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# Collaborative Research: Historic Perspectives on Climate and Biogeography from Deep-sea Corals in the Drake Passage

Rhian G. Waller

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## Preview of Award 1127582 - Final Project Report

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### Cover

Federal Agency and Organization Element to Which Report is Submitted:	4900
Federal Grant or Other Identifying Number Assigned by Agency:	1127582
Project Title:	Collaborative Research: Historic perspectives on climate and biogeography from deep-sea corals in the Drake Passage
PD/PI Name:	Rhian G Waller, Principal Investigator
Recipient Organization:	University of Maine
Project/Grant Period:	02/01/2011 - 08/31/2014
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Submitting Official (if other than PD\PI):	Rhian G Waller Principal Investigator
Submission Date:	06/16/2015
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	Rhian G Waller

### Accomplishments

**\* What are the major goals of the project?**

Polar Oceans are the main sites of deep-water formation and are critical to the exchange of heat and carbon between the deep-ocean and atmosphere. Testing hypotheses that link processes in the Southern Ocean to climate change over millennia is challenging because our knowledge of the biogeochemistry and circulation in the Southern Ocean in the past is limited by scarcity of suitable records. The skeletons of deep sea corals are abundant in the Southern Ocean, and can be dated using U-series techniques making them a useful archive of oceanographic history. By pairing U-series and radiocarbon analyses we can use deep-sea corals to reconstruct the radiocarbon content of seawater in the past. A successful pilot cruise in 2008 demonstrated our ability to collect live and fossil deep-water corals from the Drake Passage and preliminary results prove that fossil individuals date back through the Holocene, deglaciation, last glacial maximum and beyond.

RVIB Nathaniel B Palmer Cruise NBP11-03 took place between May 09 and June 11 2011 starting and ending in Punta Arenas, Chile. The two principal investigators were Laura Robinson (Woods Hole Oceanographic Institution and Rhian Waller (University of Maine). The science party consisted of 19 NSF grantees, 11 RPSC support staff and an Argentine observer.

The science aims of the project included a combined study of the past and present biogeography of cold water corals in the Drake Passage, investigations into their major controls and paleoclimate reconstruction using skeletal remains. As such the cruise was designed to image and collect samples from coral habitats and their environments stretching from the continental Shelf of South America, across fracture zones and seamounts in the Drake Passage and down to the West Antarctic Peninsula. We were able to collect Multibeam bathymetry, seafloor photographs (towed and drop camera systems) seafloor benthic fauna (live and dead) and complementary water samples. The work was carried out in six regions: Burdwood Bank (Argentine EEZ), Shackleton Fracture Zone, West Antarctic Peninsula, Interim Seamount, Sars Seamount (Chilean EEZ) and Cape Horn (Chilean and Argentine EEZs). Over-the-side operations consisted of 147 discrete stations, the majority of which were successful (75 Hein Dredges, 1 Box dredge, 1 Otter trawl, 7 Blake trawls, 8 box cores, 4 Kasten cores, 5 CTDS, 39 DropCams and 7 TowCams).

The skeletal remains of corals were collected in trawls, dredges and with the Kasten corer. The most effective sampling on shelf areas was with the Blake Trawl and the most effective sampling on seamounts and fracture zones was the newly contracted Hein dredge. With regards sub-fossil coral skeletons we collected 14,408 solitary corals, 16kg of colonial corals, 28kg of bamboo corals and 106kg of stylasterid corals covering a depth range of 320m to 2480m. The material ranged in preservation status to shiny white carbonate to heavily pitted and coated in ferromanganese crusts. More than 500 corals were sub-sampled and cleaned on board for preliminary age screening back at WHOI. In addition to coral samples we also collected bivalve shells, barnacle plates, gastropods shells, sponges and bryozoans.

Over 11475 biological samples were collected during the cruise, primarily using the Blake and Otter trawls, though also using the Hein dredge. The greatest number of biological collections were made from Burdwood Bank and Cape Horn at depths of 500-1000m, though these are the areas and depths where trawls as opposed to dredges were used. Cnidarians were common across all six sites, but the composition of genera were very different. In total 649 live solitary corals were collected and 378 lots of octocorals (representing over 1600 individuals) including 2 new species to science. All corals and most associated fauna collected were subsampled for genetics and morphological taxonomy back at the University of Maine. In addition to these physical collections over 22,000 seafloor images were collected during this cruise from 46 discrete locations, and will be analyzed for species composition.

**\* What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?**

Major Activities:

***Biogeography:***

Specific Objectives:

Over one thousand images across nine sites were examined for species

Significant Results:

composition, megafaunal density, and seafloor substrate characteristics. Benthic communities were examined at 9 discrete sites among 7 geographic areas across the Drake Passage: Burdwood Bank, Shackleton Fracture Zone, Elephant Island, Western Antarctic Peninsula shelf, Sars Seamount, Interim Seamount, and Cape Horn. Towed camera observations revealed substantial sponge and coral diversity

and abundance among several sites throughout Burdwood Bank, Cape Horn, as well as two offshore seamounts. Sars and Interim Seamounts exhibited multiple unique assemblages of invertebrate faunas including cold-water corals, anemones, and sponges compositionally similar to adjacent shelf environments. Multivariate biogeographic analyses among megafaunal communities suggest bathymetric patterns consistent within major Southern Ocean water masses including Subantarctic Mode Waters, Antarctic Intermediate Waters, and Circumpolar Deep Waters. A paper is currently submitted to PLoS ONE regarding the major biogeographic work, with another paper in preparation on the unique seamount communities discovered.

### ***Biological Samples:***

Biological samples collected during this cruise are being used for multiple purposes. All continue to be identified by experts in the field to compile a comprehensive species list. Sample sets have been used by graduate students for their individual theses (Narissa Bax - hydrocorals; Steve Auscavitch - scleractinians and octocorals; James Cusiter - octocorals; Edyta Glogowska - scleractinians) and for reproductive analysis in the Waller lab (Waller & Feehan, 2014; other papers currently being compiled).

### ***Geochemistry:***

The cruise samples have been used for the development, refinement and application of new proxies for past ocean conditions.

*Neodymium isotopes:* In collaboration with Tina van de Flierdt we have developed and refined methods for analysing neodymium in deep sea corals (van de Flierdt et al 2010. Crocket et al 2014). We published an early proof of concept paper based on museum specimens (Robinson and van de Flierdt 2009) and a new record is in preparation for publication (results shown at AGU 2014)

*Nitrogen isotopes:* In a new collaboration we have worked with collaborators from Princeton, Pomona College and Claremont college to develop a new proxy based on carbonate bound  $\delta^{15}\text{N}$  for surface nutrient utilisation (Wang et al 2014). This method allows us to couple surface and deep records and graduate student Tony Wang has now analysed fossil corals to produce an exciting new record (shown at AGU, 2014)

*Clumped isotopes:* Development of the clumped isotope thermometer at Caltech has prompted widespread excitement in this new paleo-thermometer. We have been working with Weifu Guo to further improve the method for deep sea corals, and he hopes to start analysis of fossil samples in the near future.

*Trace metals:* We used our samples as part of a calibration study to show that the trace metal ratio Mg/Li is related to temperature deep-sea corals (Case et al 2010), the basis of a paleothermometer. We are further refining this method.

*Silicon isotopes:* Kate Hendry made use of sponge spicules collected both live and from within sediment sample to assess the fractionation of silica as it is incorporated into sponges (Hendry et al 2010a, b, Hendry et al 2011). This fractionation is important as it forms the basis of a proxy for nutrient cycling in the past. The proxy is gaining traction with several published records including (Hendry et al 2010a, Hendry et al 2011b)

*Boron isotopes:* We worked in collaboration with James Rae during this post

doctoral fellowship at Caltech to generate a boron isotope record (related to pH) with the results showing a large deglacial excursion, the results were shown at AGU (2014)

*Radiocarbon:* The first set of dated corals (mainly using samples collected on pilot study NBP0805) were used by graduate student Andrea Burke to reconstruct the history of radiocarbon in the Drake Passage. This work was written up and published in a high profile journal, Science in 2012 (Burke and Robinson 2012), and has already been widely cited. We have added to this data set using targeted samples from NB1103 and are beginning to see hints of rapid changes in radiocarbon during the deglaciation.

Andrea Burke has also analysed the radiocarbon content of seawater (both dissolved inorganic carbon and dissolved organic carbon) from across the Drake Passage. The aim of this study is to assess the penetration of bomb radiocarbon and potentially the uptake of anthropogenic CO<sub>2</sub>.

*Dating techniques:* In addition we have developed a number of new dating techniques using a suite of precisely dated coral samples. These include methods based on radiocarbon at NOSAMS (Burke et al 2010, McIntyre et al 2011, Longworth et al 2013) and U-series based (Spooner et al submitted). We have used our reconnaissance dating tools to explore the history of coral populations in the Drake Passage (Burke et al 2010, Margolin et al 2014) over the last 35,000 years finding that coral populations appear to 'migrate' across fronts with a time pacing related to climate events.

*Controls on coral mineralogy:* We have also been exploring the modern day carbonate chemistry from the region. Undergraduate intern Emily Ciscato has compiled and processed the carbonate chemistry data (pH, alkalinity) collected at sea so that we can map out the aragonite and calcite saturation horizons. She has also analysed the mineralogy of the corals using XRD and raman in order to test hypotheses that link the saturation state to the distribution of corals in the deep sea.

Key outcomes or  
Other achievements:

**\* What opportunities for training and professional development has the project provided?**

Specific efforts towards inclusion of students and post docs were made on this cruise, including undergraduates who had not been to sea before. Junior personnel were exposed to all aspects of the science and cruise activities to maximise their experience. The training they received during the cruise consisted of learning technical skills of collecting at sea using a variety of over-the-side equipment, scientific processing of samples (biological, fossil, geological, water) and data analysis.

Since returning this project has contributed to numerous undergraduate (7) and graduate (6) level theses and research opportunities, and two undergraduates, Andrew Margolin and David Case on the cruise went onto graduate school at Miami and Caltech respectively to study marine sciences.

**\* How have the results been disseminated to communities of interest?**

In addition to the numerous conferences this material has been presented at, R. Waller and L. Robinson have used material from this research project to communicate with both undergraduate and graduate students, and to the general public in multiple forums. L. Robinson also presented at a TedX talk.

<https://www.youtube.com/watch?v=2R1IZ-N4-So>

A Blog education and outreach site (<http://antarcticcorals.blogspot.com/>) was created prior to the cruise and was updated almost daily.

## Products

### Books

#### Book Chapters

#### Conference Papers and Presentations

Robinson LF (2014). *Deep-sea coral records of the last deglaciation in the Drake Passage: progress and new directions Southern Ocean*. Physics and biogeochemistry meeting. Stockholm. Status = OTHER; Acknowledgement of Federal Support = Yes

Auro, M.E., L.F. Robinson, R. Anderson, M. Fleisher (2011). *Efficient analysis of seawater thorium and protactinium*. Goldschmidt Meeting. . Status = OTHER; Acknowledgement of Federal Support = Yes

LF. Robinson, A Burke, J.F. Adkins (2011). *Marine controls on atmospheric radiocarbon: the glacial and deglaciation*. Goldschmidt Meeting. . Status = OTHER; Acknowledgement of Federal Support = Yes

A Burke, LF Robinson, NJ White (2011). *Mixing of Radiocarbon from High Latitude Oceans through the Atmosphere and Ocean during the Last Deglaciation: Results from Iceland and the Drake Passage*. Goldschmidt Meeting. . Status = OTHER; Acknowledgement of Federal Support = Yes

• Waller, RG; Robinson, LF; Scanlon KM; NBP11-03 Science Party (2012). *Southern Ocean Corals: Surprising Diversity and Abundance*. 5th International Deep-Sea Coral Symposium. Amsterdam. Status = PUBLISHED; Acknowledgement of Federal Support = No

LF Robinson, A Burke, KR Hendry (2011). *Transfer of nutrients and carbon from the southern ocean to the Atlantic during the last 30,000 years*. Goldschmidt Meeting. . Status = OTHER; Acknowledgement of Federal Support = Yes

T. Struve, T. van de Flierdt, L. F. Robinson, A. Burke, K. C. Crocket, M. Lambelet & M.E. Auro (2014). *Water mass mixing in the Drake Passage during the past 40 kyrs*. Auro QRA@50 Meeting. London. Status = OTHER; Acknowledgement of Federal Support = Yes

K.R. Hendry MB Andersen LF Robinson (2011). *Zinc and silicon isotope fractionation by deep-sea sponges*. Goldschmidt Meeting. . Status = OTHER; Acknowledgement of Federal Support = Yes

### Inventions

#### Journals

Auro, M.E., Robinson, L.F., Burke, A., Bradtmiller, L.I., Fleisher, M.Q., Anderson, R.F. (2012). Improvements to 232-thorium, 230-thorium, and 231-protactinium analysis in seawater arising from GEOTRACES intercalibration.. *Limnol. Oceanogr. Meth.* 10 . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Auscavitch, S and Waller, RG (). Biogeographic Patterns Among Deep-sea Benthic Megafaunal Communities Across the Drake Passage (Southern Ocean). *PLoS ONE*. . Status = UNDER\_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Burke, A., Robinson, L.F., (2012). The Southern Ocean's Role in Carbon Exchange During the Last Deglaciation.. *Science*. 335 . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Crocket K Lambelet M; van de Flierdt T; Rehkämper M; Robinson, L.F (2014). Measurement of fossil deep-sea coral Nd isotopic compositions and concentrations by TIMS as NdO<sup>+</sup>, with evaluation of cleaning protocols. *Chemical Geology*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Hathorne EC, AC Gagnon , T Felis, JF Adkins, R Asami, W Boer, N Caillon, D Case, KM. Cobb, E Douville, P deMenocal, A Eisenhauer, C.-Dieter Garbe-Schönberg W Geibert, S Goldstein, Konrad Hughen, MInoue, H.Kawahata, M. Kölling, Florence Le Cornec, Braddock, K. Linsley, H V. McGregor, P Montagna, I S. Nurhati, TM. Quinn, J. Raddatz, H.e Rebaubier, Robinson, L.F, A Sadekov, R Sherrell, D Sinclair AW. Tudhope, G Wei, H Wong, Henry C. Wu Chen-Feng You. (2013). Inter-laboratory study for coral Sr/Ca and other element/Ca ratio measurements. *G-cubed*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Hathorne EC, Alex Gagnon , Thomas Felis, Jess Adkins, Ryuji Asami, Wim Boer, Nicolas Caillon, David Case, Kim M. Cobb, Eric Douville, Peter deMenocal, Anton Eisenhauer, C.-Dieter Garbe-Schönberg Walter Geibert, Steven Goldstein, Konrad Hughen, Mayuri Inou (2013). Inter-laboratory study for coral Sr/Ca and other element/Ca ratio measurements. *G Cubed*. xx xx. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Hendry, K.R., Robinson, L.F (2011). The relationship between silicon isotope fractionation in sponges and silicic acid concentration: modern and core-top studies of biogenic opal. *Geochimica et cosmochimica Acta*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Longworth, B.E., Robinson, L.F., Roberts, M.L., Beaupre, S.R., Burke, A., Jenkins, W.J., (2013). Carbonate as sputter target material for rapid C-14 AMS.. *Nucl. Instrum. Methods Phys. Res. Sect. B-Beam Interact. Mater. Atoms*. 294 . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Margolin, A., Robinson, L.F., A, B., Waller, R.G., Roberts, M.L., Auro, M.E., Van de Flierdt, T., (2013). Spatial and temporal distribution of scleractinian coral ecosystems from the Drake Passage over the last 35,000 years.. *Deep Sea Research*. xx (xx), xx. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Margolin, A., Robinson, L.F., A, B., Waller, R.G., Roberts, M.L., Auro, M.E., Van de Flierdt, T., (2014). Spatial and temporal distribution of scleractinian coral ecosystems from the Drake Passage over the last 35,000 years.. *Deep-Sea Research*.. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

McIntyre C.P., J. Burton, A.P. McNichol, A. Burke, Robinson, LF, et al. (2011). 'Rapid radiocarbon analysis of coral and carbonate samples using a continuous-flow accelerator mass spectrometry (CFAMS) system'. *Paleoceanography*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Robinson, L.F, Adkins JF, Frank N, Gagnon AC, Prouty N, Roark B van de Flierdt T (2013). The geochemistry of deep sea coral skeletons: applications for palaeoceanography. *Deep Sea Research*. xx (xx), xx. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Robinson, L.F, Adkins JF, Frank N, Gagnon AC, Prouty N, Roark B van de Flierdt T (2014). The geochemistry of deep sea coral skeletons: applications for palaeoceanography. *Deep Sea Research*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Robinson, L.F., Siddall, M., (2012). Palaeoceanography: motivations and challenges for the future.. *Philosophical Transactions of the Royal Society a-Mathematical Physical and Engineering Sciences*. 370 . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Spooner, P., Chen, T.-Y., Robinson, L.F., Coath, C., (). Rapid Uranium series dating of Carbonates by Laser Ablation Mass Spectrometry. *Quaternary Geochronology*.. . Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Waller RG & Robinson, LF. (2011). 'Southern Ocean Corals: Cabo de Hornos'. *Coral Reefs*,. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Waller RG, Scanlon KM, Robinson LF (2011). Cold-Water Coral Distributions in the Drake Passage Area from Towed Camera Observations – Initial Interpretations.. *PLoS ONE*. 6 (1), . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Waller, RG & Feehan K (2013). Reproductive Ecology of a Polar Deep-Sea Scleractinian Fungiacyathus marenzelleri (Vaughan, 1906).. *Deep Sea Research II*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Wang XT, Prokopenko MG; Sigman DM, Jess F Adkins, Robinson, L.F, Ren H; Oleynik S; Williams B; Haug GH (2014). Isotopic composition of carbonate-bound organic nitrogen in deep-sea scleractinian corals: a new window into past biogeochemical change. *EPSL*. . Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

## Licenses

## Other Products

## Other Publications

## Patents

## Technologies or Techniques

## Thesis/Dissertations

Steven Auscavitch. *BIOGEOGRAPHIC PATTERNS AMONG DEEP-SEA BENTHIC MEGAFUNAL COMMUNITIES ACROSS THE DRAKE PASSAGE (SOUTHERN OCEAN)*. (2014). University of Maine. Acknowledgement of Federal Support = Yes

Edyta Gologowska. *Reproduction of Balanophyllia malouensis*. (2014). National Oceanographic Center, Southampton. Acknowledgement of Federal Support = Yes

James Cusitier. *Reproduction of Southern Ocean Octocorallia*. (2014). National Oceanographic Center, Southampton. Acknowledgement of Federal Support = Yes

## Websites

## Participants/Organizations

### What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Waller, Rhian	PD/PI	9
Scanlon, Kathryn	Co-Investigator	3
Hendry, Kate	Faculty	12
van de Fliedrt, Tina	Faculty	3
Auscavitch, Steve	Graduate Student (research assistant)	12
Burke, Andrea	Graduate Student (research assistant)	12
Ciscato, Emily	Graduate Student (research assistant)	3
Guo, Weifu	Graduate Student (research assistant)	1



Longworth, Brett	Graduate Student (research assistant)	2
Prokopenko, Maria	Graduate Student (research assistant)	6
Spooner, Peter	Graduate Student (research assistant)	3
Carbee, Zachary	Undergraduate Student	3
Case, David	Undergraduate Student	4
Cefola, Robert	Undergraduate Student	3
Margolin, Andrew	Undergraduate Student	3
Villeneuve, Andrew	Undergraduate Student	3

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### Full details of individuals who have worked on the project:

#### Rhian G Waller

**Email:** rhian.waller@maine.edu

**Most Senior Project Role:** PD/PI

**Nearest Person Month Worked:** 9

**Contribution to the Project:** Project PI

**Funding Support:** NSF and University of Maine

**International Collaboration:** No

**International Travel:** Yes, Antarctica - 0 years, 2 months, 0 days

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#### Kathryn Scanlon

**Email:** kscanlon@usgs.gov

**Most Senior Project Role:** Co-Investigator

**Nearest Person Month Worked:** 3

**Contribution to the Project:** Multibeam mapping specialist.

**Funding Support:** USGS

**International Collaboration:** No

**International Travel:** Yes, Antarctica - 0 years, 2 months, 0 days

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#### Kate Hendry

**Email:** K.Hendry@bristol.ac.uk

**Most Senior Project Role:** Faculty

**Nearest Person Month Worked:** 12

**Contribution to the Project:** sponge geochemistry, distributions and paleoreconstructions

**Funding Support:** Other

**International Collaboration:** Yes, United Kingdom

**International Travel:** No

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**Tina van de Flierdt**

**Email:** tina.vandeflierdt@imperial.ac.uk

**Most Senior Project Role:** Faculty

**Nearest Person Month Worked:** 3

**Contribution to the Project:** Development and application of neodymium isotopes

**Funding Support:** Other

**International Collaboration:** No

**International Travel:** No

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**Steve Auscavitch**

**Email:** steve.auscavitch@maine.edu

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 12

**Contribution to the Project:** Masters level graduate student working on the biogeography of cold-water corals across the Drake Passage

**Funding Support:** University of Maine

**International Collaboration:** No

**International Travel:** No

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**Andrea Burke**

**Email:** ab276@st-andrews.ac.uk

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 12

**Contribution to the Project:** WHOI graduate student, now Caltech Post doc. Thesis and follow up work based on samples from this cruise and the one before.

**Funding Support:** NSF - this proposal, and WHOI fellowship

**International Collaboration:** No

**International Travel:** No

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**Emily Rose Ciscato**

**Email:** emily.ciscato@erdw.ethz.ch

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 3

**Contribution to the Project:** Master Project: Environmental Controls on Coral Mineralogy and Distribution: A Case study from the Southern Ocean

**Funding Support:** University of Bristol

**International Collaboration:** No

**International Travel:** No

**Weifu Guo****Email:** wguo@whoi.edu**Most Senior Project Role:** Graduate Student (research assistant)**Nearest Person Month Worked:** 1**Contribution to the Project:** Refinement of clumped isotope thermometer**Funding Support:** NSF**International Collaboration:** No**International Travel:** No

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**Brett Longworth****Email:** blongworth@whoi.edu**Most Senior Project Role:** Graduate Student (research assistant)**Nearest Person Month Worked:** 2**Contribution to the Project:** development of direct sputter method for dating carbonates**Funding Support:** WHOI**International Collaboration:** No**International Travel:** No

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**Maria Prokopenko****Email:** masha.prokopenko@gmail.com**Most Senior Project Role:** Graduate Student (research assistant)**Nearest Person Month Worked:** 6**Contribution to the Project:** Development and application of nitrogen isotope analyses in aragonite corals**Funding Support:** NSF**International Collaboration:** No**International Travel:** No

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**Peter Spooner****Email:** peter.spooner@bristol.ac.uk**Most Senior Project Role:** Graduate Student (research assistant)**Nearest Person Month Worked:** 3**Contribution to the Project:** Development of Laser ablation rapid U-Th dating technique**Funding Support:** NERC**International Collaboration:** Yes, United Kingdom**International Travel:** No

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**Zachary Carbee****Email:** z.carbee@maine.edu**Most Senior Project Role:** Undergraduate Student

**Nearest Person Month Worked:** 3

**Contribution to the Project:** Analysis of DropCam photographs

**Funding Support:** NSF/U Maine

**International Collaboration:** No

**International Travel:** No

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**David Case**

**Email:** dcase@caltech.edu

**Most Senior Project Role:** Undergraduate Student

**Nearest Person Month Worked:** 4

**Contribution to the Project:** development of Mg/Li thermometer

**Funding Support:** WHOI Summer Student Fellowship, and NSF

**International Collaboration:** No

**International Travel:** No

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**Robert Cefola**

**Email:** rcefola@maine.edu

**Most Senior Project Role:** Undergraduate Student

**Nearest Person Month Worked:** 3

**Contribution to the Project:** UMaine undergraduate student did capstone on Sars Seamount biogeography.

**Funding Support:** UMaine.

**International Collaboration:** No

**International Travel:** No

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**Andrew Margolin**

**Email:** amargolin@rsmas.miami.edu

**Most Senior Project Role:** Undergraduate Student

**Nearest Person Month Worked:** 3

**Contribution to the Project:** Was U Colorado Boulder undergraduate working on project as summer intern. Now graduate student at RSMAS.

**Funding Support:** NSF - this proposal

**International Collaboration:** No

**International Travel:** No

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**Andrew Villeneuve**

**Email:** avillene@bowdoin.edu

**Most Senior Project Role:** Undergraduate Student

**Nearest Person Month Worked:** 3

**Contribution to the Project:** Bowdoin College student, came to UMaine for summer internship to work on

biogeography of the Drake Passage using images from TowCam

**Funding Support:** Bowdoin College

**International Collaboration:** No

**International Travel:** No

### What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
USGS	State or Local Government	Woods Hole

### Full details of organizations that have been involved as partners:

#### USGS

**Organization Type:** State or Local Government

**Organization Location:** Woods Hole

#### Partner's Contribution to the Project:

In-Kind Support

Facilities

Collaborative Research

Personnel Exchanges

#### More Detail on Partner and Contribution:

### What other collaborators or contacts have been involved?

NO

## Impacts

### What is the impact on the development of the principal discipline(s) of the project?

Development of geochemical proxies for past climate as well as new dating techniques both provide key new tools for the paleoceanographic community. Biogeography work demonstrated new theories for deep sea dispersal and patterns via ocean currents as the primary source, rather than depth or environmental gradients.

### What is the impact on other disciplines?

Nothing to report.

### What is the impact on the development of human resources?

Two undergraduates, Andrew Margolin and David Case on the cruise went onto graduate school at Miami and Caltech respectively to study marine sciences. One masters level student, Steve Auscvaitch, went onto a Ph.D. program in deep sea ecology (Temple University).

### What is the impact on physical resources that form infrastructure?

Nothing to report.

**What is the impact on institutional resources that form infrastructure?**

Nothing to report.

**What is the impact on information resources that form infrastructure?**

Nothing to report.

**What is the impact on technology transfer?**

Nothing to report.

**What is the impact on society beyond science and technology?**

TedX talk: audience of 2000, already watched by 800 online.

<https://www.youtube.com/watch?v=2R1IZ-N4-So>

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## Changes/Problems

**Changes in approach and reason for change**

Nothing to report.

**Actual or Anticipated problems or delays and actions or plans to resolve them**

Nothing to report.

**Changes that have a significant impact on expenditures**

Nothing to report.

**Significant changes in use or care of human subjects**

Nothing to report.

**Significant changes in use or care of vertebrate animals**

Nothing to report.

**Significant changes in use or care of biohazards**

Nothing to report.

 RSR Award Detail

## Research Spending & Results

### Award Detail

Awardee:	UNIVERSITY OF MAINE SYSTEM
Doing Business As Name:	University of Maine
PD/PI:	Rhian G Waller (808) 227-4843 rhian.waller@maine.edu
Award Date:	03/04/2011
Estimated Total Award Amount:	\$ 484,774
Funds Obligated to Date:	\$ 484,774 FY 2010=\$484,774
Start Date:	02/01/2011
End Date:	08/31/2014
Transaction Type:	Grant
Agency:	NSF
Awarding Agency Code:	4900
Funding Agency Code:	4900
CFDA Number:	47.050
Primary Program Source:	040100 NSF RESEARCH & RELATED ACTIVIT
Award Title or Description:	Collaborative Research: Historic perspectives on climate and biogeography from deep-sea corals in the Drake Passage
Federal Award ID Number:	1127582
DUNS ID:	186875787
Parent DUNS ID:	071750426
Program:	ANTARCTIC EARTH SCIENCES
Program Officer:	Mark Kurz (703) 292-0000 mkurz@nsf.gov

### Awardee Location

Street:	5717 Corbett Hall
City:	ORONO
State:	ME
ZIP:	04469-5717
County:	Orono
Country:	US
Awardee Cong. District:	02

## Primary Place of Performance

Organization Name: University of Maine

Street: 5717 Corbett Hall

City: Orono

State: ME

ZIP: 04469-5717

County: Orono

Country: US

Cong. District: 02

## Abstract at Time of Award

Polar oceans are the main sites of deep-water formation and are critical to the exchange of heat and carbon between the deep ocean and the atmosphere. This award ? Historic perspectives on climate and biogeography from deep-sea corals in the Drake Passage? will address the following specific research questions: What was the radiocarbon content of the Southern Ocean during the last glacial maximum and during past rapid climate change events? and What are the major controls on the past and present distribution of cold-water corals within the Drake Passage and adjacent continental shelves? Testing these overall questions will allow the researchers to better understand how processes in the Southern Ocean are linked to climate change over millennia. This award is being funded by the Antarctic Earth Sciences Program of NSF?s Office of Polar Programs, Antarctic Division.

INTELLECTUAL MERIT: The skeletons of deep-sea corals are abundant in the Southern Ocean, and can be dated using U-series techniques making them a useful archive of oceanographic history. By pairing U-series and radiocarbon analyses the awardees can reconstruct the radiocarbon content of seawater in the past, allowing them to address the research questions raised above. Collection of living deep-sea corals along with environmental data will allow them to address the broader biogeography questions posed above as well. The awardees are uniquely qualified to answer these questions in their respective labs via cutting edge technologies, and they have shown promising results from a preliminary pilot cruise to the area in 2008.

BROADER IMPACTS: Societal Relevance: The proposed paleoclimate research will make significant advances toward constraining the Southern Ocean?s influence on global climate, specifically it should help set the bounds for the upper limits on how fast the ocean circulation might change in this region of the world, which is of high societal relevance in this era of changing climate. Education and Outreach (E/O): These activities are grouped into four categories: i) increasing student participation in polar research by fully integrating undergraduate through post-doctoral students into research programs; ii) promotion of K-12 teaching and learning programs by providing information via a cruise website and in-school talks, iii) making the data collected available to the wider research community via data archives such as Seamounts Online and the Seamount Biogeographic Network and iv) reaching a larger public audience through such venues as interviews in the popular media.

## Publications Produced as a Result of this Research

Wang XT, Prokopenko MG; Sigman DM, Jess F Adkins, Robinson, L.F, Ren H; Oleynik S; Williams B; Haug GH "Isotopic composition of carbonate-bound organic nitrogen in deep-sea scleractinian corals: a new window into past biogeochemical change" EPSL, v. , 2014, p.

Margolin, A., Robinson, L.F., A. B., Waller, R.G., Roberts, M.L., Auro, M.E., Van de Flierdt, T., "Spatial and temporal distribution of scleractinian coral ecosystems from the Drake Passage over the last 35,000 years." DEEP-SEA RESEARCH., v. , 2014, p.

Robinson, L.F, Adkins JF, Frank N, Gagnon AC, Prouty N, Roark B van de Flierdt T "The geochemistry of deep sea coral skeletons: applications for palaeoceanography" DEEP SEA RESEARCH, v. , 2014, p.

Crocket K Lambelet M; van de Flierdt T; Rehkämper M; Robinson, L.F "Measurement of fossil deep-sea coral Nd isotopic compositions and concentrations by TIMS as NdO+, with evaluation of cleaning protocols" CHEMICAL GEOLOGY, v. , 2014, p.

Waller, RG & Feehan K "Reproductive Ecology of a Polar Deep-Sea Scleractinian Fungiacyathus marenzelleri (Vaughan, 1906)." DEEP SEA RESEARCH II, v. , 2013, p.

Longworth, B.E., Robinson, L.F., Roberts, M.L., Beaupre, S.R., Burke, A., Jenkins, W.J., "Carbonate as sputter target material for rapid C-14 AMS." NUCL. INSTRUM. METHODS PHYS. RES. SECT. B-BEAM INTERACT. MATER. ATOMS, v.294, 2013, p.

Hathorne EC, AC Gagnon , T Felis, JF Adkins, R Asami, W Boer, N Caillon, D Case, KM. Cobb, E Douville, P deMenocal, A Eisenhauer, C.-Dieter Garbe-Schönberg W Geibert, S Goldstein, Konrad Hughen, Mlnoue, H.Kawahata, M. Kölling, Florence Le Cornec, Braddock "Inter-laboratory study for coral Sr/Ca and other element/Ca ratio measurements" G-CUBED, v. , 2013, p.

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Waller, RG & Robinson, LF "Southern Ocean Corals: Cabo de Hornos" CORAL REEFS, v. , 2011, p.

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J.R. Farmer; B Hoenisch; TM. Hill; M LaVigne; L.F. Robinson "Boron isotopes in deep-sea bamboo corals: pH, vital effects and environmental factors" FALL AGU, v. , 2011, p.

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## Project Outcomes Report

### Disclaimer

This Project Outcomes Report for the General Public is displayed verbatim as submitted by the Principal Investigator (PI) for this award. Any opinions, findings, and conclusions or recommendations expressed in this Report are those of the PI and do not necessarily reflect the views of the National Science Foundation; NSF has not approved or endorsed its content.

*RVIB Nathaniel B Palmer* Cruise NBP11-03 took place between May 09 and June 11 2011 starting and ending in Punta Arenas, Chile. The two principal investigators were Laura Robinson (Woods Hole Oceanographic Institution) and Rhian Waller (University of Maine). The science party consisted of 19 NSF grantees, 11 RPSC support staff and an Argentine observer. The science aims of the project included a combined study of the past and present biogeography of cold-water corals in the Drake Passage, and investigations into their major controls and paleoclimate reconstruction using skeletal remains. As such the cruise was designed to image and collect samples from coral habitats and their environments stretching from the continental Shelf of South America, across fracture zones and seamounts in the Drake Passage and down to the West Antarctic Peninsula.

Towed camera observations revealed substantial sponge and coral diversity and abundance among several sites throughout Burdwood Bank, Cape Horn, as well as two offshore seamounts. Sars and Interim Seamounts exhibited multiple unique assemblages of invertebrate faunas including cold-water corals, anemones, and sponges compositionally similar to adjacent shelf environments. Multivariate biogeographic analyses among megafaunal communities suggest bathymetric patterns are consistent within major Southern Ocean water masses including Subantarctic Mode Waters, Antarctic Intermediate Waters, and Circumpolar Deep Waters, meaning that larval dispersal and colonization may be more affected by ocean currents than prevailing environmental conditions in this region.

The skeletal remains of corals were collected in trawls, dredges and with the Kasten corer. Radiocarbon dating of sub-fossil specimens has shown that coral populations have moved across the Drake Passage over time, possibly in response to major climate transitions. Detailed geochemical analyses of these samples has been used to show that carbon dioxide stored deep in the ocean during the last glacial maximum (some 20,000 years ago) was released to the atmosphere through upwelling of carbon rich waters during the deglaciation. Additional analyses have been used to develop new ways of using the skeletal remains of deep-sea corals to examine the history of the deep ocean.

Specific efforts towards inclusion of students and post docs were made on this cruise, including undergraduates who had not been to sea before. Junior personnel were exposed to all aspects of the science and cruise activities to maximise their experience. The training they received during the cruise consisted of learning technical skills of collecting at sea using a variety of over-the-side equipment, scientific processing of samples (biological, fossil, geological, water) and data analysis. A Blog education and outreach site (<http://antarcticcorals.blogspot.com/>) was created prior to the cruise and was updated almost daily.

Last Modified: 02/20/2015

Modified by: Rhian G Waller

For specific questions or comments about this information including the NSF Project Outcomes Report, contact us.

### Images (1 of 4)



