THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

CARM Report

March 2017 – February 2018

Centre for Applications in Natural Resource Mathematics

Solving most pressing natural resource and environmental problems

www.smp.uq.edu.au/CARM

Cover photos/images courtesy of:

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CSIRO		DAF

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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 2010[1] to promote applications of mathematics and statistics in the important area of natural resource modelling.

Overall, 2017 has been a renaissance year for CARM. Importantly, the centre has assembled a trio of dynamic early career researchers consisting of **Drs Wen-Hsi Yang, Matthew Holden** and **Sabrina Streipert** and appointed **Ms Roxanne Jemison** as centre administrator. Highlights of the expanding portfolio of activities – with impact on sustainable management of natural resources - include:

- The 2017 closure of the scallop fishery was directly influenced by a study in which **Dr Wen-Hsi Yang** and **Professor Kaye Basford** worked closely with the fisheries stock assessment team from the Department of Agriculture and Fisheries to identify the current status of saucer scallop to respond to concerns about declining catches of legal-sized saucer scallop. Indeed, Dr Yang was the lead co-author of an authoritative quantitative assessment report that alerted decision makers to the urgency of the inferred decline in the saucer scallop stock. Their findings were externally reviewed by experts at the US National Oceanic and Atmospheric Administration (NOAA). The reviewers found that: *"The model is state of the art. It reflects a great deal of ingenuity to capture not only the temporal dynamics but also the spatial aspects of the fishery."*

- New 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.M. Campbell (DAF) **W-H, Yang and J. Filar (CARM)**. This project aims to improve mortality rate estimates for management of the Queensland saucer scallop fishery.

- New 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 sustainable harvest strategy that is ratified by management agencies and Islanders**. Dr Holden** will play a key role in this project.

- On a more fundamental, basic research, level the recently awarded ARC Discovery project entitled "Time consistency, risk mitigation and partially observable systems" will involve **J. Filar's** collaboration with School of Mathematics and Physics 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.

[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

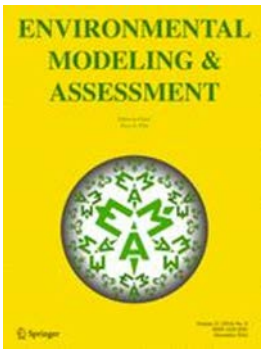
- **Dr Streipert** has stepped into a key role in redesigning DAF's stock assessment model for Barramundi, an iconic Queensland species that is a target of both commercial and recreational fishers. She is also interested in expanding our research program to the important area of protecting Queensland's forests from invasive species.

- With sponsorship from The Australian Mathematical Sciences Institute (AMSI), The Australian Mathematical Society (AustMS) and Global Change Institute (GCI), on October 3-5 2017, CARM held a Workshop on Applications in Natural Resource Mathematics (WANRM) featuring four distinguished international speakers and 52 participants in total. WANRM provided a forum for Australian and international experts in the area to disseminate their latest research findings and launch new collaborations.

- Successful R Workshops were held on the 13th - 15th June 2017 and 20th -22nd February 2017 with the June Workshop seeing the return of the popular Advanced Workshop with Bill Venables, an eminent Australian statistician.

- CARM's researchers continued to disseminate their results in high quality international journals. The latter included papers in Science, Nature Ecology & Evolution, Journal of Theoretical Biology and Journal of Mathematical Analysis and Applications.

- CARM houses the editorial office of Environmental Modeling & Assessment, an international, interdisciplinary, journal published by Springer. This journal builds bridges between the scientific community's understanding of key environmental issues and the decision makers' need to influence relevant policies and regulations on the basis of the best available information. The journal offers high quality, peer-reviewed papers that may be regarded as either instances of best practice, or as studies that advance the evolution and applicability of the theories and techniques of modeling and assessment. The journal also provides a forum where researchers can publish a complete mathematical description of important environmental models together with the accompanying analysis and underlying assumptions.

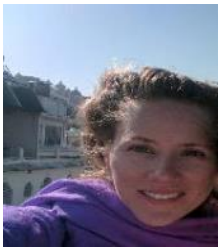


Current Staff

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 has research interests in using mathematical tools and statistics to understand the impacts of humans on marine systems, particularly climate change.

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.

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).

Marco Kienzle: Adjunct (September 2016 – present)
Marco Kienzle is a biometrician working for Queensland Department of Agriculture and Fisheries in Brisbane. Born in Switzerland, he was trained in biometry at the University of Lyon 1 (France) were he obtained a master of advanced studies in analysis and modelling of biological systems in 1999. Since 2000, he applied his knowledge in mathematics and computer sciences starting in fisheries research by evaluating the impact of marine protected areas on fish stocks along the coast of Sicily (Italy). Then to Scotland (UK) where he studied the dynamics of small pelagic in the North Sea. In 2006, he moved to Hawaii (USA) to work on south pacific albacore tuna. Since 2008, he has worked in Australia in areas such as infectious diseases for pigs and poultry, analyses of metagenomics datasets or assessing the effect of climate change on marine species.

PhD Completions

Katherine Burgess
Feeding ecology, movements and behaviour of *Manta birostris* in Ecuador
(University of Queensland : approved December 2017)

Kieran Clancy
Detecting Non-Hamiltonian graphs by improved linear programs and graph reductions
(Flinders University; approved 2017)

Andrew Jones
Estimation of genetic effective population size in fisheries
(University of Queensland :approved March 2017)

Neil Thatcher
Linear programming based approach to infinite horizon optimal control problems with time discounting criteria
(Flinders University; approved 2017).

Viv Tulloch
Ecosystem modelling and fisheries in tropical and temperate systems
(University of Queensland : approved June 2017)

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

Honours Completions

Samara French
Improving Stock Assessment of Queensland Fish Species
(University of Queensland; approved December 2017)

Robyn Lovett
Modelling a kelp ecosystem under climate change and potential management responses
(University of Queensland; approved June 2017)

Lucas Sumpter
Are distributions of species in Queensland's trawl fishery responding to climate change? (University of Queensland; approved November 2017)

Current PhD Students

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

Asia 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

Ryan Heneghan
Bioenergetics modelling of phytoplankton communities

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

Sarah Pausina
Zooplankton dynamics in Moreton Bay

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

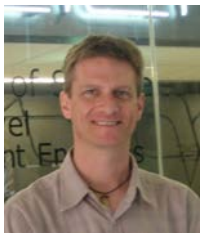
Previous Staff

Clare McGrory: Lecturer (Jan 2012 – December 2017)
Dr McGrory is a Bayesian statistician working as a Statistician at the CSIRO. Her research focuses on developing efficient and practical Bayesian statistical methodology, in particular in the area of variational Bayes and MCMC-based techniques. Her interests include applications in analysing spatial data and wave direction modelling. She is involved in carrying out fisheries stock assessment for the Queensland Government.

You-Gan Wang: Foundation Director (2010 – September 2015)
Professor Wang's interests are statistical modelling and data analysis in environmental research, in particular for stock assessment and management strategy evaluation. In statistics, his interests are robust inference, dynamic decision theory and model selection in correlated data analysis.

Dr Liya Fu: Research Fellow (Feb 2014 – August 2015)
Dr Fu was a Research Fellow. Her research interests include rank regression; longitudinal data; and survival analysis.

Shen Wang: Research Assistant (Jun 2012 – Dec 2014)
Mr Wang was finishing his PhD from the University of Wollongong and is interested in Markov Chain Monte Carlo, variational Bayesian methods, semiparametric regression, statistical modelling and data analysis. He is also interested in statistical computing and statistical software, such as R, Infer.NET and WinBUGS.



Peter Baxter: Lecturer (January 2011 – December 2014)
Dr Baxter's main research focuses on applied ecological modelling, in particular using decision theory with ecological and environmental models to find optimal strategies for invasive species control and threatened species conservation.

Ricardo Lemos: Lecturer (January 2012 - November 2014)
Dr Lemos develops Bayesian spatio-temporal methods and applies them to biological and environmental data. His research interests include high performance computing, multivariate data blending, and fingerprinting of human and natural causes of marine population fluctuations.

Research Grants

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

ARC Centre of Excellence

Possingham, H.P., McCarthy, M.A., Hobbs, R.J., Lindenmayer, D.L., Pannell, J., Wintle, B.A., **Richardson, A.J.**, Wilson, K.A., Buckley, Y., Vesk, P.A., Bekessy, S., Rhodes, J., Bode, M., McDonald-Madden, E., Drechsler, M., Kark, S., Knight, A., Martin, T., Milner-Gulland, E.J., Moilanen, A. & Nichols, J. (2011-2017). ARC Centre of Excellence*, ARC Centre of Excellence for Environmental Decisions*, $17,000,000.

ARC – Discovery

***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.

J.A. Filar, V. Gaitsgory, V. Ejov and Prof. J. Roddick. (2015-2017). *Perturbations in Complex Systems and Games*. ARC Discovery: $379,700

Suthers, I. and **Richardson, A.J.** (2015-2017). *Linking phytoplankton to fisheries using zooplankton size spectra.* ARC Discovery: $350,000

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.

J.A. Filar, S. Qin, P. Hakendorf, D. Ben-Tovim, C. Thompson. (2013-2017). *Congestion recovery and optimisation of patient flows*. ARC Linkage: $215,733.

Others

Basford, K.E., DeLacy, I.H., Arief, V.N., Barrett, B. and Jahufer, Z. (2016-2017). *Cooperative development of QU-GENE simulation platform for cross-pollinating forage species in open source format.* AgResearch Ltd: $131,500.

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.

Filar, J., McGrory, C. AMSI Research Program funding for, "Workshop on Applications in Natural Resource Mathematics (WANRM)" August 2017. $4,859.84.

Filar, J., McGrory, C. AustMS funding for, "Workshop on Applications in Natural Resource Mathematics (WANRM)" August 2017. $1035.00.

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 these skills 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

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=157586093211871541285170710714867674 41&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.

3. Forecasting future global fisheries production under climate change using systems of differential equations

The student will develop state-of-the-art size spectrum models – based on systems of DEs – for the plankton and fish in the global ocean. These will be solved by using ode solvers in R. These models will then be forced by climate change scenarios to see how many fish are likely to be in the ocean in the future, how their distributions could change, and how this would affect the fish catch in nations of the world. As wild fisheries and aquaculture provide >3 billion people with 20% of their protein intake, forecasting future global fisheries is a real-world and pressing problem.

Background:

Blanchard J, Heneghan R, Everett J, Treblico R, Richardson AJ (2017) Modeling individuals to ecosystems, from bacteria to whales. Trends in Ecology and Evolution 32(3): 174-186

Heneghan RF, Everett JD, Blanchard JL, Richardson AJ (2016) Zooplankton are not fish: improving zooplankton realism in size-based models mediates energy transfer in food webs. Frontiers in Marine Science. doi: 10.3389/fmars.2016.00201

Workshops and Conference Presentations

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

- **Jerzy Filar** gave an ASOR seminar at QUT entitled, “HESMAD patient flow simulation model and hospital’s instability wedges”, Brisbane, Queensland, 24th February, 2017.
- **Jerzy Filar** gave a presentation entitled, Hospital’s instability wedge”, at ANZIAM 2017, Hahndorf, South Australia, 7th February, 2017.
- Introduction to R, Intermediate R and Advanced R Workshops were held over three days at The University of Queensland, Australia, 5-7 February and 13-15 June 2017 presented by **Anthony Richardson**, UQ Centre for Applications in Resource Mathematics, Bill Venables, CSIRO, David Schoeman, University of Sunshine Coast and Chris Brown, Griffith University.
- **Jerzy Filar** presented a talk titled, “Some uncertainty issues in mathematical models of the environment”, at 2017 World Conference on Natural Resource Modeling, Barcelona, Spain, 9th June, 2017.
- Maria Kleshnina presented a talk titled, “Incompetence in microbial games”, at 2017 World Conference on Natural Resource Modeling, Barcelona, Spain, 9th June, 2017.
- **Matthew Holden** organized the Ecology & Crime symposium at the Society of Mathematical Biology Annual Meeting, Salt Lake City, Utah, USA, 19 July, 2017 and presented a talk titled, “Dynamics of illegal harvest: How to save the African Elephant from Poaching”.
- **Matthew Holden** organized the Wildlife Crime Bridging the Gap Between Conservation Science and Criminology Part ll at the International Congress for Conservation Biology, Cartagena, Colombia, 23-27 July, 2017 and presented a talk titled, “Innovation a necessity to save the African elephant from illegal ivory trade”.
- **CARM** organized a three day Workshop on Applications in Natural Resource Mathematics (WANRM), St Lucia, The University of Queensland, Brisbane Australia, 3rd to 5th October, 2017.
- **Matthew Holden** presented a talk titled, “The dynamics of illegal harvest”. Workshop on Applications in Natural Resource Mathematics (WANRM), St Lucia, The University of Queensland, Brisbane Australia, 3rd October, 2017
- **Vivitskaia Tulloch** presented a talk titled, “Ecosystem modelling of whale-krill interactions in the Southern hemisphere to quantify the impact of historical whaling and future climate change”. Workshop on

Applications in Natural Resource Mathematics (WANRM), St Lucia, The University of Queensland, Brisbane Australia, 3rd October, 2017

- **Tony Courtney** presented a talk titled, “Can fishing mortality estimates (F) be improved by categorizing the habitat types of the targeted species? A case study using the Queensland saucer scallop fishery (Ylistrum balloyi)”. Workshop on Applications in Natural Resource Mathematics (WANRM), St Lucia, The University of Queensland, Brisbane Australia, 4th October, 2017
- **Wen-Hsi Yang** presented a talk titled, “Quantitative assessment of the Queensland Saucer Scallop Fishery, 2016”. Workshop on Applications in Natural Resource Mathematics (WANRM), St Lucia, The University of Queensland, Brisbane Australia, 4th October, 2017
- **Marco Kienzle** and Martin Peron presented a talk titled, “Optimal Harvest Strategies according to a Markov Decision Process applied to a delay-difference model: insights from the tiger prawn fishery in Morten Bay (Australia)”. Workshop on Applications in Natural Resource Mathematics (WANRM), St Lucia, The University of Queensland, Brisbane Australia, 4th October, 2017
- **Trevor Hutton** and Beth Fulton presented a talk titled, “Atlantis and complex Ecosystem Models”. Workshop on Applications in Natural Resource Mathematics (WANRM), St Lucia, The University of Queensland, Brisbane Australia, 5th October, 2017
- **Ryan Heneghan** presented a talk titled, “Zooplankton feeding behavior mediates energy transfer from phytoplankton to fish”. Workshop on Applications in Natural Resource Mathematics (WANRM), St Lucia, The University of Queensland, Brisbane Australia, 5th October, 2017
- **Maria Kleshnina** presented a talk titled, “Modelling chemotaxis in marine bacteria under incompetence”. Workshop on Applications in Natural Resource Mathematics (WANRM), St Lucia, The University of Queensland, Brisbane Australia, 5th October, 2017
- **Phil Dyer** presented a talk titled, “Large-scale marine biodiversity modelling”. Workshop on Applications in Natural Resource Mathematics (WANRM), St Lucia, The University of Queensland, Brisbane Australia, 5th October, 2017
- **Jacob Rogers** presented a talk titled, “Aggregation, Allee effects and critical thresholds for the management of the crown-of-thorns starfish *Acanthaster planci*”. Workshop on Applications in Natural Resource Mathematics (WANRM), St Lucia, The University of Queensland, Brisbane Australia, 5th October, 2017.
- **Clare McGrory** presented a talk titled, “A Bayesian approach for detecting climate shifts”. Workshop on Applications in Natural Resource Mathematics (WANRM), St Lucia, The University of Queensland, Brisbane Australia, 5th October, 2017.
- **Clare McGrory** delivered an invited presentation on, ”A Bayesian statistical approach for detecting climate regime shifts” given at Bayes on the Beach 2017, Gold Coast, Australia, Monday 13th November, 2017
- **Wen-Hsi Yang** presented an invited talk, “Statistical analysis of coastal and oceanographic influences on the Queensland scallop fishery” at Biometrics by the Border, Kingscliffe, Australia, Wednesday 29th November, 2017.
- **Wen-Hsi Yang** presented the prize certificate and cheque to the winner of the best student talk, Kevin Wang from University of Sydney at Biometrics by the Border, Kingscliffe, Australia, November, 2017.
- **Jerzy Filar** gave an invited plenary presentation entitled, “Ordered field property in Stochastic Games” at The South Pacific Optimization Meeting in Western Australia, Perth, 9th December, 2017.
- **Maria Kleshnina** gave a presentation entitled, “Nonlinear learning in games with incompetence” at The ANZIAM 54th Meeting in Hobart, Tasmania, Australia 6th February, 2018.
- **Jerzy Filar** gave a presentation entitled, “Ordered field property in Stochastic Games” at The ANZIAM 54th Meeting in Hobart, Tasmania, Australia 8th February, 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 groups.

During the last 12 months, these included the following:

- **Associate Professor Tomasz Bednarz**, CSIRO Data61, ACEMS QUT (17 January 2017): Mathematics, **Virtual Reality, Art + Science**
- **Professor Jim Mitchell** and **Ms Jody McKerral (Fisher)**, Flinders University (30 January 2017): Turbulence and fishing influence size-abundance scaling relationships in the aquatic biosphere
- **Professor Ian Melbourne**, University of Warwick (22 March 2017): Homogenization of deterministic multiscale systems
- **Dr Duy-Minh Dang**, University of Queensland, School of Mathematics and Physics (28 March 2017): Mean variance portfolio optimization for long term investors
- **Dr Azam Asanjarani,** University of Queensland, School of Mathematics and Physics (9 May 2017): The role of information in system stability with partially observable servers
- **Dr Stella Kapodistria**, Eindhoven University of Technology (9 May 2017): The mathematics behind the performance of wind turbines
- **Professor David Stewart,** University of Iowa (23 May 2017): Dynamics with inequalities
- **Professor Moshe Haviv,** The Hebrew University of Jerusalem (25 July 2017): Regulating arrivals to a queue
- **Dr Ali Al-Yasiry,** University of Queensland, School of Mathematics and Physics **(10 October 2017):** An exact algorithm for the Pickup and Delivery problem with Time Windows and LIFO Loading
- **Professor Kate Smith-Miles,** University of Melbourne (17 October 2017): Optimization in the darkness of uncertainty
- **Robin Pearce,** University of Queensland, School of Mathematics and Physics (18 October 2017) : Solving uncapacitated facility location and network design problems
- **Professor Soren Asmussen,** Aarhus University (7 November 2017): Regular variation in a fixed point problem for multiclass queues and branching processes
- **Patrick Lamb,** University of Queensland and Aarhus University (14 November 2017): Rare-event asymptotics and estimation for dependent random sums – an exit talk, with applications to finance and insurance
- **Dr Kim De Roover,** Tilburg School of Social and Behavioral Sciences, Tilburg University, the Netherlands (5 December 2017): Lack of measurement invariance in multilevel data: a cluster-based solution for making valid attribute comparisons
- **Chan, A,** University of Queensland, School of Mathematics and Physics (6 December 2017): Brain magnetic resonance image segmentation with Markov random fields

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.

Management strategy evaluation of Queensland's east coast trawl fishery
Objectives: (i) Quantify annual fishing power increases and changes in prawn abundance; (ii) Quantify prawn catchability coefficients; (iii) Develop models and data rules for identifying target fishing effort and catch rates; (iv) Develop multi-species spatial assessment models for evaluating management and stock status reference points.

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.

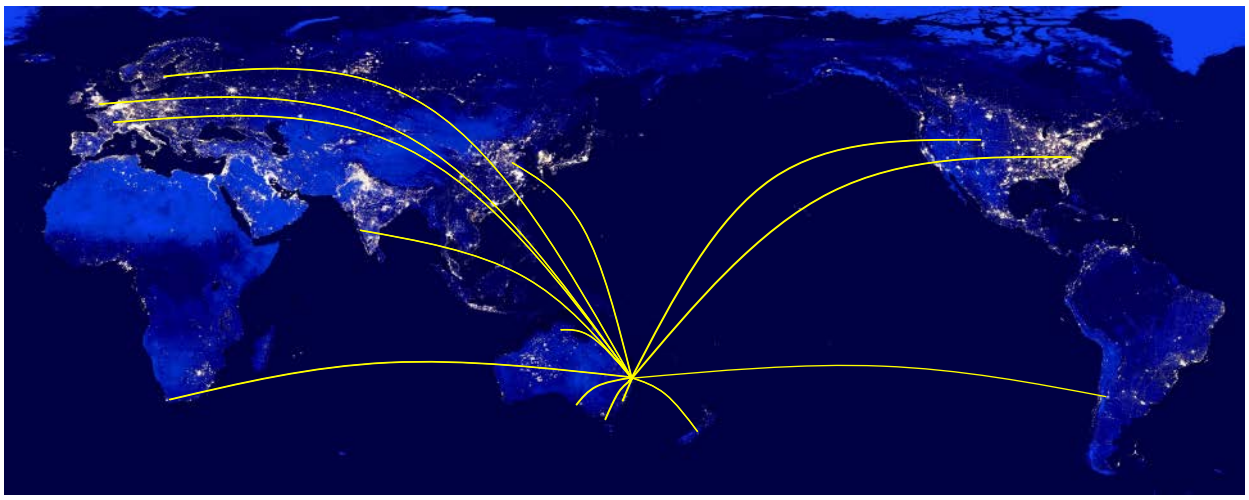
Estimation of recreational fish catches
Objectives: (i) Develop hierarchical and conditional mixed models for estimation of recreational fish catch and catch rates; (ii) Investigate the standardisation of recreational survey data collected from multiple survey methods; (iii) From survey to analysis: 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

Centre for Medical Diagnostic Technologies in Queensland (MedTeQ), Centre for Magnetic Resonance (CMR) and Imaging Research Laboratory
Joint research

Queensland Alliance for Agriculture and Food Innovation (QAAFI)
Exploring collaborative opportunities in the area of genomic research for cattle, image analysis, population modelling.

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

Matthew Holden

- ECR Travel Award, Science Meets Parliament, 2018
- Rising Star – Academic Finalist, Faculty of Science, The University of Queensland, 2018

Visitors

Professor Richard Barker, University of Otago (October 2017) Guest speaker at the International Workshop, 'Applications in Natural Resource Mathematics' by CARM.
Associate Professor Vladimir Ejov, Finders University (Oct 2017 – Nov 2017)
Ms Jody McKerral, Flinders University (May 2017)
Professor Moshe Haviv, The Hebrew University of Jerusalem (July – August 2017) Visiting Raybould Fellow
Dr Deborah Hart, NOAA Federal: Northeast Fisheries Science Center (October 2017) Guest speaker at the International Workshop, 'Applications in Natural Resource Mathematics' by CARM.
Professor Michel De Lara, Cermics, Ecole des Ponts Paris Tech (September 2017 - October 2017) Guest speaker at the International Workshop, 'Applications in Natural Resource Mathematics' by CARM.
Professor Jim Mitchell, Flinders University (May 2017)
Dr Shaowen Qin, Finders University (Aug 2017 – Oct 2017)

Publications

Journals

Arief, V., DeLacy, I., **Basford, K**., Dieters, M. (2017). Application of a dendrogram seriation alogorithm to extract pattern from plant breeding data. Euphytica. 213:85

Bennett, M.B., Coman, F., Townsend, K.T., Couturier, L.I.E., Jaine, F.R.A., **Richardson, A.J**.(2017). A historical and contemporary consideration of the diet of the reef manta ray, Manta alfredi, from the Great Barrier Reef, Australia. Marine and Freshwater Research. 68:993-997.

Berry, T.E., Osterrieder, S.K., Murray, D.C., Coghlan, M.L., **Richardson, A.J**., Grealy, A.K., Stat, M., Bejder, L., Bunce, M. (2017). DNA metabarcoding for diet analysis and biodiversity: A case study using the endangered Australian sea lion (Neophoca cinerea). Ecology and Evolution. 7, 5435-5453

Biggs, D., **Holden, M**., Braczkow, A., Cook, C., Milner-Gulland, E., Phelps, J., Scholes, R., Smith, R., Underwood, F., Adams, V., Allan, J., Brink, H., Cooney, R., Gao, Y., Hutton, J., Macdonald-Madden, E., Maron, M., Redford, K., Sutherland, W., **Possingham, H**. (2017) Breaking the deadlock on ivory. Science. 358:1378-1381

Blanchard, J**., Heneghan, R.H.,** Everett, J.D., Trebilco, R**., Richardson, A.J.** (2017). From bacteria to whales: Using functional size spectra to model marine ecosystems. Trends in Ecology & Evolution. 32:3: 174-186

Bohner, M., Dannan, F., **Streipert, A**. (2018) A nonautonomous Beverton–Holt equation of higher order. Journal of Mathematical Analysis and Applications. 457(1): 114-133

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

Brown, C., Jupiter, S., Albert, S., Klein, C., Manqubhai, S., Maina, J., Mumby, P., Olley, J., Stewart-Koster, B., **Tulloch, V**., Wenger, A. (2017). Tracing the influence of land-use change on water quality and coral reefs using a Bayesian model. Scientific Reports 7(1):4740

Brown, C., Jupiter, S., Lin, H-Y., Albert, S., Klein, C., Maina, J., **Tulloch, V**., Wenger, A., Mumby, P. (2017). Habitat change mediates the response of coral reef fish populations to terrestrial run-off. Marine Ecology Progress Series. 576:55-68

Burgess, K., Bennett. (2017). Effects of ethanol storage and lipid and urea extraction on δ15N and δ13C isotope ratios in a benthic elasmobranch, the bluespotted maskray Neotrygon kuhlii. Journal of Fish Biology. 90:417-423

Burgess, K.B., Guerrero, M., Marshall, A.D., **Richardson, A.J.**, Bennett, M.B., Couturier, L.I.E. (2018) Novel signature fatty acid profile of the giant manta ray suggests reliance on an uncharacterised mesopelagic food source low in polyunsaturated fatty acids. PLoS One 13(1): e0186464

Burgess, K.B., Guerrero, M., **Richardson, A.J.**, Bennett, M.B., Marshall, A.D. (2017). Use of epidermal mucus in elasmobranch stable isotope studies: a pilot study using the giant manta ray (Manta birostris). Marine and Freshwater Research. doi: 10.1071/MF16355

Ejov, V., **Filar, J**., Roddick, J., Rossomakhine, S. (2017). A note on using the resistence-distance matrix to solve Hamilton Cycle Problem. Annals of Operations Research. doi:10.1007/s10479-017-2571-7

Everett, J., Baird, M.E., Buchanan, P., Bulman, C., Davies, C., Downie, R., Griffiths, C., **Henegan, R**., Kloser, R., Laiolo, L., Lara-Lopez, A., Lonzana-Montes, H., Matear, R., McEnnulty, F., Robson, B., Rochester, W., Skerratt, J., Smith, J., Strzelecki, J., Suthers, I., Swadling, K., van Ruth, P., **Richardson, A**. (2017). Modeling what we sample and sampling what we model: Challenges for zooplankton model assessment. frontiers in Marine Science. 4:77 doi: 10.3389/fmars.2017.00077

Holden, M., McDonald-Madden. (2017). Conservation from the grave: Human burials to fund the conservation of threatened species. Conservation Letters, doi:10.1111/conl.12421

Jupiter, S., Wenger, A., Klein, C., Albert, S., Mangubhai, S., Nelson, J., Teneva, L., **Tulloch, V**., White, A., Watson, J. (2017). Opportunities and constraints for implementing integrated land-sea management on islands. Environmental Conservation. 44(3):254-266.

Kienzle, M., Sterling, D. (2017). Rising temperatures increased recruitment of brown tiger prawn (Penaeus esculentus) in Moreton Bay (Australia). ICES Journal of Marine Science. 74(3):741-749

McGowan, J., Bode, M., **Holden, M**., Davies, K., Krueck, N., Beger, M., Yates, K., **Possingham, H**. (2017). Ocean zoning within a sparing versus sharing framework. Theoretical Ecology.

Pascoe, S., Innes, J., **Courtney, A., Kienzle, M**. (2017). Impact of reducing investment disincentives on the sustainability of the Morten Bay prawn trawl fishery. Fisheries Research. 186:121-130

Powers, R., Coops, N., **Tulloch, V**., Gergel, S., Nelson, T., Wulder, M. (2017). A conservation assessment of Canda's boreal forest incorporating alternate climate change scenerios. Remote Sensing in Ecology and Conservation. 3(4):202-216

Rohner, C., **Burgess, K**., Rambahiniarison, J., Stewart, J., Ponzo, A., **Richardson, A**. (2017). Mobulid rays feed on euphausiids in the Bohol Sea. Royal Society Open Science. 4: 161060

Rohner, C.A., **Richardson, A.J.**, Jaine, F.R.A., Bennett, M.B., Weeks, S.J., Cliff, G., Robinson, D., Pierce, S.J. (2018). Satellite tagging highlights the importance of productive Mozambican coastal waters to the ecology and conservation of whale sharks. PeerJ. 1-24 doi: 10.7717/peerj.4161

Saunders, M., Bode, M., Atkinson, S., Klein, C., Metaxas, A., Beher, J, Beger, M., Mills, M., Giakoumi, S., **Tulloch, V., Possingham, H**. (2017) Simple rules can guide whether land- or ocean-based conservation will best benefit marine ecosystems. PloS Biol. 15(9):e2001886

Tulloch, V., Plaganyi, E., Matear, R., Brown, C., **Richardson, A**. (2018). Ecosystem modelling to quantify the impact of historical whaling on Southern hemisphere baleen whales. Fish and Fisheries. 19:117-137

Conference Papers

Bogomolov, T., **Filar J**., Luscombec, R., Nazarathy, Y., **Qin, S**., Swierkowski, P., Wood, I. (2017). Size does matter: a simulation study on hospital size and operation efficiency. In The 22nd International Congress on Modelling and Simulation (MODSIM2017) Australia: Modelling and Simulation Society of Australia and New Zealand Inc (MSSANZ). The 22nd International Congress on Modelling and Simulation (MODSIM2017) Tasmania, Australia. Dec 2017, pp1274-1280.

Diao, J., Nazarathy, Y., Taimre, T., **Filar, J**. (2017). To fish or cut bait? In The 2017 11th Asian Control Conference (ASCC), Gold Coast Convention Centre, Australia. December 17-20, 2017.

Correspondence Papers

Holden, M., Butt, N., Chauvenet, A., Plein, M., Stringer, M., Chades, I. (2017). Academic conferences urgently need environmental policies. Nature Ecology & Evolution, 1-2.