ANNUAL REPORT

2011-2012

CSIRO UTAS PhD Program in Quantitative Marine Science

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Executive Summary

We are pleased to be able to present the 2011-12 annual report for the CSIRO-UTAS PhD Program in Quantitative Marine Science (QMS), now in its 2nd year under the renewed 5-year commitment that began 1 July 2010, and in its 9th year of operation overall..

The purpose of the QMS program is to enhance the quality and number of Australian PhD graduates in quantitative marine science to address a shortage of marine scientists nationally and globally, and to develop graduate scientists with skills appropriate for potential employment by CSIRO and others in the quantitative marine science field.

Key Achievements and Challenges:

- The diversity of supervisors involved in QMS has expanded, with new participants from both CSIRO and UTAS. There are currently a total of 21 UTAS and 22 CSIRO staff involved in supervising QMS candidates.

- Enrolments in QMS have increased. In 2011-12 QMS enrolled 9 students, coming close to its target of 10. This represents a strong increase against historic annual enrolments of 3-6, and brings current student enrolment to 28 (and total students enrolled since QMS began in 2004 to 56).

- New sources of funds are flowing into the program. In the past 2 years, QMS has been successful in attracting 9 students with external scholarships valued at $232,900 (with additional value committed in future years, as detailed in the budget table provided in appendix 3).

- QMS staff arrangements have been modified to provide for greater service to the program, and now include the roles of Director (Tom Trull), Graduate Research Coordinator (Simon Wotherspoon) and Graduate Research Manager (shared by Denbeigh Armstrong and Heidi Auman). These changes have been achieved within budget. In addition, the QMS Steering Committee has been very actively involved in guiding the program over the past two years (see table for current representatives and their delegates).

- The success of QMS has motivated its emulation. UTAS and the Australian Antarctic Division are currently establishing the AAD-UTAS PhD Program in Quantitative Antarctic Science (QAS), and merger with QMS represents a significant possible synergy for the 2012-13 year, provided the new partnership delivers sufficient value and the QMS brand recognition is appropriately retained.

- Despite these successes, QMS has several challenges ahead:
  - The recruitment of quantitatively prepared students remains difficult and highly competitive, especially for domestic students. Continual expansion of our recruitment efforts is required.

In this context, we need also to carefully consider whether we could accommodate highly motivated but insufficiently prepared domestic students. Options include in-house remedial courses, training partnerships, and links to Masters programs.

- Time pressures on QMS students are increasing. UTAS seeks to reduce completion times from 3.5 - 4 years to 3 – 3.5 years, but has increased course requirements with all UTAS PhD candidates now required to take two generic units (Research Management and Research Communication) as well as their six QMS units.
- There are also new UTAS requirements for supervisor registration and ongoing training. QMS will be working to implement these in a way that maximises the increase in supervising skills and resources yet minimises the additional time commitments from our participants.

In summary, the program is currently functioning well and is close to reaching its target capacity. It has both significant opportunities and challenges in the coming year.

It is a great pleasure to be part of the program, and we are very proud of our students.

Sincerely,

Prof Tom Trull
Director

Dr Denbeigh Armstrong
Program Manager

Current Steering Committee Members and Delegates

Committee member	Delegate
Tom Trull (Director/Chair)	Stewart Frusher
Stewart Frusher	Klaas Hartmann
Zanna Chase	Pete Strutton
Campbell Davies	John Volkman
Richard Matear	Andreas Schiller

Other participants

Simon Wotherspoon (QMS GRC and director QAS)
Sjoerd Groeskamp (Student representative)
Rafael Leon (Student representative)

Enrolments, scholarships, submissions and graduations

Summary of student enrolments

Since 1 July 2010, QMS has enrolled a total of 13 students. Enrolments by year are summarised in table 1 below.

QMS is well on the way to meeting the target of 10 new students for 2012-2013 with 3 students expected to start in late 2012 - early 2013 and 4 student applications in progress.

Table 1: Enrolled students by year

Year	Number of students
2010-2011	3
2011-2012	9
2012-2013	1

Note: *target enrolment is 10 students per year*

QMS Scholarships awarded 2010-2012

Between 1.7.10 and 30.6.12 QMS has awarded a total of $138,199 in scholarships comprising a mixture of full living allowances, Elite top-ups, standard top-ups, and overseas student health cover. Relocation expenses have also been included in this figure. This does not include the value of these contributions committed beyond 1.7.12 to the end of their tenure (see budget report in appendix 3 for full details).

In addition to the scholarships offered by QMS, 9 students have received funding from sources outside of QMS including CSIRO and international funding bodies such as CONICYT, SENYCET and the Costa Rican Government. From 1.7.10 to 30.6.12 the value of these contributions to the QMS program was $232,908. This does not include the value of these contributions committed beyond 1.7.12 to the end of their tenure (see budget report for full details).

A full report of expenditure against scholarship funding is provided in the income and expenditure report in appendix 3. Table 2 below summarises the number of scholarships that have been awarded since July 2010.

Table 2: QMS Scholarships awarded 2010-2012

Scholarship	2010	2011	2012
Full living allowance	0	2	1
Elite top-up	0	2	0
Standard top-up	0	2	2
Overseas Student Health Cover	0	3	2

***Note*:** numbers of scholarships do not directly correspond with student numbers as some students have been awarded more than one scholarship or have secured funding from sources outside of QMS.

Summary of graduates

The QMS Program was launched in 2004. Since then a total of 19 students have graduated from the Program. By the conclusion of 2013 we expect this number to increase by 10.

Table 3: Graduations by year

Year	Number of students
2008	3
2009	6
2010	2
2011	4
2012	4 (3 in August)
Total	**19**

Of those students who have graduated, 4 have since been employed by CSIRO: Dr Toby Patterson, Dr Robin Thomson, Dr Evan Weller, and Dr Andrew Meijers.

Our graduates have also been employed elsewhere in Australia by ACECRC, IMOS, IMAS, JCU, ANU, UTS, Deakin, UNSW and WAMSI. Overseas our graduates have been employed by the University of Southhampton, Princeton, Lawrence Livermore National Laboratory, British Antarctic Survey, University of Paris, World Meteorological Organisation in Geneva and Massachusetts Institute of Technology.

Theses submitted in 2012

The following 2 students submitted their theses for examination in 2012. We expect a further 8 students to submit their thesis for examination in 2013.

James Dell

Supervisors: Mark Hindell (UTAS), Chris Wilcox (CSIRO) and Alistair Hobday (CSIRO)
Research Project: Fisheries oceanography of Yellowfin Tuna (Thunnus albacores) in the Tasman Sea
Thesis Abstract is in appendix 1.1, p.44

Jan Seiler

Supervisors: Neville Barrett (UTAS), Neil Holbrook (UTAS), Alan Williams (CSIRO), Richard Coleman (UTAS)
Research Project: Testing and evaluating non-extractive sampling platforms to assess deep-water rocky reef ecosystems on the continental shelf
Thesis Abstract is in appendix 1.2, p.46

Graduations 2012

Rachel Alderman

Supervisors: Stewart Nicol (UTAS), Alistair Hobday (CSIRO), Geoff Tuck (CSIRO), Rosemary Gales (DPIPWE)

Research Project: The Shy albatross (*Thalassarche cauta*): population trends; environmental and anthropogenic drivers; and the future for management and conservation.

Thesis Abstract is in appendix 1.3, p.47

Martin Marzloff

Supervisors: Craig Johnson (UTAS), Stewart Frusher (UTAS), Rich Little (CSIRO), Jeff Dambacher (CSIRO), Jean-Christophe Soulie (CIRAD)

Research Project: Towards ecosystem-based management of Tasmanian temperate rocky reefs: Community dynamics models indicate alternative community states and management strategies

Thesis Abstract is in appendix 1.4, p.48

Ernesto Molina

Supervisors: Tom Trull (UTAS), Andrew Bowie (ACECRC), Mathieu Mongin (CSIRO)
Research Project: Controls on Southern Ocean phytoplankton production – a systems approach

Thesis Abstract is in appendix 1.5, p.50

QMS students in the news and other special achievements

Martin Marzloff – Paper published in Science

QMS Alumnus, Martin Marzloff, is co-author on a paper published in the prestigious journal *Science* in 2011. The paper titled, Impacts of fishing low-trophic level species on marine ecosystems, reports on research using a range of ecosystem models to explore the effects of fishing low–trophic level species on the structure and function of marine ecosystems. Martin will graduate in August this year.

Bibliographic details: Smith, A.D.M., Brown, C.J., Bulman, C.M., Fulton, E.A., Johnson, P., Kaplan, I.C., Lozano-Montes, H., Mackinson, S., **Marzloff, M**., Shannon, L.J., Shin, Y.J. and Tam, J., 2011. Impacts of Fishing Low-Trophic Level Species on Marine Ecosystems. *Science*, 333:1147-1150.

Paul Durack – Paper published in Science

QMS Alumnus, Dr Paul Durack was lead author on a paper with Dr Susan Wijffels and Dr Richard Matera published in the prestigious journal *Science* this year. The paper *titles Ocean salinities reveal strong global water cycle intensification during 1950-2000* reports on research that demonstrates changing patterns of salinity in the global ocean during the past 50 years, marking a clear fingerprint of climate change. The publication of this research generated significant media interest in Australia and the US. Since completing his PhD, Dr Durack has secured a position in the Program for Climate Model Diagnosis and Intercomparison, Lawrence Livermore National Laboratory, California, USA.

Bibliographic details: Durack, P.J., Wijffels, S.E. and Matear, R.J., 2012. Ocean salinities reveal strong global water cycle intensification during 1950-2000. *Science*, 336:455-458.

Rafael Leon – Oral presentation commendation World Fisheries Congress, Edinburgh, UK.

At the World Fishing Congress (WFC) this year in Edinburgh, UK, QMS PhD candidates Rafael Leon walked away with a highly contested prize in the presentation talks category for Early Career Scientists. The WFC is the main forum for fisheries research worldwide and convenes once every four years, and this year over 1500 delegates attended. Out of this large delegate pool over 300 students entered the best poster and best oral presentation awards. Rafael was nominated along with only six others in each category to be considered for prizes. Rafael was commended for his oral presentation, “Do catch shares really promote resource stewardship?” Rafael is supervised by Caleb Gardner (UTAS), Klaas Hartmann (UTAS), Ingrid van Putten (CSIRO) and Rodrigo Bustamante (CSIRO).

QMS promotional activities

QMS PhD Days

In 2010 QMS flew 3 honours level students to Hobart to participate in a full day event to find out about the QMS PhD Program, meet with potential Supervisors from UTAS and CSIRO and look at the facilities and resources available at UTAS and CSIRO.

A second event was run in 2011 involving 6 students.

The combined cost of these events was $9295.79 ($3,028.76 in 2010 + $6,267.03 in 2011)

As no students chose to enrol in the QMS PhD program as a result of these events, it was agreed that QMS would not run any PhD day events in the future.

Sponsorship of the student night at the Marine Extremes and Everything in Between, AMSA-NZMSS Conference, Hobart 1-5 July 2012

QMS sponsored the AMSA-NZMSS student night, providing $2000 toward the event, held at the Metz Bar in Sandy Bay, Hobart. As part of this sponsorship QMS was listed on the conference website and we were invited to provide a short overview of the program at the student night. This sponsorship raised the profile of the program amongst PhD students at other national and international Universities.

CareerSpot

QMS placed an Ad in the following eMagazines for a period of 12 weeks from 7 June to 21 August 2012.

- EducationCareer: http://www.educationcareer.net.au/jobs/posting/?id=18535
- EngineeringCareer: http://www.engineeringcareer.net.au/jobs/posting/?id=18535
- GreenCareer: http://www.greencareer.net.au/jobs/posting/?id=18535
- ICTCareer: http://www.ictcareer.com.au/jobs/posting/?id=18535
- ResearchCareer: http://www.researchcareer.com.au/jobs/posting/?id=18535
- WaterCareer: http://www.watercareer.com.au/jobs/posting/?id=18535

QMS video

A short 3 minute video of two QMS Alumni and one current QMS student talking about the QMS program, their research and current jobs was produced by Ninna Milliken of the Bookend Trust. This video has been embedded on the QMS website at http://www.imas.utas.edu.au/qms/home and will be used in other promotional activities as appropriate.

Other planned promotional activities

VIP EDM

In the second half of 2012 we will commission Student Marketing Australia to run a marketing campaign for the QMS program using electronic direct mail to a targeted segment of the 300,000 students across Australia on their database.

We may also explore the option of distributing posters on campuses across Australia.

ADVERTISING IN STUDENT MAGAZINES

In the second half of 2012 we will develop a half page advertisement to place in student magazines at select Universities across Australia

Supervisor involvement in the QMS program

Supervision

There are currently a total of 21 UTAS and 22 CSIRO staff involved in supervising QMS candidates as detailed in table 4 below. The diversity of supervisors involved in QMS has expanded, with new participants from both CSIRO and UTAS.

Teaching

Numerous CSIRO and UTAS staff members are also involved in teaching QMS units. Details of their contribution over the first two years of the Collaboration Agreement are provided in tables 5 and 6 on page 11.

QMS sponsored Conference Travel 2011 - 2012

Student	Conference	Funding received
Tomas Remenyi	2012 Ocean Sciences Meeting, Salt Lake City 19-14 February 2012	$2,500
Felicity Graham	Australian Meteorological and Oceanography Society Conference, UNSW, Sydney, 21 Jan – 3 Feb 2012	$1,075
Felipe Briceno	Second International symposium (PICES): Effects of climate change on the world's oceans, Yeosu, Korea, 15-19 May 2012	$1,236
Rafael Leon	6th World Fisheries Congress, Edinburgh, 7-11 May 2012	$2,156
Viviane Vasconcellos de Menezes	Ocean Surface Topography Science Team Meeting: 20 year of Progress in Radar Altimetry Symposium; 4th Argo workshop; 6th Coastal Altimetry Workshop, Venice, Italy, 20-29 Sept 2012	$3,060
Cesar Penaherrera	Australian Society for Fish Biology and the Oceania Chrondrichthyan Society Joint Conference and Symposium, Adelaide 15-18 July 2012.	$1578.99

Table 4: CSIRO and UTAS Supervisors involved in the QMS Program

UTAS Supervisor	Number of current students	CSIRO Supervisors	Number of current students
Barrett, Neville Scott	2	Church, John	3
Bindoff, Nathaniel Lee	2	Brown, Jaclyn*	1
Bowie, Andrew	2	Dunstan, Piers Kyren	1
Edgar, Graham	1	Haddon, Malcolm	1
Frusher, Stewart	2	Hayes, Keith ***	1
Galton-Fenzi, Ben**	1	Hobday, Alistair	3
Gardner, Caleb	1	Hosack, Geoff***	1
Hindell, Mark	2	Ingrid Van Putten*	1
Holbrook, Neil	3	Jeffrey Dambacher	1
Hunter, John	1	Little, Rich	1
Jennings, Sarah*	1	Mathieu Mongin	2
Johnson, Craig	1	Meyers, Gary	1
MacLeod, Catriona	1	Oke, Peter	1
Michael, Kelvin	1	Patterson, Toby**	2
Mundy, Craig	1	Rintoul, Stephen Rich	3
Pecl, Gretta	1	Rodrigo Bustamante	1
Phillips, Helen	3	Schiller, Andreas	1
Semmens, Jayson Mark	3	Sloyan, Bernadette Marie	2
Stuart-Smith, Rick*	1	Smith, Tony	2
Trull, Thomas	1	Wijffels, Susan	2
Virtue, Patti	1	Wilcox, Chris	1
		Wild-Allen, Karen*	1

*Supervisors who are new to the QMS Program
** New supervisors who are also graduates of the QMS Program
*** CMIS

Table 5: Units taught in 2010-2011

Unit	Teaching Staff UTAS	Teaching Staff CSIRO	Other teaching staff
QMS 510 Introduction to Quantitative Marine Science: R and Matlab	Tom Trull		John Hoenig (consultant)
QMS511 Physical Oceanography	Nathan Bindoff Helen Phillips John Hunter Terry O'Kane		
QMS515 Techniques in Marine Remote Sensing	Kelvin Michael Andrew Meijers		Rob Massom (AAD)
QMS517 Data Analysis Methods	Nathan Bindoff John Hunter Simon Wotherspoon		

Table 6: Units taught in 2011-2012

Unit	Teaching Staff UTAS	Teaching Staff CSIRO	Other teaching staff
QMS 510 Introduction to Quantitative Marine Science: R and Matlab	Simon Wotherspoon Tom Trull Zanna Chase		Ben Raymond (AAD)
QMS512 Marine Biogeochemistry	Tom Trull Pete Strutton Zanna Chase	Richard Matear Mathieu Mongin	
QMS513 Fisheries Science	Caleb Gardner Klaas Hartmann Fay Helidoniotis	Ingrid van Putten	
QMS514 Structure and Function of Marine Ecosystems	Jeff Ross Craig Johnson	Beth Fulton Jeff Dambacher Rich Little	

Overview of current student projects (*indicates students enrolled under new collaboration agreement)

The following student profiles include all current students who enrolled prior to 30 June 2012.
A summary of students, projects, supervisors, scholarships and progress of candidature is provided in Appendix 2.

Felipe Briceno*

Supervisors: Gretta Pecl (UTAS), Caleb Gardner (UTAS), Jeffrey Dambacher (CSIRO) Jessica Andre (UTAS) and Stewart Frusher (UTAS)

Year of Candidature: 1st

Research Project: Modelling predator/prey interactions under climate change: implications for a key commercial fishery in Tasmania

Project Description

The following PhD project will evaluate how the predator-prey interactions of rock lobster and octopus are likely to alter under climate change scenarios. Using innovative approaches, the project will focus on the following aims: (i) to define those biotic and abiotic key components related to highest levels of octopus predation over various spatial and temporal scales; (ii) to define/assess the predator and prey behaviour under specific environmental scenarios; (iii) to define the thermal niche of each species based on thermal physiological experiments; (iv) to model projected prey/predator distribution and abundance using mechanistic modelling approaches.

Importance of the research

This PhD is embedded within the South-Eastern Australian Program (SEAP) which aims to address adaptation of fisheries and aquaculture to climate change through coordinated action. In this sense, outcomes from this project will provide a strong ecological framework that will result in practical adjustments and improvements to the rock lobster stock assessment model. For instance, obtaining the spatial distribution of octopus predation across Tasmanian fishery areas will allow defining predation risk assessment areas that will be useful to fishery adaptation and stock enhancement (e.g low predator releasing sites). Importantly, this study also will be important in terms of the recognition of potential conflict/trade-offs from simultaneous harvesting of food web (lobster bycatch) components which will help the development of Ecosystem Based Fishery Management (EBFM) for Tasmanian fisheries. On the other hand, one of the most important outcomes from this PhD will represent an innovation in terms of specie distribution modeling (SDM) development. The integration of biotic interactions from different organizational levels (individuals to ecosystem) into a SDM approach is a real challenge in terms of innovation since currently spatial modeling development does assume biotic interaction as uncertainties to predict future distribution and abundance of species.

Key outcomes to date

Preliminary results

Multiple regression by time series analysis of octopus predation across Tasmanian rock lobster fishery regions (2000 – 2009), *work in progress.*

Publications and other public output
Briceño, F., Frusher, S., Dambacher, J., Gardner, C., Leon, R., Tracey, S., and Pecl, G., 2012. '. Second International Symposium of 'Effects of Climate Change on the World's Oceans', **Yeosu, Korea, May 15 – 19, 2012. Oral presentation.**

Lynchpin Scholarship 2011 (AUD$1,500) *Awards and other achievements*

Travel grants for the Symposium in Korea, awarded by the following institutions (2012):
- Graduate Research Office, University of Tasmania (travel grant) (AUD$3,500)
- Quantitative Marine Science program (travel grant) (AUD$1,500)
- Institute for Marine and Antarctic Studies (travel grant) (AUD$1,500)

Matthew Cameron

Supervisors: Neville Barrett (UTAS), Graham Edgar (UTAS), Craig Johnson (UTAS), Vanessa Lucieer (UTAS)

Year of Candidature: 3rd

Research Project: Relationships between fish population and the physical structure of Australia's temperate reefs in response to marine protection

Project Description: Fisheries managers are becoming increasingly aware of the need for multi-species, ecosystem-based approaches to managing marine environments. Marine Protected Areas (MPAs) are one such approach often advocated to sustainably manage and conserve the biodiversity of the World's oceans. Such an approach requires knowledge of the relevant environmental parameters, resources and habitats at multiple scales that are important in shaping the spatial distributions and abundances of marine communities. My research is attempting to describe patterns in the spatial variability of temperate reef fish distributions and assemblages and determine how these are related to the physical structure and complexity of shallow sub-littoral reef habitats around Tasmania and Southern Australia. In addition the project is identifying how varying scale and MPA designation interact with physical structure in determining the specific structure of temperate reef fish communities.

Importance of the research: One of the biggest problems faced by policy makers and managers with the task of implementing effective MPAs is targeting suitable habitat features and locations which will maximise conservation value and safeguard over-exploited and threatened species, communities and systems. There is a need for increased focus on the scientific understanding of ecological processes which drive patterns of biodiversity in coastal regions in order to assist MPA management decisions. Quantifying fish assemblage responses to habitat structure and complexity is crucial for applied aspects of MPA management, particularly if the goals of these management approaches are to maximise biodiversity.

Ross Daley*

Supervisors: Jayson Semmens (UTAS), Alistair Hobday (CSIRO)
Year of Candidature: 1st
Research Project: Movement based conservation strategies for deepwater sharks

Project Description: Develop a set of generic management strategies that can be applied to conserve vulnerable shark species in the deep ocean

Objectives

1. Model spatial (across slope, along slope, water column) and temporal (daily, seasonal, interannual) scales of occupied space for three species of deepwater sharks with contrasting ecologies using acoustic telemetry as an indicator of the minimum scale of effective closures
2. Model the scale of segregation between male, female and juvenile Southern Dogfish using available survey data as a second type of indicator of the minimum scale of effective closures.
3. Develop predictive models of daily and seasonal movements of shark species with small-medium home ranges (miles- tens of miles) based on general linear models of shark distribution and environmental co-variates: changes in physical oceanography (light and temperature), biological oceanography, topography. Discuss the relative importance of key triggers for movement: feeding and breeding
4. Develop predictive models of daily and seasonal movements of highly migratory shark species with very large home ranges (hundreds of miles) based on behavioural switching. Identify dispersal and resident behaviours using space state models. Identify the biological or ecological drivers and timing of triggers for switching between modes of behaviour. Discuss the relative importance of key triggers for movement and compare these to species with smaller ranges.
5. Develop predictive models of the distribution of elevated food sources based on topography and ocean currents. Map the current distribution of gulper shark species using available survey catch and effort data. Compare current species distribution to historical catch and effort data as well as modelled predictions
6. Develop quantitative Management Strategy Evaluation methods to support ongoing improvements to individual fishery closed areas and integration of on and off closure measures based on the annual collection of fishery catch and effort data. Model alternative scenarios of closure size, closure season, fishing effort and post capture mortality using individual based models.
7. Develop Management Strategy evaluation methods to evaluate alternative networks of closures to meet conflicting National and multi-jurisdictional objectives for resource use and conservation. Identify and communicate the trade-offs between alternative courses of action.

Research questions

1. Which species of deepwater sharks are most vulnerable and why?
2. Is spatial management plausible in the deep ocean?
3. How can the trade-offs between resource access/use in the deep ocean and conservation of vulnerable species be measured and communicated?

Importance of the research: Some species of sharks and rays have such low productivity that they remain vulnerable to overharvesting even if they are not targeted and only ever taken as bycatch. Deepwater species are particularly vulnerable because they grow slowly and produce few young. A management strategy that includes closed areas seems like the only plausible solution. The research will analyse electronic tagging data to estimate the suitable size of closures and to help integrate spatial management with other off closure management measures such as live release of sharks captured by line fishing.

Key outcomes to date: A preliminary analysis of telemetry data was presented at the Oceania Chondrichthyan Society Meeting in 2011 highlighting diurnal movement patterns of Southern Dogfish (Centrophorus zeehaani) into shallow waters at night.

A paper, Home range and movement of Southern Dogfish, will be presented at the American Elasmobranch Society Conference in Vancouver in August 2012. This paper will also be given at the 2012 Oceania Chondrichthyan Society meeting in Adelaide, July 2012

Jessica Ford

Supervisors: Prof. Mark Hindell (UTAS), Dr Chris Wilcox (CSIRO), Dr Mark Bravington (CSIRO), Dr Toby Patterson (CSIRO)

Year of Candidature: 3rd

Research Project: Understanding animal movement using stochastic models

Project Description: Understanding what drives organism movement is central to ecology. The ability to predict movement and distribution is fundamental to many basic aspects of animal ecology, ranging from understanding individual behavioural decisions to predicting population dynamics. The applications have been used to inform the design of marine reserves through to the management of commercially harvested fish species and populations.

Individual variation is a key challenge in ecology. Inherent individual differences in movement and behaviour can introduce bias into mark-recapture estimates (most notoriously, of population size), and are often also of considerable interest in their own right. Currently, through the use of mark-recapture studies much research effort and funding are being devoted to understanding animal populations. However, until recently the analytical methods available for converting the measurements of animal sightings and movements into predictions of behaviour, exchange and distribution were in the early stages of development, and tools for answering many key questions still lacking.

This project will focus on heterogeneity of capture probability and variability in site fidelity and movement paths of North Atlantic Humpback Whales in the Gulf of Maine. The data from Provincetown Centre for Coastal Studies includes over 1200 individuals with dates of identification during the years 1979 to 2005 (over 3500 sightings).

Ultimately this research aims to demonstrate a statistical approach that allows for quantification and prediction of heterogeneity in capture probability and movement from mark-recapture data, and methods incorporating this into population movement models.

Importance of the research: This project aims to contribute toward the statistical characterisation of individual movements and detail an approach to combining data from individual to population level models. Understanding individual differences is key to understanding all ecological processes. In order to accurately understand a population, to quantify the threats faced and to develop efficient management programs, we must first understand the extent to which the individuals within a population vary.

Key outcomes from the research to date

Preliminary findings

- Development of novel statistical methods in an open source software package.
- Development of novel statistical methods which allow for identification of clusters of behaviour.

Publications and other public outputs

1. Poster presentation at International Statistical Ecology Conference, 2010 Kent UK. Student Prize for best poster.
2. Attendance at NCEAS work shop in Santa-Barbara US discussing development of non-linear ecological methods using open-source software.
3. First paper accepted for publication, not yet published.
4. Presentation of thesis work at International Statistical Ecology Conference in Sundvollen Norway July 2012

Sophie Gourguet

Supervisors: Sarah Jenning (UTAS), Stewart Frusher (UTAS), Rich Little (CSIRO, Hobart), Olivier Thebaud (CSIRO, Brisbane) and Luc Doyen (CNRS-MNHN, Paris, France).

Year of Candidature: 2nd

Research Project: Stochastic Viability Approach to Ecosystem-Based Fisheries Management

Project Description: This PhD is a co-tutelle between France and Australia.

The general objective of the PhD is to represent through mathematical and numerical modelling main biological and economic processes governing multi species fisheries in order to provide strategies for the sustainable management of these fisheries. More specifically the objective is to use a stochastic co-viability framework of analysis to address the formal modelling of trade-offs between conflicting objectives in the management of mixed fisheries. The studied fisheries are the French Bay of Biscay demersal mixed fishery and the Australian Northern Prawn Fisheries (NPF). The choice of these two cases is partly due to French-Australian collaborations (in particular with the ANR ADHOC project). Moreover these 2 case study are relevant to investigate the question of how manage multi species fisheries in a stochastic context taking into account multiple objectives regarding specifically the economic and ecological sustainability of the fisheries. These two fisheries are multi species with direct and indirect impacts on the ecosystems. Furthermore, they are both of great commercial and industrial interest. Therefore their sustainable management is a major societal concern.

To answer to the question “Which ecological and economic viability of the system both to preserve Spawning Stock Biomass (SSB) for every species and to guarantee incomes for each fleets”, a stochastic co-viability approach is applied to multi-species, multi-fleets and age-structured models.

Publications/Public output

Doyen, L., Martinet, V., Thébaud, O., Béné, C**., Gourguet, S.,** Bertignac, M., Fifas, S., Blanchard, F., 2012. A stochastic viability approach to ecosystem-based fisheries management. *Ecological Economics* 75, 32-42.

In preparation or in revision:

Gourguet, S.; Macher, C.; Doyen, L.; Thébaud, O.; Bertignac, M. & Guyader, O. Managing mixed fisheries for bio-economic viability. submitted in *Fisheries Research*

Cissé, A.A., **Gourguet, S.,** Blanchard, F., Doyen, L., Péreau, J.C. & Guyader, O. A bio-economic model for the ecosystem-based management of the coastal fishery in French Guiana. Revisions *Environment and Development Economics*.

Conference presentations

- 3/7 July 2010: Poster presentation on "A stochastic viability approach for ecosystem-based management of mixed fisheries: the case of Bay of Biscay demersal fisheries". 24th International Congress for Conservation Biology, Edmonton, Alberta, Canada.
- 13/16 July 2010: Oral communication on "A stochastic viability approach for ecosystem-based management of mixed fisheries: the case of Bay of Biscay demersal fisheries". IIFET 2010, Montpellier, France.
- 11/13 September 2011: Oral communication on "A stochastic bio-economic model for the viable management of the Bay of Biscay mixed demersal fisheries". BIOECON 2011, Geneva, Switzerland.
- 05/09 December 2011: Oral communication on "Bio-economic modelling for the viable management of mixed fisheries, the case of the Northern Prawn Fishery". 25th International Congress for Conservation Biology, Auckland, New Zealand.
- 12/16 December 2011: Oral communication: Gourguet, S., Thebaud, O., Little, R. "Bio-economic modelling for the viable management of mixed fisheries".19th International Congress on Modelling and Simulation, Perth, Australia.

Felicity Graham*

Supervisors: A/Prof Neil Holbrook (UTAS), Dr Jaclyn Brown (CSIRO), Dr Andrew Wittenberg (GFDL)

Year of Candidature: 1st

Research Project: Understanding the dynamics of El Nino Southern Oscillation and how they might change with global warming

Project Description: El Nino Southern Oscillation (ENSO) is the primary mode of variability in Australian climate. Simulating ENSO and the tropical Pacific climatology effectively in global climate models (GCMs) is essential for improving the performance of models and determining expected climate change.

We examine the leading theories of ENSO and test them against observations and climate models. We will create a set of tools allowing modellers to characterise ENSO behaviour in their climate models and assess how ENSO is expected to change in the future. Improved understanding and certainty in ENSO projections will mean better adaptation and management decisions can be formulated.

Key outcomes to date:

Publications

Graham and McDougall, 2012 (submitted to JPO Oct 2011, under revision). Title: Quantifying the non-conservative production of Conservative Temperature, potential temperature and entropy

Conference presentations
Poster presentation, Application of an ENSO unified oscillator to an ocean-only model", 18th annual AMOS 2012 National Conference, UNSW 31 January to 3 February 2012. Awarded best student poster.

Sjoerd Groeskamp*

Supervisors: Dr. Trevor McDougall (UNSW), Dr. Bernadette Sloyan (CSIRO), and Assoc/Prof Nathan Bindoff (UTAS)

Year of Candidature: 1st

Research Project: Estimating diffusion coefficients from ocean hydrography

Project Description: A prominent use of ocean models is to predict future climate change under various greenhouse gas scenarios. This is done using coupled ocean-atmosphere-ice models. A key parameter in such models is the strength of ocean mixing. Ocean mixing controls the rate at which heat and CO2 are absorbed by the ocean. These models need the strength of ocean mixing processes to be prescribed.

As ocean models have improved over past decades, their ability to accurately model the present ocean is being more obviously limited by the realism of the imposed mixing coefficients. For example, vertical mixing is commonly set as a constant, or near constant parameter despite it being known to be highly spatially variable. What are lacking are global estimates of rates of vertical and lateral mixing.

To overcome the lack of direct mixing observations we have recently developed a new inverse method; the Tracer-Contour Inverse Method, which is able to deduce the strength of both the vertical and lateral mixing in the ocean, as well as giving superior estimates of the mean ocean circulation (Zika et al. (2009a)). This Tracer-Contour Inverse Model is much more skilful than the three prior inverse methods that have been used in oceanography since 1978.

This inverse method uses the hydrographic data that is becoming available from Argo floats; autonomous floats that are providing oceanographers with more data than has been available to date from research ships, although the ship-derived data is vital below 2000m depth.

This PhD topic will develop the Tracer-Contour Inverse Method (TCIM) so that it can be applied in a general way to any region of the world ocean, and conduct inversions of an isopycnally averaged hydrographic climatology systematically around the world ocean.

For the TCIM to achieve this goal it needs to be changed from a 'single box to multibox' environment, mixed layer dynamics and communication between the mixed layer and the interior needs to be included. Finally the TCIM must be able to deal with complex topography and coastal geometries.

Possibly different parametrizations of the diffusion coefficients within the model is worth exploration.

The global application of the TCIM will provide an understanding of the spatial variation of the vertical and lateral ocean mixing that are appropriate to be used in coarse-resolution ocean models. Simple spatial functions of the magnitude of these diffusivities, accompanied by the uncertainties of the estimates, can then be included as mixing parameterizations in climate models. This will improve the model simulation and prediction of the ocean circulation and change.

An alternative approach to obtain first estimates of the global circulation is also explored in this PhD. The ocean circulation has long been investigated using stream-function in cartesian coordinates. Although such stream-functions have provided us with great understandings of the mean ocean circulation, they need averaging in one direction, so limiting their applications. As a result a better method is sought. Recently a stream-function in Temperature-Salinity space has been developed using an ocean model output. This 'thermohaline streamfunction' (THS) has proven to be of great additional value for mean ocean circulation studies (Zika et al. (2011)).

In this PhD we will derive the THS from measurements of surface freshwater and heat fluxes. Deriving the THS from measurements and constraining the results with accepted physical arguments, will provide a new tool to study the mean ocean circulation from measurements.

Even though independently both the TCIM and the THS itself provide great opportunities to study mean ocean circulation, they are likely to be combined. The estimates of parameters might be used as constraints to tune the THS with. On the other hand the THS might provide relevant estimates of the mean ocean circulation that can be used for comparison with and constraining of the TCIM.

In the end, this PhD will provide a relation between, and estimate of mixing parameters and the global overturning circulation, estimates that are needed by ocean modellers for the purpose of climate prediction.

References:
Zika, J. D., T. J. McDougall and B. M. Sloyan, 2009a: A Tracer Contour Inverse Method for estimating ocean circulation and mixing. *J. Physical Oceanography*, 40, 2647.
Zika, J. D., M. H. England, W. P. Sijp, 2011: The Ocean Circulation in Thermohaline Coordinates. In press, *J. Physical Oceanography*.

Key outcomes to date

Publications

Sjoerd Groeskamp, Leo R.M. Maas, Ship-borne contour integration for flux determination, *Journal of Sea Research*, Available online 6 June 2012, ISSN 1385-1101, 10.1016/j.seares.2012.05.007. http://www.sciencedirect.com/science/article/pii/S1385110112000652

David Gwyther*

Supervisors: Ben Galton-Fenzi (ACE CRC), Jason Roberts (AAD), John Hunter (ACE CRC) and John Church (CSIRO)

Year of candidature: 1st

Research Project: Investigating the Impact of Ocean Warming on Antarctic Ice Shelves

Project Description: In most cases, the major forcing on ice shelf evolution is the basal melt/freeze rate. Ice shelves largely isolate the ocean below from the effects of the atmosphere. The interaction between the ice shelves and the ocean is mainly thermodynamic with heat and freshwater exchanged between the ice shelf and the ocean. Of primary interest is the way in which the melting and freezing depends on the ocean temperature, which is increasing (and will continue to increase) with global warming. During the past few years there has been a large program of data collection on the Totten Glacier. These and future observations of the ocean will form the basis of numerical modelling of this ocean system. There is also an interest in modelling the cavities under other ice-shelves. Each specific application of the model would indicate the sensitivity of that particular ice-shelf to a warming ocean.

Projects could include:

- Using the model to simulate the mean basal melt rate and spatial pattern of melt/freeze and compare with glaciological estimates.
- Determine if a signal of enhanced basal melt rates is observed during the period of glaciological observations.
- Describe the ocean circulation and properties beneath the floating part of the Totten Glacier and the adjacent region over the continental shelf
- Determine the sensitivity of ice shelves to future changes in both atmospheric forcing and changes to ocean temperature and salinity.
- The model may be used in the future development of a coupled ice-stream/ice-shelf/ocean model.

Importance of the research: Of primary interest is the way in which melting and freezing of Antarctic ice shelves depend on ocean temperature and circulation, which are changing with global warming. Recent observations of rapid thinning of the Totten Glacier, East Antarctica, indicate oceanic forcing, but details remain unclear. This project aims to investigate the oceanic forcing of melting and freezing of Antarctic ice shelves and in particular, the Totten Glacier ice shelf.

Scott Hadley*

Supervisors: Craig Johnson (UTAS), Catriona Macleod (UTAS), Karen Wild-Allen (CSIRO)

Year of candidature: 2nd

Research Project: Alternative strategies for sustainable environmental management of nutrient loads in aquaculture

Project Description: To investigate the effectiveness of Integrated Multitrophic Aquaculture (IMTA) to offset nutrient loading from salmon farming. The construction of a biogeochemical model to demonstrate the growth and therefore remediation potential of species of macroalgae and filter feeding organisms. The models can be incorporated into the CSIRO's fully coupled Hydrodynamic, Sedimentary and Biogeochemical models to show the potential for IMTA in SE tasmanian waters.

Importance of the research: The project has the potential to provide a method for reducing the environmental impact of salmon farming. This method could give rise to a new industry with economic benefit to the state.

Key outcomes to date: Just over a year in I have developed a model for macroalgal growth and am in the process of producing results aimed at testing farming potential in the area. In July, I will be presenting posters at both the AMSA and then APCAB conferences.

Christopher Jackett

Supervisors: Dr Robert Ollington (UTAS), Dr Julian Dermoudy (UTAS), Dr Jenny Lovell (CSIRO)

Year of Candidature: 3rd

Research Project: Deconvolving and increasing the spatial resolution of satellite data using the Maximum Entropy Method

Project Description: Monitoring coastal environments is an important component in the sustainable management of regions which are affected by human activity, anthropogenic climate change and natural events. Remote sensing satellite instruments provide data at a range of spectral bands and spatial resolutions which are valuable to the monitoring of such regions. However, every satellite instrument has a unique spatial response function, which becomes convolved with the input radiance field and contributes to the total error in the recorded signal. A multiscale maximum entropy deconvolution technique extracts the greatest amount of information from a measurement as can be justified by the signal to noise ratio of the data. The Maximum Entropy Method (MEM) is heavily grounded in information theory and statistical mechanics, and has the potential to deconvolve and increase the spatial resolution of satellite data in a robust and unbiased manner. This research aims to investigate and develop a highly efficient and robust multiscale entropy deconvolution algorithm that can autonomously sharpen and spatially enhance data obtained from a wide range of satellite instruments. The proposed method will be used to generate enhanced quality MODIS ocean colour data products including Chlorophyll A, K490 and Suspended-Solids. The

development of multiscale entropy deconvolution and spatial resolution enhancement techniques will significantly increase satellite data quality and greatly improve our ability to manage coastal environments.

Public output

C. Jackett, P. Turner, J. Lovell, R. Williams, Deconvolution of MODIS imagery using multiscale maximum entropy*, Remote Sensing Letters* 2011

E. King, P. Mak, P. Turner, G. Smith, K. Suber, M. Paget, **C. Jackett**, P. Fearns, A. Rohl, F. Goessmann, The Australian Oceans DAAC, Proceedings of the 14th Australasia Remote Sensing & Photogrammetry Conference 2008

E. King, P. Mak, P. Turner, G. Smith, K. Suber, M. Paget, **C. Jackett,** P. Fearns, A. Rohl, F. Goessmann, Distributed Gridded Data Delivery for Marine Research, Proceedings of the eResearch Australasia Conference 2008

Nigel Keeley

Supervisors: Catriona Macleod (UTAS), Christine Crawford (UTAS), Mark Gibbs (CSIRO), Barrie Forrest (Cawthron Institute), Chris Cromey (SAMS).

Year of candidature: 3rd

Research Project: Quantifying and predicting benthic enrichment associated with southern temperate aquaculture operations.

Project Description: To identify an environmental management strategy targeted to the current and developing operational needs of southern hemisphere aquaculture by:

1. evaluating existing approaches for assessment and prediction of local and ecosystem impacts associated with aquaculture operations under southern temperate conditions
2. modifying these approaches, where necessary, to reflect local environmental conditions/ ecosystems and local ecological understanding
3. examining the transferability of selected approaches between Australia and New Zealand, with a view to establishing an approach to environmental management tailored for southern hemisphere operations.

Keeley, N., MacLeod, C., and Forrest, B. (2012). Combining best professional judgement and quantile regression splines to improve characterisation of macrofaunal responses to enrichment. *Ecol Indicators* 12, 154-166.

Keeley N, Forrest B, Macleod C, Crawford C. In Review. Exploiting salmon farm benthic enrichment gradients to evaluate the regional performance of biotic indices and environmental indicators. Submitted to *Ecological Indicators* Mar 2012

Veronique Lago*

Supervisors: Nathan Bindoff (UTAS), Susan Wijffels (CSIRO), John Church (CSIRO), Simon Marsland (CSIRO)

Year of Candidature: 2nd

Research Project: Decomposition of the impact of the ocean's surface boundary fluxes onto the subsurface properties.

Project Description: Changes in the climate over the past few decades are reflected on the oceans' physical properties. The transmission of surface boundary fluxes changes to the oceans' interior is not fully understood. The spatio-temporal features and method of propagation of an anomaly into the subsurface oceans' physical properties is possible through an ocean-sea ice coupled model. By enhancing each flux individually, a decomposed quantification of changes and method of propagation is possible. The amplitude of these changes will be compared to the observations for information about the linearity of the interactions. The results will be relevant to the interpretation of ocean observations in a climate change context.

Importance of the research: The oceans regulate the local and global climate by redistributing heat and freshwater content. The ocean has a heat capacity of approximately 1000 times that of the atmosphere. The oceans thus have an energy storing capability that can influence climate at a regional and global scale through variations in its heat uptake. Understanding the mechanisms in which changes in the global climate are transferred into the ocean interior is important to predict future changes.

Key outcomes to date

Preliminary, intermediate or final results

Preliminary results show that changes solely in surface temperature create changes in the salinity field at the subsurface. Further experiments will be required to properly assess the qualitative and quantitative amplitude and method of propagation of these anomalies.

Publications and other public output

- The oceanic response to anomalous surface contributions, talk presented at the Australian Meteorological and Oceanographic Society
- Modelling North Atlantic Circulation with Consideration of the Greenland Ice Sheet's Melt at the Atmosphere, Ocean, Fluids Seminar
- Impact of Greenland melt on the sub-polar North Atlantic through different resolution models, Canadian Meteorological and Oceanographic Society -CGU Congress.
- Effect of model resolution on the study of the impact of Greenland's ice sheet melt on the subpolar North Atlantic, ATLAS Society.
- The role of resolution on the impacts of Greenland melt on the sub-polar North Atlantic, DRAKKAR Annual Workshop.

Awards and other achievements

- Quantitative Marine Science Graduate Research Scholarship
- Profiling Alberta's Graduate Students Award
- CMOS Student Travel Bursary

Other experience:

- Research Assistant at the Institut National de Recherche Scientifique, Quebec City, Québec, Canada for the International Polar Year Circumpolar Flawlead project.

Emmanuel Laurenceau*

Supervisors: Tom Trull (UTAS), Mathieu Mongin (CSIRO)

Year of Candidature: 1st

Research Project: Controls on Organic Carbon Sequestration from the Naturally Iron-fertilised Phytoplankton Bloom over the Kerguelen Plateau

Project Description: The Kerguelen ocean and Plateau compared Study (KEOPS) which took place in 2005, aimed to describe the functioning of an ecosystem naturally fuelled by iron supply and to study the consequences of this natural fertilization on biogeochemical cycles with a special focus on carbon (Blain et al., 2008). The results demonstrated a high carbon export efficiency associated with the bloom and a downward flux of carbon processed essentially through biological aggregation and conducted by the settling of separated or aggregated zooplankton fecal pellets (Ebersbach and Trull, 2008). Observations of sinking particle flux from Underwater Video Profiler (UVP) and particles collected in polyacrylamide gel-filled sediment trap revealed higher settling rates in the HNLC surrounding waters than beneath the bloom (Jouandet et al., 2011).

The artificial and natural iron-fertilized bloom experiments conducted in the Southern ocean brought a large amount of essential information but many work still needs to be conducted in order to understand the ecosystem controls on carbon export in a naturally iron-fertilized area. Many hypotheses have to be tested to solve key-issues emerged from recent results. The major questions that this study proposes to examine are related to the understanding of the processes influencing the aggregation of particles and their settling rate in the water column with a focus on the controls by ecosystem dynamics over the Kerguelen Plateau. The data and samples needed in this project have been acquired during the second Kerguelen ocean and plateau compared study (KEOPS2) conducted in October and November 2011.

By addressing those problems, this project aims to better determine the efficiency of the carbon export (defined as the fraction of primary production exported below the winter mixed layer) and the processes that control it for the naturally iron-fertilized region over the Kerguelen plateau.

Key outcomes to date

Major results from KEOPS2 roller tank experiment (Oct. - Nov. 2011):

- Phytoplankton aggregates made in roller tanks show no increase of sinking velocity with size suggesting that physical aggregation may not accelerate carbon export.
- Particles produced in roller tank experiment show similar structures and composition than natural particles collected in polyacrylamide gel. This represents a step toward application of processes identified in this kind of experiment to those occurring in the water column.
- Relationships identified between average phytoplankton cell length and aggregate sinking velocity suggests the role of phytoplankton community structure and cell senescence in carbon export efficiency.

Publications and public output

Publications in preparation

(All titles are preliminary and likely to be modified)

- "Sinking velocity of marine aggregates, from simple theory to complex reality: insights from roller tank experiments in a naturally iron-fertilised area of the Southern Ocean."
  Co-authors: Tom Trull, Diana Davies, Christina De La Rocha, Stephane Blain.
- Sinking particle properties from polyacrylamide gel-filled sediment trap images.
  Co-authors: Tom Trull, Diana Davies, Jacqui Doran, Anya Waite.
- Modelling aggregation and sinking processes over the Kerguelen plateau.
  Co-authors: Tom Trull, Mathieu Mongin, others (?).

Conference presentations

E. Laurenceau, T.W. Trull, D. Davies, C. De La Rocha, "Investigation of parameters influencing the formation and the settling of organic aggregates made in roller tank experiments from *in situ* sampled seawater during the KEOPS2 voyage" Poster presentation, ACE CRC Symposium, *From Discovery to Cutting Edge Science*, 8-9 March 2012, Hobart, Tasmania.

Rafael Leon

Supervisors: Caleb Gardner (UTAS), Klaas Hartmann (UTAS), Elizabeth van Putten (CSIRO)

Research Advisors: Rodrigo Bustamante (CSIRO), Wolfgang Stotz (UNC), John Tisdell (UTAS)

Year of Candidature: 3rd

Research Project: The effect of catch share strength on management of marine resources

Project Description: Allocated catch shares (or individual quotas) are used in fisheries to address common pool problems such as competition for stock. The theory around these catch shares assumes equal access to the resource for all operators, but this may not always be the case. Factors that may limit access of individual fishers or vessels to the common pool include unique gear

characteristics of fishing operations, output controls on catch, and social norms that regulate interactions between fishers. Australian commercial lobster and abalone are managed using catch shares, which involves a Total Allowable Commercial Catch (TACC) split into Individual Transferable Quotas (ITQs). In contrast, the Chilean lobster fishery is also managed using a TACC system but there is no allocation of individual transferable quotas. Instead, an informal tenure system has been developed. The fishing ground is divided into spots where one trap is deployed. These spots are allocated to families and individual fishermen according to internal hierarchical rules. The other extreme is the territorial use right for fishing, which is used to manage the Chilean abalone fishery. In this system, an exclusive access to a fraction of fishing ground is allocated to an artisanal fishers' organization (Management Area, MA). This range of management strategies has produced a range of interaction patterns amongst fishers. For instance, in Australia, has emerged informal geographical segregation in the utilization of the common resource, or "ground holding". This behavioural factor may modify the economic environment and thus for the overall fleet and fishery. This project explores the strength of fishing rights, analyzing abalone and rock lobster fisheries in Australia and Chile.

General Objective: The overall objective will be to carry out an analysis of biological, social and economic variables for the lobster and abalone fisheries to assess the strength of fishing rights on management of marine resources. The mentioned variable will be assessed in light of the different management regimes in Australia and Chile.

Importance of the research: Fishing rights have been implemented in many fisheries around the world to constrain catch for biological objectives and in an attempt to create economic benefits. Despite the fact that some benefits have been achieved (e.g. fleet rationalization), stock status and economic indicators of many these fisheries have a downward trend. These results indicate that fishing rights *per se* are not sufficient to achieve the expected outcomes. Therefore, identifying the additional conditions that are required to be met, management changes may be recommended in order to achieve stock rebuilding and higher economic yield.

Key outcomes to date:
Preliminary results:

- Draft of first article, *Do catch shares really promote resource stewardship?*
- Data and first analysis for the second article

Publications and other public output

- Poster presentation, first chapter results in the Australian National Network in Marine Science (ANNiMS) Postgraduate Conference (November 2011).
- Oral presentation, first chapter in the World Fisheries Congress Edinburgh 2012 (May 2012).

Awards and other achievements

- Commendation for oral presentation in the World Fisheries Congress Edinburgh 2012 (May 2012).

Amelie Meyer

Supervisors: Dr Helen Phillips (UTAS), Dr Bernadette Sloyan (CSIRO), Prof. Nathan Bindoff (UTAS) and Dr Kurt Polzin (WHOI)

Year of candidature: 3rd

Research Project: Mixing intensity and sources in the Southern Ocean: an observational study surrounding the Kerguelen Plateau.

Project Description: A precise description of ocean mixing and its sources is vital to improve the understanding of the global overturning circulation and improve oceanic general circulation models. The Southern Ocean plays a crucial role in controlling the global climate system, with the Antarctic Circumpolar Current (ACC) allowing the exchange of properties between oceans. Eight EM-APEX floats were deployed near the Kerguelen Plateau where we expected the interaction of the ACC and the plateau would generate turbulence. Temperature, salinity, pressure and horizontal velocity observations from the floats are analysed. The distribution and intensity of diapycnal mixing is estimated along the 6550 km of float trajectory using shear-strain parameterization.

Importance of the research: Accurate climate predictions are only possible if mixing in the ocean is correctly parameterised in models. This project will provide vital observations and measurements of mixing in the interior of the Southern Ocean, leading to a better understanding of the global ocean dynamics necessary for accurate predictions of future climate.

Key outcomes to date: Eight EM-APEX floats were deployed near the Kerguelen Plateau where we expected the interaction of the ACC and the plateau would generate turbulence. Temperature, salinity, pressure and horizontal velocity observations from the floats were analysed. The distribution and intensity of diapycnal mixing was estimated along the 6550 km of float trajectory using shear-strain parameterization. We found that the mixing intensity is highly spatially variable. Mixing 'hot-spots' nearby topographical features were identified with diffusivities as high as 1 x 10-2 m2s-1, above areal mean values (3 x 10-5 m2s-1). We explored bottom roughness, current speed, wind work and eddy as sources or drivers of the observed mixing. We also identified the Subantarctic Front as the boundary between two different dynamic regimes.

Publications:

Meyer, A., Phillips, H.P., Sloyan, B. & Bindoff, N. (2010). High Resolution Current Velocity Profiling Argo Floats: Preliminary Results From Subantarctic Waters. In Proceedings of OceanObs'09, Sustained Ocean Observations and Information for Society (Annex), Venice, Italy, 21-25 September 2009, Hall, J., Harrison, D.E. & Stammer, D., Eds., ESA Publication WPP-306.

Awards and other achievements

- Australian Postgraduate Award, 2009
- CSIRO Flagship Collaboration Fund Postgraduate Top Up Scholarship, 2009
- University of Tasmania and CSIRO joint Quantitative Marine Science (QMS) Scholarship, 2008

Camilla Novaglio*

Supervisors: Assoc Prof Stewart Frusher (UTAS), Dr Tony Smith (CSIRO)

Year of candidature: 1st

Research Project: The importance of ecological baselines in developing ecosystem models

Project Description: Reliable knowledge is lacking or fragmentary concerning the "historical" aspects of fisheries and marine ecosystems. There is a growing need to establish ecological baselines for exploited communities and to incorporate this knowledge in ecosystems models.

The main objective of this project is to provide information on the evolution, over the past 100 years, of fisheries and marine exploited ecosystems, to assess the effects of fishing and environmental factors on such communities, and to recalibrate ecosystems models using the information achieved. This is being considered at a spatial scale that encompasses the demersal bioregion of South East Australia, with particular focus on Tasmanian waters.

The main specific tasks of this study are the following:

1. To collect and inter-calibrate all the available information on fishing effort and catch composition from scientific surveys, in particular trawl surveys, together with historical knowledge from fisherman, and essential environmental data.
2. To develop and validate a common analytical framework to estimate spatial and temporal trends in relative abundance indices. To describe spatial and temporal evolution of species diversity and species assemblages considering as many species/ecological groups and communities as the data allow. To find possible explanatory factors of change directly related to anthropogenic causes and environmental factors.
3. To recalibrate and improve end-to-end ecosystem models based on data achieved through the previous tasks.
4. To compare outputs from the models with and without the additional historical data, to underline the importance of early baseline data for ecosystem model calibration (and the uncertainties that can arise from not having such data).

Importance of the Research: A key motivation for this study is that existing ecosystem models show large uncertainty when projected forward under scenarios of reductions in existing anthropogenic impacts (such as cessation of fishing). This arises in part from the fact that most are calibrated starting late in the history of human impacts so that initial states are very poorly defined and do not act to inform or constrain system dynamics and behaviour. The present research project will increase substantially our understanding of the spatial and temporal evolution of communities and ecosystems in South East Australia. The results will underline the importance of historical data in developing ecosystem models, and the information achieved will not only better inform about past changes in marine ecosystems (including spatial as well as temporal changes), but also improve the predictive ability of such models.

Key outcomes to date: Despite the project is currently at its very early stage, a promising amount of historical data spanning more than a century (the survey "Thetis 1898" holds the oldest data) has already been collected and digitalised. Data regards fishing effort and catch composition from scientific surveys carried out on the continental shelf and slope of Tasmania, Bass Strait and New South Wales.

Cesar PeÑaherrera-Palma*

Supervisors: Dr Jason Semmens (UTAS), Assoc/Prof Stewart Frusher (UTAS) and Dr Alistair Hobday (CSIRO)

Year of Candidature: 1st

Research Project: Abundance, distribution and conservation value of sharks in the Galapagos Marine Reserve

Project Description: In the marine realm, apex predators like sharks play an important role maintaining the balance and health of marine ecosystems. With their presence they do not only help securing the normal functioning of trophic webs, but also support and preserve the overall ecosystem services humans received from the sea.

Unfortunately, sharks are particularly at risk from unsustainable fishing practices, making them one of the more urgent taxa requiring greater levels of protection and conservation. Several studies have indicated that shark populations have declined drastically throughout the world, while others have pointed out that ecological effects of shark declines could be significant.

In the Galapagos Marine Reserve (GMR) there is a great uncertainty on the actual state of shark populations. Dive guides with vast experience have expressed their concern of an apparent decline in shark abundance in the main dive sites during the last 20 years. Notwithstanding, a recent publication has reported, from a theoretical approach, that the GMR creation might have resulted in an increase of the biomass of bentho-pelagic shark populations. Marine Protected Areas (MPA) have proven to be effective for protecting benthic fish, but no research has assessed this in apex predators such as sharks. The lack of a baseline in shark abundance makes impossible to test these two assumptions.

In addition, Galapagos fishermen are now targeting large marine predators, such as big tunas and marlins, with fishing gears similar in construction and functionality to longlines (previously banned due to elevated rates of by-catch of shark, sea turtles and rays species). Using such gears put in threat many shark populations at the same time that might uncover illegal activities. In this case, tools to help fishermen to understand the ecological and economical value of shark are needed. Therefore, the present project will establish shark's population abundance baseline, the climate effect on their migratory movements in and around the GMR, and their economic value for the dive tourism industry operating in Galapagos.

Tomas Remenyi

Supervisors: Dr Andrew Bowie (ACE CRC, UTAS), Dr Mathieu Mongin (CSIRO) and Dr Ed Butler (AIMS)

Year of Candidature: 3rd

Research Project: Quantifying the impact of dust deposition to the Southern Ocean using dissolved aluminium concentrations

Project description: To map Al distributions on a large scale requires the development of analytical methodology that is sensitive, precise, rapid, minimises the risk of sample contamination and operable onboard research vessels. Through this project, the candidate developed and optimised an analytical method for the determination of Al in seawater using the reversed-phase high-performance liquid-chromatographic (RP-HPLC) analysis of an aluminium-lumogallion complex (derivative synthesised in the lab). The optimised system was tested against a series of archived Southern Ocean and Atlantic samples. The validated method was then be applied to the analysis of samples collected during two research cruises. Data processing and interpretation is currently underway.

Importance of the research: This research aids the understanding of trace nutrient supply mechanisms to the Southern Ocean. This is an important parameter in global models for estimating the oceans role in the carbon cycle and the climate system.

Key outcomes to date:
Preliminary results:

1. RPHPLC method has been developed and validated (two publications see below).
2. SAZSENSE cruise data has been written up to draft stage for publication.
3. SR3 cruise data is currently being assessed and written into the thesis.

Publications:

Remenyi, T. A.; Nesterenko, P. N.; Bowie, A. R.; Butler, E. C. V. & Haddad, P. R.
Fast and sensitive determination of aluminium with RP-HPLC using an ultra-short monolithic column *Anal. Method., Royal Soc Chemistry,* **2011***, 3*, 2488-2494

Remenyi, T. A.; Nesterenko, P. N.; Bowie, A. R.; Butler, E. C. V. & Haddad, P. R.
Short communication: Reversed phase high performance liquid chromatographic determination of dissolved aluminium in open ocean seawater
Limnol. Oceanogr.-Meth., **2012***, (accepted)*

Conference presentations:
Ocean Science Meeting Feb 2012, Aluminium in the subantarctic Southern Ocean south of Australia: regional comparisons during summer, **Tomas A. Remenyi**, Andrew R. Bowie, Delphine Lannuzel,

Thibaut Wagener, Edward C.V. Butler, Pavel N. Nesterenko, Paul R. Haddad

Awards and other achievements:
Travel scholarships:

- UTAS GRO funding to Ocean Sciences Meeting Feb 2012.
- COST funding to attend a workshop in Belgium May 2012.

Christopher Roach

Supervisors: Dr Helen Phillips (UTAS), Prof Nathan Bindoff (UTAS), and Dr Stephen Rintoul (CSIRO)

Year of candidature: 2nd

Research Project: Ekman Currents in the Antarctic Circumpolar Current

Project description: Using velocity profiling float and ship-board Acoustic Doppler Current Profiler data from the SOFINE voyage undertaken in late 2008 north of Kerguelen Island, we seek to identify, characterise and model wind driven (Ekman) currents within the Southern Ocean before proceeding to investigate the implications on wind driven transport (net movement of water) and possibly explore the resulting effects on the climate system.

Importance of the research: V.W. Ekman's theory of wind forcing on the ocean is a corner stone of oceanography. By considering a balance between frictional and Coriolis forces and assuming a constant vertical eddy viscosity, Ekman (1905) devised equations for the latitudinal and longitudinal velocity components as a function of depth. For steady winds the resulting solution is the Ekman spiral and has a characteristic exponential amplitude decay and anticyclonic (anticlockwise in the Southern Hemisphere) rotation.

The net transport arising from Ekman currents is of significance in meridional overturning circulation, driving the upwelling of deep waters near 50°S (Speer et al., 2000) and transporting them northward. It may also be significant in the formation of Mode Waters (Sallée et al., 2006).

Previous studies have established the validity of the relationship between wind stress and net Ekman transport and observed Ekman-like spirals in data averaged over long time periods in a coordinate frame relative to the wind. However, detection of Ekman spirals over short time frames remains rare and details of the vertical structure of both net transport and individual Ekman spirals are still not fully resolved. Additionally, there have been few previous observational studies of Ekman currents in the Southern Ocean (Elipot, 2006, Lenn and Chereskin, 2009).

Outcomes to date: Assuming a constant geostrophic velocity within the upper 200m of the ocean we successfully identified Ekman-like spirals in 249 individual profiles and in the mean profile. In

both cases the typical spirals were found to be display a more rapid decay in velocity amplitude than rotation (resulting in 'compressed' spirals), consistent with most previous studies.

Transport was found to be strongly surface intensified, with little penetration below the mixed layer. Mean transport over all velocity profiles was observed to skewed towards the wind, lying at 45° rather than 90° to the left of the wind as expected from steady-state Ekman theory. We identified three potential causes of this transport skewing: the "compression" of observed Ekman spirals; the role of transient wind forcing or geostrophic transport not included in constant near-surface geostrophic current. We are still in the process of determining which of these factors is dominant.

We have also examined the dependence of Ekman spirals on the frequency of wind forcing using a spectral technique developed by Elipot and Gille (2009). This technique involves the estimation of transfer functions using wind-stress auto-spectra and cross spectra between wind-stress and ageostrophic currents at a constant depth level to estimate transfer functions. By comparing estimated the transfer functions from observations with transfer functions derived for theoretical combinations of eddy viscosity profiles and boundary conditions it is possible to infer properties of mixing within the Ekman layer. This is still a work in progress, but initial results are generally in line with Elipot's work.

Conference Presentations

- 10th International Conference on Southern Hemisphere Meteorology and Oceanography, 23-27 April 2012, Noumea, New Caledonia
- 2012 Ocean Science Meeting, 20-24 February 2012, Salt Lake City, USA
- 3rd Australian National Network in Marine Science Conference, 29 November – 1 December 2011, Perth, Australia
- IUGG General Assembly, 28 June- 7 July 2011, Melbourne, Australia
- 11th Conference on Polar Meteorology and Oceanography, 2-5 May 2011, Boston, USA
- AMOS and MetSoc NZ - Joint Conference: Extreme Weather, 9-11 February 2011, Wellington, New Zealand
- ACE-CRC Symposium, 18-19 August 2010, Hobart, Australia
- Alpine Summer School Course XVIII: Buoyancy Driven Flows, 21-30 June, Valsavarenche, Italy

Marie Sinoir

Supervisors: Dr Andrew Bowie (ACE CRC-IMAS), Dr Mathieu Mongin (CSIRO), Dr Edward Butler (AIMS), Dr Pavel Nesterenko (ACROSS-Utas), Dr Christel Hassler (UTS)

Year of Candidature: 3rd

Research Project: Zinc speciation in the Tasman Sea and its relation to the phytoplankton community

Project Description: The main focus of my project is to identify and quantify zinc speciation in the Tasman Sea and its impact on the biology and the phytoplankton community. To do so, biological

experiments have been run with two phytoplankton species from this region. They characterise uptake and zinc requirement for these two species in two different conditions of low zinc concentrations. With the same idea in mind, chemical analysis using voltammetry technique gave the speciation of zinc for four key stations sampled during a previous voyage along a north-south transect. These analysis, in parallel with biological observations from the same cruise allow to distinguish features along this transect.

From these observations, a conceptual model linking zinc speciation and structure of phytoplankton community is been studied in order to quantify the impact of zinc speciation for phytoplankton assemblages in the Tasman Sea but also, possibly in regions were new zinc data are emerging thanks to the GEOTRACES program.

Importance of the research: The interest in trace element biogeochemistry has arisen from the well demonstrated iron hypothesis that revealed the central role that iron exerts on oceanic primary and associated biogeochemical cycles. The essentiality of zinc for key biological enzymes, coupled with a nutrient- like vertical distribution with low dissolved concentrations in many marine surface waters, provided motivation to study zinc in marine systems. Laboratory studies have confirmed the importance of zinc to sustain phytoplankton growth and its influence on the composition of the phytoplankton community. However, mixed results were obtained in the field with which suggest a more subtle effect of zinc on oceanic phytoplankton growth than iron. As a consequence, consensus on its biological role, mechanisms at play or regional versus global relevance is currently lacking and highlights the need for new conceptual models of zinc in marine systems. The recent GEOTRACES program is generating new data approaches to discuss and understand further zinc behaviour in the ocean.

Preliminary findings: To date, two species from the Tasman Sea have been cultured and their requirement in Zn has been quantify and their uptake characterized for this element. They did not show strong limitation in this particular region. However, recent data obtained from pigments analysis during the studied cruise have shown a relation between phytoplankton communities and a possible link with Zn speciation measured for the first time in the Tasman Sea. These observations have been confirmed by statistical analysis on data from SAZ-SENSE and a previous cruise. The link found between communities assemblage and Zn speciation is being explored in a model incorporating two phytoplankton species.

Publications/public output:

Sinoir, M., Butler, E. C. V., Bowie, A. R., Mongin, M., Nesterenko, P., and Hassler, C. S. (2012), Zinc marine biogeochemistry in seawater: a review, *Marine and Freshwater Research* (Accepted).

Hassler C.S., **Sinoir, M**., Clementson, L. A., and Butler, E. C. V. (2012), Exploring the link between micro-nutrients and phytoplankton in the Southern Ocean during the 2007 austral summer, *Frontiers of microbiology* (Accepted)

German Soler*

Supervisors: Graham Edgar (UTAS), Rick Stuart-Smith (UTAS), Tony Smith (CSIRO)
Year of candidature: 1st
Research Project: Influence of environmental covariates on food webs involving reef fishes

Project description: I propose to investigate environmental influences on marine food webs through an alternative process of letting the data speak for itself. Using continent-scale datasets on reef fish size-distribution and abundance compiled by my supervisor Assoc Prof Edgar, and further developed through this project, I will describe the full range of trophic interactions between fish species and prey at sites using network analysis, including graph theory.

Importance: The great significance of the project relates to addressing the following questions in the marine realm at continental scales for the first time:

- How do major trophic groups (herbivores, planktivores, benthic carnivores, higher carnivores) vary with geospatial, environmental and socio-economic covariates?
- Which environmental covariates most affect food web metrics associated with connectivity?
- Do particular elements of food web structure (particularly robustness) influence community and population stability?

Kilian Stehfest

Supervisors: Dr Jayson Semmens (UTAS), Prof Mark Hindell (UTAS), Dr Toby Patterson (CSIRO)

Year of candidature: 3rd

Research Project: Quantifying movement behaviour of predatory fish from animal tagging data

Project description: The last few decades have seen a vast amount of data collected on the movement of free ranging predatory fish using methods ranging from simple mark-recapture techniques to deploying highly sophisticated satellite linked data recorders. And although recently there have been great advances in the analysis of individual movement data, a large proportion of animal tagging studies is still lacking quantitative metrics for the analysis of animal movement behaviour. This project aims to develop novel methods for quantifying the movement behaviour of highly mobile predatory fish and answer ecological questions of management relevance using traditional mark-recapture data, automated acoustic tracking data and pop-up archival satellite tagging data from both tropical tunas (skipjack, yellowfin and bigeye) from the Eastern Pacific and Indian Ocean and a temperate shark species (broadnose sevengill shark) from Tasmania.

Importance of the project: The importance of this project lies both in the advancement of methods for quantifying animal movement behaviour and in the contribution to the knowledge of the ecology of globally important apex predator species.

Tropical tunas are amongst a number of pelagic fish species that are known to aggregate around floating objects, a behavioural trait that has been exploited by tuna fishermen for decades by deploying both drifting and moored artificial fish aggregating devices (FADs) to enhance catch rates. This practice has rapidly become an integral part of tropical tuna fisheries the world over, leading to a large increase in floating object densities in the habitat of tropical tunas. While large amounts of movement data have been collected for these species using a wide range of technologies, novel methods are required to determine the impact of this increase in floating object densities on both the large and the fine-scale movement of tropical tunas and its potential ramifications for the management of these highly exploited and commercially valuable species.

The broadnose sevengill shark is a large demersal shark which can be found in temperate coastal areas around the world, where it is one of the most important apex predators, due to the high diversity of its diet, which includes marine mammals, chondrichthyans and teleosts. While not a target species, the broadnose sevengill shark is often caught as by-catch in commercial shark fisheries and targeted by recreational fishermen. Although its global fisheries status is not well known, in the Southern Australian shark fishery it is considered to be highly vulnerable to gillnetting gear and at high ecological risk in terms of abundance and catch susceptibility with the current fishing mortality rate estimated to be higher than the maximum sustainable fishing mortality. Recently, a large amount of acoustic tracking as well as pop-up archival satellite tagging data has been collected to determine the movement of this species both in the Tasmanian coastal areas and during their winter migration, indicating possible sex-specific differences in movement behaviour. Developing novel methods for quantifying these differences will be highly important as differences in movement behaviour might lead to differential fishing mortality of the sexes with potential ramifications for management and conservation.

Key outcomes to date

The first chapter of my PhD, titled “Differences in large-scale movement between free swimming and fish aggregating device (FAD) caught tuna” was presented at the 12th session of the Indian Ocean Tuna Commission Working Party on Tropical Tunas in Victoria, Seychelles (http://www.iotc.org/files/proceedings/2010/wptt/IOTC-2010-WPTT-06.pdf) and is currently under peer-review at Fishery Bulletin.

The second chapter of my PhD titled “Social networks in the ocean: Determining the structure and stability of fish aggregations from acoustic tracking data” is currently under peer-review at Animal Behavior.

The third chapter of my PhD titled “Movement, dive behavior and vertical habitat preferences of the broadnose sevengill shark (Notorynchus cepedianus)” has been reviewed by PhD supervisors and is now in the final editing stage for submission to Marine Biology.

The fourth and final chapter of my PhD, tentatively entitled “Sex-specific movement behavior in the broadnose sevengill shark (Notorynchus cepedianus)” is currently in the data analysis stage.

Roger Stevens

Supervisors: Petra Heil (AAD), Kelvin Michael (UTAS), Steve Rintoul (CSIRO).

Year of Candidature: 3rd

Research Project: Dynamic and thermodynamic contributions to Antarctic sea ice and controls on the sea-ice edge location using the numerical model CICE4: 1998 to 2008

Project Description: I've use CICE4 in a stand-alone, Antarctic regional configuration and forced it with output from the atmospheric model PolarLAPS and the AusCOM ocean model for the year 1998 to 2008. The initial growth of sea ice is by thermodynamic processes. Subsequent increases in sea ice thickness are through a combination of thermodynamic and dynamic growth. Therefore early in the location of the ice edge is determined by thermodynamic processes via in situ growth of sea ice. Later in the ice growth season advection of ice from further south determines the location of the ice edge in an increasing fraction of zones. The zonal average northward advection of ice remains fairly constant throughout the year. Thermodynamically grown ice at the ice edge decreases as the ice growth season progresses. Eventually, the zonal average ice edge location is maintained by ice advection only. After ice maximum the thermodynamic ice decay processes overwhelm ice advection and the ice edge retreats southward. On shorter time scales total ice area varies primarily due to dynamic processes related to the wind.
Importance of the research: An understanding of polar sea ice is important to an understanding of Earth's climate and how this is changing. Sea ice is very sensitive to changes in climate and so can be used as "the canary in the mine" to give us an early warning. The Arctic has shown dramatic reductions in sea ice due to the warming climate. The signal from the Antarctic is less clear, i.e. total sea ice extent has slightly increased during the interval of satellite observations. Understanding how this occurs and weather it means the volume of Antarctic sea ice is increasing is important. Arctic sea ice was thinning (decreasing volume) long before a decrease in ice extent was observed from space. Modelling studies are one method for gaining an understanding of how ice area and extent relate to ice volume (thickness). Also, IPCC has identified improvements in the modelling of sea ice as necessary for the refinement of global climate models.

Key outcomes to date:

Stevens, R. P. and P. Heil (2010). "The interplay of dynamic and thermodynamic processes in driving the ice-edge location in the Southern Ocean." *Annals of Glaciology* 52(57)

Jose Mauro Vargas Hernandez

Supervisors: A/Prof. Neil Holbrook (UTAS), Dr. Susan Wijffels (CSIRO) and Dr. Gary Meyers (CSIRO)

Year of candidature: 2nd

Research Project: Decadal changes in global subsurface ocean temperatures and ocean heat control.

Project Description This project focuses on decadal variability in the Indo-Pacific subsurface ocean temperatures and upper ocean heat content, identify and quantify the main decadal patterns of variability, to diagnose the underling dynamics. This project also investigates the relationship with known surface patterns of decadal variability and possible mechanisms that underpin them as well as evaluate the quality of ocean states estimates (SODA and GECCO) for studies of decadal ocean variability and change. The project will also compare the results from the ocean states estimates with CMIP5 datasets to better understand the physical mechanisms of decadal variability.

Research questions

1. Can ocean states estimates (SODA and GECCO) be used to study decadal ocean variability? Are those products able to capture well known decadal variability patterns like the IPO/PDO?
2. How is the vertical structure of the decadal variability in the Indo-Pacific region? What is its vertical extension?
3. And how does this decadal variability evolve in space? Is the movement due to wave propagation or advection?
4. What physical mechanisms underpin observed decadal global ocean variability? In particular what mechanisms are behind the IPO and decadal variability observed in the Indian Ocean? What drives the decadal variability in the vertical structure of the Indo-Pacific oceans? A comparison between ocean states estimates (SODA and GECCO) and CMIP3/CMIP5 models.

Importance of the Research: Historical observations of subsurface ocean temperatures and heat content are typically irregular and sparse in space and time. Most purely observational datasets are no longer than back to the 1950s, although the synthesis of these data is a challenge for heterogeneous sampling.

Better understanding of the mechanisms behind decadal ocean variability is fundamental for the attribution of observed secular trends in the climate system (Feng et al. 2010) and the associated climate change. Some decadal variability patterns are linked to climate phenomena, for instance the Interdecadal Pacific Oscillation (IPO) has been related to tropical rainfall patterns (Meinke et al. 2005) that is why the importance of understanding its dynamics.

Public output

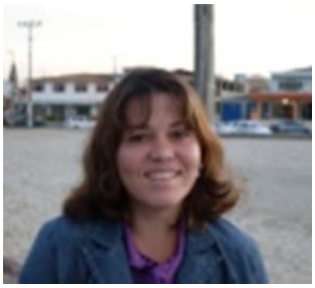
Vargas, J. M., Decadal Changes in Global Subsurface Ocean Temperatures: 2010, Australian National Network in Marine Science, Second Conference, 21-22 July 2010, James Cook University, Townsville, Queensland, Australia, Oral presentation about my PhD research plan.

Vargas, J. M., S. Wijffels, G. Meyers, N. J. Holbrook, USING REANALYSIS AND TIDE-GAUGE DATA TO DETERMINE OCEAN DECADAL CLIMATE VARIABILITY SINCE 1950: 2011, Australian National Network in Marine Science, Third Conference, 29 November-1 December 2011, University of Western Australia, Perth, Australia, Oral presentation.

Vargas, J. M., S. Wijffels, G. Meyers, N. J. Holbrook: 2011, USING REANALYSIS AND TIDE-GAUGE DATA TO DETERMINE OCEAN DECADAL CLIMATE VARIABILITY SINCE 1950, 2012 Ocean Science Meeting, - Salt Lake City, Utah, USA, 20-24 February 2012 , Poster presentation.

Vargas, J. M., Wijffels, S., Meyers, G., and Holbrook, N., 2012: Using reanalysis and tide-gauge data to determine ocean decadal climate variability since 1950, 2012 10th International Conference on Southern Hemisphere Meteorology and Oceanography (10thICSHMO), Noumea, New Caledonia, 23-27 April 2012, Oral presentation.

Viviane Vasconcellos de Menezes*



Supervisors: Dr. Helen Phillips (UTAS), Dr. Catia Domingues (ACE CRC), Prof. Nathan Bindoff (UTAS) and Dr. Andreas Schiller (CSIRO)

Year of Candidature: 1st

Research Project: The dynamics of remarkable near-surface eastward flows in the South Indian Ocean

Project Description: A remarkable aspect of the upper ocean circulation in the south Indian Ocean (SIO) is the presence of near-surface eastward flowsacross this basin. Parts of the eastward flow are concentrated into discrete bands and have been identified as the south Indian Countercurrent (SICC) and the Eastern Gyral Current (EGC). These features have been detected in observations, although details about their precise location, intensity and variability are still to be described. These currents have been simulated successfully by some numerical models, although their basic dynamics remain unclear. The most remarkable aspect of the eastward flows is that they are in the opposite direction to that predicted by both Ekman and Sverdrup theory. Recent advances have been made linking Australian and regional climate variability to variability in the Indian Ocean. Before we can further our understanding of the Indian Ocean's influence on Australian climate, we need to understand the first-order dynamics controlling its circulation and watermass variability.

Modelling studies have proposed three mechanisms for the cause of the eastward flow, which is compensated by subsurface westward flows. The first is the damping of Rossby waves, forced by the Indonesian Throughflow (ITF), away from the eastern boundary. The second is localised regions of downwelling, such as caused by convection south and southwest of Australia and at the West Australian coast in the Leeuwin Current. The third is the large decrease in steric height in the SIO due to the meridional density gradient from light ITF and tropical waters to denser southern waters, giving rise to eastward flow. In support of the latter idea, when the ITF is shut off in numerical ocean models there is a reduced meridional density gradient and weaker eastward flows.

Ideas for why the eastward flow concentrates in bands (EGC and SICC) include 1) winds and/or buoyancy fluxes causing a convergence of the surface flow; and 2) Rossby waves emanating from regions of subduction south of Australia propagating west and being deflected north by the subtropical gyre. In support of the latter process, revealed in model simulations, the southern edges of the observed eastward flow all connect to the SW tip of Australia.

The **objectives of the research** are twofold:

1. Build a detailed picture of the location, intensity and variability of circulation pathways in the southeastern Indian Ocean using observations (mean dynamic topography, altimetry, climatology) and model output (CSIRO Bluelink), and compare with comparable circulations in the Atlantic and Pacific oceans.
2. Use the Bluelink 1/10-degree global model hindcast sumulation to investigate the time-varying interaction of the eastward flows with the Indonesian Throughflow, Leeuwin Current, subduction of water around Australia, Rossby waves and atmospheric forcing

Importance of the research: The importance of the ubiquitous narrow eastward zonal currents (width of order of a baroclinic Rossby Radius) in the world ocean has been only recently assessed as a consequence of the new era of satellite altimetry. These currents are known to be probably generated by zonal density fronts related to areas of surface water subduction and interact with westward propagating geostrophic turbulence, caused by nonlinear westward propagating planetary waves and eddies. These currents are usually called Countercurrents, and have dynamical impacts on eastern ocean boundary currents (e.g. the Leeuwin in western Australia). They are the locus of large tuna abundance, and are important for lobster larval cycles, especially modulating the return pathways, which can be a key factor determining the efficiency of lobster production in western Australia.

Key outcomes: Two conference abstracts have been submitted:

- OSTST 2012 Meeting (22-29 September, Venice, Italy): Menezes, V.V.; Bingham, R.; Vianna, M.L.; Phillips, H. Dominance of Eastward Currents in Southern Hemisphere: the Impact of GOCE Data
- AGU Chapman Conference “The Agulhas System and its Role in Changing Ocean Circulation, Climate and Marine Ecosystems” (8-12 October, Western Cape, South Africa). Menezes, V.V.; Vianna, M.L. and Phillips, H. Multi-scale Variability in the South Indian Upper Ocean Circulation: Impacts on the Agulhas Current System

Cathryn Wynn-Edwards

Supervisors: Dr Patti Virtue (UTAS), Dr Peter Nicols (CSIRO), Dr So Kawaguchi (AAD), Dr Andrew Davidson (AAD), Dr Simon Wright (AAD)

Year of Candidature: 3rd

Research Project: Indirect effects of ocean acidification on the Antarctic food web: changes in the biochemical composition of Antarctic phytoplankton species under elevated pCO2 and the subsequent effects on development of Euphausia superba larvae

Project description: The hypothesis for this research project was that elevated pCO_2 concentration can alter the biochemical composition of Southern Ocean phytoplankton species in a way that will render it inferior as food for Antarctic krill larvae during their first feeding stages. To address this question,

a. a suitable phytoplankton incubation system that could accommodate Antarctic temperature and light conditions and specifically maintain constant seawater carbonate chemistry, i.e. pH and CO_2 concentration, had to be designed and manufactured
b. different methods for Antarctic larval krill feeding experiments were explored
c. several ecologically important Southern Ocean phytoplankton species were assessed for their susceptibility to elevated CO_2 concentrations
d. the most affected phytoplankton species was tested for its effect on developing larval krill in a fully replicated experiment including the isolated effect of altered food along with the combination of lowered pH seawater and altered food quality

Preliminary and early findings have been presented at the following conferences and workshops:

December 2009	Poster presentation at Australian National Network in Marine Science Inaugural Conference, Hobart, Australia
December 2009	National Climate Change Adaptation Research Facility – Marine Adaptation Summer School, Hobart, Australia
July 2010	Poster presentation at Australian Marine Sciences Association 47th Annual Conference, Wollongong, Australia
October 2010	Oral presentation at Australia New Zealand Climate Forum 2010, Hobart
August 2010	Poster presented by my supervisor at 31st SCAR and Open Science, Buenos Aires, Argentina
March 2011	Poster presented by my supervisor at 5th International Zooplankton Production Symposium, Pucon, Chile
June 2011	Oral presentation at the Ocean acidification and implications for living marine resources in the Southern Hemisphere conference, Canberra, Australia
June 2011	Oral presentation at the Seventh EGU Alexander von Humboldt International Conference on Ocean acidification: consequences for marine ecosystems and society, Penang, Malaysia

This research is funded by the following scholarships and grants:

March 2009 to date	Endeavour International Postgraduate Research Scholarship (EIPRS)
April 2009 to date	CSIRO Wealth from Oceans Flagship top – up Scholarship
October 2009 to date	ANZ Trustees Foundation – Holsworth Wildlilfe Research Endowment

Appendix 1 Thesis Abstracts

1.1 James Dell

Fisheries oceanography of Yellowfin Tuna (Thunnus albacores) in the Tasman Sea

Sustainable fishing is required to protect and maintain marine biodiversity and to ensure fisheries that are both economically viable and productive. Effective management of living marine resources requires well-informed decisions through an appreciation of past, present and future pressures. Understanding "why fish are caught where they are?" is the oldest question in fisheries research and is a central issue for the sustainable catch, management and conservation of marine resources. Here we look at the Australian longline fishery to better understand where yellowfin tuna (Thunnus albacares) are caught on the hooks set by the eastern tuna and billfish fishery (ETBF) in the Tasman Sea. We view the catch of this species in the context of the recent oceanography of the Tasman Sea, sixty years of fishermen's knowledge and experience, a future climate scenario, declining stocks of other large pelagic predatory fish and an increasing demand in products derived from these species.

The physical environment directly influences the distribution, abundance, physiology and phenology of marine species. Relating species presence to physical ocean characteristics to determine habitat associations is fundamental to the management of marine species, however, direct observation of highly mobile animals in the open ocean, such as tunas and billfish, is challenging and expensive. As a result detailed data on habitat preferences using electronic tags has only been collected for the large iconic, valuable or endangered species. An alternative is to use commercial fishery catch data matched with historical ocean data to infer habitat associations. Using catch information from an Australian longline fishery and Bayesian hierarchical models we investigate the influence of environmental variables on the catch distribution of yellowfin tuna (Chapter 1). The focus was to understand the relative importance of space, time and ocean conditions on the catch of this pelagic predator. We found that pelagic regions with elevated eddy kinetic energy, a shallow surface mixed layer and relatively high concentrations of chlorophyll a are all associated with high yellowfin tuna catch in the Tasman Sea. Time and space information, while important, were less informative than oceanic variables in explaining catch. An inspection of model prediction errors identified clumping of errors at margins of ocean features, such as eddies and frontal features, which indicate that these models could be improved by including representations of dynamic ocean processes which affect the catch of yellowfin tuna.

We use the same catch prediction model to consider where yellow fin tuna catches may occur in the context of a future climate scenario (Chapter 2). We used global climate model (GCM) from the IPCC 2007 AR4 summit to produce predictions of surface ocean characteristics for the Tasman Sea in the 2060s. These data were used to initialize a biogeochemical model to create an ocean productivity product for the surface ocean that was equivalent to the chlorophyll a concentration as estimated by the ocean color SeaWiFS product. We use these products as inputs for the YFT catch prediction model to determine where YFT may be caught in the Tasman Sea in 2060s. We compare these predictions to those from the 1990s and the 2000s to show how the pattern of modelled YFT catches differ from those estimated by the model for the earlier time periods. Identifying possible shifts in the availability of YFT to commercial longlining over such long time period inform the construction of long-term goals upon which strategies for resource management; coastal infrastructure development and fleet management can be considered. This approach can also be applied at shorter time scales if biogeochemical downscaling is available.

Successful sustainable management of living marine resources can occur when the enhanced details of the resource, industry and market are thoughtfully integrated into the planning and implementation of management strategies. Engaging the fishing community in the management process is a proven approach to the successful implementation of management strategies with sustainable outcomes. We report on a 2006 survey of the ETBF which recorded the perspectives of the resource users and cooperative managers regarding the location and catch of YFT in the Tasman Sea. We show that the fishing community hold varied perspectives on the most influential ocean characteristics with respect to YFT catch and show how perspectives relate to the fishing region. Further work collecting, analysing and incorporating the opinions and knowledge of the fishermen of the ETBF into habitat and catch models is recommended as a direction for future work. Utilizing the qualitative information from fishers would minimise biases in the catch information, associated with the multispecies targeting and markets prices, and encourage better collaboration between fishermen, scientists and management for the sustainable future of the resource and fishing community of the east coast of Australia.

Overall, the work presented here show that YFT catches in the Tasman Sea can be partially explained by variation in the surface ocean environment. To achieve this goal, we used machine learning techniques to identify the most informative variables from the available ocean data and used a generalized linear model based on a hierarchical Bayesian framework to characterise the relationship between these variables and YFT catch. These techniques have not previously been used for this purpose in the Tasman Sea. The algorithms and model structures employed here provide a valid alternative to conventional habitat modelling techniques.

1.2 JAN SEILER

Testing and evaluating non-extractive sampling platforms to assess deep-water rocky reef ecosystems on the continental shelf

Traditional, extractive sampling methods to assess species diversity, size and abundance such as netting and trawling are unable to sample complex, hard substrates. This inability led to the development of alternative, non-extractive sampling tools such as digital stills- and video cameras mounted onto stationary or moving platforms. This thesis examined two moving platforms (1) Automated Underwater Vehicle (AUV) and (2) towed video sled and one stationary platform: stereo Baited Remote Underwater Video System (BRUVS). These platforms were used as sampling tools to assess demersal fish diversity, qualitative and quantitative size distribution, and relative abundance in complex, deep-water rocky reefs in temperate Australia (Tasmania). Each platform was evaluated with respect to their efficacy and reliability within a resource management framework. Imagery was also used to devise a novel approach to automate habitat mapping to reduce processing time.

The randomForest classification tree algorithm was used to automatically assign habitat classes to images based on extracted image features such as colour, texture and terrain rugosity after initial training. Classifier accuracy was assessed using a human scored image set. Habitat prediction accuracy was 84% (with a kappa statistic of 0.793).

The evaluation of stereo BRUVS as a tool to inventory and monitor deep-water temperate reef fish diversity can inform resource managers of advantages and disadvantages of this particular sampling tool. Species richness and relative abundance across different sites over two years were investigated. In addition, stereophotogrammetric fish length estimation of Striped Trumpeter (Latris lineata) and blue-throated wrasse (Notolabrus tetricus) were utilised to set a benchmark for future reference. All three platforms were compared to assess their ability to sample demersal fish diversity and relative abundance. Sample variability for each tool was assessed statistically and synergy between platforms proposed. The cost-effectiveness of each platform was assessed qualitatively.

An assessment of the size and abundance distribution of the ocean perch Helicolenus percoides was conducted using photographic records taken by the AUV. Stereophotogrammetric size estimates were converted into biomass and examined with respect to depth and habitat. Habitat preferences of adult and juvenile ocean perch were also investigated. The results suggest that AUV 'Sirius' is a mature survey platforms in complex hard substratum environments. The utility of this non-extractive sampling tool in a fisheries context is discussed.

Non-extractive, imagery-yielding sampling gear provides useful alternatives when sampling complex environments. Data quality from imagery is benefitting from rapidly developing technology. In a MPA context non-extractive methods provide the only means to sample protected areas. Advantages and disadvantages of each platform are now readily accessible to advise resource management agencies.

1.3 Rachel Alderman

The Shy albatross (Thalassarche cauta): population trends; environmental and anthropogenic drivers; and the future for management and conservation.

Albatross continue to be amongst the most threatened group of birds and they remain a significant conservation concern. Worldwide, they are impacted on land and at sea by a range of processes, particularly fisheries bycatch. In spite of their high conservation profile, albatross pose challenges for monitoring and recovery actions because they are long-lived, spend most of their life at sea and return to breed at colonies that are often located on remote, relatively inaccessible islands.

This thesis offers a comprehensive assessment of the population status and trends of Australia's endemic shy albatross, Thalassarche cauta, which breeds exclusively on three Tasmanian offshore islands. The main anthropogenic, physical and environmental processes that influence each of the three breeding populations are elucidated and the influence of processes that shape key demographic parameters and trends are assessed.

These aims are addressed through four analytical chapters which follow the introductory chapter. Chapter two provides a direct analysis of existing long term population and demographic data principally from Albatross Island which, as the most accessible and comprehensively monitored colony, serves as a reference population for this species. The colony and age-specific differences in at-sea distribution of shy albatross are investigated in the third chapter, which also considers the resulting environmental and fisheries related influences. These underlying processes are then compared and contrasted and the implications considered in relation to known population and demographic data to infer trends in survival, recruitment and breeding parameters for each of the three populations.

Given the increasing focus of managers and researchers on understanding climate impacts on threatened species, Chapter four assesses the efficacy of existing long term monitoring protocols on Albatross Island for detecting the influence of climate change on the breeding success of this population. The fifth chapter takes the existing breeding success time series and investigates the relationship of this important life-history parameter with a range of local and regional environmental variables. The population implications of these climate-biology relationships under future predictions under climate change are discussed.

These findings are synthesised to produce the first comprehensive report of the overall conservation status of the shy albatross and a key conclusion of this research is that the species is not as secure as previously believed. In addition to contributing to our understanding of the status of the species, this thesis highlights a range of threatening processes and their underlying mechanisms and provides clear guidance for future management and monitoring of this species, lessons that can be extended to other threatened seabird species.

1.4 Martin Marzloff:

Towards ecosystem-based management of Tasmanian temperate rocky reefs: Community dynamics models indicate alternative community states and management strategies

Worldwide, ecosystems have demonstrated the potential for dramatic shifts to an alternative persistent state under gradual long-term environmental changes or following sudden short-term perturbations. Such shifts are documented for numerous marine examples from coral reef to pelagic communities and may become more common as ecological dynamics adjust to climate-driven changes. These shifts are often sudden, challenging to predict and can have disastrous and unpredictable consequences on both ecosystem functioning and the human activities that rely on the associated natural resources. These shifts, which often result in irreversible dramatic changes in community structure and productivity, represent a growing concern for managers of natural systems. In ecosystems where the presence of an alternative persistent state is well documented, the drivers of these shifts (e.g. anthropogenic stressors or changes in environmental conditions) can be analysed retrospectively so as to address key management questions, as has occurred in several applications to coral reefs.

However, phase shifts are often swift and observed a posteriori, i.e. once the ecosystem has shifted to the alternative state. Thus, albeit crucial for sound management of marine resources, thresholds in ecosystem dynamics are difficult to identify empirically. Additionally, controlled experimental assessment of the effects of alternative management scenarios on community state is hardly ever achievable in marine ecosystems. When they occur, phase shifts are unique to each ecosystem, hence case-specific simulation models present a valuable tool to explore ecological dynamics with alternative persistent community states, test the effects of management scenarios and inform decision-making.

On the east coast of Tasmania, shallow exposed rocky reef communities mainly occur in two alternative persistent states: (1) the seaweed bed state characterised by a dense productive canopy of macroalgae; or, (2) the sea urchin 'barren' state characterised by a poorly productive rocky habitat largely bare of seaweeds as a result of destructive grazing by the long-spined sea urchin (Centrostephanus rodgersii). The establishment of these widespread sea urchin barrens result from a combination of both: (1) the climate-driven range extension of the long-spined sea urchin C. rodgersii from Australia's mainland to Tasmania; and (2) the depletion of key reef predators by fishing. Large southern rock lobster (Jasus edwardsii) individuals constitute the main predator of the long-spined sea urchin in Tasmania. Relative to the seaweed bed state, C. rodgersii barrens represent dramatic losses of habitat, species diversity and productivity, including commercial species such as blacklip abalone (Haliotis rubra) and southern rock lobster, the two most valuable fisheries in Tasmania. Thus, the spread of sea urchin barrens has been ranked as a major pressing threat for the lobster and abalone fishing industries.

This thesis presents a suite of models specifically developed to better understand the dynamics of Tasmanian rocky reef communities and inform management interventions with respect to destructive grazing of seaweed beds by the invasive long-spined sea urchin. Chapter 2 investigates the causal relationships between positive feedback and the occurrence of alternative states in

community dynamics. Modelling of community feedback informed by available qualitative knowledge about ecosystem structure constitutes a valuable framework to detect the potential for alternative states in ecological dynamics as illustrated with some examples from Tasmanian rocky reef communities. Qualitative modelling assists to understand the essential features of temperate reef dynamics around Tasmania, and provides a useful first step towards quantitative modelling of rocky reef dynamics. The approach provides an ideal framework to (i) collate all available information about rocky reef ecology, (ii) test model structure uncertainty, and (iii) identify key drivers of alternative states in ecosystem dynamics.

The quantitative model presented in the subsequent chapters solely captures the dynamics of the three key groups, species (i.e. rock lobster, sea urchin) or assemblages (seaweed bed), directly involved in the positive feedback that drives the shift between alternative states on Tasmanian rocky reef. Chapter 3 describes the development, parameterisation and calibration of a mean field model of the local population dynamics (reef area of 100 m2 - 10 ha) of a reef community. The model ability to capture the potential for phase shifts, from the seaweed bed to the sea urchin barren state and back, is validated against large-scale patterns observed on rocky reefs where C. rodgersii occurs. In simulations, time for extensive sea urchin barrens to form is of the order of two decades, while restoration of seaweed beds from the urchin barren state takes about three decades if relying on regional management interventions that cannot effectively reduce urchin density to zero.
Thus, restoration of seaweed beds seems unrealistic to implement within the current timeframe of management plans. Comprehensive model-independent sensitivity analysis of model behaviour to parameter estimates also suggests that, in addition to lobster fishing mortality, recruitment rates of sea urchins and rock lobsters, which are strongly influenced by large scale oceanographic features and highly variable in eastern Tasmania, are key factors in determining the potential for sea urchin barren formation in the model.

In Chapter 4, sets of Monte-Carlo simulations with this model are used to address three sets of key management questions related to mitigation of sea urchin destructive grazing of Tasmanian seaweed beds. Model behaviour suggest that (i) thresholds, in shifting from seaweed bed to sea urchin barren or, conversely, for the restoration of the seaweed bed state, show the existence of a hysteresis in model dynamics. The hysteresis implies that the establishment of sea urchin barrens cannot be reversed easily. These threshold estimates provide valuable ecological reference points to prevent the establishment of sea urchin barren; (ii) culling of sea urchin in combination with a reduction in lobster fishing appears as the most effective management strategy to minimise the ecological impact of C. rodgersii on Tasmanian reef communities. Indirect interventions relying solely on the rebuilding of rock lobster population (through reduction in fishing or implementation of a maximum legal catch size) perform poorly but, when combined with direct control of sea urchin population, they can provide optimal outcomes both in terms of minimising barren formation and fishery performance; and (iii) finally, to allow for lobsters to play an ecological role in the prevention of sea urchin barren formation, a reduction in lobster fishing mortality is required. A maximum sustainable yield as estimated from the single species stock assessment model does not account for these ecosystem services delivered by larger lobsters and this thesis emphasises the need for an ecosystem-based fishery management approach. This suite of models contributes to the general understanding of mechanisms and drivers that can facilitate shift between alternative states in ecological dynamics.

The quantitative simulation model provides specific information to managers about the drivers of shift between the seaweed bed and the sea urchin barren state in the dynamics of Tasmanian rocky reefs. In particular, the presence of a hysteresis in reef community dynamics means that the prevention of barren formation constitutes a much more viable management strategy than the restoration of seaweed beds once barren habitat has extensively formed. Commercially-fished rock lobster is an essential reef predator delivering key ecosystem services to Tasmanian rocky reefs and model simulations highlight the necessity for fisheries management to move away from a single species focus and account for the ecological role of targeted commercial species. The tools implemented here to inform an ecosystem-based management of Tasmanian rocky reefs are quite generic and transposable to other ecosystems with alternative states. While C. rodgersii barrens currently constitute a pressing concern for managers of reef communities and fisheries in Tasmania, the long-spined sea urchin is an example of one species that is dramatically restructuring Tasmanian reef communities and there are many other natural invaders, whose ecosystem impacts are unknown, currently extending their home range from Australia's mainland to warming Tasmanian waters. In the coming decades, climatedriven changes are likely to bring more surprises to Tasmanian rocky reefs, and as many challenges for the associated fisheries and their managers.

1.5 Ernesto Molina

Controls on Southern Ocean phytoplankton production – a systems approach

Plankton ecosystems of the world ocean play a significant part in the global cycle of carbon by contributing around 40% of total annual primary productivity. The modification and application of dynamic models of plankton ecology is one facet of the study of this cycle. This thesis focuses on the Nutrient Phytoplankton Zooplankton Detritus (NPZD) mixed layer ecosystem model of Oschlies and Garcon [1999]. Several investigations of its properties and parameterisation were undertaken to examine the sensitivity of Southern Ocean phytoplankton production to iron inputs, light levels, grazing and other controls on production and loss of biomass.

The NPZD model was used to investigate the biogeochemical dynamics that occurred both inside and outside of the naturally-fertilised Kerguelen Plateau bloom. Direct comparison with surface chlorophyll observations derived form satellite ocean colour measurements showed that the base model cannot achieve chlorophyll concentrations greater than ~ 0.6 mg m-3, in comparison to the observed levels of ~ 2.7 mg m-3. However, a model incorporating an indirect simulation of iron-fertilisation improved the simulated pattern of phytoplankton in the surface waters over the plateau, providing a relaxation of grazing pressure. Simulations without a seasonal cycle of the key photosynthetic parameters, □□ (initial slope of the photosynthesis/irradiance curve) and □max (maximal growth rate), underestimated the magnitude of the central plateau bloom by a factor of ~ 4.3. To capture the observed high summer chlorophyll values and at the same time the low winter values, zooplankton mortality in the model was increases by a factor of ~7.0, temporal changes on □ and □max imposed (based on the observed results after the iron infusions at Southern Ocean Iron Release Experiment (SOIREE) and IronExII), and phytoplankton mortality increased by a factor of 1.2.

The same modelling framework was used to examine the role of seasonality in determining the response of marine plankton ecosystem to temporary iron fertilisation in the Southern Ocean. By artificially raising the parameters □ and □max by a factor of 2.5 for a short duration (i.e., 13 days), the model was able to simulate the phase and amplitude patterns of the SOIREE bloom. Through a series of SOIREE-like experiments along different points of the seasonal cycle, the model showed that while blooms induced in spring resulted in higher surface chlorophyll levels, blooms induced in summer resulted in higher potential carbon export. These findings highlighted the importance of low overwintering biomass of phytoplankton and its principal grazers for the occurrence of the spring biomass peak. By expanding the simulations to a range of seasonal cycles characteristic of the wider Southern Ocean, the model provided a distinct pattern of iron fertilisation response, confirming that both the timing and location of the fertilisations are important factors. The model results suggested that the optimal time and location for iron fertilization events to be more effective in terms of potential carbon export were mid-summer infusions in the Subantarctic zone.

Appendix 2: Summary information of all students enrolled in the CSIRO-UTAS PhD Program in Quantitative Marine Science

Students appointed under CSIRO-UTAS Collaboration Agreement

Student Name	Project title	Supervisors (does not include research advisors)	Year started	Target Completion Date	Published Outputs	scholarship	Scholarship end date	Current status	Progress of candidature
German Andres Soler	Influence of environmental covariates on food webs involving reef fishes	Graham Edgar (UTAS) Rick Stuart-Smith (UTAS) Tony Smith (CSIRO)	2012	6.18.16		Full external funding		FT	1%
David Gwyther	Investigating the impact of ocean warming on Antarctic ice shelves	Ben Galton-Fenzi (UTAS) Jason Roberts (AAD) John Hunter (UTAS) John Church (CSIRO)	2012	3.4.16		Elite top-up	4.3.15	FT	8%
Camilla Novaglio	The importance of ecological baselines in developing ecosystem models	Stewart Frusher (UTAS) Tony Smith (CSIRO)	2012	3.4.16		CSIRO living allowance and CSIRO top-up		FT	8%
Cesar Penaherrera-Palma	Abundance, distribution and conservation value of sharks in the Galapagos Marine Reserve	Jayson Semmens (UTAS) Stewart Frusher (UTAS) Alistair Hobday (CSIRO)	2012	4.3.16		QMS Elite top-up	4.3.15	FT	8%
Viviane Vasconcellos de Menezes	The dynamics of remarkable near-surface eastward flows in the South Indian Ocean	Helen Phillips (UTAS) Catia Domingues (ACECRC) Nathan Bindoff (UTAS) Andreas Schiller (CSIRO)	2012	3.4.16	2 conference abstracts (*submitted*)	QMS living allowance and QMS Elite Top-up	19.2.15	FT	8%
Ross Kelvin Daley	Movement based conservation strategies for deepwater sharks	Jayson Semmens (UTAS) Alistair Hobday (CSIRO)	2011	9.11.19	1 conference paper (*to be presented in July and Aug '12*)	QMS Standard top-up		PT	10%
Emmanuel Laurenceau	Controls on Organic Carbon Sequestration from the Naturally Iron-fertilised Phytoplankton Bloom over the Kerguelen Plateau	Tom Trull (UTAS) Mathieu Mongin (CSIRO)	2011	30.9.15	1 conference poster 3 papers (*in prep*)	QMS living allowance and Standard Top-up	30.9.14	FT	18%
Felicity Susan Graham	Understanding the dynamics of El Nino Southern Oscillation and how they might change with global warming	Neil Holbrook (UTAS) Jaclyn Brown (CSIRO) Andrew Wittenberg (GFDL)	2011	17.7.15	1 A1 paper (*in review*)	CSIRO top-up	17.7.14	FT	23%
Felipe Andres Jacques Briceno	Modelling predator/prey interactions under climate change: implications for a key commercial fishery in Tasmania	Gretta Pecl (UTAS) Caleb Gardner (UTAS) Jeffrey Dambacher (CSIRO) Jessica Andre (UTAS)) Stewart Frusher (UTAS)	2011	3.7.15	1 conference paper	QMS Elite top-up	3.7.14	FT	24%
Sjoerd Groeskamp	Estimating diffusion coefficients from ocean hydrography	Nathan Bindoff (UTAS) Bernadette Sloyan (CSIRO) Trevor McDougall (UNSW)	2011	26.6.15	1 A1 paper	CSIRO living allowance and CSIRO top-up	27.6.14	FT	25%
Scott Alistair Hadley	Alternative strategies for sustainable environmental management of nutrient loads in aquaculture	Craig Johnson (UTAS) Catriona Macleod (UTAS) Karen Wild-Allen (CSIRO)	2011	28.4.2015		QMS Elite Top-up	28.4.14	FT	29%
Veronique Lago	Testing of Climate Models and Sea Level Rise Projections Using Observations of Ocean Heat Uptake	Nathan Bindoff (UTAS) Susan Wijffels (CSIRO) John Church (CSIRO) Simon Marsland (CSIRO)	2011	5.4.15		QMS living allowance	5.4.14	FT	30%

Students appointed under original QMS funding

Student Name	Project title	Supervisors (does not include research advisors)	Year started	Target Completion Date	Published Outputs	scholarship	Scholarship end date	Current status	Progress of candidature
Rafael Ivan Leon	The effect of catch share strength on management of marine resources	Caleb Gardner (UTAS) Klaas Hartmann (UTAS) Elizabeth van Putten (CSIRO)	2010	29.6.14	1 conference paper 1 conference poster	QMS Standard top-up	29.6.13	FT	50%
Nigel Brian Keeley	Quantifying and predicting benthic enrichment associated with southern temperate aquaculture operations	Catriona Macleod (UTAS) Christine Crawford (UTAS) Mark Gibbs (CSIRO) Barrie Forrest (Cawthron Institute) Chris Cromey (SAMS)	2010	19.3.14	2 A1 publications (*1 accepted, 1 in review*)	QMS Elite Top-up	19.3.13	FT Ext	56%
Jose Mauro Vargas-Hernandez	Decadal changes in global subsurface ocean temperatures and ocean heat control	Neil Holbrook (UTAS) Susan Wijffels (CSIRO) Gary Meyers (CSIRO)	2010	21.3.14	3 conference papers 1 conference poster	CSIRO Top-up	21.3.13	FT	56%
Christopher Roach	Ekman Currents in the Antarctic Circumpolar Current	Helen Phillips (UTAS) Nathan Bindoff (UTAS) Stephen Rintoul (CSIRO)	2010	18.4.14	7 conference presentations	CSIRO Top-up	18.4.13	S	57%
Sophie Gourguet (Cotutelle) Enrolled through School of Economics so can't show bar in far right column	Stochastic Viability Approach to Ecosystem-Based Fisheries Management	Sarah Jennings (UTAS) Stewart Frusher (UTAS) Rich Little (CSIRO) Olivier Thebaud (CSIRO) Luc Doyan (CNRS-MNHN)	2009	Data not available – enrolled through a school other than IMAS	3 A1 papers (*1 published, 1 submitted, 1 in revision*) 4 conference papers 1 conference poster	QMS living allowance	31.3.13	FT Ext	
Christopher Jackett Enrolled through School of Computing and Information Systems so can't show bar in far right column	Deconvolving and increasing the spatial resolution of satellite data using the Maximum Entropy Method	Robert Ollington (UTAS) Julian Dermoudy (UTAS) Jenny Lovell (CSIRO)	2009	31.5.13	1 A1 paper 2 Conference papers	QMS Standard Top-up APA	28.12.12 28.12.12	FT	
Marie Sinoir	Zinc speciation in the Tasman Sea and its relation to the phytoplankton community	Dr Andrew Bowie (ACE CRC-IMAS) Dr Mathieu Mongin (CSIRO) Dr Edward Butler (AIMS) Dr Pavel Nesterenko (ACROSS-Utas) Dr Christel Hassler (UTS)	2009	31.5.13	2 A1 Papers (*accepted*)	QMS living allowance	1.12.12	FT	76%
Kilian Michael Stehfest	Quantifying movement behaviour of predatory fish from animal tagging data	Dr Jayson Semmens (UTAS) Prof Mark Hindell (UTAS) Dr Toby Patterson (CSIRO)	2009	5.4.13	3 A1 papers (2 *in review, I in prep*) 1 conference paper	IPRS QMS standard top-up IMAS top-up	5.4.12 5.10.12 5.10.12	FT	80%
Cathryn Ann Wynn-Edwards	Indirect effects of ocean acidification on the Antarctic food web: changes in the biochemical composition of Antarctic phytoplankton species under elevated pCO2 and the subsequent effects on development of Euphausia superba larvae	Dr Patti Virtue (UTAS) Dr Peter Nicols (CSIRO) Dr So Kawaguchi (AAD) Dr Andrew Davidson (AAD Dr Simon Wright (AAD)	2009	25.6.13	4 conference papers 3 conference posters	IPRS CSIRO top-up	1.3.12 15.10.12	FT	80%
Matthew James Cameron	Relationships between fish population and the physical structure of Australia's temperate reefs in response to marine protection	Neville Barrett (UTAS) Graham Edgar (UTAS) Craig Johnson (UTAS) Vanessa Lucieer (UTAS)	2009	20.2.13		CERF TAFI top-up QMS top-up QMS tuition Thomas Crawford tuition	20.8.12 20.8.12 20.8.12 20.8.12 20.8.12	FT	83%

Jessica Helen Ford	Understanding animal movement using stochastic models	Prof. Mark Hindell (UTAS) Dr Chris Wilcox (CSIRO) Dr Mark Bravington (CSIRO) Dr Toby Patterson (CSIRO)	2009	1.2.13	1 A1 paper (*accepted*) 1 conference paper 1 conference poster	CERF CSIRO top-up	2.8.12 1.9.12	FT	84%
Amelie Meyer	Mixing intensity and sources in the Southern Ocean: an observational study surrounding the Kerguelen Plateau.	Dr Helen Phillips (UTAS) Dr Bernadette Sloyan (CSIRO) Prof. Nathan Bindoff (UTAS) Dr Kurt Polzin (WHOI)	2008	22.10.13		APA CSIRO top-up QMS top-up	27.2.12 22.10.12 22.10.12	PT	84%
Tomas Andrew Remenyi	Quantifying the impact of dust deposition to the Southern Ocean using dissolved aluminium concentrations	Dr Andrew Bowie (ACE CRC, UTAS) Prof Paul Haddad (UTAS) Prof Pavel Nesterenko (UTAS) Dr Mathieu Mongin (CSIRO) Dr Ed Butler (AIMS)	2008	21.11.12	2 A1 papers (*1 published, 1 accepted)* 1 conference paper	APA QMS top-up ACECRC top-up	12.5.12 14.5.12 14.5.12	FT	90%
Roger Paul Stevens	Dynamic and thermodynamic contributions to Antarctic sea ice and controls on the sea-ice edge location using the numerical model CICE4: 1998 to 2008	Petra Heil (AAD) Kelvin Michael (UTAS) Steve Rintoul (CSIRO)	2008	12.11.12	1 A1 paper (*published*)	APA QMS top-up	14.5.11 14.5.11	PT	95%
Jan Seiler	Testing and evaluating non-extractive sampling platforms to assess deep-water rocky reef ecosystems on the continental shelf	Neville Barrett (UTAS) Neil Holbrook (UTAS) Alan Williams (CSIRO) Richard Coleman (UTAS)	2008	Submitted 25.6.12 Abstract attached		CERF QMS Top-up	19.2.12 19.2.12	TS	96%
Timothy Jon Karlov (this student is unlikely to complete)			2004					PT	98%
Martin Pierre Marzloff	Towards ecosystem-based management of Tasmanian temperate rocky reefs: Community dynamics models indicate alternative community states and management strategies	Craig Johnson (UTAS) Stewart Frusher (UTAS) Rich Little (CSIRO) Jean-Christophe Soulie (CIRAD) Jeff Dambacher (CSIRO)	2008	Completed 13.7.12 Abstract attached	6 A1 papers (*4 published, 2 in prep*)			G	100%
Ernesto Molina	Controls on Southern Ocean phytoplankton production – a systems approach	Tom Trull (UTAS) Andrew Bowie (UTAS) Mathieu Mongin (CSIRO)	2006	Completed 26.6.12 Abstract attached				G	109%
James Thomas Dell	Fisheries oceanography of Yellowfin Tuna (*Thunnus albacores*) in the Tasman Sea	Mark Hindell (UTAS) Chris Wilcox (CSIRO) Alistair Hobday (CSIRO)	2005	Submitted 14.6.12 Abstract attached				TS	116%

PT **Part Time**
FT **Full Time**
FT Ext **Full time External**
TS **Thesis Submitted**
G **Graduated**
S **Suspended**

Appendix 3: CSIRO-UTAS PhD Program in Quantitative Marine Science Budget Report 1 July 2011- 30 June 2012