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| DAF | Matthew Holden (CARM) Coral Trout, colour. <i>Cephalopholis miniatus</i> (Forsk.) Marshall's "Tropical Fishes of the Great Barrier Reef" (1966) colour plate 12 No 167 by Queensland State archives. Artwork by George Coates | Kathy Townsend of The University of Queensland (UQ) |
| CARM Amir Moghaddam | | Tony Courtney DAF |
| Tony Courtney of DAF | | Peter Kyne of The University of Queensland (UQ) |
| CSIRO | CARM Amir Moghaddam | DAF |

CONTENTS

Establishment, Aims and Growth..... 1

Current Staff..... 4

PhD Completions..... 5

Honours Completions..... 6

Current PhD Students..... 6

Research Grants 8

Teaching and Supervision..... 9

Potential PhD Projects 10

Workshops and Conference Presentations..... 11

Seminar Series 12

Major Collaborations..... 13

External Service, Engagement and Awards..... 15

Visitors 16

Publications..... 16

CENTRE FOR APPLICATIONS IN NATURAL RESOURCE MATHEMATICS (CARM)

Establishment, Aims and Growth

Initiated by Queensland's Department of Agriculture, Fisheries and Forestry to support research in the quantitative fisheries science, the Centre for Applications in Natural Resource Mathematics (CARM) in the School of Mathematics and Physics at The University of Queensland was established in April 2010¹ to promote applications of mathematics and statistics in the important area of natural resource modelling.

Overall, 2018 has been a strong year for CARM. Three dynamic early career researchers **Drs Wen-Hsi Yang, Matthew Holden** and **Sabrina Streipert** have ably supported **Professors Filar and Richardson** in advancing the centre's mission and are being mentored by them, in the process. These three young researchers have been critical to CARM's mission in view of our expanding portfolio of activities and external projects that have a measurable impact on sustainable management of natural resources both in Queensland and elsewhere. These included:

1. New ARC Discovery project entitled "Future fisheries under climate change: the missing role of zooplankton" led by CARM's **A.J. Richardson**, joint with a team of collaborators. This project aims to develop the first global ecosystem model with a more realistic representation of zooplankton. Fish are the main source of protein for 3 billion people, yet fish catches are declining. Current models of future fish biomass under climate change do not consider the complex role that zooplankton play in transferring energy from phytoplankton to fish. By resolving the link between phytoplankton and fish, this project will vastly improve estimates of future global fisheries production and regional variation. Such knowledge is vital for future food security in Australia and globally, and also to understand the role of zooplankton in carbon export in the ocean.
2. New ARC DECRA project entitled "The value of model complexity for fisheries management" by CARM's **M. Holden**. This project aims to quantify the benefits of using dynamic multi-species models for harvest decisions. Expected outcomes of the project include 1) guidance for fisheries scientists on when to use multi-species models for management, 2) improved decision making to reduce the risk of fishery collapse, 3) a new method for dynamic model validation in the face of limited data, and 4) enhanced collaboration between modellers and applied agencies.
3. Continuing Fisheries Research Development Corporation (FRDC) Project titled, "Stock predictions and spatial population indicators for Australia's east coast saucer scallop fishery" joint with M.F. O'Neill, A.J. Courtney, G. Leigh., M.J. Campbell (DAF) **W-H, Yang, J. Filar (CARM)**. This project aims to improve spatial indicators and stock model predictions to estimate the current population size of saucer scallops and develop management procedures.
4. Continuing Australian Fisheries Management Authority (AFMA) funded project led by CSIRO titled, "Harvest strategies for the Torres Strait Finfish fishery". Joint with T. Hutton (CSIRO); M.F. O'Neill, G. Leigh (DAF); A. Tobin (Tobin Fish Tales); **K. Basford, J. Filar and M. Holden (CARM)**. The project will contribute to defensible and robust management decisions including the potential mechanisms for fishery expansion. It will assist in a development of a

¹ The vision for CARM was conceived by the department and Professors Hugh Possingham and Anthony Richardson some two years before Professor You-Gan Wang became the Foundation Director in 2010.

sustainable harvest strategy that is ratified by management agencies and Islanders. **Dr Holden** has a key quantitative modelling role in this project.

5. On a more fundamental, basic research, level work has begun on the 2018-2020 ARC Discovery project entitled “Time consistency, risk mitigations and partially observable systems” will involve **J. Filar’s** collaboration with SMP colleagues and distinguished international partner investigators. This theoretical investigation is inspired by the problem arising in sustainable management of fisheries: design harvest policies that, consistently, minimize the risk of fishery collapse. Research Fellow **M. Jansen** who recently received his PhD from the University of Amsterdam has joined the research team.
6. **J. Filar** with partners from the Queensland Department of Agriculture and Fisheries (DAF) initiated a new pilot project entitled, “Incorporating abiotic environmental factors into both detailed and rapid stock assessment models of fisheries to support management decisions” supported by The University of Queensland, Science with Impact Fund.
7. **Dr Streipert** has stepped into a key role in redesigning DAF’s stock assessment model for Barramundi, an iconic Queensland species that is a target of both commercial and recreational fishers. She is also involved in theoretical investigations of dynamical systems and risk analysis.
8. The Introduction to R workshop was held on 5th February 2018 with Professor **Anthony Richardson**, Associate Professor Chris Brown and Associate Professor Dave Schoeman. The trio then held the Intermediate to R Workshop from the 6th – 7th February 2018. The focus throughout was on ecological applications and particularly marine habitats. Dr Bill Venables conducted the Advanced R Workshop from 5th – 7th February 2018.
9. Two of CARM’s PhD students submitted their theses in 2018. **Ryan Heneghan** who was supervised by **A.J. Richardson** has taken up an International Postdoctoral Fellowship at the Autonomous University of Barcelona, Spain. **Maria Kleshnina**, who was supervised by **J. Filar**, will be taking up a prestigious IST plus Postdoctoral Research Fellowship at the Institute of Science and Technology in Vienna, Austria. This project has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 754411.

Growing national and international recognition in applications of natural resources mathematics.

CARM’s researchers continued to disseminate their results in high quality international journals. In 2018, CARM’s output of 1 book, 3 book chapters, 1 edited book and 28 journal articles included many high-impact publications, focusing on the impact of climate change on biodiversity and the role of protected areas as well as on some more foundational problems of mathematical sciences. The latter included papers in Science, Nature Ecology & Evolution, Journal of Mathematical Biology and Journal of Mathematical Analysis and Applications. A complete list is supplied at the end of this report.

In addition we highlight a few less tangible but also significant developments that are serving to further raise CARM’s national and international profile. These include:

- CARM was included among case studies demonstrating engagement and impact in the University’s 2018 EI submission to ARC. The impact study document was prepared by **J.Filar** and **R. Jemison**.
- **Jerzy Filar** will be a plenary speaker at the forthcoming 2019 World Conference on Natural Resource Modelling to be held in Montreal, Canada, May 22-24, 2019.

- **Sabrina Streipert** gave an invited lecture on 'Dynamic epidemic models' at the Workshop on Dynamic Equations at the Banach Institute's meeting in Bedlewo, Poland (30.06-5.07.2018). This is a prestigious institute and participation is by invitation only. The number of participants is limited to 20 researchers who made major contributions in the field.
- **Matthew Holden** was invited to speak at the Universitas 21 Early Career Researcher Workshop in Shanghai, China and presented, "The benefit of demand reduction campaigns to reduce poaching". As an indication of Matthew's growing reputation, in 2018, Fellow of the Royal Society, Professor Andrew Balmford, at Cambridge University, sought out Dr Holden and has started an active collaboration with him.
- The Australian Mathematical Sciences Institute (AMSI) published a feature story on CARM's very successful 2017 Workshop on Applications of Natural Mathematics. See pages 15-17 in <https://amsi.org.au/wp-content/uploads/2018/12/research-report-2018-web.pdf>. Springer's Environmental Modeling and Assessment will publish a special issue based on selected papers from that workshop. Guest co-editors of this special issue will include our ECRs, **W-H Yang** and **M. Holden**.
- On 28/09/2018 **Minister Mark Furner** announced that the winner of the Queensland Seafood Industry Award (QSIA) in the Research, Extension and Development category was the FRDC-funded project, "Physical oceanographic influences on Queensland reef fish and scallops". The project was led by **Tony Courtney** of DAF and sought to link climatic and oceanographic influences to the catch of coral trout and saucer scallops. The research team included former CARM scientists **R. Lemos** and **J. Thomas**.
- CARM houses the editorial office of Springer's Environmental Modeling and Assessment, where **J. Filar** serves as editor-in-chief. Serendipitously, a member of the journal's editorial board, Professor W.D. Nordhaus, received the 2018 Nobel Prize in Economics for his fundamental work on climate change.



Current Staff



Jerzy Filar: Director (December 2016-present)

Professor Filar is a Professor of Applied Mathematics in the School of Mathematics and Physics at UQ. Prior to joining UQ he was Strategic Professor of Mathematics and Director of Flinders Mathematical Sciences Laboratory. A Fellow of the Australian Mathematical Society, Jerzy is a broadly trained applied mathematician with research interests spanning a wide spectrum of both theoretical and applied topics in Operations Research, Applied Probability, Environmental Modelling, Optimisation, Game Theory and Perturbation Analysis. He spent the first thirteen years of his academic career in the US, which included long-term consulting for the Environmental Protection Agency in Washington. He is the editor-in-chief of Springer's Environmental Modelling and Assessment.



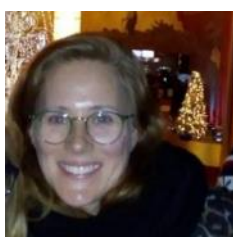
Anthony Richardson: Deputy Director (2010 - present)

Professor Richardson is a mathematical ecologist with a joint position between UQ and CSIRO Oceans and Atmosphere. Anthony has research interests in understanding human impacts on marine systems and how we can improve their management and conservation. He uses statistical and mechanistic ecosystem models to understand marine systems currently, and then projects these models into the future under different climate change and fishing scenarios. He has made significant contributions to describing how marine species are responding to climate change and was the first to show changes in the timing of marine species. His current research focus is on how climate change could affect the movement of biodiversity and functioning of marine systems, and where we might best place protected areas, fish differently, or use other approaches to conserve ecosystems.



Matthew Holden: Research Fellow (June 2017 – present)

Matthew's research program integrates the fields of mathematics, theoretical ecology, fisheries management, and conservation. Matthew uses dynamic models and decision theory to improve conservation planning when conservation benefits depend on how humans modify their behaviour in response to policy. He earned his PhD in Applied mathematics at Cornell University, winning a National Science Foundation Graduate Research fellowship to work on optimization problems in fisheries management, invasive species control, and sustainable agriculture. He received his bachelor's degree from the University of California, Davis, where he won the University Medal, working on the effect of habitat fragmentation on species persistence.



Sabrina Streipert: Research Fellow (October 2017 – present)

Sabrina received a Diplom (Master) in Mathematical Economics from the University of Ulm and a Master of Applied Mathematics from the Missouri University of Science and Technology (MST). Her PhD research at MST focused on the analysis of dynamical systems on time scales with applications in population dynamics and epidemiology. After receiving her PhD in Applied Mathematics in 2015, she became a Research Associate in the Department of Psychiatry at the University of Wisconsin-Madison, working on the mathematical theory of Consciousness.



Wen-Hsi Yang: Research Fellow (June 2016 – present)

Dr Wen-Hsi Yang is a CARM Research Fellow with previously held positions in CSIRO, U.S. Geological Survey, Institute of Space Science, National Central University. Wen-Hsi received his bachelor's degree and Master's degree at the National Central University, Taiwan and earned his PhD in statistics at the University of Missouri. Wen-Hsi has research interests in statistical analysis, modelling and theory for spatial, temporal and spatio-temporal data, in particular for fisheries data.



Marijn Jansen: Research Fellow (July 2018 – present)

Marijn studied mathematics at VU University in Amsterdam. After that, was a PhD student in applied probability, jointly at Ghent University and the University of Amsterdam. Marijn joined CARM as a postdoctoral researcher and works on partially observable systems.



Zhihao Qiao: Occupational Training Student (March 2018 – present)

Zhihao graduated from the Australia National University in 2016, with a first honour degree in Mathematics. He is currently an occupational training student at CARM. Zhihao is working in the field of stochastic modelling and numerical optimisations.



Roxanne Jemison: Centre Administrator (March 2017 – present)

Roxanne has held positions throughout UQ in the Schools of Medicine, Economics and the Biomedical Sciences and is currently completing her MBA and has interests in preserving our natural resources for future generations.



Kaye Basford: Interim Director (October 2015 – November 2016)

Professor Basford is a Professor of Biometry in the School of Agriculture and Food Sciences at UQ and holds directorships with the Australian Academy of Technological Sciences and Engineering, Crawford Fund Limited, and Grains Research Foundation Limited.



Alexander Campbell: Adjunct Senior Lecturer (2016 - present)

Dr Alexander Campbell is a computer scientist and applied mathematician with ten years experience in fisheries stock assessment. He specialises in continuum approaches to population modelling (i.e. partial differential equations) and dynamical systems approaches to uncertainty characterisation (e.g. shadowing).

PhD Completions



Ryan Heneghan

Resolving the role of zooplankton in the marine ecosystem with functional size spectra (University of Queensland; approved February 2019)



Nanxi Zhang
Robust inferences for analysis of longitudinal data
(University of Queensland; approved February 2018)

Honours Completions



Max Campbell
Testing macroecological patterns that drive community structure using zooplankton in the global ocean
(University of Queensland; approved November 2018)

Current PhD Students



Amelia Armstrong
Population genetics and movement of manta rays in Eastern Australia and the South Pacific



Asia Haines (Armstrong)
Ecology of Reef Manta Rays *Mobula alfredi*: Habitat Use, Threats and Connectivity



Tina Berry (with Curtin University)
Molecular genetics of zooplankton



Philip Dyer
Global biodiversity, climate change and marine protected areas



Sarah Pausina

Resilience of Moreton Bay to climate change: Links between nutrient inputs and plankton dynamics



Maria Kleshnina

Incompetence and evolutionary dynamics



Chris Lawson

Bioenergetic of elasmobranchs



Jody McKerral (with Flinders University)

Universal laws in ecological systems



Isaac Brito Morales

Climate velocity and the effects on marine protected areas



Rosemary O'Connor (MPhil)

The impact of climate change and geoengineering on marine biodiversity



Anura Ratnasiri

Surveillance of low birthweight, preterm deliveries and infant mortality in California, 2006-2013: Application of multivariable statistics to explore socioeconomic status by maternal morbidity interactions



Jacob Rogers

Developing models of intermediate complexity for ecosystem assessment (MICE) for Australian marine ecosystems: Managing fisheries and climate change

Research Grants

(includes grants initiated outside of CARM that involve CARM co-investigators).

ARC – DECRA

M. Holden. (2019 – 2021). *The value of model complexity for fisheries management*. \$329,538.00

ARC – Discovery

A.Richardson., J. Blanchard., D. Schoeman., R. Watson., I. Suthers., D. Tittensor., A. Lenton. (2019 – 2021). *Future fisheries under climate change: the missing role of zooplankton*. ARC Discovery: \$493,000.

J.A. Filar, Y. Nazarathy, T. Taimre, V.Borkar, M. Mandjes. (2018-2021). *Time consistency, risk-mitigation and partially observable systems*. ARC Discovery: \$386,828.

P. G. Howlett., A. Albrecht and **J.A. Filar**. (2016-2018). *The Fundamental Equations for Inversion of Operator Pencils*. ARC Discovery: \$392,653.

ARC – Linkage

Bennett, M., Ovenden, J., **Richardson, A.J.**, Townsend, K., Dudgeon, C., van Keulen, M., McGregor, K., Nichols, C., Carter, D. (2016-2018). *Distribution, connectivity and sustainability of manta ray populations: Species of national ecotourism value and conflicting international pressures*. ARC Linkage: \$510,000.

Others

J.A.Filar. (2018). Incorporating abiotic environmental factors into both detailed and rapid stock assessment models of fisheries to support management decisions. The University of Queensland, Faculty of Science, Science with Impact Fund with Project Partner Queensland Department of Agriculture and Fisheries (DAF). \$69,711.

Hutton, T., O'Neill, M.F., Leigh, G., Tobin, A., Basford, K., Filar, J., Holden, M. (2017-2018). Harvest strategies for the Torres Strait Finfish fishery. AFMA funded project led by CSIRO. \$71,500.

O'Neill, M.F., Courtney, A.J., Leigh, G., Campbell, M.M., Yang, W-H., Filar, J. (2017-2018). Stock predictions and spatial population indicators for Australia's east coast saucer scallop fishery. FRDC Project \$67,500.

Richardson, A.J., Condie, S.C., Kingsford, M. and Pitt, K. (2016-2018). *Early warning systems to minimize the risk of box jellyfish stings by empowering stakeholders*. NESP (Commonwealth Government): \$250,000.

Teaching and Supervision

Collectively, CARM staff have a wealth of specialised knowledge and skills in research areas in which there is a recognised skills shortage both nationally and internationally. We were invited and pleased to contribute to teaching established undergraduate courses in the School of Mathematics and Physics.

We have also expanded student learning opportunities through the introduction of new courses such as our “flagship” course in Natural Resource Mathematics, a special topic in longitudinal data analysis, and a reading course in Bayesian statistics which was run in response to student demand. CARM is also contributing to the teaching of a large “Theory & Practice in Science” undergraduate course. This foundation course in science introduces students to the broad range of mathematical, analytical, conceptual and computational tools employed by scientists to develop, analyse and interpret models of scientific processes. These courses help to bridge a crucial gap in students’ training, that is, the gap between mathematical theory and the ability to apply it in real world or workplace settings.

As well as undergraduate teaching, we also provide expert supervision to research students (from mathematics and other disciplines) who may not otherwise have been able to access this knowledge. For example, CARM staff have provided training in the highly specialised area of state-space modelling to UQ research students. This methodology was applied to the significant problems of modelling Queensland fish movements and building Bayesian economics models, and was achieved through CARM’s collaboration with students working in environmental sciences and economics, respectively.

Mathematical skills will be in even more demand in the future as technology advances rapidly and pressure on natural resources increases. In this way, CARM’s active and enthusiastic role in helping to train new generations of scientists in these fields not only brings value to this leading institution, but also strengthens the key capacities that will ensure that our graduates will continue to make Australian scientists internationally competitive into the future.

Natural Resource Mathematics – CARM Flagship Course

MATH2070/MATH7704 Natural Resource Mathematics. Semester 2 (since 2012). **Filar, J., Holden, M., Leigh, G., Richardson, A.** Students taking this course learn to: apply modern mathematical and statistical methods for dynamic systems; model populations and investigate impacts of climate change, overfishing, pollution and habitat destruction; and communicate their work to scientists and decision makers. All practicals are delivered in MATLAB. CARM members have designed the course so students will be employable in a number of growing fields of natural resource management and conservation, especially with State and Federal Governments, universities and NGOs

MATH3070 Natural Resource Mathematics. Semester 2 commenced 2018

Other Courses

SCIE1000 Theory and Practice in Science. Semesters 1 and 2 (since 2014). Adams, P., O’Donoghue, P. and **Richardson, A.J.** This is a strongly recommended first year course for all science students.

MARS3012 Physical-Biological Oceanography. Semester 1 (since 2012). **Richardson, A.J.** and Weeks, S. This is an Introduction to Oceanography course that covers physical, chemical and biological oceanography, including remote sensing.

Potential PhD Projects

CARM has potential PhD projects on offer. Information on these can be found on the CARM web site <http://www.smp.uq.edu.au/CARM/projects>. Smaller versions would be suitable for research masters projects. Examples of some potential joint projects with DAF are as follows:

1. Queensland state-wide estimation of recreational fish catches

Objectives:

- Improved estimation of state-wide recreational harvests, including resampling, bootstrap and MCMC techniques
- Quantify changes in survey angler avidity and recall bias between survey years and methodologies; adjust previous survey data to obtain improved estimates
- Evaluating sampling frames - develop methods to generate state-wide harvest estimates (and associated measures of uncertainty) from several synchronous samples taken from different sampling frames (e.g. a licence frame and a residential telephone number list)
- Develop hierarchical and conditional mixed models for estimation of recreational fish catch and catch rates
- Investigate the statistical modelling of recreational survey data collected from multiple survey methods
- From survey to analysis: dealing with differences in the scale at which survey data are collected and the scale at which data are analysed
- Examine appropriate estimation methods for different fish species
- Develop statistical methods for low fish abundance or recreational species caught by 'hard-to-reach' fishers
- Develop methods to engage and retain recreational fishers in volunteer data contribution programs

Background:

<https://www.daf.qld.gov.au/fisheries/monitoring-our-fisheries/statewide-and-regional-recreational-fishing-survey>

Henry, G.W., and Lyle, J.M. (2003) *The National Recreational and Indigenous Fishing Survey*. New South Wales Fisheries Final Report Series 48, National Heritage Trust and Fisheries Research Development Corporation Project No. 99/158.

Higgs, J. (2001) *Recreational catch estimates for Queensland residents: RFISH Technical report 3 results from the 1999 diary round*. Queensland Department of Primary Industries

Higgs, J., Olyott, L., and McInnes, K. (2007) *Experimental results from the third statewide Recreational Fishing Information System diary program (2002)*. Department of Primary Industries and Fisheries, Queensland. No. PR 07-2707.

O'Neill, M.F., and Faddy, M.J. (2003) Use of binary and truncated negative binomial modelling in the analysis of recreational catch data. *Fisheries Research* **60**(2-3), 471-477.

Sarndal, Swensson and Wretman. (1992) *Model Assisted Survey Sampling*, Springer Series in Statistics.

Lumley, T. 2010, *Complex Surveys: A guide to analysis using R*, Wiley

<https://www.stat.auckland.ac.nz/showperson?firstname=Thomas&surname=Lumley>

Sharon Lohr's book is also useful and is a bit simpler to follow:

http://www.cengage.com/search/productOverview.do?jsessionid=7EFFA13A60CDA3D6193215DBEFDA412E?N=16+4294922413+4294966842+4294959837&Ntk=P_EPI&Ntt=15758609321187154128517071071486767441&Ntx=mode%2Bmatchallpartial

2. Fishery-dependent monitoring of Queensland's fisheries

Objectives:

- Review and evaluate efficient sampling programs: Is the right amount of sampling occurring for each species? Are there any significant biases in the sampling programs for each species?
- Assess whether routine analyses are being carried out correctly and to develop new analyses for fisheries management
- Project components include developing:
 - Quantitative analyses to optimise fishery-dependent sampling across multiple species and regions
 - Routine methods for assessing precision of current sampling of fish length and age
 - New methods for turning fish length and age data into advice (indicators) about fishing pressure and the status of fish stocks
 - A corresponding harvest strategy and reference points for judging the performance of the indicators

Background:

- Sloan, S., Smith, T., Gardner, C., Crosthwaite, K., Triantafillos, L., Jeffriess, B. and Kimber, N. (2014). *National guidelines to develop fishery harvest strategies*. FRDC report - project 2010/061. Primary Industries and Regions, South Australia, Adelaide, March. CC BY 3.0. http://frdc.com.au/research/Documents/Final_reports/2010-061-DLD.pdf(last accessed 27th October 2015).
- Aanes, S. and Volstad, J.H. (2015). Efficient statistical estimators and sampling strategies for estimating the age composition of fish. *Canadian Journal of Fisheries and Aquatic Sciences* **72**: 938-953.
- Zhou, S., Pascoe, S., Dowling, N., Haddon, M., Klaer, N., Larcombe, J., Smith, A.D.M., et al. (2013). *Quantitatively defining biological and economic reference points in data poor fisheries*. Final report on FRDC project 2010/044. Canberra, Australia. 306 pp.
- Smith, M.W., Then, A.Y., Wor, C., Ralph, G., Pollock, K.H. and Hoenig, J.M. (2012). Recommendations for catch-curve analysis. *North American Journal of Fisheries Management* **32**: 956-967.
- Millar, R. B. (2015). A better estimator of mortality rate from age-frequency data. *Canadian Journal of Fisheries and Aquatic Sciences* **72**: 1-12.
- Francis, R. and Campana, S.E. (2004). Inferring age from otolith measurements: a review and a new approach. *Canadian Journal of Fisheries and Aquatic Sciences* **61**: 1269-1284.
- Mapstone, B.D., Little, L.R., Punt, A.E., Davies, C.R., Smith, A.D.M., Pantus, F., McDonald, A.D., et al. (2008). Management strategy evaluation for line fishing in the Great Barrier Reef: Balancing conservation and multi-sector fishery objectives. *Fisheries Research* **94**: 315-329.

Workshops and Conference Presentations

CARM staff have presented their research results at national and international conferences.

- **Maria Kleshnina** presented a talk titled, "Nonlinear learning in games with incompetence", ANZIAM Conference, Hobart, Tasmania, 6th February, 2018.
- **Jerzy Filar** presented a talk titled, "Ordered field property in stochastic games", ANZIAM Conference, Hobart, Tasmania, 8th February, 2018.
- **Jerzy Filar** presented an invited seminar titled, "The power and limitations of mathematical models", School of Information Technology & Mathematical Sciences, University of South Australia, 26th April, 2018.
- **Maria Kleshnina** presented a seminar titled, "Game theoretic approach to marine bacteria optimal foraging strategies in fluctuating environments", Centre for Biodiversity and Conservation Science, The University of Queensland, 1st May, 2018.
- **Jerzy Filar** presented a talk titled, "Sensitivity of threshold risk", Statistics Society Research Symposium, Brisbane, Australia, 19th May, 2018.
- **Sabrina Streipert** presented a talk titled, "Exact solution to a dynamic Lotka-Volterra model", 24th International Conference on Difference Equations and Applications (ICDEA 2018), Dresden, Germany, May 21st, 2018.
- **Matthew Holden** presented a twitter talk, "Campaign or Police?", Twitter conference on Environmental decisions (#CEEDTC2018), Brisbane, Australia, 22nd May, 2018.

- **Maria Klesnina** presented a seminar, “Evolutionary games under incompetence”, ACEMS, The University of Queensland, Brisbane, 30th May, 2018.
- **Sabrina Streipert** presented a talk titled, “Exact solution to a dynamic SIR model”, Banach Centre’s workshop on Dynamic Equations on Time Scales, Bedlewo, Poland, June 1st, 2018.
- **Maria Kleshnina** presented a talk titled, “Evolutionary games under incompetence” The 12th International Conference, Game Theory and Management (GTM2018) Saint Petersburg, Russia, 27 June, 2018.
- **Maria Kleshnina** presented a talk titled, “Incompetence in evolutionary games” 18th International Symposium on Dynamic Games and Applications. Genoble, France, 12 July, 2018
- **Matthew Holden** presented a talk titled, “Campaigning to reduce ivory demand – is it cost effective? “, 2018 Annual Meeting of the Society for Mathematical Biology & the Japanese Society for Mathematical Biology, Sydney, Australia 8-12 July, 2018.
- **Joanne Wortmann** presented a keynote speech titled, “Informing inter-jurisdictional snapper management in eastern Australia”, ASFB 2018 Conference (Australian Society for Fish Biology Conference) in Melbourne 7-11 October, 2018
- **Maria Kleshnina** presented, “Learning advantages in evolutionary games”. AustMS student Society Conference, The University of south Australia, Adelaide, November 28th – 30, 2018
- **Maria Kleshnina** presented, “Learning advantages in evolutionary games”. AustMS Annual Meeting, The University of Adelaide, 4th December, 2018.

Seminar Series

To better engage with staff in the School of Mathematics and Physical Sciences, CARM has been running research seminars jointly with the Statistics, Modelling and Operations Research (SMOR) groups.

During the last 12 months, these included the following:

- **Dr Kim-Anh Do**, The University of Texas (27 February 2018), Personalised cancer-specific integrated network estimation.
- **Dr Sabrina Streipert**, CARM, The University of Queensland (1 May 2018), Modelling environmental factors in a population in the example of *Lates calcarifer* (Barramundi).
- **Dr Matthew Holden**, CARM, The University of Queensland (12 June 2018), Dynamics of illegal harvest: how to protect natural resources from criminal behavior.
- **Dr Wen-Hsi Yang**, CARM, The University of Queensland, (17 July 2018), Quantitative assessment of the Queensland Saucer Scallop Fishery 2018.
- **Professor Anthony Richardson**, CARM, The University of Queensland (11 September 2018), Understanding the amount and distribution of fish in the ocean using size spectrum models.
- **Professor Jerzy Filar**, CARM, The University of Queensland (26 September 2018), Sensitivity of threshold risk.
- **Professor Peter Bartlett**, University of California at Berkeley (4 October 2018), Efficient optimal strategies for prediction games.
- **Mr Robin Pearce**, The University of Queensland (9 October 2018), Efficiency through laziness: an approach to mathematical optimization.
- **Peter Van Staden**, The University of Queensland (4 December 2018), Mean-quadratic variation (MQV) portfolio optimization as an alternative to time-consistent mean-variance (TCMV) optimization.
- **Mr Ali Alyasiry**, The University of Queensland (11 December 2018), Exact algorithms for the vehicle routing problems with pickups and deliveries.

Major Collaborations

With DAF

Stock predictions and spatial population indicators for Australia's east coast saucer scallop fishery

Objective: This FRDC funded project aims to improve mortality rate estimates for management of the Queensland saucer scallop fishery.

Harvest strategies for the Torres Strait Finfish fishery

Objective: The CSIRO led project, funded by AFMA, will contribute to defensible and robust management decisions including the potential mechanisms for fishery expansion. It will assist in a development of a sustainable harvest strategy that is ratified by management agencies and Islanders.

Assessments of the status of Queensland's east coast and Gulf of Carpentaria shark fisheries

Objectives: (i) Develop standardised indices of abundance for the major species/taxa; (ii) Reviewing monitoring strategies and developing assessment modelling tools; (iii) Reviewing the status of the "stock" in relation to the commercial catch quota; (iv) Develop empirical management procedures.

Estimation of recreational fish catches

Objectives: (i) Develop hierarchical and conditional mixed models for estimation of recreational fish catch and catch rates; (ii) Investigate the standardisation of recreational survey data collected from multiple survey methods; (iii) From survey to analysis: dealing with differences in the scale survey data are collected at and the scale data are analysed at, (iv) Assess changes in angler avidity and recall bias between survey years and methodologies; (v) Examine appropriate estimation methods for different species; (vi) Develop methods for low abundance or recreational species caught by 'hard-to-reach' fishers.

Fishery-dependent monitoring of Queensland's fisheries: Reviewing routine collection of length and age data, and routine analysis

Objectives: Review and evaluate efficient sampling programs: Is the right amount of sampling occurring for each species? Are there any significant biases in the sampling programs for each species? Assess whether routine analyses are being carried out correctly, and to develop new analyses for fisheries management.

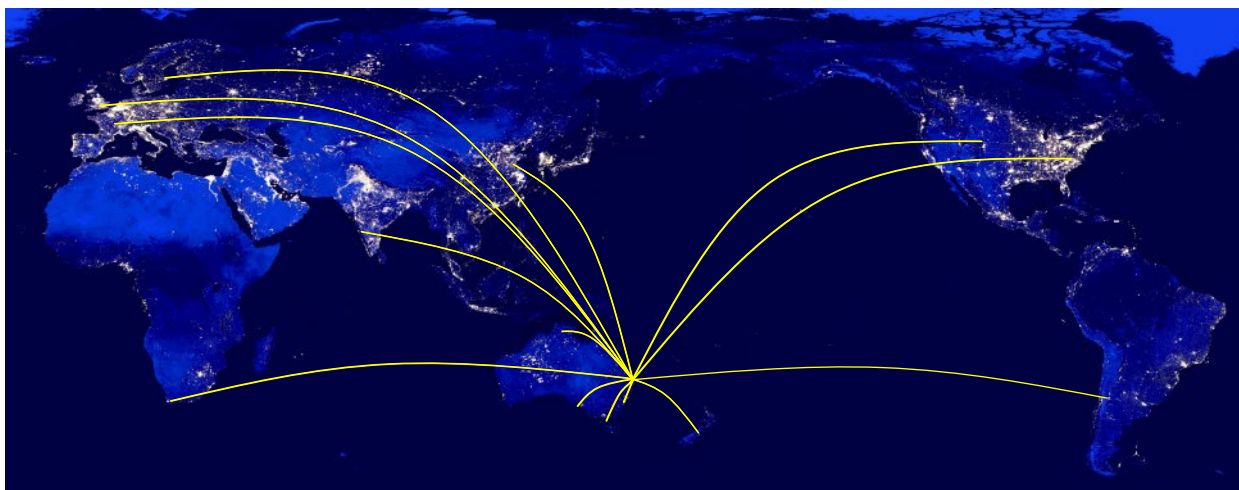
Physical oceanographic influences on Queensland reef fish and scallops

Objectives: (i) review recent advances in the study of physical oceanographic influences on fisheries catch data and describe the major potential influences on Queensland reef fish and saucer scallops; (ii) collate Queensland's physical oceanographic and fisheries data; (iii) develop stochastic population dynamics models for reef fish and saucer scallops, which can link environmental influences (e.g. sea surface temperature) to catch rates, biological parameters (e.g., growth, reproduction, natural mortality) and ecological aspects (e.g., spatial distribution); (iv) forecast the dispersion of reef fish and scallop larvae in the southern GBR region.

East Queensland grey mackerel stock assessment

Objective: Develop a regional, sex- and age-structured population model for the east Queensland grey mackerel; estimate east coast wide and regional quota levels; suggest regional management responses.

Other External Collaborations



Australia

- CSIRO
- Institute of Geography and Limnology, Charles Darwin University
- University of New England
- University of Adelaide
- University of Melbourne
- Queensland University of Technology
- University of Sydney
- University of the Sunshine Coast
- Flinders University
- Queensland Department of Agriculture and Fisheries

Overseas

- Chinese Academy of Sciences, China
- Harvard University, USA
- Landcare Research, New Zealand
- AgResearch, New Zealand
- Swedish University of Agricultural Sciences, Sweden
- University of Glasgow, UK
- University of the Western Cape, South Africa
- University of Cape Town, South Africa
- Sir Alister Hardy Foundation for Ocean Science, UK
- University of Alberta, Canada
- UC Santa Cruz and NOAA
- INRIA, Sophia-Antipolis, France
- IIT, Mumbai, India
- Universiteit van Amsterdam, The Netherlands
- Center for Mathematical Modeling (CMM), Chile
- National Institute for Mathematical and Biological Synthesis, USA
- MIRA Research Group, France

Within UQ

School of Mathematics and Physics

Joint supervision of PhD and honours students, joint research projects, lectures

School of Geography Planning and Environmental Management

Joint supervision of PhD and honours students, lectures

School of Biological Sciences

Joint supervision of PhD and Honours students, lectures and joint UQ FirstLink Genetic stock assessment of Queensland and New South Wales snapper (*Pagrus auratus*) fishery

School of Agriculture and Food Sciences

Joint supervision of PhD students and AFMA funded project, "Harvest strategies for the Torres Strait Finfish fishery".

ARC Centre of Excellence for Environmental Decisions (CEED)

Research collaborations and joint supervision of PhD and Honours students

External Service, Engagement and Awards

Jerzy Filar

- Editor-in-Chief: Environmental Modeling and Assessment, Springer.
- Associate Editor: Journal of Mathematical Analysis and Applications, Elsevier.
- Associate Editor: Dynamic Games and Applications, Springer.
- Associate Editor: *Applicationes Mathematicae*, Polish Academy of Sciences.
- Associate Editor: International Game Theory Reviews, World Scientific.
- Served as Chair of the Awards and Medals Selection Committee of ASOR (Australian Society of Operations Research).
- Panellist in the BrisScience public event, "Mother nature inspiring science" at The Edge, State Library of Queensland.

Kaye Basford FTSE, FAICD, FIS, FQA

- Deputy Chair, Board of Trustees of the International Rice Research Institute (IRRI)
- Vice President, Australian Academy of Technological Sciences and Engineering (ATSE)
- Director, Crawford Fund Limited (and Chair of the Queensland Committee)
- Member, UQ Union College Board
- Associate Editor, *Crop and Pasture Science*
- Life member, International Biometric Society
- Life member, Statistical Society of Australia Incorporated

Anthony Richardson

- Editorial Board: Journal of Plankton Research
- Head, Australian Continuous Plankton Recorder Survey
- 2018 Global Highly Cited Researcher list. This list recognizes researchers who have produced highly cited papers that rank in the top 1% for their field in 2018

Matthew Holden

- Selected by the Australian Society of Operations Research to attend Science Meets Parliament, Canberra
- Elected Treasurer of the Queensland Branch of the Australian Society for operations Research (ASOR)
- Nominated for the UQ, Faculty of Science, Rising Star Academic Award

Maria Kleshnina

- Received one of the two honourable mentions for student talks at the AustMS Annual Conference, Adelaide, Australia, 2018.

Phil Dyer

- At the UQ School of Mathematics and Physics annual Poster Day, Friday 14th September, 2018 Phil Dyer (PhD candidate) was awarded the Student Poster Award for Mathematics for his poster titled, "Data-Driven Models of Biodiversity in the Australian Pelagic Ocean".

Visitors

Dr Ali Eshragh, University of Newcastle (Jan 2018 – Feb 2018)

Associate Professor Vladimir Ejov, Flinders University (Feb 2018)

Professor Vivek Borkar, Indian Institute of Technology Bombay (June 2018)

Publications

Books

1. Dudgeon, C.L., Bansemar, C., Armstrong, A., Armstrong, A., Bennett, M.B., Bowden, D., **Richardson, A.J.**, Townsend, K.A., Hawkins, E. (In press, 2/2/2018). The role of citizen science photographic identification in understanding marine megafauna populations in Moreton Bay. Moreton Bay Book.

Book Chapters

2. **Pausina, S.**, Greenwood, J., Pitt, K., Rissi, D., Rochester, W., Skerratt, J., Uribe-Palomino, J., **Richardson, A.J.** (in press, 2/2/2018) Zooplankton of Moreton Bay. Moreton Bay & Quandamooka Catchment: Past, Present and Future
3. **Richardson, A.J.**, Uribe-Palomino, J., Slotwinski, A., Coman, F., Miskiewicz, A.G., Rothlisberg, P.C., Young, J.W., Suthers, I.M. (2019). Chapter 8. Coastal and marine zooplankton: identification, biology and ecology. In *Plankton: A Guide to Their Ecology and Monitoring for Water Quality*. Edited by Suthers I, Rissik D, Richardson AJ. 2nd edition. CSIRO Publishing. pp. 141-208
4. Rissik, D., Ajani, P., Bowling, L., Gibbs, M., Kobayashi, T., Pitt, K., **Richardson, A.J.**, Suthers, I. (2019). Chapter 3. Use of plankton for management. In *Plankton: A Guide to Their Ecology and Monitoring for Water Quality*. Edited by Suthers I, Rissik D, Richardson AJ. 2nd edition. CSIRO Publishing. 37-61
5. Roe, T., **Richardson, A.J.**, Suthers, I. (2019) Chapter 9. Educating with Plankton. In *Plankton: A Guide to Their Ecology and Monitoring for Water Quality*. Edited by Suthers I, Rissik D, Richardson AJ. 2nd edition. CSIRO Publishing. pp. 209-222
6. Suthers, I., **Richardson, A.J.**, Rissik, D. (2019). Chapter 1. The importance of plankton. In *Plankton: A Guide to Their Ecology and Monitoring for Water Quality*. Edited by Suthers, I., Rissik, D., **Richardson, A.J.** 2nd edition. CSIRO Publishing

Edited Books

7. Suthers, I., Rissik, D., **Richardson, A.J.** (2019). Editors of *Plankton: A Guide to Their Ecology and Monitoring for Water Quality*. Edited by Suthers I, Rissik D, Richardson AJ. 2nd edition. CSIRO Publishing. 230 pp.

Journals

8. Avrachenkov, K., Ejov, V., **Filar, J.A.**, Moghaddam, A. (2019) Zero-sum stochastic games over the field of real algebraic numbers. *Dynamic Games and Applications*. [EPub]
9. Bohner, M., Torres, D, **Streipert, S.** (2019) Exact solution to a dynamic SIR model. *Nonlinear Anal. Hybrid Syst.* 32: 228 - 238.
10. Baker, C., **Holden, M.**, Plein, M., McCarthy, M., **Possingham, H.** (2018). Informing network management using fuzzy cognitive maps. *Biological Conservation*. 224: 122-128.
11. Ben-Tovim, D., Bogomolov, T., **Filar, J.**, Hakendorf, P., Qin, S., Thompson, C. (2018). Hospital's instability wedges. *Health Systems* [EPub]
12. **Berry, T.**, Saunders, B., Coghlan, M., Stat, M., Jarman, S., **Richardson, A.**, Davies, C., Berry, O., Harvey, E., Bunce, M. (2019). Marine environmental DNA biomonitoring reveals seasonal patterns in biodiversity and identifies ecosystem responses to anomalous climatic events. *PLOS Genet* 15 (2):e1007943

13. Bessey, C., Jarman, S., Stat, M., Rohner, C., Bunce, M., Koziol, A., Power, M., Rambahiniarison, J., Ponzo, A., **Richardson, A.J.**, **Berry, O.** (2019). DNA metabarcoding assays reveal a diverse prey assemblage for Mobula rays in the Bohol Sea, Philippines. *Ecology and Evolution* 2019: 1-16.
14. Beutel, T., Corbet, D., Hoffmann, M., Buck, S., **Kienzle, M.** (2018). Quantifying leucaena cultivation extent on grazing land. *The Rangeland Journal*. 40: 31-38.
15. Boss, E., Waite, A., Muller-Karger, F., Yamazaki, H., Wanninkhof, R., Sosik, H., Sloyan, B., **Richardson, A.**, Miloslavich, P., Karstensen, J., Gregori, G., Fennel, K., Claustre, H., Comejo, M., Berman-Frank, I., Batten, S., Acinas, S. (2018). Beyond chlorophyll fluorescence: The time is right to expand biological measurements in ocean observing programs. *Limnology and Oceanography Bulletin*
16. Brackowski, A., **Holden, M.**, O'Bryan, C., Choi, C-Y., Gan, X., Beesley, N., Gao, Y., Allan, J., Tyrell, P., Stiles, D., Brehony, P., Meney, R., Brink, H., Takashina, N., Lin, M-C., Lin, H-Y., Rust, N., Salmo, S.G., Watson, J.E.M., Kahumbu, P., Maron, M., **Possingham, H.P.** (2018). Reach and messages of the world's largest ivory burn. *Conservation Biology*. 32(4): 765-773
17. **Brito-Morales, I.**, Molinos, J.G., Schoeman, D.S., Burrows, M.T., Poloczanska, E.S., Brown, C.J., Ferrier, S., Harwood, T.D., Klein, C.J., McDonald-Madden, E., Moore, P.J., Pandolfi, J.M., Watson, J.E., Wenger, A.S., **Richardson, A.J.** (2018). Climate velocity can inform conservation in a warming world. *TREE* 33 (6): 441-457.
18. Broadhurst, M., **Kienzle, M.**, Stewart, J. (2018). Natural and fishing mortalities affecting eastern sea garfish, *Hyporhamphus australis* inferred from age-frequency data using hazard functions. *Fisheries Research*. 198: 43-49
19. Brown, M.V., van de Kamp, Ostrowski, M., Seymour, J.R., Ingleton, T., Messer, L.F., Jeffries, T., Siboni, N., Laverock, B., Bibiloni-Isaksson, J., Nelson, T.M., Coman, F., Davies, C.H., Frampton, D., Rayner, M., Goossen, K., Rober, S., Homes, B., Abell, G.C.J., Craw, P., Kahlke, T., Li San Sow, S., McAllister, K., Windsor, J., Skuza, M., Crossing, R., Patten, N., Malthouse, P., van Ruth, P.D., Paulsen, I., Fuhrman, J.A., **Richardson, A.**, Koval, J., Bissett, A., Fitzgerald, A., Moltmann, T., Bodrossy, L. (2018). Systematic, continental scale temporal monitoring of marine pelagic microbiota by the Australian Marine Microbial Biodiversity Initiative. *Nature Scientific Data*. 5:180130.
20. Couturier, L.I.E., Newman, P., Jaime, F.R.A., Bennett, M.B., Venables, W.N., Cagua, E., Townsend, K.A., Weeks, S.J., **Richardson, A.J.** (2018). Variation in occupancy and habitat use of Manta alfredi at a major aggregation site. *Marine Ecology Progress Series*. 599: 125-145.
21. Davies, C., Ajani, P., Armbrrecht, L., Atkins, N., Baird, M., Beard, J., Bonham, P., Burford, M., Clementson, L., Coad, P., Crawford, C., Dela-Cruz, J., Doblin, M., Edgar, S., Eriksen, R., Everett, J., Furnas, M., Harrison, D., Hassler, C., Henschke, N., Hoenner, X., Ingelton, T., Jameson, I., Keesing, J., Leterme, S., McLaughlin, M., Miller, M., Moffatt, D., Moss, A., Nayar, S., Patten, N., Patten, R., **Pausina, S.**, Proctor, R., Raes, E., Robb, M., Rothlisberg, P., Saeck, E., Scanes, P., Suthers, I., Swadling, K., Talbot, S., Thompson, P., Thomson, P., Uribe-Palomino, J., van Ruth, P., Waite, A., Wright, S., **Richardson, A.** (2018). Data Descriptor: A database of chlorophyll a in Australian waters. *Scientific Data*. 5:18001
22. Dornelas et al., including **Richardson, A.J.** (2018). BioTIME: a database of biodiversity time series for the Anthropocene. *Global Ecology and Biogeography*. 27: 760-786
23. Duarte de Paula Costa, M., Mills, M., **Richardson, A.J.**, Fuller, R.A., Muelbert, H., **Possingham, H.P.** (2018). Efficiently enforcing artisanal fisheries to protect estuarine biodiversity. *Ecological Applications*. 28(6):1450-1458
24. Ejov, V., **Filar, J.**, Haythorpe, M., Roddick, J., Rossomakhine, S. (2018). A note on using the resistance-distance matrix to solve Hamiltonian cycle problem. *Ann Oper Res*. 261:393-399
25. Eriksen, R., Davies, C., Bonham, P., Coman, F., Edgar, S., McEnnulty, F., McLeod, Miller, M., Rochester, W., Slotwinski, A., Tonks, M., Uribe-Palomino, J., **Richardson, A.** (2019). Australia's long-term plankton observations: the Integrated Marine Observing System National Reference Station network. *frontiers in Marine Science*. doi: 10.3389/fmars.2019.00161
26. **Filar, J.**, Haythorpe, M., Taylor, R. (2018). Linearly-growing reductions of Karp's 21 NP-complete problems. *Numerical Algebra, Control and Optimization*. 8(1): 1:16
27. **Holden, M.**, Biggs, D., Brink, H., Bal, P., Rhodes, J., McDonald-Madden. (2018). Increase anti-poaching law-enforcement or reduce demand for wildlife products? A framework to guide strategic conservation investments. *Conservation Letters*. e12618
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29. **Kleshnina, M.**, **Filar, J.**, Ejov, V., **McKerral, J.** Evolutionary games under incompetence. *Journal of Mathematical Biology*. 77(3): 627-646.
30. **Leigh, G.M.**, Hearn, W.S. (2018). Nonparametric tests of double-tagging assumptions. *Fisheries Research*. 197: 45-49.
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32. **Ratnasiri, A.**, Parry, S., Arief, V., DeLacy, I., Halliday, L., DiLibero, R., **Basford, K.** (2018). Recent trends, risk factors, and disparities in low birth weight in California, 2005-2014: a retrospective study. *Maternal Health, Neonatology, and Perinatology*. 4:15

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34. Skerratt, J.H., Mongin, M., Baird, M., Wild-Allen, K.A., Robson, B.J., Schaffelke, B., Davies, C.H., **Richardson, A.**, Margvelashvili, N., Soja-Wozniak, M., Steven, A.D.L. (2019). Simulated nutrient and plankton dynamics in the Great Barrier Reef (2011 - 2016). *Journal of Marine Systems*. 51-74
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36. Stewart, J.D., Jaime, F.R.A., **Armstrong, A.J., Armstrong, A.O.**, Bennett, M.B., Burgess, K.B., Couturier, L.I.E., Croll, D.A., Cronin, M.R., Deakos, M., Dudgeon, C.L., Fernando, D., Froman, N., Germanov, E.S., Hall, M.A., Hinojosa-Alvarez, S., Hosegood, J.E., Kashiwagi, T., Laglbauer, B.J.L., Lezama-Ochoa, N., Marshall, A.D., McGregor, F., Notarbartolo di Sciara, G., Palacios, M.D., Peel, L.R., **Richardson, A.J.**, Rubin, R.D., Townsend, K.A., Venables, S.K., Stevens, G.M.W. (2018) Research priorities to support effective manta and devil ray conservation. *Frontiers in Marine Science* 5 (314): 27 pp.
37. Tulloch, V., Plaganyi, E., Matear, R., Brown, C., **Richardson, A.** (2019). Future recovery of baleen whales could be hampered by climate change. *Global Change Biology*. 1-19.