ANTARCTIC CLIMATE
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Ms Theresa Fyffe
Great Barrier Reef Foundation
Research Portfolio Manager
9 Longland Street Newstead Australia
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Dear Theresa:

Please find our final report for the Elephant Seals Research project below.

Elephant Seals Research Project – Final Report

Research Provider:
Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC)

Principal Investigators:
Dr Stephen R. Rintoul, ACE CRC and CSIRO
Prof Mark Hindell, ACE CRC and University of Tasmania

Project Goal (from contract):
The project will support the collection of data by southern elephant seals to better understand how the temperature, salinity, pH and other characteristics of the waters of the Southern Ocean are changing. Changes to the

The ACE CRC is a unique collaboration between core partners the Australian Antarctic Division, CSIRO, the University of Tasmania, the Australian Government's Department of Climate Change & Energy Efficiency, the Alfred Wegener Institute for Polar and Marine Research (Germany) and the National Institute of Water and Atmospheric Research Ltd (New Zealand) and a consortium of supporting partners. It is funded by the Australian Government's Cooperative Research Centre Program.

characteristics in cool and cold water, where they are experienced first, will be key precursors to similar and subsequent change in tropical and subtropical regions like those surrounding the Great Barrier Reef. Responding to those changes will require the earliest warning possible, predictions of change will immensely valuable to the effectiveness of adaptation efforts on the GBR.

Scientific Highlights:

The tags purchased by the Qantas project were deployed at Davis Station in February 2011. They were deployed on 5 juvenile male southern elephant seals. This is the first time that seals have been tagged at Davis, and the behaviour of the seals over the subsequent 8 months has provided some important new insights into their biology. So far, the five seals have been transmitting location, dive behaviour and oceanographic data for 8 months, providing 15,667 at-sea locations (figure 1), 30,770 dive profiles, and 3997 temperature (figure 2) and salinity profiles (figure 3).

The key findings from the deployments were:
1. The seals stayed in the region of the Vestfold Hills for several weeks, often returning to land for several days . This was unexpected as it was previously thought the seals only came ashore to moult.
2. The seals remained in the Prydz Bay region for much longer than expected, some remaining there until July, by which time the sea ice was near its maximum extent. Contrary to our previous understanding the seals foraged deep in the pack-ice, making use of coastal polynas, or the northern ice edge.
3. All the seals returned to Kerguelen, a French subantarctic island 2200 km north of where they were tagged, for a four week mid-year haul-out. The purpose of the haul-out is not understood. It represents a considerable cost, in terms of both energy and lost foraging opportunities, to the animals to travel this distance from their foraging grounds.
4. After this time ashore the seals displayed a range of behaviours:, three of the seals returned to the ice, one all the way to the coast, two staying at the ice edge, and two staying close to Kerguelen feeding on the relatively shallow waters of the Kerguelen Plateau.
5. In terms of behaviour these young seals were constantly diving much deeper than anticipated. All dived to depths greater than 1300m, in some cases diving to these depths for weeks at a time. The deepest dive recorded was 1850m - a round trip of more than 3 km on a single breath. These are depths more typically

associated with much larger adult seals, and are indicative of the very high importance of benthic foraging to this age group of seals.
6. All five tags were still working in late September, continuing to provide new data on the springtime activities of the seals.
7. When the seal tags finally stop transmitting (when the seal moult again in January), the movement, diving and oceanography data will be combined to identify the important habitats for the seals. In particular the temperature and salinity data will be used to define the water masses used by the seals, in both the horizontal and vertical dimensions. Understanding the key habitats of the seals is a major step in understanding how distribution and foraging success of the animals will change as the marine environment changes.

In terms of oceanography, the temperature and salinity data from the seals will be used to determine ocean current patterns and sea ice formation rates along the margin of Antarctica (e.g. Williams et al., 2011). These observations are from a particularly important area for the global ocean circulation and climate, the Adélie / Wilkes Land coast, where dense Antarctic Bottom Water forms and spreads throughout the deep ocean. Of particular interest are the data provided by the seals that used coastal polynas in western Prydz Bay. This is a key region where water flows north from the Amery Ice Shelf, but measurements from traditional oceanographic platforms are scarce. The profiles obtained by seals in this region will be used to assess how rapidly the ice shelf is melting and to determine ocean currents.

In a recently submitted paper, seal data are used to determine sea ice formation rates around the entire coastline of East Antarctica (Bestley et al., 2011). The seals also collected measurements from parts of the Antarctic shelf where no previous oceanographic measurements had been made. The data reveal locations where relatively warm water from offshore reaches the floating ice shelves around the Antarctic coastline. As these warm waters melt the ice from below, more ice tends to flow off the Antarctic continent and into the sea, raising sea levels. This study shows that the potential for ocean melt of ice shelves is greater than anticipated in this part of Antarctica: the melt rate is 50% larger than previously estimated, for a given change in temperature.

During the International Polar Year (March 2007 – March 2009), the Southern Ocean was observed in a comprehensive way for the first time (Rintoul and

Fahrbach, 2011a,b). Seals played an important part in this achievement, through a program involving scientists from Australia, Norway, USA, UK and France.

We have been leading the development of plans for a sustained Southern Ocean Observing System (SOOS), which will include seal tags as an important platform. The strategy for implementation of the SOOS has been developed by several hundred scientists from around the world over the last few years (Rintoul et al., 2011).

Seals have also been prominent in planning for the next decade of global ocean observations (Charassin et al., 2010; Rintoul et al., 2010; Boehme et al., 2010).

Activities undertaken:

We supplied content to the website designers (text, photos, graphs, maps) to support the launch of the Seals for the Reef web site (http://www.sealsforthereef.com.au).

We have supplied material for blogs on the web site, which includes 17 posts. Four seals were named as part of a competition held for Qantas staff (Leonie, Sammy, Mirounga and Coral).

Steve visited the Narraweena Public School on November 25, as part of the prize for the colouring-in competition. Steve spoke to 120 nine and ten year old students about climate change, Antarctica, and the Seals for the Reef Project. The school and students seemed to enjoy the visit and get a lot out of it.

Steve joined Professors Will Steffen and Ove Hoegh-Guldberg to brief staff at KPMG and Qantas in Sydney about climate change and to introduce the Seals for the Reef project (November 30 – December 1).

Steve led an Antarctic voyage in January – February. While not directly linked to Seals for the Reef, the presence of an ABC film crew on board led to extensive media coverage and raising of awareness of the importance of Antarctica in the global climate system. (The ABC journalist Karen Barlow's blog can be found at: http://blogs.abc.net.au/news/breaking-the-ice/ . Steve's

daily updates ("sitrep," for situation report) can be found at http://its-app3.aad.gov.au/proms/public/schedules/voyage_sitreps.cfm?season=1011&voyage_no=MS&ship=Aurora%20Australis).

The project has been advertised in a number of presentations since June 2010, including:

- Antarctic Science Lecture, Scientific Committee for Antarctic Research, Buenos Aires, Argentina
- W. S. Jardetzky Lecture, Lamont Doherty Earth Observatory, Columbia University, USA
- International Union of Geodesy and Geophysics, Melbourne
- 4th International Bio-logging Conference in Hobart
- Museum of Natural History, Paris
- South American Antarctic Symposium, Sao Paulo, Brazil
- Woods Hole Oceanographic Institution, USA
- Princeton University, USA
- ACE CRC Annual Symposium, Hobart
- Phillip Law Symposium, Melbourne

Publications:

We have published a number of scientific papers since June 2010 that have used data from elephant seals, including:

Williams, G. D., M. Hindell, M-N Houssais, T. Tamura, and I.C. Field, 2011. Upper ocean stratification and sea ice growth rates during the summer-fall transition, as revealed by Elephant seal foraging in the Adélie Depression, East Antarctica. Ocean Science, in press.

Bestley, S. , S. R. Rintoul and J.-B. Charassin, 2011. Seals reveal ocean – ice interaction in East Antarctica. Proceedings of the Royal Society – Interface, submitted.

Rintoul, S. R. and E. Fahrbach, 2011a. The Southern Ocean (Chapter 2.3). In: Understanding Earth's Polar Challenges: International Polar Year 2007-2008, Smithsonian Institution, USA. In press.

Rintoul, S. R. and E. Fahrbach, 2011b. The Southern Ocean Observing System (Chapter 3.3). In: Understanding Earth's Polar Challenges: International Polar Year 2007-2008, Smithsonian Institution, USA. In press.

Rintoul, S. R. & Co-Authors (2010). "Southern Ocean Observing System (SOOS): Rationale and Strategy for Sustained Observations of the Southern Ocean" in Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 2), Venice, Italy, 21-25 September 2009, Hall, J., Harrison D.E. & Stammer, D., Eds., ESA Publication WPP-306, in press.

Rintoul, S. R. et al., 2011. The Southern Ocean Observing System: Initial Science and Implementation Strategy. Scientific Committee for Antarctic Research.

Boehme, L. & Co-Authors (including S. Rintoul) (2010). "Biologging in the Global Ocean Observing System" in Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 2), Venice, Italy, 21-25 September 2009, Hall, J., Harrison D.E. & Stammer, D., Eds., ESA Publication WPP-306.

Charrassin, J. & Co-Authors (including S. Rintoul) (2010). "New Insights Into Southern Ocean Physical and Biological Processes Revealed by Instrumented Elephant Seals" in Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 2), Venice, Italy, 21-25 September 2009, Hall, J., Harrison D.E. & Stammer, D., Eds., ESA Publication WPP-306.

Figure 1. Map of the movements of the five seals tagged at Davis Station in February 2011.

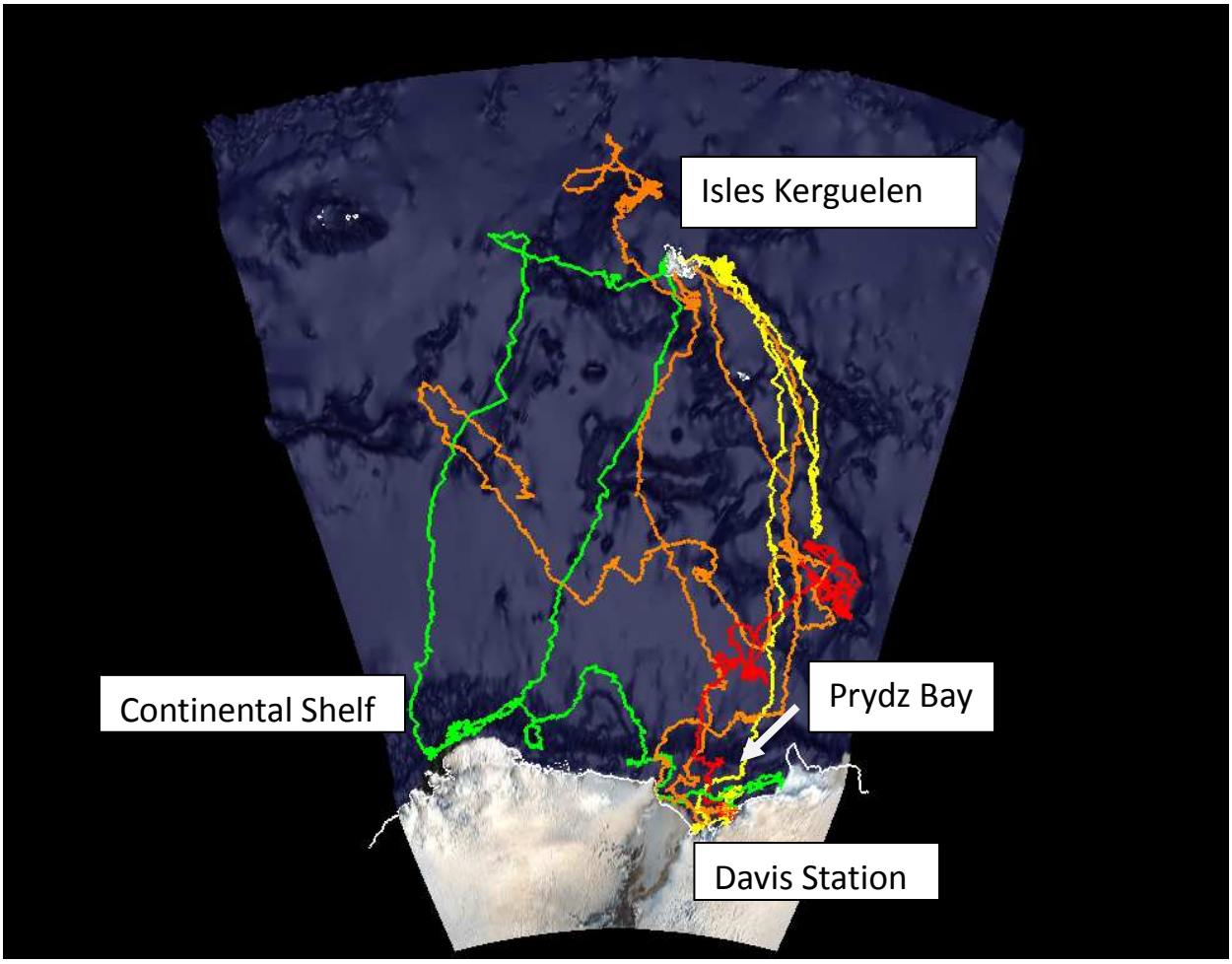

Figure 2. Map of the 3997 temperature and depth profiles collected by the 5 seals. This figure clearly shows the seals diving to the ocean floor on the Kerguelen Plateau, on the Antarctic Continental shelf and on isolated seamounts. Also indicated are the cold, well mixed water over the continental shelf, the more stratified water further north and the warm surface water overlying the cold water in the region of the Antarctic Polar Front.

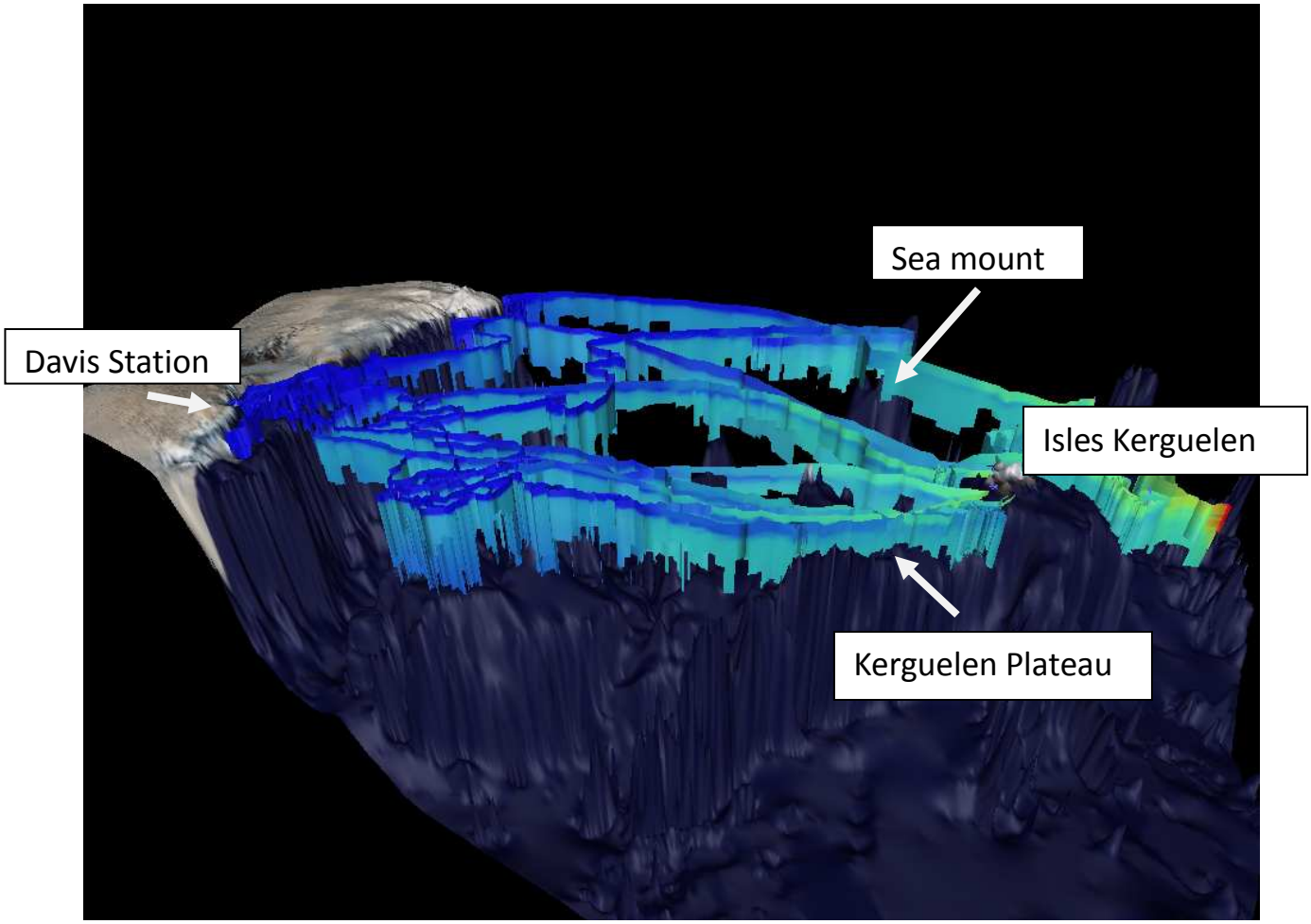

Figure 3. Close up of salinity and depth profiles collected in the Prydz Bay region. Note the lower salinity water (blue dots) occurs closer inshore and also in surface waters further offshore. The most saline waters(red dots) are deeper and further offshore. This is a consequence of sea-ice formation and the resulting brine rejection