AUSTRALIAN

ANTARCTIC

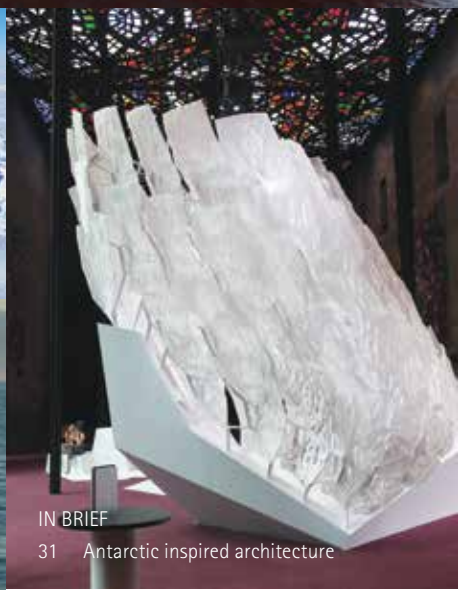
MAGAZINE

ISSUE 34 | 2018

ICEBREAKER
2 Three ships in one

SCIENCE
16 Seismic surprise on Totten Glacier

SCIENCE
22 Noisy sperm whales forage to the beat



IN BRIEF
31 Antarctic inspired architecture

CONTENTS

ABOUT THE COVER

Information Technology Officer, Brett Wilks, took this photo of Antarctic krill in a small display tank at head office. Brett took several shots with his Canon 6D with 50 mm macro lens. To reduce the blur on the krills' fast-moving legs, this image was taken at ISO 8000, 1/1600 s, with some post-processing noise reduction in Adobe Lightroom.

The Australian Antarctic Division, a Division of the Department of the Environment and Energy, 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.

Australia's Antarctic national interests are to:

- Preserve our sovereignty over the Australian Antarctic Territory, including our sovereign rights over the adjacent offshore areas.
- 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).

Australian Antarctic Magazine is produced twice a year (June and December). *Australian Antarctic Magazine* seeks to inform the Australian and international Antarctic community about the activities of the Australian Antarctic program. The views and opinions expressed in this publication are those of the authors and do not necessarily reflect those of the Australian Government or the Minister for the Environment and Energy.

Editorial enquiries, including requests to reproduce material, or contributions, should be addressed to:

The Editor
Australian Antarctic Magazine
Australian Antarctic Division
203 Channel Highway
Kingston, 7050
Tasmania, Australia.

Australian Antarctic Division
Telephone: (03) 6232 3209
(International 61 3 6232 3209)
email: magazine@aad.gov.au
Facsimile: (03) 6232 3288
(International 61 3 6232 3288)

Editor: Wendy Pyper
Production: Nisha Harris, Jessica Fitzpatrick
Graphic Design: Giraffe VCM
ISSUE 34: June 2018

ISSN 1445-1735 (print version)
Australian Antarctic Magazine is printed on Monza satin recycled paper; a 50% post consumer waste and 50% FSC certified fibre stock.

Australian Antarctic Magazine can be viewed online:
www.antarctica.gov.au/magazine

@AusAntarctic
AusAntarctic
AusAntarctic
ausantarctic

From the Director

Since our last magazine, exciting progress has been made on a number of critical projects that will carry the Australian Antarctic Program into the future.

Among these has been progress on building our new scientific icebreaker, RSV *Nuyina*. As this magazine goes to press, almost all of the 10 000 tonnes of steel that will comprise the hull and superstructure have been cut and welded into blocks (page 4). The hull will soon be moved from the dry dock into a wet dock, for consolidation of the superstructure and fit out.

When complete, the RSV *Nuyina* could be considered the triathlete of Antarctic vessels – a scientific research platform, icebreaker and resupply ship in one. Just like any multidisciplinary specialist, the new ship will be an adaptable all-rounder, able to undertake each role at the highest level. Achieving this feat of design and engineering has required significant expertise and collaboration from within and outside the Antarctic Division (page 2).

This season has also seen the first 360 degree virtual tour of Macquarie Island research station completed, to assist the station modernisation project and provide an historical record of the current buildings (page 8).

Specifically, the virtual tour will help the future Managing Contractor of the station's redevelopment to prepare for the design and construction phase of the project, and decommissioning of the current station buildings, given limited access to the remote and challenging site.

These types of digital technologies will provide opportunities for new and flexible ways of doing business. For example, virtual tours of our Antarctic and sub-Antarctic stations could assist in the recruitment, education and training of future Antarctic expeditioners.

The RSV Nuyina could be considered the triathlete of Antarctic vessels

Virtual technology also provides an exciting way to raise public awareness of our research and other activities in Antarctica. This season, Davis research station hosted the first virtual reality (VR) documentary about Antarctica (page 6). *The Antarctica Experience* will take viewers on an immersive journey into the life of a small Antarctic community, the scientific research being undertaken, and the stunning landscapes and wildlife. It will premier at the Western Australian Museum, before international distribution, and dissemination on major hardware platforms such as the Apple store, Samsung and Oculus. Visitors to the Australian Antarctic Division will also be able to view the film on VR headsets.

Among the science featured in the VR documentary is our krill research. The Australian Antarctic Division is fortunate to have one of the best facilities in the world to study krill. Largely as a result, the Antarctic Division has led globally important discoveries on krill biology, ecology, fisheries, and adaptation to environmental change, as the feature, starting on page 9, reveals.

Our understanding of the Totten Glacier – one of the fastest flowing and largest glaciers in Antarctica – has also significantly advanced. This season scientists found that more of the Totten Glacier is floating on the ocean than previously thought (page 16). As they continue to map out the boundary where the bedrock below the ice sheet meets the ocean, the ability to accurately model and monitor the glacier's movement will improve, allowing them to assess the potential impact on sea level under various future scenarios.

Photo: Chris Crerar

While we are looking to the future, we have also taken time to reflect on the past with the celebration of some significant anniversaries.

Just over 70 years ago, in November 1947, the maiden expedition of Australia's Antarctic Program (then the Australian National Antarctic Research Expeditions – ANARE) established the first of Australia's research stations in the southern polar region. The 1947 Heard Island expedition laid claim to Heard Island and McDonald Islands and established a research station at Atlas Cove (page 29). In March 1948, Macquarie Island research station was opened, with a team of 14 expeditioners staying for winter.

I was privileged to speak at the 70th Heard Island Commemoration Luncheon in December last year, where I enjoyed meeting some of the 91 hardy souls who wintered during the nine years of the station's operation. As a young biologist, I was lucky to spend a memorable five months on the island over three summers between 1985 and 2003. The ANARE Club did a wonderful job organising and hosting the event and I'm looking forward to their next event, the Macquarie Island 70th Anniversary celebration, on 6 August this year.

As the stories in this issue show, expeditioners in today's modern Antarctic Program continue the bold steps of those early pioneers with a similar foresight, determination and adventurous spirit.

Dr NICK GALES
Australian Antarctic Division

Three ships in one

The RSV *Nuyina* is the triathlete of Antarctic vessels – a scientific research platform, icebreaker and resupply ship in one. And just like any multidisciplinary specialist, the new ship will be an adaptable all-rounder, able to undertake each role at the highest level.

For Australian Antarctic Division Icebreaker Project Manager, Nick Browne, the scientific requirements of the icebreaker were the primary driver of the ship's design, followed closely by its icebreaking and resupply capabilities.

"The ship needs to be quiet so scientists can use their acoustic instruments, which rely on radiated and reflected sound to map the sea floor or measure the biomass of marine organisms in the water column," Mr Browne said.

"But we also need our ship to break 1.65 metres of ice at a continuous speed of three knots. So this immediately sets up a conflict in designing a propulsion system and hull form.

"In icebreaking mode we want to break ice with high thrust on the two propellers, and this generates a lot of noise. In science mode we want the propellers to operate at lower speeds so they produce less noise, with no or few bubbles, which make noise when they pop."

To achieve this dichotomy in operation the ship is being built to a design specification known as 'Silent R', for speeds up to eight knots. This sets thresholds for the decibel levels permitted for the different range of sound frequencies the ship emits.

To help achieve this rating the ship has a hybrid propulsion system. Two big diesel engines directly drive the 'controllable pitch' propellers when icebreaking, while quiet electric motors, powered by diesel generators on flexible mounting systems (to absorb vibrations), power the ship for silent research operations.

As well as these modifications, the hull and propeller shapes were optimised using a mathematical modelling technique known as computational fluid dynamics (CFD). Their shapes ensure any bubbles, formed as the ship moves through the water, don't interfere with the acoustic equipment.

While being quiet is one thing, the ship still needs to be able to break thick ice at a set speed and operate in open water in a variety of sea and wind conditions.

To test it can do all three, the designers built a six metre scale-model of the vessel to conduct physical tests in facilities that included calm water tanks, wave tanks and an ice basin. The tests focussed on powering, manoeuvring, 'sea keeping' (motion response to waves), icebreaking, and bubble formation and movement.

"Computational fluid dynamics is mature enough that you can see whether one design option is better than another. So the grunt work is done with CFD and the physical model testing provides validation and confirmation that the chosen design works," Mr Browne said.

When the ship is in icebreaking mode the bow hull shape allows it to ride up on to the ice, while a 'skeg' (a forward extension of the keel) prevents it from riding up too far. The weight of the ship and the shape of the hull together provide a downward force that breaks the ice by flexion, rather than compression.

1. *The* Nuyina's *hull shape allows it to ride up on to sea ice and bend it until it breaks, while a 'skeg' (a forward extension of the keel) prevents it from riding up too far. Her sea keeping capacity is also a critical part of both scientific and resupply operations. (Photo: AAD/Damen)*

2. *The forward thruster tunnels under construction in the Damen shipyards. (Photo: Damen/AAD)*

"It's like breaking a chocolate bar. It's difficult to break by pushing the ends together and compressing it, but if you bend it, it breaks," Mr Browne said.

"The hull of *Nuyina* is shaped so that we have continuous, steady icebreaking as the ship moves forward, rather than relying on backing and ramming."

In terms of sea keeping, the ship is designed so that helicopter operations can be conducted in up to sea state 3 (1.25 m wave height), while small cranes to deploy watercraft can operate in moderate seas, up to sea state 4 (2.5 m wave height). The ship can also transit at 12 knots, or conduct stationary scientific equipment deployments, in rough seas, or sea state 5 (4 m wave height).

> *"Sea keeping is a critical part of both scientific and resupply operations"*

"We have set certain sea and wind conditions in which the vessel must be capable of operating, and our numerical and scale-model sea keeping tests indicate that the vessel will be suitable."

The final tests will come when the ship enters the harbour for 'harbour acceptance trials' in 2019, followed by 'sea acceptance trials'. Both these trials are standard ship building activities that look at propulsion, bilge, ballast and other auxiliary systems. It will then go into 'special sea trials' designed to ensure the ship can operate in its unique environment.

These special sea trials will include deep water testing for scientific research deployments, measurement of acoustic noise – to see whether the ship achieves its Silent R rating – and whether it is suitable for operating in ice and low temperatures.

"We can't completely replicate the Antarctic operating environment during the testing program, but we'll get to the point where we'll be confident that our requirements are met," Mr Browne said.

What is certain is that the ship will open up new opportunities for Australian scientists and international collaborators and that it will have the flexibility to support current and future research priorities.

"I can't think of any Antarctic vessel that will be able to deliver the combination of icebreaking, science and logistics capabilities, at these levels, better than *Nuyina*," Mr Browne said.

WENDY PYPER

Australian Antarctic Division

3. *Placement of four conjoined blocks encompassing the deck forward of the engine room and the moon pool hull aperture, within the dry dock. (Photo: Damen/AAD)*

4. *The* Nuyina *takes shape in the dry dock in Romania in December 2017. (Photo: Rob Bryson)*

Ship of steel

The RSV *Nuyina* is being built from 10 000 tonnes of steel, moulded into 57 steel blocks – some weighing almost 300 tonnes.

Each steel block is built from smaller 'sections' that are welded together, and made up of a combination of steel plate, structural steel bars ('stiffeners') and 'bulkheads' – upright walls within the hull.

Australian Antarctic Division Icebreaker Project Manager, Nick Browne, said a number of high tensile grades of steel are being used to ensure the ship can cope with freezing Antarctic temperatures.

"The grade refers to the strength and toughness of the steel to withstand the cold, before it becomes brittle and loses its ability to withstand impact," he said.

"Above the water line the steel can withstand temperatures down to -40°C, but it's optimised for -30°C, while the steel below the water line can withstand -10°C."

Before any steel plate is cut, computer software is used to arrange the shapes of the parts that need cutting, to minimise wastage. A combination of laser and plasma technology and high pressure water is used to cut the plate, some of which is 130 mm thick. Any leftover steel is melted down and reused in new plates.

After the parts are cut they are welded to big panels of deck plate. Then the steel bars or stiffeners are added to create a skeleton, and the outside of the hull, called the shell plate, is welded over the top.

Once a block is complete, it is painted and moved from the construction warehouse to the dry dock, where it is craned into place. It can then be welded to other blocks in a process known as consolidation.

1. *Structural steel bars or stiffeners being welded on to plate steel. (Photo: Damen/AAD)*

2. *Steel plate cut into parts using laser and plasma technology and high pressure water. (Photo: Damen/AAD)*

3. *A block of the aft starboard hull being transferred to the dry dock by a 300 tonne gantry crane. (Photo: Damen/AAD)*

The Nuyina *has been brought to life in LEGO bricks. (Photo: Brickman Exhibitions)*

Ship of LEGO

She may not be seaworthy, but the RSV Nuyina has been brought to life in LEGO.

At 2.8 metres long, the model uses 113 098 LEGO bricks and took a team of three people 237 hours to build.

The inspiration to build the model came to Ryan 'The Brickman' McNaught while he was in Hobart in 2016 and saw RSV *Aurora Australis* preparing for one of its annual Antarctic resupply voyages. He discovered the ship was nearing the end of its service life and that a replacement icebreaker was under construction.

Mr McNaught is one of only 14 LEGO Certified Professionals in the world, and the only one in the Southern Hemisphere. He uses his brick-laying skills to create award-winning sculptures, historical dioramas, architectural and engineering models, and mosaics. His creations often include 'Easter eggs' (hidden jokes or secret features) – such as an alien in an ice block and some angry penguins on the RSV *Nuyina*!

SACHIE YASUDA
Australian Antarctic Division

"The keel consists of three blocks and was the first part of ship to be consolidated in August 2017," Mr Browne said.

The block construction method allows the shipyard to build different parts of the ship at the same time, to make best use of the resources (labour and yard space) available. At Damen Shipyards in Romania the block sizes are limited to 300 tonnes, which is the lifting capacity of the cranes.

> *Once a block is complete, it is painted and moved to the dry dock, where it is craned into place*

"The building strategy broadly reflects the cranes' lift capacity," Mr Browne said.

"It will take 58 building steps to produce 229 sections that will be consolidated into 57 blocks. There are so many sections because the steel is thick and heavy, due to the structural requirements of icebreaking."

Because of its weight, only about half the ship will be constructed in the dry dock, before it is floated out to a wet dock for completion.

"The ship will have a displacement of 25 500 tonnes when complete and a draught – the distance between the waterline and bottom of the hull – of 9.3 metres," Mr Brown said.

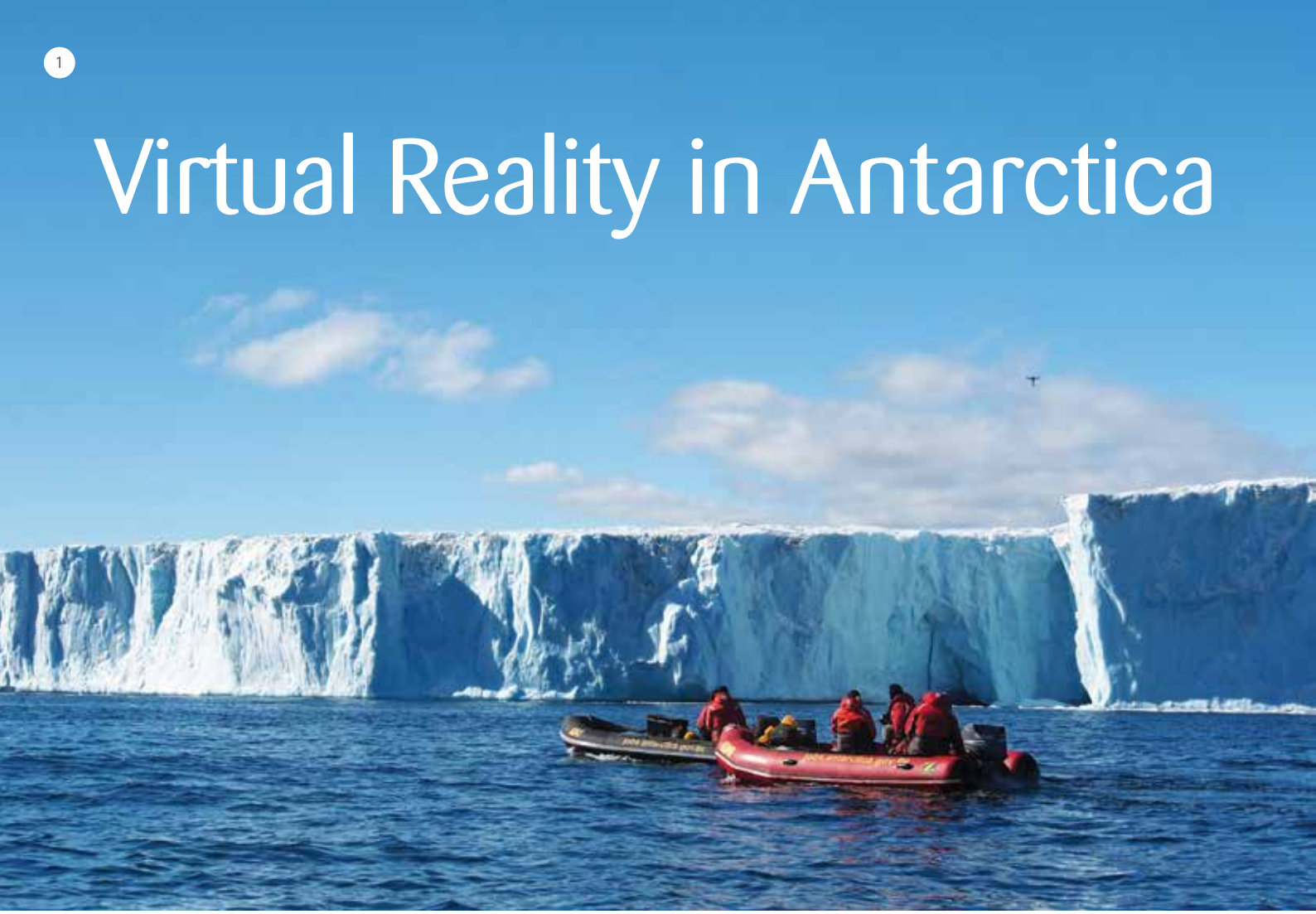
"In the dry dock there's a gate with a draft restriction of 4.5 metres, so if we tried to build the whole ship there it would get stuck."

Once the superstructure of the ship (area above the main deck) is constructed, the fun begins, with the interior fit-out of laboratories, cabins, offices and other spaces. Some interior sections, such as moulded bathroom cubicles, will be prefabricated and simply dropped into place. To save arguments amongst future users of the vessel, the interior decoration is being left to the "professionals" – the ship builders and a Norwegian outfitter.

One thing the Australian Antarctic community can agree on though, is that *Nuyina* will be painted in an iconic International Orange, reminiscent of the nation's current icebreaker, the much-loved *Aurora Australis*.

WENDY PYPER
Australian Antarctic Division

Virtual Reality in Antarctica



Maintaining eye contact with Wilson and treating him like any other Antarctic expeditioner is a challenge. He doesn't interact, he has no personality, and his six all-seeing eyes can be a little off-putting.

The ball-shaped 360 degree virtual reality camera on a tripod – named after the *Wilson*-branded volleyball that featured in the movie *Cast Away* – also needs to be the centre of attention.

Wilson is part of a team led by natural history filmmaker Briege Whitehead, who visited Australia's Davis research station for 10 days in February, to film the first virtual reality documentary about Antarctica.

The Antarctica Experience aims to take viewers on an immersive journey into the life of a small Antarctic community, the scientific research being undertaken, and the stunning landscapes and wildlife. Threading through the different facets of the experience is a message about climate change.

1. *Dean (in the black boat) flies the Matrice 600 pro drone over the Sørsdal Glacier. (Photo: Wendy Pyper)*

"I've always been interested in showing how important Antarctic research is to understanding climate change and how it will impact the planet," Briege said.

"Virtual reality provides a new and exciting way to do this. When viewers wear a special 3D, surround-sound head set, they will be transported into the heart of the action, to experience the Antarctic landscape, and hear and see Australian scientists as if they were actually standing with them on the ice."

To achieve her vision Briege (who owns White Spark Pictures) teamed up with UK-based director and producer Phil Harper, who previously worked on David Attenborough's *Great Barrier Reef VR Dive*. Together the pair scripted and directed each story chapter and used Wilson to capture the experience.

"Wilson is the eyes and ears of future virtual expeditioners, so the people we're filming need to talk directly to him, as if he is a person," Briege said.

"The six individual cameras on his 'head' record vision and sound all the way around. So when you put on a head set, if a penguin squawks behind you, you can turn around and see it."

To complement the vision on the ground, Briege secured the skills of Western Australian drone pilot Dean Chisholm. Dean used a DJI Matrice 600 pro drone to carry Wilson above and around icebergs, glaciers and Davis station, providing viewers with a spectacular and rarely-seen vantage. A smaller Phantom drone captured similar footage that will be used for interactive maps, virtual tours and 2D videos, both within and separate to the virtual reality film. Both drones were operated according to the Australian Antarctic Division's environmental permit and CASA certified procedures.

"I don't fly over concentrations of wildlife, I always have an emergency landing point and I never lose visual contact with the drones," Dean said.

I was lucky enough to join the film crew, as they worked with the Davis station team to capture the sights and sounds of Antarctica by foot, boat and helicopter.

One of the first challenges was unloading and unpacking 158 kilograms of filming and technical equipment, and assembling it all. The next was lugging gear and survival packs to a range of locations, all while kitted out in full Antarctic survival clothing.

Among our first outings was a visit to a penguin colony with seabird ecologist Dr Louise Emmerson. We travelled in two boats, with Wilson taking prime position in the centre of one of the boats, as Louise talked about the biology of the birds and the impact climate change may have on them and their ecosystem.

Field Training Officer and coxswain, Marty Benevente, then dropped Louise, Phil, Briege and Wilson on an island, to conduct an interview overlooking one of the colonies Louise has been studying using remotely operated cameras. Later in the day, Dean launched Wilson on his large 30 kilogram drone (nicknamed 'The Kraken'), from an unpopulated island, and followed Louise, Briege and Phil in their boat as they navigated around icebergs and bergy bits.

We returned to the water a few days later to fly The Kraken across the face of the Sørsdal Glacier, to provide a dramatic backdrop to glaciologist Sarah Thompson's research. Sarah is part of a team monitoring the formation of lakes on the outlet glacier's surface over the past few years, to see if the drainage of meltwater has any effect on how fast the glacier slides over the bedrock below (*Australian Antarctic Magazine* 33: 12-13, 2017).

To capture the visual spectacle, Dean needed to launch The Kraken from two plastic tubs positioned at the front of the four-metre long boat, while Marty maintained position in the sea-sick inducing swell.

Dean expertly piloted the 1.5 metre wingspan drone away from the boat and above the glacier, monitoring what Wilson was seeing in real time using a GoPro attached to the drone. After 20 minutes of flying he guided The Kraken back to the boat, where he kept it hovering until he was able to catch it. Later, as we reviewed some of the footage, we were awed by towers of blue glacial ice and the cracks, crevasses and caverns that would be impossible to view any other way.

Wilson and the film crew also visited an elephant seal wallow with field biologists, helicoptered to the Sørsdal Glacier research site, took a station tour with the Station Leader, learnt about krill research, and looked at ice cores retrieved from Mount Brown during a 70-plus day drilling project (*Australian Antarctic Magazine* 33: 31, 2017).

The Antarctica experience will premier in June at the Western Australian Museum, before international distribution through Atlantic Productions and Seventh Gate Media. The virtual reality experience will also be available on every major hardware platform (such as the Apple store, Samsung, Oculus and HTC Vive) and at the Australian Antarctic Division.

One of the first things viewers will see is a drone's-eye view of Station Leader Robb Clifton, standing out the front of the station exclaiming "Welcome to Antarctica!"

We certainly experienced a warm welcome. Now hundreds of thousands more can experience it too.

WENDY PYPER
Australian Antarctic Division

2. *Dean prepares the Matrice 600 pro drone ('The Kraken') for a flight, with Wilson attached by a gimbal. The yellow foam was to keep the drone afloat if the worst happened. (Photo: Wendy Pyper)*

3. *Phil Harper (left) and Briege Whitehead (centre) talk about station activities with Station Leader Robb Clifton, prior to filming. Wilson (wearing a protective lens sleeve) looks on. (Photo: Wendy Pyper)*

4. *Phil Harper discusses the script for a scene on the Sørsdal Glacier with glaciologist Sarah Thompson, from the University of Swansea in the UK. (Photo: Wendy Pyper)*

Macquarie Island station goes virtual

Macquarie Island research station was captured in 360 degree virtual reality in March, to assist station redevelopment and provide a historical record of the current buildings.

Australian Antarctic Division Macquarie Island Modernisation Project Manager, Adrian Young, travelled to the sub-Antarctic island for a two weeks, with a team from Tasmanian business Sky Avenue Photography and Design.

Mr Young said the photographic team took 360 degree images from inside and outside the station and surrounding environment, and stitched these together to provide a virtual tour of the site.

"The tour will help the Australian Antarctic Division and the future Managing Contractor to prepare for the design and construction phase of the project, as well as the decommissioning of the current station buildings," Mr Young said.

"As access is limited, the virtual tour will be a valuable tool to help the Managing Contractor design the new station and understand how the existing facility operates."

The footage will also give the designers an understanding of the dynamic environmental conditions experienced on the island, especially those in which construction materials will need to be unloaded from the ship, transported to and on the island, and stored.

"We have to transport everything from the *Aurora Australis* to shore using LARCs [amphibious vehicles] or helicopters, often in challenging weather conditions. This will help them gain an understanding of how cargo operations are undertaken on the island," Mr Young said.

Over eight days, in between episodes of rain, wind and snow, Sky Avenue father-daughter team, David and Madeleine Rayward, used DSLR cameras with fish eye lenses to capture thousands of images of the site, and a small drone to provide aerial views.

Once stitched together, the images appear similar to those in Google Street View.

"The 360 degree imagery is superimposed on an aerial image, so you can see a clear view of the site and little hotspots for each building or location that you can click on," Mr Rayward said.

"When you click on a building it opens up and you can look around inside. There's also a navigation menu system for each building that directs you to different areas, like the kitchen or a scientific lab. You can also follow arrows around the floor or across the ground outside.

Mr Rayward said the pair took about 1350 photos to create 90 000 web files for the virtual tour.

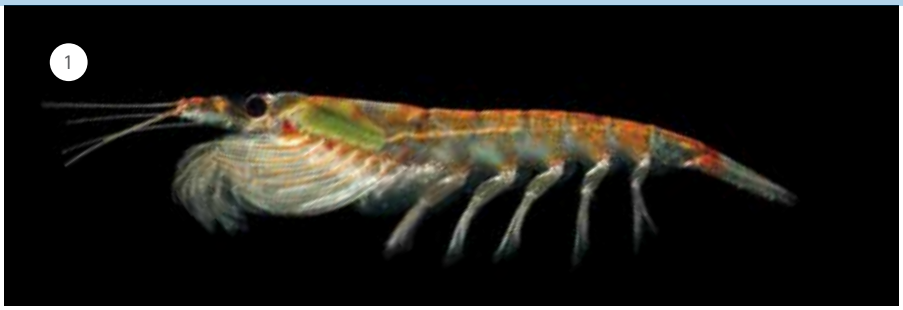
The tour will be viewable on mobile phones and desktop computers, as well as through virtual reality headsets.

WENDY PYPER
Australian Antarctic Division

1. *David (left) and Madeleine Rayward (front right) from Sky Avenue Photography and Design on Macquarie Island, working on the first 360 degree tour of the island's research station to assist the design and construction of a new station. (Photo: Chris Roulston)*
2. *Madeleine waits out the weather on Macquarie Island. (Photo: David Rayward)*

What have we learnt about krill?

Fifteen years ago, senior krill biologist Dr So Kawaguchi left his fisheries research job in Shimizu, Japan, to take up a position in "the best place in the world to study krill, with the world's best facility to do krill research".



Dr Kawaguchi's praise for the Australian Antarctic Division's krill aquarium has proved well founded. Since his appointment, Dr Kawaguchi and his team have significantly advanced scientific knowledge about the biology and behaviour of Antarctic krill (*Euphasia superba*), and contributed to a precautionary approach for the management of the Southern Ocean krill fishery through the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).

As one of only two krill aquariums in the world – the other is a public aquarium in Japan – it supports a large number of international collaborations, including with Germany, United Kingdom, United States, China, Japan, Poland and Korea.

Critical to the aquarium's success has been the ability to 'close the life cycle' of the crustacean – raising krill from egg to adult, through 12 larval stages – and maintaining them in conditions that support natural behaviour. These captive-bred krill supplement the 20 000 wild krill caught each year and enable experiments on specific life stages or animals of known age.

So how has the Australian aquarium advanced the collective understanding of krill?

Reproduction

To breed krill in captivity, scientists had to first develop a way of maintaining wild krill in healthy condition. The breakthrough came with a mechanism that enabled the aquarium water to be filtered at 20°C rather than 0°C. This increased the rate of gas exchange (adding oxygen and removing carbon dioxide) and the speed with which nutrients and waste products could be removed through a biologically active filter.

"These two advantages permitted the maintenance of more krill, and importantly, each individual could be fed a large amount of food, re-creating natural levels of food intake during krill maturation," Dr Kawaguchi said.

With these systems in place and krill successfully spawning, the team was able to build on the work of the Port of Nagoya Aquarium in Japan and extend their understanding of the reproductive process and how they might be able to manipulate it.

In Antarctica, krill experience four months of darkness over winter, between June and September. During this time they actually shrink in size and lose their mature reproductive characteristics – a process known as regression. As spring approaches and the day length and food supply increases, they begin to grow and become sexually mature again, before mating begins in December and continues until about February.

In 2003, Japanese research showed that abrupt changes in the daily cycle of light and dark could trigger maturation and spawning. Then in 2009, the Antarctic Division team showed that it was the timing of the period of complete darkness, rather than the changing light, which alters the reproductive cycle in krill.

"We found that the annual cycle of krill maturation and reproduction can be altered by a period of darkness immediately after spawning," Dr Kawaguchi said.

"We were able to reset the animals' internal clocks so that they became sexually mature three months earlier than if they were exposed to a natural Antarctic life cycle."

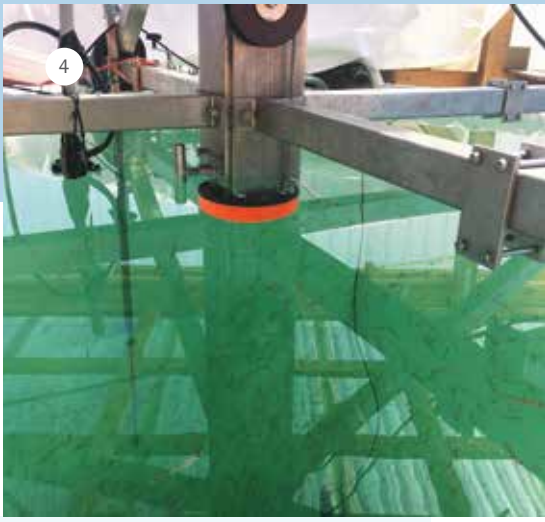
The discovery allowed scientists to control when different groups of krill spawn, so that they have access to all phases of the life cycle all year round, for experiments and breeding.

Scientists' understanding of the sex lives of krill took another leap forward in 2011 when, in a world first, video footage of krill mating in the wild was captured at 507 m depth (*Australian Antarctic Magazine* 20: 11, 2011). The sighting provided the first evidence that mating can take place near the sea floor.

"This research challenges the assumption that most krill live within the top 200 m of the ocean and suggests that deeper layers are significant habitat for krill," Dr Kawaguchi said.

1. *Antarctic krill is a keystone species of the Southern Ocean, providing food for many important and charismatic marine creatures, from fish to whales. (Photo: Rob King)*

2. *Dr So Kawaguchi monitors phytoplankton cultures fed to krill in the Australian Antarctic Division's krill aquarium. (Photo: Lucia Simion)*



Behaviour

Besides reproduction, another benchmark of healthy krill is the demonstration of natural behaviour.

In 2005 the Australian Antarctic Division aquarium managed to achieve repeated krill schooling behaviour in captivity. This means the team can now study the animals' natural behaviour and response to various stimuli, and collect more accurate information on their growth and metabolism.

"Krill are very social animals, but in captivity they tend to behave individually, rather than as a group, so the information you can gather from them is limited," aquarium manager and marine scientist, Mr Rob King, said.

"Normal behaviour, including schooling, means they should be physiologically normal, rather than stressed."

Observations and measurements made on schooling krill are important because the information is used in modelling for fisheries research. It also contributes to scientists' understanding of the interactions between krill, their predators, and the fishery, to improve krill fishery management under CCAMLR.

The team is now taking advantage of this success to conduct behavioural experiments using the latest camera and acoustic technologies.

3. Mr Rob King and Dr So Kawaguchi have managed to get krill to school in captivity. This natural, wild behaviour gives the research team confidence that experiments are being conducted on 'normal' krill. (Photo: Stephenie Cahalan)

Sound profile

The aquarium team has observed that when krill are feeding they swim around randomly, but when schooling, they swim faster, with their bodies close to horizontal and all pointing in the same direction. This information is important when measuring the abundance of krill at sea using acoustic 'echosounders'. These instruments send pulses of sound at different frequencies into the water and record the echo strength as the sound waves bounce off objects. However, as the echo-sounder is sensitive to the body orientation of the krill, the echo strength may be different depending on what the krill are doing. If they are swimming horizontally, for example, the echo strength will be far stronger than when the krill are more vertical.

"When we use an echo sounder to observe a krill swarm on a ship like the *Aurora Australis*, we want to be able to convert the signals received into the number of krill that make up the swarm," biological oceanographer Dr Martin Cox said.

"Modern echosounders use a range of frequencies and we don't know what krill look like at these different frequencies and when they're oriented differently to the source of the sound. To find out, we need to understand the reflection profile of an individual krill."

To do this, Dr Cox has developed a new aquarium experiment.

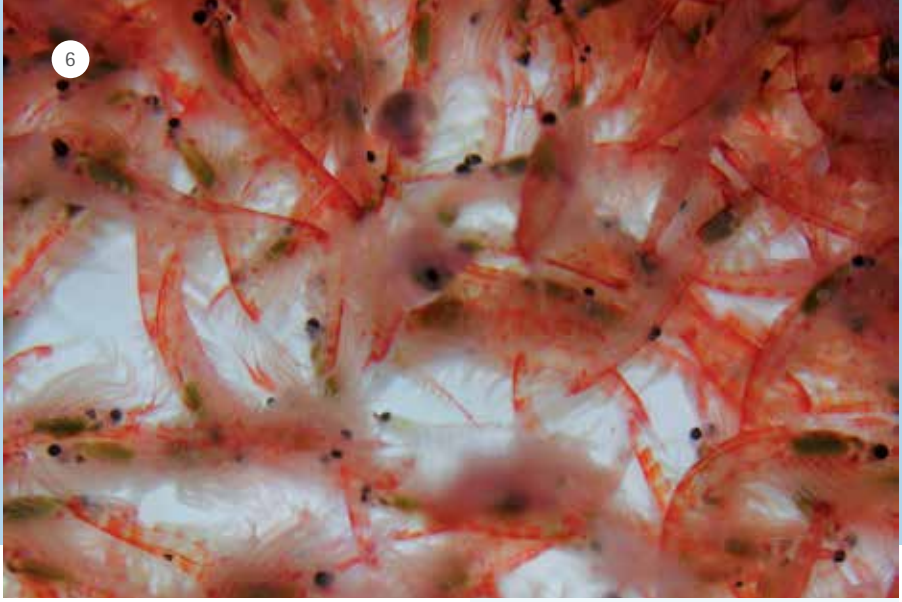
"We're taking individual krill of known lengths from the Antarctic Division's aquarium, putting them in a purpose-built tank and measuring the sound that bounces off them across a range of frequencies. At the same time we'll monitor their position with underwater cameras," Dr Cox said.

Based on each individual krill's sound profile, scientists will be able to scale up to determine the number of krill in a swarm. Dr Cox said the experimental results will also allow scientists to interpret data collected by krill fishing vessels.

"There are a lot of fishing boats that are using advanced echo sounders, but they often use them on a different frequency to the ones we have traditionally used and we don't have data on how krill reflect sound on these frequencies," he said.

"This work will ultimately enable more accurate measurements of krill density in the field, which is important for developing sustainable catch limits."

4. An echosounder and underwater camera are being used to identify the 'sound of krill'. The echosounder transmits pulses of acoustic energy into the water. When these hit the krill, the energy is reflected back, amplified and illustrated on a digital display. (Photo: Eliza Grey)



Lifespan

The question of how long krill live has been occupying scientists for decades, and was a focus of the 'father of modern krill research', Dr Tom Ikeda, when he joined the Australian Antarctic Division from Japan in 1982. During his five-year tenure Dr Ikeda undertook pioneering work on krill longevity that showed they lived longer than the conventional wisdom of 3-4 years, and more like 5-6 years in the wild. He also demonstrated that krill shrink in the absence of food.

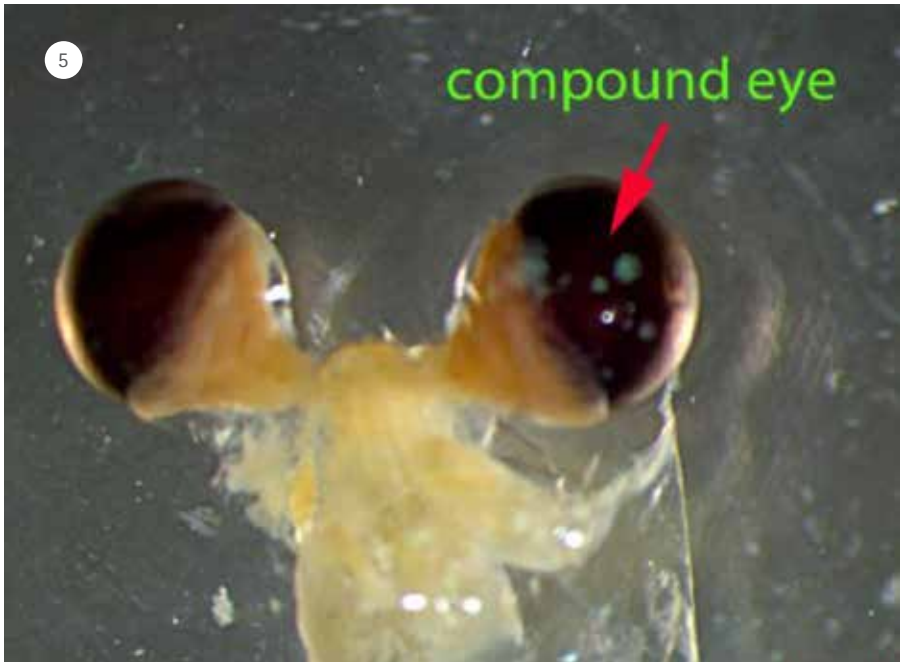
As a result of this quirk of nature, wild krill have proved difficult to age, adding a layer of complexity to krill fishery management. However, in early 2017, Dr Kawaguchi and collaborators from Canada, United States and Japan, showed that krill grow annual bands in their eyestalks, much like growth rings in trees, and that these correlate directly with their age.

There's almost no size difference in krill beyond two years of age, and their regular moult means they can actually shrink in size, depending on the time of year and food availability," Dr Kawaguchi said.

"Our research has shown that we can look at a longitudinal section of the eyestalk to identify the light and dark growth bands and count exactly how many years the specimen has been alive."

The age-based assessment methods will now provide information on stock structure to assist with determining catch limits and management options for the krill fishery through CCAMLR.

5. Antarctic Division scientists and international collaborators have shown that krill can be aged using annual growth bands in their eye stalks. (Photo: R. Kilada, University of New Brunswick)



Growth rates

To accommodate krills' ability to shrink and grow in size, Antarctic Division scientists have also recently developed a new model of krill productivity (growth and reproduction) to assist in sustainable krill fishery management.

The 'energetics and moult cycle model' couples the energy required from food for metabolism, growth and reproduction, and the constraints on growth during moulting – when krill shed and regrow their exoskeleton. The model also accounts for the effects of environmental change (temperature and food) on krill growth and reproduction.

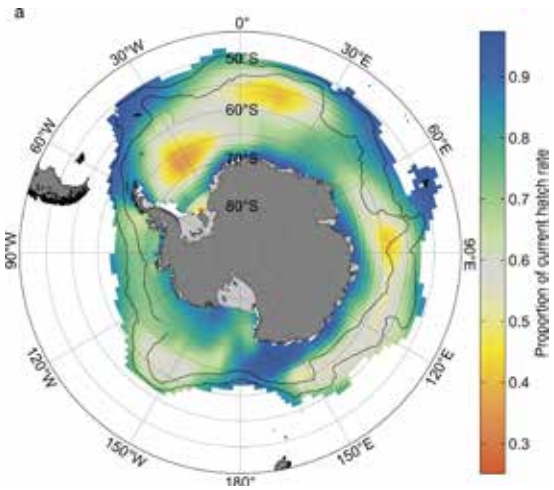
"The interaction between food, temperature and the moult cycle is important in determining growth and reproduction in Antarctic krill," Dr Kawaguchi said.

"The moult cycle physically limits the rates of shrinkage and growth in krill, and they can gain and lose weight within their exoskeleton. The extreme seasonality of the Antarctic means that reproduction is also dependent on food and whether the animals' reproductive organs are active after winter.

"Our new model is sensitive to variability in regional, inter- and intra-annual food and temperature, and allows projections of krill growth in future environments."

6. Research has shown that the interaction between food, temperature and the moult cycle (where krill shed their exoskeleton) is important in determining growth and reproduction. Scientists have developed a new 'energetics and moult cycle model' that accounts for these factors, to provide growth rates that assist in sustainable krill fishery management. (Photo: Steve Nicol)

7



8

Ocean acidification

As more carbon dioxide (CO_2) is pumped into the Earth's atmosphere through human activities, oceans around the world, and particularly the Southern Ocean, absorb large amounts of the gas. This sets up chemical reactions in seawater that lead to a gradual increase in the oceans' acidity.

For more than 10 years, Dr Kawaguchi and Mr King have been studying the effect of ocean acidification and other climate-related stressors on Antarctic krill reproduction and development. Their experiments have shown that if carbon emissions and ocean acidification continue unabated, krill reproduction and development could be significantly reduced by 2100 and the entire Southern Ocean population could collapse by 2300. Current atmospheric CO_2 levels are about 410 parts per million (ppm).

"We found egg hatch rates significantly decreased at CO_2 levels of or above 1250 ppm with almost no hatching at 1750 and 2000 ppm," Dr Kawaguchi said.

"We also found that embryonic development was significantly impaired if eggs are exposed to 1750 ppm during the first three days following spawning."

Risk maps developed by the team show that much of the present habitat for Antarctic krill will experience damagingly high CO_2 levels of above 1000 ppm by 2100 if emissions continue unchecked (*Australian Antarctic Magazine* 25: 4-5, 2013).

7. Ocean acidification experiments allowed Dr Kawaguchi and Mr King to develop this risk map showing krill egg hatching success in 2100 under the highest carbon dioxide emissions scenario. The Weddell Sea and the Haakon VII Sea are identified as the first areas where krill egg hatching success is most likely to be at risk (yellow-orange patches). (Graphic: AAD)

The results of this work will be incorporated into models of the dynamics of krill populations to assess the regional impacts of ocean acidification on the reproductive success of these populations. This information will be used to inform ecosystem and krill fishery management models under different carbon emission scenarios.

Genetic catalogue

Genetic technologies enable scientists to investigate a range of ecological questions about krill and other Antarctic animals, such as diet, population structure, and response to environmental stressors.

Molecular biologist, Dr Bruce Deagle, has been using krill DNA to determine whether different krill populations exist around Antarctica, and whether there is a genetic basis behind the sensitivity of krill to ocean acidification (*Australian Antarctic Magazine* 29: 6-7, 2015).

To look at population structure, Dr Deagle and his colleagues sequenced genetic markers across the krill genome, from krill collected from five areas of the Southern Ocean – covering the Atlantic, Pacific and Indian Ocean sectors. However, the team was unable to identify distinct DNA 'fingerprints' that would suggest the krill were from different populations.

"This supports the idea that there is a continuous flux of krill between regions carried by the Antarctic Circumpolar Current, and that genes are mixed before any regional genetic structuring develops," Dr Deagle said.

To examine the genetic response of krill to ocean acidification, Dr Deagle looked at how the expression of different genes change under different CO_2 concentrations. To do this he had to first create a detailed catalogue of krill genes (a 'transcriptome') through DNA sequencing.

While about 60 000 genes were already known from research by others, Dr Deagle's team, and colleagues from the Univeristy of Padova in Italy, identified at least another 80 000 (the transcriptome database is available online at http://krilldb.bio.unipd.it/).

"This catalogue is being used in several other projects at the Antarctic Division and internationally, looking at everything from how krill synchronise with their seasonal environment, to the mechanisms of krill sex determination," Dr Deagle said.

"We have now produced a web-accessible database to make this transcriptome information widely available."

By looking at the effect of CO_2 exposure on the expression of these genes, Dr Deagle has been able to identify a number that appear to be affected. These genes and their functions are still being investigated in krill aquarium experiments and by collaborators from the Alfred Wegener Institute in Germany.

8. Dr Deagle and his collaborators have produced a detailed catalogue of krill genes (a 'transcriptome') through DNA sequencing, and are now examining the effect of CO2 exposure on the expression of these genes. (Photo: Glenn Jacobson)

Fisheries management

Another aspect of the team's work involves analysing information on the size of krill catches and fishing fleet behaviour (where ships catch krill and for how long), which is voluntarily provided to CCAMLR by most member countries.

"You can't put scientific knowledge in place without understanding the commercial nature of the fishery," Dr Kawaguchi said.

"It is also important to understand fleet behaviour in relation to the krill predators' foraging ground. CCAMLR allows rational use of the resource, but we need to make sure that as the fishery develops it does not have any irreversible effect on the ecosystem."

Some krill boats have recently begun using new equipment that allows larger volumes of krill to be caught and processed efficiently. This will change the dynamics of how fishing fleets interact with the resource, and the impact on krill predators – something Dr Kawaguchi and his colleagues will monitor with interest.

9. Biologists using nets to collect small samples of krill from under the sea ice. (Photo: Wendy Pyper)

Catching krill for the future

Krill is collected from the wild for the Antarctic Division aquarium each year, using nets and a range of unique traps and pumps developed by Mr King and the Antarctic Division's Science Technical Support team.

Among the novel technologies tested were deep sea light traps and cameras, to see if krill were feeding at the sea floor, up to 5800 m below, and to bring samples to the surface.

In 2012 Mr King trialled a modified fish pump to suck 400 litres per minute of water from beneath the sea ice and run it across a filter table onboard the ship (*Australian Antarctic Magazine* 23: 9, 2012). While it sounds like a good way to turn krill to mush, the pump was much gentler on the animals than traditional zooplankton nets, and more than 95% of the krill captured were in good condition and survived.

Further trials and improvements since then have shown the technique is a viable way to catch krill and other fragile marine creatures in good condition for experiments. The work has resulted in the inclusion of a specially designed 'wet-well sampling space' in Australia's new icebreaker, currently under construction (*Australian Antarctic Magazine* 31: 7-8, 2016).

"In the wet well, water will gravity feed to large viewing tanks and filter tables," Mr King said.

"Adult and larval krill will end up at the end of these tables where we can collect them and transfer them to an aquarium, while more fragile organisms, such as jellyfish, can be collected from the viewing tanks.

"There are many fragile species that we know little about because only divers can collect them in perfect condition. The wet well should allow us to collect these creatures alive, so that, for the first time, we'll be able to study their growth rates, physiology, reproduction and behaviour."

Krill research at the Australian Antarctic Division has come a long way in 35 years, and the krill team is well placed to continue advancing research into this keystone Southern Ocean species into the future.

WENDY PYPER

Australian Antarctic Division

10. Dr Rob King trialling a fish pump to collect krill, onboard the Aurora Australis *in 2012. (Photo: Wendy Pyper)*

Antarctic krill break down microplastics

Antarctic krill are physically breaking down microplastics before excreting them back into the environment in an even smaller form, according to research published in Nature Communications *in March.*

The experiment, run at the Australian Antarctic Division's krill aquarium and led by Dr Amanda Dawson from Griffith University*, found krill have the ability to physically change the size of ingested microplastics and turn them into nanoplastics.

Australian Antarctic Division krill biologist and research co-author, Dr So Kawaguchi, said the experiment was the first time scientists have examined microplastics digested by the crustaceans.

"The Division's krill aquarium facility allowed us to alter the diet of the krill and study the digestion process as they ingested the microplastics," Dr Kawaguchi said.

"We found the krill have the ability to break the majority of the microplastics down into smaller fragments, effectively turning them into nanoplastics."

The study found all the experimental krill contained a mixture of whole polyethylene (PE) microplastic beads and PE fragments. The fragments were, on average, 78% smaller than the original beads, with some fragments reduced by 94% of their original diameter.

"It's a new pathway for microplastics to interact with the ecosystem that we need to learn more about," Dr Kawaguchi said.

Dr Dawson said the research fills important knowledge gaps regarding the abundance and likely impact of microplastics in the marine environment.

"The phenomena of digestive fragmentation has never before been reported in other planktonic crustaceans, despite the fact that many possess similar gastric mills and mouthparts designed for mechanical disruptions," she said.

The researchers also identified the potential for translocation (movement across biological membranes) to occur after an organism has physically altered the ingested plastics. As a result, evaluating the harmful effects of plastic pollution must account for the physical effects on organisms from macro and microplastic ingestion, as well as the potential cellular effects of nanoplastics.

Dr Kawaguchi said the research suggests that other zooplankton with a similar digestive system to krill may also be able to fragment microplastics into nanoplastics.

The experiment is one of many collaborative research efforts taking place in the Australian Antarctic Division's krill aquarium.

ELIZA GREY
Australian Antarctic Division

*Australian Antarctic Science Project 4037

1. *Chewy: Antarctic krill can convert ingested microplastics into smaller nanoplastics. (Photo: Brett Wilks)*

Wind accelerates glacial melt in East Antarctica

Strengthening winds over the Southern Ocean could cause the largest glacier in East Antarctica to melt faster, according to an international team of Australian Antarctic Program scientists.

The team's research on the Totten Glacier has shown changing wind speeds over the Southern Ocean drive an upwelling of warmer ocean waters off the Antarctic coast.

This warmer water then penetrates beneath the floating part of the glacier (the 'ice shelf'), causing the underside of the ice to melt and accelerate the flow of the glacier into the ocean.

Dr David Gwyther from the Institute for Marine and Antarctic Studies at the University of Tasmania, and a contributor to the new research, said the study combined satellite images of the ice sheet, wind stress data, and oceanography observations, to determine the chain of events that bring warm water to the Totten.

1. *Changing wind speeds over the Southern Ocean drive an upwelling of warmer ocean waters off the Antarctic coast. (Photo: Nick Roden)*

"Computer modelling shows that the atmosphere influences melting below East Antarctic ice shelves and affects the stability of the ice sheet," Dr Gwyther said.

"Our new research provides strong evidence of the mechanistic links of heat transfer from the atmosphere, via the ocean, all the way to the ice sheet.

"This study also suggests that as wind speeds over the Southern Ocean are projected to increase with climate change, the Totten Glacier will melt faster and contribute more to global sea level rise."

As the largest glacier in East Antarctica, the Totten Glacier has the potential to be a significant contributor to sea level rise. It drains 538 000 square kilometres of East Antarctica and discharges about 70 billion tonnes of ice each year.

Glaciologist Dr Jason Roberts, of the Australian Antarctic Division and Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC), said the new research explains variations in the presence of warm water beneath the glacier reported in previous studies (*Australian Antarctic Magazine* 28: 12, 2015)

"Periods of stronger wind push surface water aside, allowing deeper and warmer water to rise up – or upwell – and replace it," Dr Roberts said.

"This water can then flow into the shallower and colder seas of the continental shelf around Antarctica. In places such as the Totten Glacier, canyons in the sea floor allow this relatively warm water to penetrate deep under the floating ice and increase melting.

"The wind-driven upwelling explains why these submarine canyons get flushed with warm water in some years and cold water in others, and the subsequent variability in the melting of the Totten Glacier."

This summer, Australian Antarctic Division scientists recovered instruments deployed on the Totten Glacier in 2016-17, to measure changes in ice thickness and flow, and ocean-driven melting from below (see next story). The data will further refine understanding of the fundamental processes involved in ice shelf thinning.

The study, published in *Science Advances*, was led by Chad Greene of the University of Texas. Australia's contribution was funded through the Australian Research Council Antarctic Gateway Partnership and Australian Antarctic Division.

WENDY PYPER
Australian Antarctic Division

Seismic surprise on Totten Glacier

More of the Totten Glacier is floating on the ocean than previously thought, increasing its potential to contribute to global sea level rise.

2. Packed field equipment on the Totten Glacier. (Photo: Ben Galton-Fenzi)

Glaciologist, Dr Ben Galton-Fenzi, said the Totten Glacier is one of the fastest flowing and largest glaciers in Antarctica and, until now, satellite observations suggested that more of it was grounded on Antarctic bedrock.

As part of the Australian Antarctic Program*, Dr Galton-Fenzi's team of researchers, including scientists from the Australian Antarctic Division, University of Tasmania's Institute for Marine and Antarctic Studies, and the Central Washington University, spent the summer in Antarctica studying the glacier.

The team conducted a ground-based geophysical survey, using a hammer and plate system to send sound waves into the ice and geophones to 'listen' to the sound reflected back. The idea was to map the structure of the upper layers of ice, but the team got back more than they expected.

1. Scientists had to dig out a buried equipment tower and solar panel on the Totten Glacier, after heavy snowfall over winter. (Photo: Ben Galton-Fenzi)

"We were surprised the technique allowed us to see through up to two kilometres of ice and into the ocean beneath," Dr Galton-Fenzi said.

"When we conducted a geophysical test at a site on the glacier we'd previously thought was grounded on bedrock, we discovered there was ocean underneath – so the glacier was actually floating at that location."

Professor Paul Winberry from Central Washington University said if more of the glacier is floating on a warming ocean, it may help explain recent periods of accelerated melting and flow.

"It also means the Totten might be more sensitive to climate variations in the future," he said.

Dr Galton-Fenzi said the new geophysical data would improve the accuracy of models of the glacier's (and the broader ice sheet's) sensitivity to a warming climate. These models will in turn inform the placement of instruments on the Totten Glacier to best measure ice flow and thickness.

Next season the team plan to continue their geophysical survey using small quantities of explosives, rather than the hammer and plate system.

"Explosives will allow us to see right through to the bedrock below the glacier, so we can map the boundary where the ice sheet moves from being grounded, to a floating ice shelf," Dr Galton-Fenzi said.

The Totten Glacier contains enough ice to raise global sea levels by about three metres if it all melted. Since the 1900s the global sea-level has risen by about 20 centimetres and by the end of the century the Intergovernmental Panel on Climate Change projects it could rise by up to one metre or more, if global emissions of carbon dioxide continue unabated.

"These precise measurements of Totten Glacier are vital to monitoring changes and understanding them in the context of natural variations, and the research is an important step in assessing the potential impact on sea level under various future scenarios," Dr Galton-Fenzi said.

Instruments to measure the glacial flow, speed and thickness have been left on the glacier for another 12 months collecting data. The field season was supported by the Australian Antarctic Division and the Australian Research Council Antarctic Gateway Partnership.

ELIZA GREY and WENDY PYPER
Australian Antarctic Division

*Australian Antarctic Science Project 4287

Toothfish tagging program turns 21

More than 50 000 Patagonian toothfish have been tagged in the Heard Island and McDonald Islands (HIMI) fishery, as part of the longest running toothfish tagging program in the world.

After 21 years, scientists at the Australian Antarctic Division have gained valuable insights into the biology and movement of these long-lived monsters of the deep.

Fisheries scientist, Dr Dirk Welsford, said the tagging and survey program was started by Antarctic Division scientists in 1998, a year after the fishery started. Since then the Division has collaborated with industry and the Australian Fisheries Management Authority (AFMA) to tag about 2500 fish per year.

"The fishing companies run the vessels, and AFMA provide the permits and scientific observers on each vessel to monitor the catch and deploy the tags," Dr Welsford said.

"The Antarctic Division designs the scientific program, stores and analyses the data, and provides advice to the Commission for the Conservation of Antarctic Marine Living Resources, to assist them in setting sustainable catch limits for the fishery."

During fishing operations, the small plastic tags are attached near the dorsal fins of roughly two fish per three tonnes caught. When the tagged fish are re-caught years or decades later, they provide information on longevity, size, age and movement.

"We've found that the fish generally don't move much – no more than tens of kilometres – and often we'll pull up fish in the same numerical order in which they were tagged, so they seem to remain in their original habitat," Dr Welsford said.

"However a small percentage of fish do travel long distances. We've found some more than 3000 kilometres from their original capture and it's still a bit of a mystery as to why.

1. *The HIMI Patagonian toothfish fishery supplies markets in Australia, Japan, US, China and eastern Europe, and holds Marine Stewardship Council (MSC) accreditation that is supported by research and management. (Photo: AFMA)*

"The fish are also very robust, as they don't have a gas filled swim bladder, so they can survive capture from depths of over 2000 metres. They also tend to get bigger the deeper they live."

Recently, Dr Welsford's scientific team identified a 63 year old toothfish by the growth rings in its ear bones ('otoliths') – the oldest toothfish found so far.

"We've been collecting otoliths since the fishery started, as they help us understand growth and mortality rates, so that the stocks aren't fished too hard," he said.

"This is a good sign that the stock assessment strategy we're using is sustainable, as we wouldn't be finding such old fish if it wasn't."

In 2016-17 the total allowable catch for Patagonian toothfish in the HIMI fishery was 3405 tonnes and the fishery has held Marine Stewardship Council accreditation since 2012.

Dr Welsford credits the sustainability of the fishery with the collaborative approach to decision making, because "once you reach an agreement, everyone owns it".

However, there are still many questions that need to be answered, including whether there is a difference in the movement of large, older fish compared to small, younger ones; a difference that could affect the management strategy of the fishery.

As Patagonian toothfish move between Australian and French Exclusive Economic Zones in the HIMI region, scientists in both countries are also working together to share data and stock-structure models to account for fish that move across the 'line'.

Scientists are also looking at whether genetic technology that identifies relationships between individuals, such as parent and child (close-kin genetics), could provide additional and independent information about population structure.

"If the population is large, the chance that you'd find parents and children in a sample would be small, and vice versa," Dr Welsford said.

"The smaller and more related a population is, the smaller your catch should be.

"So this method could provide independent verification and validation of the answers we get from tags, and that our current stock assessment method is correct."

The Antarctic Division is now applying the knowledge gained in the HIMI Patagonian toothfish fishery to the multi-national Antarctic toothfish fishery - working with the five other countries that currently fish for toothfish, to tag and age fish.

"From our experience in the HIMI fishery, we are optimistic this pathway can lead to a sustainable fishery in the long term," Dr Welsford said.

WENDY PYPER
Australian Antarctic Division

2. *A scientific observer measures a Patagonian toothfish captured in the HIMI fishery. (Photo: AFMA)*

Deepening understanding of the Antarctic toothfish gene pool

An international team of scientists is investigating the gene pool of Antarctic toothfish in an effort to better conserve the species.

As part of a collaborative project, scientists from nine countries will collect tissue samples from toothfish in the Southern Ocean, which will be analysed using the latest DNA genotyping techniques at the Australian Antarctic Division.

The Antarctic Division's fisheries research assistant, Dale Maschette, spent two months in the Southern Ocean earlier this year, on a fishing vessel operated by Australian Longline Pty Ltd.

He collected tissue samples and recorded the weight, sex and maturity of some 2800 toothfish, from the research catch allocated to the Australian vessel.

"Antarctic toothfish in the Ross Sea, Amundsen Sea and East Antarctica are often thought to be from different gene pools, but no one has examined, in the detail that we will, where the fish stock boundaries are," Mr Maschette said.

"DNA genotyping of the samples will allow us to identify hundreds of genetic markers, which means we'll be able to determine the population structure of the toothfish around the Antarctic continent.

"From a fisheries management perspective, it's important to know the make-up of the different stocks. This will help to ensure that the approach by the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) to managing these fisheries is ecologically sustainable in the long term."

CCAMLR takes a precautionary approach to setting catch limits and the East Antarctic fishery currently has a catch limit of 587 tonnes.

The research is supported by funding from the Fisheries Research and Development Corporation on behalf of the Australian Government and commercial fishing company, Australian Longline Pty Ltd, with in-kind support from the Australian Antarctic Division.

ELIZA GREY

Australian Antarctic Division

1. *Antarctic toothfish can exceed 100 kg in weight and live for over 50 years. (Photo: AFMA)*

2. *Australian Antarctic Division fisheries research assistant, Dale Maschette, is helping to analyse the genetic makeup of Antarctic toothfish populations. (Photo: Dale Maschette)*

Hot and cold collaboration drives energy efficiency

A new collaboration bringing expertise and technology from the hot deserts of the United Arab Emirates to the cold desert of Antarctica, aims to improve energy efficiency at Australia's Antarctic research stations.

Michel Abi Saab, Manager of Sustainability at Masdar – an energy efficiency and renewable energy company based in Abu Dhabi – visited Casey research station in February, accompanied by Australian Antarctic Division Infrastructure Engineer, David Waterhouse.

Together the pair surveyed energy and water use on the station and options for savings.

"We did a qualitative survey of electricity consumption for domestic, industrial and scientific purposes, and on our heating systems and water use," Mr Waterhouse said.

"Most of our buildings are 30 years old, and while everything works, technology and the philosophy of resource use has moved on."

The pair found a range of potential savings, including consolidating functions currently housed in multiple small buildings into fewer large buildings, replacing conventional lights with LEDs, replacing tap fittings with modern low-flow ones, reducing temperature set points in buildings, and using variable speed drives for fans and pumps.

While some of these changes are already underway or planned, others are more difficult to implement because of the age of control systems used to run some infrastructure.

"We use hot water to transfer heat from the main powerhouse to buildings around our stations, and you can control the speed of flow based on the heating demand," Mr Waterhouse said.

"At the moment we pump water around at a fixed speed, but if we varied the speed to fit with demand we could reduce the energy the pump is consuming. However, we need good data logging and analysis capabilities to optimise such a change, and our ageing building control systems have limited capacity to do this."

These and other issues will be examined in a report by Mr Abi Saab, so that Masdar and the Antarctic Division can identify the forms further collaboration on energy efficiency will take.

As part of the new relationship, the Masdar Insititute, which is part of the Khalifa University of Science and Technology, will also collaborate on a sea ice research project.

Australian Antarctic Division Director, Dr Nick Gales, said the project would be led by the Masdar Institute's Dr Marouane Temimi, an expert in the development of information on weather and water processes, through the use of remote sensing and geographic information systems. Dr Temimi will work with leading sea ice researchers from the Australian Antarctic Division and the Antarctic Climate and Ecosystems Cooperative Research Centre.

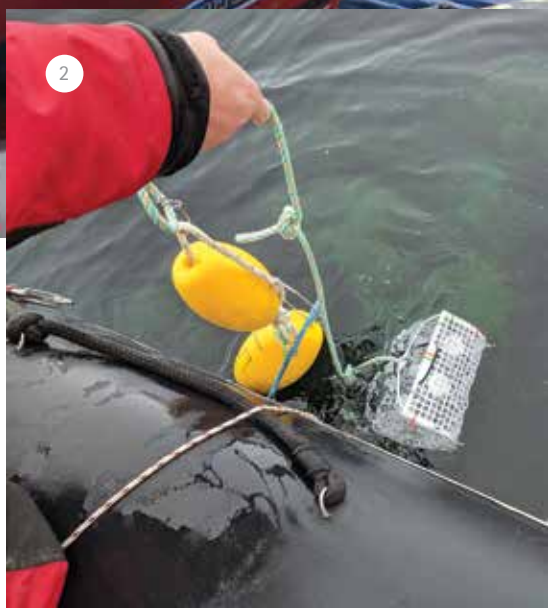
"The sea ice research project aims to combine the latest advances in remote sensing, data assimilation and forecasting, to better understand the effects of climate change on the characteristics and behaviour of Antarctic sea ice," Dr Gales said.

"We hope that this work will be an important step towards an improved ability to forecast future sea ice coverage from a scientific, operational and shipping perspective."

The collaboration was formally agreed in January through the signing of a Letter of Intent by Chief Executive Officer of Masdar, Mohamed Jameel Al Ramahi, Australia's Ambassador to the United Arab Emirates, Mr Arthur Spyrou, on behalf of the Australian Antarctic Division, and Dr Arif Sultan Al Hammadi, Interim Executive Vice President, Khalifa University of Science and Technology.

WENDY PYPER and ELIZA GREY
Australian Antarctic Division

1. *A collaboration between the Australian Antarctic Division and Abu Dhabi-based company, Masdar, is looking at energy efficiency options for ageing power generation infrastructure at Australia's Antarctic stations. (Photo: Vas Georgiou)*
2. *Service piping transfers heat and water around Australia's Antarctic stations. (Photo: Nisha Harris)*



Measuring metal pollution in the Antarctic environment

A device that measures metal contaminants in the environment, could help scientists to better assess the risks that metals pose to Antarctic organisms.

The device, known as DGT (Diffusive Gradients in Thin films), has previously been used to measure contaminants in Antarctica, as well as tropical and temperate environments.

For the first time at Casey research station last summer, a team, led by Professor Dianne Jolley of the University of Wollongong,* aimed to test the device in the Antarctic environment and correlate metal concentrations measured by the device, with toxicity to Antarctic organisms.

"There are some sites in Antarctica where human activities have left a legacy of metal and other contaminants," Professor Jolley said.

"Metals may be locked up in soil in mineral form and unavailable to organisms, or they may occur as ions that are free to interact with the environment.

"We want to understand what concentration of these metals are free or 'bioavailable'. Once we know this, we may be able to predict how toxic the metals are to organisms living in those environments.

"This information will allow metal concentration thresholds to be established which, if exceeded, will trigger decisions on whether a site should be remediated."

While DGT could provide a way to measure these bioavailable metal ions, Dr Jolley said the team also needed to conduct further tests on the device's performance in extreme temperatures, and confirm its suitability in field and laboratory-based applications.

The team was specifically looking at five metals – copper, cadmium, nickel, lead and zinc – which occur in fuels, and historic general tip waste, old laboratory and photography chemicals, and batteries.

University of Wollongong PhD student, Darren Koppel, helped deploy DGTs in nearshore waters and freshwater melt streams, and collected soils and sediments for testing in the laboratory. Testing sites were selected from contaminated, partially remediated and pristine areas, to reflect the broad range of site conditions and potential metal concentrations.

Mr Koppel said the DGTs are effectively a three-layered sandwich that is applied to wet samples.

"The first layer is filter paper that only lets dissolved metals pass through," he explained.

"The second layer is a water-based gel that sets up a gradient to facilitate the diffusion of dissolved contaminants. The final layer is a resin that binds the specific metal ions that we're studying."

1. *Teams working with Dr Dianne Jolley and Dr Catherine King collect water samples for metal analysis off Casey research station this summer. (Photo: Evelyn Sandoval)*

2. *Marine DGT probes were moored in place for up to 30 days, to measure metals in the marine environment at contaminated and pristine sites around Casey. (Photo: Darren Koppel)*

To measure contaminants in nearshore environments around Casey, the team put DGTs in plastic baskets and moored them in place with a buoy. For soils, samples were taken back to the laboratory and wetted down, and probes were placed on their surface.

To measure contaminants in marine sediments, cricket-bat shaped DGTs were placed in large containers of marine sediment and seawater in the laboratory, or in fresh meltwater streams in the field.

The bat shape allows the sediment DGTs to measure a depth profile of the metals – from the overlying water to a sediment depth of about 10 cm. The interface between the sediment and surface water is where many organisms dwell and feed, and much of the chemistry happens.

"One of the aims of this project was to see how useful DGTs are in the polar environment," Mr Koppel said.

"We had some challenges with the sea ice at our marine sites, which moved some of the DGT moorings and we lost two of the 11 that we deployed.

"As temperatures changed over the summer months we also found that some melt streams froze over during the experiment, making the DGTs inoperable."

The devices were collected after one to two weeks in soils and sediments, and four weeks in waters, and the binding resins were removed. The resins are now being analysed for the five metal concentrations. The results will reflect the free metal concentrations that are available, over time, to interact with organisms.

"We've also taken samples of the sediments, soils and waters to look at the total concentration of metals in each, so that we can compare that to the concentrations measured by the DGTs," Mr Koppel said.

"This will allow us to judge how much biologically available metal is leaching into the environment and potentially posing a risk to Antarctic organisms."

If the DGTs function well in Antarctic conditions, the team will be able to compare the results with research on toxicity thresholds for a range of Antarctic organisms.

This ecotoxicological research has been conducted by a team at the Australian Antarctic Division, led by Dr Catherine King†, over the past 10 years.

Dr King's team has been assessing the toxicity of a range of contaminants on marine and terrestrial Antarctic organisms (*Australian Antarctic Magazine* 27: 3, 2014). This season they continued tests with the five metals, individually and in mixtures, on an aquatic micro-invertebrate and a moss collected from areas where the DGTs were deployed.

"If the DGTs are found to be suitable for Antarctic conditions, we'll be able to deploy them at suspected sites of contamination to see if there's a risk of toxicity to the organisms living there," Dr King said.

"They will be a useful addition to our current ecotoxicology tool kit, and will provide a further line of evidence to direct our remediation activities and prioritise sites for clean-up."

WENDY PYPER

Australian Antarctic Division

*Australian Antarctic Science Project 4326

†Australian Antarctic Science Project 4100

3. Cricket-bat shaped sediment DGT probes deployed in a meltwater stream at Casey research station. (Photo: Darren Koppel)

4. a: Sediment DGT probes in the field, measure the depth profile of bioavailable contaminants, and b: in marine sediment in the laboratory. (Photos: Darren Koppel)

Noisy sperm whales forage to the beat

Underwater listening devices moored off East Antarctica have captured a cacophony of sperm whale clicks as they hunt prey during summer and autumn.

Australian Antarctic Division acoustician, Dr Brian Miller, and consulting ecologist Dr Elanor Miller, made the chance discovery while reviewing six years of acoustic recordings made for a blue whale and fin whale study.

They found thousands of hours of loud 'usual clicks', which have the regular, even beat of a metronome, and are used to echolocate prey such as fish and squid.

"Sperm whales have four types of vocalisations – slow clicks, usual clicks, creaks and codas," Dr Brian Miller said.

"Slow clicks and codas are thought to be linked to communication, while usual clicks and creaks are linked with echolocation and foraging.

"Usual clicks are produced about 80 per cent of the time the whales are underwater, which makes the whales very easy to detect acoustically."

Faced with more than 46 000 hours of recording data from moorings deployed at three sites off East Antarctica, the pair wrote an algorithm to detect when sperm whale clicks occurred in the recordings. This reduced the length of recordings to be manually checked to 1065 hours.

"The recordings showed that sperm whales were only present in summer and autumn in the Antarctic and they departed our study sites when sea ice became heavy," Dr Miller said.

"We also found that that the whales predominantly foraged during daylight hours and were silent at night, possibly due to the behaviour of their prey.

"This is the first study to directly measure the seasonal presence and daily behaviour of sperm whales in Antarctica."

The recordings were made using equipment designed and built by the Australian Antarctic Division Science Technical Support team.

Electronics Design Engineer, Mark Milnes, said ocean sounds are detected by a hydrophone and recorded on to SD cards inside a vacuum-sealed glass chamber, which can withstand 0°C water temperature at depths of up to 3500 metres. The recorder can run continuously for more than a year.

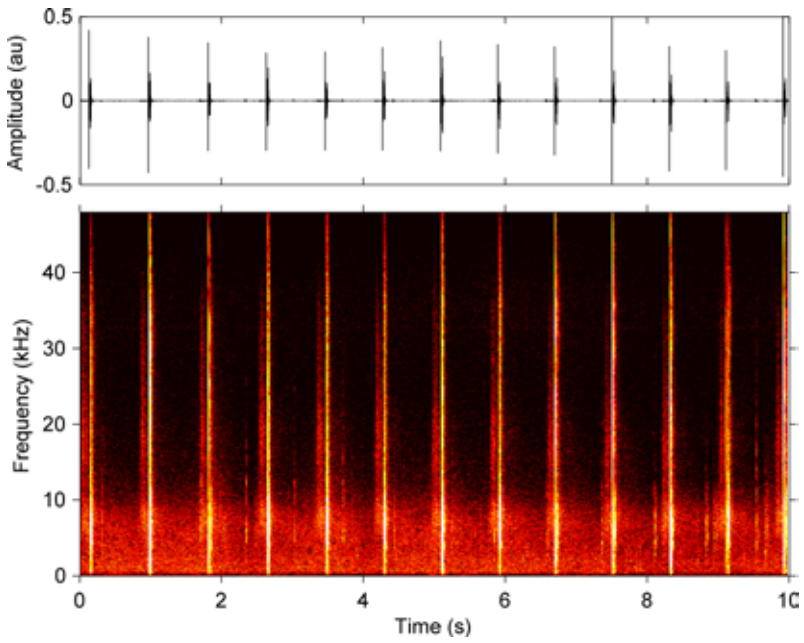
"The glass recording chamber sits within a specially constructed frame that can be easily deployed and retrieved from the rear deck of the *Aurora Australis* during resupply voyages," Mr Milnes said.

"Weights keep the frame grounded on the sea floor, while buoys keep the mooring upright and eventually allow it to float to the surface when an acoustic release from the weights is triggered. When the mooring reaches the surface, a satellite beacon provides a GPS location to the ship."

Sperm whales are noisy animals, making them easier to study with acoustic instruments than to look for them visually

The first acoustic recordings of sperm whale sounds in Antarctica has shown that the whales are present in summer and autumn but depart the region once winter sets in. Only adult male sperm whales travel as far south as Antarctica. (Photo: ©Elanor Miller)

The regular beat of a sperm whale's 'usual clicks'. Click repetition rates vary, but are usually within 0.5–2 seconds (twice per second to once every two seconds). (Photo: Brian Miller)



The technology has enabled scientists to gain new insights into the behaviour and ecology of sperm whales in the Antarctica. Sperm whales are a key predator in the Southern Ocean ecosystem and the work will inform environmental management decisions for this vulnerable species.

"These studies are an important stepping stone for measuring the number of sperm whales using Antarctic waters," Dr Miller said.

"As acoustic technology continues to develop, our ability to glean information from these underwater recording devices is going to improve.

"This is frontier science and we're potentially hearing things that have never been heard before."

The research was published in *Scientific Reports* in April.

WENDY PYPER
Australian Antarctic Division

The crew of the Aurora Australis *retrieve a moored acoustic recorder from the Southern Ocean. The moorings remain in place for more than a year, continually recording whale sounds. (Photo: Gerard O'Doherty)*

Antarctic microbes living on air

Microorganisms survive in frozen, nutrient-poor Antarctic soils by scavenging trace gases from the atmosphere for energy and cell growth, according to research published in the journal Nature in December.

The finding suggests that if atmospheric gases can support life on Earth, they could support life on other planets.

With the support of the Australian Antarctic Program, the research team, led by the University of New South Wales (UNSW), used genetic and biochemical techniques to show that many Antarctic soil microbes use atmospheric hydrogen, carbon dioxide and carbon monoxide to survive.

Senior author of the research, UNSW Associate Professor Belinda Ferrari*, said that until now, it was unclear how Antarctic soil microbes survived with limited water and soil carbon (for growth and reproduction) and no or limited ability to produce energy from the sun.

"We found that Antarctic microbes have evolved mechanisms to live on air instead, and they can get most of the energy and carbon they need by scavenging trace atmospheric gases, including hydrogen and carbon monoxide," Associate Professor Ferrari said.

Soil samples were collected from Robinson Ridge near Casey research station, and Adams Flat, about 240 kilometres from Davis research station. The team then analysed the community structure and the presence and activity of genes that confer the ability to use trace gases for energy.

They found the dominant species in the soils had genes that gave them a high affinity for hydrogen and carbon monoxide, allowing them to remove the trace gases from the air at a high enough rate to sustain their predicted energy needs and support growth.

"This new understanding about how life can still exist in physically extreme and nutrient-starved environments like Antarctica opens up the possibility of atmospheric gases supporting life on other planets," Associate Professor Ferrari said.

Further research is needed to see if the use of atmospheric gases as an alternative energy source is more widespread in Antarctica and elsewhere.

WENDY PYPER

Australian Antarctic Division

*Australian Antarctic Science Project 4406

1. *Adams Flat is a sediment-filled glacial valley near Davis station and home to microbes that can live on air. (Photo: Robert Isaac)*
2. *The Australian Antarctic Program supported research at Casey (pictured) and Davis that found that soil microbes in the region use atmospheric hydrogen, carbon monoxide and carbon dioxide as both energy and carbon sources. (Photo: Nisha Harris)*

Tom Maggs

Photo: Glenn Jacobson

A champion for the Antarctic environment

Tom Maggs was a long-serving Australian Antarctic Division staff member, a regular contributor to this publication, and a well-known Antarctican. Sadly, Tom passed away on 24 December 2017. His loss has been felt deeply by the Antarctic community in Australia and overseas. The following articles pay tribute to a much-loved husband, father, friend and colleague.

When I was invited to write an article about Tom, I was in equal parts enthusiastic and daunted. Anyone who had the great fortune to meet Tom will agree that his was a life worth celebrating, but that he was not someone whose character and achievements can be easily or succinctly described on paper. It only took a few a moments of being in Tom's company to get some of the 'big picture' parts – generous, humble, enthusiastic, larrikin, professional, greenie, devoted dad – but, like most humans, he was a complex and layered soul. So I was pleased, and somewhat relieved when the editor agreed it would be fitting to focus on Tom's role and contributions in the protection and management of Antarctica's environment; an area in which Tom had work responsibilities, a keen personal interest, and a great passion.

I met Tom shortly after my arrival in Tasmania in 1999, to study at the then Institute of Antarctic and Southern Ocean Studies. I couldn't help but be drawn in the direction of the engaging and somewhat furry bloke from the Australian Antarctic Division, who had presented some lectures on Antarctica's environmental protection. When a tentative email query about a possible thesis project was met with an almost immediate, enthusiastic and – typical of Tom – humorous response, I knew I was onto a good thing. When I later had the opportunity to work for Tom at the Antarctic Division, I couldn't have been more delighted.

When we first met, Tom had been the Antarctic Division's Environmental Manager for several years, and he continued in the role for more than a decade. Tom's prior experience of wintering in Antarctica on several occasions, including as a station leader, meant that he was well placed to reality-check proposed environmental policies and practices – will that actually work down south? Working for Tom I quickly came to realise that environmental management is mostly about managing people, and that played to some of Tom's strengths. He was a great communicator, a keen listener, and he loved working in teams to nut through curly issues. ("PDW", he would often say – for 'pas de wuckers', a fantastically Tom-esque intermingling of Australian slang and French, for 'no worries').

Tom's first role as Environmental Manager was to set up and lead the new Environmental Management Section at the Antarctic Division, which aimed to support the Division and Australia to meet the obligations arising from an international agreement called the Protocol on Environmental Protection to the Antarctic Treaty. Australia had been instrumental in developing the Environmental Protocol, so the Environmental Management Section had an important and high-profile role; one that Tom recognised and tackled with characteristic understated professionalism.

As the Minister's delegate for many matters under several Australian laws, Tom had ultimate responsibility for authorising the activities of Australians in Antarctica, and for ensuring their proposals – dozens each year – would reflect Australia's international commitment to comprehensively protect Antarctica as a natural reserve. Again, Tom's Antarctic experience and people skills were crucial. He worked with people to help them understand how to avoid or minimise impacts, rather than looking to throw the book at them if it all went pear-shaped.

Tom was always contemplating how things could be done differently, to achieve a better environmental outcome. As an example, he championed the replacement of individually bottled soft drink on stations with bulk post-mix. Probably not the most popular of suggestions initially, but one that Tom massaged through, meaning that tens of thousands of bottles do not make the round-trip to Australia's stations each year.

1. *Tom (second from left) on a tea break at Mawson, 1980. (Photo: Syd Kirkby)*

Tom's loss is deeply felt by the Australian and international Antarctic community

A broader example is Tom's championing of an Environmental Management System (EMS), to support the Antarctic Division to continually improve its environmental performance. When the EMS was established in 2002, Australia became the first country with a national Antarctic program certified to the relevant international standard. This was an example of the way Tom's positive influence extended beyond the Australian sphere, and contributed to the nation's standing in the international community.

Tom also made significant contributions through his work with other countries active in Antarctica, as Australia's representative over many years to the Antarctic Committee for Environmental Protection (CEP). In that role, Tom was the face and voice of Australia. He was highly respected for his experience and knowledge of the southern continent, and his willingness and ability to bring people, and countries, together. Tom organised successful professional exchanges, giving environmental managers from other countries valuable first-hand experience of Australia's Antarctic activities. He also represented Australia in several formal inspections of other Antarctic stations.

One of my favourite CEP-related memories of Tom is from the meeting in Cape Town in 2004. One evening we came across a male choral group, in the style of Ladysmith Black Mambazo, giving an energetic performance at the waterfront. Afterwards Tom, as he was wont to do, went up for chat and bought the CD. On perusing the cover over dinner, he noticed a contact number. "Let's get these blokes" he suggested, and following a slightly clunky phone conversation, he had lined up the basis for a most memorable CEP reception. Tom keenly understood that fostering close personal connections between the national representatives – who threw off their suit jackets, enjoyed each other's company, and probably took the chance to work through some of those curly issues – can only promote the international cooperation essential for achieving outcomes in Antarctica.

I reached out to some CEP colleagues in other countries when Tom passed away. They were devastated, recognising that we had all lost a very good man, who had made significant contributions to Antarctica. One recalled having praised Tom's tie, upon which he was immediately gifted the tie direct from Tom's neck. One expressed hope that we can all carry on Tom's passion for the environment and social justice, and his wonderful kindness. Another poignantly recalled Tom as a good friend to many people around the world.

I will remember Tom for so many reasons – the 'deep and meaningful' chats over breakfast, his all-stops-pulled-out and loving approach to raising his kids, the fact that he isn't in the group photograph from my wedding because he had gone ahead to set up drinks for the reception. But he should also be remembered by us all for the lasting legacy he leaves in the positive environmental culture of the Antarctic Division, and for Australia's high standing among the nations working together the keep Antarctica protected. As Tom would have said, "well done that man"...very well done indeed.

EWAN McIVOR

Senior Environmental Policy Adviser, Australian Antarctic Division, and Chair, Committee for Environmental Protection

2. Tom (left) during an Antarctic Treaty inspection of Japan's Syowa Station in 2010. (Photo: Tom Maggs).

A humble, generous and gifted man

Tom Maggs was already a veteran of the icy south when I first met him in 1987, as he prepared to leave Hobart for his third Antarctic winter. In contrast, I had just started a desk job at headquarters, and knew very little about where Tom was headed or what happened there.

One thing I had learned was that in the unique community of people who work for the Australian Antarctic Program, or ANARE (Australian National Antarctic Research Expeditions) as we knew it then, an Antarctic wintering expeditioner is top dog, and highest bragging rights go to those who have spent more than one winter there.

Tom's ANARE star shone bright in 1987. Having twice wintered at Mawson station, he was about to enter the rarefied ranks of three-time winterers, this time as station leader at Casey. But no-one would have known it; to all outward appearances, Tom was just one of the lads.

Greg Corbin, a friend of Tom's since their childhood in Melbourne, revealed at his funeral service in January that Tom was a ranking officer in his school's cadet corps – something that came as a surprise to me. It shouldn't have been; Tom was unquestionably a leader.

As Greg described it, Tom's leadership style was not top-down, but from within his group. Over many years I saw that in operation, while working alongside him in our policy, planning and information branch. He was a facilitator, an encourager, getting results without making a fuss.

At Tom's farewell service, his daughters Bonnie and Georgina gave eloquent testimony to those same qualities at home: to his warmth and good humour and his unconditional love for them.

1. *Tom shared a strong bond with the huskies at Mawson in the 1970s, where he was a sledge dog handler and radio operator. (Expeditioner photo)*

There were other loves, epitomised in two winters at Mawson in the 1970s where, besides being the radio operator, Tom served as sledge dog handler. At that time Mawson was the only station with dogs, which is why he returned there for a second stint.

Tom was a wonderful communicator. ANARE veteran Shelagh Robinson provided the perfect vehicle for three of Tom's passions – words, dogs and the great outdoors – in a book she edited to celebrate Australia's Antarctic dogs, *Huskies In Harness*, published in 1995.

Take these reflections on an autumn sledging trip to Fold Island, west of Mawson ["Fold Island, black and white, May 1977"]. The first is about the obstinate refusal of his lead dog, Dan, to turn left as ordered to get them to their destination, a hut named Alice's Restaurant:

> What is humble pie? Humble pie is when half a million years of walking upright, using tools, and landing on the moon does not make you any smarter than a dog.... God knows where we would have finished had he obeyed our commands.... As the sledge slowed to a halt on the slope, the boys [dogs] sat puffing and gulping snow, and we stared silently in the gloom at the little red box with the sign "Alice's Restaurant", right in front of us.

Then the return to base:

> Remember that final run up towards the doglines... the trudge trudge trudge delivering dogs to their place on the lines and clipping them on. Removing their harness for the last time that trip, rubbing them down, hugging and being hugged, oblivious to that incessant tongue and that wet salty nose. Looking over your shoulder at those magnificent animals as you walk up to Shacko at the end of the day for a shower; and sitting there quietly before bed that night, clean and fed, hearing the jingle of a chain in the distance, and trying to find words for it all.

He found the words well enough. I wish I had such a gift. I am proud to have known this warm, humble, generous man and sad indeed that he is lost to us.

PETER BOYER

Peter Boyer managed the Australian Antarctic Division's public information services from the late 1980s to 2002. He now writes a weekly column in the Hobart Mercury *on the science and politics of climate change.*

Robert John Tingey

(1940–2017)

Robert (Bob) John Tingey, a prominent Antarctic scientist and Australian Antarctic Medal recipient, passed away on the 17th November 2017 after a long battle with Parkinson's disease.

Bob joined the Bureau of Mineral Resources in 1966, answering an advertisement for geophysicists for Antarctic service, and was promptly offered a position in the Bureau's Port Moresby office. However, after several years working in Papua New Guinea, the Antarctic finally called.

For many years Bob led the Bureau's Antarctic Program, overseeing and participating in major field mapping campaigns in remote areas; places rarely visited even today. He participated in seven field seasons in Antarctica and had several geographic features named after him*, including Tingey Rocks in the western Amery region, Tingey Nunataks in Enderby Land and the Tingey Glacier in the southern Prince Charles Mountains.

Bob recognised the value of international collaborations in the Antarctic, in particular with the then Soviet Antarctic Expeditions, which resulted in a number of joint publications including the Australian Geological Survey Organisation bulletin *Geology of the Prince Charles Mountains*. Bob fostered much international respect and was regularly invited to present keynote talks at International Antarctic conferences. He served as Secretary of the Scientific Committee of Antarctic Research Working Group on Geology for eight years, standing down in 1988 due to poor health.

In 1990 Bob received the coveted Australian Antarctic Medal for services to Australia's Antarctic Program, in part due to his seminal work, *The Geology of Antarctica* (1991), a comprehensive volume compassing all geological disciplines and eras, from the Archaean to the Holocene. This volume still stands as an authoritative stocktake of Antarctica geology.

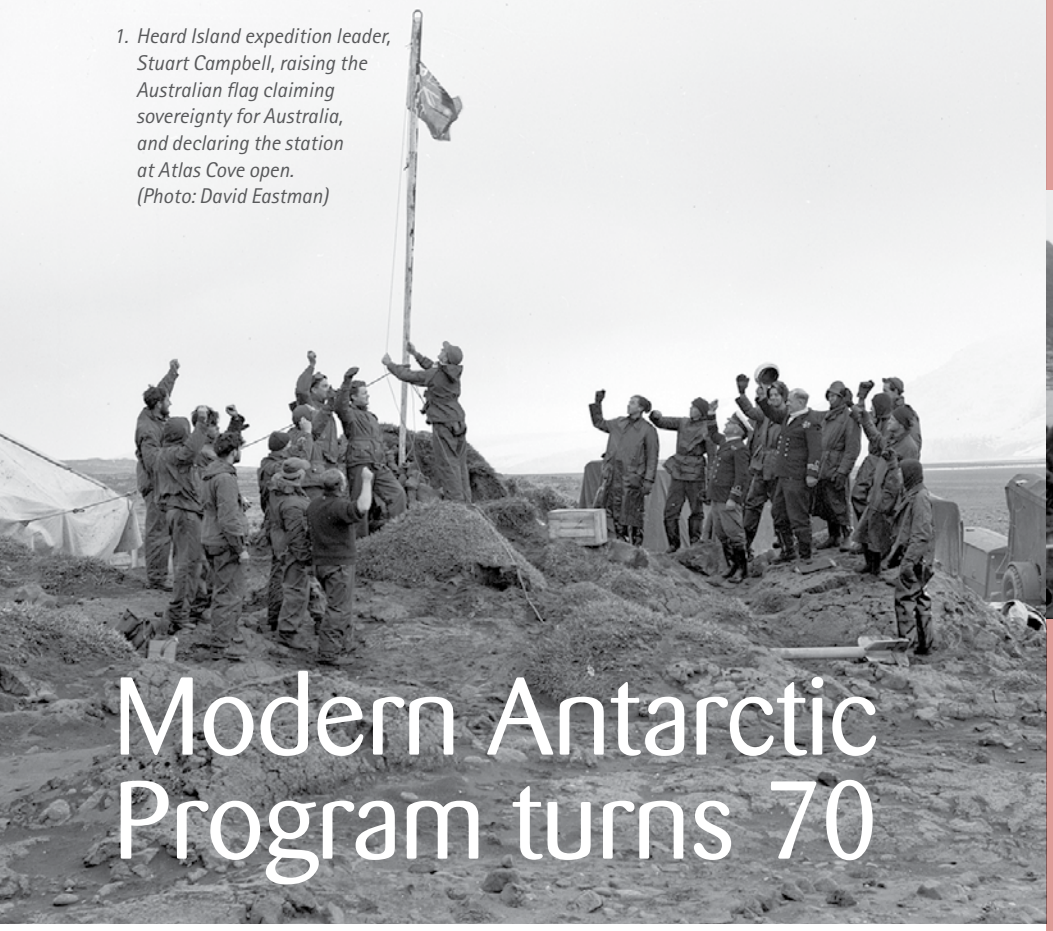
After 30 years Bob retired from the Bureau of Mineral Resources in 1996, due to Parkinson's disease, but his passion and enthusiasm for geology and the Antarctic remained, and he always took an interest in Geoscience Australia's Antarctic activities.

More recently, Bob was a valued contributor to Geoscience Australia's Antarctic Field Notebook Citizen Science Transcription project (see page 30). His presence during all of the project's major events greatly enriched the project and we are grateful to Bob, his wife Nancy and the Tingey family for their support and enthusiasm in ensuring that Bob's Antarctic legacy lives on.

CHRIS CARSON and JANE BLACK
Geoscience Australia

**View an interactive map of geographic features in Antarctica named after Geoscience Australia employees at* http://geoscience-au.maps.arcgis.com/apps/OnePane/storytelling_basic/index.html?appid=bb956e835f44421da9160b7557ba64a6

1. *Geologist Bob Tingey collecting samples at Proclamation Island (Enderby Land) in 1977. Enderby Land contains some of the world's oldest rocks, providing glimpses into the evolution of the very early Earth. Bob edited the seminal work,* The Geology of Antarctica, *which provides an authoritative stocktake of Antarctic geology. (Photo: Bob Tingey/Geoscience Australia)*



1. *Heard Island expedition leader, Stuart Campbell, raising the Australian flag claiming sovereignty for Australia, and declaring the station at Atlas Cove open. (Photo: David Eastman)*

Modern Antarctic Program turns 70

Just over 70 years ago, the maiden expedition of Australia's Antarctic Program established the first of the nation's research stations in the southern polar region.

Australian Antarctic Division Director, Dr Nick Gales, said the 1947 Heard Island expedition marked the beginning of Australia's permanent presence in the region.

"After the Second World War, Australian heroic era explorer Sir Douglas Mawson lobbied the Government to build on his early exploration of the continent and undertake expeditions to Antarctica and establish permanent stations there," Dr Gales said.

"The Government agreed and funded three scientific expeditions over the summer of 1947–48 to the sub-Antarctic Heard Island, Macquarie Island, and the Antarctic continent."

The 14-strong team bound for the wild and rugged Heard Island was the first to leave Australia, departing Fremantle on 28 November 1947.

The expedition sailed across the Southern Ocean on a Royal Australian Navy ship (HMALST 3501), laying claim to Heard Island and McDonald Islands and establishing a research station at Atlas Cove, which operated until 1955.

"These early expeditioners faced harsh conditions with rain three days out of four, temperatures hovering between -1°C and 5°C and an average wind speed of about 30 kilometres per hour," Dr Gales said.

A second expedition set sail for Antarctica on HMAS *Wyatt Earp* in December 1947, however mechanical problems, bad weather and sea ice stopped the voyage from reaching the icy continent.

The third voyage that summer was to Macquarie Island, with an expedition landing on 7 March 1948.

Despite not being able to reach the Antarctic continent in 1947, Australia pushed ahead with plans to establish a permanent presence on the ice, and in 1954 Mawson research station was commissioned.

"Seven decades on, we now have three Antarctic research stations and one on sub-Antarctic Macquarie Island, an air link between Antarctica and Australia, and a state-of-the-art icebreaker under construction," Dr Gales said.

The Australian Antarctic Program was originally known as the Australian National Antarctic Research Expedition (ANARE).

ELIZA GREY

Australian Antarctic Division

2. *Landing stores at Garden Bay, Macquarie Island, on 20 March 1949, with LST 3501 in the distance. (Photo: Peter King)*

Celebrating 70 years on Macquarie Island

Macquarie Island research station celebrated its 70th anniversary in March, as scoping work began for a new station on the shores of the rugged Tasmanian outpost.

The sub-Antarctic station was officially opened on 21 March 1948, with a team of 14 expeditioners staying for winter.

Prior to the station's establishment, Macquarie Island was home to sealing gangs who harvested skins, oil and blubber, until the island was declared a sanctuary by the Tasmanian Government in 1919.

Unfortunately the sealers and other visitors brought pests to the island, in the form of rabbits, rats and mice. These were successfully eradicated in 2014 after a seven year pest eradication program.

In 2016 the Australian Government announced it would spend $50 million to build a new state-of-the-art research station on Macquarie Island. The new station is expected to be finished in 2021–22, with the decommissioning of the existing station to follow.

The primary focus of construction will be to minimise the station's physical size, simplify and reduce long-term station maintenance, and incorporate new technologies such as automation of long-term science projects.

The sub-Antarctic island is named after an early governor of New South Wales, Lachlan Macquarie when it was discovered by sealing brig, *Perseverance*.

ELIZA GREY

Australian Antarctic Division

1. *Geoscience Australia's Antarctic field notebook citizen scientist transcribers and retired Antarctic geologists at a luncheon at Red Hill, Canberra, celebrating a successful completion of the transcription project.*

   L-R Back Row: John Van Der Heul, Bev McLeod, Ian McLeod, David Trail Teresa Van Der Heul, Nancy Tingey, Sam Tingey, Marie Davidson, Ross Davidson, Ian Barwell, David Ellis, Lance Black.

   L-R Front Row: Chris Carson, Jane Black, John Bain. (Photo: Jane Black)

Transcribing Antarctic geological history

Thanks to the efforts of volunteer citizen scientist transcribers, Geoscience Australia's geological Antarctic field notebook collection is now available for all to access and enjoy.

The aim of the collaborative project between the Geoscience Australia Library and Antarctic Geoscience team, was to make the notebooks discoverable, accessible and reusable to a worldwide audience (see *Australian Antarctic Magazine* 31: 25, 2016).

Over five and a half months, 57 online volunteers from around Australia worked on the Australian Museum's DigiVol website to transcribe 87 field notebooks, containing nearly 5500 pages of detailed observations, geological sketches and photographs of Antarctica. The bulk of the transcriptions were then validated across the next 10 months by retired geologist Ian Barwell. This rigorous two-step process ensured that the final transcriptions reflected a high level of accuracy and scientific robustness.

The scans of the notebooks and accompanying transcriptions are available from several locations on the internet, including Geoscience Australia's eCat portal, the Biodiversity Heritage Library and through the Geoscience Australia Library catalogue (see box).

Accompanying the transcribed notebooks is a series of short films featuring interviews with the original geologists, who bring the content of the notebooks to life through their reminiscences of their time on the frozen continent. Local geologists David Trail, Ian McLeod, Bob Tingey and John Bain, have been enthusiastic supporters of the project, and their involvement in the milestone events and interviews have enriched the project.

The Antarctic field notebooks project is Geoscience Australia's first formal citizen science project partnering with the public. The success of the project highlighted the valuable part that volunteers can play in unlocking scientific data and in making existing knowledge more accessible and discoverable.

The volunteers also benefited from the experience.

"The major satisfaction that I attained from working on the Antarctic notebooks was that I played a small part in making the work that these geologists had undertaken in Antarctica 50 to 60 years ago, available to the rest of the world," volunteer Teresa Van Der Heul said.

"[It was] an honour to put the notes to print, so that others may also read them; so that our great grandchildren and beyond will know the sacrifices that certain people went through to make the world such a great place to live in," volunteer Ian Barwell said.

The Antarctic field notebooks are now available to a new generation of Antarctic scientists from around the world.

JANE BLACK and CHRIS CARSON
Geoscience Australia

View the notebooks online

Geoscience Australia's geological Antarctic Field Notebooks are available to view online.

On the Geoscience Australia website (https://ecat.ga.gov.au/geonetwork/srv/eng/search) each notebook record contains:

- PDF scans of the original notebooks
- PDF of the notebook transcription
- CSV file with TEI (Text Encoding Initiative) tags of transcription

Search for the notebooks in the search field using the terms 'Antarctica' and 'notebook'.

The Biodiversity Heritage Library site will eventually display all 87 notebooks and 31 are currently available (https://www.biodiversitylibrary.org/browse/collection/GeoscienceAustraliaNotebooks).

Juarez Viegas from the US Atmospheric Radiation Measurement program launches a radiosonde from the deck of the Aurora Australis. *(Photo: Doug Thost)*

Cloud study success

Australian and American scientists collected vast amounts of information on clouds, aerosols and precipitation across the Southern Ocean last summer, for the US Atmospheric Radiation Measurement program.

During four voyages aboard the Aurora Australis teams:

- installed and operated 64 ship-based instruments;
- deployed some 600 radiosondes (weather balloons), with launches occurring four times every day; and
- collected more than 100 terabytes of atmospheric data.

Twelve US technicians came out to Hobart to install and commission the instruments in October 2017 and eight returned to decommission the instruments in March 2018. Three technicians travelled on each voyage to keep the 'ones and zeroes' flowing.

The voyage allowed scientists to collect a large and unique dataset, including as the ship traversed the sea ice. Australian Antarctic Division scientists, along with those from numerous national and international research institutes and universities have begun the data analyses, with early results to be available soon..

This research was supported by Australian Antarctic Science Project 4292 and previously featured in *Australian Antarctic Magazine* 33: 8-9 (2017).

SIMON ALEXANDER
Science Branch, Australian Antarctic Division

Antarctic inspired architecture

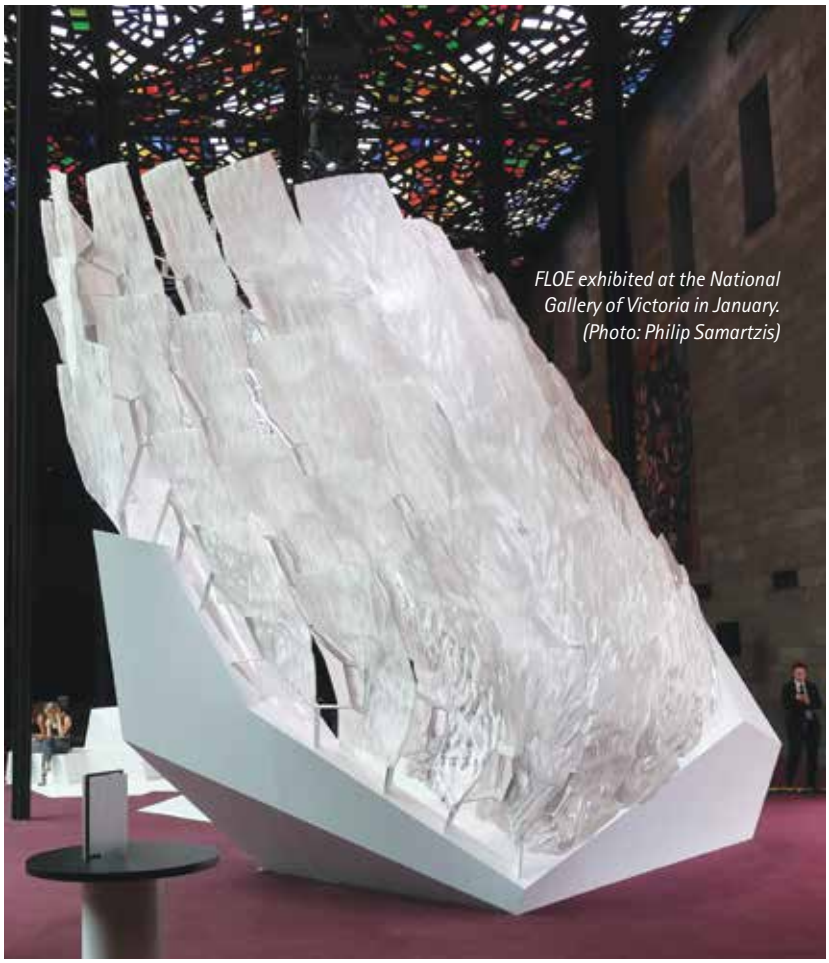
Former Australian Antarctic Arts Fellow and sound artist, Philip Samartzis, and architect Roland Snooks, developed an Antarctic-inspired art installation for the National Gallery of Victoria's Triennial Extra Festival in January.

The installation, titled *FLOE*, included sounds Philip recorded in Antarctica of "constantly shifting ice shelves, glaciers, icebergs and sea ice". These sounds inspired Roland, Director of the RMIT Architectural Robotics Lab, to design an ice tower made of 70 overlapping, translucent polymer panels, which were 3D printed by a robot (see image).

Gallery visitors were invited to step inside the installation for a visually and aurally immersive experience of Antarctica, which the artists hoped would challenge their perception of Antarctica as "an unchanging landscape, suspended in time and place".

Philip's sound and video recordings from Davis research station also featured in an exhibition of sound and vision called *Super Field* at the RMIT Design Hub in January and February. The exhibition explored social, economic and environmental concerns affecting isolated regions and communities.

Read more about Philip's Antarctic work at http://www.antarctica.gov.au/about-antarctica/antarctic-arts-fellowship/alumni/2000-2009/philip-samartzis-2009 and his website http://bogongsound.com.au/



FLOE exhibited at the National Gallery of Victoria in January. (Photo: Philip Samartzis)

(Photo: ANMM)

Heroic era walking stick

A carved timber walking stick made from the plank of Douglas Mawson's ship, SY *Aurora*, was recently gifted to the Australian National Maritime Museum.

The museum received the gift from Mr Geoff Truscott, in response to a blog about the 100th anniversary commemoration of the loss of the *Aurora* at Newcastle Cathedral in June 2017 (*Australian Antarctic Magazine* 32: 30, 2017).

Mr Truscott's father had acquired the stick, however, how he acquired it and the link with its purported maker, Brown, is unknown.

The walking stick is made from a piece of planking souvenired from below the waterline while the ship was undergoing repairs at the Williamstown Dock (Victoria) in October 1913, prior to the *Aurora*'s third voyage to Antarctica to rescue Douglas Mawson and his small party who had remained at Commonwealth Bay.

The walking stick carries the following inscriptions; 'From bottom plank of the SS *Aurora* before leaving for the South Pole Expdn'(sic), and 'Docked at Williamstown Dock Vic 18-10-1913'.

The name of H. C. Brown is carved into the stick; allegedly the maker and thought to be a shipyard worker at the Williamstown Dock.

The walking stick now joins other rare physical remnants from SY *Aurora*, including the powerfully symbolic lifebuoy, the Royal Thames Yacht Club Burgee and the ship's wheel.

DAVID DODD
ANARE Club

The site of the paved runway near Davis research staton. (Photo: Andrew Garner)

Building Antarctica's first paved runway

The Australian Government has announced its intention to construct a paved runway near Davis research station, subject to environmental approvals.

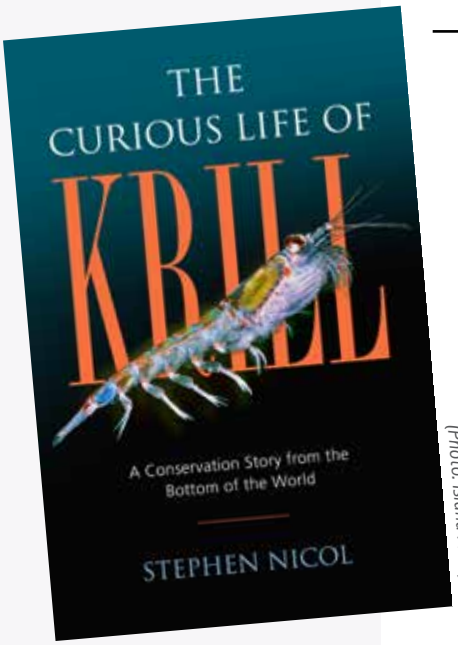
The new runway will complement Australia's existing summer-only ice runway at Wilkins Aerodrome, near Casey research station, and will provide more reliable access to Antarctica throughout the year, improving our ability to conduct year-round, world-class scientific research and respond to emergencies.

The runway will be almost 5000 kilometres from Hobart, with a flight time of around six hours, and 1400 kilometres from Wilkins Aerodrome. It will be 2700 metres long, based on the length required by large commercial aircraft.

The project will be subject to extensive environmental and other government approval processes, including to meet the requirements of the *Antarctic Treaty (Environment Protection) Act 1980* and the *Environment Protection and Biodiversity Conservation Act 1999.*

The runway is part of the Government's commitment to a new era of Antarctic endeavour and will integrate with the new state-of-the-art icebreaker, RSV *Nuyina*, an expanding overland traverse capability, replacement station on Macquarie Island and new Antarctic science funding announced in the recent budget.

Read more at http://www.antarctica.gov.au/living-and-working/travel-and-logistics/aviation/New-Davis-Runway



(Photo: Island Press)

The Curious Life of Krill

Dr Stephen Nicol, a former research scientist and program leader at the Australian Antarctic Division, has turned his 24 years of experience working with Antarctic krill into an engaging and accessible story about this globally important but poorly understood species.

In *The Curious Life of Krill*, Dr Nicol takes readers into the crustaceans' underwater habitat, observing their life and habits first-hand, and revealing the critical role they play in the Antarctic ecosystem and how, in an era of climate change, they need our protection.

Described as insightful, humorous, personal and thought-provoking, *The Curious Life of Krill* is a valuable contribution to human understanding of these incredible creatures. The book was published by Island Press in May (https://islandpress.org/book/the-curious-life-of-krill).

PHOTO MARK BAKER

SHANE BILSTON

Freeze Frame

Mawson station plumber, Shane Bilston, captured this 'Happy Feet' moment of emperor penguins at Auster Rookery. Shane was lying on the ice when the curious birds wandered up to him. Not wanting to take his gloves off, he had the camera sitting on the ice and was randomly pushing the shutter button. Shane used an Olympus Tough point and shoot camera set on auto mode. The photo makes him smile every time he sees it.

Shane Bilston was one of the two wintering plumbers at Mawson Research Station in 2017, responsible for the water supply, waste management, heating and fire services. This was his first trip to Antarctica, in complete contrast to his normal plumbing job in Broome, Western Australia. Shane loves to travel and has now finally achieved his ambition of living and working on all seven continents.

ANTARCTICA
valued, protected and understood

Australian Government
Department of the Environment and Energy
Australian Antarctic Division

AUSTRALIAN ANTARCTIC PROGRAM

www.antarctica.gov.au