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# Collaborative Research: Abandoned Elephant Seal Colonies in Antarctica: Integration of Genetic, Isotopic, and Geologic Approaches toward Understanding Holocene Environmental Change

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**Principal Investigator:** Hall, Brenda L.

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**Organization:** University of Maine

**Submitted By:**

Hall, Brenda - Principal Investigator

**Title:**

Collaborative Research: Abandoned Elephant Seal Colonies in Antarctica: Integration of Genetic, Isotopic, and Geologic Approaches toward Understanding Holocene Environmental Change

### Project Participants

#### Senior Personnel

**Name:** Hall, Brenda

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

**Name:** Newsome, Seth

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Seth participated in the field work and will analyse samples for H isotopes.

**Name:** Hoelzel, Rus

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Rus is in charge of the DNA analysis and will directly supervise a postdoc.

**Name:** Baroni, Carlo

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

This person participated in field work.

**Name:** Salvatore, Maria

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

This person participated in field work.

#### Post-doc

**Name:** DeBruyn, Mark

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Mark is carrying out DNA analyses of the samples as his postdoctoral research.

**Name:** Corrigan, Laura

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Laura has recently joined the DNA part of the project.

#### Graduate Student

**Name:** Bamberg, Audrey

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

This person participated in the field work and is carrying out part of the project work as her M.S. thesis. She has responsibility for producing geomorphological maps and for setting up a GIS system for the project.

**Name:** Garhart, Kimberly

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Kim prepared samples for radiocarbon dating.

**Name:** Garcia, Juan

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Juan Luis located references and organized maps and papers.

### **Undergraduate Student**

**Name:** Doughty, Alice

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

Alice participated in field work and has worked on the samples after returning from Antarctica.

**Name:** Chase, Brenda

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

This person served as a field assistant and participated in lab work.

### **Technician, Programmer**

### **Other Participant**

**Name:** Koch, Paul

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**

This person participated in field work and is carrying out isotope analyses.

### **Research Experience for Undergraduates**

#### **Organizational Partners**

##### **University of Durham**

We are carrying out our DNA analyses in the ancient DNA lab at the University of Durham.

##### **Universita di Pisa**

We are collaborating with Dr. Carlo Baroni at the Universita di Pisa. We are combining our data on the elephant seals with his data on penguins.

##### **University of California-Santa Cruz**

We have a collaborative project with the University of California, Santa Cruz. Dr. Paul Koch will explain their activities in his report.

#### **Other Collaborators or Contacts**

We have carried out collaboration with G. Henderson and S. Burgess at the University of Oxford on samples related to this study and concerning Holocene environmental change along the Victoria Land Coast.

## Activities and Findings

### **Research and Education Activities:**

Over the course of this grant, we have been very active in research and education. We deployed parties to Antarctica during two field seasons. These groups 1) mapped the geomorphology (particularly raised beaches) along the entire Victoria Land coast (74-78S), 2) collected numerous samples of southern elephant seal skin and hair for isotopic and genetic analyses, and 3) discovered and measured the bones of numerous seal mummies and skeletons, primarily of southern elephant seals, but also of other varieties.

At home, in the labs, we have 1) dated more than 200 samples of seal remains in order to place the genetic and environmental data into temporal context, 2) amplified the mtDNA control region from 223 ancient southern elephant seal samples from the Victoria Land Coast and compared these with 269 samples from modern populations at seven extant breeding sites, 3) used phylogenetic, coalescent and population genetic methods to interpret the pattern of population demographics and connectivity for the VLC population over time in the context of environmental change, 4) performed stable isotopic analyses to document past foraging habitat and preferences (see Koch report), 5) created detailed geomorphologic maps of the Victoria Land Coast in a GIS system, and 6) analyzed the morphology and sedimentology of the raised beaches in the context of sea-ice and storm changes in the Holocene.

Our work contributed to the education of several graduate students and undergraduates. Nearly all students involved in this project have completed their degrees and advanced to either higher degrees or university positions. For example, post-doc Mark De Bruyn is now employed as a research with the University of Bangor (Wales). Both undergraduates involved in the project have gone on to graduate study.

We also maintained close connectivity among the group, which included members in four different institutions and three countries. We continued our close work with Drs. Baroni and Salvatore with the Italian Antarctic Program and integrated the seal results with their data from Adelle penguins. We held a 3-day group meeting, which everyone attended, at the University of Maine.

### **Findings:**

We are very excited about this work. Our major finding is that an extensive population of southern elephant seals, which we estimate at several hundred thousand individuals, occupied the western coast of the Ross Sea during much of the middle and late Holocene. Our radiocarbon database allows us to track any changes in seal distribution over time. Seals appeared immediately after retreat of the grounded Ross Sea ice sheet ~8000 years ago along the Victoria Land Coast. There may have been a slight shift in the seals to more northerly locations at about 2500-3500 years ago, but they returned in full force shortly after that time and occupied nearly every ice-free area. We also record the disappearance of seals about 500 years ago, a time that corresponds to increasing sea ice and generally colder temperatures. We make the case that encroaching sea ice made the Victoria Land Coast unsuitable for southern elephant seals, which today generally do not live in areas with perennial land-fast sea ice. We also make the case that the presence of seals earlier in the Holocene means that sea-ice extent was less than it is today.

Our seal distribution data agrees very well with the genetic information. Ancient mtDNA samples show a rapidly expanding population in the middle Holocene, consistent with the seals founding a new colony as soon as glaciers retreated from the Victoria Land coast.

Our interpretation of the genetic data is that the population was large and that they must have been breeding along the Victoria Land coast (something backed up by not only the diversity in the genetic data, but also the presence of pup remains on the beaches), as opposed to simply using the area for moulting. This would elevate the status of the Victoria Land colony to something on par with any of the major subantarctic colonies of today. The presence of breeding animals would also require a longer duration of open water at the coastline than if the seals were only there to moult.

Our results particularly show how a highly mobile marine species responded to the gain and loss of new breeding habitat. The Victoria Land Coast habitat was released after retreat of the grounded ice sheet ~7,500-8,000 cal yr B.P., and is within the range of modern foraging excursions from the Macquarie Island colony, 2500 km to the north. Using ancient mtDNA and coalescent models we found a clear expansion signal in the Victoria Land Coast population ~8,000 YBP, followed by directional migration away from the Victoria Land Coast and a population crash together with the loss of diversity at ~1,000 YBP when sea ice is thought to have expanded. Our data suggest that Victoria Land seals came initially from Macquarie, and that some returned there once the Victoria Land Coast habitat was lost, ~7,000 years later. We tracked the founder-extinction dynamics of a population from inception to extinction in the context of Holocene climate change, and show that an unexpectedly diverse, differentiated breeding population was founded from a distant source population soon after habitat became available. The specific implication is that the future release of breeding habitat in the Antarctic could lead to an expansion of the southern elephant seal population that may impact other, competing species. The broader implication is that species with the potential for habitat discovery due to extensive dispersion (in this case on annual foraging excursions into Antarctic waters) may be able to respond quickly to emerging habitat, while those that are more insular (perhaps as was the case for the established Victoria Land Coast population) are less able to respond and more

likely to experience a population crash when habitat is lost.

We also had several other results, such as the discovery of storm intensity variations during the Holocene, which are in the process of being integrated into our emerging paleoenvironmental picture for the Victoria Land Coast. Additional findings involving the stable isotopic data and the morphology of skeletal and mummified remains will appear in co-PI P. Koch's report.

#### **Training and Development:**

This work has provided Antarctic field research experiences for Audrey Bamberg (M.S., 2007), two undergraduates (Alice Doughty, Brenda Chase), and a recently graduated Ph.D. (Seth Newsome). It also has afforded lab experiences for the above people, as well as for Mark DeBruyn and Laura Corrigan, our postdocs, and K. Garhart and J.Garcia, both graduate students. Alice Doughty has since gone on to a M.S. program and is now pursuing her Ph.D. Brenda Chase is in our M.S. program.

#### **Outreach Activities:**

This work was the subject of an article for National Geographic News and the Discovery Channel news and was featured in the New York Times, the Bangor Daily News, and the University of Maine alumni magazine. It was also featured on the NSF website and has been the subject of 2 Antarctic Sun articles. We also count at least a dozen other news stories.

We also have visited several classrooms (both elementary and high school) in rural Maine to talk about the work and about careers in science. In addition, we have presented data from this project to numerous audiences at other universities. This project was part of our outreach with Expanding Your Horizons, an event to attract young girls to science and featured prominently in a lecture given by the PI on women in field science, presented at the University of Lund (Sweden) in 2008.

#### **Journal Publications**

Hall, B., Hoelzel, R., Baroni, C., Denton, G., LeBoeuf, B., Overturf, B., and Topf, A., "Holocene elephant seal distribution implies warmer than present climate in the Ross Sea", *Proceedings of the National Academy of Sciences*, p. 10213, vol. 103, (2006). Published,

Koch, P., Hall, B., Baroni, C., Newsome, S., and Salvatore, M.C., "The distribution and ecology of southern elephant seals and Adelie penguins along the Holocene Ross Sea coast", *Journal of Vertebrate Paleontology* (abstracts from Society of Vertebrate Paleontologists annual meeting), p. , vol. , (2007). Published,

Hall, B., Hoelzel, A.R., Baroni, C., Denton, G., LeBoeuf, B., Overturf, B., and Topf, A., "Holocene elephant seal distribution implies warmer-than-present climate in the Ross Sea", *National Academy of Sciences, Kavli Frontiers of Science Symposium* (abstract), p. 0, vol. , (2006). Published,

De Bruyn, M., Hall, B., Chauke, L., Baroni, C., Koch, P., and Hoelzel, A.R., "Rapid response of a marine mammal species to Holocene climate and habitat change", *PLoS Genetics*, p. , vol. 5, (2009). Published, e1000554

Burgess, S. Henderson, G., Hall, B., "Reconstructing Holocene conditions under the McMurdo Ice Shelf using Antarctic barnacle shells", *Earth and Planetary Science Letters*, p. , vol. , (2009). Submitted,

Burgess, S. Henderson, G., Hall, B., "Holocene Antarctic seasonality reconstructions from Antarctic barnacle shells", *Goldschmidt Conference* [abstract], p. , vol. , (2008). Published,

Henderson, G., Hall, B., Baroni, C., and Kellogg, T., "Holocene Southern Ocean surface radiocarbon ages: Implications for ocean circulation and ice-shelf flow rates", *American Geophysical Union Annual Meeting* [abstract], p. , vol. PP12A-0, (2007). Published,

Bamberg, A., "Geologic and biologic indicators of climate change in the Ross Sea, Antarctica", *University of Maine, M.S. thesis*, p. 91pp, vol. , (2007). Published,

#### **Books or Other One-time Publications**

**Web/Internet Site****URL(s):**

[http://gcmd.nasa.gov/getdif.htm?Antarctic\\_Mirounga\\_leonina](http://gcmd.nasa.gov/getdif.htm?Antarctic_Mirounga_leonina)

**Description:**

Metadata URL

**Other Specific Products****Contributions****Contributions within Discipline:**

Our findings have influenced our understanding of past climate change (particularly sea-ice extent) in the Ross Sea. Moreover, we have described and identified the now extinct Victoria Land Coast seal colony and shown that it is on-par with extant colonies in terms of size and diversity (more diverse than existing populations). We tracked the founder-extinction dynamics of this Victoria Land Coast population from inception to extinction in the context of Holocene climate change, and showed that an unexpectedly diverse, differentiated breeding population was founded from a distant source population soon after habitat became available.

**Contributions to Other Disciplines:**

This is a multidisciplinary project and made substantial contributions not only to biology/genetics but also to earth science. For example, our work on the Victoria Land Coast beaches led to the idea that storms in this area have changed in intensity over the course of the Holocene. Paleoclimate data derived from this study will inform not only ongoing debates concerning the origin of abrupt climate change, but also help us to understand the retreat history of the West Antarctic Ice Sheet through the Ross Sea during the Holocene.

**Contributions to Human Resource Development:**

This work already has afforded research opportunities for two undergraduates, two M.S. students, a Ph.D. student, and two postdocs. All of the undergraduate and M.S. students, as well as one of the postdocs, have been female, which will make a contribution towards improving the representation of females in sciences.

**Contributions to Resources for Research and Education:****Contributions Beyond Science and Engineering:**

Our work will address questions of climate change, which are of societal relevance. We also will gain insight into elephant seal population dynamics, which may influence policy in the future. For example, the expected future release of breeding habitat in the Antarctic due to melting of ice shelves and glaciers could lead to an expansion of the southern elephant seal population that may impact other, competing species.

**Conference Proceedings****Categories for which nothing is reported:**

Any Book

Any Product

Contributions: To Any Resources for Research and Education

Any Conference