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The Australian Antarctic Division, a Division of the Department for Sustainability, Environment, Water, Population and Communities, leads Australia's Antarctic program and seeks to advance Australia's Antarctic interests in pursuit of its vision of having 'Antarctica valued, protected and understood'. It does this by managing Australian government activity in Antarctica, providing transport and logistic support to Australia's Antarctic research program, maintaining four permanent Australian research stations, and conducting scientific research programs both on land and in the Southern Ocean.

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- Take advantage of the special opportunities Antarctica offers for scientific research.
- Protect the Antarctic environment, having regard to its special qualities and effects on our region.
- Maintain Antarctica's freedom from strategic and/or political confrontation.
- Be informed about and able to influence developments in a region geographically proximate to Australia.
- Derive any reasonable economic benefits from living and non-living resources of the Antarctic (excluding deriving such benefits from mining and oil drilling).

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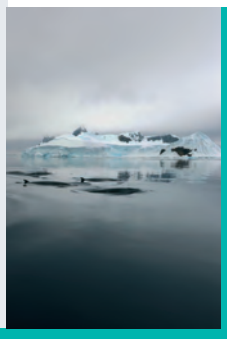
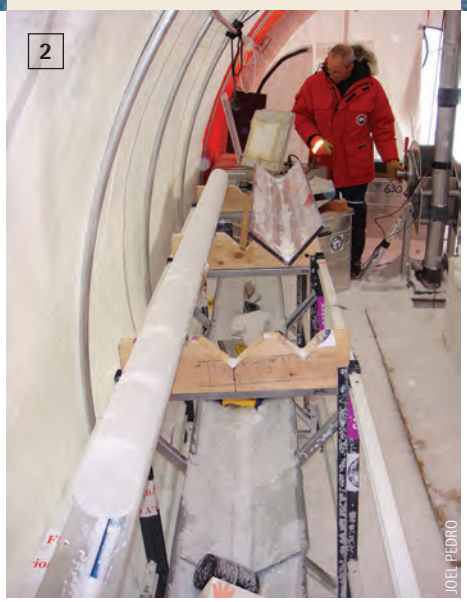


ABOUT THE COVER

This pod of Antarctic minke whales was photographed in Wilhelmina Bay, Antarctic Peninsula, by Dr Ari Friedlaender, a research scientist from Duke University in the United States. Dr Friedlaender led a team gathering insights into the diving and feeding behaviours of humpback and minke whales, using data logging and satellite tags. A green tag is visible on one of the whales in this photo (back cover). Read more about the research on page 4. (Image courtesy of Ari S. Friedlaender, NMFS Permit 14097, ACA Permit 2009-013).

Getting to the core of climate

1. An Australian ice core drilling camp set up at Law Dome in 2008.
2. Experienced Australian Antarctic Division ice core driller Dr Tas van Ommen in the drilling tent at Law Dome, 2008.



Plans are afoot to drill an ice core climate record, dating back more than 2000 years, in the heart of the Australian Antarctic Territory this summer.

Over six weeks the Aurora Basin North ice coring team will drill a 400 m-long ice core at a site some 500 km inland from Casey station. Chief Investigator, Dr Mark Curran, from the Australian Antarctic Division, said the ice core would fill a gap in the international science community's climate knowledge.

'According to the Intergovernmental Panel on Climate Change Fourth Assessment Report, our ability to reconstruct Southern Hemisphere climate is limited by the sparsity and quality of well resolved climate records, particularly over the last 2000 years,' Dr Curran says.

'This timeframe spans both the industrial era and a significant length of time before humans began influencing climate.

'The Aurora Basin North site has a relatively high snow accumulation rate, equivalent to 13 cm of water per year, which will allow us to discern annual climate records over this critical time period, for the first time in the region.'

Australian Antarctic scientists have climate records spanning the last 2000 years and beyond, from ice cores taken from the coast at Law Dome and inland at Dome C – albeit with limited measurements and different resolutions. However, differences in the snow accumulation rate at these two sites, and the low resolution of some of the records, make annual climate interpretation difficult. To address this problem the international ice core community has established the International Partnerships in Ice Coring Sciences (IPICS) to coordinate efforts to build an array of 2000 year old ice core records across Antarctica.

'The Aurora Basin North project will provide one core for this array and it will also help us resolve uncertainties in the climate record between the Law Dome and Dome C sites,' Dr Curran says.

The ice coring team plan to drill further back in time to about 3000 years, if all goes well, to get an understanding of natural climate variability, on global and regional scales.

'Our previous ice core work has allowed us to establish a link between reduced rainfall in south-west Western Australia and increased snowfall in East Antarctica over the past 750 years,' Dr Curran says.

'We've also found a link between increased sea salt accumulation in Antarctic ice – associated with El Nino events and stronger winds in the Southern Ocean – and increased rainfall in Queensland and New South Wales over the past 1000 years.

'We will use the detailed Aurora Basin record to continue to investigate regional climate linkages between the Antarctic and Australian climate.'

Aurora Basin North is a truly collaborative project with 12 international organisations involved: Australian Antarctic Division, Antarctic Climate and Ecosystems Cooperative Research Centre, Australian Nuclear Science and Technology Organisation, Curtain University, CSIRO, Desert Research Institute (United States), Institut Polair Francais (IPEV, France), Laboratory of Glaciology and Geophysical Environment (LGGE, France), Macquarie University, National Centre for Scientific Research (CNRS, France) University of Copenhagen and the University of New South Wales.

Climate chemistry

To reconstruct climate the Aurora Basin North team, which includes scientists from Australia, France, Denmark and the United States, will measure a number of chemical constituents in the ice core.

One of the first things they'll measure in the field are oxygen isotopes (different nuclear forms of oxygen), which provide a temperature record. Ice formed under cooler conditions will contain more ^{16}O, while ice formed under warmer conditions will contain more ^{18}O.

'We've purchased a laser spectrometer to measure oxygen isotopes, which has been tested and proven in the field by our Danish colleagues in Greenland,' Dr Curran says.

'So we'll have a 2000 year temperature record as soon as we come out of the field, which will be a first for Australia. Previously we'd have to wait about two years to finalise our analysis using older, slower measurement techniques back in the laboratory.'

The team will also cut samples for later methanesulphonic acid (MSA) analysis. MSA is produced from the oxidation in the atmosphere of dimethylsulphide, which is itself produced by certain species of phytoplankton in the Southern Ocean. The amount of MSA in an ice core was found to be related to the maximum extent of sea ice in the region. In simple terms, this is because in years where there is more sea ice, there is more phytoplankton activity following sea ice decay and therefore more MSA production.

Back in their laboratories, scientists will also measure carbon dioxide (CO_2), sulphates and beryllium-10 to assess the greenhouse gas 'forcing' (impact), volcanic forcing and solar forcing, respectively, on climate.

'Measuring these elements will allow us to assess of the importance of these forcings for natural climate variations over time, and assess the extent of man-made greenhouse gas forcing,' Dr Curran says.

Air for CO_2 analysis will also be extracted in the field in the 'firn' ice at the top of the core. Firn ice is unconsolidated ice that contains a lot of air spaces – unlike consolidated ice where the air is trapped in bubbles. To collect the gas a core is drilled to the region of interest and a bladder is lowered into the resulting hole and pumped up to seal the hole. A tube inserted through the bladder is connected to a vacuum pump at the surface. Once in position, the pump is turned on to suck the air out of the surrounding firn. The recovered air will be stored in cylinders for analysis in Australia.

'The firn air is "fresher" or more modern than the air trapped within the ice core. So to get the fullest record possible, it's important that we capture the firn air and not contaminate it with today's air,' Dr Curran says.

Scientists from the Desert Research Institute in the United States will produce much of the fine detail climate record for the project using a unique continuous ice core melter coupled to a system that measures a range of chemical species and elements. These include dust tracers, such as magnesium and iron, ash from fires, seawater tracers such as sodium and bromine, and volcanic tracers such as copper and cadmium. These analyses will help date the ice core and provide information about natural aerosols and pollution levels in the recent era.

Here's the drill

The tool of choice to drill the 400 m core is a Danish Hans Tausen drill. Dr Curran and Dr Andrew Moy, also from the Australian

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Antarctic Division, have both spent time in Greenland with a Danish ice coring team, learning to use the drill. They, along with Trevor Popp from the University of Copenhagen, will be the chief drillers. The trio will lead two three-person drill teams, operating in shifts across a 14 hour day.

The teams will also operate two narrower French and Australian drills. The Australian Antarctic Division's Eclipse drill is capable of drilling to 400 m but has not been tested to that depth. Both it and the French drill will drill cores side by side to 120 m, providing more ice for large volume analyses, covering the last 800–1000 years. The French core will be used solely to measure sulphur isotopes, which require a large amount of ice for a single measurement.

Advanced planning

The Aurora Basin North ice coring project is an ambitious project but it has already achieved significant logistical success. Five shipping containers of equipment – including the drills, fuel and an entire field camp for 16 people – had to be shipped to the French station at Dumont D'Urville on the *L'Astrolabe* in March this year, for a traverse to the drill site in November.


ANDREW MOY


4
GLENN JACOBSON


5
JOE MCCONNELL

'We had to do all our field preparation a year in advance. So we had to set up the camp in Hobart to make sure everything worked, and then pack it in the order we wanted it unpacked in the field,' Dr Curran says.

'Then we had a nail-biting week where it looked like the ship wouldn't get in to Dumont D'Urville because the ice was so thick. But they did get in and they pumped all the fuel for the traverse, got our gear off the ship, and departed the station; all within 24 hours.

'It has been a huge team effort across the Australian Antarctic Division as well, with the science branch, store, and logistics sections working together through project manager Alan Elcheikh and project officer Meredith Nation, to achieve what we have so far.'

In November this year a French-led traverse team will depart Dumont D'Urville to deploy the fuel and equipment to the field site. This traverse will include an Australian mechanic, an air-ground support officer and ice core scientist Dr Tas van Ommen. The group will establish a ski-way for air support by a Basler and Twin Otter aircraft and set up initial camp infrastructure.

In December the first drill team, including Dr Curran, will fly to the site and begin drilling. A partial personnel changeover is planned mid-way through the season. Drilling is expected to finish in late January 2014.

One million year ice core

If all goes well the team will have demonstrated a capability to run an internationally collaborative project in an unexplored area of Antarctica. They will also have data they can use to help them locate a suitable site for an even more ambitious project – drilling a one million year old ice core.

'The Australian Antarctic Territory has some of the thickest and likely the oldest ice in Antarctica,' Dr Curran says.

'Once we've extracted our shallower, 2000–3000 year old core, we'll be able to combine our analyses from that core with aerial radar surveys of ice thickness and structure that have been conducted in the region recently through the ICECAP project [*Australian Antarctic Magazine* 19: 7, 2010]. This will allow us to identify a site most likely to contain one million year old ice.'

WENDY PYPER
Australian Antarctic Division

3. An ice coring camp set up by Danish scientists in Greenland for the North Greenland Eemian Ice Drilling project in 2011, where Dr Mark Curran and Dr Andrew Moy learnt how to operate the Hans Tausen drill.
4. The Aurora Basin North camp had to be set up in its entirety a year in advance, to ensure all the equipment functioned as it should. Here Dr Mark Curran (right) explains the process of ice core drilling to members of the Senate Standing Committee.
5. Dr Andrew Moy preparing the Danish designed and built Hans Tausen ice core drill during drilling in Greenland.

Tag team track whale feeding habits

Antarctic scientists have deployed data-logging and satellite tags on Antarctic minke whales to learn more about where and how the animals feed.

1. Dr Nick Gales successfully tags a minke whale from the bow of the inflatable rubber boat. From a distance of 5-8 metres, he aims for a point on the whale's dorsal (upper) side. The tag must stick out of the water when the whale breaches the surface in order to transmit its signal to a satellite.
2. An acoustic suction cup tag is attached to a minke whale.

Australian Antarctic Division Chief Scientist, Dr Nick Gales, and colleagues from the United States Antarctic Program, successfully deployed the tags on 15 minke whales during a two-week voyage to the Gerlache Strait off the Antarctic Peninsula. The team also deployed 26 tags on humpback whales.

The data collected by the tags will provide the first insights into the diving and feeding difference between the two whale species.

'In the Southern Ocean, most whale populations were hunted almost to extinction,' Dr Gales said.

'As these heavily hunted whale species recover, along with other Southern Ocean predators such as Antarctic fur seals, there is a great deal of interest in understanding how and where each predator feeds on their common prey – Antarctic krill. We know a little about this from ship-based

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ARI FRIEDLAENDER

1

JOHN DURBAN

3. The Australian-American tagging team, including Australian Antarctic Division Chief Scientist Dr Nick Gales with the tagging gun at the bow.
4. A humpback whale carrying a satellite tag.
5. A pod of minkes, including one recently tagged with a green acoustic tag, in their feeding grounds in Wilhelmina Bay. Dr Gales said the research team observed the whales engaging in cooperative feeding behavior – diving and surfacing at the same time.

surveys, where we have observed the range of habitats we see the different species in, but we know almost nothing of the movements of individual animals and what happens when they go below the water surface to feed.'

The United States-led voyage in February aimed to address this information gap by tagging minke and humpback whales foraging in a shared feeding ground.

Short-term data-logging tags, attached by suction cups, remained on the whales for up to 24 hours and collected comprehensive data on their movement through a krill swarm, including dive depth, fluke strokes, acceleration, and the pitch and roll of their bodies. At the same time, scientists onboard the United States National Science Foundation research vessel, *Point Sur*, monitored the krill swarm size and location using scientific echo sounders.

'With software we can reconstruct the movement of the whale in three dimensions and see where and how the animal is feeding,' Dr Gales said.

'When we deploy this type of tag we also use echo sounders on our boat to see where the whales' prey is located. We integrate the whale tag data with the echo sounder data to get fine resolution pictures of the whale, its behaviour and its immediate environment, including the prey.'

A second, long duration satellite tag was fired into the blubber of the animals, where it is hoped it will remain for several months.

'The satellite tags provide us with information about the medium to large scale movements of the whales; so how they move around their feeding grounds to search for prey, where they go when they leave the feeding grounds, and we hope the tags last long enough to tell us where the whales go for their winter breeding,' Dr Gales said.

The team used different approaches to tag the minke and humpback whales.

'Minke whales are much smaller and faster than humpback whales,' Dr Gales said.

'We soon worked out that we just had to behave like a minke whale. So we slowly manoeuvred into a group of whales and when one surfaced at the right distance, I was able to fire a tag into the blubber from the bow of the boat.

'Humpback whales, on the other hand, tend to sleep at the surface after they've been feeding, so we were able to drift alongside them and tag them quite easily.'

As well as providing foraging information, the research on minke whales will contribute to abundance estimates.

'We've been trying to estimate the population size of minke whales for decades and they're hard to count because they spend an unknown amount of time underwater and in and under the pack ice,' Dr Gales said.

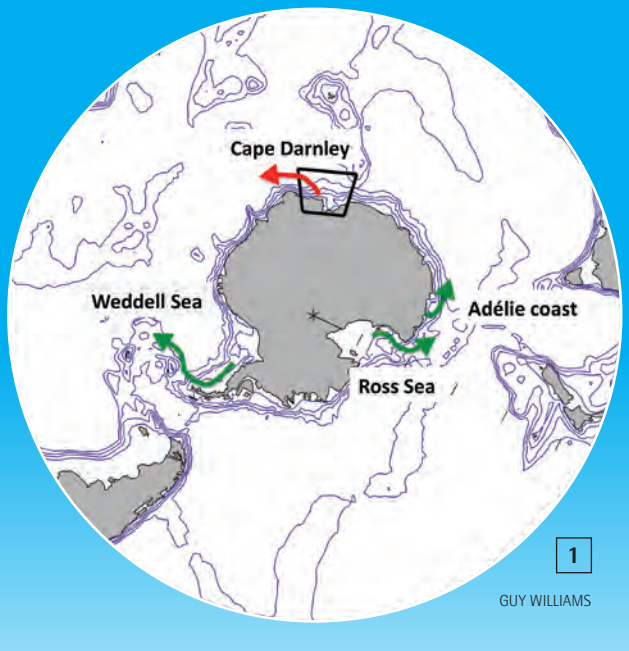
'Data from the tags we deployed this summer will provide measures of the amount of time minke whales spend at the surface and the amount of time they spend in ice and open water habitats. These data will contribute to sophisticated statistical models that are used to derive the abundance estimates.'

The work is contributing directly to the Southern Ocean Research Partnership, a collaborative consortium for non-lethal whale research at the International Whaling Commission. The results from the voyage will be reported to the International Whaling Commission's Scientific Committee in Korea in June.

WENDY PYPER
Australian Antarctic Division

Seals get to the source of Antarctic Bottom Water

Southern elephant seals have inadvertently helped oceanographers discover a new source of Antarctic Bottom Water, solving a 35 year mystery surrounding the formation of this cold, salty, and globally important water mass.



1

GUY WILLIAMS

Carrying small IMOS* oceanographic instruments on their heads, the seals, which were part of an unrelated ecological study, foraged to depths up to 1800 m off Cape Darnley, East Antarctica, into a 'waterfall' of newly formed bottom water heading for the abyssal zone, more than 5000 m below.

The data they collected, along with data from oceanographic moorings and satellites, confirm Cape Darnley as the location of a fourth source of Antarctic Bottom Water – a cold, dense (salty) water mass that drives ocean currents around the world.

Writing in *Nature Geoscience* in February, Dr Guy Williams, from the Antarctic Climate and Ecosystems Cooperative Research Centre, and colleagues from Japan, Sweden and Australia, said scientists knew Antarctic Bottom Water originated at three different locations in Antarctica – the Weddell Sea, the Ross Sea and the Adélie Coast (see map). Thirty-five years ago, a fourth source was speculated to exist somewhere in the Prydz Bay region. But until now, scientists have been unable to confirm if, where and how it is being formed.

'Since 1977 we suspected there was a source of Antarctic Bottom Water off Mac Robertson Land (60–70°E), but the inaccessibility of the area has meant that it has taken another 30 years to locate and observe how it is being formed,' Dr Williams said.

Antarctic Bottom Water is created when sea ice forms in winter, close to the continent. As it forms, the sea ice rejects salt, making the water below salty and therefore dense, causing it to sink down the continental shelf to the abyssal depths.

2

IAIN FIELD

'While sea ice grows everywhere around Antarctica in winter, there are only a handful of regions where enough sea ice forms to produce the dense water necessary for Antarctic Bottom Water,' Dr Williams said.

'Typically this occurs in large polynya regions, also known as "ice factories", where the shape of the coastline and associated glaciology, together with complementary winds, conspire to create an ongoing cycle of sea-ice production-removal-production. This results in enhanced levels of sea ice production and dense water formation on the continental shelf.'

In 2008–09, as part of the International Polar Year, Japanese scientists from the Institute of Low Temperature Science, Hokkaido University and the Tokyo University of Marine Technology, deployed moorings measuring salinity and temperature in the Daly and Wild canyons, off the continental shelf at Cape Darnley. These sites were selected based on satellite analysis, which showed the Cape Darnley Polynya was the second highest producer of ice around Antarctica, after the Ross Sea Polynya.

Data from the moorings showed that cold, salty water did indeed appear 'after the onset of active sea ice production', drifting west along the continental slope and down into Daly Canyon. Instruments attached to the seals confirmed the origin of this water.

'The moorings found the down slope flow and proved bottom water was being produced, but the Japanese team also wanted to get to the top of the "waterfall" where it all began,' Dr Williams said.

'So in 2011 we were excited to learn of the IMOS-instrumented seals at nearby Davis, which were involved in an unrelated ecological project into seal behaviour.'

1. This map shows the location of the four known sources of Antarctic Bottom Water and the direction of travel of that water. Antarctic Bottom Water drives the southern limb of the global ocean circulation, the so-called 'global conveyor belt' that in its simplest description transports surface waters from the equator to the poles and 'bottom waters' equator-ward.
2. Southern elephant seals on the beach at Davis.
3. Two Southern elephant seals at Davis carrying CTD instruments. The instruments record conductivity (salinity), temperature and depth (CTD) as the seal dives, and transmits this information to satellites when the seal surfaces.
4. This map shows the location of the four Japanese oceanographic moorings (M1-M4) and the position of oceanographic data collected by seals (red dots). The colour bar at the bottom left corner of the image indicates the depth of the continental shelf and sea floor. Green lines outline polynya regions. Yellow lines outline fast ice. The inset map shows the tracks made by the 20 satellite-tagged seals.

3

IAIN FIELD

The 'CTD' (conductivity, temperature and depth) instruments attached to each seal had a small satellite relay which transmitted data on a daily basis during the five to 10 minute intervals when the seals surfaced.

'Several of the seals travelled into the Cape Darnley polynya in the middle of winter, providing information on the dense shelf water source of this bottom water, in an area that has so far proven impossible to access by ship,' Dr Williams said.

'Some additional seals tagged by French colleagues at Kerguelen Island also foraged on the continental slope as far down as 1800 m, punching through into a layer of this dense water cascading down to the abyss.

'The seals have returned very rare and invaluable winter-time measurements of this process.'

The team estimate that the Cape Darnley source of Antarctic Bottom Water represents between six and 13 per cent of the circumpolar total.

The newly identified source is different from the other three sources in that it has a relatively narrow section of continental shelf, and therefore low storage volume, for the accumulation of dense shelf water – previously thought to be necessary for bottom water formation. This opens the door for further discoveries of Antarctic Bottom Water production from the other polynya regions around the Antarctic coastline.

Dr Williams said the discovery redraws the map of large-scale Antarctic oceanography in the Atlantic sector.

'It is now vital that this new information be incorporated into the assessment of Antarctic Bottom Water variability and change, and its input to the global overturning circulation,' he said.

'This will improve numerical modelling efforts to predict its response to long-term climate change.'

WENDY PYPER[1] and MIRANDA HARMAN[2]

1 Australian Antarctic Division

2 Antarctic Climate and Ecosystems Cooperative Research Centre

** Instruments were provided by Australia's Integrated Marine Observing System (IMOS), a national array of observing equipment to monitor the open oceans and coastal marine environment around Australia, covering physical, chemical and biological variables. The instrumented seals were part of an ecological study conducted by the Institute for Marine and Antarctic Studies and Macquarie University.*

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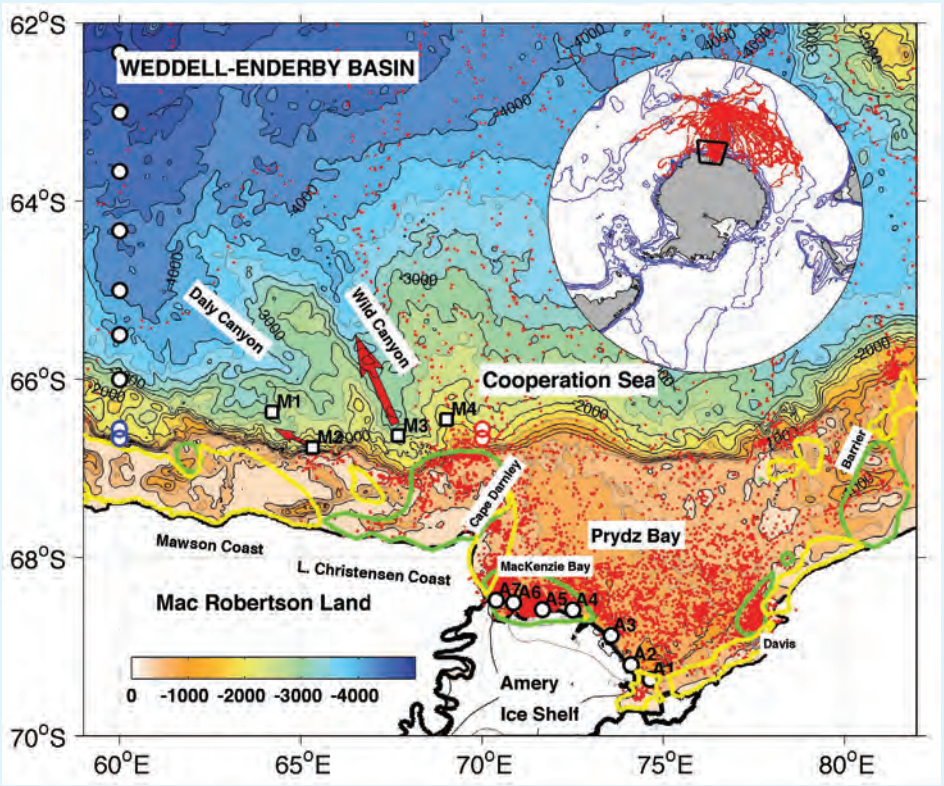
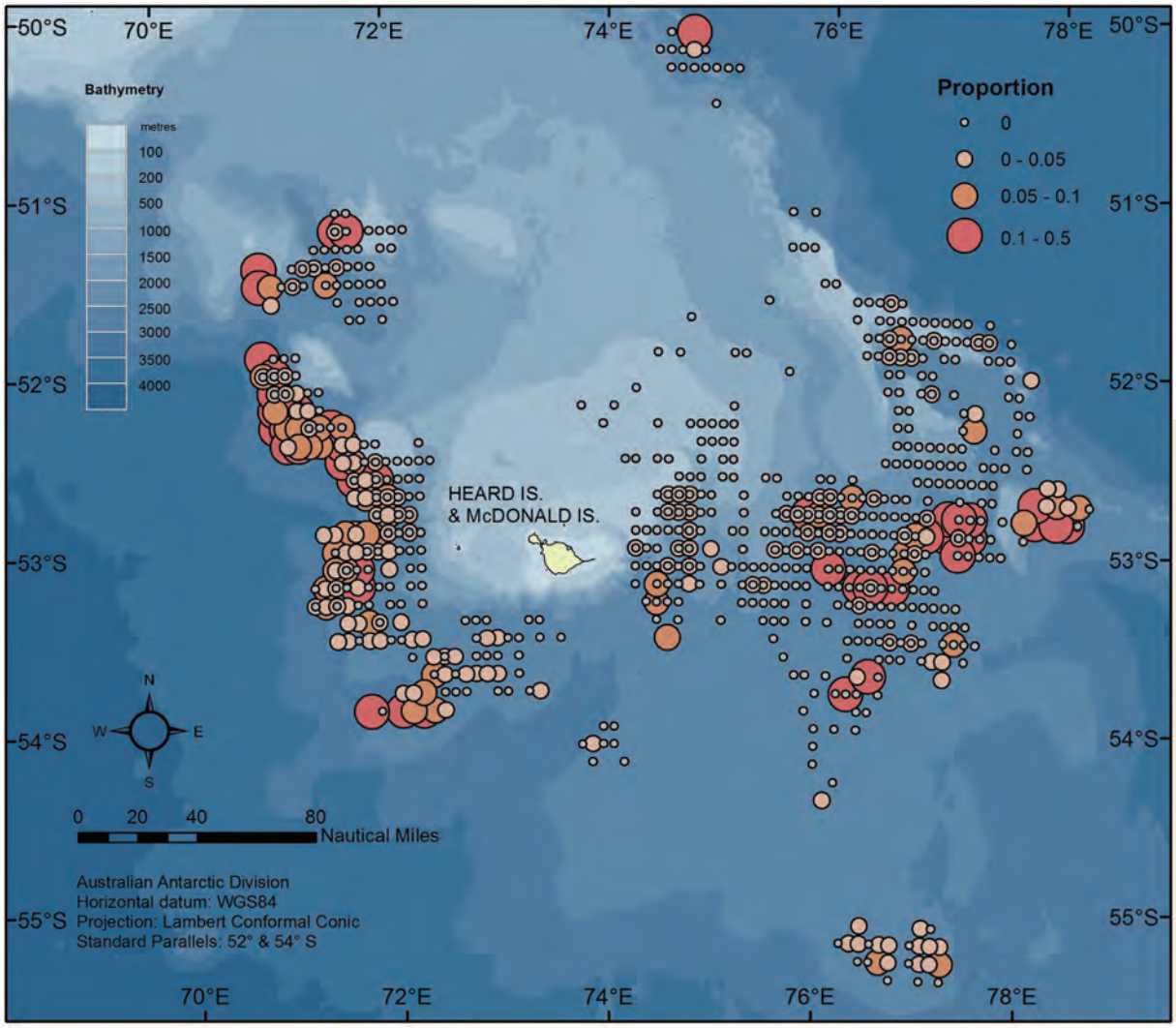


GUY WILLIAMS



This map shows the location of spawning of female Patagonian toothfish as the proportion of females with gonads assessed as mature or in the process of maturing. Males showed a similar spawning pattern. Bathymetry data courtesy of the Australian Antarctic Data Centre.

Toothfish research spawns new understanding

Antarctic scientists have acquired the first detailed information about the reproductive maturity of Patagonian toothfish in the Heard Island and McDonald Islands (HIMI) fishery, including the location and timing of spawning.

The research will improve the accuracy of stock assessment models that contribute to the setting of sustainable catch limits for the toothfish fishery, and will inform future harvest strategies that account for the movement of toothfish at different life stages, in the region.

Australian Antarctic Division fisheries scientist, Dr Dirk Welsford, said that for most of the Patagonian toothfish fishery's 15 year history, very few spawning toothfish had been recorded. But in 2009 a number of spawning toothfish were captured during prospective longline fishing on the deep slope (at about 1700 m) to the west of HIMI.

'The Fisheries Research and Development Corporation and industry helped fund a systematic survey of the area in the winter of 2011 and we sampled over 11 000 fish,' Dr Welsford says.

'For the first time we were able to collect and study male and female toothfish at all stages of reproductive development, which allowed us to better define the size and age at which the fish mature and to produce a map of where they spawn and how deep they spawn.'

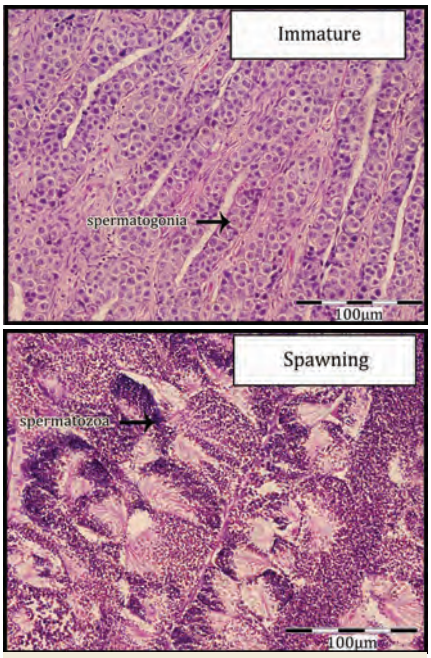
To do this the research team analysed thin sections of the ovaries and testes from the captured fish under the microscope, and matched sexual maturity to fish size, age estimates, and catch location.

Their analysis showed that the majority of female Patagonian toothfish begin spawning by about the age of 10, while most male fish reach reproductive age at about seven.

Before female toothfish spawn, the eggs in their ovaries go through 10 distinct stages of development. This includes a 'yolk provisioning' phase and a final hydration of the eggs, which visibly distends the abdomen of the fish, before they are released into the water column. Sperm go through three developmental phases before they too are released into the water column.

Microscopy also revealed that a substantial proportion of the mature female population may not spawn every year, possibly due to the relatively high cost of provisioning large quantities of large, yolky eggs.

Matching maturity to catch location showed that the toothfish spawn predominantly on the slopes of the Kerguelen plateau (see map) to



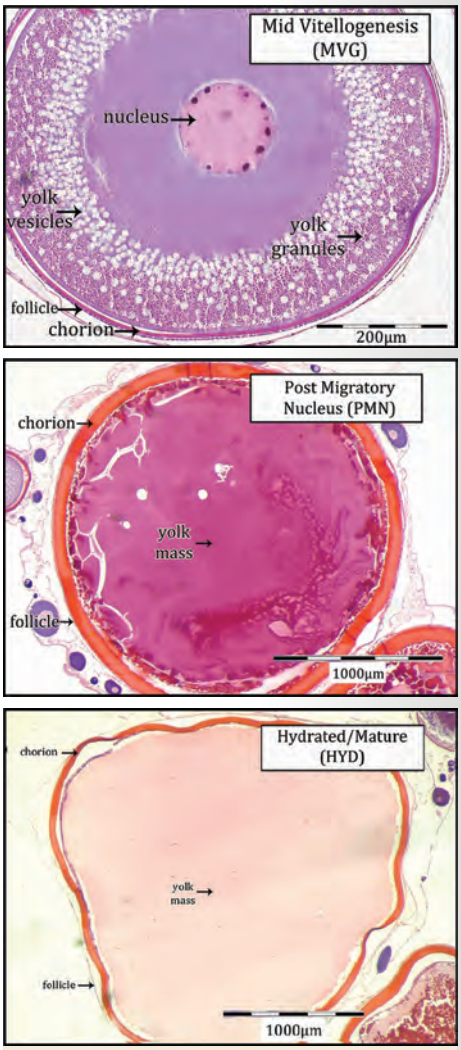
The appearance of developmental stages in Patagonian toothfish testes stained with haematoxylin and eosin.

the northwest, west and south of HIMI at 1500–1900 m depth in the late autumn to winter months (May-August). Juvenile fish are usually restricted to waters less than 1000 m, while larger adult fish are encountered at depths of up to 2700 m.

'These findings are important in terms of assessing the growth, death and reproductive output of toothfish and the major locations used by spawning fish, to ensure fishing doesn't cause an unsustainable impact,' Dr Welsford says.

'However, now that we know that spawning activity is widespread, and the HIMI longline fleet is relatively small and fishing effort is dispersed, it is unlikely that the fleet will substantially disrupt reproductive activity.'

The research will inform a new collaborative project being developed between the Australian Antarctic Division, the University of Tasmania and the Museum Nationale d'Histoire Naturelle in Paris. The project will develop models and sustainable harvest strategies that account for the spawning locations, the movement of juvenile fish to spawning areas, and the differences in growth and maturation rates between male and female toothfish across both the Australian and French Exclusive Economic Zones on the Kerguelen Plateau. This work will in turn inform HIMI fishery management decisions made by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).



The appearance of egg (oocyte) developmental stages in Patagonian toothfish ovaries stained with haematoxylin and eosin. The less advanced stage (mid-vitellogenesis) is at the top and the most advanced stage – hydration of the egg – is at the bottom.

'The harvest strategies in fisheries managed by CCAMLR ensure that enough spawning stock remain to maintain ecological relationships and the natural levels of recruitment of young fish to the population,' Dr Welsford says.

'CCAMLR has agreed to our recommendation that the new information we've collected about age, growth and size at maturity, is incorporated into models for future stock assessments.'

The HIMI toothfish fishery is one of very few fisheries that have data on key population parameters such as size-at-age, catch-at-age, natural mortality and age-at-maturity. Dr Welsford says this standing is critical for ensuring organisations such as CCAMLR and the Marine Stewardship Council **(see sidebar)** continue to recognise Australia's sustainable management of this fishery.

WENDY PYPER
Australian Antarctic Division

AUSTRALIAN-CAUGHT TOOTHFISH A 'BEST CHOICE' FOR CONSUMERS

Australian-caught Patagonian toothfish was labelled 'best choice' by the Monterey Bay Aquarium's Seafood Watch program in April, less than a year after the fisheries' independent certification as sustainable and well managed by the Marine Stewardship Council.

The Monterey Bay Aquarium (MBAQ) provides 'ocean friendly' purchasing advice to consumers on over 2400 fisheries around the world and is widely respected for the high quality and independence of its work.

Australia has two fisheries for Patagonian toothfish (also known as Chilean Seabass) – the Macquarie Island Toothfish Fishery and the Heard Island and McDonald Islands (HIMI) Fishery. Both fisheries were accredited as sustainable by the Marine Stewardship Council last year, after years of scientific research and the adoption of conservation and management measures in the region, through the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).

The Patagonian toothfish fishery was once plagued by illegal, unregulated and unreported fishing. However, a collaborative effort by industry, government and conservation groups has seen illegal fishing of toothfish decline significantly and no illegal fishing vessels have been sighted in the Australian Fishing Zone since January 2004.

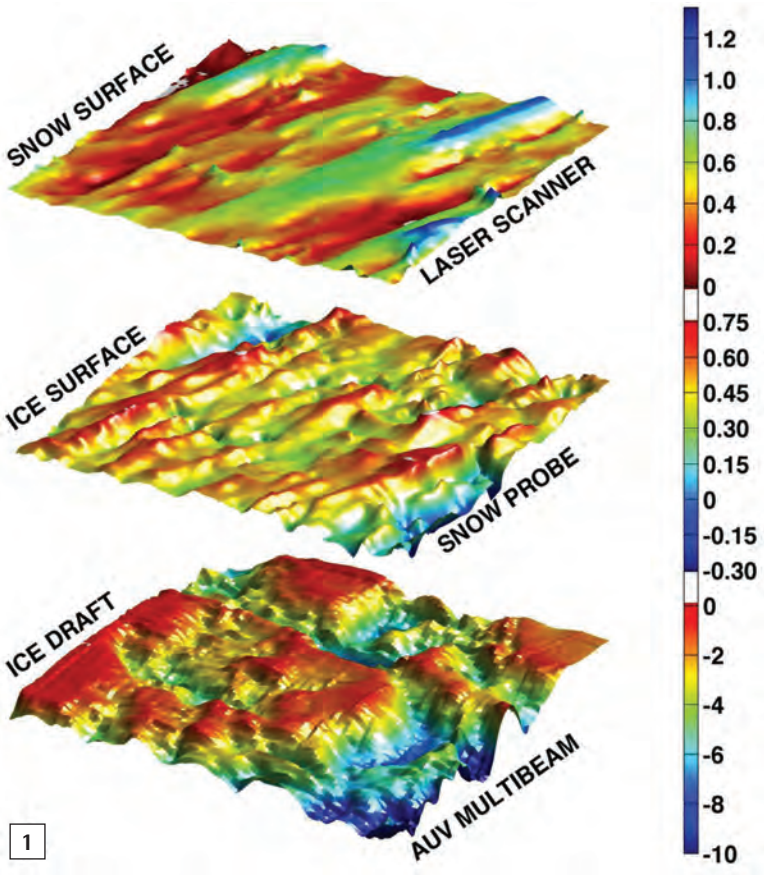
'Now, the MBAQ has reviewed all the available information relating to the collaborative research and management efforts of the Australian Antarctic Division, the HIMI fishery, CCAMLR, and the Australian Fisheries Management Authority, and this best choice label reflects those efforts, Australian Antarctic Division fisheries scientist, Dr Dirk Welsford, says.

WENDY PYPER
Australian Antarctic Division

The HIMI and Macquarie Island Patagonian toothfish fisheries are managed by the Australian Fisheries Management Authority using principles set by the Commission for the Conservation of Antarctic Marine Living Resources.

A NEW WAY OF LOOKING AT SEA ICE THICKNESS

Antarctic scientists have produced the first detailed three-dimensional map of an ice floe using an underwater sonar, terrestrial laser scanner and snow probe, to make measurements below, above and within the ice floe.



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Reporting in *Eos Transactions* in February, Dr Guy Williams, of the Antarctic Climate and Ecosystems Cooperative Research Centre, said maps generated by combining such technologies would enhance comparison with and calibration of airborne or satellite measurements of sea ice thickness. These measurements are used to monitor climate-related changes in sea ice thickness, distribution and snow cover on a large scale.

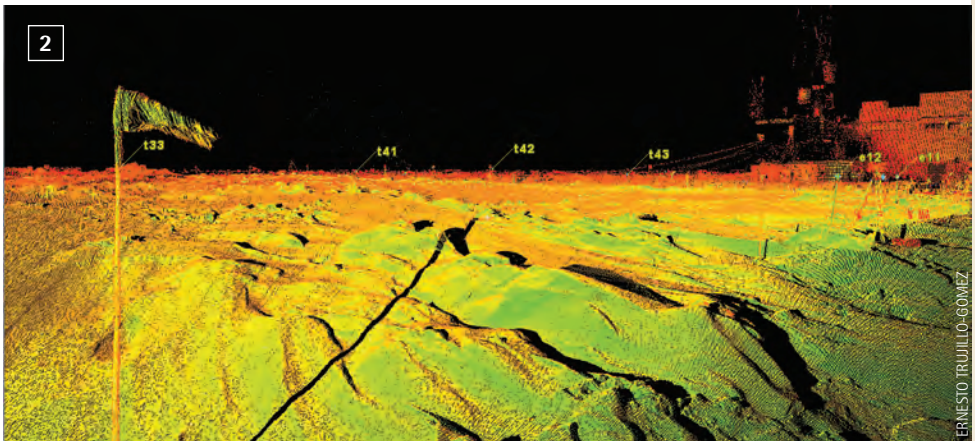
Previously, scientists made local or 'point-based' measurements of sea ice thickness by drilling hundreds of holes in a floe and measuring the ice depth in each.

'The limited scope of point measurements makes them difficult to compare with methods that can monitor large spatial extent, such as airborne or satellite surveys,' Dr Williams said.

'However, our floe-scale survey method can be scaled up to provide a direct comparison for airborne surveys, bridging the gap between point scale measurements and satellite measurements of sea ice thickness. It can also be downscaled for biological studies such as the effect of sea ice thickness on sea ice algae distribution.'

Dr Williams was part a team operating an autonomous underwater vehicle (AUV) to map the underside of sea ice during the second Sea Ice Physics and Ecosystem eXperiment (SIPEX-II) voyage to East Antarctica, between September and November 2012 (*Australian Antarctic Magazine* 23: 8, 2012).

The SeaBED-class AUV 'Jaguar', developed and operated by the Woods Hole Oceanographic Institution, was equipped with a multibeam sonar that recorded the structure of the



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1. Ice floe maps showing (from top to bottom) snow surface topography (in metres) from the terrestrial laser scanner; the ice surface (in metres) beneath the snow taken by the snow probe; and the under-ice thickness and structure from the AUV multibeam sonar. All heights/depths are relative to sea level.
2. A combination of laser scans made by Dr Ernesto Trujillo-Gomez, showing a flag marking part of the survey area and the target points used to align the scans (marked with numbers). Undulations in the snow surface are clearly visible as is the ship at the right of the image. Black areas that appear like shadows are regions where the laser was unable to scan due to objects in its line of sight.
3. The autonomous underwater vehicle (AUV) used to map the topography underneath ice floes in Antarctica.
4. Dr Ernesto Trujillo-Gomez with his laser scanner.
5. Dr Ted Maksym uses a snow probe to measure snow depth and ice surface topography.


3
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under-ice surface by sending out a swath of 'pings' and measuring the amount of time it took for the sound to bounce back.

'We operated at a depth of 20 to 30 metres beneath the ice and drove the AUV in a lawnmower pattern across a 400 by 400 metre grid, with overlapping swaths, to map the ice thickness beneath the ocean surface, at a resolution of better than 0.25 metres,' Dr Williams says.

'This resolution enabled us to discriminate individual ridge keels and rafted ice blocks.'

At the same time, on the surface of the ice floe, Dr Ted Maksym of the Woods Hole Oceanographic Institution in the US, and Dr Ernesto Trujillo-Gomez of the École Polytechnique Fédérale de Lausanne in Switzerland, took surface measurements of the snow and ice in a GPS-located 100 x 100 m survey grid.

Dr Maksym used an automated snow probe to measure the snow depth and the position of his measurements at 1000–2000 points on the ice floe, with a spatial resolution of 1–3 m. These provided point-scale measurements of the snow depth and information about the ice 'topography' (surface features) underneath.

Dr Trujillo-Gomez used a terrestrial laser scanner to obtain highly detailed images of the snow topography. The laser had a range of about 300 m and scanned objects at an accuracy of within 5 cm at 100 m, with an even greater resolution closer to the laser. Three scans of the survey area were made at different angles to get a 360 degree view, allowing Dr Trujillo-Gomez to 'see' around objects in the snow, such as rafted ice or snow drifts that blocked the laser's sight of the snow surface behind. He then aligned the different scans using markers that he had precisely located in the survey grid.

His combined scans featured some 50 million data points, most only 2 mm apart, generating an image that showed every bump or undulation in the snow and any penguin that stood around for long enough.

By combining their data, the three scientific teams were able to deliver the first complete, coincident, whole-of-floe measurements of sea ice, at modest cost and using logistics typical of a standard sea ice voyage. The maps were also generated quite rapidly, providing information relevant to other projects conducted at the same study site.

'This work could pave the way for a new era of field experiments exploring ocean and sea ice processes on scales of 10 to 100 kilometres, providing an important link between point-scale and satellite measurements,' Dr Williams said.

WENDY PYPER
Australian Antarctic Division


5
GUY WILLIAMS

The Golden rule of sea ice permeability

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KAREN FREY

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WENDY PYPER

During the second Australian-led Sea Ice Physics and Ecosystem Experiment (SIPEX-II) to the sea ice zone off East Antarctica, between September and November 2012, mathematicians investigated a new 'rule' of sea ice permeability. Their work will provide clues to how climate change will affect sea ice formation and longevity and how changes in sea ice permeability will affect biological productivity in Antarctica.

University of Utah mathematics professor, Ken Golden, vividly remembers the moment in 1994 when all the threads of his academic career came together in a pivotal realisation.

'I was out on the ice at midnight in the eastern Weddell Sea in a raging storm and I saw seawater suddenly percolate up and flood the surface,' he says.

'I'd just spent years of my life proving rigorous theorems about percolation models and I knew enough about the structure of brine inclusions in sea ice to realise that what I was seeing was a

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1. The formation and drainage of melt-water ponds in the Arctic is strongly influenced by the rule of fives.
2. Ken uses a lasso to help remove another perfect ice core.
3. David takes microwave measurements of a thin section of ice core in his 'wave guide'.

percolation threshold – a "tipping point" in the connectedness of these inclusions.'

In that one moment Ken realised that when sea ice reaches a critical temperature, the pockets of brine connect up to form brine channels, shifting the ice from an impermeable state to a permeable one. When this happens, seawater underneath the ice can percolate upwards and flood the ice surface, where it combines with snow to form snow ice.

As sea ice warms, the volume of brine in the ice (the 'brine volume fraction') increases. Through analysis of the data from their 1994 expedition and previous work on brine drainage, Ken was able to deduce that the tipping point occurred at a brine volume fraction of about 5%. By coincidence, the threshold from impermeable to permeable ice occurs when the temperature is -5°C, for a typical bulk salinity of the ice of 5 parts per thousand. Ken went on to prove this hypothesis and coined the term the 'rule of fives'.

The rule of fives applies to columnar ice (long, downward-growing ice crystals formed under calm conditions), which comprises most of the ice in the Arctic and a significant proportion in the Antarctic. In the Arctic the permeability of sea ice is important in the formation and longevity of dark melt-water ponds on the surface of the ice, which absorb sunlight (and heat) and affect the 'albedo', or light reflecting properties, of the region.

'Sea ice albedo is one of the least understood parameters in the climate system in terms of modelling, and a significant source of uncertainty in climate projections,' Ken says.

'Whether these Arctic melt ponds drain in a day or pool up and cover more of the ice is largely controlled by the rule of fives. So the brine microstructure of the ice and its fluid flow properties control larger scale processes that are critical for climate modelling.'

The rule of fives also affects the availability of nutrients for sea ice algae which, in Antarctica, provide an important food source for krill. Once the tipping point for changing permeable ice into impermeable ice reaches an algae layer, the algae are stuck with the nutrients they have and there can be a dramatic decrease in their growth rate.

'So biological activity often turns on and off according to the rule of fives,' Ken says.

Since his light-bulb moment, Ken has conducted numerous studies in the Arctic and Antarctic, including the first Sea Ice Physics and Ecosystem eXperiment (SIPEX) in 2007, gathering data on the permeability of different ice types.

As well as columnar ice, Antarctic ice is comprised of about two thirds granular ice, which is finer grained than columnar ice. It forms in turbulent weather and sea conditions, and as snow ice. Back in 1998 Ken predicted that the more randomly distributed brine pockets in granular ice would exhibit a percolation threshold at a higher critical brine volume fraction than in columnar ice, making it harder for fluid to flow through the ice. In other words, the rule of fives would not apply. But perhaps another rule would.

He saw hints of this on the first SIPEX. So on SIPEX-II (between September and November 2012), Ken and his PhD student Christian Sampson and electrical engineering graduate student David Lubbers, applied all their experience, observations, theory, and technology to begin investigating the difference in permeability between columnar and granular ice.

To do this the team extracted an ice core and measured temperatures along its length – the bottom of ice is warmer (and more permeable) than the top, because it's close to the ocean. They then measured the electrical conductivity of the core (in the vertical direction), which relates to permeability. The higher the conductivity – the ability to move electrons from one end of the core to the other – the higher its permeability.

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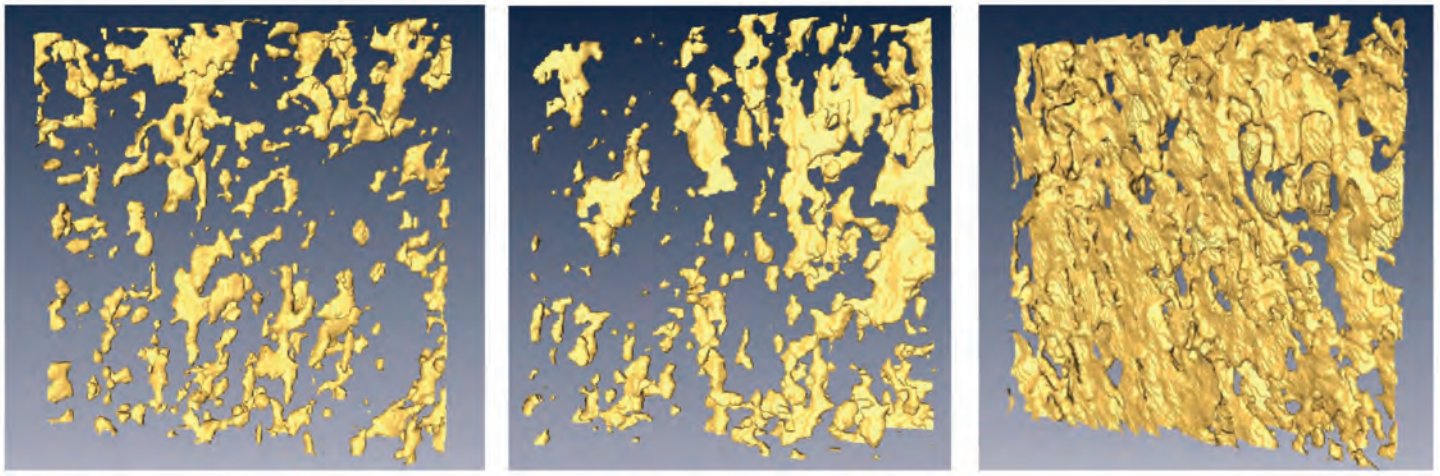

HAJO EICKEN, DANIEL PRINGLE, JEREMY MINER, AND KEN GOLDEN

'It makes sense that conductivity and permeability are linked because to have electricity flow through the core you need a path for the electrons to flow,' David says.

'The electrons will move through brine, which is salty and electrically conductive. But if the brine channels are isolated from each other, fluid can't move through them and, similarly, the electrons can't move through them because there's solid ice in the way.'

The team then examined the core's crystal structure and measured its salinity to obtain the brine volume fraction. They also drilled several 'partial permeability holes' of different depths, near where their core was taken, to look at how quickly sea water percolated up through the bottom of the ice.

'Then we deployed pressure sensors into the holes to see how, over time, the water level changed,' Ken says.

'If the ice is permeable then a lot of water moves in quickly; if not, then the water takes a long time.'

Finally, the team took microwave measurements through a thin section of ice to see how the electromagnetic properties of the ice altered the returning microwave signal and whether it correlated with the rule of fives.

These measurements will be combined with experiments by their colleagues from New Zealand and Alaska using 'cross-borehole tomography'. Here, electrode strings are frozen vertically into the ice and the effective electromagnetic properties of the ice between the electrodes are reconstructed mathematically. If it works, it could be scaled up to collect information about the ice type, fluid movement and temperature, from buoys deployed on the ice, or from satellites.

'Then we could electrically classify ice as impermeable enough to allow melt ponds in the Arctic to grow, or highly permeable ice that allows for carbon dioxide pumping and the build-up of sea ice algae,' Ken says.

For now though, Ken and his team are continuing to analyse and model their new data. They have found strong evidence that the percolation threshold for fluid flow in Antarctic granular ice is quite a bit higher than in columnar ice. As these preliminary findings are examined and made more precise, they will impact models of transport processes in Antarctic sea ice, and ultimately, our projections of climate change and the response of Antarctic ecosystems to this change.

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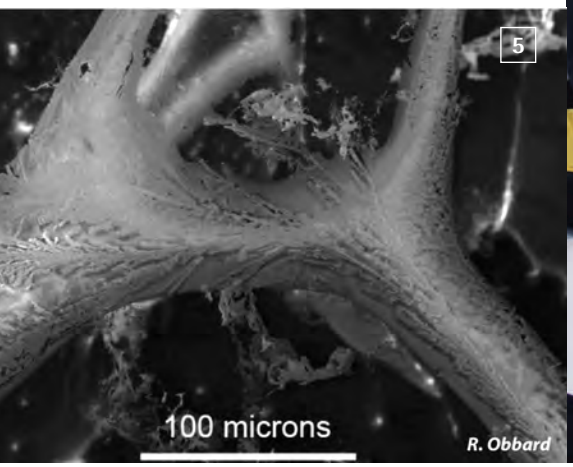

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4. X-ray computed tomography images of brine pockets in the sea ice (left) which merge to form brine channels (right) at a tipping point of temperature, salinity and brine volume fraction. In columnar ice this tipping point follows the 'rule of fives'; -5°C, 5 parts per thousand and 5%, respectively. Ken Golden's team was the first to study sea ice structure in this way.
5. A brine channel in sea ice captured by Scanning Electron Microscopy.
6. University of Utah mathematics PhD student Christian Sampson measures the electrical conductivity of an ice core. Electrical clamps are attached to nails inserted along the length of the ice core.

TRAVIS LONGMORE AND THE US EMBASSY, CANBERRA

David (centre) with Mr Peter Varghese of the Department of Foreign Affairs and Trade (left) and United States Ambassador to Australia Jeffrey L. Bleich.

MODEL YEAR FOR FULBRIGHT STUDENT

A warm, Texan summer and a prestigious collaborative opportunity await PhD student David Gwyther when he takes up a Fulbright Postgraduate Scholarship at the University of Texas, Austin, in July.

David, whose research involves modelling the impact of ocean warming and circulation change on the thinning of the Totten Glacier ice shelf in East Antarctica, received his scholarship invitation at an award ceremony at Parliament House on 21 March.

The $40 000 scholarship will enable a 12 month collaboration with American scientists involved in the ICECAP project (Investigating the Cryospheric Evolution of the Central Antarctic Plate).

ICECAP is an international collaboration involving the Jackson School of Geosciences at the University of Texas, the Australian Antarctic Division, and the University of Edinburgh. Using airborne observations, ICECAP scientists aim to uncover information critical to ice sheet modelling and an understanding of the role of the East Antarctic ice sheet in global climate and sea level rise.

As one of the fastest-thinning glaciers in East Antarctica and a contributor to sea level rise, the Totten Glacier is of great interest to the ICECAP project. The glacier is thinning up to 1.9 metres per year and has undergone a three-fold increase in thinning over the past 10 years.

During his PhD research, through a CSIRO–University of Tasmania Program in Quantitative Marine Science, David has been working on an ice shelf–ocean model that models the interaction between ocean currents and the cavity under the Totten ice shelf, and calculates melt rates under different scenarios (*Australian Antarctic Magazine* 21: 14–15, 2011). The Totten ice shelf-ocean model builds on existing modelling capability at the Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) (*Australian Antarctic Magazine* 19:6, 2010) and utilises supercomputer resources from the National Computing Infrastructure and the Tasmanian Partnership for Advanced Computing.

'While we're confident with how the model portrays the oceanography, we don't have much information about the roughness at the base of the ice shelf, or the bathymetry of the sea floor below it,' David says

'This information is important because as water flows over rough surfaces it becomes more turbulent and this mixes more heat to the underside of the ice shelf, causing more melting. '

Fortuitously, the ICECAP team in Texas, in collaboration with the Australian Antarctic Division and ACE CRC, has recently taken measurements of ice thickness and topography over the Totten Glacier and its ice shelf using an air-borne, ice-penetrating radar and gravimeter. These measurements will provide the roughness and bathymetry data David needs to improve his model simulations.

'The Fulbright scholarship will allow me to take this model to Austin and incorporate the ice roughness and bathymetry observations, to better model the structure of the cavity under the ice shelf and, subsequently, how ocean currents interact with it under different climate change scenarios,' he says.

David will also share his knowledge and experience of the model with the Austin team.

'This model is open source but there's a steep learning curve to using it. Once you know how to use it though, you can apply it anywhere where there is an interaction between water and another surface,' he says.

David's research is a far cry from the theoretical quantum optomechanics he studied as an undergraduate, although he does draw on the problem-solving and numerical computing skills he learnt at the time. His current research is taking him in quite a different direction.

'I had a friend at university from the Polynesian nation of Tuvalu who told me that sea level rise had left his parents' land half the size it once was,' David says.

'My conversations with him made me think I'd like to focus my energy on climate change research, and it changed the course of my career.'

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Australian Antarctic Division

The international Fulbright Program was established by US Senator J. William Fulbright in 1946 to facilitate world peace through cultural and educational exchange. The Australian-American Fulbright Program established in 1949 is funded by both governments, and sponsors and donors.

Songs reveal elusive giants

1. An Antarctic blue whale surfaces for air. Adult blue whales can grow more than 30 m long and weigh up to 180 tonnes.
2. A team approaches a blue whale in the small boat *Remora*, with satellite tagger Dr Virginia Andrews-Goff in the bowsprit.
3. The acoustics team in the sound lab aboard the *Amaltal Explorer*.

The scarcity of Antarctic blue whale sightings may be a thing of the past, thanks to acoustic technology that locates and tracks the leviathans from their songs.

By using sound rather than sight to find the whales, an Australian-led team of researchers got close to some 80 Antarctic blue whales during a seven week voyage to the Southern Ocean between February and March this year.

The 18-strong team of cetacean biologists, acousticians and observers, onboard the New Zealand trawler *Amaltal Explorer*, made 57 photo-identifications of the animals, obtained 23 skin samples for genetic analysis and attached satellite tags to two.

The research aims to estimate the abundance and distribution of this rare and iconic species, and gain insights into their behaviour. The work is part of the Southern Ocean Research Partnership – a collaborative consortium for non-lethal whale research involving ten countries*.

Lead acoustician, Dr Brian Miller, from the Australian Antarctic Division, said the acoustic technology used on the voyage – previously used by the military to detect submarines – could revolutionise the way scientists work with blue whales in the future.

'Sonobuoys have been used to record whales for at least 30 years, but we've refined the technology to the point where we can hear and track the whales in real time,' he said.

'We do this by analysing the whale songs for pitch, duration, intensity of sound, rhythm and direction. A single sonobuoy can ensure that we are always moving towards a new group of blue whales. As we approach and the intensity of the calls increases, we deploy multiple sonobuoys to triangulate the whales' position.

'Using this method we located whales to within a few kilometres; close enough for the visual observers to spot them. Our success rate on this voyage was very high and we detected whales up to 600 miles away.

'I'm hopeful we've provided a new blueprint for future whale voyages.'

Voyage science coordinator, Dr Jay Barlow, from the Southwest Fisheries Science Centre in La Jolla, US, agreed.

'The most exciting achievement is that we have the ability now to find blue whales in the really

thin soup that is blue whales in the Southern Ocean,' he said.

'Before the advent of whaling there used to be 200 000 blue whales in these waters and today there's less than two percent of that number, so it's really hard to find them. This acoustic technology allows us to find them with unprecedented speed and accuracy.'

Dr Miller and his colleagues made 626 hours of recordings in the study area, with 26,545 calls of Antarctic blue whales analysed in real time. Once the whales were located, a team in a small boat was deployed to gather photo identifications and skin biopsies.

'With photo identification data you can estimate population abundance, you can delineate stock structure between different populations of blue whales and you can track movements on fine and large scales, such as migrations routes,' said lead observer Paula Olsen, from the Southwest Fisheries Science Centre in San Diego, US.

Skin biopsies allow scientists to obtain DNA profiles of individuals, which will contribute to an existing DNA database. Now and in the future, these samples will allow scientists to determine if they see the same animal multiple times on one voyage, or different voyages, providing information on movement within and between seasons.

Dr Virginia Andrews-Goff, from the Australian Antarctic Division, enhanced this data collection when she successfully deployed two satellite tags from the bowsprit of the small boat.

The tags, which send location data to the ARGOS satellite system, will provide information on how the whales move between their breeding and feeding grounds and what they do in their feeding grounds.

Within the first few days after tagging, the whales travelled over 100 km a day. The first tagged whale initially travelled north and by early April was 2000 km to the west of its original location and far removed from the ice edge. The second tagged whale travelled southwards, straight to the ice edge, covering almost 2000 km in two weeks. The tags will continue to transmit the location of the whales until they fall out.

'This was the first time, to my knowledge, that Antarctic blue whales have been tagged, although blue whales have been tagged elsewhere,' Dr Andrews-Goff said.

'Being so close to an Antarctic blue whale is mind-blowing and slightly intimidating. I felt as though I was the size of an ant next to one. When I tagged that first Antarctic blue whale I was in a state of disbelief. But once my colleagues confirmed that it had actually happened, I was grinning from ear to ear.'

Australian Antarctic Division Chief Scientist and cetacean expert, Dr Nick Gales, said the information gathered on the voyage will contribute to the conservation and management of the species through the International Whaling Commission.

'Like many whale species, Antarctic blue whales came close to extinction as a result of whaling. But the recovery of this species is a lot slower than that of other whale species and it's our responsibility to understand what might be impeding that recovery and to do something to ensure they become a more common sight in the Southern Ocean,' he said.

'The data collected on this voyage will contribute to our understanding of how many Antarctic blue whales there are, where their populations are, where they feed and how they interact with their environment.

'We'll share our results with the Scientific Committee of the International Whaling Commission to inform conservation and management policies for this species.'

Dr Gales said the success of the voyage would have even further ramifications.

'This voyage has demonstrated a new way of working with whales in the high seas, using listening devices and small boats to get close enough to obtain photographs, acquire genetic material and to deploy satellite telemetry technology,' he said.

'Australia has made a strong case for a long time, that information for whale conservation can be acquired using non-lethal techniques. This voyage proves you can get all the information you need without killing them.'

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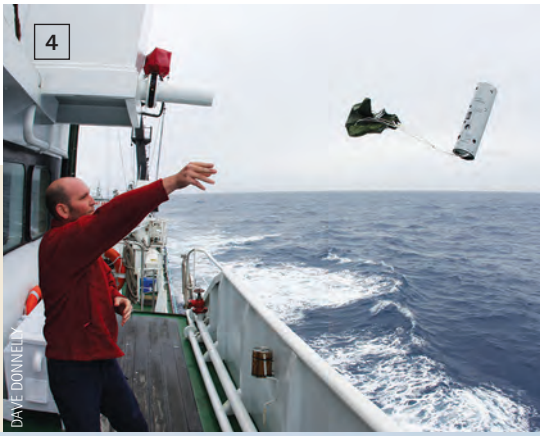
Australian Antarctic Division

** The Southern Ocean Research Partnership currently involves Argentina, Australia, Brazil, Chile, France, Germany, New Zealand, Norway, South Africa and the United States.*



4. Acoustician Dr Brian Miller deploys a sonobuoy to listen for whales.
5. Blue whales are big but the scenery is bigger. Here the New Zealand trawler, *Amaltal Explorer*, used by the research team, is dwarfed by an iceberg.

Building a future ocean

Antarctic scientists are working to create a future ocean in an underwater 'bio-dome', 20 m beneath the sea ice off Casey station.

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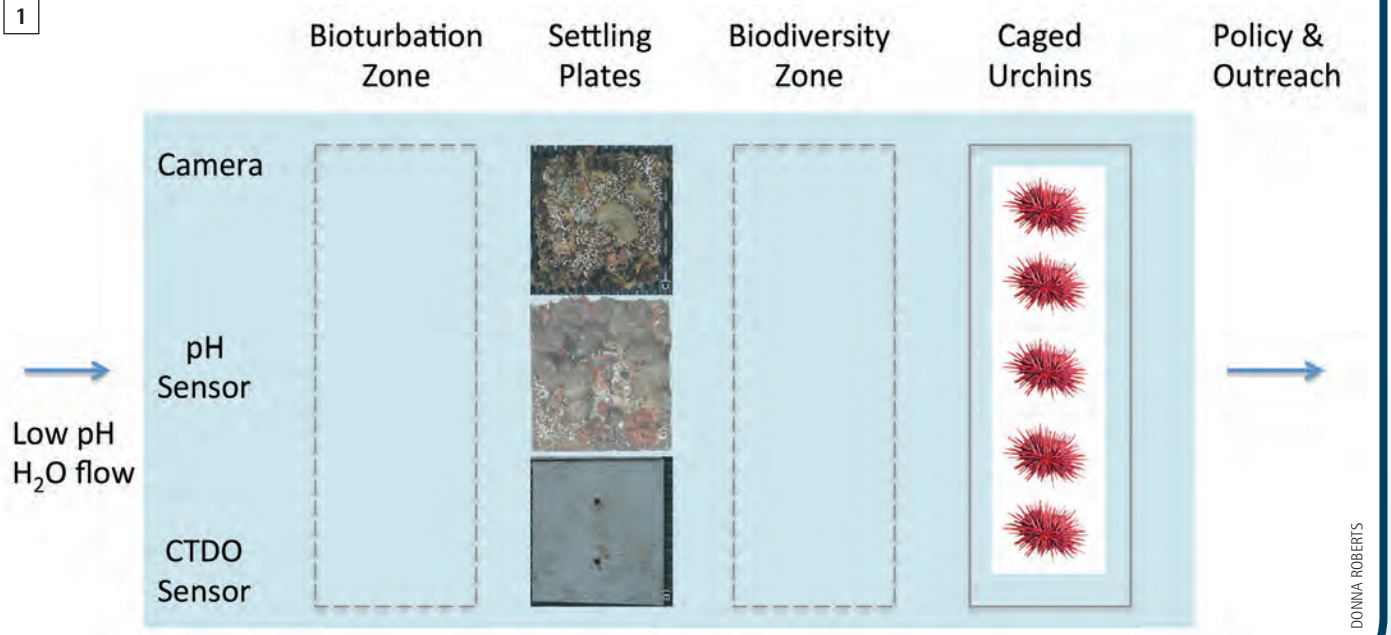

DONNA ROBERTS

In a world-first experiment, marine scientists Dr Donna Roberts and Dr Jonny Stark, will assess the impact of ocean acidification – caused by increasing amounts of atmospheric carbon dioxide (CO_2) dissolving in the ocean – on polar sea floor ('benthic') communities.

To do this Dr Roberts, an ocean acidification expert from the Antarctic Climate and Ecosystems Cooperative Research Centre and the University of Tasmania, will work with Australian Antarctic Division benthic ecologist, Dr Stark, and a team of Antarctic Division technicians, engineers and divers, to adapt 'Free Ocean CO_2 Enrichment' (FOCE) technology for Antarctic deployment. These semi-enclosed underwater chambers allow scientists to vary the CO_2 concentration in the water without changing light or nutrient conditions.

'Basically we're going to build a bio-dome on the sea floor with a future ocean inside it,' Dr Roberts says.

'We'll do this by modifying a prototype FOCE system developed by Bill Kirkwood and his team at the Monterey Bay Aquarium Research Institute in California, to suit Antarctic conditions and the research questions we want to answer.'

Ocean acidification leads to a drop in the pH of seawater and affects the ability of some marine organisms, including corals, sea urchins, bivalves and some phytoplankton, to form shells and other hard, 'calcareous' structures.

The Intergovernmental Panel on Climate Change Fourth Assessment Report in 2007 found that since 1750 there has been an average decrease in ocean pH of 0.1 unit. Under a 'business as usual' CO_2 emissions scenario, ocean pH is projected to decrease by another 0.3 to 0.4 units by 2100.

JAMES BARRY, MBARI

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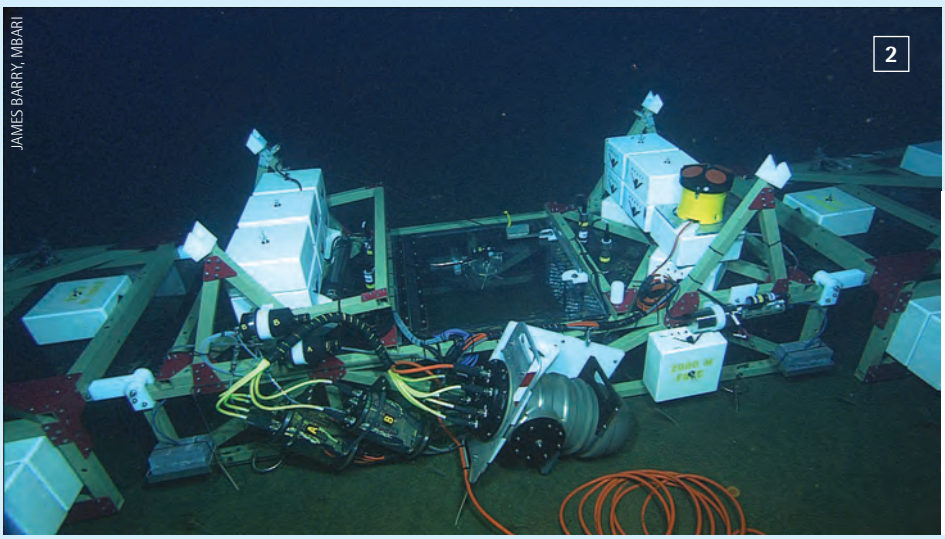


1. The control and experimental FOCE chambers will be divided into four zones to look at changes in community biodiversity and the growth rate of sea urchins at current and future seawater CO_2 concentrations.
2. A deep sea Free Ocean CO_2 Enrichment system deployed at 900 m in the Monterey Canyon, California.

As cold waters absorb more CO_2 than warmer waters, the effects of ocean acidification are expected to appear first in polar ecosystems.

While Dr Roberts and others have studied ocean acidification's effects on individual organisms living in the open oceans, there has been little research on sea floor communities.

'Polar sea floor communities contribute to fundamental ecological processes within the global marine ecosystem,' Dr Roberts says.

'They enhance sediment stability, recycle nutrients that support productivity, and provide habitat, shelter and nursery grounds for small invertebrates and fish, which in turn are food for fish, krill, seals, penguins and whales. So the effects of changing ocean chemistry on these sea floor communities will likely cause major ripple effects up the food chain.

'This new technology will allow us to bring the laboratory to the sea floor and deliver urgently needed research on the community-scale effects of high CO_2 waters.'

Since the prototype FOCE system was developed by the Monterey Bay Aquarium Research Institute in 2005, modified systems have been deployed in tropical and temperate waters to study the effect of high CO_2 levels on deep sea marine communities, coral reefs and sea grasses.

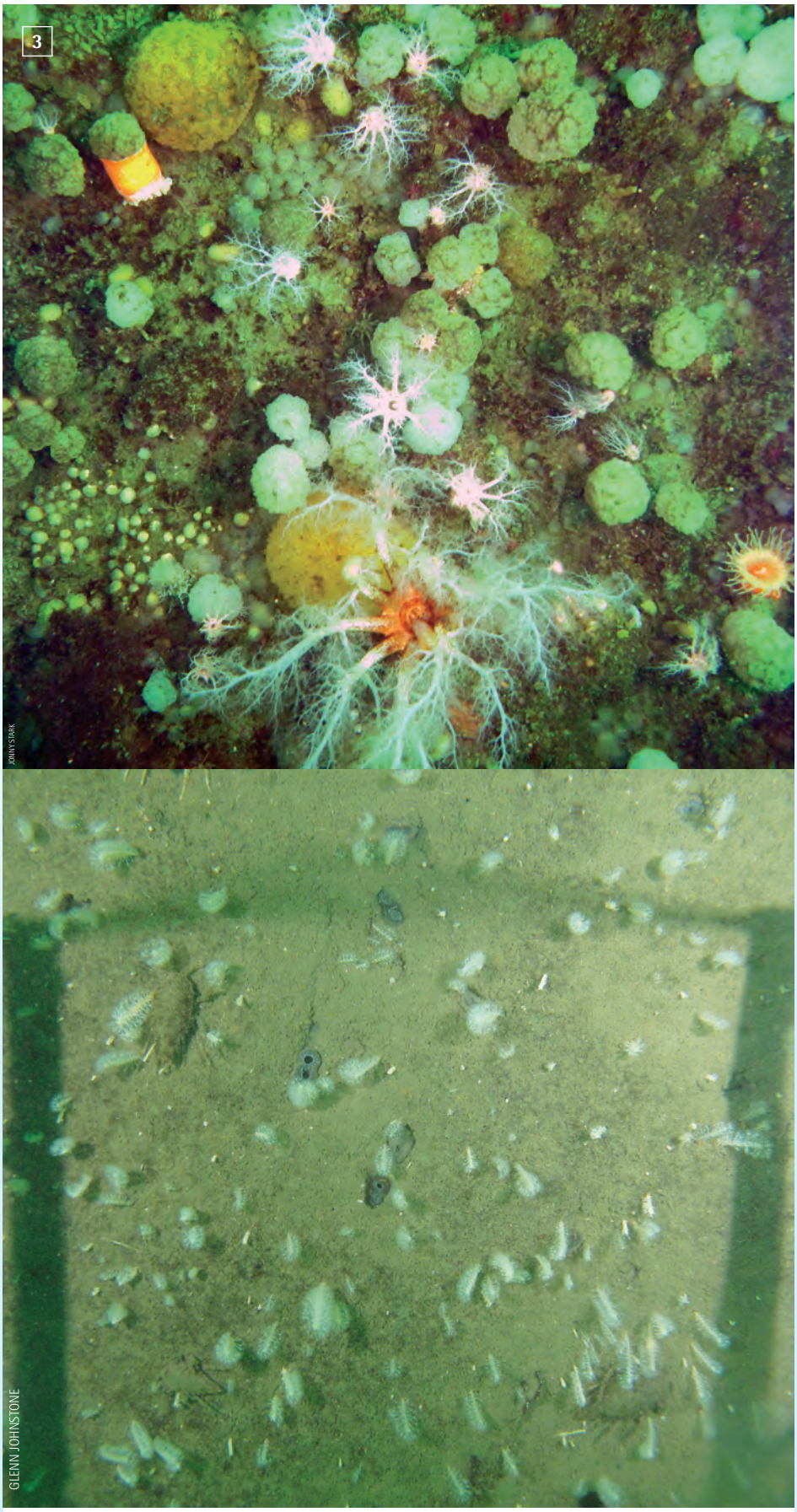
The Antarctic FOCE system will consist of a coffee table-sized acrylic chamber (2m x 0.5 m x 0.5 m), anchored to the sea floor and sufficiently robust to withstand the -1.8°C water temperature and sea ice. A series of pipes and cables, linked to pumping, power and telecommunication equipment at the surface, will provide a constant flow of CO_2 –enriched sea water through the chamber, and power to a range of instruments monitoring pH, conductivity, temperature, depth and oxygen concentration. Time lapse cameras will also record changes in the chamber over time.

Dr Stark, alongside other scientific divers, will deploy two experimental and two control FOCE chambers through the sea ice early in the 2014 Antarctic season, and retrieve them from open water about four months later.

'The two control chambers will track natural fluctuations in pH, while the experimental chambers will be dosed with CO_2 -enriched sea water at 0.4 pH units below the naturally fluctuating pH,' Dr Stark says.

The CO_2 -enriched sea water will be generated by pumping water piped from the environment through a CO_2 supply installed at the surface and close to the shoreline at Casey station. This water will then be pumped back to the experimental chambers. Untreated seawater will be pumped through the control chambers.

Each FOCE chamber will be divided into four connected but distinct 'zones' (see figure).



3. These two photographs illustrate some of the organisms living in Antarctic benthic communities that will be studied within the FOCE chambers. The top image shows sea cucumbers, anemones and ascidians and the bottom image illustrates sediment-dwelling organisms including feathery sea pens, a giant isopod (top left) and bivalve siphons.

The first 'bioturbation zone' will look at changes in the recycling of nutrients by sediment-dwellers. The second 'biodiversity zone' will contain settling plates – like bath tiles – to provide habitat for non-sediment dwellers (other than predatory sea urchins) and microscopic larvae in the water column to colonize. In the third 'biodiversity zone' divers will extract small sediment cores to examine communities of sediment dwellers. The biodiversity zones will allow scientists to examine community composition and any changes in diversity and numbers in different habitats between the experimental and control chambers over time. The fourth zone will corral sea urchins and look at their behaviour and growth rate as the experiment progresses. Throughout the experiment time lapse cameras will also capture changes such as the rate of burrowing in sediment and the rate of community development on settling plates.

The team must now identify a study site that will accommodate four chambers, hosts a suitable sea floor community and can support the power and telecommunication infrastructure that needs to be installed.

BILL KIRKWOOD, MBARI

A group photo taken at a Free Ocean CO_2 Enrichment workshop in Nice, France, in December 2012, including Dr Donna Roberts in the red scarf and Mr Jonno Reeve behind and to the left.

It's an ambitious project, but a critical one.

'Southern Ocean communities are predicted to be among the first to respond to ocean acidification and this project will determine whether they have any resilience to these changes,' Dr Roberts says.

'This community level research will assist governments, scientists, modellers and society to understand the emerging impacts of ocean acidification on marine ecosystems and to ensure that the most relevant information underpins decisions to manage this threat.'

WENDY PYPER
Australian Antarctic Division

Making FOCE work

Sea ice and fast ice pose one of the biggest challenges to the installation and success of the Free Ocean CO_2 Enrichment (FOCE) experiment in Antarctica.

'There's a reasonable tidal range at Casey so there will be a few metres of sea ice grinding against the shore, bringing one tonne of force per cubic metre of sea ice,' says Australian Antarctic Division Science Technical Support Manager, Jono Reeve.

'This means the transition tube that sits at the air-sea interface between the power and telecommunication systems on the surface, and the underwater chamber, will have to handle this large downward force, as well as occasional low frequency swells.

'Once we choose a site for the experiment though, we'll have a good idea of how we can design and protect all the services that run from the surface to the sea floor'.

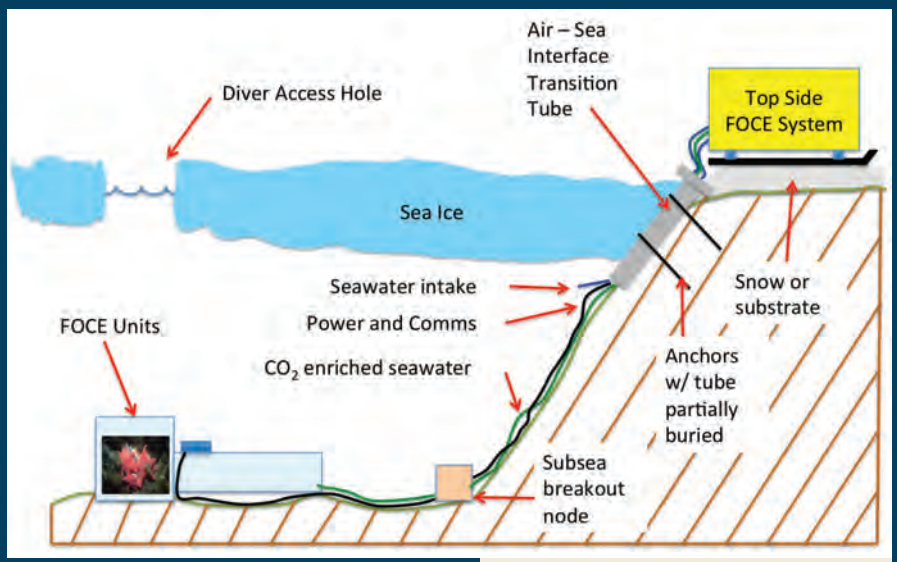
Integrating all the components of the system will also prove challenging.

'This is a very complex integration task across a range of areas,' Mr Reeve says.

'The Australian Antarctic Division has used all the sensors in the FOCE units, or variants of them; we've made sled systems and run electronics on the ice; we've run things below the water under the ship. So all these things are do-able but they all have to be integrated.

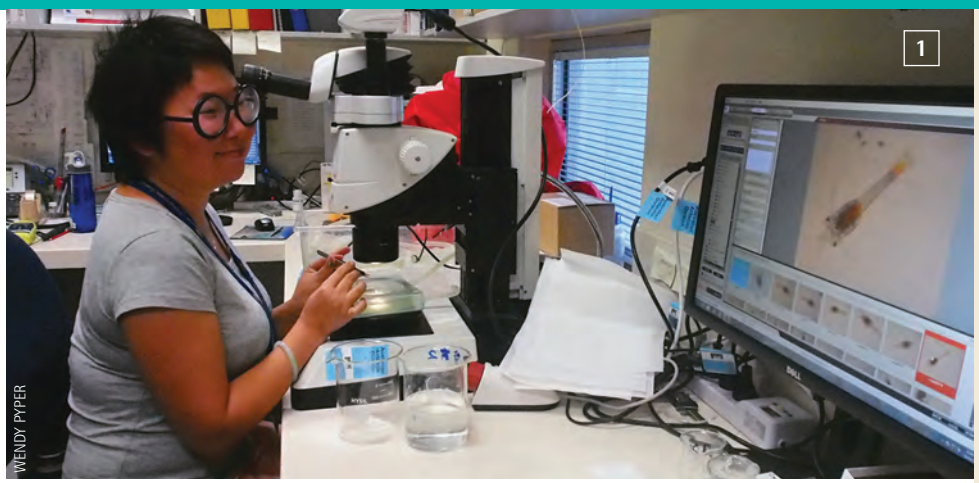
'If something goes wrong with the electronics once the FOCE units are installed under the ice, it will be difficult to get in there and fix it.'

The team will spend some time testing the FOCE units in cold water at the Australian Antarctic Division and off the coast of Tasmania before their Antarctic deployment.



BILL KIRKWOOD, MBARI

Components of the experiment include the Free Ocean CO_2 Enrichment (FOCE) units linked to pumping, power and telecommunications services at the surface and protected from ice via an air-sea interface transition tube. Divers will deploy the FOCE units through a hole in the sea ice at the beginning of the season and retrieve them from open water some four months later.


WENDY PYPER

1. The Leica microscope Molly used precisely focuses along the vertical axis, or Z axis, of a three-dimensional object, allowing scientists to take detailed photographs at different depths or layers in the object. These layers may only be microns (thousandths of a millimetre) apart. The photographs are then stitched together to give a clear view through the object, providing detail and clarity greater than the human eye can resolve by looking directly at the object.
2. The hatching of the nauplius larva about 141 hours after spawning.
3. The Metanauplius stage of larval development.
4. The third stage of the Calyptopis I phase, showing a distinct cephalothorax and abdomen.
5. The first stage of the Furcilia phase where the krill takes on the shape of a juvenile, with developed mouthparts and eyes.

Focusing on krill development

The first photographic record of all the life stages of Antarctic krill, from newly fertilised egg to juvenile, has been painstakingly documented by PhD student Zhongnan (Molly) Jia at the Australian Antarctic Division.

Over five months Molly, who is studying through the Institute for Marine and Antarctic Studies, photographed the 12 stages of embryo development and 12 stages of larval development, from eggs spawned in the Australian Antarctic Division's krill aquarium. At times Molly had to camp in her office to ensure she captured every moment.

'The krill spawned at about one o'clock in the afternoon and that night I slept in my office with my alarm on so that I could photograph embryo development every three hours,' she says.

'By the third day I couldn't do it anymore, but by then the embryos weren't changing as rapidly and I was able to leave them for longer.'

After six days the first larval stage hatched and Molly spent another 138 days recording larval development, taking photographs every five days using a Leica M205C dissecting stereo-microscope.

This microscope allowed her to focus on and photograph different layers of her subject, before combining the images for a clear view through the animal.

'I photographed between eight and 10 layers so, for example, I could see the shell of the developing larva, the eyes and under the eyes,' she says.

At times she had to subdue her subjects by spiking their water with alcohol.

'Once the larvae developed tails they swam too fast to focus on, so I had to calm them down with a drop of ethanol,' she says.

The result is the first detailed photographic documentation of live Antarctic krill development under controlled laboratory conditions. Prior to this work krill biologists relied on detailed 1930s drawings of krill captured in net trawls and less detailed embryo photographs produced in the 1980s.

'Because of the technical difficulties of maintaining live krill in the laboratory and obtaining fresh eggs in the field, there has been no detailed description of the entire life history of this species until now,' Molly says.

'The Australian Antarctic Division krill aquarium is the only place in the world where we can do this detailed work because we can maintain eggs and larvae from wild-caught Antarctic krill.'

The work will provide an important baseline reference for future studies on the effects of climate change on these sensitive krill life stages.

Molly is pleased this research for the first chapter of her PhD thesis is finished, but she has fond memories of her five months glued to the microscope.

'It was really fun to see so many changes that I normally wouldn't have noticed,' she says.

'I learnt so much about krill. It was almost like watching a baby grow up.'

WENDY PYPER
Australian Antarctic Division

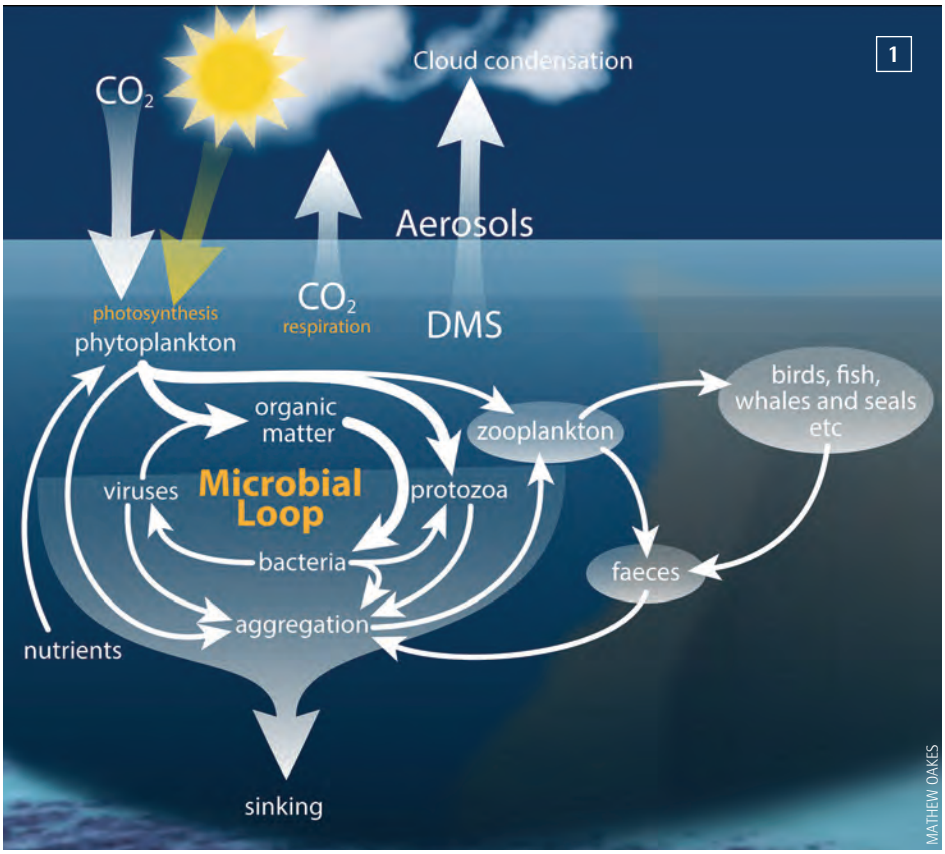

ZHONGNAN JIA


ZHONGNAN JIA


ZHONGNAN JIA


ZHONGNAN JIA

Changes forecast for marine microbial communities



Antarctic marine microbial communities – bacteria, phytoplankton and protozoa – are the base of the food web and, directly or indirectly, support all life in the Southern Ocean. However, the concentration of carbon dioxide (CO_2) predicted in seawater by the end of this century may dramatically change the composition of these communities, with consequences for iconic Antarctic wildlife and climate.

To investigate the effects of increasing CO_2 on Antarctic marine microbes, we installed six 650 litre 'minicosms' (incubation tanks) in a shipping container on the shore at Davis station in 2008–09. The tanks were filled with seawater, which was filtered to remove any organisms larger than 200 µm (0.2 mm).

Different volumes of CO_2-saturated, sterile seawater were then added to each of the tanks to achieve CO_2 concentrations of 84, 643, 1281, 1848, 1942 and 2423 ppm (parts per million). These corresponded to approximately 600 ppm increments from ambient Antarctic concentrations in summer, to the maximum seawater CO_2 concentration predicted for 2300.

Antarctic marine microbes naturally experience a wide seasonal range in CO_2 concentrations. In summer, intense phytoplankton blooms consume the CO_2, reducing its concentration from the current global average of approximately 386 ppm* to only 100 ppm. In winter the CO_2 concentration can increase to about 450 ppm, due to upwelling of CO_2-rich deep water, little or no light for photosynthesis, and the presence of sea ice which limits gas exchange between the atmosphere and ocean.

Perhaps unsurprisingly, our experiments using natural communities of Antarctic marine microbes at Davis showed that they can tolerate the large seasonal fluctuations they experience in nature, as there was little effect at 84 and 643 ppm CO_2 (0.2 and 1.7 times the current atmospheric levels). However, there were dramatic changes in the species composition and size of microbial cells at higher CO_2 concentrations.

When we exposed the microbial community to 1281 ppm CO_2 and above (≥3.3 times current CO_2 levels) we saw a rapid shift in the size of phytoplankton. The abundance of large phytoplankton above about 20 µm (0.02 mm) in size greatly declined, while there was an increase in the number of small species less than 5 µm.

The decrease in the size of phytoplankton coincided with a decline in the amount of phytoplankton (chlorophyll *a* and carbon). Thus, at CO_2 concentrations predicted for around the end of this century (near 1000 ppm), we saw a threshold above which productivity drops and cells get smaller.

At concentrations ≥ 1281 ppm CO_2 we also saw the abundance of bacteria increase, but the growth of protozoa, which graze on bacteria and small algae, slowed.

These results suggest that protozoan grazing controlled the abundance of small cells at low CO_2. At ≥ 1281 ppm, inhibition of protozoan growth allowed small cells to escape this control and their abundances increased. So, the effects of CO_2 concentration are seen as changes in the relative abundance of species within a single level of the food web (e.g. phytoplankton), but can be driven by CO_2-induced changes in the interactions among organisms across trophic levels (e.g. between phytoplankton and protozoa).

The decline of larger phytoplankton under higher CO_2 levels could have a dramatic impact on the entire Antarctic ecosystem towards the end of this century. Krill are one of the key grazers of phytoplankton, but can only eat cells bigger than 6 µm. A decline in suitable food would reduce krill abundance, with knock-on effects for the many other species that eat krill, including seabirds, seals and whales.

But the consequences don't end there; the increased abundance of small phytoplankton cells could affect the global carbon cycle. Under normal conditions phytoplankton incorporate CO_2 into their cells during photosynthesis. Some cells, often the large ones, sink to the deep ocean, carrying this carbon with them. This process mediates the concentration of CO_2 in the Earth's atmosphere. The changes we observed, however, would act as a positive feedback on global warming. Small phytoplankton cells sink more slowly and are commonly consumed in near-surface waters by protozoa and bacteria. Much of the carbon stored in these cells is respired by the protozoa and bacteria, and released back to the atmosphere as CO_2.

If our experiments are to help us understand the consequences of rising CO_2 to Southern Ocean ecosystems, we must be confident that the contents of the minicosms mimic what is happening in the natural environment. We plan to repeat our experiments at Davis in the 2013–14 summer to determine whether the responses are consistent among years. And we need to refine our estimate of the threshold CO_2 concentration at which the change in the microbial community occurs.

We also need to better understand the possible mechanisms causing these responses. Iron, for example, is a limiting micronutrient over much of the Southern Ocean. When you change the chemical quality of seawater you change the dynamics of its trace metal chemistry – so there might be plenty of iron in the water but it may be in a form that is unavailable to phytoplankton. CO_2 might also affect the process of photosynthesis in some species, and we don't yet understand the mechanism by which CO_2 is inhibiting the small protozoa.

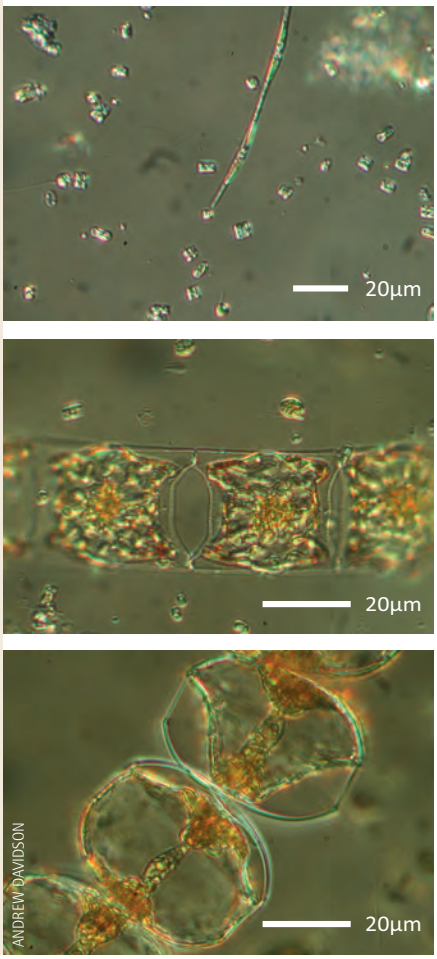
So much remains to be learned quickly if we are to predict future marine microbial community responses, inform policy development, and avoid possible catastrophic effects on the Antarctic ecosystem.

ANDREW DAVIDSON
Marine microbial ecologist, Australian Antarctic Division

** At the time of the experiments in 2008-09 the atmospheric concentration of CO_2 was 386 ppm. In 2013 it is 394 ppm.*

1. This schematic shows the transfer of carbon in the marine ecosystem and how marine microbes affect concentrations of climate-active gases. Phytoplankton convert sunlight and carbon dioxide into oxygen and organic carbon (cellular material) during photosynthesis. Bacteria and protozoa graze, break down and respire phytoplankton (and each other), consuming oxygen and releasing carbon dioxide. When phytoplankton, bacteria, protozoa (and viruses) are eaten or die, some cells sink to the deep ocean, taking their stored carbon with them. Phytoplankton also provide food for zooplankton (tiny marine animals, including krill), which in turn provide food for higher organisms. DMS is dimethylsulfide, a gas produced by some phytoplankton that contributes to cloud formation, thereby altering the reflectance of sunlight before it reaches the Earth's surface.
2. Three of the minicosms used in the marine microbial experiment, housed in a shipping container at Davis.
3. The abundance of the small diatom *Fragilariopsis cylindrus* (top image) was lowest at low CO_2 concentrations and increased greatly with increasing CO_2. Conversely, concentrations of the large diatoms including *Chaetoceros* spp (not shown), *Eucampia antarctica* (middle image) and *Stellarima microtrias* (bottom image) declined as the CO_2 concentrations increased. Changes in the abundance of *Fragilariopsis*, *Chaetoceros* and *Eucampia* at different CO_2 concentrations are indicated graphically at right.
4. This graphic shows changes in the abundance of some phytoplankton species over 10 days exposure to different CO_2 concentrations. The abundance of the small phytoplankton species *Fragilariopsis cylindrus* (top) was low at 84 and 643 ppm CO_2 (red and black lines), but increased with increasing CO_2 concentration. In contrast, the abundance of larger phytoplankton species such as *Chaetocerous spp* and *Eucampia antarctica* (middle and lower graphs), was high at 84 and 643 ppm CO_2 and declined as the CO_2 concentration increased.

3



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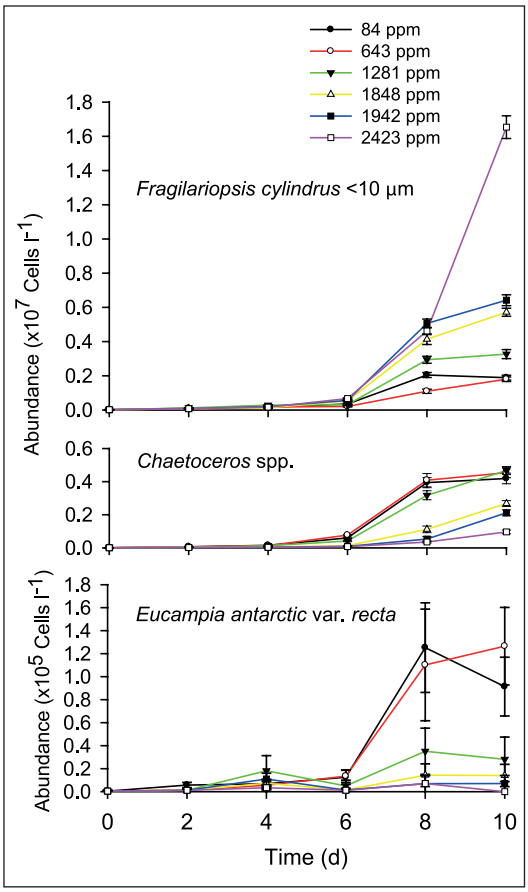


1. A common seastar, *Diplasterias brucei*, amongst a complex mix of epifaunal species including sponges and polychaete fan worms near Davis station.
2. A mix of soft sediment and hard substrate in O'Brien Bay near Casey station. The muddy soft sediment may contain tens of thousands of individual organisms per square metre.
3. *Philomedes charcoti*, or is it? Taxonomists have uncovered nine different species and, potentially, a new genus from what, to the untrained eye, looks like a single species.

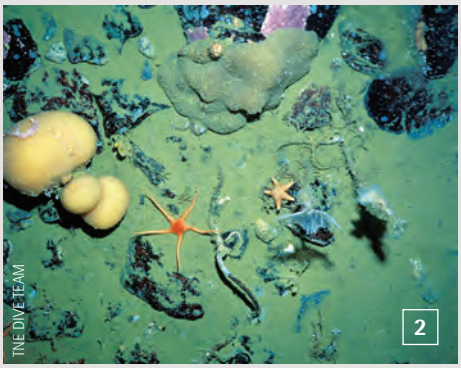
Marine biodiversity – more than meets the eye

New research combining traditional taxonomy with DNA technology has found that Antarctic marine communities are more biologically diverse than previously thought.

Few organisms brave the rare, exposed rocky sections of Antarctica's coastline, but just a few metres below the ocean's surface, diverse and colourful marine communities thrive throughout the year.

Epifaunal habitats – hard, rocky substrates – support a profusion of colourful marine life, including groups that are common inhabitants of rocky reefs the world over; sea urchins, starfish, sponges, seaweeds, sea cucumbers and a multitude of other critters. Infaunal habitats – soft sediments such as mud and sand – support an abundance of small species. These are less well known and mostly just a few millimetres long, but present in large numbers – thousands to more than 100 000 individuals per square metre.

Infaunal communities are widely used as biological indicators of the health of marine environments. These dynamic communities thrive in surprisingly stable environmental conditions, which vary relatively little throughout the year; a constant



-1.8°C water temperature and low current, wave and wind action due to sea ice cover that can last for 10 months or more each year.

The Terrestrial and Nearshore Ecosystems group at the Australian Antarctic Division has been sampling these communities for various purposes since the mid-1990s. Using traditional taxonomic methods combined with genetic techniques we have identified over 530 species of infaunal and epifaunal invertebrates from nearshore habitats (to 30 m depth) around Casey and Davis stations. This effort represents perhaps the most intensive and long-term sampling to date of shallow coastal marine habitats in East Antarctica; an area that is relatively poorly sampled compared to other coastal Antarctic regions.

Ongoing work to curate this valuable collection of reference specimens has involved identifications by taxonomists in Australia and overseas, as well as the sequencing of DNA identity markers. This work has uncovered new species and, potentially, a new genus, each separated from one another in remarkably subtle ways.

A prime example is the unanticipated diversity uncovered for a critter that is relatively featureless to the untrained eye. Ostracods are small (mostly 1–2 mm across), somewhat unremarkable crustaceans, whose hinged shells superficially resemble bivalve molluscs. Very fine details separate species; details not always obvious even to ecologists that work with them regularly. Taxonomic work on what we thought was a single species, *Philomedes charcoti*, has revealed four other *Philomedes* species, differentiated from each other by fine shell details and the number of bristles on their legs and antennae. Even more surprising was the presence of five potentially new and undescribed species, as well as a new Ostracod genus, in the same samples. Such diversity, hidden until now, suggests far greater diversity may be uncovered as taxonomic and genetic work continues and future sampling explores a wider variety of habitat types.

The proximity of these marine communities to coastal Antarctic stations makes them vulnerable to local and global impacts and useful systems in which to monitor natural and human induced ecological change. Continuing work to describe, identify and catalogue the nearshore marine invertebrates of East Antarctica is fundamental to this monitoring work and to efforts to remediate past impacts from human activities. Both traditional taxonomy and current and evolving genetic techniques will be key to understanding, protecting and conserving Antarctic marine biodiversity and to fully realising their potential as indictors of global issues, such as climate change and ocean acidification.

GLENN JOHNSTONE, JONNY STARK and FELICITY McENNULTY
Australian Antarctic Division


KRISTIN RAW

Former Australian Prime Minister Bob Hawke (left) congratulates Dr Bruce Deagle, the first recipient of the R.J.L. Hawke Post-Doctorial Fellowship for Antarctic Environmental Science, in 2011.

Hawke fellowship recipient thrilled with krill project

Two years into his R.J.L. Hawke Post Doctoral Fellowship for Antarctic Environmental Science, Dr Bruce Deagle has made good progress in research examining the genome (DNA) of Antarctic krill. Prior to receiving the fellowship, Dr Deagle spent more than 10 years applying genetic technologies to research on many aspects of animal ecology, including DNA-based analysis of seal diet and characterization of genetic structuring in fish populations. His inaugural three-year fellowship was named in honour of former Prime Minister Bob Hawke's contribution to protecting the Antarctic environment (see story page 27).

My fellowship research, which is based within the ecological genetics group of the Australian Antarctic Division, involves two projects focused on characterising genomic variation in Antarctic krill (*Euphausia superba*).

The original aim of the fellowship was to document the complete genetic code of an individual krill. However, recent estimates of krill genome size indicate that it is huge. At 50 billion base pairs it is about 15 times larger than the human genome, making a comprehensive sequencing and genome assembly project infeasible. Instead, I am part of a team using 'high-throughput DNA sequencing' to characterise smaller parts of the genome, and at the same time address ecologically important questions about this keystone Antarctic species.

One aspect of my work involves developing krill genomic markers suitable for studying population structure. Such markers are DNA sequences shared by all krill, which vary enough to be able to detect potential differences amongst different krill swarms occurring locally or separated by great distances. To find useful genetic markers we are using a new technique called 'restriction associated DNA sequencing'. This method allows many individuals to be examined and genetic variation between them documented.

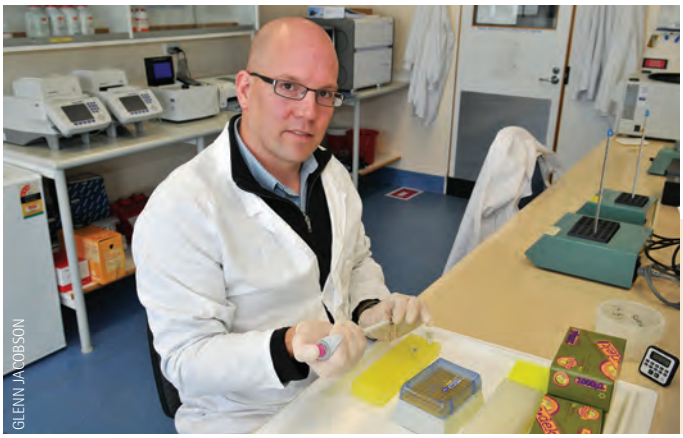
So far we have analysed about 100 krill and have over 40 billion bases of DNA sequence data – more than ten complete human genomes worth of DNA sequence! The krill were collected from five sites around Antarctica, both during previous Antarctic Division marine research voyages and by collaborators from the Alfred-Wegener Institute in Germany. The characterised genetic variation will be used to estimate levels of connectivity between Antarctic regions and provide information on stock structure for fisheries management. It will also produce a catalogue of genetic variation in krill, providing a valuable reference for a range of future genetic studies.

A second part of my project involves producing a detailed 'transcriptome' (a list of functional genes) for krill by sequencing the subset of the genome that is being actively used (transcribed) within krill tissues. The analysis of data produced so far is a major undertaking and we are currently working with colleagues from the University of Padova in Italy to assemble an annotated transcriptome database (a list of krill genes and details of their function).

We are applying this data to investigating findings from experiments carried out in the Antarctic Division krill aquarium, which show that elevated carbon dioxide (CO_2) levels can severely impact normal development of krill embryos. In this component of the project we have sequenced the transcriptome of larval krill exposed to various levels of CO_2. Once our analysis is complete we will have a list of genes in these krill that are responding to changes in CO_2. Analysis of the function of these genes will allow examination of the underlying physiological pathways that are being affected.

With a year left in this fellowship there is still a large amount of data analysis to be done and millions of DNA sequences clogging up my computer's hard-drive waiting to be analysed. However, we have already come a long way towards the goal of characterising the genome of Antarctic krill and these data promise to revolutionise the study of this important species.

BRUCE DEAGLE
R.J.L. Hawke Post-Doctoral Fellow, Australian Antarctic Division


GLENN JACOBSON

Dr Bruce Deagle at the Australian Antarctic Division's ecological genetics laboratory.

Historic visits to Antarctica

The Wilkins Runway crew hosted a number of senior guests in Antarctica this season during a successful summer flying program for Australia's A319 aircraft.


TONY FLEMING

1

First was Federal Environment Minister, the Hon. Tony Burke, who flew to Wilkins Runway, about 70 km south-east of Casey station, on 13 December 2012. He was accompanied by Members of the Senate Standing Committee on Environment and Communications and the Joint Standing Committee on the National Capital and External Territories.

The Minister and his party were shown around the operations at Wilkins, including a deep-field camp and a demonstration of ice coring. They then proceeded to Casey station for further briefings on Australian activities and a tour via aircraft and small boat. The Minister spent a night at Robbo's hut, near Casey – the first overnight stay of an Australian Cabinet Minister at an Australian Antarctic station. He also visited nearby Shirley Island, where he learned more about Australia's research on penguin biology and ecology.

At a dinner on the eve of 14 December, 2012, the Minister gave a short speech to mark the 100th anniversary of the death of Douglas Mawson's sledging companion, Lieutenant Belgrave Ninnis.

Minister Burke said the visit had helped him to better understand the operational challenges in Antarctica and the importance of maintaining a strong operational capability in support of science.

'While the work that we do is very much science driven, to make that science possible the logistics required are enormous…[for example] the team of people who've been working for six weeks to make sure than an airplane can land,' Minister Burke said.

'I've got a much better handle on the emphasis on logistics now and the fact that if you don't have your logistics in place, none of the science can occur at all.'

On 5 February 2013, Governor-General, Ms Quentin Bryce AC CVO, became the first Australian Governor-General to travel to Antarctica.

Her Excellency flew from Hobart to the Wilkins runway as part of the ongoing centenary celebrations of the Australasian Antarctic Expedition 1911–1914 led by scientist and polar explorer, Dr Douglas Mawson.

Ms Bryce was greeted at Wilkins by Casey Station Leader, Allan Cooney, and a number of scientists and support personnel. She also toured the communications facilities and living quarters, and experienced the confines of a remote field camp.

In honour of the Mawson-led expedition 100 years ago, Her Excellency unveiled a plaque that had been set behind a sheet of ice. Ms Bryce cracked the ice with a small hammer to reveal its inscription marking the event.

2


TONY FLEMING

1. Federal Environment Minister the Hon Tony Burke (centre) and the ground crew of Wilkins Runway in front of the A319 Airbus.
2. The Hon R J L Hawke AC Living Quarters, or 'Hawke's Hut' (green building at centre) is a two-storey facility housing a mess, kitchen, lounge, laundry and bathroom facilities for runway crews during the summer season. The hut honours former Australian Prime Minister Bob Hawke.
3. Governor-General Ms Quentin Bryce after cracking the ice over a plaque commemorating the centenary of Australian Antarctic exploration.

JAMES CROUCHER

Ms Bryce paid tribute to Douglas Mawson's courage in adversity, his dedication to scientific exploration and his foresight in recognising the significance of Antarctic science not just to Australia but to the rest of the world. She said that Mawson's discoveries and painstaking research resonated today as modern science continues in the region.

The Governor-General was accompanied on the early morning flight from Hobart by the Director of the Australian Antarctic Division, Dr Tony Fleming, and Climate Program Leader, Dr Tas van Ommen, among others. She flew back to Hobart that afternoon along with expeditioners returning from a successful summer season.

One week later, on 12 February, former Australian Prime Minister Bob Hawke flew to Antarctica to officially open the Wilkins Runway Living Quarters, named in honour of his contribution to Antarctic protection and conservation.

The Hon R J L Hawke AC Living Quarters, or 'Hawke's Hut', is a two-storey facility housing a mess, kitchen, lounge, laundry and bathroom facilities for runway crews during the summer season. The Hut is sled-mounted to ensure minimal impact on the environment and can be easily moved during winter months to avoid snow build-up.

More than 20 years ago Mr Hawke's Government led a push to reject mining in Antarctica. That action eventually led to the signing of the Madrid Protocol in 1991, designating the frozen continent as a natural reserve, devoted to peace and science (see box story below).

NISHA HARRIS and WENDY PYPER
Corporate Communications

REFLECTING ON AN ANTARCTIC LEGACY

Protecting the Antarctic environment became a cause celebre for Australia's Prime Minister, Bob Hawke, in 1989.

At the time he caused something of a stir by going against the prevailing international view that mining was an inevitable part of Antarctica's future. In fact the Antarctic Treaty nations had already adopted the Convention on the Regulation of Antarctic Mineral Resource Activities.

However, that didn't sit well with Mr Hawke and he set about ensuring that the Convention, and, in his view, the unacceptable future scenario of mining in Antarctica, would not proceed. Through a close alliance with his French and Spanish counterparts, and with strong support from conservation groups, Mr Hawke led intensive diplomatic efforts to promote an international treaty on comprehensively protecting Antarctica.

The result was the Madrid Protocol, which established a permanent and legally binding ban on mining or mineral resource activity in Antarctica and proclaims Antarctica as a natural reserve devoted to peace and science.

During Mr Hawke's visit to Antarctica this year, to open a Wilkins Runway facility named in his honour, he spoke candidly about his role in establishing the protocol.


GLENN JACOBSON

Former Australian Prime Minister Bob Hawke (right) with former French Prime Minister Michel Rocard, during 20th anniversary celebrations of the signing of the Madrid Protocol in 2011.

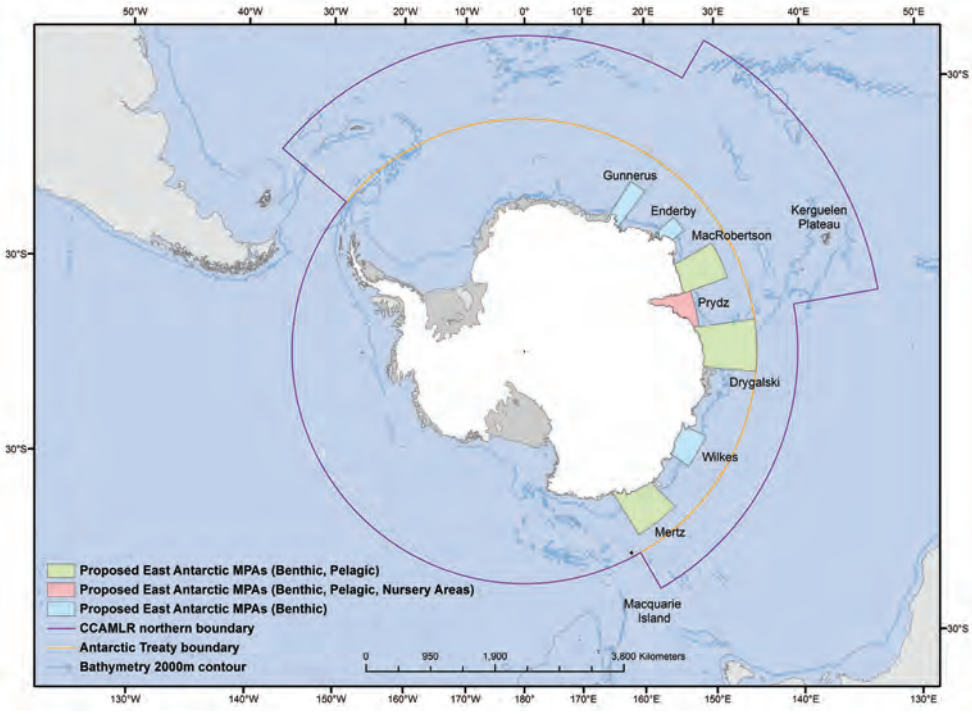
'I could not believe that civilized nations of the world were going to destroy the pristine quality of the last remaining pristine continent, by implementing the Convention on the Regulation of Antarctic Mineral Resource Activities.

'You just imagine mining down here and the accidents that could have occurred, so I was determined that this wouldn't happen. People said we had no chance, but with the cooperation of my good friend Michel Rocard, the Prime Minister of France, and Felipe Gonzalez, from Spain, we turned it over, which was marvellous. Now it's fulfilled my nomination of it as nature reserve and a land of science.

'I've got a great sense of proprietorship over the place because I've been involved in seeing that it was preserved. It's almost impossible to describe the feeling of pride and excitement that I have being here. The other immediate impression I have is the enthusiasm of all the people that are here.

'The work that they are doing is not only important for Australia but important for the world. And they should feel proud of themselves for the contribution that their colleagues in the past have made and that they are making now. I would like to congratulate the Australian Antarctic Division. I think the work that you are doing in protecting the Australian commitment and involvement in this area, and doing it in such a constructive way is a matter in which you should all be very proud.'

CORPORATE COMMUNICATIONS
Australian Antarctic Division



A map showing the location of the seven proposed marine protected areas. (MMU and AADC)

Southern Ocean Marine Protected Areas

In 2005 Members of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) committed to establishing marine protected areas as a means of ensuring the long-term conservation and sustainable use of marine environments – principles that underpin CCAMLR's core objective. The adoption of a system of seven marine protected areas off the East Antarctic coast would be a significant step towards achieving this goal.

In July this year a Special Meeting of CCAMLR will discuss the establishment of one of the world's largest systems of marine protected areas – the East Antarctic Representative System of Marine Protected Areas.

The proposal was initially developed in 2010 using the principles of comprehensiveness, adequacy and representativeness. It was endorsed by the Scientific Committee of CCAMLR at its 2011 meeting as being based on the best scientific evidence available. In 2012, Australia, France and the European Union jointly proposed the establishment of a system of marine protected areas in East Antarctica. CCAMLR agreed to convene a Special Meeting specifically to discuss proposals for marine protected areas, including this proposal and a Ross Sea marine protected area proposal by New Zealand and the USA.

The East Antarctic Marine Protected Areas aim to conserve representative areas of biodiversity for future generations and provide critical reference areas for understanding the effects of fishing and the consequences of climate change in the Southern Ocean. The proposal provides for comprehensive management, research and monitoring plans for managing multiple uses within the marine protected areas, including fishing, and for refining the system in the future.

The seven areas aim to conserve examples of open ocean and seabed biodiversity in East Antarctic waters, including important ecological processes such as nursery areas for toothfish and krill, and foraging areas for marine mammals and penguins.

Among the areas' attributes are:

The Gunnerus area has unique continental ridge and seamount features and biodiversity related to the shelf, canyon and slope seafloor ecosystems. These seafloor features are thought to support a greater diversity of marine life than surrounding habitats.

The Enderby area contains unique, endemic molluscs – relations of snails and clams found only in the area. It also has important seafloor features, including the shelf, canyon and slope, which are likely to support distinct seafloor ecosystems.

The MacRobertson area contains highly productive coastal and oceanic food webs, where marine mammals and Adélie and emperor penguins forage during the summer. It also includes a diverse set of seafloor ecosystems, including on the shelf, slope and seamounts.

The Prydz area has a number of unique features including that it contains the southern-most waters in the East Antarctic region, with Prydz Bay extending to 69° south. It is also considered to be an important nursery area for Antarctic krill and toothfish.

The Drygalski area has a diverse sea floor environment, including canyons and ice shelves. It covers coastal and oceanic food webs and important foraging areas for Adélie and emperor penguins, marine mammals and flying seabirds.

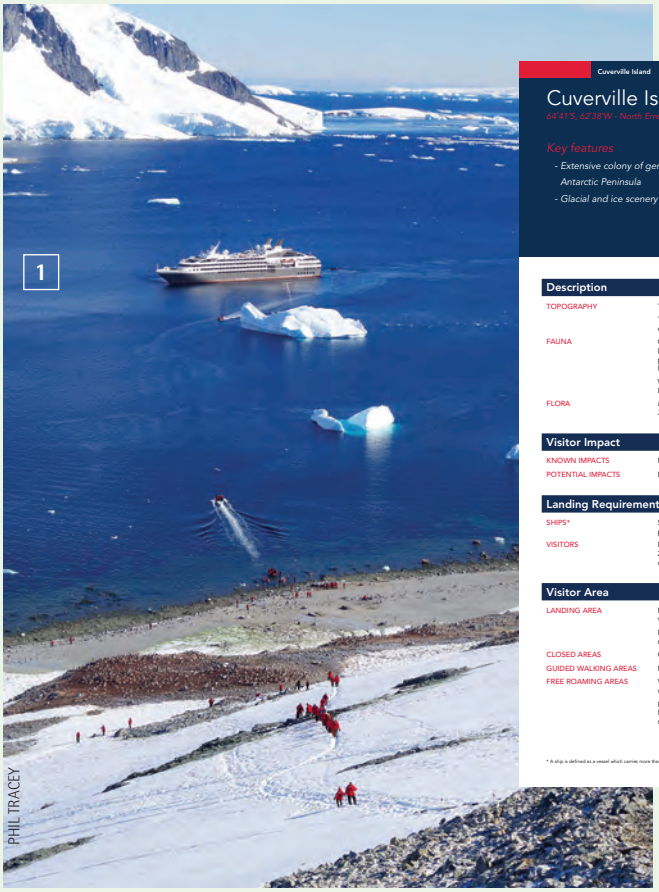
The Wilkes area is the only area that is representative of the biodiversity that inhabits shelf, canyon and slope ecosystems in the region and offers a reference area for evaluating the effects of bottom fishing in adjacent areas.

The D'Urville Sea-Mertz area is a site of Antarctic Bottom Water formation and is important for our understanding of climate change. It contains a diverse set of seafloor habitats, a nursery area for Antarctic silverfish and the foraging ranges of marine mammals and seabirds. The area also contains CCAMLR-registered vulnerable marine ecosystems.

As the 25 Members of CCAMLR meet in Bremerhaven, Germany this year, the Australian delegation, led by the Australian Antarctic Division's Director Dr Tony Fleming, will be working hard to see to establishment of the East Antarctic Representative System of Marine Protected Areas and will be calling on CCAMLR Members to act now to protect these unique and significant marine ecosystems.

RHONDA BARTLEY and ELOISE CARR
Territories, Environment and Treaties, Australian Antarctic Division

A guide to visiting Antarctica



PHIL TRACEY

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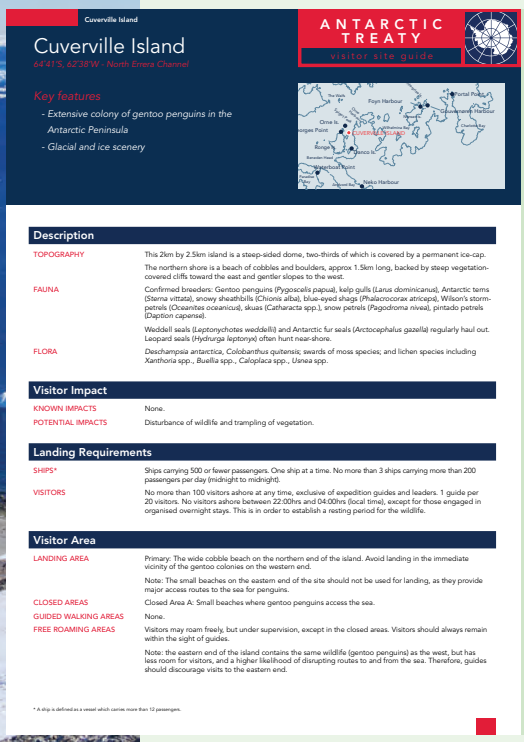


Cuverville Island

Cuverville Island

64°41'S, 62°38'W - North Errera Channel

ANTARCTIC TREATY

visitor site guide

Key features

- *Extensive colony of gentoo penguins in the Antarctic Peninsula*
- *Glacial and ice scenery*

Description

TOPOGRAPHY — This 2km by 2.5km island is a steep-sided dome, two-thirds of which is covered by a permanent ice-cap. The northern shore is a beach of cobbles and boulders, approx 1.5km long, backed by steep vegetation-covered cliffs toward the east and gentler slopes to the west.

FAUNA — Confirmed breeders: Gentoo penguins (*Pygoscelis papua*), kelp gulls (*Larus dominicanus*), Antarctic terns (*Sterna vittata*), snowy sheathbills (*Chionis alba*), blue-eyed shags (*Phalacrocorax atriceps*), Wilson's storm-petrels (*Oceanites oceanicus*), skuas (Catharacta spp.), snow petrels (*Pagodroma nivea*), pintado petrels (*Daption capense*).

Weddell seals (*Leptonychotes weddellii*) and Antarctic fur seals (*Arctocephalus gazella*) regularly haul out. Leopard seals (*Hydrurga leptonyx*) often hunt near-shore.

FLORA — *Deschampsia antarctica*, *Colobanthus quitensis*; swards of moss species; and lichen species including *Xanthoria* spp., *Buellia* spp., *Caloplaca* spp., *Usnea* spp.

Visitor Impact

KNOWN IMPACTS — None.

POTENTIAL IMPACTS — Disturbance of wildlife and trampling of vegetation.

Landing Requirements

SHIPS* — Ships carrying 500 or fewer passengers. One ship at a time. No more than 3 ships carrying more than 200 passengers per day (midnight to midnight).

VISITORS — No more than 100 visitors ashore at any time, exclusive of expedition guides and leaders. 1 guide per 20 visitors. No visitors ashore between 22:00hrs and 04:00hrs (local time), except for those engaged in organised overnight stays. This is in order to establish a resting period for the wildlife.

Visitor Area

LANDING AREA — Primary: The wide cobble beach on the northern end of the island. Avoid landing in the immediate vicinity of the gentoo colonies on the western end.

Note: The small beaches on the eastern end of the site should not be used for landing, as they provide major access routes to the sea for penguins.

CLOSED AREAS — Closed Area A: Small beaches where gentoo penguins access the sea.

GUIDED WALKING AREAS — None.

FREE ROAMING AREAS — Visitors may roam freely, but under supervision, except in the closed areas. Visitors should always remain within the sight of guides.

Note: the eastern end of the island contains the same wildlife (gentoo penguins) as the west, but has less room for visitors, and a higher likelihood of disrupting routes to and from the sea. Therefore, guides should discourage visits to the eastern end.

* A ship is defined as a vessel which carries more than 12 passengers.

2

1. Tourists visit Danco Island in the Antarctic Peninsula region. Ships provide transport and accommodation, and tourists make shore visits using small boats. Revised site guidelines for Danco Island will be considered by the 36th Antarctic Treaty Consultative Meeting, following the January 2013 site visit by Antarctic specialists.
2. Australians are the second most common nationality visiting Antarctica after people from the United States, and Australian companies operate tourism activities, including at the Antarctic Peninsula. Australia is active in the management of Antarctic tourism through Antarctic Treaty meetings, and contributes to the development of site guidelines such as this one for Cuverville Island.

Antarctic Treaty and tourism operator representatives recently revised management guidelines for sites used by visitors on the Antarctic Peninsula.

Many people visit Antarctica as tourists each summer, travelling aboard ships, and making shore landings to see wildlife, historic remains, scenery, and other features. Some sites are particularly popular, and some are more sensitive than others, because of their wildlife, vegetation, topography or other factors.

If not carefully managed, tourism could have an impact on the environmental and scientific values of these sites. To help ensure that visits take into account the individual features and sensitivities of these sites, the Antarctic Treaty countries have put in place 'site guidelines' which convey site-specific management arrangements for many of these places. There are currently site guidelines for 35 sites, with the majority in the Antarctic Peninsula region (the most commonly visited area), and others in the Ross Sea and East Antarctic regions.

The site guidelines are designed for tour guides and other visitors to use in planning shore landings, and while ashore. The guidelines take into account the physical and biological characteristics of the sites, as well as the practical aspects of how visitors can access and move around the areas.

The guidelines employ various management measures, including zoning (for example closed areas), recommended boat landing sites, preferred routes, limits on group sizes or on numbers of visitors, and information on protecting the values of each site. Maps and photos are used to show locations of key features, wildlife breeding areas or congregations, vegetation, routes, and dangerous areas.

In January 2013 a small international team, including Antarctic specialists from the United Kingdom, Australia, the United States, and Argentina, as well as a representative of the tourism industry, conducted a management visit in the Antarctic Peninsula region. The objective was to review, on site, some of the site guidelines for popular and sensitive sites used by visitors. The visit was organised by the United Kingdom, and was supported by the multi-purpose icebreaker HMS Protector.

The team inspected 12 sites where guidelines are in place, focussing on the physical and biological features of the sites (for example wildlife congregations and breeding areas, and areas of vegetation). They looked at areas of interest to visitors such as scenic points, or routes to features, as well as the management arrangements in place under the existing guidelines (for example closed areas, recommended routes, limits on numbers, and landing sites). Feedback from the tourism industry about using the sites and the site guidelines was also considered. The team looked to see whether any changes to the site were evident, and whether any impacts could be observed.

Taking the on-site observations into account, the team revised the guidelines to ensure that the management for these sites remains up-to-date and relevant. The team also drafted new site guidelines for two additional sites that are used by visitors.

The proposals for the new and revised site guidelines will be considered for adoption by the 36th Antarctic Treaty Consultative Meeting in Brussels, Belgium, in May 2013.

PHIL TRACEY
Senior Policy Adviser, Australian Antarctic Division

Inspiring a new generation of Antarctic doctors


FELIX HO 1

When former science teacher John Cherry led three students on an expedition to Union Glacier in West Antarctica two years ago, he met a doctor who inspired him to change the course of his career.

'I learnt about his work in Antarctica and his contribution as a doctor to communities around the world,' Mr Cherry said.

'I thought he'd left such a great legacy that I wanted to become a doctor myself.'

Mr Cherry is now in his second year of a medical degree at the University of Wollongong. He, and two other second-year medical students, Jessie Ling and Felix Ho, are also participating in an extra-curricular medical placement program at the Australian Antarctic Division's Polar Medicine Unit, to learn more about what it takes to be a doctor in Antarctica.

Their placement is part of the John Flynn Placement Program, which aims to encourage medical students to work in rural and remote areas when they graduate. Each year 300 students are selected to join the program and they spend at least two weeks a year for four years with a rural doctor.

The Antarctic Division's Chief Medical Officer, Dr Jeff Ayton, said it's important for young doctors to be exposed to career opportunities outside metropolitan areas.

'When working in smaller communities you can become a generalist doctor, and learn and practice a huge range of skills that you may not get the chance to pursue or may have to give up, if working in larger centres,' he said.

'In Antarctica, our doctors are the only medical care available for up to 100 people on station and they need to be able to perform general practice, surgery, emergency medicine, anaesthetics and even dentistry.

'We hope that through the John Flynn Placement Program we will be able to introduce student doctors to the excitement and challenge of working in Antarctica and entice them to come back at the completion of their degrees for a stint down south.'


TROY DANIELS 2

After his Antarctic experience Mr Cherry was keen to spend his placement at the Polar Medicine Unit. During his two week stay in December 2012 he said he learnt a lot about expedition medicine and the unique challenges of practicing in a remote environment.

'At medical school we're training to be part of a hospital or general practice environment where you're part of a team. But in Antarctica you're the only doctor there. So it was interesting to see how the Polar Medicine Unit has recreated the team environment with teleconferencing facilities and regular contact with the doctors at each station,' Mr Cherry said.

'It was also fascinating to see that Antarctic doctors are well resourced, and have access to cutting-edge research and treatment through the Polar Medicine Unit. They're able to handle almost any medical situation that arises.'

Mr Cherry said the pre-departure medical screening process for expeditioners was also a vital tool for doctors to identify people at risk of developing medical conditions that would be difficult to treat in Antarctica.

Like Mr Cherry, Jessie Ling, who is studying at the University of Tasmania, has a link to Antarctica that motivated her visit to the Polar Medicine Unit.

'My father worked in Antarctica in 1991 as a Field Training Officer at Australia's Casey station,

1. John Cherry reviews the medical supplies inventory for the resupply of Antarctic stations.
2. Chief Medical Officer Dr Jeff Ayton with Jessie Ling.
3. John Cherry hopes his photo will one day be added to this pin-board of Antarctic doctors.
4. Felix Ho from the Flinders University Northern Territory Medical Program enjoyed learning about the unique challenges of polar medicine during his placement.

so I guess that family connection ignited a passion in me to go south as well,' she said.

'I never thought I'd be able to get there until many years after graduation, but my placement may allow me to get there much sooner.'

Ms Ling spent her two weeks at the Polar Medicine Unit in February 2013 going through pre-departure medical reports, updating drugs and equipment for the resupply of the Antarctic stations and the ship, *Aurora Australis*, and sitting in on the medical information sessions for expeditioners travelling to Macquarie Island.

'I'm really only at the stage of "advanced bandaids" in my medical degree, so my two weeks were an amazing learning experience in terms of how to treat polar injuries, the sort of equipment needed in Antarctic first aid kits, and all the different drugs and what they're used for,' Ms Ling said.

'I also learnt about policies and procedures and the role of the Polar Medicine Unit in the Antarctic Division and the broader Australian Antarctic program.'

Felix Ho, who is studying his degree through the Flinders University Northern Territory Medical Program, based in Darwin, had a similar experience.

'My placement was truly an eye-opener,' he said.

'I learnt about the unique challenges of polar medicine, the need to be highly skilled and independent, the importance of the psychological and holistic health of a person, rather than just their physical illness, and the diversity of skills and equipment needed by an Antarctic Medical Practitioner to perform such things as dentistry, taking an X-ray or running lab equipment for diagnostic results.'

The John Flynn Placement Program is funded by the Australian Government's Department of Health and Ageing and administered by the Australian College of Rural and Remote Medicine (ACRRM). For more information visit https://www.acrrm.org.au/about-john-flynn-placement-program

WENDY PYPER
Australian Antarctic Division

An Antarctic library inspires adventure

Don Howell, an avid reader and collector of Antarctic books and member of the Friends of Mawson, describes some of the books that inspired him to undertake his own Antarctic adventures.

I cannot recall when I purchased my first book on Antarctica. But I do remember my first interest for gathering information and experience in the southern polar continent was when a visiting expeditioner from the Australian National Antarctic Research Expeditions (ANARE) came to my school in 1959 to give an illustrated lecture. I was also fortunate to have a great geography teacher and mentor at Kings College in Adelaide, who set my thirst for Antarctica. Unfortunately, ANARE did not need or want a Bachelor of Commerce graduate; only scientists and diesel mechanics.

In the early 1980s I purchased *Verdict on Erebus* by Peter Mahon (QC) and, years later, I found a copy of the *1981 NZ Royal Commission into the Air NZ DC 10 crash into Mt Erebus* in a second hand bookshop. Some 25 years later I sailed past Mt Erebus and whilst at McMurdo Station I was able to look into the active caldron of that volcano via a live video camera.

One book leads to another to collect and read. If you read Mawson's *The Home of the Blizzard*, you can then read his first book (off-prints of his first papers bound together) *Geology of the New Hebrides* (1904). Other related books by Mawson include the scientific papers of his three expeditions – the volumes on geography, birds and animal are beautifully illustrated with Frank Hurley's photographs. Then you discover that *The Home of the Blizzard* was printed in colour and in German, with a leather cover in two volumes, in 1921.

In 1915, only 200 volumes of Mawson's first edition of *The Home of the Blizzard* were sold in Australia. More were sold in the UK and USA. This led Mawson to publish cheaper, abridged, popular editions in 1930 and a small pocket edition in 1938. The Soviets had great respect for Mawson as the USSR published their version of *The Home of the Blizzard* in 1935, with more reprints later. Today, a two volume first edition set of *The Home of the Blizzard* costs around $1200. A signed copy for the eighth Prime Minister of Australia, Stanley Melbourne Bruce, cost over $5000.

In 1960 a Soviet journalist, E. M. Suzyumov wrote a biography of Mawson, *A Life Given to the Antarctic*. Paquita Mawson wrote her biography of her husband in 1964, but it was not until some 50 years later that others were published – why was Mawson such a forgotten hero in his own country? *Mawson a Life*, by Philip Ayres (1999), is a good biography, but is light on Mawson's later career in mining and directorships (he was a Founding Director of Santos – an Australian oil and gas company).

Other Mawson books of interest include: his great, great granddaughter Emma McEwin's book *An Antarctic Affair*; Nancy Flannery's (ed) *This everlasting silence: the love letters of Paquita Delprat and Douglas Mawson, 1911–1914*; Harold Fletcher's *Antarctic days with Mawson: a personal account of the British, Australian, and New Zealand Antarctic Research Expedition of 1929-31*; *With the Aurora in the Antarctic*, by ship's Captain and best man at Mawson's wedding, John King Davis; and of course the facsimile reproduction of *The Adelie Blizzard – Mawson's forgotten newspaper* (1913), published by the Friends of the State Library of South Australia in 2010, in time for the centenary of Mawson's Australasian Antarctic Expedition (1911–1914).

During this centenary period, more diaries of Mawson's fellow expeditioners are being published, giving further insights into the true history of Antarctic expeditions and adventure. There are also books on earlier Australian expeditions: Carsten Borchgrevink's 1898 Southern Cross Expedition – the first expedition to overwinter in Antarctica; the early 1928 pioneer aeroplane flights of Hubert Wilkins; John Rymill's British Graham Land expedition in 1934 in the *Penola*, and Phillip Law's expeditions to establish Australia's three Antarctic stations.

1. Don at the Proclamation flagpole at Mawson's Huts Historic Site in 2004.
2. Don at Macquarie Island in 2004.

Earlier readings give one the impression that Britain dominated polar exploration, until you discover books about expeditions by the Japanese, Norwegians, French, Argentines, the Third Reich of Nazi Germany, the USA and the USSR.

One of the most exciting books for me was about the USA project in 1957 to build the South Pole base, using aircraft to land and drop building equipment and men at the inhospitable pole, some 2800 m above sea level. The brave Americans did not know if an aeroplane could land and take off again, what extreme temperatures they would experience, or even if humans could survive a long, dark winter. You can read about it in Paul Siple's excellent book *90 degrees South*.

Another interesting biography is the life of Bertram Armytage, titled *Body at the Melbourne Club*. Armytage was an Australian and a member of Shackleton's 1907 expedition. He decided to take his own life at 41 years old, but he first dined at his club, put on his Polar Medal and then shot himself there.

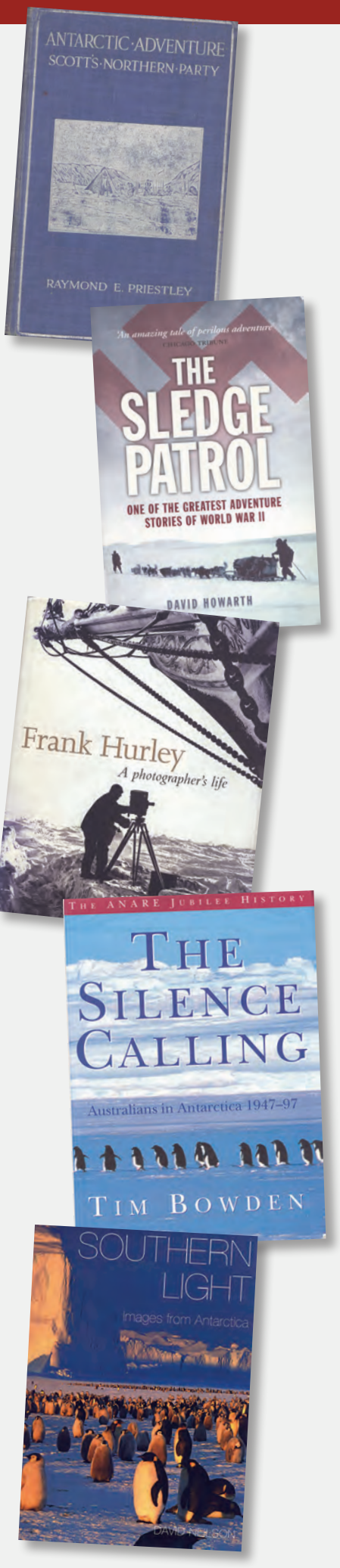
My books have inspired me to go on four 'tourist' expeditions to Antarctica on Russian ice breakers – to Mawson and Davis stations, South Georgia, the Antarctic Peninsula, Elephant Island, Macquarie Island, Mawson's Huts and to McMurdo and Scott bases. I travelled with heroes like the late Phillip Law of ANARE, Dr David Lewis – first to sail a yacht solo to Antarctica – and Everest climber Greg Mortimer...but that is another story.

DON HOWELL
Friends of Mawson

The cover of the facsimile reproduction of Mawson's forgotten newspaper, *The Adelie Blizzard*, published by the Friends of the State Library of South Australia. Facsimile copies are available from www.australianapublications.org.au in hard cover ($150) and soft cover ($60) versions.

POLAR BOOKSHELF

Australian Antarctic Division staff are enthusiastic readers of polar fiction and non-fiction. A small group tells which polar books inspired them and why.



My grandfather Raymond E. Priestley's book *Antarctic Adventure – Scott's Northern Party*. It inspired me as a young child to see the Antarctic and be an adventurer.

Tony Fleming, Director, Australian Antarctic Division

The Sledge Patrol by David Howarth. Set during World War II, it tells the true story of the 'Greenland Army' (which at its peak strength totalled nine men) as it battled against a German army detachment over hundreds of miles along the remote north east coast of Greenland. The book chronicles inspiring and understated courage and endurance; and is remarkable in its thoughtful reflection on what happens when the most peaceful people and places on earth are brought to war.

Warwick Barnes, Web Manager

Frank Hurley: A photographer's life by Alasdair Macgregor. Frank's life story is fascinating, but the tale of his involvement in Shackleton's remarkable escape from the ice, along with the rest of the expedition and crew from the *Endurance*, is gripping. There are few greater tales of triumph from positions of almost certain death, and Frank not only documented it but made it famous. A bit of a hero in my opinion.

Jeff Keogh, Procurement Coordinator

I liked Tim Bowden's *The Silence Calling: Australians in Antarctica 1947-97* for the insight it provided into the history of the Australian Antarctic Division and the larger Australian Antarctic program. Besides that, *Ice Station*, by Matthew Reilly, was a good read on the way south on the *Aurora Australis*, to fill time between storm fronts.

Rob Bryson, Operations Manager

The stunning photographs and essays in *Southern light: images from Antarctica* (2012) by David Neilson reveal the beauty and majesty of Antarctica. The essays narrate the six photographic journeys over 20 years made by the author. Through its words and images, this book vividly communicates the importance of protecting Antarctic wildlife and the impact of climate change.

Tess Egan, Librarian

BODIES OF ICE

1

1. Five dancers representing Antarctic ice in Polarity.
2. Polarity being performed in Melbourne's Federation Square in 2011.
3. Tina in her solo performance of Body of Ice in Buenos Aires, 2012.

'Antarctic ice is fragile, dynamic and alive. The journey of an ice form is continually transient. Layering, compressing, flowing, cracking, floating, crumbling, dissolving, freezing and reforming occurs at a molecular level and large scale. The diverse textures, qualities and forms of Antarctic ice are extraordinary. Seasonal cycles of ice see Antarctica double in size as it expands through fierce winter and contracts through summer. Snow forms in layers on the plateau and compresses, forming ice. Glaciers flow to the coast to form ice shelves that break as icebergs. Such cycles take thousands of years, yet are always in motion. Our bodies are made up of pure water that at some point has been Antarctic ice. We are a part of the ice as well as its signs of a changing climate.'

These program notes were written for my dance presentation, Polarity, inspired by my visit to Antarctica on an Australian Antarctic Arts Fellowship in 2010.

Polarity and Body of Ice are dance works I directed, choreographed and recently performed, that explore the movement and nature of Antarctic ice.

I was the first dance artist ever awarded an Australian Antarctic Arts Fellowship and I travelled to Antarctica for several weeks in 2010 for creative research to develop my work. I spent time at Davis and Mawson stations and although only there a short time, I connected with the ice in many ways. I explored how the shapes and layers of an ice structure reveal its movement history; the many processes of action and reaction that created its current, yet continually changing form. I collected a vast range of movement and choreographic stimulus, ice imagery, visual and written responses, and sensory impressions.

My diary read: 'I am full of awe, wonder and passion. The ice lives and breathes. Beautiful, severe, natural. Delicate fluidity, rock hard strength. Staggering.'

I researched the different ice types and their extreme diversity, composition and nature. I looked at ice cycles and ice behaviour as well as signs of climate change. I reflected on the human body and its water content and how this connects us directly to Antarctic ice. I serendipitously met sound artist Philip Samartzis on the journey, whom I then collaborated with. The soundscapes used in my dances were born from the incredible raw, richly diverse and intricate sounds of Antarctic ice recorded by Philip in Antarctica.

My first presentation of Body of Ice was at the 2011 Antarctica Festival and Conference in Canberra. I worked with five dancers, and used projected ice imagery, vibrant lighting and the spectacular soundscapes of ice, to create a sensory representation of Antarctic ice in motion.

Body of Ice was developed into the full length work, Polarity, performed at the 2011 Melbourne Fringe Festival on a large rooftop space surrounded by the city at Federation Square. The presentation integrated the cityscape, which reflected our impact on Antarctic icescapes – white bodies melting beneath the city lights. I received good media coverage, reviews and responses from the audience and it was fantastic to see it come together in this space after such a journey.

When I was invited to perform at the 2012 Antarctica Art and Culture Festival and Conference in Buenos Aires, Argentina, I evolved Body of Ice into a solo piece. The set became white fabric and I depicted a full ice journey, from layering ice on the plateau to dissolving icebergs. I performed at the festival and also presented a talk on my work and met many international artists from diverse artistic disciplines.

Antarctica is the most spectacular, raw, powerful, fragile and extreme place on Earth and I believe that translating this into relevant art of today is truly necessary to connect Antarctica to the world. I plan to continually evolve my work and present again in 2013 and into the future.

For more information and videos see http://tinaevansperformance.com/polarity.

TINA EVANS
Australian Antarctic Arts Fellow, 2010

TONY FLEMING

A Ken Borek Air twin otter aircraft (front), similar to the one that crashed, at Australia's Wilkins Runway this year. The air crew were loved and respected colleagues of Australian Antarctic expeditioners.

VALE: Ken Borek Air Crew

The Antarctic community lost three much-loved and respected colleagues and friends in a plane crash on 23 January 2013.

Pilots Bob Heath and Mike Denton, and engineer Perry Andersen, were killed when their Twin Otter aircraft, operated by Canadian-based Kenn Borek Air, crashed in the Queen Alexandra Range, halfway between the South Pole and Mc Murdo station. Search and rescue teams located the crash site near the summit of Mt Elizabeth, at an altitude of 13 000 ft.

The air crew were en-route from the Amundsen-Scott South Pole Station to the Italian research station at Terra Nova Bay. They had just finished a season supporting the Australian Antarctic program, flying expeditioners and scientists between stations.

Bob, Mike and Perry were great friends of the Australian Antarctic program and our expeditioners, and I had flown with them on many occasions. They were well respected and embraced as part of our Antarctic station communities.

Mike's first job was with the Australian Antarctic Division. He was so enthusiastic and a delight to be with. He was liked by all. It is a tragedy that he was lost so young.

Perry will be remembered by us as a loveable larrikin, liked by all on station. He was dedicated to his job; to keeping the aircraft flying and keeping it safe.

Bob had close friendships with many of our Australian expeditioners. Obviously, he was a great pilot, but that doesn't even begin to describe what he brought to the Australian Antarctic program. He was an educator, a story teller and a central part of the social fabric of our communities.

I will be eternally grateful that Bob, Mike and Perry kept our people safe in a hazardous environment. It wasn't just a job for them; they were connected to our people, our program and the work our scientists do.

Our hearts go out to their families, friends and colleagues at Kenn Borek Air as we share their grief. They were special people. They kept us safe. They were our colleagues and our friends. We will never forget them.

TONY FLEMING
Director, Australian Antarctic Division

Ken Borek Air has created a memorial page to Bob, Mike and Perry on their website. Messages of condolence can be left at http://www.borekair.com/memorial/

Chinese visit to Hobart

The Chinese Antarctic vessel, *Xue Long*, called into Hobart in January, as part of the Chinare 29 voyage. The ship came out of the Ross Sea region of Antarctica, used Hobart to resupply and refuel, and then headed south to Zhongshan Station in Prydz Bay – neighbouring Australia's Davis Station.

The Australian Antarctic Division hosted a one-day workshop with colleagues from the Xue Long, to exchange ideas, particularly on opportunities for collaboration. The Australian Antarctic program has committed to working with the key Chinese Antarctic institutions to identify collaborative projects, building on our long and close relationship (Australia took the first Chinese Antarctic expeditioners south in the 1980s).

After the workshop the Australian Antarctic Division hosted a dinner with representatives of Chinare 29. Also attending were the Tasmanian Premier, the former Tasmanian Governor, the Lord Mayor of Hobart, representatives of Hobart's key scientific institutions and private sector interests with connections to Antarctica, and senior representatives of the Tasmanian Government. The Chinese were led by Mr Qu Tanzhou – the voyage leader of Chinare 29 and also the Director of the Chinese Arctic and Antarctic Administration.

Mr Qu spoke about the close relationship between China and Australia in Antarctica, and he focussed on strengthening those relationships. China is seriously considering using Hobart as one of their points of access to Antarctica.

The Chinese visit to Hobart symbolises the growing collaboration between the Australian and Chinese Antarctic programs. Hobart is Australia's gateway to Antarctica and it is hoped that the city can become an expanded international gateway for both scientific activity and logistics.

TONY FLEMING
Director, Australian Antarctic Division

Members of the Chinare 29 voyage with Australian Antarctic Division colleagues at Kingston headquarters.

AAD

STEPHENIE CAHALAN

New biosecure hub for Antarctic gateway

A new state-of-the-art Australian Antarctic Division cargo and quarantine hub opened on Hobart's waterfront in April, with the aim of banishing bugs, rats and other 'alien' hitch-hikers from boarding ships travelling south.

The federally funded $2.5 million facility is located at the eastern end of the re-developed Macquarie Wharf 2 shed. It has vermin traps, impenetrable walls and automatic shutter doors to reduce the risk of introduced species reaching the fragile Antarctic and sub-Antarctic environments. It also has a cold and cool store, fumigation area, briefing rooms, and warehousing space.

In addition to the facility, Tasports spent $7 million redeveloping the Macquarie Wharf 2 building into an Antarctic and cruise ship precinct.

The cruise terminal will provide a spacious and comfortable area for expeditioners and their families to farewell or welcome home their loved ones, as well as providing easier access to Antarctic ships.

The development further cements Tasmania's status as a dedicated gateway to Antarctica and the Southern Ocean.

NISHA HARRIS
Corporate Communications

Mawson's Huts Management Plan

Conserving and protecting Mawson's Huts – one of Australia's most significant Antarctic historic sites – is not an easy job. But a new, recently finalised management plan, aims to do just that.

The Mawson's Huts Historic Site is the setting of the buildings, structures and relics of the Main Base of the Australasian Antarctic Expedition (1911–1914), led by Dr (later Sir) Douglas Mawson. The site at Cape Denison is one of only six sites remaining from this era, and is the least disturbed.

Mawson's Huts have received national recognition from their inclusion on the Commonwealth Heritage List (2004) and the National Heritage List (2005) under the *Environment Protection and Biodiversity Conservation Act 1999*. They have also been inscribed on the Antarctic Treaty List of Historic Sites and Monuments, and designated an Antarctic Specially Protected Area within an Antarctic Specially Managed Area, under the Protocol on Environmental Protection to the Antarctic Treaty.

Amazingly, the huts are still standing after over 100 years of exposure to extreme cold and regular blizzards. Under the guidance of the previous management plan, the site underwent some major conservation works with the assistance of the Mawson's Huts Foundation. These works included the over-cladding of the Main Hut, ice removal from the interior, fitting of a frame to help stabilise the Transit Hut, and artefact conservation.

The new management plan provides the framework to guide management decisions, and on- and off-site actions. It aims to protect and conserve the National Heritage, Commonwealth Heritage and other values of the Mawson's Huts Historic Site, while allowing the fabric of the site to continue to represent both a moment in time and the passage of time.

Environmental factors are the main pressures on the site's National and Commonwealth Heritage values; wind, humidity, salt, snow and ice, and the associated freeze/thaw action. During the life of the new management plan there will be further monitoring and analysis of these key pressures to inform work plans and the development of the next management plan.

The new management plan replaces the *Mawson's Huts Historic Site Management Plan 2007–12* and will be reviewed within five years.

DEBORAH BOURKE
Senior Policy Adviser, Australian Antarctic Division

The Mawson's Huts Historic Site at Commonwealth Bay.


TONY FLEMING

FREEZE FRAME

DR TONY FLEMING has travelled to Antarctica many times in his role as Director of the Australian Antarctic Division; a position he has held since early 2011. Tony is the grandson of eminent Antarctic scientist Dr Raymond Priestley, who was part of Scott's Terra Nova Expedition (1910–13). Tony undertook a private trip to the Ross Sea to mark the centenary of this expedition and a few months later he was pleased to officiate at Australia's Antarctic centenary celebrations at Commonwealth Bay, marking 100 years since Douglas Mawson's Australasian Antarctic Expedition (1911–14). This photo of a black-browed albatross was taken during his voyage to Commonwealth Bay in early 2012.

ANTARCTICA
valued, protected and understood

Australian Government
Department of Sustainability, Environment, Water, Population and Communities
Australian Antarctic Division

www.antarctica.gov.au