institution of Oceanography, San Diego, California, USA.

Fraser, WR. 2009. It does matter where you breed: Landscape effects on the long-term population trends of Adélie penguins. May, Hopkins Marine Laboratory, Stanford University, Monterey, California, USA.

Fraser, WR. 2009. Looking back in time through marine ecosystem space: A predator's perspective on climate and change in the Western Antarctic Peninsula. October, Simon Fraser University, Vancouver, British Columbia, Canada.

Fraser, WR. 2010. A predator's perspective on tipping points and the changing structure of avian communities in the Western Antarctic Peninsula. July, Jornada LTER, Las Cruces, New Mexico, USA.

Schofield, O. (April 2010). Ocean observing in the melting poles: A case example from the West Antarctic Peninsula. (Department of Earth and Oceans, University of Massachusetts)

Schofield, O. (April, 2010). Building a robust cyberinfrastructure to enable science for the National Science Foundation's Ocean Observatory Initiative (Arizona State University, Tempe, AZ)

Schofield, O. (May 2010). Hot days in the Southern Ocean: Climate change and ecosystem response. (Southampton University and the United Kingdom National Oceanographic Office, United Kingdom).

Stammerjohn, S., Disappearing Sea Ice: a Bi-Polar Concern, Invited Talk at the Whole Earth Seminar Series presented by the Earth and Planetary Department, UCSC (17 November, 2009, CA).