

2019 *the* UPDATE 8th ed.

CHOOSING MATHS EDUCATION

*From the cities to the bush:
supporting our teachers*

BEAUTY IN NUMBERS

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poetry and launching SMRI*

UPPING THE RUN RATE

*Econometrics, cricket and why Gary
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AMSI MEMBERSHIP**FULL MEMBERS**

La Trobe University
 Monash University
 Queensland University of Technology
 RMIT University
 The Australian National University
 The University of Adelaide
 The University of Melbourne
 The University of New South Wales
 The University of Newcastle
 The University of Queensland
 The University of Sydney
 The University of Western Australia

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 The University of New England
 University of South Australia
 University of Southern Queensland
 University of Tasmania
 University of Technology, Sydney
 University of Wollongong
 Victoria University
 Western Sydney University

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 Australian Mathematics Trust
 Australian Mathematical Society
 ABACBS
 ANZIAM
 Bureau of Meteorology
 CSIRO
 DST Group
 MERGA
 Reserve Bank of Australia
 Statistical Society of Australia

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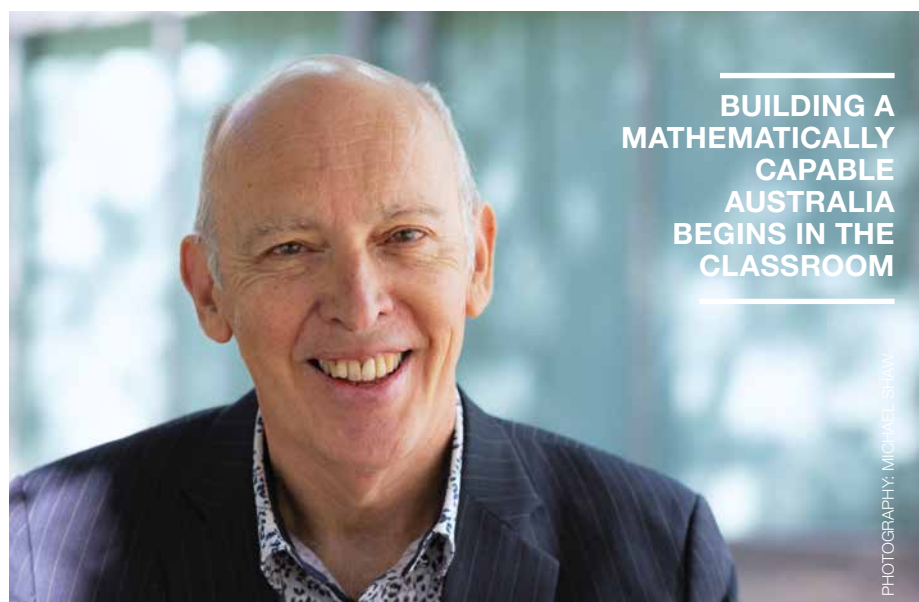
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Welcome to the eighth issue of the Update and my first as AMSI Director.

It has been a marvellous first month in the job, particularly the chance to meet with AMSI staff members individually and gain deeper understanding of all areas of the organisation. Also high on my agenda, I look forward to visiting all member universities within the first four months. One of the big tasks ahead is to refresh AMSI's strategy leading to the May Board meeting. Our membership will play a critical role in this process.

On reading this issue, I was once again struck by the breadth and depth of AMSI's impact from education to research and industry. This pipeline impact is what makes AMSI so effective in providing a national voice for mathematics and statistics. A role that has never been more critical, as we seek to skill Australia for the future and protect prosperity and well-being.

Building a mathematically capable Australia begins in the classroom. To be future ready, we need to equip today's students with an understanding of the fundamental concepts, context and applications of mathematics. This issue features an in-depth showcase of the powerful impacts of AMSI's Choose Maths project. AMSI Outreach Officer, Helen Booth shares what she's learnt working with teachers and students in regional and remote SA and WA schools, while Deputy Principal, Brian Birrell,

reveals the powerful impact Choose Maths has had on Port Hedland Primary School.

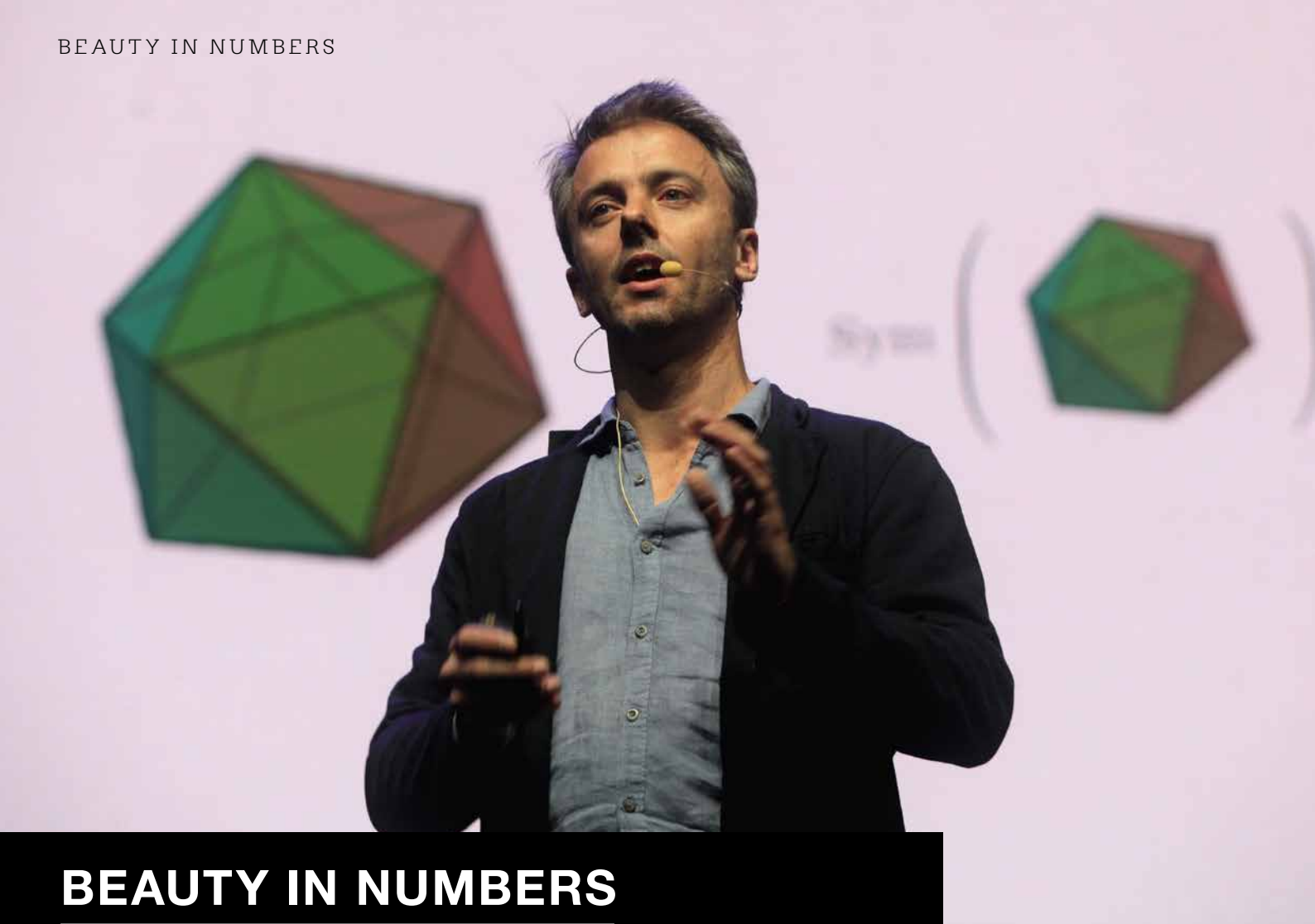
Further along the pipeline we chat with Australian mathematics and statistics research leaders Professor Geordie Williamson and Professor Kate Smith-Miles about the beauty of numbers and why now is the most exciting time to be in mathematics and statistics.

At the frontline of strengthening research-industry collaboration, APR.Intern is placing Australian STEM PhDs in industry to complement research expertise with industry skills and experience. Director of APR.Intern and Melbourne Enterprise Professor, Gary Hogan AM talks about his vision for the program and plans for 2019.

Also, in this issue, Professor Jerzy Filar and Dr Matthew Holden take us into the world of natural resource mathematics and its role in maintaining and managing natural systems in the face of threats such as climate change and habitat destruction.

I would like to end my first Update message by acknowledging my predecessor, Professor Geoff Prince. His retirement in 2018 leaves very big shoes to fill and an indelible impact on AMSI and the Australian mathematical sciences. I look forward to building on Geoff's extraordinary legacy to ensure AMSI continues to provide a national voice for mathematics and statistics at every stage of the pipeline. Happy reading.

Professor Tim Brown



BEAUTY IN NUMBERS

Geordie Williamson talks maths, poetry and launching SMRI

By Laura Watson

Professor Georgie Williamson has had a busy year. Not only has he been setting up the new Sydney Mathematical Research Institute (SMRI) at the University of Sydney, but he's been gathering awards and accolades too, most recently the Australian Mathematical Society Medal.

Acknowledged as the world leader in modular representation theory, Professor Georgie Williamson's work addresses the most fundamental questions in representation theory, transforming the field and opening up new questions. For the past half century, fundamental yet unproved conjectures, including Lusztig's and James' conjectures, underpinned much of the work in representation theory. Georgie's paradigm-breaking series of counterexamples to the expected bounds in Lusztig's 1980 conjecture about reductive groups also invalidated James' 1990 conjecture. In collaboration with others, he followed up this breakthrough with the remarkable achievement of a new character formula for irreducible representations of reductive groups

in characteristic p , replacing Lusztig's disproved conjecture, and providing an unconditional proof of a correction of Lusztig's character formula whenever p is at least $2h-2$. This extraordinary result provided a new framework for thinking about these conjectures, thus opening the field of modular representations to new ideas. On another front, Williamson has collaborated with Lusztig to develop a new approach for such questions. Their conjecture, supported by the available computer evidence, would imply the striking consequence that the modular decomposition numbers for the symmetric groups grow at least exponentially.

Geordie's breakthroughs have not gone unnoticed – in 2018 alone, he was elected both Fellow of the Royal Society (where he is also the youngest living Fellow) and Fellow of the Australian Academy of Science, and was the first mathematician working in Australia to give a plenary address at the International Congress of Mathematicians.

In 2017 he shared the New Horizons in Mathematics Prize, worth \$US100,000, with Ben Elias from the University of Oregon, ⇒

and in 2016 he received the Clay Research Award, the European Mathematical Society Prize and the Chevalley Prize of the American Mathematical Society.

After a number of years with Max Planck Institute in Bonn, Geordie returned to Australia in 2017 to head the new SMRI after accepting a mathematics professorship with the University of Sydney. Following a similar researcher-in-residence model as the Max Planck Institute, the institute will increase the number of international mathematicians researching in Australia.

IT WOULD BE FAIR TO SAY 2018 HAS BEEN A BIG YEAR FOR YOU, WHAT DO YOU CONSIDER YOUR BIGGEST HIGHLIGHT?

Giving a talk in front of so many great mathematicians in Rio was a major highlight. Barry Mazur calls mathematics “the world’s longest conversation”, and I love this phrase. Sometimes we work for decades just to be able to make one small remark at the big round table of mathematics.

Probably the biggest highlight is launching the new Sydney Mathematical Research Institute. It has been a dream of mine for some time to be involved in such an institute in Australia. That it happened so fast was a big, and very pleasant, surprise. I think it has great potential ... now we need to get to work!

CAN YOU TELL US ABOUT ONE OF THE OUTSTANDING PROBLEMS IN YOUR FIELD?

We have this tremendously useful and versatile theory of representations of finite groups over the real or complex numbers. However, over fields of positive characteristic (like finite fields) the classical theory breaks down. For about a century, a few visionaries have suspected that there is also a beautiful theory there, that lies much deeper than the theory over the complex numbers. Potentially we are on the verge of knowing what this theory is. Fascinating connections to number theory are also emerging.

HOW IMPORTANT IS COLLABORATION TO YOUR WORK IN MATHEMATICS?

Collaboration is an extremely important part of my research. I’ve learnt more from my collaborators than I’ve learnt from books or papers. It is an honour to be able to work with such amazing people. Certainly, the most useful parts of conferences for me are the coffee breaks and walks.

WHAT ARE THE BENEFITS OF BRINGING INTERNATIONAL MATHEMATICIANS TO AUSTRALIA FOR EXTENDED RESEARCH?

The benefits will be threefold: mathematical research in Australia will grow and develop; the reputation of Australian mathematics world-wide will increase; and the institute will help foster integration within Australian mathematics. The Institute supports visits to any

Australian university to carry out research, and visits to multiple destinations are encouraged.

AUSTRALIAN HIGH SCHOOL MATHS PARTICIPATION REMAINS LOW. IS A LACK OF AWARENESS OF ITS IMPACT A FACTOR?

These statistics are very concerning. I can’t really comment on why this is happening as I’ve been outside of Australia for most of the last 15 years. There is certainly a lack of appreciation in our society both for the beauty of mathematics, and for the extent to which our world is becoming reliant upon mathematics. I would like to see this change.

WHAT DO YOU THINK NEEDS TO BE DONE TO TRANSFORM THE WAY MATHS IS VIEWED BY THE AVERAGE AUSTRALIAN?

My feeling is that a cultural change needs to take place. A friend commented recently to me that many are taught in school to hate maths. Perhaps there is some truth to that, sad as it may be. How do we fix this? Many people have thought more about this than I have,

but my two cent’s worth: one can work on showing the general public the joy of mathematics (with small sudoku-like problems, with fun and humour) at the same time as showing the bigger picture (how does google work? How secure is the internet?).

WOMEN ARE UNDER-REPRESENTED IN THE MATHEMATICAL SCIENCES. HOW CAN THIS BE IMPROVED?

This is a cultural phenomenon. For example, the representation of women in the mathematical sciences does vary dramatically between different countries. How does one fix this? One obvious potential fix is to hire more women in senior roles in academia. There are numerous examples showing that this works. Fostering inclusiveness is also a wonderful thing (and this goes beyond gender issues, and beyond mathematics).

YOU HAVE LIKENED MATHS TO POETRY. DOES THAT MAKE MATHEMATICIANS THE BARDS OF SCIENCE? DO YOU HAVE A FAVOURITE POET?

One of my heroes, Yuri Manin, has advocated the theory that human language did not advance linearly, but rather came in jumps. There is an enormous creative leap involved in naming the unnamed. Poetry is the language of the things slightly beyond our capacity to express them. Mathematicians occupy a similar space in the sciences. Before Galois, Ruffini and Lagrange we spent millenia not knowing what a group is. However, once the concept was expressed it is difficult to imagine the mathematical world without it.

My favourite poet? I love the Australian poet Les Murray, I also love Auden and Borges. The way that Beilinson writes mathematics borders on poetry sometimes. □

Professor Geordie Williamson is the Director of the newly opened Sydney Mathematical Research Institute, at the University of Sydney



MENTORING PhDs is VITAL FOR INDUSTRY

APR Mentor, Professor Asha Rao

*“The main benefit
is experiencing the moment
interns realise how their
work fits into industry.”*

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BREAKING THROUGH THE GLASS CEILING

Identifying the Opportunities Key to Career Progression

By Melissa Trudinger

A MSI's first Women in the STEM Workforce event and webinar has highlighted the need for flexibility and support to keep women progressing in their careers.

Collaborative, diverse and inclusive company culture as well as access to networking and mentorship are critical to support career progression and retention of women in STEM, according to Women in the STEM Workforce 18 keynote speaker and CSL Data Science Head, Dr Milica Ng.

Speaking at the Women in the STEM Workforce event hosted by the Australian Mathematical Sciences Institute's APR.Intern program in Melbourne in September, Dr Ng said she was proof women could have career success later and career changes and breaks were not a full stop to advancement.

"It is important women are supported with the flexibility to manage their careers and progression in a way that acknowledges their future potential and present needs," she said.

Ng was one of two keynotes at the event, with the President of Chief Executive Women, Kathryn Fagg, also addressing the 47 attendees (from organisations including Telstra, Aurecon and Deloitte among others), and 366 national viewers of the livestream webinar event.

With a focus on identifying existing initiatives and new opportunities to address barriers for women in STEM, the event also included two powerful Q&A sessions featuring thought leaders and industry champions. Speakers included representatives from Westpac, Telstra, Alcoa, STA Superstar of STEM, IMNIS, Australian Academy of Science, Australian Research Council, Engineers Australia and SAGE Athena Swan.

Dr Ng experienced a career renaissance in her 40s when she was hungry for new

challenges, and says women shouldn't feel pressured to reach their career peak early or made to feel they need to accelerate their careers during time out or slowing of professional development. It is possible for women to have it all, but not all at the same time.

"To me career pathways are more like a game of snakes and ladders rather than a straight ladder, the journey includes pauses and changes of direction, these are not full stops and shouldn't be barriers to progression," she said.

Women currently account for only 16 per cent of the STEM workforce, with family pressures, isolation in male-dominated industries and lack of confidence – Tabcorp's Advancing the STEM Conversation report* revealed they are 55 per cent more likely to doubt their capability than men – key contributors.

But panellists at the Women in STEM Workforce event noted that women should push through the confidence barrier and take risks.

"A big part for me was you can't be what you can't see...I think once we get more and more women in leadership roles that will become less daunting for young women in their career. They'll become more courageous and more prepared to take risks," said Dr Kylie Hollins, Alcoa Analytics and Digital Manager. Dr Hollins' comments were echoed by others at the event. "Be prepared to try something, even when you don't feel confident, and then get better at it," said Telstra Head of Diversity and Inclusion, Kylie Fuller.

Keynote speaker Kathryn Fagg, the President of Chief Executive Women, said that part of the challenge facing women was a

WOMEN CURRENTLY ACCOUNT FOR ONLY 16 PER CENT OF THE STEM WORKFORCE, WITH FAMILY PRESSURES, ISOLATION IN MALE-DOMINATED INDUSTRIES AND LACK OF CONFIDENCE KEY CONTRIBUTORS

willingness to be open about career goals.

"You've got to let people know what you want to do – particularly those stretch roles," Ms Fagg said. "One of the challenges is us all coming to terms with what we're willing to do and letting other people know what we're willing to do – then to live with that. And recognising that there are always trade-offs and consequences of decisions that we make."

This event marks the first in a series of events planned by APR.Intern to identify and address barriers such as flexibility in the workplace, unconscious bias and lack of confidence, that contribute to the low representation of women in the sector. □

Women in the STEM Workforce 2018 was livestreamed across the country. Keynote presentations can be viewed on the APR.Intern website aprintern.org.au/video-library/

**Advancing the STEM Conversation, Tabcorp, June 2017*

UPPING THE RUN RATE

Econometrics, Cricket and Why Gary Hogan is Excited About APR.Intern



Melbourne Enterprise Professor Gary Hogan AM, CSC recently joined AMSI to lead APR.Intern as it moves into a new phase of industry-PhD Research engagement. AMSI Update talked to him about what he brings to the table.

YOU HAVE WORKED IN DEFENCE, HIGHER EDUCATION AND GOVERNMENT. TELL US ABOUT YOUR ROLES TO-DATE?

Sure, I'd be delighted to. As you pointed out, the bulk of my career has been as a military intelligence officer (Yes, I've heard all the jokes!). The private sector calls it risk management, but it's also got bits of data analytics, parametric science, behavioural science, process optimisation, systems engineering, advanced manufacturing, cyber security, cryptography, satellite sensing, threat modelling and a bunch of other cool stuff like predictive analysis, alternative futures and imagineering.

Of course, I've worked extensively within the machinery of government, at both federal and state levels. But I think I learned more about the imperatives which drive government decision-making from the outside looking in, through the various reviews of departmental processes I did as Senior Adviser National Security with professional services firm KPMG.

HOW DO YOU THINK THIS EXPERIENCE WILL INFORM YOUR ROLE AT AMSI?

So, it's like this: throughout my military career, there were times when I experienced extreme levels of discomfort, whether due to rebel insurgents on Bougainville, or extremist terrorists in Southeast Asia, or conventional forces in the Middle East.

Interestingly, I noticed each time that fear was not manifest when →

I HAVE THIS AMAZING OPPORTUNITY TO ENRICH 1200 LIVES, TO TRANSFORM 1200 FUTURES, TO DELIVER INNOVATION AND EFFICIENCIES INTO HUNDREDS OF AUSTRALIAN BUSINESSES, NOT-FOR-PROFITS AND GOVERNMENT AGENCIES

danger materialised. I guess my Neanderthal ancestors must have been those who stood and fought the sabre-tooth tigers; probably on a dare...or because they were hungry...or had discovered the fermentation process...maybe all three.

Anyway, I can honestly say the time in my life when I experienced the most fear, was during the struggle to recreate my identity after leaving the Defence Force. I found myself flailing to realign my skills to the outside world, with no compass to guide me through some rocky shoals. The implications for my self-esteem, my self-confidence, the fear of not making mortgage payments, of not giving my kids the start in life I had dreamed of giving them – the fear of being unable to readjust was truly terrifying.

I imagine my anxiety was much like the PhD researcher at her career crossroads, searching for an illuminated pathway to the real world, just like I did. APR.Intern provides a solid platform for taking that first giant leap from acquiring knowledge to gaining employment – it serves a huge purpose in that respect.

So, what do I bring to the table from my past experiences, you ask?

I bring a consuming passion for co-creating with industry the conditions for incredibly smart and talented Australian citizens and future citizens to convert the sweat, tears and time they've invested in their PhD study, into sustainable employment.

When I first saw the APR.Intern logo, I had a *Rorschach Test* moment – you know, those ink blot tests. I saw a doorway, with the door opening into a brighter beyond. Can you see that, too? That's how I saw it – and that has shaped my response to the program ever since.

If any of your readers think the APR.Intern program is about anything other than creating jobs, then they probably don't pay tax. Or else they're endearingly naïve and I'd like to sell them a large bridge in Sydney....

Governments spend piles of public monies to create jobs.

So, why do I consider APR.Intern such a sensible piece of public policy?

Let's consider the following facts:

- In the 18 months since it received Australian Government funding in July 2017, APR.Intern has placed almost 200 PhD interns into Industry research projects
- On the current trendline, 35 per cent of those PhD interns eligible to work get employed by their Industry sponsors – I happen to think this percentage will increase as internship numbers grow
- The reputable employment research site, [payscale.com](https://www.payscale.com), places

the average salary of a PhD graduate at \$100,000 p.a. – I think this is too skinny, but who am I to gainsay [payscale.com](https://www.payscale.com)

- According to the Australian Tax Office, an employee on \$100,000 pa, will be liable for PAYG income tax of \$25,000 p.a. and a Medicare Levy of \$2000 p.a. – total \$27,000 p.a. directly into government revenues each year, from every co-created PhD job from APR.Intern
- On top of that, increased Industry productivity usually translates into higher revenues, so company taxes will be traveling north as well
- The incredibly attractive 50 per cent rebate to the industry partner is a lot cleaner and easier to administer than the red tape of some other government schemes, such as R&D tax credits
- By the end of 2020, when Australian Government funding for APR.Intern will be reviewed and either continued or discontinued, the program is on track to co-create 350 jobs with industry for Australian PhD graduates
- Though I can't say for certain how many of these jobs would only have been created through APR.Intern, I can say for certain that APR.Intern is a crucial catalyst in creating the conditions for these jobs to emerge

Of course, an econometrician would view these numbers differently to a mathematician.

The econometrician would come up with a bunch of clever algorithms to show how many other jobs are created by each \$100,000 p.a. job, from hairdressers, to restaurateurs, to primary producers, to construction workers.

But I'm no econometrician, so you'll just have to stick with my conservative calculations...Class dismissed!

WHAT EXCITES YOU MOST ABOUT THE APR.INTERNS PROGRAM?

Well, I went through my six years of High School in Sydney, at Punchbowl Boys high school. My father didn't finish high school and his father never even went to school.

So, for me, education has been the lifelong gift that has unlocked every career door I've ever entered. Nowadays I get to help unlock those same doors for some of the brightest minds in the country, including Australians-to-be, powered by their Australian industry sponsors. I never take that privilege for granted. Ever.

The APR.Intern program is Australia's only government-sponsored, multi-sector, road-tested and proven mechanism for best practice industry-PhD research engagement. The opportunity to constantly improve and future-proof this national model for matching industry need and academic offering is enormously exciting!

The opportunity to be part of APR.Intern speaks to my higher self. ⇨

I've heard my job described as placing around 1200 interns into industry over the next two years or so.

But that's not how I see it. To my mind, I have this amazing opportunity to enrich 1200 lives, to transform 1200 futures, to deliver innovation and efficiencies into hundreds of Australian businesses, not-for-profits and government agencies.

When I'm asked, how many lives did you change this week? – I can actually point to a quantum that is rising exponentially.

But I'm more excited by something else... weirdly enough, I actually love hearing how impossible it will be to secure internships for over 1200 PhD candidates in the next two years.

Those who doubt these internships can be delivered have obviously never met the amazing team I have the privilege to lead.

So, APR.Intern has two years to place over 1200 internships. 2020 is a leap year. So we have 731 days, or 17,544 hours, or 1,052,640 minutes to achieve our objective.

Each one of those million minutes is vital; my amazing colleagues are straining at their crampons to climb the mountain together – that excites me to no end!

YOUR ROLE IS TO DRIVE HIGH LEVEL PUBLIC AND PRIVATE SECTOR ENGAGEMENT. WHERE WILL YOU BE CONCENTRATING YOUR EFFORTS?

Yep, as you suggest a significant part of my role is to create awareness and excitement around the program at the big end of town, among the big banks, professional services firms, finance and superannuation funds, government agencies like AUSTRAC and the ATO, energy providers, Telcos, ports and harbours, transport and logistics, engineering and construction, infrastructure operators, defence industry primes, the health sector, livestock and agriculture collectives, the airline industry and a whole bunch more.

But I'm conscious this needs to be kept in perspective. Am I allowed to use a cricket metaphor? Sorry, I'm a cricket tragic.

In the last 18 months, APR.Intern has been playing Test cricket – doing an impressive job of hitting some crowd-pleasing boundaries; but mainly ticking over the run rate with singles off every third or fourth ball. And there are very good reasons for that; building a versatile Test side and trialling batters and bowlers in the nets takes patience and time. Working out team tactics, batting order and optimal field placements requires trial and error.

But in 2019, APR.Intern is going to transition from five-day Test cricket to ODIs and the Big Bash League – a bit riskier sure, but relying more on fours and sixes, to push the run rate along.

But we can't take our eye off the value of the singles we need to keep hitting in the SME sector. Ricky Ponting is the most prolific run-making machine in Australian cricket history, but he still got more of his 13,378 Test runs from singles than from boundaries!

So, where do I see myself concentrating my efforts? On upping the run rate, certainly. But also on about a dozen other things as well, like

monitoring how best to join up the supply and demand ends of the delivery platform.

WHAT ARE THE KEY ISSUES IN TERMS OF INCREASING ENGAGEMENT?

My decades of service in the great game of intelligence have produced quite a "glass-half-empty" attitude to things, to dig for the downside, to assume that every silver lining has a cloud. And that has influenced how I see many things.

Do I believe Team APR.Intern can and will drive increased engagement among industry sponsors and PhD researchers? Well, of course I do! I've been tinkering under the hood of APR.Intern now for six months and it seems that every party to the program – government, the taxpayer, universities, PhD students and their supervisors, Australia's knowledge economy and innovation sector, and the AMSI joint venture of participating universities itself – gets a serious drink

from it; and that's the secret to any successful negotiation and every enduring business relationship.

So, where do I see the unintended consequences lurking? I guess I just have an uneasy feeling that we could become victims of our own success. For a start, my team and I take very seriously our duty of care towards those young Australians and Australians-to-be who place their trust in the APR.Intern program.

As we now aim to increase our engagement with both the supply side (universities) and the demand side (industry,

government and commerce) by a degree of magnitude, with the intent of expanding participant numbers exponentially, we will need – commensurately – to increase the degree to which we manage and monitor those participants.

We need to ensure that every PhD researcher, every industry partner, enjoys results that exceed their expectations, within a program that delivers an elegant user experience for both sides. We can't cut corners on this – our reputation is critical to the sustainability of our unique delivery model.

We'll need to ensure that PhD researchers and industry sponsors we bring together, leave the program as active ambassadors and advocates for APR.Intern – research shows that a satisfied client will influence eight others; and research shows that a dissatisfied client will influence eight others!

So ensuring best practice oversight and support for 1200 interns over the next two years will be a key consequence of our strategic ambition to increase engagement and drive participation rates through the roof.

We fully anticipate we'll need to test and adjust a few things to cope with the rapid growth of the APR.Intern program. On balance, though, this is the better problem to have.

WE NEED TO ENSURE THAT EVERY PHD RESEARCHER, EVERY INDUSTRY PARTNER, ENJOYS RESULTS THAT EXCEED THEIR EXPECTATIONS

Gary Hogan AM, CSC and Melbourne Enterprise Professor, joined AMSI in October 2018 as Director of the APR.Intern program

CRUNCHING THE DATA

PhD Interns Help Defence Research Surge Ahead

A bevy of Australia's brightest PhD students have begun undertaking short-term 3-5 month internships at Defence Science and Technology Group (DST) in win-win partnerships with APR.Intern.

DST gains access to PhD expertise, enthusiasm and their team of academic mentors, while students are able to build essential industry research skills at the frontline of Defence and national security innovation. The partnership with DST will see 100 interns placed over four years.

DAYSİ DIVES INTO THE DEEP LEARNING END

RMIT PhD student, Ana "Daysi" Ruvalcaba Cardenas, was matched with DST to explore object recognition using deep learning on low-resolution time-of-flight data, and mentored by RMIT's Dr Francisco Tovar Lopez.

For Daysi, it was an interesting challenge working with data from highly-sensitive Single Photon Avalanche Detector (SPAD) chips. Compared to more traditional academic work, one of the challenges included imaging outdoors and long range adding significant atmospheric disturbance to the recording and greatly complicating the process.

"My project aimed to investigate deep learning techniques with a new type of data to identify different objects and localise them in certain areas. I've implemented and reviewed several techniques and filtering, with good results," said Daysi.

The strength of deep learning for image recognition arises from training the system on a large number of images. Faced with only a tiny SPAD dataset, Daysi grafted SPAD image recognition capability onto a pre-existing neural framework that had been trained on millions of non-SPAD images.

"I took another framework, eliminated certain classification layers and added new ones. By doing that I was able to train the network with the new SPAD data to classify our objects," Daysi added.

The initial results demonstrate the success of Daysi's technique. After some training, her network was able to correctly classify different types of chairs, UAVs and planes.

MATHEMATICS TO ASSIST FLEET PLANNERS

The University of Melbourne PhD intern, Nick Davey, is working with Joint and Operations Analysis Division (JOAD) scientists, David Marlow and Joyanto Mukerjee, on scientific methods to assist Defence aircraft fleet planners. The team's aim is to provide a range of scientific and modelling techniques to help military aircraft fleet owners improve their ability to meet the requirements at all stages of their fleet's life.

"The project will provide a robust predictive capability which will also reduce the workload for fleet planners," said David.

For the problem Nick is working on, a monthly planning horizon of three to four years is considered. The project's aim is to develop an optimal plan for a fleet of military aircraft for this timeframe, with the objective of meeting all ongoing requirements regarding flying and deployments. Aircraft may rotate between multiple squadrons, where each squadron may have different flying and fatigue loans.

"Nick is applying his PhD skills to improve the existing model formulation and solution quality," David continued.

Nick was mentored by the University of Melbourne's Professor Saman Halgamuge, a specialist in artificial intelligence, data science and optimisation. □

This article was first published in DST Connections Issue 237



CHOOSING MATHS EDUCATION

Supporting Teachers From the Cities to the Bush

By Helen Booth

A MSI's Choose Maths outreach officers spend most of the school year on the road, visiting schools to help them engage their students in maths and provide support to teachers. Here, Helen Booth tells why she loves her work as an outreach officer.

I started working at AMSI in January 2016, as AMSI's Choose Maths outreach program began in earnest. In the first six weeks of the job, I visited Whyalla, Port Augusta, Woomera, Roxby Downs and Andamooka, all in South Australia, as well as Hedland, both Port and South, in the Pilbara, Western Australia. Since then, I have visited schools, worked with teachers, students and leadership, delivered professional learning sessions, and attended and presented at maths conferences, workshops and career expos in all states and territories except Tasmania. I'm hoping to get the chance to visit schools there next year.

There are eight of us on the Choose Maths outreach team, working within 120 schools throughout Queensland, NSW, Victoria, South Australia and Western Australia, with and alongside teachers, students and leadership from the MacKay region on the east coast to Port Headland on the west, and in urban, regional and remote schools. The remotest outreach is Newman in Western Australia, 1186 km NNE of Perth and 450km from the coast. Getting to our places of work is at times a job in itself. Lost luggage, airport hotels, racing from one end of the concourse to the other, driving from one airport to the next because your flight has been cancelled on you or driving six hours for a meeting the next day because, due to bad weather, you have missed your connecting

flight and there isn't another for two days as tomorrow's seats are all sold, are all part of the experience. As are fires, floods, Australian wildlife and searing heat, but we all keep coming back for more. Why? Because we all believe in what we are doing.

As an outreach officer, I work at the points of need of both the teachers and school or team. One of my first conversations with teachers is around their relationship with mathematics, which is just as important with secondary teachers as with primary and kindergarten teachers. Understanding how each teacher feels about their own experiences when learning maths, helps me to ask the right questions about how they see themselves as teachers of maths. I then support in a way that suits all involved (see box).

AS TEACHERS, WE ALL TREASURE THOSE INSTANTS WHEN STUDENTS HAVE 'AH-HA' MOMENTS; WHEN THE PENNY DROPS, AND THEY START TO JOIN THE DOTS AND TAKE CHARGE OF THEIR LEARNING. AS AN OUTREACH OFFICER, I RELISH THOSE MOMENTS WHEN A TEACHER EXPRESSES A SIMILAR AWARENESS WHILE WORKING WITH ME

The outreach team meets back in the office regularly for "back to base" weeks, where we enthusiastically share our successes, talking about lessons or conversations, the reception we received, what our plans are with various schools and, of course, the dreaded paperwork. We each have our strengths and areas of development, so we love the opportunity to throw around ideas when it comes to

teaching a particular topic. For example, one outreach officer had organised a ballistics engineer from the RAAF to attend a Choose Maths Day as a guest speaker. This immediately had us developing an activity to demonstrate the mathematical concepts involved in ballistics. The ping pong ball-shooting plastic cup cannon with basic clinometer was born and the resulting chaos was enjoyed by all who participated.

We love taking lessons and unit plans and updating, expanding, revising and aligning with research and the appropriate curriculum. We get excited over the smallest things when we see an opportunity to enhance the learning and teaching of mathematics. We support one another as soon as a call goes out, whether we are in the office or on the far side of the country: "HELP, I'm doing a demo lesson on Monday, Year 2 topic, quarter to and quarter past. I have already used up my ideas with this teacher so I'm open to some others." Within minutes, I receive replies from five colleagues with two or three ideas each. A question sent out about when, how and why to teach long division resulted in an email thread 20-plus replies long. We all have opinions because we are passionate about the effective learning and teaching of mathematics. We want the articles, lessons and units that are published on the AMSI Schools website **calculate.org.au** to be the best we can possibly make them, so we share and discuss, trial and refine our ideas.

While I enjoy my time in the AMSI office, my favourite space is in my cluster schools working with teachers, particularly graduate teachers. As teachers, we all treasure those instances when students have 'ah-ha' moments; when the penny drops, and they start to join the dots and take charge of their learning. As an outreach officer, I relish those moments when a teacher expresses a →



PHOTOGRAPHY: MICHAEL SHAW

OUTREACH IN ACTION

Choose Maths outreach officers support schools in many different ways:

- running demonstration lessons for individuals or teams
- working alongside teachers in their classes
- observing a teacher's lesson and giving feedback
- evaluating both topic and common assessment tasks for multi-age groups
- Providing ideas for long and short-term planning of topics, scope & sequence and whole school maths programs
- discussing and highlighting through practice, research-backed pedagogical frameworks and ideas
- listening to teachers as they express their worries and concerns about their teaching, their students and the curriculum
- running professional learning sessions for both teaching and support staff on anything and everything mathematical, depending on school need and direction
- developing unit and lesson plans to support effective teaching of mathematical concepts
- coordinating Choose Maths Days to highlight the role of mathematics in numerous careers
- highlighting the need to promote positive mathematical discussions particularly with girls and women
- delivering parent information sessions to raise awareness through Choose Maths Family Nights for school communities
- analysing school NAPLAN results for misconceptions
- helping teachers to understand the Australian and/or other Curriculum so that it is implemented consistently in their classrooms
- improving teachers' mathematical content knowledge so that they are familiar and confident with mathematical concepts before they teach them; and
- running research lessons in Years 5, 6, 7, 8 and 9 classes

TALES FROM THE CLASSROOM

Some of my favourite and scariest moments have occurred when delivering a demonstration lesson to a team of teachers. Normally this involves teaching a lesson with a particularly structure or pedagogy around an identified concept. We all get a little nervous when other professional educators are watching – you want to make sure you are presenting something that is worthwhile and useful. It works best when there is the opportunity for questions and discussion with the team after the demonstration, which regularly happens at Port Hedland Primary School, where I take a lesson with one class while the year level team

WE GET EXCITED OVER THE SMALLEST THINGS WHEN WE SEE AN OPPORTUNITY TO ENHANCE THE LEARNING AND TEACHING OF MATHEMATICS

observe. Afterwards, we have the opportunity to discuss what I did and why, how the students responded to the lesson and how the team think they could use the ideas, pedagogy and/or content in their own classes. While I thoroughly enjoy the opportunity to engage with the students as much as the teachers, having six secondary maths teachers, including the Deputy Principal, watch, all in a line at the back of the room, while you try to engage a group of passive Year 11 learners in the

contextual use of simultaneous equations, can be a little intimidating. The conversation and questions generated about the pedagogy I was using was, however, well worth the butterflies.

At the other end of the education spectrum is the tale of a reception/Year 1 class. The teacher wanted some ideas on how to teach ordinal numbers; how difficult could that be? As it turned out, harder than I thought as the students were simply not ready for the activity I had in mind. I asked them to count out ten unifix cubes, each a different colour. Their teacher and I stood and watched the mayhem that ensued as counting to ten was hard enough for some, while finding ten different colours was optimistic to say the least. I apologised to the teacher, but she wouldn't have a bar of it. "No, this was great, because it gave me the opportunity to really see what the kids could do. I thought they were ready for this but obviously not yet. Thank you." Providing that chance for the teacher to really observe her students gave her a great deal of insight into their skill level. In the follow-up discussion, we were able to identify ways for her to move them forward from where they were at rather than from what the term planner said they should be learning. I frequently ask teachers, "What is your mantra; have I taught it or have they learnt it?" □

I FREQUENTLY ASK TEACHERS, WHAT IS YOUR MANTRA; HAVE I TAUGHT IT OR HAVE THEY LEARNT IT?

similar awareness while working with me; the comments, "I finally understand why," when discussing content, "that makes so much sense," when discussing pedagogy and/or structure, "thank you for listening," for simply being there and "so I am heading in the right direction," when affirming their hard work, keep me coming back for more. Working in a school on Friday, second to last week of a very long semester, teachers who are meeting with me are looking tired and disinterested when we start a discussion about next term. These teachers choose to use their non-teaching time to engage in conversation with me, even when they really just want to get to through to the end of term and have a break. After an hour, they walk away happy, knowing they have just made extra work for themselves, but excited about next term's topic and the learning possibilities they will create for their students. They are excited about teaching maths; I've done my job.

When you are passionate and/or excited about teaching a subject, you pass that on to your students. We can all remember a particular teacher who really engaged us in our learning through their teaching and enthusiasm. For me, it was Mr Massey, my Year 11 english teacher, who brought Shakespeare alive and encourage me to develop a great appreciation for english literature. Working with numerous graduate primary teachers, I encounter so many who did not have that experience with a maths teacher and they have little enthusiasm for teaching maths; some exhibit trait maths anxiety, which results in them only doing what they must. I see part of my job as building that passion and excitement in young teachers by supporting their growth as a teacher of mathematics; giving them resources, ideas, research and examples that not only excite the students about learning and using maths but give them a sense of achievement and satisfaction of a job well done.

An aspect of my job I really enjoy is working with the ancillary staff, or teaching assistants (TAs). I have had the opportunity to provide professional learning opportunities for this dedicated group of people in the majority of my schools. Often, because of the highly transient nature of the teaching staff in the remote and regional areas, the TAs are among the longest serving staff. They also work →



closely with students who are struggling, yet they are the first to admit that their educational experiences were often not very successful, particularly in maths. One of the presentations I deliver early on in a school is 'Maths, Girls and the Stories we Tell,' which highlights the importance of how we talk about our attitudes and beliefs around mathematics and around mathematics and gender. Little throw away lines such as, "never mind dear, I was never very good at maths either," or "don't ask me, ask your father," or "don't worry, you're just better at english," often inadvertently reinforce stereotypes about girls and maths or being a 'maths person' or not.

Another focus with the TAs is on supporting not doing; many students find mastering mathematical concepts hard work, and rile against the challenge and struggle. Often there is a temptation to do it for the student they are working with rather than asking another question and encouraging the student to come up with their own answer. TAs appreciate the opportunity to learn to think about mathematical concepts in different ways as their approach to tackling problems is generally using an algorithm

I LOVE VISITING AND LIVING IN REGIONAL AUSTRALIA; I LOVE WORKING WITH TEACHERS; AND I LOVE TALKING ABOUT THE TEACHING AND LEARNING OF MATHEMATICS

as that is what they see as school maths. Exploring other strategies and realising that they have a vast range of mathematical skills that they can utilise is liberating for many of them. A large number of TAs admit to me that they have actively avoided maths; they are there to help with literacy, which is where they feel comfortable. By participating in the workshops, they feel more confident about working with students during maths lessons, gaining insight into why students exhibit



certain learning behaviours, as we focus on common misconceptions and the big ideas in numbers. Frequently they share stories about the learning behaviours they have observed and are excited that they now have strategies to change those behaviours and move students forward.

The final aspect of my job that I love is running Choose Maths Days in secondary schools. Working with the maths teachers, we organise local people, whom we refer to as regional champions, to come in and speak to Year 9 and 10 students about where and when they use mathematics in their jobs. In a regional area, it is important to ensure we have a range of occupations because a minority of students have plans for tertiary education. Once you start engaging with the working community about the need for maths, students are amazed at who comes forward saying "YOU NEED MATHS TO DO THIS JOB!" In Port Augusta, one of the first Regional Champions to volunteer was a business woman and hairdresser. In Port Hedland, it was another business woman and jewellery designer who really connected with the students. We had engineers, a diesel fitter, an electrician and health care professionals, but the designer was the only person who had an equation written up on the board behind her for the students to see as they walked in. It answered the frequently lamented question about algebra, "when will I ever use this?" extremely well, as it was how she determined the price to charge for her jewellery, once she calculated the cost of every element and the time taken to create it. I love that at Choose Maths Days, I learn so much about the maths

used in different jobs. I mean, did you know the calculation that need to be done to ensure that when you lift something with a crane, the object doesn't bend, break or unbalance the crane? I didn't because I'd never thought about it but now I do.

Being a Choose Maths outreach officer is a very rewarding job. It is also exhausting, but in the long run, if someone invented a teleport, I would keep doing this until I retire. I love visiting and living in regional Australia; I love working with teachers; and I love talking about the teaching and learning of mathematics. □

Helen Booth has taught both primary school and high school in New Zealand, UK and Australia. She has a Bachelor of Education from Surrey University and a Master in Instructional Leadership from the University of Melbourne. She has worked in the Choose Maths outreach team for three years.

A national collaboration between AMSI and the BHP Foundation, CHOOSEMATHS is empowering Australian students to pursue mathematics. Working across the pipeline from the classroom to university and industry, this initiative aims to strengthen capability, improve public perceptions and increase engagement of women and girls. Visit choosemaths.org.au



A TREMENDOUS OPPORTUNITY

By Brian Birrell

Port Headland Primary School Deputy Principal Brian Birrell explains the impact of Choose Maths on his school.

Choose Maths began at Port Hedland Primary School in 2016. As a school with a coaching culture that supports our young graduate teachers we saw this as a tremendous opportunity. There was a focus on encouraging girls in maths as well as promoting problem solving across the school.

We realised an optimum use would be for Helen, the outreach officer assigned to our school, to undertake demonstration maths lessons at teachers' 'point of need'. From the beginning, Helen with her experience and strong skill set base was able to engender an enthusiasm for maths in all the classrooms she visited. This was then followed up by discussion with the teachers to emphasise the strong teaching points covered in the lesson. This proved to be valuable to not only for the teachers but also the students in the class.

Teachers were also given professional learning that recognised the strong emphasis of problem solving and also to engender a common language for problem solving across the school. Helen was also able to run a very successful Parent Information Evening that demonstrated how parents can support their children in maths. This success has led to us to now plan an information session for our current and future kindergarten parents to support them with their children's maths development.

An important plank of Helen's work is with our year level based coaching groups, allowing for deeper discussion around maths in both planning as well as in classroom instruction and assessment. These sessions are driven by teachers' needs at the time. With a high transient population of students and staff we sometimes need to repeat previous sessions to generate consistency across the school.

THE CHOOSE MATHS PROJECT IS A BOON TO A SCHOOL LIKE OURS IN A REMOTE PART OF WA. AS WE HAVE A HIGH NUMBER OF TEACHERS IN THEIR EARLY YEARS IT HAS ALLOWED US TO PROVIDE EXPERT PROFESSIONAL DEVELOPMENT IN MATHS WE COULD NOT HAVE OTHERWISE GIVEN

The input from the project has given teachers added skills and confidence in the classroom and promoted positive professional conversations across the school and within year groups. The parents have seen the benefit through parent workshops and their own child's development in mathematics.

Where this heads in the future will be driven by our school and community needs to better promote maths in the school. This will happen in the current state of the project as well as through new initiatives across the school such as melding maths into the STEM program, to be introduced in 2019. □

Brian Birrell is the Deputy Principal at Port Hedland Primary School, in Western Australia

Photograph: Helen Booth with Year 9 and 10 students at the Choose Maths Careers day held at Caritas College in Port Augusta

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EXCITING TIMES FOR MATHS

Opportunities and Challenges Drive AustMS Engagement

Outgoing President Professor Kate Smith-Miles talks about her achievements at Australian Mathematical Society (AustMS) and the challenges ahead.

WHAT DO YOU SEE AS THE MAJOR ISSUES FACING MATHEMATICS IN AUSTRALIA RIGHT NOW?

This is a very exciting time to be a mathematician! We are embarking on a critical period of rapid transformation over coming decades, with the rise of artificial intelligence and societal demand for trustworthiness of future technologies. I have been thinking a lot lately about the role of mathematics in providing the necessary rigour to support and help shape this future, and how we can ensure enough mathematicians engage in this agenda. It necessitates that we think about the essence of mathematics and its principles, and acknowledge the imperative to continually reshape the scope of a modern mathematics agenda as society evolves. History is filled with numerous examples of new mathematical and statistical techniques being pulled by intended applications (e.g. calculus), as well as more curiosity-driven fundamental research being pushed into the corpus of mathematical knowledge to be later exploited for unanticipated applications (e.g. compressed sensing and MRI technology). It is this powerful push-pull duality of mathematics, advancing through both fundamental and far-reaching applied research, that earns the mathematical sciences the reputation of a critical enabler of technological innovation.

Our new challenge is to embrace this reputation and coordinate efforts across our full spectrum (from pure to applied) to ensure mathematics stays relevant as we approach this next period of rapid technological change. There is a tremendous opportunity for mathematicians to engage with interdisciplinary colleagues to ensure

rigorous mathematical underpinning of future technologies and decision-making. But there are some challenges to consider: How do we ensure that those who fund research continue to support the longer-term fundamental research as well as invest in more urgent development of new technologies? And how do we encourage enough mathematicians to turn their attention to deliver the necessary mathematical insights being pulled by a technological innovation agenda?

HOW DO YOU THINK WE SHOULD BE TACKLING THEM?

I think clear communication and advocacy is at the core of both of these challenges. It's one of the reasons that AustMS so values the partnership we have with AMSI which helps strengthen the voice of all players in the mathematical sciences in such public debate. We need to ensure that governments, funding agencies and the general public are well aware of the benefits of investing in fundamental mathematical research, and certainly the dangers of not investing. One analogy is that if we want to continue to reap the rewards of picking the fruit from the tree, we need to keep watering it to ensure its root system stays strong. National research priorities and a focus on research impact are essential to drive innovation towards critical challenges, but the fundamental research that underscores future innovation should never be neglected or future generations will find themselves lacking the foundations to support innovations that their society needs.

Communication and advocacy is also critical within the mathematical sciences community as we challenge the very definition of what is mathematics in a modern era. Where does data science fit? Is artificial intelligence just for computer scientists, or are there interesting mathematical questions? How can we train the next generation of young mathematicians to be strong partners

...ONE OF THE THINGS WE NEED TO DO BETTER IS COMMUNICATE OUR SUCCESS STORIES, AND MAKE SURE THE CEO KNOWS ABOUT HOW MATHEMATICIANS ARE HELPING, AND TO ELEVATE THE SIGNIFICANCE OF THE PROJECTS WE ARE INVOLVED IN, FROM SMALL SCALE ONES TO THE KIND THAT ATTRACTS THE ATTENTION OF THE CEO AND MEDIA

PHOTOGRAPHY: MICHAEL SHAW

in interdisciplinary collaborations? How can we convince them of the need to engage, and equip them with the right background knowledge, in addition to their mathematics training, to be successful collaborators? Thinking about the future and training the next generation is very much on the radar of many of us, in AustMS, AMSI and certainly is a focus for those of us involved in the ARC Centre of Excellence in Mathematical and Statistical



elevate the significance of the projects we are involved in, from small scale ones to the kind that attracts the attention of the CEO and media. Of course, there is always room to do more. Trying to grow the pool of academic mathematicians who want to have an impact in industry, and who know the right kind of mathematics that is relevant, is an essential strategy. I am sure these considerations are at the forefront of universities' agendas given the growing importance of engagement and impact metrics.

THERE IS A TREMENDOUS OPPORTUNITY FOR MATHEMATICIANS TO ENGAGE WITH INTERDISCIPLINARY COLLEAGUES TO ENSURE RIGOROUS MATHEMATICAL UNDERPINNING OF FUTURE TECHNOLOGIES AND DECISION-MAKING

I think it is vitally important that mathematicians engage with others in society to open up our toolkit of mathematical "tricks" and ensure they have an impact. If we don't find ways to demonstrate how relevant mathematics is to tackle problems of great significance, then who will? Much of advanced mathematics is quite inaccessible to most people, and we can't expect industry to find the right mathematics to solve their problems most effectively. So I have been engaged in many industry projects over the years, aiming to ensure that the tax-payer return on investment into university research delivers tangible outcomes. Some of these projects have been quite routine, and not so mathematically interesting, but a great opportunity to develop a nice case study for outreach purposes, or a training opportunity for a student. But even better is when the industry problem can't be solved by existing mathematics, and we gain a new set of interesting research questions that push the boundaries of our field. That's the win-win situation that we applied mathematicians love to encounter. ➡

Frontiers. As I said before, it is an exciting time to be a mathematician!

AUSTRALIA HAS ONE OF THE LOWEST RATES OF RESEARCH-INDUSTRY ENGAGEMENT IN THE OECD. HOW CAN THE MATHEMATICAL SCIENCES BETTER ENGAGE INDUSTRY?

That's an interesting question. I am actually of the view that we are doing a pretty good job

already. That often quoted statistic, according to IP Australia, was apparently the result of asking CEOs if they engage with universities (most thought their organisations did not). But if you ask universities, or if you check the joint patents, apparently we are above average in the OECD. So I think one of the things we need to do better is communicate our success stories, and make sure the CEO knows about how mathematicians are helping, and to

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HOW IMPORTANT ARE PROGRAMS SUCH AS APR.INTERN IN TERMS OF STRENGTHENING THIS COLLABORATION?

I have supervised several APR.Intern projects which have led to longer term collaborations in the form of ARC Linkage grants, Research Connections projects, and contract research. I don't think any of these projects were on topics that I originally considered to be within my specific area of expertise. But as an applied mathematician, I believe we need to be willing to learn any branch of mathematics that becomes relevant to a problem, if the problem is important enough and we can justify the time it will take to become familiar with the techniques. Sometimes when you move into a new area of mathematics, coming from another, you find yourself able to bring fresh ideas and you can have an impact in the new area as well. I have given several keynote addresses at conferences in Australia as well as Oxford over the last 12 months, on a topic that I knew little about a few years ago (expensive black-box optimisation) but was exposed to through an industry collaboration that started with an APR.Intern and finished with an ARC Linkage project. Now I have a new set of methods that we have developed for a problem that quite a few industry partners share. So I am very grateful to APR.Intern!

WHAT HAVE BEEN YOUR BIGGEST ACHIEVEMENTS AS AUSTMS PRESIDENT?

One of the challenges of volunteer-run organisations like AustMS is engaging enough of the membership in the running of the society. One of my goals has been to ensure our team – office-bearers, Steering Committee and Council – is supported by greater engagement across the mathematical sciences community to ensure our planning and decision making is responsive to the views and needs of our members. We now have several new structural mechanisms to support society activities:

- a new role of Vice-President (Learning and Teaching) – Professor Diane Donovan (from University of Queensland) - who will be leading many aspects of our implementation of the Decadal Plan for the Mathematical Sciences, as well as re-igniting the dormant accreditation program
- a new Equity, Diversity and Inclusion Committee – chaired by Professor Nalini Joshi (from University of Sydney) – whose agenda includes overseeing the implementation of the gender equity best practice recommendations from a working party chaired by Professor Aidan Sims (from University of Wollongong)
- a new Finance Committee – chaired by Professor Nigel Bean (University of Adelaide) – who are reviewing the society's budget and investment strategies and making recommendation to Council for how we can grow the society's income to better support members; and
- a new Website Redevelopment Implementation Committee – chaired by Associate Professor Jerome Droniou (Monash University) – that will be providing technical expertise and recommendations to Council about the long-awaited website upgrade and redevelopment project

This structural reform provides Council with much valuable input from across the country with which to advance many aspects of the society's business.

One of the other ways I have tried to increase engagement within the society is with the introduction of an annual debate. Last year's topic was *The traditional mathematics blackboard lecture is dead!* and this year's is

PHOTOGRAPHY: JEMMA LEE



Mathematics is better done by computers than humans! While intended to add a fun and entertaining element to our annual meetings, they also prime the society for a more well-considered purpose. With increased engagement of our members in a range of issues that will affect our discipline in coming years, and a culture of engaged debate and input, the society is hopefully in a stronger position now. I look forward to supporting the incoming President – Professor Jacqui Ramagge (The University of Sydney) – as she leads the society to embrace future challenges and opportunities.

We have also increased engagement with other societies: new cooperation agreements with the European Mathematics Society and the Japanese Society for Industrial and Applied Mathematics have been signed; and – subject to Council approval – we will be holding a joint meeting with the American Mathematical Society and the New Zealand Mathematical Society in 2023. Reciprocal agreement for our members with other Australian societies, such as the Australian Society for Operations Research, are also underway. Our agreement with AMSI is up for renewal too, which provides important joint funding for so many workshops, conferences, lecture tours, and joint promotion of AMSI and AustMS activities. I look forward to signing the renewed AMSI-AustMS agreement as one of my last acts as President! □

Professor Kate Smith-Miles is an ARC Georgina Sweet Australian Laureate Fellow in Mathematics and Chair of Applied Mathematics at the University of Melbourne. Her two year term as the President of AustMS ended in December 2018. She is also the chair of AMSI's Choose Maths Advisory Committee

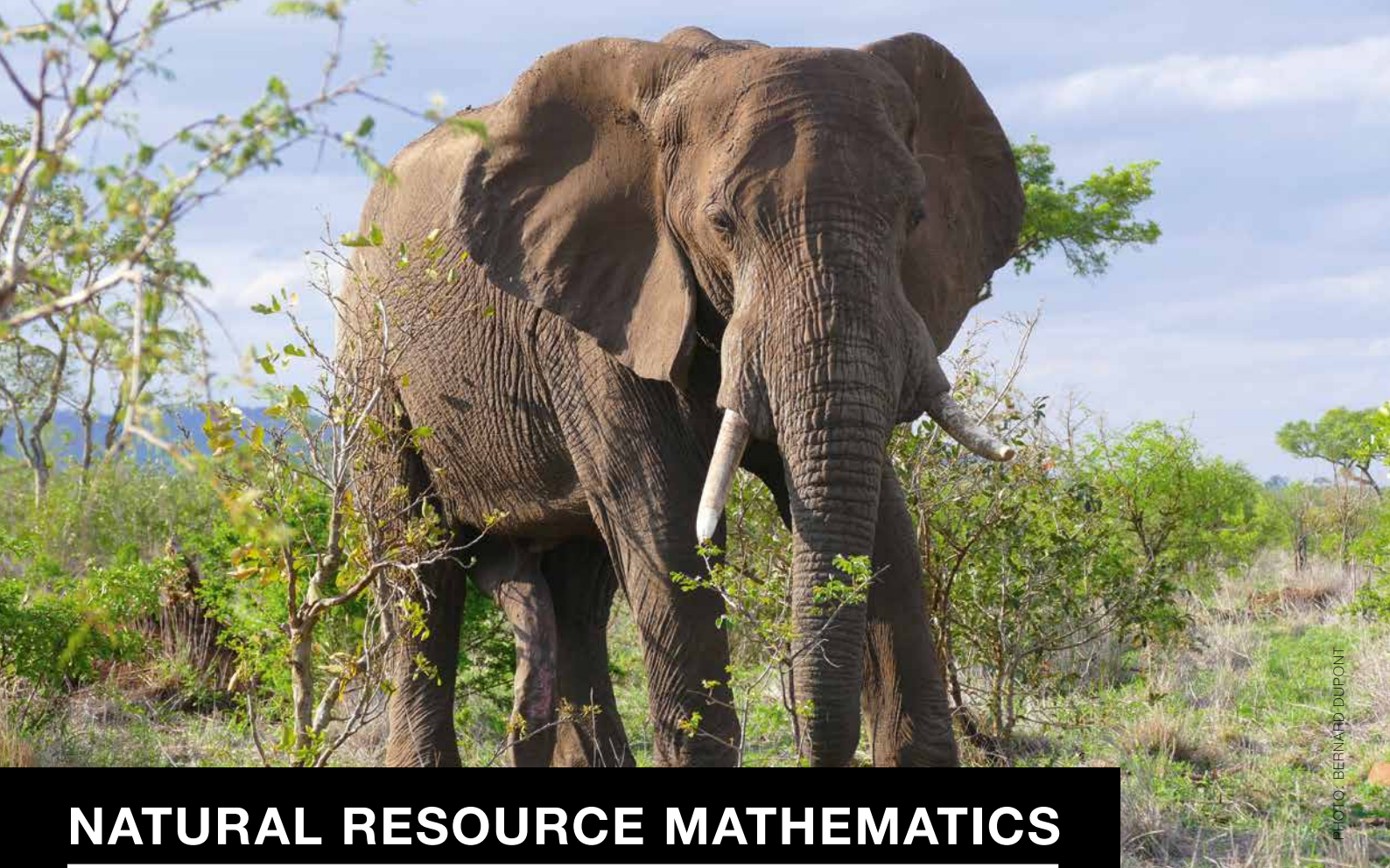


PHOTO: BERNARD DUPONT

NATURAL RESOURCE MATHEMATICS

New Theories and Tools to Better Manage the Natural World

By Professor Jerzy Filar and Dr Matthew Holden, University of Queensland

The biggest challenge facing Australia and, indeed, our planet is how to maintain and manage our natural systems such as fisheries, forestry and biodiversity in the face of habitat destruction, climate change, pollution and over-harvesting. **Natural Resource Mathematics is the field of mathematics which seeks to develop new theory and quantitative tools to better understand and manage our natural world, with an aim to help us overcome this grand challenge.**

It is an eclectic field, lying at the interface of three branches of mathematics: (1) **Dynamical systems**, which provide us the tools to study the evolution of population trajectories over time under different scenarios, (2) **Applied Probability & Statistics**, which allow us to assess the state of natural resources and quantify key uncertainties, and (3) **Operations Research**, which can inform the most cost-effective actions to achieve environmental objectives.

This workshop brought together national and international experts using these branches of mathematics to understand and aid the management of natural resources. Researchers from around the world talked about applications as diverse as invasive species control, fire management and fisheries.

CASE STUDY 1: IMPROVING THE SUSTAINABLE HARVEST OF SCALLOPS

In a plenary talk, Dr Deborah Hart from the National Oceanic and Atmospheric Administration (NOAA, USA), demonstrated new methods being used to quantify uncertainty of scallop abundance (and more generally, any species) given the issue of spatial scale. One way to reduce uncertainty is through incorporating data from photographic surveys of the ocean's floor, which can be used to estimate absolute measures of abundance without any assumptions regarding natural mortality and catch.

Several other talks focused on the scallop fishing industry and its management. As discussed by Dr Wen-Hsi Yang from the University of Queensland, in 2017, the Queensland Government chose to partially close the fishery due to overfishing. The latter was revealed by state-of-the-art statistical analyses. However, trying to estimate the abundance of a



population is actually quite challenging. Dr Yang provided strong statistical evidence that scallop abundance in Queensland was at an all-time low.

CASE STUDY 2: THE FATE OF POPULATIONS UNDER ILLEGAL HARVEST

A well-known theory in ecology postulates that species' populations above some minimal threshold size tend to increase, and below that threshold tend to decrease towards extinction. In 2008 it was proposed that harvest by humans can also induce such thresholds. The theory assumes that if consumers are willing to pay high prices for rare species, small populations are destined to extinction because poachers are willing to exert high effort to capture the rare prize and receive the big payout (see fig. a).

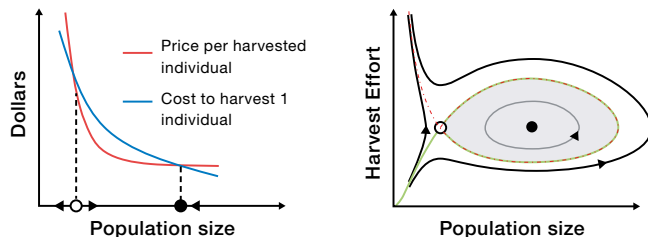


Figure a. The classic argument: if price is higher than poacher costs, the population declines through increased harvest. This leads to a hypothesised small extinction threshold (open circle).

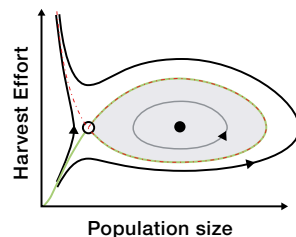


Figure b. Analysis demonstrates the population dynamics in two-dimensional phase space (harvesters vs population) given by the curves in (a). Populations to the right of the black dot in (a) can go extinct by cycling around the grey region in (b), via the green curve.

Dr Matthew Holden from the University of Queensland addressed this issue using dynamical systems theory. He showed that the fate of illegally harvested species can be even worse than what was previously thought in this theory. Consider a population of size x that grows at rate r . It is harvested at a rate proportional to the number of poachers, y , and animals, x . Poachers increase their effort proportionally to profit, where price is a function of population size. These assumptions can be summarised as the coupled differential equations:

$$\begin{aligned}\frac{dx}{dt} &= rx - qxy \\ \frac{dy}{dt} &= \delta[p(x)qxy - cy].\end{aligned}$$

Large initial population sizes can cross hypothesized thresholds, on a predestined path towards extinction, through the existence of a two-dimensional extinction barrier. This barrier is actually a “homoclinic orbit” from dynamical systems theory (see fig b). Because past theory, ignoring this two-dimensional complexity, has been used to conceptualize extinction risk of many harvested species, modifying it is essential so as not to underestimate the risk of illegal harvest. Dr Holden then showed how the theory could be used to protect African elephants from poaching. □

Workshop on Applications in Natural Resource Mathematics was held at the University of Queensland in October 2017. This report was originally published in AMSI's 2017-2018 Research Report – available at amsi.org.au/research-report-2018

FUTURE DIRECTIONS

Much of the workshop centred on new ways of calculating and incorporating uncertainty to aid decision making. From uncertainty in population abundance estimates, to the effect of price on poaching, to the spread of wildfires, to bi-stability and the prediction of tipping points, uncertainty is a major component of environmental risks. In the next decade uncertainty quantification and its inclusion in decision science will play an increasingly important role. It is evident from this workshop that, from advances in viability theory techniques, presented by Professor De Lara, to new ways to approximately solve partially observable Markov decision processes, discussed by Dr ladine Chades and Martin Peron, mathematicians are developing new and clever ways of incorporating uncertainty in mathematical frameworks to aid natural resource management decisions.

A special issue of Springer's *Environmental Modeling and Assessment* inspired by this workshop is currently in preparation. It is expected to appear in 2019.

SPEAKER PROFILES

PROFESSOR MICHEL DE LARA

Michel De Lara is a professor at the French applied mathematics research centre CERMICS, at the École des Ponts ParisTech, specialising in control theory and stochastic optimisation. In particular, he has developed new quantitative methods for the sustainable management of natural resources, with an emphasis on biodiversity and energy.

DR DEBORAH R. HART

Deborah (Dvora) Hart received her PhD in mathematics from the California Institute of Technology and has published in a number of fields, including pure and applied mathematics, mathematical and theoretical ecology and fisheries. Since 1999 she has worked at the Northeast Fisheries Science Center in Woods Hole, Massachusetts (USA) where she is a member of the stock assessment methods group that develops new methods for assessment of fish and invertebrate stocks off the North-Eastern US coast. She has been particularly involved with assessment and management of the Atlantic sea scallop fishery. She developed a theory of rotational fisheries that was the basis of a rotational fisheries management plan for sea scallops that helped rebuild this fishery and made it one of the most valuable fisheries in the US.

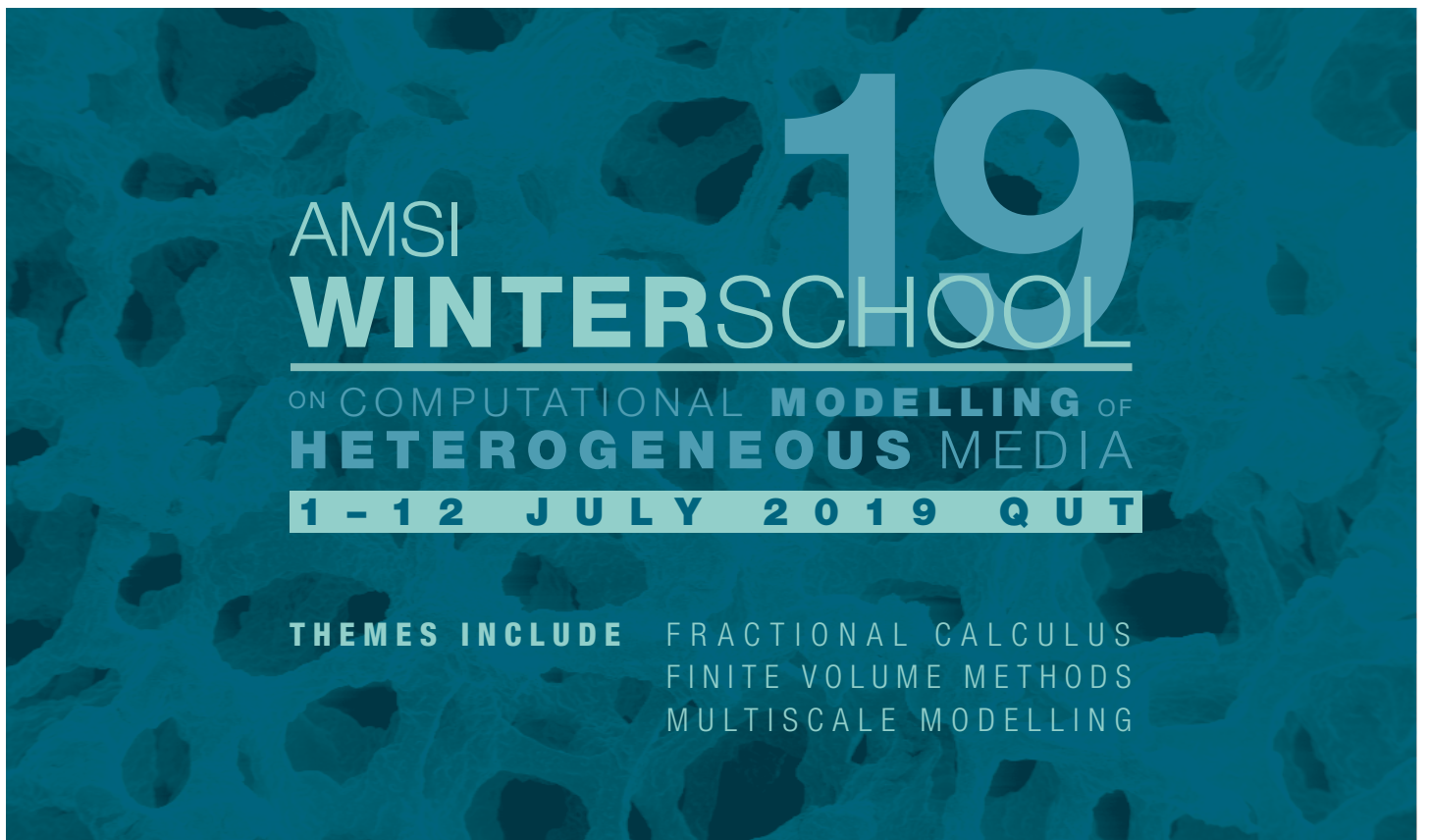
PROFESSOR RICHARD BARKER

Richard Barker is a professor, and Chair in Statistics, within the Department of Mathematics and Statistics at the University of Otago (New Zealand), and is currently Pro-Vice-Chancellor of the Division of Sciences. He began his career as a Fish and Game officer before working at the Patuxent Wildlife Research Centre in the United States in the early 1990s, prior to earning his PhD in Statistics at Massey University. He specialises in Bayesian inference, hierarchical models, ecological statistics and mark-recapture models.

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